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Geology of Parker County, Texas

LEO HENDRICKS

BUREAU OF ECONOMIC GEOLOGY

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John T. Lonsdale, *Director*

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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ABSTRACT

The surface rocks of Parker County, Texas, are of Pennsylvanian, Cretaceous, Pleistocene, and Recent geologic age.

Pennsylvanian rocks of upper Strawn and lower Canyon age are exposed along the western side of the county in a series of cuesta scarps and for several miles down Brazos River valley in the southern part of the county. Because of generally northwest direction of the dip, the oldest beds are exposed in the Brazos Valley, and the youngest occur in the northwest corner of the county. The exposed section is 2,000 feet thick, made up mostly of shales but containing several thin limestones and sandstones. Two of the sandstones are in part conglomeratic. The limestones and sandstones serve as key beds for mapping and for defining formations. In some cases mapping is complicated by facies changes. Seven formations can be defined. Fossils occurring chiefly in the limestones are useful in stratigraphic correlation, with fusulinids furnishing the best data.

Cretaceous rocks of Comanche age underlie the eastern five-sixths of the county. The outcrop of the lower, or Trinity, group of beds extends north-south across the county immediately east of the Pennsylvanian outcrop. Because of gentle east-southeast direction of dip, the outcrop of the middle, or Fredericksburg, group of beds lies east of the Trinity outcrop. The basal beds of the upper, or Washita, group of formations are present in the eastern part of the county. The Trinity consists of 500 feet of beds composed of very fine sands and silty clays and containing one large limestone unit, which unit is reduced by lateral gradation from a thickness of over 100 feet at the south county line to one bed 2 to 3 feet thick at the north county line. The sands of the Trinity are almost barren of fossils, but the limestone has an abundance of marine pelecypods, gastropods, and the foraminifer *Orbitolina*. The Fredericksburg and basal Washita consist of less than 200 feet of alternating limestone, marl, and shale, with limestone predominating. The beds contain an abundance of fossils, including pelecypods, gastropods, ammonites, and echinoids.

The southwest half of Parker County is drained by the Brazos River and its tributaries and the northeast half by streams of the Trinity River system. The southwest portion exhibits greater dissection because the strong, through-flowing Brazos has been able to degrade faster than the relatively weak streams of the Trinity system.

Commercial oil production from the Lower Pennsylvanian has been developed in one small area near the northern boundary of the county. Commercial production of gas from the Pennsylvanian may be developed over a large part of the northwestern portion of the county. Brick and tile clay has been produced from Pennsylvanian shales, and Pennsylvanian limestones have been extensively quarried for rock ballast. Caliche deposits suitable for road-base material occur in a few places in the Cretaceous outcrop. Some of the weathered Pennsylvanian conglomerates can be worked for chert gravel.

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

INTRODUCTION

Location.—Parker County is located in the northern part of Texas, approximately 60 miles south of the northern boundary of the State (fig. 1). The east line of the county is 15 miles west of Fort Worth. Weatherford, located in the center of the county on U. S. Highway 80, is the county's largest town. This highway crosses the county in a west-southwest direction, and U. S. Highway 180 begins at Weatherford and extends westward across the county. Texas State Highway 199 crosses the northeast part of the county, and numerous other paved roads radiate from Weatherford or branch off from the highways. Parker County is located on the western edge of the vast Cretaceous outcrop that covers a large part of northeast Texas. The Cretaceous boundary within the county has a deep southeastward indention caused by the Brazos River valley. The rocks on which the Cretaceous rests are Pennsylvanian in age, and the oldest Pennsylvanian beds exposed in north Texas crop out along Brazos River and in Kickapoo Creek valley in the southwestern part of the county.

Previous work.—References to the geology of Parker County and partial descriptions of some of the formations exposed are among the earliest reports on the geology of Texas. R. T. Hill (1887)

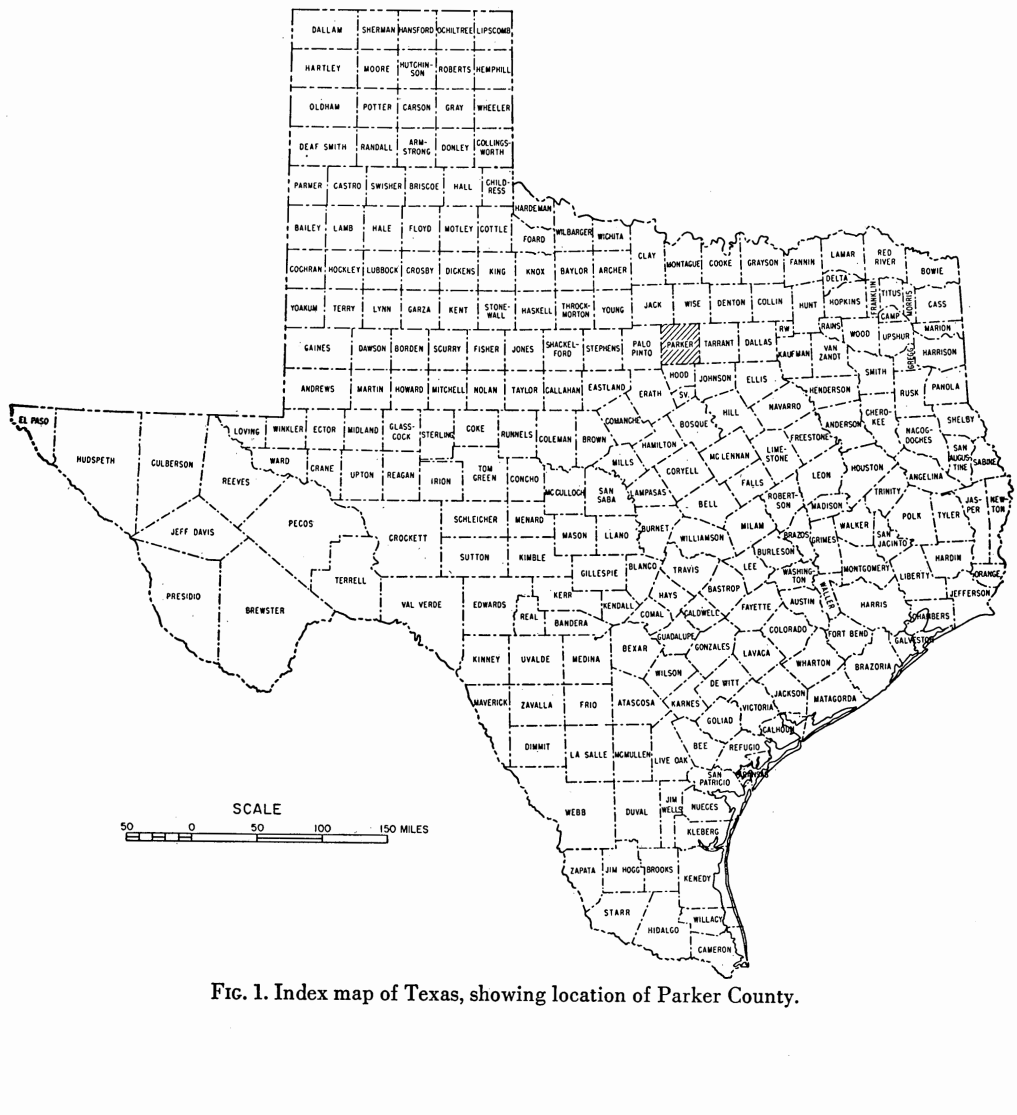


FIG. 1. Index map of Texas, showing location of Parker County.

showed the correct sequence of the Cretaceous rocks in a section that begins at the base of the Cretaceous near Millsap in the western part of the county and extends eastward across the county along the Texas & Pacific Railroad. Hill (1901) later included the results of more extensive studies in the county in a report on the geology of the Black and Grand Prairies of Texas. Cragin (1893) described Cretaceous fossils from localities in Parker County southeast of Weatherford. Cummins (1891) described Pennsylvanian formations exposed in Parker and adjoining counties. Plummer and Moore (1922) included the Pennsylvanian rocks of Parker County in their study of the Pennsylvanian of north-central Texas.

Between 1925 and 1930 the details of the geology of Parker County were studied and mapped by Gayle Scott of Texas Christian University and J. M. Armstrong of Prairie Oil Company; Scott (1930a) published a discussion of the stratigraphy of the Trinity beds in the county as a result of the work. A geologic map of the county by Scott and Armstrong (1930) was reproduced by means of photoprints and distributed by the Bureau of Economic Geology of The University of Texas, Austin, Texas. A description of the geology of the county by Scott and Armstrong exists in manuscript form. The manuscript has been used for authoritative reference in the description of the geology of Texas (Sellards, 1933) and in the description of the geology of Palo Pinto County (Plummer and Hornberger, 1935). Geologic names proposed for the first time in the manuscript by Scott and Armstrong have been placed in the literature in the two publications cited, have been accepted, and have become a part of the common usage of geologists, even though the original authority for the names has never been published. The stratigraphic column and some details of the geology of the county have been published in field guidebooks (West Texas Geol. Soc., 1941; Abilene Geol. Soc., 1949, 1954).

Plan of the present work.—The work by Scott and Armstrong was done over a period 20 to 25 years ago, without benefit of air photographs or adequate base map. Dr. Scott, who did all the work on the Cretaceous and much of the Pennsylvanian, is now deceased. Because it was deemed impractical to revise the manuscript and publish it as a text for the map by Scott and Armstrong (1930), it seemed advisable to re-map the county completely, using late flight air photographs for field guidance and base map, and rewrite the geologic report on the basis of new field studies. This paper is based very largely on the results of the work required to make a new geologic map of the county. The study has been a project of the Bureau of Economic Geology, The University of Texas.

All but one of the rock units defined for the first time by Scott and Armstrong are recognized and a type section designated for each. The geologic names used by them are retained and are presented in the stratigraphic charts for the Pennsylvanian beds and Cretaceous rocks (figs. 2 and 4). Some units of the Pennsylvanian classed as members by Scott and Armstrong are reclassed as formations. Descriptions of the rocks are based on extensive restudy of the outcrops. The occurrences of fossils are noted, but no comprehensive collections were made from beds whose fossils were listed by Scott and Armstrong. The fossils listed in this paper are largely from their manuscript.

Acknowledgments.—The most important contribution to this paper is the excellent original work of Scott and Armstrong. Their additions to the classification of the Pennsylvanian rock units are incorporated in this paper. Their fossil lists for both Cretaceous and Pennsylvanian have been included after checking for necessary taxonomic changes. Special thanks are due Dr. B. F. Perkins, of the University of Houston; Dr. Keith Young, of The University of Texas; Professor Edward Heuer, of Texas Christian University; for their kindness in doing the very important work of bringing the fossil lists up to date taxonomically.

The following graduate students of Texas Christian University gave invaluable aid in many phases of the work: Frank Markovic described the basal red beds of the Cretaceous; W. E. Russell mapped the details of the Pennsylvanian in the Lazy Bend area; Garner Wilde collected and identified the fusulinids of the Pennsylvanian; Henry Ohlen aided in the correlation of the surface and subsurface sections; Alfred Wright did a careful study of the Brazos River sandstone; David Knopp and Dale Hodgson have contributed a detailed stratigraphic study of the lower Trinity sand section; Charles Menut's very careful investigation of the structure and stratigraphy of the Pennsylvanian in the Kickapoo Creek and Dennis areas has made possible a dependable correlation between those areas; Oattis Parks made a detailed topographic study and geomorphic analysis of the Brazos River valley.

Over 500 aerial photographs needed for stereoscopic coverage of Parker County were purchased from Texas Christian University research funds.

Painstaking criticism of the manuscript by Dr. John T. Lonsdale, Dr. V. E. Barnes, and Miss Josephine Casey has removed errors and contributed to the clarity of the writing. Responsibility for the preparation of the geologic map and other illustrations has been fulfilled in excellent manner by Mr. J. W. Macon, cartographer.

Grateful acknowledgment is made to all those who have added so largely to the quality of the work.

SURFACE STRATIGRAPHY

The geologic section exposed in Parker County, Texas, consists entirely of sedimentary rocks of Pennsylvanian, Cretaceous, and Pleistocene age. The unconformity between the Pennsylvanian and Cretaceous is angular, with the beds of the two systems dipping in almost opposite directions.

Pennsylvanian Rocks

Formations of Pennsylvanian age crop out in a narrow, irregular band along the western edge of Parker County (Pl. I, in pocket). The Brazos River and its tributaries have removed younger rocks and developed a topographic pattern strongly influenced by the attitude and nature of the bed-rock. The direction of regional dip is northwesterly, and the angle of dip varies from 1 to 2 degrees. The formations consist of soft shales with resistant sandstone and limestone members. The resultant topography is a series of roughly parallel scarps capped by the hard members. The sandstones and limestones are the key beds for mapping purposes.

Pennsylvanian rocks are present at the surface in a small area along the southern edge of Parker County, west of Brazos River. The exposure is part of an inlier in Kickapoo Creek valley, lying chiefly in Hood County. A few feet of Pennsylvanian beds are also exposed in the extreme northwest corner of the county, separated from the main Pennsylvanian outcrop in the county by a westward extension of the Cretaceous rocks.

The Pennsylvanian rocks of north-central Texas have been variously classified as members, formations, and groups on the basis of mappable units. They have also been classified into series on the basis of geologic age. The history of the classifications advocated in publications concerning the beds occurring in Parker County is summarized in figure 3. Following is a member-by-member description of the nature and occurrence of the mappable units in Parker County, beginning with the oldest.

Kickapoo Creek Section

An outcrop of Pennsylvanian beds extends into the south edge of Parker County from Hood County along Kickapoo Creek 4 miles south and slightly west of Dennis. The exposures do not offer opportunity for accurate measurement of thicknesses, but there appears to be less than 100 feet exposed. The lowest beds are gray to maroon, silty shale with thin lensing sandstone beds. The shale is overlain by a massive sandstone in part cross-bedded which varies in thickness from 4 to 10 feet. Above the sandstone is a brown to maroon shale generally less than 10 feet thick which is remarkably fossiliferous at a locality about 300 yards south of the Parker County line. The exposure is at the foot of an east-facing scarp, known as Dickerson scarp, and is about 200 yards east of the road to Lipan in Hood County. A list of fossils reported by Scott and Armstrong (MS) is given below. Above the maroon shale are 2 or 3 feet of fine-grained sandstone. Above the sandstone the succession is somewhat obscure but apparently contains a silty shale, a bed of brown, fossiliferous limestone, a gray shale, and immediately under the Cretaceous, a gray limestone 3 to 6 feet thick. The gray limestone can be mapped southwestward into Hood County to Kickapoo Falls on Kickapoo Creek, thus identifying it as the Kickapoo Falls limestone (Plummer, 1919, p. 138).

Fusulinid species *Fusulina euryteines* and *Wedekindellina euthysepta* have been reported from the Kickapoo Falls limestone and underlying shale (Wilde, 1952). The succession cannot be seen in one continuous section. Exposures occur intermittently along Onion Branch southeast of old Rayville townsite and along the next tributary to the east. Plummer (1919) named the limestone the Kickapoo Falls, with type locality at Kickapoo Falls in Kickapoo Creek, about 1 mile south of the

Parker County line. The writer has not been able to duplicate the details of lithology or thicknesses of a section one-half mile northeast of Rayville, described by Plummer and Moore (1922, p. 70). Following is a list of fossils, with recent taxonomic corrections, from the shales underlying the Kickapoo Falls limestone as reported by Scott and Armstrong (MS):

Foraminifera—
Fusulina sp.

Anthozoa—
Lophophyllidium sp.
Lophophyllidium cf. *L. plummeri* Jeffords
Lophophyllidium cf. *L. spinosum* Jeffords
Caninia torquia (Owen)

Bryozoa—
Species

Brachiopoda—
Derbyia cf. *D. crassa* (Meek and Hayden)
Dictyoclostus coloradoensis (Girty)
Neospirifer cameratus (Morton)
Punctospirifer kentuckiensis (Shumard)
Marginifera sp.
Chonetes granulifer Owen
Juresania nebrascensis (Owen)
Linoproductus sp. aff. *L. meniscus* Dunbar and Condra

Scaphopoda—
Dentalium sp. aff. *D. indianum* Girty
Plagioglypta sp.

Scyphozoa—
Conularia spp.

Pelecypoda—
Astartella cf. *A. concentrica* (Conrad)
Nucula (Nuculopsis) girtyi Schenck

Gastropoda—
Pseudozygopleura multicostata (Meek and Worthen)
Pseudozygopleura scitula (Meek and Worthen)
Strobeus sp.
Strobeus primogenius (Conrad)
Bucanopsis sp.
Murchisonia sp.
Bellerophon sp.
Naticopsis sp.
Worthenia tabulata (Conrad)
Euomphalus sp.
Straparolus (Amphiscapha) catilloides (Conrad)
Straparolus (Euomphalus) cf. *S. (E.) pernodosus* Meek and Worthen
Trachydomia sp.

Nautiloidea—
Metacoceras sp.
Several indeterminate genera

Ammonoidea—
Pseudoparelegoceras brazoense Plummer and Scott

Crinoidea—
Woodocrinus sp.
Stems

The Kickapoo Creek and Brazos River valley exposures of Pennsylvanian rocks are separated by an area 2½ to 3 miles wide covered by Cretaceous rocks. Facies changes and local irregularities in dip and strike make correlation difficult from one area to the other. As a consequence there has been lack of agreement in placing the Kickapoo Creek section in the Pennsylvanian succession. Plummer and Moore (1922, p. 72) considered the limestone beds exposed near old Rayville site to be younger than the Dennis Bridge limestone, exposed at the south end of Dennis bridge on the Brazos River. Accordingly the beds of the Kickapoo Creek section would belong in the Hill Creek member of the Lazy Bend formation, described below. Scott and Armstrong (MS) placed the Kickapoo Falls limestone of the Kickapoo Creek section 90 feet below the Dennis Bridge limestone of the Brazos River section on the basis of field evidence from plane-table work done by the Prairie Oil and Gas Company. They applied the name Dickerson beds to the section from the base of the Kickapoo Falls limestone downward for an unknown depth to the Smithwick of the lower Pennsylvanian. The name apparently was taken from a small escarpment of that name that extends from Hood County into Parker County along the northwest side of Kickapoo Creek and dies out at the intersection of the Kickapoo and Onion Branch valleys. The interpretation of the section by Scott and Armstrong was accepted and published by Sellards (1933) and Cheney (1940). S. P. Ellison (personal communication) on the basis of detailed field work done by graduate students under his supervision, believes the Kickapoo Falls limestone is younger than the Dennis Bridge limestone.

After a careful analysis of the structural and stratigraphic evidence observed in the rocks in Kickapoo Creek valley and in the Dennis area on the Brazos River, the writer is of the opinion that the Kickapoo Falls limestone occupies a slightly higher stratigraphic position than the Dennis Bridge limestone. It is believed that the Dennis Bridge limestone lenses out and does not appear in the Kickapoo Creek valley. The Kickapoo Falls limestone may be present in the Dennis area, exposed in a small creek on the south side of the Brazos River one-fourth mile west of the bridge at Dennis.

The rocks occurring below the Kickapoo Falls and Dennis Bridge limestones in Parker and Hood counties are not sufficiently exposed to offer a type section for naming a stratigraphic unit. The stratigraphic designation of the beds between the Dennis Bridge and the lower Pennsylvanian Smithwick of north Texas would be more properly based on good sample descriptions from a well, since only the top of the unit is exposed at the surface. Cheney has applied the term Parks group to beds (Cheney et al., 1945, p. 162) probably equivalent to those exposed along the southern boundary of Parker County.

BASAL BEDS IN THE BRAZOS VALLEY

Pennsylvanian beds are exposed intermittently for a distance of approximately 1 mile along the meanders of Patrick Creek, about 1 mile east of Dennis. Exposures begin a short distance above the mouth of the creek. The oldest bed is a fine-grained, thick-bedded sandstone exposed in the bed of the creek near the north end of the prominent westward meander of the creek. Gray to purplish, nonfossiliferous shale is exposed in the bluffs along the meander. Total thickness of the exposed section is approximately 15 feet.

A small exposure of similar purplish shale occurs in a gully on the south side of Brazos River one-fourth mile east of the Dennis bridge over that river.

The topographic position of these isolated outcrops places the beds stratigraphically below the Dennis Bridge limestone, but the outcrops are too meager and the lithology too undistinguished to deserve a specific stratigraphic name. The beds therefore could best be classified by correlation with subsurface studies.

LAZY BEND FORMATION

Beds cropping out along Brazos River upstream from the Dennis bridge to beyond Lazy Bend are placed in the Lazy Bend formation. Base of the formation is the base of the Dennis Bridge limestone, and the top is at the top of the Brannon Bridge limestone. Cheney has included the Dennis Bridge in the Parks group (Cheney et al., 1945), but it is more feasible to map it with the Lazy Bend beds. There is no continuous type section of the formation. Knowledge of the succession is gained by mapping key beds between separated outcrops, and type sections are established member by member. The formation is predominantly shale but contains some sandstones and includes several prominent limestone beds.

This definition of the base of the Lazy Bend differs from the one accepted by Sellards (1933) on the authority of the Scott and Armstrong manuscript, which placed the base of the Lazy Bend at the base of the Kickapoo Falls. The change is justified because of lack of a clear-cut correlation of the Kickapoo Falls limestone.

Hill Creek member.—The oldest member of the Lazy Bend formation is named for Hill Creek, a small tributary flowing from the southwest into the Brazos River at a point approximately midway of the outer curve of the Lazy Bend of the river (Pl. I). The member consists of 277 feet of beds between the base of the Dennis Bridge limestone and the top of the Meek Bend limestone. Outcrop of the beds extends to the Cretaceous on either side of the Brazos River and from the bridge at Dennis westward to a scarp west of Hill Creek. Tracing of key beds in the member is complicated by small-scale faulting in the area immediately southwest of Lazy Bend. The middle portion of the member is exposed along the north bank of the Brazos 2 miles west of Dennis, where river erosion has created bluffs 25 to 30 feet high. Other exposures occur in steep walls of small tributary valleys entering the Brazos. There are no outcrops that expose more than 40 feet of continuous section. The member can be measured by plane-table and hand level, shifting on key beds from one measurable portion to another. The section thus measured across the strike south of the Brazos River is designated the type section.

The Dennis Bridge and Meek Bend limestones are designated as beds instead of members because of their insignificant thickness and minor outcrop extent.

Dennis Bridge limestone bed.—The oldest bed of the Lazy Bend formation is a limestone cropping out at the south end of the bridge over the Brazos River at Dennis, in the southwest part of the county. The bed is named the Dennis Bridge limestone, and the outcrops at the end of the bridge constitute the type locality. Cheney (1940) called the Dennis Bridge a member of the Lazy Bend formation, but the small size of its known extent hardly justifies that designation. The limestone exposure extends westward along the Brazos for one-fourth mile to the valley of a small tributary. The basal 3 feet of the Dennis Bridge limestone is exposed in a small outcrop in a stream bank one-half mile east of the south end of the bridge at Dennis. These outcrops are the only surface occurrence of the limestone. Along the strike the bed is covered by alluvium and Cretaceous rocks.

The Dennis Bridge limestone is 10 feet thick with massive bedding in its lower part and irregular, thin bedding in its upper part. The texture is very fine grained to sublithographic. The rock is medium gray on fresh surfaces and weathers to a very light gray. Calcareous fossil shells and fragments are very tightly cemented in the crystalline matrix with brachiopods and gastropods as the principal megafossils. Fusulinds are abundant in the top few inches of the limestone, are present in the basal 3 feet of the limestone, and occur in the upper few inches of shale immediately beneath the limestone.

Scott and Armstrong (MS) report the following fossils collected from the Dennis Bridge limestone. The taxonomy has been brought up to date by recent corrections.

Foraminifera—
Fusulina euryteines Thompson

Anthozoa—
Lophophyllidium cf. *L. plummeri* Jeffords

Bryozoa—
Fenestella sp.
Tabulipora sp.

Brachiopoda—
Dictyoclostus coloradoensis (Girty) ?
Neospirifer cameratus (Morton)
Phricodothyris perplexa (McChesney)
Cyurithyris planoconvexa (Shumard)
Composita subtilita (Shepard)
Composita sp.

Pelecypoda—
Solemya sp.

Gastropoda—
Bembexia sp.
Porcellia sp.
Murchisonia sp.
Naticopsis sp.
Meekospira sp.

Crinoidea—
Stems

Trilobita—
Ditomopyge scitula (Meek and Worthen)

Vertebrates—
Fish tooth

Beds above Dennis Bridge limestone.—At the south end of the bridge at Dennis the Dennis Bridge limestone is overlain by 3 feet of shale. Above the shale is a massive sandstone body with both cross-bedding and thick normal bedding. Maximum thickness is 12 feet. Composition ranges from very fine quartz sand to quartz and chert grains of gravel size. The cross-bedded portion has the coarsest texture. The sand body lenses out completely within one-fourth mile to the west. Outcrops are insufficient to offer conclusive evidence that the sand was a bar deposit, but it is so interpreted.

Slightly over one-fourth mile southwest of the bridge at Dennis approximately 5 feet of a dense, gray, fossiliferous limestone is exposed in the bed of a small creek. Lying on top of the limestone is an impure, brownish calcareous layer, 1 to 3 inches thick, that contains an abundance of fusulinids and scattered traces of woody plant remains. The limestone bears close resemblance to the Dennis Bridge limestone, but the writer is of the opinion that it is slightly higher in the section. The limestone possibly at one time was draped over the sandstone lens described above and has been removed from over the sand by erosion. Structural and stratigraphic evidence supports the correlation of the limestone with the Kickapoo Falls limestone in Kickapoo Creek valley, but the two limestones may be separate lenses at slightly different stratigraphic levels.

The limestone is overlain by 10 feet of purplish, green, and yellowish weathering shale. Above the shale is a hard, light brown, very fine-grained limestone bed ranging from 1 to 2 feet thick. Crinoid stems are fairly abundant, and a cross section of a straight nautiloid was seen.

Above the brown limestone bed is a shaly succession 113 feet thick containing silty and sandy layers and lenses and a few thin beds of sandstone. The lower portion contains purplish to yellowish shales, and the upper portion is gray, poorly laminated, and contains microscopic lignite flakes. Above the shale occurs a traceable sandstone (Bed n, geologic map, Pl. I) from 6 to 10 feet thick. It is massive, medium to fine grained, grains mostly angular, poorly bedded where thickest, and well bedded in its thinner portions. The sandstone is noncalcareous but is well indurated by compaction and a small amount of argillaceous cement. Above the sandstone is 56 feet of shale with lensing sandstone layers near the top. The lower part of the shale is soft, gray, poorly laminated. The upper part becomes purplish upon weathering. Sandstone molds of fragments of the scale tree *Lepidodendron* occur in the sandstone layers near the top. One of the thin sandstones exhibits remarkably well-developed current-made ripple marks (Pl. II, B).

The next limestone of the Hill Creek beds lies above the shale and sand beds. The bed can be mapped in a northeast-southwest direction across Brazos River, passing beneath Cretaceous rocks in each direction (Bed m, geologic map, Pl. I). The bed becomes very thin before passing under the Cretaceous to the southwest. It forms a capping bed on top of the ridges between small tributaries south of the Brazos and east of Hill Creek. Dip carries the limestone down to the bed of Hill Creek. A good exposure occurs in a small waterfall one-fourth mile above the mouth of the creek. The limestone varies from 1 foot at its southwest exposure to 6 feet in the bed of Hill Creek. It is medium to thin bedded. The upper surface is somewhat hummocky, and the texture is very fine crystalline; color on fresh surfaces varies from gray to slightly brownish. Small brachiopods and fragments of other fossils occur sparingly in the limestone where it is less than 3 to 4 feet thick. The upper part is a finely divided bioclastic limestone where it thickens to 6 feet, as in the bed of Hill Creek.

The Hill Creek beds above the limestone are shales enclosing sandstone lenses and containing one discontinuous limestone bed (Bed l, geologic map, Pl. I) in the middle of the interval that reaches 8 feet in thickness (Pl. II, A). Total measured thickness of the interval in the Hill Creek area is 82 feet. The shales are grayish weathering, poorly laminated, and range from pure clay to slightly silty clay. The limestone is light gray, crystalline, well to irregularly bedded where it is more thickly developed, but where it is 3 feet or less in thickness it is brown, slightly silty, and in places finely arenaceous. The limestone and the shales immediately associated with it contain a variety of fossils, including foraminifers, sponges, echinoderm fragments, bryozoans, brachipods, pelecypods, gastropods, and nautiloids. The fusulinid *Fusulina euryteines* has been identified from a zone a few feet above the limestone.

The sandstone lenses in the upper Hill Creek beds thicken very rapidly, suggesting that they may be sand bars or channel fillings. They are fine-grained, massive bodies, with generally poor bedding. The most notable lens is exposed in the west bluff of the Brazos River about one-half mile north of the mouth of Hill Creek (Pl. III, B). It is 40 feet thick, replacing the shales and lensing limestone normal to the section. Exposures are insufficient to outline the three-dimensional shape of the lenses.

Meek Bend limestone bed.—The Meek Bend limestone (Bed k, geologic map, Pl. I) is named for Meek Bend of Brazos River, although the limestone dips below the surface about halfway between Lazy Bend and Meek Bend. The limestones that crop out near Meek Bend are the Brannon Bridge limestones higher in the section. The type section of the Meek Bend limestone is in the scarp northwest of Hill Creek approximately 1½ miles southwest of the mouth of Hill Creek. The limestone forms the top of an irregular scarp extending from Brazos River southwestward to the Cretaceous rocks near the southwest corner of Parker County. It underlies an extensive dip slope northwest of the scarp and is well exposed in the bed and bluffs of Rocky Creek.[2] The Meek Bend is not exposed east of Brazos River because of alluvial cover.

Maximum thickness of the Meek Bend limestone is 12 feet, measured in the scarp northwest of Hill Creek. Bedding of the limestone varies considerably, ranging from thin, flaggy to massive. Bedding surfaces are characteristically hummocky (Pl. III, A). Texture is fine to medium crystalline. Color is generally gray, with some beds exhibiting light mottled brown and others a dark gray color, and all weather to a uniform light gray color.

The most abundant fossils in the Meek Bend are brachiopods and crinoid stems, with pelecypods and gastropods occurring more sporadically.

Steussy shale member.—The Steussy member of the Lazy Bend formation is defined as those beds occurring between the Meek Bend limestone and the lower Brannon Bridge limestone. The origin of the name Steussy is not clear in the Scott and Armstrong manuscript. The upper part of the shale is exposed in a long, prominent scarp northwest of Rocky Creek west of the Brazos River. The feature is called Steussy Scarp by Scott and Armstrong, giving the impression that the geological name is after the topographic feature bearing that name. Outcrop of the member extends northeast-southwest along the valley of Rocky Creek, southwest of the straight portion of the Brazos River between Meek and Lazy bends. Outcrops east of the Brazos are in the valley of a small tributary entering the Brazos approximately 1 mile north of the mouth of Rocky Creek. The lower portion of the member is completely exposed on the west side of a small, very steep-sided hill located on the southeast side of Rocky Creek, just southwest of the crossing of the main north-south ranch road through the area. The hill is capped by a thickened portion of a sandstone in the middle of the member (Bed j, geologic map, Pl. I). A type section for the member is based on exposures on the west side of the hill and in cuts of the ranch road crossing Steussy Scarp to the north.

Total thickness of the Steussy is 180 feet. The lower 90 feet of shale overlain by 40 feet of sandstone is well exposed on the west side of the small hill described above. Poor exposures of the beds immediately above the sandstone occur in gullies crossing the slope between Steussy Scarp and Rocky Creek. The upper 30 feet of the member are intermittently exposed along Steussy Scarp below the capping Brannon Bridge limestone.

The lower Steussy shale beds range from smooth, clay shales with conchoidal fracture to slightly brittle, poorly laminated, silty shale. Color is from light to dark gray. A small amount of fine, lignitic material occurs throughout the unit, and a slight increase in the lignitic material accompanies an increase in siltiness of the shale. A sandy zone near the middle of the Steussy member consists of alternating beds of sand and sandy shale. The sandstone beds are from 1 inch up to 18 inches thick and appear to be lensing beds. The top of the zone exhibits discontinuous massive sand bodies reaching 15 feet in thickness. Cross-bedding is developed in the massive sand bodies. Grain size ranges from very fine in the thin beds to medium coarse in the thick massive beds. The sand grains are almost all pure quartz, angular to sub-rounded. The sandstones are noncalcareous and contain a small amount of

[2] Rocky Creek flows from the southwest into Brazos River just north of Lazy Bend. Rock Creek flows from the north into Brazos River at the northeast corner of Littlefield Bend. The similarity of names can cause confusion.

clay-cementing material. The upper Steussy beds are clay shales with one thin limestone bed near the top. The shales are dark gray and in part slightly mustard green. The limestone is dark, somewhat impure, and develops yellowish weathering surfaces. Exposures are not sufficient to reveal whether the limestone is lensing or continuous.

The lower Steussy shales and the sandstones appear to be barren of fossils. A sparse occurrence of fusulinids has been found at one locality in the upper shales, immediately underneath the thin limestone (Wilde, 1952). *Wedekindellina excentrica* has been identified.

Brannon Bridge limestone member.—The Brannon Bridge limestone is the top member of the Lazy Bend formation. The name is from a former highway bridge that spanned the Brazos River at a point three-fourths of a mile south of the present U. S. Highway 80 bridge. The cable supports at the east end of the old bridge were anchored in the upper of the two prominent limestones in the member. Outcrop of the member extends south of U. S. Highway 80 along the west side of the ingrown meander of the Brazos River forming Meek Bend. Alluvium covers its outcrop along the southeast side of the bend. Beds of the member emerge from beneath the alluvium at the northeast corner of the bend, swing northward up the valley of Grindstone Creek, and extend southward a short distance along the straight portion of the river leading to Lazy Bend. The outcrop widens to a maximum of 1½ miles and extends eastward from the mouth of Grindstone Creek to the Cretaceous cover. A large portion of the widened outcrop is a dip slope on top of the lower limestone.

Outcrops of the Brannon Bridge member on the west side of the Brazos River are in the bluffs along the west and south sides of Meek Bend. Much of the area within the northward loop of the river east of Meek Bend is underlain by the member. The southeast edge of the outcrop forms Steussy Scarp, which begins near the river and extends southwestward across the county line. The outcrop northwest of the scarp is chiefly a dip slope on the upper limestone. Excellent exposures occur along the scarp, where rapid erosion of the underlying Steussy shale has created steep slopes. Jointing is not especially well developed in the limestones but is sufficient to cause large blocks to slump down the slope along the scarp. Fresh exposures of the upper limestone occur in two large rock quarries located west and southwest of Meek Bend (Pl. I). The type section of the Brannon Bridge member is the succession of beds exposed in Steussy Scarp.

The Brannon Bridge member is composed of two limestones (Pl. IV) separated by shale and discontinuous sand bodies. The lower limestone (Bed i, geologic map, Pl. I) is 15 feet thick and the shale 22 feet thick measured at Steussy Scarp where a ranch road crosses the scarp approximately 1½ miles west of Brazos River. The lower limestone is fairly pure and well crystallized. The gray limestone weathers to a light gray. Bedding surfaces are mostly uneven and hummocky. Bedding thickness ranges from 2 to 18 inches. The rock is somewhat fossiliferous, small brachiopods being the most abundant. Ostracods are scattered in occurrence, and fusulinids are very sparse. Calcite has replaced many unidentifiable fragments. The shale overlying the lower limestone is a soft, poorly laminated clay-shale that weathers to a slightly greenish gray. No fossils have been found in the shale. A lensing sandstone in the upper part of the shale has a maximum thickness of 4 feet in exposures in the drainage immediately south of Meek Bend. The sandstone is fine grained, well sorted, and bedding is poorly developed. The upper limestone of the Brannon Bridge (Bed h, geologic map, Pl. I) is 17 feet thick in a quarry located on top of the cliffs south of Brazos River at Meek Bend. The rock is finely crystalline with coarser crystalline calcite bodies that may be replacements. The color is a uniform light gray. Small dark chert lenses parallel with the bedding occur in the upper part of the limestone, and the chert has the same texture as the limestone. Bedding is poorly developed, with uneven planes. Thickness of beds ranges from 3 inches to 2 feet. The limestone is sparingly fossiliferous with scattered occurrences of brachiopods, bryozoans, and fusulinids. Fusulinids from the basal portion of the exposure in the quarry mentioned above have been identified by Wilde (1952) as *Wedekindellina excentrica* and *Fusulina novamexicana. Fusulina haworthi* was collected by Wilde from the top of the Brannon Bridge limestone exposed in a small creek at a locality approximately one-fourth mile south of U. S. Highway 80 and one-fourth mile east of Brazos River.

GRINDSTONE CREEK FORMATION

The Grindstone Creek formation is chiefly a succession of shales, sandy shales, and sandstones occurring immediately above the Brannon Bridge limestone. The top of the formation has been defined in Palo Pinto County (Plummer and Hornberger, 1935) as being at the base of the Thurber coal where present and at the top of the Goen limestone where the coal is missing. The Thurber coal is missing in Parker County, and the Goen limestone can be traced from Palo Pinto County only one-half mile eastward into Parker County. Remnants of the limestone occur on the highlands west of the Bennett brick yards, located immediately north of Littlefield Bend[3] of the Brazos River. Northeastward from that locality the boundary between the Grindstone Creek and the overlying Garner formation is mapped by projection of the topographic and structural position of the Goen limestone. This procedure is highly unsatisfactory for mapping in Parker County, but it is judged best to leave the formation boundary defined as above because of the rather extensive area in Palo Pinto County where the boundary can be mapped on key beds.

The chief outcrop of the Grindstone Creek formation in Parker County is south of Millsap and east of Littlefield Bend. Grindstone Creek flows across the extreme eastern edge of the outcrop and is the source of the name. The best exposures of the formation occur in scarps and artificial cuts near the Brazos River. The lower shales are exposed in the scarp immediately north of U. S. Highway 80, east of the river. The middle portion of the formation is beautifully exposed in the road cut southeast of Bennett, just north of the mouth of Rock Creek (Pl. V, A). Approximately the same portion of the section is also exposed in the clay pits at Bennett. The upper part of the section composes the scarp west of Bennett. The type section is designated as including the above exposures and extending from the top of the Brannon Bridge limestone to the top of the easternmost Goen limestone on the highland west of Bennett.

Few exposures of the Grindstone Creek occur in Parker County west of the Brazos River, most of the formation being covered by alluvium on the slip-off slope of the Littlefield Bend meander.

Thin beds of siltstone and sandstone are encountered at irregular intervals in the shales of the Grindstone Creek formation. Some of the sandstones preserve well-developed current-made ripple marks. Many of the sandstones are small, lenticular bodies (Pl. V, B), few of which have a maximum thickness of as much as 2 feet. Aside from the silty, sandy zones the shales are largely clay-shales with poor to fairly well-developed lamination. Shales in the upper half of the formation furnish material for brick making at Bennett, and the faces of the clay pits offer excellent opportunity to study fresh exposures. No significant variation in the Grindstone Creek shales can be established by field study and examination of samples under low magnifications.

Mappable sandstones and limestones in the Grindstone Creek are key beds in the field study of the formation. The lower 185 feet of the formation can be measured in a traverse starting on the Brannon Bridge limestone approximately one-fourth mile southeast of U. S. Highway 80 Brazos River bridge and proceeding northward to the top of the ridge north of Highway 80. The top of the ridge is capped by 33 feet of sandstone whose base is 152 feet

[3] It is believed that the name Littlefield is correctly used here. Plummer and Hornberger (1935, geologic map) applied the name to the next southward loop of the river upstream.

above the base of the Grindstone Creek formation (Bed g, geologic map, Pl. I). The lower 13 feet of the sandstone is medium grained, fairly well sorted, and well bedded, with beds ranging up to 2 feet in thickness. The upper 20 feet is massive, cross-bedded, and locally exhibits curiously twisted, contorted bedding. Grain size ranges from medium to very coarse. The sandstone can be traced northward along the east side of the Brazos River for approximately 1 mile to where the topography is suitable for measuring above the sandstone.

Sixty-seven feet higher than the above-described sandstone is a medium-grained sandstone 12 feet thick. The lower 5 feet of the sandstone is massive, and the upper 7 feet is well bedded. The sandstone is not well exposed along the outcrop and is not shown on the map.

Santo limestone bed.—A limestone 23 feet higher in the section is identified as the Santo limestone, named by Plummer and Hornberger (1935) from outcrops in Palo Pinto County. The outcrop of the Santo limestone is interrupted by the large Littlefield Bend of the Brazos River. Correlation of the Parker County exposures is made on similarity of lithology and stratigraphic position. The limestone is gray to brownish gray and is fairly pure. Thickness ranges from 2 to 4 feet, and bedding is irregular to massive. Fusulinids are fairly abundant and include *Wedekindellina excentrica* and *Fusulina haworthi.* Outcrop of the limestone (Bed f, geologic map, Pl. I) is on the highland and in the steep slope along the Brazos River immediately east of Littlefield Bend. The bed dips underneath the alluvium of Rock Creek approximately one-fourth mile upstream from the mouth of the creek.

A fairly well-bedded, fine-grained sandstone occurs 126 feet above the Santo limestone. The bed varies in thickness, with a maximum of 6 feet.

Fifteen feet above the sandstone is the level of an impure, sandy, lensing limestone. Scattered fusulinids are present in its outcrops on top of the high hill immediately east of the mouth of Rock Creek and in the cuts of the road to Millsap on the north edge of Bennett.

A prominent sandstone with a maximum thickness of 22 feet occurs 48 feet higher in the Grindstone Creek formation. The sandstone is medium grained and fairly well sorted. It shows very little evidence of bedding where exposed on the hilltops east of Bennett but is thick bedded where the Millsap road crosses it at the top of the scarp immediately north of Bennett. The trace of the outcrop (Bed e, geologic map, Pl. I) partially surrounds and extends southeast of Bennett.

Goen limestone bed.—The Goen limestone (Plummer and Hornberger, 1935, p. 16) is 35 feet higher than the above-described sandstone on the top of the highland west of Bennett. The limestone either lenses out to the east, or its eroded edge is covered by debris from the dissected dip slope of the underlying sandstone. Its approximate position is indicated on the geologic map by the dashed-line boundary between the Grindstone Creek and overlying Garner formation. In Parker County the limestone is only 1 to 2 feet thick; it is gray to yellowish gray. Fossils in and immediately underneath the limestone include brachiopods, clams, gastropods, straight cephalopods, crinoid and echinoid fragments, and fusulinids. It is locally crowded with fusulinids at localities approximately 2 miles westward in Palo Pinto County.

The limestones and associated beds furnish the only fossils found in the Grindstone Creek formation. The most notable fossil locality in the formation is 1 mile due northwest of the intersection of Farm Road 1543 and U. S. Highway 80, where several feet of shale beds are exposed in the east bank of Grindstone Creek. The beds are at the approximate stratigraphic position of the Santo limestone, although the Santo cannot be traced from its outcrop to the locality because of an intervening colluvium-covered area. A layer containing irregular calcareous nodules overlies fossiliferous shales from which has been collected an abundance of echinoid fragments, gastropods, brachiopods, solitary corals, bryozoans, and the fusulinid *Fusulina haworthi.*

GARNER FORMATION

The Garner formation consists of the Mingus (Plummer and Moore, 1922) shale member overlain by the Brazos River (Plummer, 1919; Plummer and Moore, 1922) sandstone member. Both rock bodies were named from exposures in Palo Pinto County. Chief exposures in Parker County are along the valleys of Rock Creek and Dry Creek and their smaller tributaries in the area between the Mineral Wells & Western Railroad and the Texas & Pacific Railroad. Original mapping identified the sandstone and conglomerate beds exposed in Dry Creek near Garner as the Brazos River member; hence the name Garner for the formation. Detailed mapping on air photographs places the sandstone beds near Garner in the overlying East Mountain formation. The basal portion of the Garner formation is not well exposed in Parker County except for a few feet of shale and sandstone above the Goen limestone outcrops west of Bennett. The type section is chosen where the best and most nearly continuous exposure of the formation occurs along the Millsap to Mineral Wells highway as it ascends a scarp 2½ miles west of Millsap. Approximately the basal 45 feet of the formation is not exposed in the type section, and the section does not exhibit a thin coal seam or lensing limestones present in other localities. The resistant Brazos River member caps the steep scarp in which the exposures are found.

Mingus shale member.—The basal 12 feet of the Mingus member includes a fine-grained sandstone with a maximum thickness of 4 feet. The sandstone caps the highest topography on top of the scarp west of Bennett. The base of the member is not exposed elsewhere in the county, so the extent of the sandstone cannot be established.

Eighty-five feet of the Mingus is well exposed in the type section of the Garner formation west of Millsap. The base of the exposed section is approximately 45 feet above the base of the Mingus. A small topographic projection in front of a steep scarp is capped by a sandstone, and the shale is exposed in the steep slopes below the sandstone. The shale is a gray to slightly buff-weathering clay-shale. The upper 40 feet of shale in the section is very slightly silty and contains small fragments and films of lignitic material. The sandstone is very fine grained, well bedded, and is 13 feet thick. A bed of the sandstone near its base is calcareous and contains fossil fragments. Fusulinids are rare in the bed, *Fusulina similis* having been identified (Wilde, 1952). The bed is more calcareous in exposures to the north and northeast of Millsap, where the sandstone is less well developed. The trace of the base of the sandstone, or the calcareous bed where the sandstone lenses out, is shown as Bed d on the geologic map (Pl. I).

A few exposures of the Mingus near the foot of the scarp along the west side of Dry Creek east of the Mineral Wells airport contain a thin coal seam, a few feet below the sandstone mapped as Bed d and 85 feet below the base of the Brazos River sandstone. The seam is only 6 to 12 inches thick at the surface, but it was the source of coal for the small-scale coal mining at one time conducted in the area by Texas & Pacific Coal Company. Several old mine shafts are present along Rock and Dry creeks south of the Texas & Pacific Railroad. W. F. Cummins (1891, p. 519) reported the seam in the mines to be 18 to 26 inches thick. Cummins (1891) and Plummer and Hornberger (1935) correlated the seam with the Thurber coal in Palo Pinto County. It is here considered to be somewhat younger than the Thurber because in one of its outcrops it is approximately 110 feet above the base of the Garner formation and only 85 feet below the Brazos River sandstone. In Palo Pinto County the Thurber coal is the basal bed of the Garner formation, 140 to 210 feet below the Brazos River sandstone (Plummer and Hornberger, 1935, p. 199).

The upper part of the Mingus is exposed in outcrops near Cool, located at the intersection of U. S. Highway 180 and Farm Road 113 from the south. The upper 25 feet of the shale is exposed in steep erosional slopes of Dry Creek valley just at the north edge of Cool. The next underlying 45 feet is exposed in highway cuts 1½ miles west of Cool. The shale in the highway cuts is a gray to dark gray, poorly laminated clay-shale. The shale in the slopes north of Cool is buff gray with a maroon-weathering zone at the top. It is slightly silty, with thin siltstone layers. A few feet below the top is a nodular limestone layer whose nodular character gives it the appearance of a limestone conglomerate. Approximately 1 mile north, across the valley of a tributary to Dry Creek, a well-developed limestone is present at the same stratigraphic position. The limestone is very fine grained, light gray, very irregularly bedded, and reaches a maximum of 6 feet in thickness. The nodular phase near Cool and the well-developed phase are fossiliferous, containing crinoid stems and a variety of brachiopods.

Total thickness of the Mingus is 210 feet measured in a traverse from the approximate base of the member in the bed of Rock Creek to the base of the Brazos River sandstone in the scarp west of Millsap.

Brazos River sandstone member.—The conglomeratic sandstone exposed in high bluffs along the Brazos River southwest of Mineral Wells was originally named the Brazos sand (Plummer, 1919). The name was altered to Brazos River sandstone (Plummer and Moore, 1922) because "Brazos" was preoccupied. The bluffs along the Brazos River with the sandstone at the top become a very prominent scarp that crosses from Palo Pinto County into Parker County about 1 mile south of the Millsap to Mineral Wells highway. The scarp extends northeast until it blends into the higher topography near Cool. The scarp is indented by the valley of Rock Creek a short distance inside Parker County. The best exposures of the Brazos River sandstone are in the highway cuts of the Millsap—Mineral Wells highway and U. S. Highway 180, where full thicknesses of the member are exposed. Other excellent exposures are found in the steep slopes along Rock and Dry Creek valleys. The Mineral Wells airport on the Parker—Palo Pinto County line is built on the dip slope of the member.

The nature of the Brazos River sandstone changes radically within its Parker County outcrop. The sandstone is massive, cross-bedded, and contains lenses and beds of coarse conglomerate in the exposures along the highway 2½ miles west of Millsap (Pl. VI). The member remains essentially the same in character south of the highway along its outcrop into Palo Pinto County. In a distance of 100 yards north of the highway the member largely loses its conglomeratic character and is a well-bedded, medium- to fine-grained sandstone. The well-bedded phase composes the remainder of the outcrop northeast to the Cretaceous cover. The vertical walls of the U. S. Highway 180 cut 2 miles west of Cool offer perfect exposures of the well-bedded phase. Detailed study by Wright (1955) disclosed a similar gradation between bedded sandstone and conglomerate along the outcrop across Palo Pinto County.

The conglomerates of the Brazos River member contain a remarkable variety of chert pebbles. Light-colored pebbles are predominant, but green, black, yellow, red, and blue pebbles occur, with occasional occurrences of banded pebbles. Shapes are angular to subrounded; size ranges up to 2½ inches, with the majority near one-fourth inch; and occasional alignment of the pebbles occurs in the conglomerate lenses. Clay balls and flakes are rare. Iron oxide is the commonest cementing material. Bay (1932) has published the results of detailed study of the nature of some Pennsylvanian conglomerates including the Brazos River. He considered the conglomerate exposed near Garner to be a part of the Brazos River, but present mapping places it in the overlying East Mountain formation.

The well-bedded phase of the Brazos River member is made up of beds ranging from flaggy to massive. The beds are separated at intervals by thin, sandy shale layers. The composition is rather pure quartz sand, with scattered occurrences of conglomeratic lenses in the lower portion of the member.

Clay-ironstone pebbles are more abundant than in the conglomeratic phase and are especially noticeable near the transition zone from the bedded to the conglomeratic phase. Majority of the sand is medium grained, with minor portions ranging to coarse and fine. Grains are angular to subangular.

The thickness of the Brazos River sandstone is uniformly 25 to 30 feet in the Parker County outcrop. It appears to be one sand or conglomerate body with only minor shale beds. No evidence was seen to support the statement by Plummer and Hornberger (1935, p. 28) that "The member along its outcrop east of Mineral Wells is made up of two thick sand layers separated by a clay member."

EAST MOUNTAIN FORMATION

The East Mountain was named by Plummer and Moore (1922, p. 77) from exposures on the slopes of East Mountain in the eastern part of Mineral Wells, Palo Pinto County. The outcrop of the formation in Parker County underlies Wolters Military Base and Lake Mineral Wells and extends northeast to the Cretaceous cover north of Garner. The length of the outcrop in Parker County measured parallel to the strike is 5 miles. The lower part of the formation is exposed in the hill slopes south and east of Lake Mineral Wells. Especially good exposures are present below and immediately above the lake spillway and in a clay pit just west of the U. S. Highway 180 crossing of the W.M.W. & N.W. Railroad. The upper part of the formation is exposed in the scarp north of the buildings and roads on Wolters Military Base and in the steep slopes of Rock Creek valley. A portion of the middle of the formation is not well exposed in Parker County.

The East Mountain formation in Parker County consists of shale, one sandstone body, and one conglomeratic sandstone body. The sandstone body has been named the Hog Mountain sand (Plummer and Hornberger, 1935), but the conglomeratic body is unnamed. The shale section below the Hog Mountain is 88 feet thick in a section measured along U. S. Highway 180 at W.M.W. & N.W. Railroad. It is a gray to buff-weathering clay-shale, showing poor lamination. The upper part becomes silty and contains sandstone lenses.

Hog Mountain sandstone bed.—The Hog Mountain sandstone is well exposed in a small quarry just south of Lake Mineral Wells dam. Here 22 feet thick, it is fine to medium grained, poorly to well cemented, and ranges from thick bedded to flaggy. The Hog Mountain caps the highest topography immediately south of Lake Mineral Wells and some small hills and one elongate, narrow ridge southwest of the lake. Its trace is Bed c on the geologic map (Pl. I).

The clay-shale above the Hog Mountain is exposed in a clay pit immediately south of the Mineral Wells waterworks located on the scarp west of Lake Mineral Wells and approximately one-half mile north of the dam. The clay-shale is gray at the base of the exposure and maroon to purple at the top. Thickness of the beds cannot be determined accurately, but field evidence indicates them to be 30 to 35 feet thick. The overlying beds are lensing sandstones that grade upward into a thick, massive conglomerate. The lower layers of the conglomerate are comparatively fine grained and are fairly well bedded. The lower beds were channelled and the channels filled with coarser material. The composition of the conglomerate is similar to that of the Brazos River conglomerate—varicolored, angular to subrounded chert pebbles ranging in size up to nearly 3 inches. The matrix of the conglomerate is sand, cemented with siliceous and ferruginous cement. Spectacular exposures of the conglomerate occur in vertical cliffs along the east side of Lake Mineral Wells. Fifty feet of conglomerate is exposed at a point approximately 1¼ miles by park road from the dam. Much of the surface east and northeast of the lake is covered by the conglomerate. Several shallow road-gravel quarries are located where weathering has loosened the pebbles in the upper few inches. In many cases blocks of the conglomerate have slumped and settled until they are virtually in contact with the Hog Mountain sandstone. Exposures in the bed of Dry Creek west and north of Garner contain conglomerate in the lower portion and well-bedded, coarse- to medium-grained sandstone in the upper part. Bay (1932) described conglomerate samples from near Garner which he identified as Brazos River, but they apparently came from the body here considered a part of the East Mountain formation. The scarp west of Lake Mineral Wells is capped by the conglomerate. No good exposures occur from the crest of the scarp down the dip slope that passes under Wolters Military Base. Where exposures occur along the strike in the eastern edge of Palo Pinto County the conglomeratic phase has graded into a thick-bedded, coarse- to medium-grained sandstone.

The upper 35 to 40 feet of the East Mountain is exposed in a southeast-facing scarp that crosses Wolters Military Base. The beds are poorly laminated clay-shale that weathers light gray from a natural dark gray color. The interval includes the stratigraphic position of the Village Bend limestone mapped in Palo Pinto County (Plummer and Hornberger, 1935), but the limestone cannot be traced into Parker County. No limestone considered to be at the position of the Village Bend as mapped in eastern Palo Pinto County has been observed in Parker County.

The thickness of the East Mountain is 330 feet in a traverse located east of Lake Mineral Wells. The traverse began on the top of the Brazos River sandstone on U. S. Highway 180, carried to the top of the conglomeratic bed on the southeast edge of Lake Mineral Wells, offset down the dip slope on top of the conglomeratic bed to near the mouth of Rippy Branch, and continued north to the base of a sandstone bed considered to mark the top of the formation. Approximately 100 feet of the formation above the conglomeratic bed is not exposed in Parker County. This interval is assumed to be shale because of the absence of any topographic expression such as would be produced by resistant limestone or sandstone beds.

SALESVILLE FORMATION

The lithologic unit immediately above the East Mountain formation is a sandstone body named the Lake Pinto member of the Mineral Wells formation (Plummer and Moore, 1922, p. 77) from outcrops near Lake Pinto one-half mile west of Mineral Wells. The Lake Pinto is overlain by a shale unit named the Salesville member of the Mineral Wells formation (Plummer and Moore, 1922, p. 77) for a small town near the northeastern edge of Palo Pinto County. Cheney (1940) applied the term Salesville formation to rocks including the Lake Pinto sandstone and the original Salesville shale. The writer believes it is confusing to expand the meaning of a rock name vertically to include a previously named rock body. The name Salesville should be considered preoccupied, and a new name given the newly defined formation. Members raised to formation rank should retain the original definition as to the included rocks. But the writer does not wish to add to the complexity by proposing a new name and will use Salesville as defined by Cheney.

Lake Pinto sandstone member.—The Lake Pinto sandstone and associated beds show facies changes in Parker County that considerably complicate their mapping. The beds are medium- to thick-bedded, fine- to medium-grained sandstone where the outcrop crosses the western Parker County line. Outcrops are poor for measuring section, but the thickness is approximately 50 feet a short distance east of the county line. The basal beds of the sandstone form the top of an irregular southward-facing scarp that crosses Wolters

Military Base, and higher sandstone beds underlie the area northward of the scarp. A highly calcareous bed in the middle portion of the Lake Pinto is exposed at a locality one-half mile due east of the intersection of a northern boundary of the military base and the Parker County line. A bed of arenaceous limestone at approximately the same stratigraphic position is present on the back slope of the scarp about three-fourths of a mile southeast of the above locality. One-half mile farther east a fine-grained, light brown limestone 4 feet thick occurs at about the same stratigraphic position as the arenaceous limestone. The brown limestone is exposed at the top of the scarp and can be traced across Rock Creek and its tributaries to the Cretaceous. The field evidence presented above indicates that a limestone lens grades into the middle portion of the Lake Pinto sandstone near the western edge of Parker County. The trace of the limestone is Bed b on the geologic map (Pl. I). Where the limestone becomes prominent the sand bodies above and below the limestone become thinner. The lower sand becomes lenticular at Rock Creek and cannot be found continuously along the outcrop east of the creek. A lens that reaches 10 feet in thickness is present where a north-south road 2.7 miles east of the county line crosses the Lake Pinto outcrop. Scattered occurrences of the sandstone are present at the surface in the southeastern one-half square mile of Wolters Military Base. In that area thin siliceous layers contain excellent imprints of fern leaves. The sandstone above the limestone also thins, possibly becomes lenticular, and cannot be traced continuously across the valley of Rock Creek to the Cretaceous.

The limestone lens in the Lake Pinto portion of the section contains a normal assemblage of marine fossils including brachiopods, bryozoans, and gastropods. Intensive search of the bed has not revealed fusulinids or other fossils with restricted stratigraphic range.

Mapping the contact between the East Mountain and the Salesville formations becomes arbitrary where the lower sand lenses out of the section. The contact has been projected along the outcrop from one sand lens to the next in the area east of Rock Creek. The contact line is dashed where its position is not defined by the presence of Lake Pinto sand.

Shale member.—The shale of the Salesville formation is very poorly exposed in Parker County. It contains one limestone bed whose outcrop can be followed fairly continuously (Bed a, geologic map, Pl. I). The limestone and underlying 25 feet of shale are well exposed in Rock Creek just north of the northern boundary of Wolters Military Base. The upper 15 to 20 feet of the shale member is exposed in the low, south-facing scarp formed by the overlying resistant Turkey Creek sandstone. The lower portion of the shale in that exposure is gray, fairly well laminated, and free of silt. The upper beds weather light gray, are slightly silty, and contain very thin, sandy layers. Average thickness of the shale member is about 100 feet. The thickness increases where the upper Lake Pinto beds grade into shale and are included in the member.

Dog Bend limestone bed.—The limestone in the lower portion of the shale member (Bed a, geologic map, Pl. I) is continuous with a bed mapped and named Dog Bend limestone in Palo Pinto County. The name first appeared on a map published by the Bureau of Economic Geology of The University of Texas (Plummer, 1929). Sellards (1933, p. 106) gave Plummer as authority for the name. Plummer and Hornberger (1935) used the name on their geologic map, but the limestone is not mentioned in the text of their report on the geology of Palo Pinto County. The limestone must have been named from exposures in the Dog Bend of the Brazos River 5 miles west of Mineral Wells. In Parker County the limestone is buff to light gray and very fine grained. Bedding is medium in thickness, with irregular bedding planes. The beds contain brachiopods, gastropods, and scattered crinoid fragments, but no fossils with restricted stratigraphic significance have been found.

KEECHI CREEK FORMATION

The beds overlying the Salesville in Parker County form a sandstone body continuous with a sandstone mapped in Palo Pinto County and named the Turkey Creek sandstone member of the Mineral Wells formation by Plummer and Moore (1922, p. 77) from exposures on Turkey Creek 5 miles west-northwest of Mineral Wells. Above the sandstone is a shale and sandstone succession mapped in Palo Pinto County and named Keechi Creek member of the Mineral Wells formation by Plummer and Moore (1922, p. 78) from exposures on Keechi Creek 7 miles northwest of Mineral Wells. Cheney (1940) used the name Keechi Creek formation to include both the Turkey Creek sandstone and the shale. The same objection applies to this usage as expressed in the above discussion of the Salesville. But the name Keechi Creek as defined by Cheney will be used to avoid adding to the literature a new name for the same beds.

Turkey Creek sandstone member.—The Turkey Creek sandstone forms a continuous trace from the Parker County line to the main east fork of Rock Creek and marks the base of the Keechi Creek formation. The sandstone is thin to massive bedded, with only faint evidences of cross-bedding. The texture ranges from fine grained in the lower beds to coarse in the upper beds. No conglomerate was observed in Parker County. Thickness averages 10 to 12 feet. The sandstone has thinned from a thickness of 26 feet in Palo Pinto County, where the member is conglomeratic (Plummer and Hornberger, 1935).

Shale and sandstone member.—The shale and sandstone member of the Keechi Creek formation is almost totally concealed in Parker County. A fine-grained sandstone near the middle of the member is poorly exposed across the narrow Pennsylvanian outcrop between the county line and the Cretaceous 3 miles southwest of Whitt. The upper 15 feet of the shale can be seen immediately underneath the overlying limestone just west of the Parker County line. The locality is 100 yards south of the first road south of Farm Road 52 running west from Whitt to Oran. The shale grades from gray at the base of the exposure to dull maroon in the upper few feet. The beds are abundantly fossiliferous, containing many crinoid stems and calyx plates, bryozoans in great variety, brachiopods, and gastropods. The upper few inches of the shale are very rich in fusulinids, it being possible to collect dozens of specimens in a few minutes. Wilde (1952) identified *Triticites nebraskensis* and *T. neglectus* from the locality.

Thickness of the Keechi Creek shale and sandstone member cannot be determined in Parker County because poor exposures obscure the dip and strike. A traverse was made 1½ miles west of the county line along the Mineral Wells-Jacksboro highway. Control on dip and strike is poor, but the evidence indicates that the member is at least 150 feet thick. Near-by well sections indicate that the interval is somewhat thicker.

PALO PINTO FORMATION

The succession of limestone and shale beds that overlies the Keechi Creek was named the Palo Pinto formation (Plummer and Moore, 1922, p. 92) from the town of that name in Palo Pinto County. The outcrops of the formation in Parker County west-southwest of Whitt consist of gray shales with three prominent limestone beds. A fourth limestone is exposed just west of the county line but is covered by the Cretaceous in Parker County. The lower three limestones are 2 to 3 feet thick, somewhat irregularly bedded. They are light brown, weathering gray. All are rich in organic material, with brachiopod and crinoid fragments being the most abundant material. Fusulinids are especially abundant in the lower limestone. The fourth limestone is similar in character to the lower three but is thicker. It is 6 feet thick just west of the Parker County line and is 12 feet thick one-half mile farther west on the Mineral Wells–Jacksboro highway. *Triticites nebraskensis* and *T. neglectus* have been identified from the limestones. Total thickness of the Palo Pinto from the base of the first limestone to the top of the fourth limestone is 52 feet. Measurement was made along the Mineral Wells–Jacksboro highway in Palo Pinto County, one-half mile west of Parker County.

The Palo Pinto beds are exposed in Parker County for 1½ miles along Farm Road 52 west of Whitt. The lowest limestone is also well exposed in the bed of the main east fork of Rock Creek, 1 mile northeast of Whitt. The base of the lowest limestone is mapped as the base of the Palo Pinto formation since that complies best with the original definition of the formation. Where the thin limestone is not exposed, the base of the formation has been projected along the approximate topographic position of the limestone.

SECTION IN NORTHWEST CORNER OF COUNTY

A succession of Pennsylvanian rocks not more than 50 feet thick is exposed in a small area in the northwest corner of Parker County. Exposures do not offer opportunity to measure thicknesses. The following succession of lithologic units is present.

Top
- Basal portion of a shale whose outcrop extends beyond Parker County boundaries.
- Sandstone, 2 to 3 feet thick; very fine grained.
- Shale, sandy, with marly layers at the top.
- Sandstone, upper 5 feet exposed in creek bed; fine to medium grained; irregularly bedded and cross-bedded.

Base

The beds represent some portion of the lower part of the Graford formation, defined and mapped in Palo Pinto County by Plummer and Moore (1922, p. 95).

CORRELATION WITH ADJACENT SUBSURFACE SECTIONS

Correlation of the Pennsylvanian beds exposed in Parker County with any one subsurface section is complicated by the fact that the surface section is spread laterally over such a long distance. Change in facies and thickness prevent any well section from duplicating in much detail the succession presented as a composite section on Plate I, but a study of many logs of wells in Wise, Jack, Palo Pinto, and Parker counties reveals the consistent occurrence of certain recognizable portions of the section in the subsurface. On the basis of lithologic similarity, position, and succession of beds, it is possible to recognize the following rock units in the down-dip area immediately adjacent to the exposures:

Dog Bend limestone
Lake Pinto sandstone
Brazos River sandstone
Brannon Bridge limestone
Meek Bend limestone

Recognition of these units makes it possible to place the tops of the Lazy Bend and Garner formations in the well sections. The tops of the Grindstone Creek, East Mountain, Salesville, and Keechi Creek formations are not so readily placed. Correlation of the Palo Pinto limestone cannot be made with assurance on the basis of the Parker County section because of poor control of thickness of the interval below the limestone and no control of section above the limestone.

Traces of the electric logs of two wells, one in northeast Palo Pinto County and the other in northwest Parker County, are shown on figure 2. Tops of the recognizable rock units are indicated on each log. Extensive correlation into the subsurface demands time and techniques beyond the scope of this paper.

STRATIGRAPHIC ANALYSIS

Materials.—The principal Pennsylvanian outcrop area of Parker County includes 2,000 feet of almost entirely clastic sediments (geologic map, Pl. I). All the limestones together total only 75 feet, or 3.75 percent of the thickness. Total sand thickness is difficult to determine because of the thinness and lenticular nature of many of the beds. The combined thickness of mappable sandstones in the section is 260 feet, or 13 percent of the total. This thickness includes some lensing conglomerate beds. Shale then composes 83 percent of the succession. An undetermined portion of the section included as shale is sandstone in thin, lenticular beds, and highly silty to sandy shale. One coal

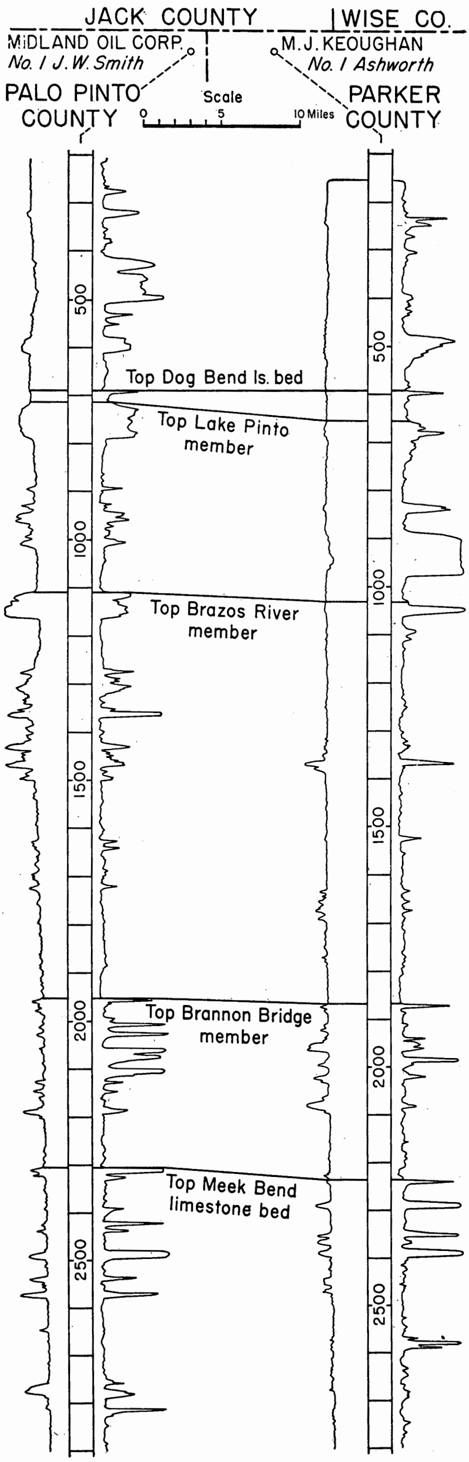


FIG. 2. Correlation of the Pennsylvanian section with the adjacent subsurface.

seam of negligible thickness occurs in the section.

Source.—The Pennsylvanian beds offer little conclusive evidence concerning the direction from which sediments came to the Parker County area. The Brazos River sandstone is highly conglomeratic where its outcrop crosses the west Parker County line but grades abruptly into a well-bedded, medium-to-fine-grained sandstone along the outcrop to the northwest. It is conglomeratic for some distance along its outcrop southwestward into Palo Pinto County, then again grades into bedded sandstone in southwestern Palo Pinto County (Plummer and Hornberger, 1935; Wright, 1955). Accepting Plummer and Hornberger's statement that the conglomerate grades northwestward into marine sands rules out that direction as the source. As far as surface evidence indicates, the coarse material may have come from any direction between slightly north of east and southeast.

The conglomerate in the East Mountain formation grades to sandstone in a westerly direction and becomes more sandy and less conglomeratic northeast along the outcrop. No information is in hand concerning its underground extent. From surface information its source could have been from the northwest or some easterly direction. Similarity of material suggests the same general source as the Brazos River sandstone.

The rapid thinning of the Lake Pinto sandstone along its outcrop in an easterly direction suggests some direction other than east for its source. The Plummer and Hornberger (1935) map indicates that the Lake Pinto is no longer a mappable unit in southwestern Palo Pinto County. Thinning in both easterly and westerly directions implies a northerly or southerly source for that body.

The Turkey Creek sandstone is much finer grained in its Parker County outcrops than in Palo Pinto County, indicating an area to the west as being closer to the source or nearer the main trend of distribution of Turkey Creek material.

The shale and limestone beds do not offer evidence as to source. Changes in thickness of intervals are not significant, varying chiefly with the lensing of overlying and underlying sand bodies. It is logical to assume that the source of the shales was largely the same as the coarser materials.

It has been assumed that the source of Pennsylvanian sediments in north Texas was from the east (Bay, 1932; Plummer and Hornberger, 1935). The evidence in the Parker County area does not necessarily support the conclusion for all parts of the section. Some of the sand bodies, such as the Lake Pinto sandstone, exhibit a north-south trend that implies a northern or southern source.

Environments.—The shales of the Pennsylvanian show evidences of deposition in medium to deep water. The silty shales are thin bedded to laminated, with occasional crumpled, distorted beds. Thin sandstone beds in such shales carry molds of small-scale channel fillings on the bottom of the beds. These features are interpreted as indicating deposition in water of medium depth, just beyond normal wave action, but still strongly influenced by current action. Uneven distribution of sedimentation under the influence of currents resulted in an uneven depositional surface. Crumpling and distortion of bedding was caused by slumping of soft material on overburdened depositional slopes. The relatively pure clay-shales are massive in appearance, with lamination poor or absent. The uniformity of material and structure is interpreted as due to deposition in comparatively deep water, beyond the reach of both wave and effective current action. Interpretation of the depositional environment must be based on physical evidence since fossils are so rare in the shales.

The absence of fossils in much of the shale is difficult to explain. Conditions seemingly were good for preservation, so the best explanation seems to be absence of abundant life because of abnormal conditions affecting such factors as salinity and turbidity.

The conglomerates and conglomeratic sandstones are either cross-bedded or structureless. Alignment of particles is heterogeneous from one conglomerate lens to another. The conglomerate grades rather abruptly into bedded sandstone. Deposition probably was fluviatile grading to marine on a plain bordering or built into ocean water. The conglomerates and their bedded sandstone equivalents are underlain and overlain by shales containing marine fossils. Plant fossils are occasionally found in the sands. The nonconglomeratic sandstones range from well bedded to massive, some bear current-type ripple-marks, and some exhibit distorted bedding on a larger scale than the shales. The sands were deposited in shallow water, subject to both wave and current action, or in medium depths affected chiefly by currents. Lensing of many of the sands and distorted bedding indicate uneven distribution and uneven depositional surfaces.

An outstanding characteristic of all the Pennsylvanian limestones is the wavy, hummocky unevenness of the bedding surfaces. All the limestones are fossiliferous and in some cases are crowded with fossil fragments. Some of the limestones are interrupted laterally by sand bodies that probably were deposited concurrently with the limestones. The limestones apparently were deposited in shallow to medium depths where water movements disturbed the depositional surfaces. In some areas currents carried sand masses into the limestone depositional environment. The water was fairly clear, as indicated by the purity of the limestones. No true reefing characteristic of such environment is present, but some of the limestones do thicken and thin abruptly.

The shallow, medium, and deep sedimentary environments as used above correspond approximately to the unda, clino, and fondo environments of Rich (1951, p. 2018).

Interpretations.—Nearly all the Pennsylvanian beds displayed in Parker County were deposited in shallow to medium depths of probably marine waters. The absence of fossils in most of the shales is puzzling but probably does not mean total absence of life in the waters. Conditions for living and preservation must have had great lateral variation, for fossiliferous shale zones in some cases grade laterally into nonfossiliferous beds. The vertical succession of changes in water depths and sedimentary materials is due to the combination of tectonics and rates of deposition affecting the region. There is no rhythmic or cyclic pattern of changes discernible. It is for the most part an alternation between shallow- and medium-water deposition, reflecting slow changes in the ratio of deposition to subsidence. The beds most indicative of strong tectonic effects are the conglomerates. Relief great enough to furnish the weathered source rock surfaces and the transporting currents was present from time to time within delivery distance of the area. The combination of distance, relief, and climate was such that only the resistant cherts of the source rocks reached the site of deposition.

Conformability.—Physical evidence of unconformity is prominent at only one level in the 2,000 feet of Pennsylvanian beds exposed in Parker County. Limestone beds in the upper part of the Hill Creek member of the Lazy Bend formation exposed south of the Lazy Bend of the Brazos River exhibit a series of small-scale anticlines. Some of the anticlines are truncated, creating angular unconformities between the flank beds of the structures and the overlying beds. The Meek Bend limestone above shows no evidence of folding. The structures may be the result of an original deposition of limestone conforming to the tops of sand bars plus some compaction of shales between the sand bars.

Elsewhere in the Pennsylvanian normal bedding planes are parallel in all exposures observed. Sand bodies that "cut out" shale and limestone beds seem best explained as resulting from uneven distribution of sediments in a shallow-water environment. No buried erosional surface of any extent can be demonstrated. Local erosion most likely occurred, and there may have been times of fairly widespread building or raising of the depositional surface above sea level. The coarser conglomerates appear to be nonmarine, and channel erosion doubtless occurred within the deposits while being put down. But for the area as a whole, deposition was more rapid than normal during conglomerate deposition. The coal seam in the Mingus shale indicates near sea level swampy conditions for the area at that time. Cheney (1940) and Cheney and Goss (1952) emphasized an unconformity at the base of the Lake Pinto sandstone. Field evidence of such unconformity is not present in Parker County.

STRATIGRAPHIC CLASSIFICATION

The rocks exposed on the western edge of Parker County have been classified as Carboniferous or equivalent Pennsylvanian from the earliest studies of their fossil content (Dumble, 1890). Broad subdivision of the system on the basis of lithology and conformity followed reconnaissance studies, largely outside the Parker County area. Additional lithologic subdivisions and some redefinition of names followed more detailed field work. A summary of the development of that part of the classification affecting the Parker County section is presented in figure 3. The figure includes the classifications that offered new names or important redefinitions. The Strawn and Canyon groups of formations had been established before any detailed work was done in Parker County. Field work by Scott and Armstrong (MS) was the basis for further subdivision of the lower portion of the exposed Strawn. The names of the lithologic units recognized by Scott and Armstrong were published by Sellards (1933). The names have subsequently had widespread usage, but this paper offers the first formal descriptions and designation of type sections to be published. The changes in rank suggested by Cheney (1940) as shown in figure 3 are acceptable for the units established in this paper.

Cheney introduced a change in the basis for the broader subdivisions of the Pennsylvanian in Texas in his 1940 publication. His chief concern was the definition of usable units for subsurface and regional correlation. He therefore proposed a subdivision of the system into a number of series, two of which involve the Parker County section. He used the terms Strawn and Canyon for the two units, since the rocks in each series coincided somewhat with the groups of formations originally put in each group. The series are essentially defined by fossil ranges, although Cheney placed the boundary between his Strawn and Canyon where he considered an unconformity to exist. The boundary as chosen places the top of the Strawn series stratigraphically above the known occurrence of *Mesolobus* and *Fusulina,* which are characteristic fossils of the Des Moines as defined in the Mid-Continent area. The Strawn-Canyon series boundary was placed at the base of the Lake Pinto sandstone chiefly on the basis of fossil evidence but in part because of the idea that an unconformity exists at the base of the sandstone. Cheney felt that lithologic classifications must also fit fossil unit classifications, so in his 1940 paper he proposed the changes in lithologic classification at the group level indicated in figure 3. The name Mineral Wells was dropped to avoid placing a series boundary within a group. A new grouping of formations was proposed so that group boundaries and series boundaries coincided. The necessity for such reclassification of the lithologic units may be questioned, since the groups and series are defined on different bases.

Moore and Thompson (1949) proposed a revision of classification of the series and stages subdividing the Pennsylvanian system. Cheney (1947, pp. 206–209) extended the Lampasas series (Cheney, 1940) upward to include the Dennis Bridge limestone exposed in Parker County, making it the top member of his proposed Kickapoo Creek group. In 1952 Cheney and Goss (p. 2255) defined the Kickapoo Creek stage as the upper subdivision of the Lampasas series. The Kickapoo Creek stage is represented by the formations of the Kickapoo Creek group.

The older meaning of the terms Strawn and Canyon as applied to groups and the newer meaning as applied to series are both shown on the stratigraphic column of the geologic map (Pl. I). The mapping of a comparatively small area such as the Pennsylvanian outcrop of Parker County does not offer adequate basis for judging the validity of the broad-scale stratigraphic nomenclature revision offered by Cheney. Hence the classification used in this paper (fig. 3, C) is purely lithologic and does not go above formation rank.

PRE-CRETACEOUS EROSIONAL SURFACE

Generally the contact between the Cretaceous and the Pennsylvanian rocks in the Parker County area shows very little large-scale irregularity. The Pennsylvanian surface below the unconformity appears to be a buried plain on which there were local irregularities due to ridge- or scarp-forming resistant rocks. One such topographic feature is well exposed at a locality 2¼ miles slightly west of north of Garner. A buried scarp topped by a limestone near the base of the Salesville formation cuts out approximately 50 feet of basal Cretaceous beds. This is the maximum relief noted along the unconformity in Parker County. Indications are that the pre-Cretaceous surface was a plain much less dissected than the present erosional surface of the Pennsylvanian. Hill (1901, pp. 363, 367) has called the old surface the Wichita Paleoplain.

CRETACEOUS ROCKS

Rocks representing the Comanche (Hill, 1887) series of the Cretaceous system occupy approximately five-sixths of the Parker County area. They compose the surface outcrops, except for the narrow strip of Pennsylvanian rocks along the western edge of the county and the bottoms of alluviated stream valleys. The very gentle dip of 30 to 40 feet to the mile causes the outcrops of formations to resemble the patterns developed by stream dissection of flat-lying beds. Formation boundaries outline the drainage patterns, and outliers of formations occur along the tops of drainage divides. Well-developed scarps and dip slopes are not common because the dip is too gentle. Topographic benches and low waterfalls are the commoner developments resulting from erosion of alternating hard and soft layers. Best exposures are in the many road cuts. Natural exposures occur on the steeper hill slopes and in bluffs where stream meanders have undercut valley walls. The most notable bluffs are along the Brazos River near the southern edge of the county.

The long-established classification of the Comanche series of Cretaceous rocks in Texas and Oklahoma (fig. 4) is adequate for mapping and describing the Cretaceous beds exposed in Parker County. The greatest problem encountered is in presenting the changing facies in the Trinity group. A combination of terms already in use is utilized, and no new stratigraphic names are proposed. Following is a description of the Cretaceous succession, beginning with the oldest beds.

CRETACEOUS SYSTEM	COMANCHE SERIES	WASHITA BEDS	Duck Creek formation
		FREDERICKSBURG BEDS	Kiamichi formation
			Goodland formation
			Walnut formation
		TRINITY BEDS	Paluxy formation
			Glen Rose formation
			Undifferentiated

FIG. 4. Stratigraphic classification of Cretaceous rocks exposed in Parker County.

TRINITY BEDS

The term Trinity (Hill, 1889) has been applied to the lower Comanche sedimentary beds of Texas. The Trinity is composed of a mass of genetically related sedimentary materials deposited on land and in a sea that gradually spread north and westward from the present coastal plain of Texas (Hill, 1901; Adkins, 1933). Changing sedimentary environments in the advancing sea created varying lithologies that grade into each other both vertically and horizontally. In general there is what Adkins has called a sandy marginal facies that grades eastward into marls and limestones at all stratigraphic levels. In the widening sea limestones and marls were deposited on older sandy marginal deposits. Three formations have been defined from outcrops in central and north-central Texas:

Paluxy sand (Hill, 1891)
Glen Rose limestone (Hill, 1891)
Travis Peak sand (Taff, 1892)

The Travis Peak was defined from study of beds deposited mostly in the marginal facies in the central Texas area. The type Glen Rose consists of beds deposited in the limestone and marl facies in the Somervell County area over 100 miles north of the Travis Peak type area. The Paluxy was defined in the same general area as the Glen Rose and represents marginal type deposition on top of the Glen Rose in a major oscillation of the sea. The boundaries between the three formations are gradational and transgress the section as the lithology of one formation grades laterally into the lithology of the other.

The Trinity exposures on the southern edge of Parker County are approximately 30 miles north of the type Glen Rose and Paluxy areas. They extend another 30 miles northward across the county. The outstanding feature of the beds is the gradation of the main body of the Glen Rose into the sandy marginal facies. The transition occurs first in the marl and shale beds between the limestones of the formation. The marls become sandy and grade to fine, argillaceous sands, so that the section becomes predominantly arenaceous with a few limestone layers. The limestones become arenaceous and finally grade into the sands. Clear-cut stratigraphic designation becomes difficult where the gradation occurs. An alternating limestone and sandstone section is not typical of any one of the formations in their original definition. The problem is solved on the geologic map of Parker County by making the Trinity portion essentially a lithofacies map. The calcareous phase is typical of the Glen Rose, the arenaceous phase is typical of the lower Trinity beds and the Paluxy formation. The formation names are useful where the calcareous Glen Rose phase is a mappable unit. Where the Glen Rose is represented by limestone ledges separated by sand beds, or by sand beds only, it is best to use the term Trinity sands, since the lower Trinity beds and Paluxy cannot be differentiated. The section is in part the equivalent of the Antlers sand (Hill, 1894, p. 303) of Oklahoma.

Lower Trinity.—Patches of a discontinuous conglomerate appear to be the oldest rocks found lying on the eroded edges of the Pennsylvanian in Parker County. The bed has been observed in only a few localities and in exposures only a few hundred feet long. Thickness ranges from a few inches to 9 feet. Limestone, sandstone, and chert pebbles, and sand grains are moderately consolidated with calcareous cements. The particles are subangular to well rounded in shape and range up to 2 inches in size but average less than one-half inch. No fossils have been found. The attitude of the layer is concordant with the Cretaceous, so the deposits are assumed to be Cretaceous in age; they could very well be older. Best exposures are seen in the vicinity of Cool, along the Pennsylvanian-Cretaceous contact between Cool and Farm Road 113 north of U. S. Highway 180. The thickest lens is exposed at a locality one-tenth of a mile south of U. S. Highway 180 and three-fourths of a mile west of Farm Road 1543.

The oldest continuous beds mapped as Cretaceous in Parker County are maroon "red bed" type clays containing a sand member. The clays are massive, structureless units that offer little clue as to origin and type of deposition. They rest on Pennsylvanian or the above-described conglomerate in a sharp contact. The color is very predominantly maroon, but the lower clays have large, irregular green-colored portions. The green coloration apparently is due to differential oxidation or hydration of the iron compounds responsible for the colors of the clays, the green being less oxidized than the maroon. The lower clays contain scattered pebbles of sandstone and chert and occasional rounded, frosted quartz grains. A thin zone containing hard irregular, calcareous masses is also a feature of the lower clays. The masses range from a fraction of an inch to 6 inches in size. The sand member is near the middle of the red bed unit. It is a uniformly fine-grained, friable, quartz sand with varying amounts of clay cement. The sand body, generally ranging from 2 to 8 feet in thickness, pinches out and perhaps is overlapped near the south county line. Normal bedding is irregular or absent. Well-developed cross-bedding is shown in most exposures. Round "sand balls" up to 12 inches in size are in the base of the sand member in an exposure in a creek bed on the north side of U. S. Highway 180, 1 mile east of Cool. The sand is in irregular but sharp contact with the maroon clay above and below. The sand and maroon clays together average 30 feet in thickness, and the unit is represented everywhere along the basal Cretaceous contact except where it is overlapped by younger Cretaceous on the sides of old buried hills. The thinnest exposed section is near the south county line, where 20 feet of maroon clay is present. The sand body and lower clays may be overlapped at that locality. No fossil evidence has been found, and a Cretaceous age for the unit is assumed because of its concordance with the overlying Cretaceous rocks. Complete exposures are rare because softness of the material creates gentle soil-covered slopes. The exposure 1 mile east of Cool on the north side of U.S. Highway 180 is typical where the middle portion of the unit is well exposed.

A conglomeratic, complexly cross-bedded sand member lies above the basal clay member of the lower Trinity beds in Parker County (Pl. VII, B). The contact between the two is poorly exposed but is sharp and nongradational in the few places it can be seen. The member is composed of poorly sorted quartz sand, ranging from very fine to coarse, and variegated chert pebbles. The pebbles are mostly less than one-fourth inch in size, but some layers and lenses contain larger pebbles, ranging up to 2 inches. The smaller pebbles are subangular to subrounded, the larger ones are subrounded to rounded. Most pebbles are light colored, but black, green, and reddish ones are found. The member is generally poorly cemented and colored red by small amounts of iron oxide. Locally the conglomerate is well consolidated with a calcareous cement. This cementation may have occurred after exposure to weathering. The sand body ranges from 15 to 25 feet in thickness before grading upward into the overlying beds. There is evidence of its presence continuously along the strike, either as actual outcrops or in the form of loose gravel and chert pebbles on the surface. The unit probably is the "basal sand" described by other writers, the underlying clay unit being either overlooked or absent in areas outside Parker County. Good exposures are in the road cuts of U. S. Highway 80, one-fourth of a mile west of Farm Road 1543 intersection, and on U. S. Highway 180 three-fourths of a mile east of Cool.

The conglomeratic sand grades upward rather abruptly into very fine, argillaceous sand. The succeeding 65 to 75 feet of beds consist of very fine, soft sand grading laterally and vertically into very finely arenaceous clay in an unpredictable manner. The thickness of the sand and clay is rather uniform over the Parker County area, with thicknesses ranging from 67 to 75 feet in sections measured at intervals along the strike.

Overlying the sand and clay section is a very distinctive unit of predominantly maroon to purplish clays that is near 30 feet in average thickness. The clays are finely arenaceous to silty and contain beds and lenses of very fine sands. The most noticeable feature of the clays is the presence of layers of very unusual calcareous masses. The masses have a generally nodular shape but have very rough, irregular surfaces. They do not have a layered, concretionary type internal structure. Veinlets of clear, crystalline calcite are characteristic internal features. Sizes range from less than 1 inch to more than 12 inches. The masses are restricted to specific levels in any given outcrop of the clays, but it is not possible to prove correlation of individual nodular layers between widely scattered outcrops. In some places the clays contain only one well-developed nodular level and in other places exhibit as many as four levels. Some exposures of the clays contain a very poorly developed, argillaceous and silty limestone layer. On exposure the limestone weathers to very irregular masses similar to the irregular nodules described above. Presumably the limestone represents increased calcareous deposition to the point of forming a massive layer of irregular masses. No exposures have been observed where the limestone can be traced laterally into a level containing discrete nodules. It is believed that the nodule-bearing clay unit is a good stratigraphic marker in the Parker County area, and in this paper the top of the unit is used to mark the top of beds designated as lower Trinity.

Further mapping between the type areas of the Glen Rose and Travis Peak formations must be done before lateral equivalents of the lower Trinity beds of Parker County can be established.

Fossil material in the lower Trinity is limited to silicified wood. The wood is found intermittently throughout the outcrop area of the beds but is more abundant near the southern edge of the county.

Upper Trinity.—The Trinity section above the purplish, nodule-bearing clay unit consists of two lithofacies, one predominantly sandy and one predominantly calcareous. The lower part of the unit consists of the sandy lithofacies throughout the county. The mid-portion of the unit has sand interbedded with limestone layers in the west-central and northwest part of the county and grades laterally into the calcareous lithofacies in the southern half of the county, as shown on Plate I. Sand predominates in the upper part of the unit all across the county. The calcareous body of beds is the Glen Rose formation, and the upper sand body is the Paluxy formation.

Sandy lithofacies, including the Paluxy formation.—The extreme fineness of the sand is the outstanding characteristic of the sandy portion of the upper Trinity. No coarse grains have been observed anywhere and very few beds contain any medium grains. The most notable occurrence of medium-grained sand is in a somewhat massive bed at the very base of the upper Trinity. In some places slumped fragments of sand occur on the weathered slopes of the underlying purplish clay unit, giving the impression that it occurs in that unit. The bed is lenticular in nature, being absent in some sections. An interesting feature of the bed is the presence of pelecypod shell fragments and internal molds.

Since the bulk of the sands in the upper Trinity beds are very fine, grading to silt size, an extremely efficient sorting occurred in transportation, if the sands were ever part of coarser grained rocks. Composition is remarkably pure quartz sands interlensed with argillaceous sands and arenaceous clays (Pl. VII, A). Sand bodies predominate and range up to 25 feet in maximum thickness. Cementing material is almost entirely absent, causing the beds to be characteristically soft and friable. Pyrite nodules and iron concretions have scattered occurrence in the upper sands. Cross-bedding is a common feature of the sandy bodies. Thick normal bedding is present where the individual bodies are large. Lamination of the fine sands and clays is occasionally observed. The color of the pure sands is invariably white to light gray. The argillaceous sands and sandy clays vary from light gray to light green, with some maroon and purplish beds scattered through the section. Thin, residual soils formed on the sandy lithofacies are characteristically red.

The thickness of the sandy upper Trinity beds varies slightly along the strike. The lower section is approximately 30 feet thick in the southern part of the county and thins to 20 feet in the vicinity of Garner in the northwest part of the county. Measurements were made from the purplish, nodular zone to the first overlying limestone layer. The middle portion of the upper Trinity containing three thin limestone layers is 45 feet thick in the northwest part of the county, according to measurements east of Garner. This portion grades southward into the calcareous Glen Rose lithofacies. The upper section is 192 feet thick in the southern part of the county and 183 feet thick in the northwest part of the county. Measurements were made between the base of the Walnut and the top of the Glen Rose or between the base of the Walnut and the top of the highest limestone layer equivalent of the Glen Rose in the northwest area beyond the extent of the Glen Rose as a mapped formation. The entire section of middle and upper portions of upper Trinity in the northwest part of the county consists essentially of sandy lithofacies and totals 237 feet in thickness.

The upper sand section can be identified and mapped as the Paluxy formation where it is underlain by a predominantly calcareous section recognizable as the Glen Rose formation.

The outcrop of the sandy lithofacies of the Trinity extends entirely across the northern edge of the county and southward across the western part of the county just east of Pennsylvanian outcrop. The outcrop of the sands is split by the Glen Rose from the west-central part of the county to the south county line. The lower sands form the steep slopes of low scarps topped by limestones along the western edge of the Glen Rose outcrop. The upper sands are exposed in many bluffs and topographic benches topped by the Walnut limestone in the northeastern and east-central part of the county. The outcrops extend far down the valleys of the Trinity River drainage system because the streams flow down dip at only slightly less gradient than the dip of the beds. The most notable exposure of the sands in the county is near the headwaters of Dry Creek, 3¾ miles north of Adell. The exposures are in a bluff and deep gullies on the west side of a Walnut outlier. An east-west road from Farm Road 920 to Whitt crosses just south of the best exposures. Scott (1930a, p. 48) published a detailed section of the beds exposed at the locality, showing 84 feet of sand and sandy clay. Part of the clays are colored deep purple.

The most abundant fossil material in the sandy lithofacies is silicified wood, fragments of which have been found in all portions of the section. Individual trunks are as large as 18 inches in diameter. Carbonized fragments of twigs and stems are usually quite rare but in a few instances are abundant enough to form lignitic layers. One such layer is exposed in the bank of the east tributary to Grindstone Creek immediately north of the Texas & Pacific Railroad where the railroad makes a sharp bend to the south. Torrey (1923) has described a few fossil plants from the sands exposed near Weatherford. Poorly preserved clams occur in a lensing sandstone bed a few feet above the base of the upper Trinity. A species of small clam and the oyster *Exogyra texana weatherfordensis* occur in a calcareous layer approximately 25 feet below the Walnut at a locality on U. S. Highway 80 in the west edge of Weatherford.

Calcareous lithofacies: Glen Rose limestone.—The main body of calcareous lithofacies beds of the Trinity group in Parker County can properly be identified and mapped as the Glen Rose limestone. The Glen Rose is composed of limestone, marl, and calcareous shale. The percentage of limestone is greatest where the outcrop crosses the south county line and decreases to the northwest. The decrease in limestone is due more to thinning of individual beds than to complete lensing out, and only the uppermost layers lens out completely in Parker County. The thinning of the formation as a whole to the northwest is in proportion to the decrease in limestone, the number of feet of shale in the formation decreasing only a minor amount. The shales become predominant as the limestones thin and begin to contain beds of arenaceous clay. The shales decrease in thickness as the arenaceous clays increase and fine-grained sand beds come in. It seems best that the term Glen Rose no longer be applied to the beds where the arenaceous material predominates, even though several limestone layers are still present in the section. It is more confusing than helpful to the geologist to try to distinguish a Glen Rose section where the typical calcareous shales have been replaced by sandy lithofacies. The exact limits of the Glen Rose cannot be shown on a map, since the limiting boundary is a transition zone. The area where the interlensing of facies occurs is just south of U. S. Highway 180, 7 to 8 miles west of Weatherford. It is equally confusing to use the term Paluxy for the upper sands where they are no longer separated from the lower sands by a distinguishable Glen Rose section.

The basal bed of the Glen Rose is highly fossiliferous throughout the Parker County extent of the formation. Chief fossils are pelecypods, with a fair number of gastropods. Locally the gastropods outnumber the pelecypods. The fossils are internal molds for the most part, but in some places the shell material is preserved, usually as fragments. The bed in such places is an organic shell breccia. The foraminifer *Orbitolina* and the plant (?) *Porocystis* occur sparingly. In the southern part of the county the bed is 6 to 8 feet thick, lies on the sandy lithofacies, and is overlain by a massive limestone bed. Exposures along Sanches Creek and its tributaries north-northwest of Tintop show the relationship. The bed thins to the northwest and becomes separated from the overlying limestone by shale. The bed is 4 feet thick where the Weatherford-Dennis road crosses it 3 miles northeast of Dennis. Farther northwest, along the sides of Patrick Creek valley, the bed is thinner and separated from the overlying limestone by arenaceous clay and sand. From about the vicinity of U. S. Highway 80 northward the bed is contained within the sandy lithofacies of the Trinity and is not considered a part of the Glen Rose formation. The bed becomes more nodular and less consistently fossiliferous. It thickens and thins along the outcrop and is traced with some difficulty, but with the aid of air photographs it can be mapped around the drainage patterns of the northwest part of the county to the north county line. The most northwesterly occurrence of the bed is on the interstream area due north of Whitt. An exceptionally good exposure of the limestone is on U. S. Highway 180, 2 miles east of Cool, where it is a shell breccia 4 feet thick. The bed corresponds approximately to Scott's (1930a, p.43) zone of *Orbitolina texana* (Roemer), *Porocystis globularis* (Giebel), *Pecten stantoni* Hill, and *Trigonia stolleyi* Hill.

Overlying the above-described bed in the southern part of the county is a white limestone bed distinguished by its massive structure, fine, chalky texture, and the presence of a zone of abundance of *Orbitolina texana*. Pelecypod and gastropod molds are common and the regular echinoid *Loriolia texana* (Clark) occurs rarely. The bed is over 15 feet thick at the south county line and decreases gradually in thickness along the outcrop to the northwest. It is 12 feet thick 2 miles north of Tintop, 6 feet in Sanches Creek, 2 miles west of Bethel Methodist Church, 3 feet at a locality about 3 miles northeast of Brock. The bed can be traced northward to U. S. Highway 80, where it is about 2 feet thick. As the bed becomes thinner, the *Orbitolina* becomes less abundant. The bed may continue north of U. S. Highway 80 but cannot be recognized because of change in texture and loss of its characteristic fossils. The bed constitutes the middle zone of Scott (1930a, p. 43).

The Glen Rose section above the *Orbitolina* bed consists of alternating limestone and shale beds. The limestone beds normally range from 6 to 18 inches thick. Ripple marks are fairly common in the west-central part of the county. Some of the beds are largely organic, while others are very fine grained with relatively few fossil fragments. A bed immediately above the *Orbitolina* bed contains rudistids. One bed near the top of the formation as mapped in Parker County carries an abundance of large, thick-bodied clams identified by Scott (1930a) as *Modiola branneri* Hill. This bed can be recognized northward to the area between U. S. Highways 80 and 180, where it apparently pinches out. Scott (1930a, p. 43) considered the bed a paleontologic zone and designated it his third zone of the Glen Rose in Parker County. All the Glen Rose limestones except the basal bed described above and two beds in the middle of the section lens out into sands and arenaceous clays. The limestones become increasingly arenaceous as they lens out. The three beds are all that can be traced north of U. S. Highway 180. The Glen Rose shales are calcareous and slightly to highly silty. They are thin bedded to laminated; colors are gray to yellowish gray. The calcareous shales become interlensed with noncalcareous, arenaceous clay and fine sands along the strike to the northwest. The calcareous shales disappear from the section north of U. S. Highway 180.

The Glen Rose formation is 106 feet thick in a continuous section measured 2½ miles north of Tintop. It appears to thicken southward, although no complete sections were measured. Scott (1930a, p. 41) assigned 195 feet of section to the Glen Rose in the Tintop area, but he included some sandy beds below and arenaceous clays with one limestone above what is here considered the Glen Rose. The formation thins to the northwest by thinning of limestone beds, chiefly at the top. Only 50 feet of typical Glen Rose section is found where the old paved Weatherford to Millsap road crosses the outcrop. From that point northward the section becomes increasingly arenaceous and no longer typically Glen Rose.

The Glen Rose beds are sparsely to highly fossiliferous. Clams, gastropods, and one genus of Foraminifera are the most abundant. Echinoids are rare. Scott (1930a) reports a few plant fragments and fish teeth. A list of fossils from the Glen Rose reported by Scott and Armstrong (MS) but with recent taxonomic corrections follows:

Plants?—
- *Porocystis* sp.

Foraminifera—
- *Orbitolina texana* (Roemer)

Marine worm tube—
- *Serpula paluxiensis* Hill

Pelecypoda—
- *Ostrea franklini* Coquand
- *O. franklini ragsdalei* Hill
- *O. franklini cameliana* Cragin
- *Gryphaea wardi* Hill and Vaughan
- *Exogyra texana* Roemer
- *E. texana weatherfordensis* Cragin
- *Trigonia taffi* Cragin
- *T. wenderli* Whitney
- *Pecten (Chlamys) stantoni* Hill
- *P. (Neithea) occidentalis* Conrad
- *Anomia* sp.
- *Modiola branneri* Hill
- *Pholadomya? knowltoni* Hill
- *Homomya solida* Cragin
- *Cucullaea (Idonearca) terminalis* Conrad
- *C. (I.) gracilis* Cragin
- *C. (I.) gratiota* Hill
- *C. (I.) comanchensis* Hill
- *Astarte (Eriphyla) pikensis* Hill
- *Isocardia medialis* (Conrad)
- *Lithodomus* sp.
- *Toucasia* sp.
- *Monopleura* sp.

Gastropoda—
- *Lunatia? pedernalis* (Roemer)
- *L.? pedernalis* Hill non Roemer
- *Cassiope branneri* (Hill)
- *Nerinea austinensis* Roemer

Echinoidea—
- *Loriolia texana* (Clark)

Vertebrates—
- Fish teeth and bones

One limestone appears within the sandy lithofacies well above the highest Glen Rose beds. It is 72 feet above the Glen Rose in a section measured from the bed of Shaw Creek to the top of Mt. Nebo, about 12 miles south of Weatherford. The limestone consists of a lower, brownish bed and a crystalline, organic upper bed in the southern part of the county. Total thickness is 3 to 4 feet. The limestone can be traced more or less continuously from the south county line northward to Spring Creek community (Bed pl, geologic map, Pl. I). Northward from Spring Creek a similar limestone appears intermittently at approximately the same position in the section. A good exposure is 1 mile west-southwest of Greenwood Baptist Church, west of Weatherford.

Two limestones appear in the sand section exposed in Walnut Creek in the northeast part of the county. The lower one is a massive, organic limestone, similar to the upper bed of the limestone described above. It is well exposed under the bridge across Walnut Creek at Reno. The upper limestone is approximately 40 feet above the lower and is exposed along the banks of Walnut Creek north of Azle. The limestone is light brown, arenaceous, and very hard and thickness ranges from 2 to 4 feet. Both limestones apparently lens into the sand section to the west. It is not possible to support positive correlation of either of the limestones with the limestones exposed south of Spring Creek. The nature and position of the lower one make it most likely to be the same.

FREDERICKSBURG BEDS

The Fredericksburg beds (Hill, 1887, 1891) of the Comanche series are represented in Parker County in their typical north Texas development. The formations according to the presently accepted classification (Adkins, 1933) are:

Kiamichi (Hill, 1891)
Goodland (Taff and Leverett, 1893)
Walnut (Hill, 1891)

The name for the succession of beds is from the central Texas town of Fredericksburg in Gillespie County. The type locality of the Walnut formation is at Walnut Springs in Bosque County, about 50 miles south of the southern edge of Parker County. The Goodland is named from exposures in Oklahoma approximately 100 miles north-northeast of the Parker County area. The Kiamichi is also an Oklahoma formation name from exposures along the Kiamichi (original spelling "Kiamitia") River in southeastern Oklahoma, about 150 miles northeast of Parker County. The formations are changed in thickness and somewhat in character as compared to the type localities but are sufficiently similar to justify recognition and use of the same formation names.

Walnut Formation

The beds recognizable as the Walnut formation in Parker County are all limestone or highly calcareous marl. The calcareous beds lie directly on noncalcareous sands mapped with the Trinity group, with no intervening clay beds. There may be an unconformity at the base of the Walnut, as stated by Scott (1930a, pp. 38, 51), but detailed study in Parker County does not produce conclusive evidence of such. The sands below the Walnut may be the sedimentary products of both regression and transgression. A hiatus resulting from regression may be within the sands rather than at the top of the sands.

The Walnut lithology is of two distinct types—a lower series of thin- to medium-bedded, nodular, fossiliferous limestones and an upper shell agglomerate bed composed largely of shells of the oyster *Gryphaea mucronata* Gabb. The nodular beds are separated by thin shale seams that weather out easily, so that the edges of the nodular beds stand out. This gives a characteristic rough, ragged appearance to the natural bluffs and road cuts exposing the beds. The shell bed at the top is extremely well cemented and hard. It is massively bedded, containing no bedding planes whatsoever in many of its outcrops. Its extreme hardness coupled with the softness of the underlying beds causes it to be the most important cliff- and waterfall-forming bed in the Cretaceous section. The overlying soft marls are easily stripped away, leaving the bare top of the bed exposed. A typical feature is a large, bare, semicircular area on the top of the bed above a waterfall that marks the head of a ravine eroded in the soft underlying bed.

Well-developed ripple marks are an interesting feature of the basal bed of the Walnut. They have been described in detail by Scott (1930b). The crests of the ripples are 3 to 3½ inches high and are normally about 30 inches apart. The crests trend northeast-southwest and are asymmetrical, with the steep side to the south. Examples occur in the outliers near Peaster and near Veale Station Church. An excellent exposure is in a small outlier north of the one on which Reno triangulation station is located in the northeast corner of the county.

The thickness of the Walnut is 25 to 30 feet, with remarkable uniformity across the county. The minor variations occur chiefly in the upper shell agglomerate, the lower succession of nodular beds being near 20 feet thick everywhere it was measured.

The outcrop of the Walnut forms a tremendously tortuous pattern around the dendritic drainage patterns of the east half of the county. Many outliers of every conceivable shape occur on the interstream divides along the western edge of the formation's extent. Some of the widest outcrops are found on the outliers; for example, the one between the South Fork of the Clear Fork of Trinity River and Willow Creek, northwest of Weatherford. All the highest hills in Weatherford are capped by Walnut.

The oyster *Gryphaea mucronata* Gabb is

the most abundant fossil in the Walnut, even in the nodular beds below the shell agglomerate. But the Walnut contains a rich and varied fossil assemblage in addition to the Gryphaeas. Another oyster, *Exogyra texana* Roemer, is a characteristic and abundant fossil, though not limited to the Walnut. Pelecypods, gastropods, cephalopods, and echinoids are represented. Following is the list of fossils from the Walnut recognized by Scott and Armstrong (MS), with recent taxonomic corrections:

Pelecypoda—
- *Gryphaea mucronata* Gabb
- *Exogyra texana* Roemer
- *Exogyra texana weatherfordenis* Cragin
- *Protocardia texana* (Conrad)
- *Protocardia filosa* (Conrad)
- *Trigonia emoryi* (Conrad)
- *Pecten (Neithea) irregularis* Böse
- *Cyprimeria texana* Roemer
- *Anatina texana* Cragin

Gastropoda—
- *Natica pedernales* Roemer
- *Turritella seriatim-granulata* Roemer

Ammonoidea—
- *Oxytropidoceras* aff. *multifidum* Steinmann
- *Engonoceras* sp.

Echinoidea—
- *Heteraster texanus* (Roemer)
- *Epiaster whitei* (Clark)
- *Phymosoma texanum* (Roemer)
- *Holectypus planatus* (Roemer)

Goodland Formation

The basal member of the Goodland is a soft calcareous marl, usually weathering with a slight yellowish color. It contains thin, nodular, calcareous layers in some outcrops. It is persistent throughout the county, measuring 15 to 18 feet in thickness. The marl is followed by a massive white limestone 2 to 3 feet thick upon which is usually found a thin *Gryphaea* shell agglomerate. A distinctive feature of the shell bed is the occurrence of giant ripple marks. The crests of the marks are as much as 5 inches above the troughs and range up to 5 feet from crest to crest. They are symmetrical, oscillation-type marks. The trend of the ripples is generally northeast-southwest. Scott (1930b) has described them in detail.

The ripple-marked bed is overlain by 3 to 4 feet of calcareous clay. Above the clay is a poorly bedded, blue-gray limestone 20 to 25 feet thick. It is usually the most prominent feature of the exposed Goodland sections. Following the limestone is usually 20 to 25 feet of alternating dark gray shale and nodular limestone layers. The top member of the Goodland is an irregularly bedded limestone 16 to 18 feet thick.

Individual beds of the Goodland are quite persistent, with few layers lensing out within a given exposure. Even the nodular, poorly developed layers may be followed for long distances. All the Goodland limestones weather to pure white. White-faced cliffs held up by the resistant members are characteristic features of the formation's outcrop.

The Goodland is uniform in thickness across the county. It is 86 feet thick in a measured section 4 miles north of Baker School in the southeast part of the county. The thickness is 92 feet in a measured section 2 miles north-northeast of Friendship Baptist Church, which is 8 miles northeast of Weatherford. Other checks on thickness along the outcrop gave approximately the same figure.

The outcrop of the Goodland covers a large portion of the east half of the county, from just east of Baker School on the south to just south of State Highway 199 on the north. It forms many outliers and occupies the ridges along the western and northern edges of its outcrop. The dip carries it down to the floor of the valleys along the eastern edge of the county.

The Goodland formation contains fossils at practically all levels. The fauna is rich and varied, with an abundance of both species and specimens. Many of the fossils have been reported and figured by Adkins and Winton (1920). The ones most useful in regional correlation are the ammonites. Following is the list, from the Scott and Armstrong manuscript, of fossils found in the Goodland in Parker County, with necessary taxonomic changes:

Foraminifera—
- *Flabellammina alexanderi* Cushman
- *Haplostiche texana* (Conrad)
- *Dictyoconus walnutensis* (Carsey)

Anthozoa—
Parasmilia austinensis Roemer
Coelosmilia americana Roemer

Pelecypoda—
Pinna guadalupae Böse
Pteria pedernalis (Roemer)
Ostrea crenulimargo Roemer
Gryphaea mucronata Gabb
Exogyra texana Roemer
E. texana weatherfordensis Cragin
Trigonia concentrica Cragin
T. guadalupae Böse
Pecten (Neithea) duplicicosta Roemer
P. (N.) occidentalis (Conrad)
Chondrodonta munsoni (Hill)
Lima (Mantellum) bravoensis Böse
Homomya bravoensis Böse
Anatina texana Cragin
Astarte washitensis Shumard
Opis texana Cragin
Protocardia texana (Conrad)
P. filosa Conrad
Cyprimeria texana (Roemer)
C. crassa Meek
Tapes hilgardi Shumard
T. whitei Böse
T. guadalupae Böse

Gastropoda—
Trochus (Textus) texanus Roemer
Lunatia? pedernalis (Roemer) non Hill
Tylostoma chihuahuense Böse
Turritella seriatim-granulata Roemer
Trichotropis shumardi Cragin
"Cerithium" bosquense Shumard
Avellana tarrantensis (Cragin)

Ammonoidea—
Oxytropidoceras "acutocarinatum (Shumard)"
O. supani (Lasswitz)
O. trinitense (Gabb)
Protengonoceras? planum Hyatt
Engonoceras pedernale (von Buch)
E. gibbosum Hyatt
E. stolleyi Bohm
E. complicatum Hyatt
Metengonoceras inscriptum Hyatt
M. ambiguum Hyatt

Echinoidea—
Salenia mexicana Schlüter
Phymosoma texanum (Roemer)
Holectypus (Coenholectypus) planatus Roemer
Enallaster texanus (Roemer)
Epiaster bösei Lambert
E. whitei (Clark)

Kiamichi Formation

A fairly sharp contact separates the Goodland from the Kiamichi. The Kiamichi is composed largely of calcareous, slightly silty clay. The clays are soft, poorly laminated to massive. The color is dark gray on fresh surfaces but weathers to a slightly mustard green. Exceptions to the clay composition are a few thin, flaggy, silty limestone layers and argillaceous, nodular limestone beds. The most prominent of the limestone layers occurs near the base of the formation in the northeast part of the county. The layer is 2 to 4 inches thick and weathers out in small slabs along the outcrop. Thin shell limestone lenses occur near the top of the formation in some places. The shells are chiefly the oyster *Gryphaea navia* Hall.

The thickness of the Kiamichi increases steadily from south to north in the southern part of the county. It is 36 feet in a measured section 4 miles north of Baker School in the southeast part of the county, 46 feet in a section 3 miles farther north on the Weatherford-Cresson road, and 48 feet thick in a measured section 3 miles north-northeast of Friendship Baptist Church, northeast of Weatherford. Thus the Kiamichi maintains a uniform thickness from south to north across the central and northern part of the county.

The outcrop of the Kiamichi is chiefly on the stream divides in the eastern third of the county. It is so soft that streams quickly eroded through it. The outcrop is usually a narrow band on a steep slope where the overlying Duck Creek is present or along the tops of interstream ridges where the Duck Creek has been removed. The best exposures of the formation in the county are in the cuts of the G. C. & S. F. Railroad southeast of Weatherford.

The fossils of the Kiamichi are fairly abundant and varied. Diagnostic fossils of the formation are the ammonite *Oxytropidoceras belknapi* (Marcou) and the oyster *Gryphaea navia* Hall. Scott and Armstrong (MS) list the following fossils from Parker County, with necessary taxonomic changes:

Foraminifera—
Flabellammina alexanderi Cushman
Many other genera and species

Pelecypoda—
Pteria leveretti (Cragin)
Gryphaea navia Hall
Gryphaea corrugata Say
Exogyra plexa Cragin
Pecten (Neithea) occidentalis (Conrad)
Pholadomya sancti-sabae Roemer
Homomya aff. *ligeriensis* (d'Orbigny)

Gastropoda—
Turritella leonensis (Conrad)

Ammonoidea—
Oxytropidoceras belknapi (Marcou)
Oxytropidoceras bravoense (Böse)
Oxytropidoceras chihuahuense (Böse)
Craginites spp.

WASHITA BEDS

The Washita (Hill, 1887) group includes six formations in north Texas:

Mainstreet (Hill, 1894)
Pawpaw (Hill, 1894)
Weno (Hill, 1901)
Denton (Taff and Leverett, 1893)
Fort Worth (Hill, 1891)
Duck Creek (Hill, 1891)

The lower part of the Duck Creek formation is the only part of the Washita group in Parker County.

Duck Creek Formation

The basal Duck Creek is a white to light gray, thick-bedded limestone. The contact with the Kiamichi is sharp and seemingly regular. There is no evidence of unconformity in Parker County, other than the sharp, nongradational contact. The bedding surfaces of the limestones are somewhat irregular, but individual beds are generally continuous for long distances.

Maximum thickness of Duck Creek beds in Parker County is approximately 20 feet. The full thickness of the formation eastward is 60 feet, but all except the basal portion has been removed by erosion in Parker County.

The Duck Creek limestone caps the highlands in the east and southeast parts of the county. Good exposures are rare, the best ones being along the Texas & Pacific Railroad southeast of Aledo.

Fossils are fairly abundant in the Duck Creek of Parker County, but collection from the dense limestones is difficult. The most important for correlation are the ammonite genera *Idiohamites* Spath and *Eopachydiscus* Wright. The following fossils were collected from the Duck Creek in Parker County by Scott and Armstrong (MS); recent taxonomic corrections have been made.

Pelecypoda—
Inoceramus comancheanus Cragin
Gryphaea washitaensis Hill
Pecten (Neithea) subalpinus (Böse)
Lima (Mantellum) wacoensis Roemer
Protocardia texana (Conrad)

Ammonoidea—
Hamites nokonis (Adkins and Winton)
Idiohamites fremonti (Marcou)
Eopachydiscus brazoense (Shumard)
Pervinquieria "trinodosa (Böse)"
P. spp.
Prohysteroceras spp.
Craginites sp.

Echinoidea—
Enallaster mexicanus Cotteau
Holaster simplex Shumard

STRATIGRAPHIC ANALYSIS

Materials.—The maximum thickness of Cretaceous sediments in Parker County is 670 feet, exposed in the southern part of the county. The section is made up of approximately 26 percent limestone, 31 percent clay and shale, and 43 percent sand. The limestone is limited almost entirely to the Glen Rose, Walnut, Goodland, and Duck Creek formations. The clays and shales are interbedded with the limestones and sand bodies and compose the Kiamichi formation. Sand is the predominant material in the Trinity below and above the Glen Rose. Sand is practically absent from the Fredericksburg group and the Duck Creek. The Trinity group is 16 percent limestone, 20 percent shale and clay, and 64 percent sand.

The minimum combined thickness of all formations is approximately 570 feet, in the northern part of the county. Composition is approximately 20 percent limestone, 30 percent shale and clay, and 50 percent sand. The changes in proportion are due entirely to the lensing out of the Glen Rose limestone. The Trinity in the northern section is approximately 3 percent limestone, 20 percent clay, and 77 percent sand.

Source.—The source of the Cretaceous clastic sediments in the Parker County area must have been land areas to the west and possibly northwest. There are no clues in the clastics as to their stratigraphic origin. The limestone fragments in the basal discontinuous conglomerate indicate transportation distances insufficient to destroy the limestone. The source of the maroon clay material in the basal portion of the section may have been red soils developed on lands bordering the Cretaceous seas. The completely siliceous conglomeratic sand above the maroon clay bed contains a heterogeneous mixture of many types of chert. The absence of all less resistant materials and the rounding of the grains indicate extended transportation with perhaps a great deal of reworking. The stratigraphic source probably was Pennsylvanian chert conglomerates and cherty limestones.

The source of the very fine sands and silts of the sandy facies of the Cretaceous could have been the same general area as the coarse sands. The fine materials were winnowed out and spread much farther seaward. The Pennsylvanian, Permian, and possibly younger rocks undergoing erosion contained many sandstones to serve as sources for the sand. Clay material from the same general source area were in some cases deposited with the sand to form sandy clays. Some of the clay was carried farther seaward to form alternating beds with limestone.

The limestones of the Cretaceous are partly organic, partly chemical in origin. The upper part of the Walnut limestone and certain beds of the Glen Rose limestone are almost entirely organic. The Goodland and Duck Creek limestones contain many fossils, but the bulk of their strata are very fine to chalky textured and probably originated from calcareous muds due to chemical precipitation.

Environments.—The red beds at the base of the Cretaceous in Parker County offer no conclusive evidence of depositional environment. The maroon-red color implies absence of sufficient organic matter to reduce the iron oxide responsible for the color. Organic matter is scarce in continental deposits under arid condition or in aqueous deposits in water toxic to life. There are no anhydrite or dolomite lenses to indicate deposition in highly saline water. The sand member in the middle of the red-bed unit is water laid, possibly by fluviatile distribution. The best assumption for the red beds seems to be that they are continental deposits, possibly spread over a flat plain by winds and intermittent floods.

The sands and associated clays in the Trinity group are aqueous deposits. The coarse, conglomeratic sand lying on the basal red beds has the appearance of a beach deposit and is for the most part very poorly sorted. The cross-bedding varies in magnitude and direction. The thickness varies considerably. The heterogeneous effects of wave and current action reworking material encountered along the beach of a transgressing sea seem the most likely causes of the features exhibited by the sand. The conglomeratic sand may be the coarse portion of a blanket of alluvium from which waves and currents removed the finer fractions. The extremely fine sands making up the rest of the Trinity sands can be explained as deposits in a very broad zone transitional from continental to marine. Both normal and cross-bedding indicate aqueous deposition. Irregularity of clay and sand bodies implies unequal distribution by currents. The almost complete lack of organic remains means a depositional environment abnormal to life, or at least to the preservation of fossils. The only important fossil material is silicified wood. The plant fragments were floated to the sites of deposition and are not indigenous to the depositional environment. A few sand beds associated with the limestones contain marine fossils, but the bulk of the Trinity sands are without fossils and could have been deposited on a very broad, very shallow shelf, too subject to the effects of tidal and salinity changes to support life that could leave a fossil record.

The limestones of the Cretaceous are all marine in origin. The thin limestone beds of the Trinity resulted from deposits in shallow water, probably near the margin of the sedimentary basin. They show irregularities of bedding and thickness characteristic of deposits subject to wave and current action. The organic beds are in some cases made up of shell debris. Some of the beds grade laterally into sandstone by progressive increase in sandy material, showing close relationship with sand environment. Several of the limestones in the Fredericksburg carry evidence of shallow deposition. The large ripple marks in the Walnut and Goodland beds were made on bottoms within reach of storm waves. The shell agglomerate at the top of the Walnut must have formed in fairly shallow water, for the *Gryphaea* shells have a heterogeneous arrangement and partial fragmentation indicating wave and current action. Some of the Goodland limestone beds contain the thin-bodied ammonite *Oxytropidoceras,* which has been interpreted by Scott (1940) as indicating shallow environment where water movements are fairly strong. The present area of outcrop of the shallow-water limestones of the Goodland was not necessarily near the margin of the basin.

The thicker limestone beds of the Glen Rose, Goodland, and Duck Creek formations represent deposition in the more stable environment of bottoms below the reach of strong wave and current action. The *Orbitolina* bed of the Glen Rose is especially massive and uniform in composition, indicating continuous deposition with little disturbance for long periods. The thick beds of the Duck Creek with the thick-bodied ammonite *Eopachydiscus* also imply at least moderately deep bottoms (Scott, 1940).

In summary, the Cretaceous limestones exposed in Parker County represent depositional environments ranging from near-marginal, shallow, disturbed bottoms to deep, quiet depositional surfaces.

The clay deposits of the Trinity are closely associated with the sands and for the most part represent transitional and marginal marine, shallow-water deposits. The thin, calcareous shales of the Glen Rose limestone and the Fredericksburg group probably were deposited in shallow to moderately deep waters similar to the associated limestones. Increased turbidity from causes outside the Parker County area produced the argillaceous deposits. The comparatively thick clay body composing the Kiamichi formation represents a longer period of turbid-water environment in the area. The fossil oyster *Gryphaea navia* Hall and the thin ammonite *Oxytropidoceras* indicate shallow-water deposition for the beds in which they occur.

Conformability.—There is no evidence of important unconformity in the Cretaceous section of Parker County. The stratigraphic significance of the discontinuous conglomerate at the base of the section is uncertain. The radical change in lithology from the basal maroon beds to the overlying conglomeratic sand is not readily explainable, but the consistent occurrence and fairly uniform thickness of the weak clay member implies absence of strong erosion before deposition of the conglomeratic sand. Most probably there are many diastems in the Trinity sands and clays but none affecting the beds strongly enough to be recognized. No rapid changes in thickness of mappable units or significant divergences in dips of normal bedding occur anywhere in the Cretaceous succession. The Paluxy sand is intercalated between the marine Walnut and Glen Rose formations and may not represent continuous deposition. Its many lensing sand and clay bodies and truncated cross-bedding indicate contemporaneous erosion, but no continuous level of unconformity can be traced.

Post-Cretaceous

The post-Cretaceous material of Parker County occurs as remnants of high-level terraces, as valley fill, and as blankets of alluvium inside the Brazos River meanders. No fossils contemporaneous with deposition have been found in any of the deposits. Scott and Armstrong (1932, pp. 63, 64) assumed the higher terraces in Wise County to the north to be Pliocene and Pleistocene in age. It is reasonable to assume that the Parker County terraces correlate with the Wise County terraces.

The highest and oldest terraces occur as widely scattered remnants along present valley slopes. Materials are characteristically quartz pebbles, limestone fragments, and fossil shells in the terraces in the Cretaceous area. The terraces in the Pennsylvanian area are composed of quartz sands and gravels. The terraces with calcareous materials in the Cretaceous area are consolidated with a caliche-type cement in some cases. The areas covered by the terraces are too small to be shown except on a large-scale map. One good example of a terrace consolidated with caliche is on the west side of Spring Creek valley just south of Spring Creek Church on Farm Road 51, 8 miles south of Weatherford.

The post-Cretaceous valley-fill deposits in Parker County are composed chiefly of sand, silt, and clay, with occasional gravel lenses. The deposits are quite extensive, with all the larger streams having well-developed flood plains. The flood-plain deposits range from 20 to 30 feet thick. In some places a small-scale braided stream pattern has developed, as, for example, in the valley of Dry Creek 2 miles northeast of Garner. Two well-developed sets of terraces are present in the valley fill of the Brazos River. The higher set is about 40 feet above present normal river level; the lower set is 20 feet above the river. Natural levees 3 to 4 feet high parallel the present stream bank in places. A good example of natural levees occurs on the west side of the river at the U. S. Highway 80 bridge.

The largest areas covered by alluvium are the slip-off slopes inside the large, ingrown meanders of the Brazos River. The material is chiefly fine sand, with minor amounts of clay. A few remnants of terraces are preserved, but for the most part the present surface of the alluvium slopes gently toward the river. The deposits probably average 15 to 20 feet in thickness. The thin covering of alluvium caps high bluffs of bed-rock near the river where the river has recently cut into the old slip-off slopes. A good example of alluvium-capped bluffs occurs just east of Lazy Bend, on the north side of the river.

Most of the valley fill material probably is recent. The remnants of high terraces along the sides of valleys and the alluvium on the upper parts of the slip-off slopes of the Brazos River meanders may be Pleistocene.

STRUCTURAL GEOLOGY

The surface geology of Parker County bears evidence of that portion of the area's structural history that can be interpreted from Pennsylvanian and Cretaceous rocks.

Structural Evidence in Pennsylvanian Rocks

The present attitude of the Pennsylvanian beds is in general a northeast-southwest strike, with a northwesterly dip that ranges from 60 to 150 feet per mile. Along the Brazos River from Dennis west to Lazy Bend thence northward approximately 3 miles the strike is east-northeast measured on limestones in the Lazy Bend formation. In the Meek Bend area and northward the average strike is approximately due northeast with one notable exception.

In the area immediately northeast of Lake Mineral Wells, largely within the boundaries of Wolters Military Base, the strike swings to a northwesterly direction. The attitude of the beds can be measured on the limestone associated with the Lake Pinto sandstone in the basal portion of the Salesville formation and on the Dog Bend limestone above. Measurement on the lower limestone midway between Rock and Rippy Creeks showed the strike to be N. 56° W., with a dip of 45 feet per mile to the northeast. At Rock Creek the Dog Bend limestone strikes W. 7° N. and has a dip of 94 feet per mile to the north. The attitude of the Turkey Creek sandstone cannot be measured closely, but it appears to be near normal. There appears to be similar structural anomaly in older beds in the general area of Lake Mineral Wells, but dip and strike cannot be mapped accurately for lack of key beds. The conglomeratic sandstone in the East Mountain formation has some easterly dip, but the amount is difficult to determine because of slumping and weathering of the sandstone.

There is some evidence of local disturbance in the Parker County area during the Pennsylvanian. There are several small anticlinal structures in the Lazy Bend area that are buried and in some cases truncated by younger, undisturbed Pennsylvanian beds. The structures have as much as 40 feet of closure and are one-half to three-fourths of a mile in length (Russell, 1953). Trend of the axes is northeast-southwest. Evidence of the disturbance can be seen in the bed of Hill Creek one-half mile upstream from the mouth of the creek. The apparent folding may be the result of draped deposition of limestone over sand bars with some differential compaction. Small-scale faulting occurs in the same area, but so far as the field evidence indicates it may all be post-Pennsylvanian. Similar small faults occur in the Pennsylvanian beds south of the Brazos River in the area between Lazy Bend and Dennis.

Structural Evidence in Cretaceous Rocks

The structure of the Cretaceous beds is extremely simple and uniform. The average direction of dip is to the east-southeast at an average rate of 35 feet to the mile. Along the southern edge of the county south and west of the Brazos River the dip on the basal beds is more nearly to the east. No notable deviations were discovered elsewhere. More detailed checking of structure probably would reveal many small irregularities.

Structural History

The structural history revealed in the surface geology of Parker County is composed of two major periods of subsidence and deposition and two major periods of emergence and erosion. The Pennsylvanian beds prove major subsidence and deposition during the late Paleozoic. The Pennsylvanian-Cretaceous unconformity proves a tremendous period of emergence and erosion. Any deposits placed in the area between Pennsylvanian and Cretaceous have been destroyed because of the dominance of erosion during the time. Also, there is no evidence of interruption of general erosion in the area since post-Cretaceous emergence.

The Pennsylvanian subsidence is by far the more important. Over 2,000 feet of beds can be measured at the surface, and near 4,000 feet of older Pennsylvanian beds are known from well records. Conglomerates, coal beds, and perhaps disconformities indicate changes in the rate of subsidence in relation to deposition, with possibly some periods of uplift. But the general effect during the Pennsylvanian was subsidence and deposition. The attitude of the beds at the present is the composite result of subsidence during the Pennsylvanian and regional movements since the Pennsylvanian. Some eastward tilting of the older beds occurred during Pennsylvanian because of subsidence in the Fort Worth basin immediately east of the Parker County area (Cheney and Goss, 1952). Northward shifting of the center of maximum subsidence during the Pennsylvanian may be responsible for the present slight difference in strike of the Lazy Bend beds and the overlying beds. Westerly subsidence during the Permian and possibly the Triassic (Cheney and Goss, 1952, p. 2259) changed the tilt of the older Pennsylvanian beds from easterly to northerly and gave the younger beds a northwest dip. Pre-Cretaceous Mesozoic uplift and erosion created the truncated edges of Pennsylvanian beds on which the Cretaceous was deposited. Regional subsidence during the Cretaceous cycle of deposition may not have had much effect on the attitude of the Pennsylvanian beds in the Parker County area. Post-Cretaceous continental uplift and eastward tilting may have reduced slightly the rate of dip of the Pennsylvanian beds.

The Cretaceous sediments in Parker County indicate deposition in an advancing sea with minor oscillations causing the changes in lithology. The extent of the relative subsidence of the area cannot be determined, because an unknown thickness of Cretaceous beds has been removed by erosion. Post-Cretaceous uplift has resulted in a gentle southeastward tilting of the beds.

GEOMORPHOLOGY

General Physiography

The portion of Texas that includes Parker County lies within the Great Plains Province of central United States. Parker County is partially in two of the subdivisions of the Great Plains (fig. 5) recognized by Hill (1901, Pl. 1). The western part of the county, underlain by the Pennsylvanian, is in Hill's Central Province, and more specifically the Palo Pinto country portion of that province. The remainder of the county is in Hill's East-Central Province and includes the Western Cross Timbers belt of that province on the outcrop of the Trinity sands. The outcrops of the Fredericksburg and Washita rocks form a portion of the Grand Prairie part of the East-Central Province. Both provinces in Parker County are under the same general climatic controls, with differences in land form, soil, and vegetation being caused by differences in structure of the bed-rock and geomorphic history of the drainage systems.

Parker County occupies portions of two drainage systems, the Brazos and the Trinity. The Brazos River and its tributaries drain the southwest half of the county. The north and eastern portions of the county lie in the drainage area of the West Fork of the Trinity River and include its chief tributary, the Clear Fork of the Trinity. The West Fork of the Trinity does not enter Parker County but crosses Tarrant, the next county to the east. The Clear Fork and its tributaries drain a strip 10 to 12 miles wide extending northwest-southeast between the Brazos and the West Fork of the Trinity drainage areas. The divides

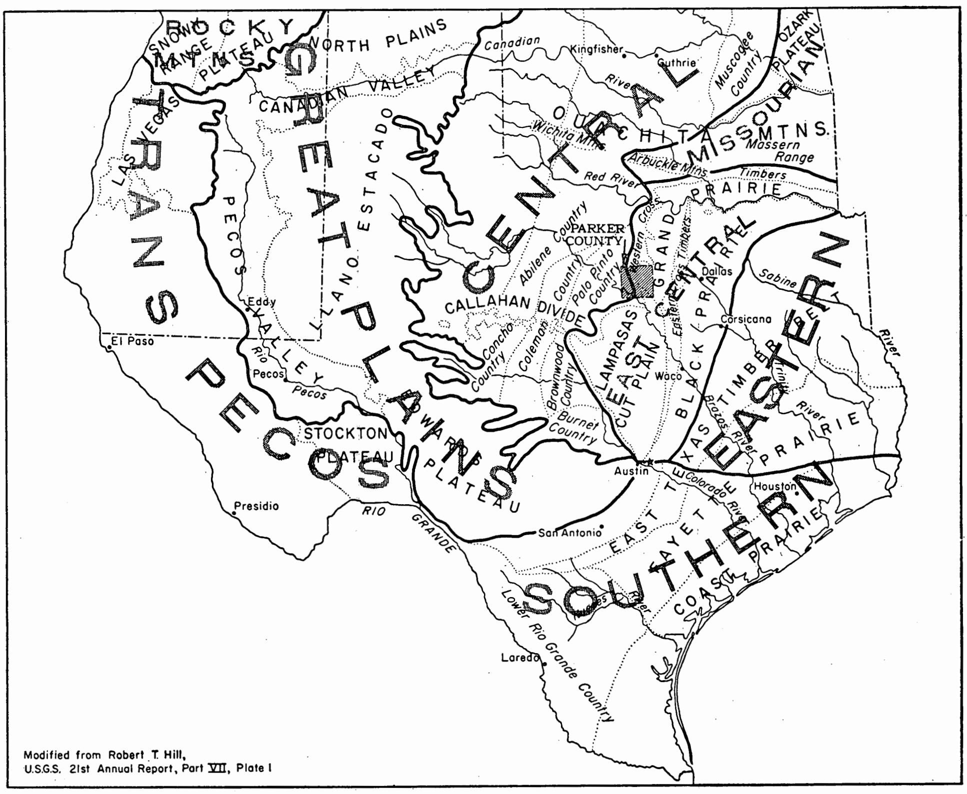


Fig. 5. Physiographic map including the Parker County area (from Hill, 1901).

on either side of the Clear Fork drainage are gently scalloped ridges with crests following a slightly sinuous path around the heads of tributaries to the main streams.

The Brazos River valley is more deeply entrenched and has a much lower gradient than the Clear Fork of the Trinity. Headwaters of the Clear Fork are over 400 feet higher than the Brazos channel at its point of entry on the west line of Parker County. The Clear Fork point of exit on the east county line is only 40 feet higher than the Brazos exit on the south county line.

The divide between the two systems forms the highest surface elevations of the county. The highest portion of the divide is in the northwest part of the county, west of the headwaters of the Clear Fork, and is about 1,400 feet above sea level. The lowest point in the county is the channel of the Brazos where it crosses the south county line at an elevation of approximately 675 feet.

The county area as a whole exhibits uniformity of geomorphic stage of land form development. There are marked differences of detail between the Brazos Valley features and those of the Trinity valleys.

Brazos River Drainage

The Brazos River is a through-flowing stream in the Parker County area, its headwaters being far to the northwest, near the eastern edge of the Llano Estacado portion of the Great Plains. Its tributaries in the county are short, intermittent, and contribute a minor amount to the yearly flow of the river. Gradient of the Brazos is about 2 feet per mile in the Parker County area.

River meanders.—The outstanding feature of the Brazos River is its large-scale meander pattern. The length of the river in the county is 36 miles. The air-line distance from its point of entry to point of exit is 13 miles, a ratio of almost 3 to 1. There are only eight major meanders in the 36 miles distance, and they are unevenly distributed and dissimilar in size and shape. The meanders are cut deeply into bed-rock, the river being as much as 150 feet below the tops of bluffs and ridges on either side of the valley. Cutting of the bed-rock has progressed laterally along the outside curve of the meanders as well as downward. The results have been continuous enlargement of the meanders, lengthening of the river valley, and the development of an extremely asymmetrical cross profile of the valley within the meanders. Thus the meanders are typical of those classified by Rich (1914) as ingrown meanders.

The area within each meander is an alluvium-covered slip-off slope cut by lateral planation of the river. The slope is in general toward the river but is slightly tilted downstream, indicating some downstream shifting of the meanders as they were developed laterally. No true meander cut-offs are exhibited. A small portion of one meander is in the process of being cut off in the bend immediately east of Horseshoe Bend where sediment brought in by Sanches Creek has influenced deposition by the Brazos. Large-scale terraces are present in the alluvium on the slip-off slopes, and meander scars and terrace scars in lower portions of the slopes are visible on aerial photographs. These indicate comparatively recent lateral shifting of the river channel.

The absence of a well-developed drainage pattern is an interesting feature of the slip-off slopes. This is probably due to the high permeability of the alluvium cover and the geologically recent development of the slopes.

The origin of the Brazos River meanders is lost in the earlier geomorphic history of the river. Their present sizes, shapes, and locations are strongly influenced by structure. Littlefield Bend at the north has cut laterally approximately 3 miles more or less down the dip of the shales of the Grindstone Creek formation. Meek Bend has moved southwest in the Steussy shale. Lazy Bend has a very large slip-off slope cut chiefly in the shales of the Hill Creek beds. Horseshoe Bend, which turns through 330 degrees and has the narrowest meander neck, is cut in the soft Trinity beds below the Glen Rose limestone.

River terraces.—There are well-established terrace levels in the alluvial deposits of the Brazos. The lowest is the present flood plain of the river and is an average of 23 feet above normal river level. It is continuous on either side of the river except where interrupted by tributaries or cliffs of bed-rock against the channel. The edge of the flood-plain terrace is commonly marked by a natural levee 4 to 5 feet high. The terrace varies in width from a few feet to over 300 feet.

The middle terrace level is approximately 40 feet above normal river level. Evidence of the terraces is intermittent, probably due largely to natural and man-made destruction. The alluvium makes good farm land, and many of the natural features of the slip-off slopes have been destroyed by cultivation. In a few places in most of the meanders the sharp rise from the flood-plain terrace to the middle terrace has been preserved. The edge of the terrace is well marked for part of the distance along the east side of the slip-off slope in Littlefield Bend.

The upper terrace level is an average of 60 feet above normal river level. The terraces have been largely altered by erosion and cultivation, and their original edges probably are no longer preserved at any place.

Evidences of the middle and upper terraces are confined to the slip-off slopes of the river meanders. A few scattered evidences of still higher terraces appear near the upper edges of the slip-off slopes, but no particular terrace level can be established. The upper edge of the alluvium covering the slip-off slopes is usually approximately 120 feet above normal river level. This indicates that the Brazos has cut downward over 100 feet while accomplishing the enormous amount of lateral planation necessary to develop its present meander pattern.

Tributaries.—Rock Creek, with headwaters in the extreme northwest part of the county, has an air-line length of 20 miles. Tributaries to the east of Rock Creek become progressively shorter as the Brazos and the Clear Fork of the Trinity drainages converge toward the southeast. Spring Creek, south of Weatherford, has an air-line distance from head to mouth of 8 miles. The Kickapoo Creek drainage south of the Brazos is 6½ miles long from the head of Onion Branch to the mouth of Kickapoo and is the longest tributary on that side of the river.

The tributaries exhibit well-developed dendritic drainage patterns. Their valley profiles are essentially symmetrical, but small tributaries to the main creeks are more numerous and longer on the southeast side of the larger creeks. The valley of Rock Creek immediately north and south of the Millsap-Mineral Wells highway is an exception to the general rule of symmetry. Here the scarp maintained by the Brazos River sandstone creates a much steeper slope on the west side of the valley. Individual streams have somewhat crooked channels, with true meanders being present in the lower reaches of the larger creeks. Rock Creek and its chief tributary, Dry Creek, are meandering over more than half their entire length. Dry Creek north of Garner and some of the smaller branches of Rock Creek have a slightly developed braided stream pattern.

Well-developed valley flats are present in the meandering portions of the larger creeks. The flats are depositional features, and the meanders are free meanders within the alluvium covering the floor of the valley. Seldom is bed-rock exposed in the channels of the streams where valley flats are well developed. Bed-rock is usually exposed where the tributary channels cross the flood plain of the Brazos. The ingrowth of the Brazos meanders has lowered the mouths of the tributaries below the alluvial cover of the river flood plain.

Interstream land forms.—The interstream land forms in the Pennsylvanian outcrop are largely controlled by structure. The sandstones and limestones of the Hill Creek beds of the Lazy Bend formation form somewhat flattened ridges between streams in the area south of the Brazos and east of Hill Creek. The Meek Bend limestone forms a well-developed scarp along the west side of Hill Creek valley extending southwestward from the river to the west county line. A broad dip slope is developed on the Meek Bend between Hill and Rocky Creeks. A more prominent scarp is created by the Brannon Bridge limestone outcrop. It begins a short distance from where the limestone emerges from underneath the Cretaceous southwest of Brock and extends west-southwest to the Brazos. The lower limestone forms the main scarp with the upper limestone forming a secondary scarp and erosional remnants on the dip slope of the lower limestone. West of the Brazos the outcrops of the two limestones are closer together and form a single scarp southwestward across the county line. The extensive dip slope on the Brannon Bridge covers the area northwest of the scarp and southwest of Meek Bend.

The next prominent ridge extends along the north side of U. S. Highway 80 from near the junction of Farm Road 1543 southwest to the county line, being interrupted by the Brazos Valley. The ridge is topped by a massive sandstone and is asymmetrical with the steeper slope on the southeast side. The northwest side is not a true dip slope, having been dissected and modified by erosion. The area from the northern end of Littlefield Bend northeastward toward Millsap has high, rugged ridges between the streams held up by another massive sandstone. No true scarp remains except immediately west and northwest of Bennett.

The most prominent scarp in the county is developed by the Brazos River sandstone and underlying sandstones. The scarp crosses the west county line about 1 mile south of the Millsap-Mineral Wells highway and extends north along the west side of Rock Creek valley. The Mineral Wells airport is built on the dip slope of the Brazos River sandstone west of the scarp. The valleys of Rock and Dry Creeks make very deep reentrants in the scarp. East of Rock Creek and south of U. S. Highway 180 erosion has created two scarps on the resistant beds in the succession. The lower one follows a very irregular line from Rock Creek valley eastward to the Cretaceous overlap northeast of Millsap, crossing Farm Road 113 just south of the double curves 2 miles north of Millsap. The upper scarp extends from the Cretaceous overlap at Cool southwestward to a junction with Rock Creek valley 2½ miles northwest of Millsap.

The rugged ridges either side of Lake Mineral Wells are held up by the Hog Mountain sandstone and an overlying conglomerate. Small erosional outliers near the county line and south of U. S. Highway 180 are capped by Hog Mountain sandstone. The scarp extending northeastward across the northern part of Wolters Military Base is caused by the Lake Pinto sandstone. The next scarp northward from the base is created by the Turkey Creek sandstone. A few low benches formed by the limestones of the Palo Pinto appear on the stream divides just south of the Cretaceous outcrop west of Whitt.

All the Pennsylvanian scarps are of the cuesta type with more or less well-developed dip slopes to the northwest. The scarps are highest toward the Brazos and die out away from the river as the valleys in front of them become shallower. The highest is the Brazos River sandstone scarp, which is approximately 150 feet above the valley of Rock Creek west of Millsap.

Structural influence on topography is less evident on the Cretaceous than on the Pennsylvanian because of the very low dip of the Cretaceous beds. The west edge of the Cretaceous outcrop is characterized by gentle slopes and low stream divides developed on the soft Trinity sands and clays. Deep gullies are characteristic of the upper parts of many of the slopes. The first scarp eastward from the west edge of the Cretaceous is caused by the lowest Glen Rose limestone. It is by no means a continuous scarp, being destroyed where the creeks cross it, so that it is better described as a series of interstream scarps. The steepest slopes face west, but in many places the scarp continues around the point of an interstream divide at the junction of two creek valleys and joins steepened slopes on the east side of the divide. Slopes on the Glen Rose are steeper in the southern part of the county where the limestone thickens, and the valleys are lower as they approach the Brazos. Valley sides have 30 to 40 percent grades in the lower portions of the creek valleys and are near vertical in some places along the Brazos Valley. Bench topography is developed to some extent where the Glen Rose consists of alternating hard and soft layers. Stream divides in the Glen Rose are comparatively flat on top.

East of the Glen Rose outcrop is another belt of gentler slopes and low divides in the Paluxy sand outcrop. Gullies are prominent at places on the Paluxy slopes. Topography typical of the Paluxy and lower Trinity sands predominates in the northern part of the Brazos drainage where limestone in the section is reduced to one thin bed.

The steep slopes along the east side of the Paluxy outcrop are due to the overlying Walnut limestone. Many flat-topped outliers of the Walnut cap steep hills that stand well above the more deeply eroded Paluxy area. Mt. Nebo on the east side of Farm Road 51, 12 miles south of Weatherford, is the largest of the outliers. It is 175 feet above the valley of Shaw Creek to the north of it.

The ridge dividing the Brazos and the Clear Fork of the Trinity begins just west of Poolville in the northwest part of the county. The divide has a gently rounded crest and moderately dissected slopes in its northern portion where the Trinity sands and clays are the bed-rock. In the area west of Peaster the divide changes to a comparatively flat-topped land form and maintains that form southeastward through the city of Weatherford to the junction of State Highway 171 and Farm Road 51. The even character of the divide top is due to the resistant Walnut and Goodland limestones from which the soft overlying Kiamichi has been stripped.

South of the junction of State Highway 171 and Farm Road 51 the top of the Brazos-Trinity divide is more rounded, because the Kiamichi clay is still present. The Kiamichi does not contain any resistant beds to form flat-topped surfaces. Farther south along the divide the lower Duck Creek limestone is present above the Kiamichi, and the ridge again is flattened on top. It is a rather broad, flat feature where it crosses the south county line.

Trinity Drainage

All the tributary systems of the Trinity drainage area in Parker County drain southeastward into the West Fork of the Trinity in Tarrant County. All the streams rise in Parker County and form a typically consequent dendritic drainage pattern on the gently dipping homoclinal structure of the Cretaceous formations, the entire drainage system being confined to the Cretaceous outcrop.

The dominant stream of the area is the Clear Fork of the Trinity. It rises 4 miles west of Poolville at the northern edge of the county, flows eastward 5 miles, then turns and flows southeastward down a remarkably straight valley to the east edge of the county. The point of exit from the county is 4½ miles north of the southeast corner of the county. The gradient of the Clear Fork is about 15 feet per mile of channel length in the upper part of the stream and decreases to 10 feet per mile where the stream leaves the county. Gradient of the flood plain is about 17 feet per mile in the upper part of the valley and decreases to 11 feet per mile in the lower part.

A divide almost as straight as the Clear Fork valley parallels the valley along its northeast side. The crest of the divide is only 2½ to 3 miles from the river, so the northeast tributaries to the Clear Fork are all very short, small drainage units. West of the Clear Fork the drainage is divided between several large creeks that are tributary to the Clear Fork. From south to north the creeks are: Bear Creek and its south fork; South Fork of the Clear Fork and its main tributary, Willow Creek; and an unnamed creek that crosses Farm Road 920 between Peaster and Poolville.

The area east of the Clear Fork valley is drained by east- and southeast-flowing creeks that enter the Clear Fork or the West Fork of the Trinity River in Tarrant County to the east. From south to north the creeks are: Mary's Creek, Silver Creek, Ash Creek, and Walnut Creek. The largest is Walnut Creek, whose drainage forms an appreciable lowland in the northeast corner of the county.

Valley characteristics.—The cross profiles of streams in the Trinity River system are essentially symmetrical. Slopes vary in steepness with differences in bed-rock, being gentle on the soft clays and shales of the Trinity beds and steep on the resistant limestones. Upper slopes are almost vertical cliffs in many cases where the resistant beds form the tops of the interstream areas. Bench topography is especially well developed on valley slopes where the alternating hard and soft layers of the Glen Rose form the bed-rock. A special type of bench forms where the Walnut shell bed is at the heads of the small streams developed on the slopes of the stream divides. The edge of the bench at the head of a stream is usually an undercut cliff where headward erosion has removed softer beds underneath the shell bed. The edge of the cliff forms a semicircle convex upstream that varies with the size of the drainage from a few feet to over 100 feet across. The top of the bench is also somewhat semicircular so that the feature forms a shallow, amphitheater-like depression on the side slope of the drainage divide. The floor of the amphitheater is bare Walnut shell limestone near the edge of the cliff and has a thin soil covering over the limestone in the remainder of the depression.

The larger valleys have alluvium-covered floors, as is shown on the geologic map (Pl. I). The alluvium floors are flat with one well-developed terrace level. The entire flat of each stream is still subject to flooding during maximum flood stage and thus constitutes the flood plain of the stream. Stream channels meander within the alluvium, but the meander belt is generally narrower than the flood-plain width. No bed-rock meanders have been observed. The gradient of the streams in the alluviated valleys is slightly less than the structural dip of the beds in the direction of flow.

A few terrace-like deposits occur on the north side of the Clear Fork valley northeast of Poolville near the northern edge of the county. The material includes limestone pebbles and cobbles and an abundance of *Gryphaea* shells of the type that compose the Walnut shell bed. The features appear to be debris from destroyed Walnut outliers rather than stream-terrace deposits.

Interstream land forms.—Details of interstream land forms in the Trinity drainage system are dominated by the nature of the bed-rock. The positive forms are chiefly gentle, rounded ridges in the north and northeast portions of the county where soft Trinity beds make up the outcrop in Walnut Creek and Clear Fork valleys. The forms over the remainder of the system are strongly modified by the resistant limestone formations of the Fredericksburg and Washita.

The most prominent feature in the Fredericksburg outcrop area is the steep slope commonly developed at the edge of the Walnut limestone outcrop along the sides of interstream ridges. The cause of the slope is the tremendous difference in competency between the limestone and the unconsolidated sands below. The degree of the slope varies, with relief ranging from 15 to 20 percent grade to vertical. The relief of the slope is generally 25 to 30 feet but varies with the amount of Trinity sands included. The prominency of the slope decreases southeastward as the dip of the beds carries the limestone lower topographically. In the area along the Clear Fork south of Aledo the limestone does not form a prominent feature. The very intricate pattern of the lower edge of the Walnut outcrop (geologic map, Pl. I) traces the location of the slope around all the stream patterns in the area northward from Aledo. Headward erosion of small tributaries into the Walnut limestone outcrop has given a highly dissected edge to the interstream ridges.

Many outliers of the Walnut form high areas on the stream divides. The slopes around the edges of the outliers generally are not steep enough to give a mesa-like form, but a few small outliers along the deeper valleys may be described as buttes. The best development of topographically high outliers is in the area between Peaster and Poolville, northwest of Weatherford.

The interstream ridges with Walnut on top are remarkably flat. Where Goodland is still present the ridge tops have gently rolling topography. The presence of Kiamichi gives a smooth, rounded contour to the ridges since the formation has no extensive resistant beds to maintain flat surfaces. The Duck Creek outcrop marks the occurrence of flattened ridges similar to those of the Walnut because of the thick, resistant limestone beds making up the portion of the formation present.

Soils and Vegetation

The soils of Parker County appear to be immature soils and are more strongly influenced by the nature of the parent rock than by other factors such as slope and exposure. There are four distinct types of parent rock and corresponding soils in the county:

1. The sandstones of the Pennsylvanian and the sands of Cretaceous Trinity beds.
2. The noncalcareous shales of the Pennsylvanian.
3. The limestones and calcareous shales of the Cretaceous and Pennsylvanian.
4. The alluvium of post-Cretaceous.

Differences of color and vegetation are the most readily observed characteristics of the soils.

The soils on the sands and sandstones are recognized by their typical reddish to red color and the abundance of the deciduous post-oak trees they support. The silt and sand content is very high and consequently the soils are very permeable. They are excellent soils for trees, shrubs, and grasses under optimum conditions of slope and cover, but a slight depletion of plant cover or over-steepening of slope causes them to erode very badly. Poor soil conservation practices have destroyed hundreds of acres of the sandy bed-rock soils in the county.

The noncalcareous shale soils are light grayish in color, and their characteristic plant feature is the abundance of mesquite trees. The texture is fine and permeability is low, hence they are described as tight soils. They are not highly productive soils but are fairly stable under varying conditions of slope and plant cover.

The soils formed on the limestones and calcareous shales are dark colored, and many can be identified by the presence of the evergreen live-oak trees. Where shale predominates mesquite may be the dominant tree. The live-oaks are fairly numerous on the outcrops of the Pennsylvanian limestones and the Cretaceous Glen Rose limestone and are very abundant on the Walnut outcrop. Aerial photographs made in the winter time show the outcrops of the above beds very distinctly because of the dark foliage present on the live-oaks. Trees are scarce on the Goodland and Kiamichi soils and are absent from the Duck Creek limestone outcrops. All the calcareous soils have excellent natural grass covers. Texture of the soils is fine, but high humus content makes them fairly permeable. They are rather stable against sheet or gully erosion, maintaining a good cover on comparatively steep slopes of the Goodland and Kiamichi outcrops.

Soils formed on the alluvium are dark, sandy to silty soils that support a heterogeneous assemblage of plants. Trees peculiar to the alluvium soils along the streams include elm, cottonwood, walnut, salt cedar, and willow. Soils on the slip-off slopes of the Brazos River meanders have the highest sand, those on the flood plains the highest silt content.

The soils most extensively cultivated in Parker County are the alluvium soils and the Trinity sand soils.

Summary of Geomorphic History

The following conclusions concerning the geomorphic history of the Parker County area can be drawn from the field evidence.

1. Erosion possibly has been predominant since early Tertiary. The only post-Cretaceous sediments are fluvial in nature, associated with land drainage systems.

2. The Brazos River drainage is the "oldest" in terms of geomorphic stage of development. Details of its drainage may have changed many times during the Tertiary, but in order to cut its deeply ingrown meanders the river must have maintained its present general pattern since the Tertiary. The large volume and maintained flow of the Brazos has caused it to lower its channel toward grade much more rapidly than the comparatively minor streams in the Trinity drainage portion of the county.

3. In the recent geologic past alluviation has predominated over downcutting in the larger stream valleys. Well-developed valley flats formed by flood-plain deposition are characteristic, indicating that mass wasting from the interstream areas furnished more material than the carrying power of the streams could handle. Bed-rock is seldom exposed in the stream channels.

4. There are no clear-cut evidences of effects of climatic changes associated with the glacial epochs.

5. There is little evidence of an exhumed erosional surface exposed by erosion of the Cretaceous beds from over the Pennsylvanian. Recent erosion has largely destroyed exhumed features.

6. Mass wasting has been rapid enough to prevent maturity of the soils. The nature of the bed-rock is still a dominating factor in the soil make-up.

ECONOMIC GEOLOGY

Oil and Gas

Springtown area.—Oil and gas have been found in commercial quantities in the Springtown area at the north edge of the county. Production is from Lower Pennsylvanian conglomerate, encountered at depths ranging from 3,600 to 3,800 feet. The oil-bearing formation is identified officially as the Caddo by the Oil and Gas Division of the Texas Railroad Commission. The oil is 40° to 42° API gravity. Initial production potentials ranged from 25 to 170 barrels per day.

The producing area is divided into two parts, separated by dry holes. Each area includes approximately 2 square miles: The southernmost one is immediately west of Poolville and is called the Springtown field. The northern area extends across the county line into Wise County and is called the Peel field. Most of the wells in the two fields were drilled during 1952. As of January 1, 1956, a total of 374,531 barrels of oil had been produced from the two fields (Lockwood, 1956).

One deep well in the Springtown area has produced gas from the lower part of the Lower Pennsylvanian at a total depth of 5,707 feet. One deep well has produced a small amount of oil from Ellenburger dolomite at a total depth of 6,688 feet.

A gas-producing area called the Toto field has been developed 7 miles west-southwest from Springtown. The area is approximately 4 miles long and crosses the valley of the Clear Fork of the Trinity River. The gas is produced from limestone and conglomerate of the Lower Pennsylvanian at depths ranging from 5,000 to 5,200 feet. One well has produced some oil from a lower Strawn sand at 3,110 to 3,120 feet, and one well has produced gas from the Caddo portion of the Lower Pennsylvanian at 3,566 to 3,592 feet.

Brock gas field.—A shallow gas field has been developed 4 miles southwest of Brock. Production is from lower Strawn sands in the section below the Lazy Bend formation, at depths near 2,300 feet. The producing area covers about 2 square miles.

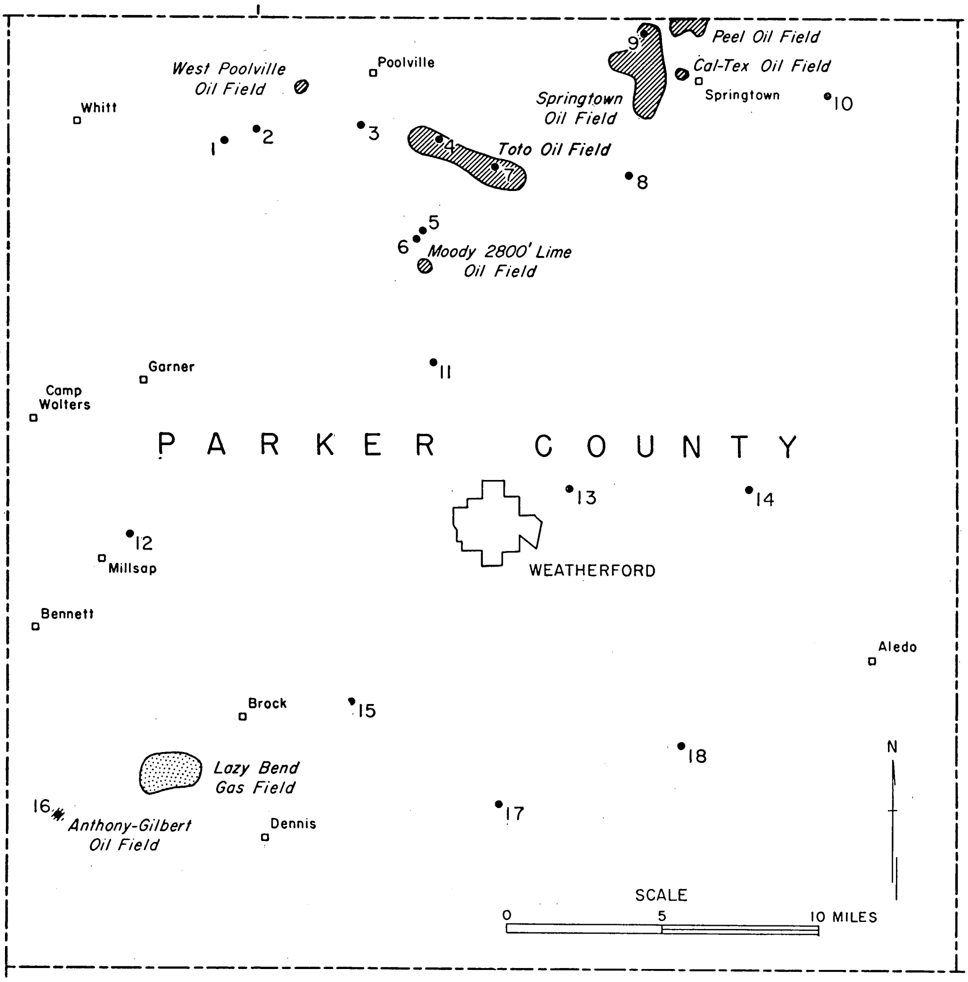
Saunders ranch.—One well drilled on the Saunders ranch 5 miles southwest of Weatherford produced gas and distillate from Lower Pennsylvanian conglomeratic sand from 4,543 to 4,551 feet. Another well one-half mile north on the Saunders ranch produced gas and distillate from a porous limestone at 4,992 to 5,002 feet. Volume of gas was insufficient and production declined too rapidly to warrant further development in the area.

Gilbert ranch.—A small amount of oil and gas has been produced from two wells drilled on the Gilbert ranch near the southwest edge of the county. The wells are located 2 miles southeast of U. S. Highway 80, near the ranch road shown on Plate I. Production in the oil well was from the Lower Pennsylvanian sand topped at 4,012 feet and in the gas well from lower Strawn sand topped at 1,955 feet. Potentials were small and production declined rapidly.

Miscellaneous.—Gas has been produced in the area immediately west of Millsap near the west county line and at the present time is produced for domestic use on the Strain ranch 2 miles west of Millsap. Production probably is from sand in the upper portion of the Lazy Bend formation.

Several wells northwest of Weatherford in the area between Poolville, Peaster, and Whitt have encountered gas in commercial quantities from the Lower Pennsylvanian. A sizeable gas reserve is indicated that may be developed as market demand for the gas is created.

Deep exploration.—Wells penetrating the Lower Ordovician Ellenburger limestone have been drilled in several parts of the county (fig. 6). One well on the Gilbert ranch drilled through all Paleo-



1. Continental Oil Co. No. I C. P. Johnson; T. & P. R. R. Co. survey, section 275. T. D. 6170 feet.
2. Continental Oil Co. No. I Davidson; T. & P. R. R. Co. survey, section 242. T. D. 6507 feet.
3. Continental Oil Co. No. I C. P. Woody; D. A. Deal survey, A-2141. T. D. 6444 feet.
4. Illinois Exploration Co. No. I Durham; T. & P. R. R. Co. survey, section 176. T. D. 6199 feet.
5. Moran Brothers No. I Howry; A. J. Stratton survey, A-1258. T. D. 6306 feet.
6. Jones Assoc. et al. No. I Darnall; T. & P. R. R. Co. survey, section 173. T. D. 6128 feet.
7. Continental Oil Co. No. I J. W. Dobbs; Hugh Brown survey, A-79. T. D. 6397 feet.
8. Cities Service Oil Co. No. I Hutcheson; L. L. Tackitt survey, A-2268. T. D. 7027 feet.
9. Buzz Morgan et al. No. I Darrell O'Neal; M. Waugh survey, A-1615. T. D. 6688 feet.
10. Kadane & Sons No. I R. T. Land; T. & P. R. R. Co. survey, section 31. T. D. 6817 feet.
11. Humble Oil & Refining Co. No. I C. H. Tompkins; T. & P. R. R. Co. survey, section 169. T. D. 7726 feet.
12. Humble Oil & Refining Co. No. I J. H. Doss; J. H. Gaines survey, A-1748. T. D. 5895 feet.
13. Rowan Oil Co. & Texas Gulf Prod. Co. No. I Carter; Desiderio de la Cruz survey, A-223. T. D. 7100 feet.
14. Cities Service Oil Co. No. I W. H. Glenn; Wm. McCarver survey, A-909. T. D. 6753 feet.
15. Roger B. Owings No. I T B. Saunders; H. Westbrook survey, A-2474. T. D. 6498 feet.
16. G. Anthony Oil Co. No. I E. Gilbert (Hammonds); J. Johnson survey, A-741. T. D. 7795 feet.
17. Sunray Oil Co. & Skelly Oil Co. No. I H. B. Fletcher; E. E. Taylor survey, A-2473. T. D. 6253 feet.
18. Devonian Oil Co. No. I Buck; I. & G. N. R. R. Co. survey No. 2, block 9. T. D. 7124 feet.

Fig. 6. Map showing location of wells drilled to the Ellenburger.

zoic rocks to the Precambrian. The deep well in the Springtown area mentioned above is the only one to find appreciable shows of oil in the Ellenburger.

Summary.—Oil in commercial quantities has been found only in the Springtown area of Parker County. Cumulative production in the county to January 1, 1956, was 402,081 barrels of oil (Lockwood, 1956).

Occurrence of gas is much more widespread than the occurrence of oil, and gas production may become important with increased demand.

Clay and Shale

The most extensive deposits of clay and shale in Parker County occur in the Pennsylvanian beds exposed along the western edge of the county. The Kiamichi outcrop offers the only notable occurrence of clay in the Cretaceous beds. The Pennsylvanian clays are all sedimentary and all the thicker deposits are probably marine. Only one thin layer of underclay, associated with the coal seam in the Garner formation, is known.

The clays and shales of workable thickness are classed as sewer-pipe and brick and tile clays. They are being used extensively in the manufacture of those products.

The Acme Brick Company has a large plant at Bennett on the extreme west edge of the county just north of the Littlefield Bend of the Brazos River. Brick and construction tile are made from clay-shale immediately above the Santo limestone in the Grindstone Creek formation. The clay is normally red-burning but colors ranging from very dark gray through various shades of red can be obtained by controlled burning of the products.

The Texas Vitrified Pipe Company has obtained sewer-pipe clay from clay-shale in the basal portion of the East Mountain formation along U. S. Highway 180 just west of the N.M.W. & N.W. Railroad. The same company also obtained sewer-pipe clay from the uppermost Mingus shale in the Garner formation in exposures immediately north of Cool. The clays vitrify well with good strength. The chief problem in their use is a rather narrow temperature firing range, necessitating close control of temperature throughout the load in a kiln. Both sites are abandoned at present in favor of clay pits in the basal East Mountain near the plant at the east edge of Mineral Wells in Palo Pinto County.

The upper East Mountain clays and shales have not been worked in Parker County, but they have been produced extensively at the Reliance plant in Mineral Wells. The beds are present at the surface in Parker County in the area northeast of Lake Mineral Wells and northwest of Garner.

Actual use has proven an abundant supply of brick and tile and sewer-pipe clay in Parker County with production having come from the Grindstone Creek, Garner, and East Mountain formations. Other Pennsylvanian clays and shales may be of equal value. The Kiamichi clay in the Cretaceous section may have possibilities as a constituent in cement making should the limestones of the area be developed for that purpose.

Limestone

Limestone occurs in abundance in the Fredericksburg and Washita portions of the Cretaceous outcrops in the eastern portions of Parker County. Sizeable limestone outcrops are formed by the Glen Rose in the southern part of the county. Limited limestone outcrops occur in the Pennsylvanian along the western edge of the county.

The Pennsylvanian limestones are hard, fairly pure, and durable under weathering conditions. Bedding is too irregular to make easily worked dimension stone, but the rock makes good material for riprap, aggregate, and ballast. Extensive quarries are in the Brannon Bridge limestone of the upper Lazy Bend formation. The quarries are located on the dip slope of the limestone along the west side of the Brazos River, south of U. S. Highway 80. Rock faces 15 to 20 feet high can be developed.

The dip slope of the limestone covers several hundred acres and offers good opportunities for opening quarries with very little overburden. Riprap was taken from the south quarry for the large Benbrook Dam on the Clear Fork of the Trinity River southwest of Fort Worth in Tarrant County.

The Walnut limestone has furnished road material from many places in the extensive outcrop of the formation in the county. The best material is found where the upper layer of shell agglomerate has been largely weathered away and the underlying layers partially disintegrated. The resulting material is somewhat like caliche, with limestone nodules and small masses of shells acting as aggregate in the calcareous matrix. The material has been used as topping for the road base of many of the asphalt paved farm-to-market roads in the county.

Commercial uses have not been developed for limestone from the Goodland and Duck Creek limestones in Parker County. The best possibility of using them is as raw material for lime and cement making. The rocks are too soft and chalky for building stone purposes. The same is largely true of the Glen Rose limestone, although it is a somewhat harder, more resistant rock than the Fredericksburg-Washita limestones.

Sandstone

The well-consolidated sandstones of Parker County are limited to the Pennsylvanian, and only a minor amount of the Pennsylvanian sandstone is well bedded and durable enough to furnish usable stone. Small-scale quarries have been opened in a few places for limited building projects. An example of such a quarry is located in the Hog Mountain sand outcrop immediately south of Lake Mineral Wells dam. The stone was used in the construction of cabins built for a camp site on top of the hill. The stone has stood up well, but it has developed an unattractive, dull, dark-red color on weathering.

Many flaggy sandstone beds are associated with the various sand bodies in the Pennsylvanian. Some are extensive enough to support individual operations, but none has been discovered that is large enough to merit large-scale commercial development. The sand beds are too lensing in nature.

The best source of a large amount of usable dimension sandstone in Parker County is the bedded phase of the Brazos River sandstone similar to that exposed in the U. S. Highway 180 road cuts a short distance west of Dry Creek bridge.

Sand and Gravel

Sand occurs in great abundance in the Pennsylvanian sandstones, the Trinity beds of the Cretaceous, and in the alluvium deposits of Parker County. But to date no commercial production of sand has been developed. Chief difficulties are the lack of friability of the Pennsylvanian sandstones, the extreme fineness of the Trinity sands, and the silt and clay impurities of the alluvium sands.

Some of the Trinity sands are relatively pure and uncolored. Their use as glass sand has been suggested, but generally they do not meet the required specifications. Damon (1948) examined samples from exposures along the old Fort Worth road 3.9 miles east of the Pythian Children's Home east of Weatherford. The samples showed a range of 0.047 to 0.130 Fe_2O_3, 0.024 to 0.550 T_1O_2, 1.30 to 1.83 Al_2O_3, and 0.08 to 0.540 CaO. Over 50 percent of the material in most samples passed through an 80-mesh screen.

The gravel deposits of importance in Parker County are limited to the weathered conglomerates of the Pennsylvanian. The weathered zone on the dip slope of the conglomerate in the East Mountain formation furnishes the best source of quartz gravel. The rock is fairly well disintegrated and can be excavated by ordinary power-excavating equipment. At the present, large-scale production is coming from operations at a locality 2 miles southwest of Garner. Many older sites in the same general vicinity have been worked.

Small occurrences of usable gravel are found on the weathered outcrop of the conglomeratic sand near the base of the Cretaceous. In the unweathered bed-rock the gravel beds are irregular and discontinuous. Where weathering has disintegrated the sandstone and the gravel concentrated by winnowing out of the finer sand, a layer of usable gravel can be stripped from the surface.

The gravel deposits in the alluvium are comparatively small and patchy. There are no extensive stream terraces built largely of gravel like those along the West Fork of the Trinity River in Tarrant County.

Ground Water

The principal ground-water supply of Parker County is in the Trinity sands of the Cretaceous. Comparatively minor amounts are obtained from Pennsylvanian sandstones and from alluvium deposits along the major streams.

The Trinity beds contain many water-bearing sand bodies that range from thin sand lenses to blanket sands. The most extensive sand is the conglomeratic bed near the base of the Cretaceous. Its texture is the coarsest of any of the sands, allowing free movement of the water. It supplies water from its outcrop to as far down dip as is practical to drill to it. It is the chief source of water for the municipal wells at Weatherford, where it is encountered at near 400 feet below the surface.

Above the conglomeratic bed many of the water-producing sands are lenses, so that near-by wells may not obtain water from the same level. The production of the wells varies with the thickness and extent of the sand in each lens. Circulation of ground water through the complex of sand and clay beds is sufficient to keep all the sand bodies supplied, but generally low permeability limits the rate at which the water can be produced. Where the Glen Rose limestone is present it divides the Trinity water-bearing section into two parts, the Paluxy above and the lower Trinity below. Water has been obtained from the Paluxy and equivalent or lower sands throughout their extent in the county.

A few of the sandstones in the Pennsylvanian formations exposed along the west edge of the county furnish weak supplies of water. Intergranular permeability is very poor, and water movement occurs chiefly along bedding and joint planes. Much of the water from the Pennsylvanian sands is too high in mineral content to be desirable for domestic use. Wells completed in the Brazos River sandstone and in the conglomeratic bed of the East Mountain formation have furnished the best supplies of water from the Pennsylvanian.

The alluvium along the Brazos River contains sand and gravel lenses from which good water has been obtained. Wells have been dug in the alluvium from the vicinity of Dennis eastward.

In summary, Parker County has an abundant supply of ground water for domestic purposes throughout the Cretaceous outcrop. The supply is fairly adequate for municipal needs but would be insufficient for heavy industrial demands or for irrigation. Along the western edge of the county there is no dependable source of ground water.

A detailed summary of water well data for Parker County has been published by Stramel (1951).

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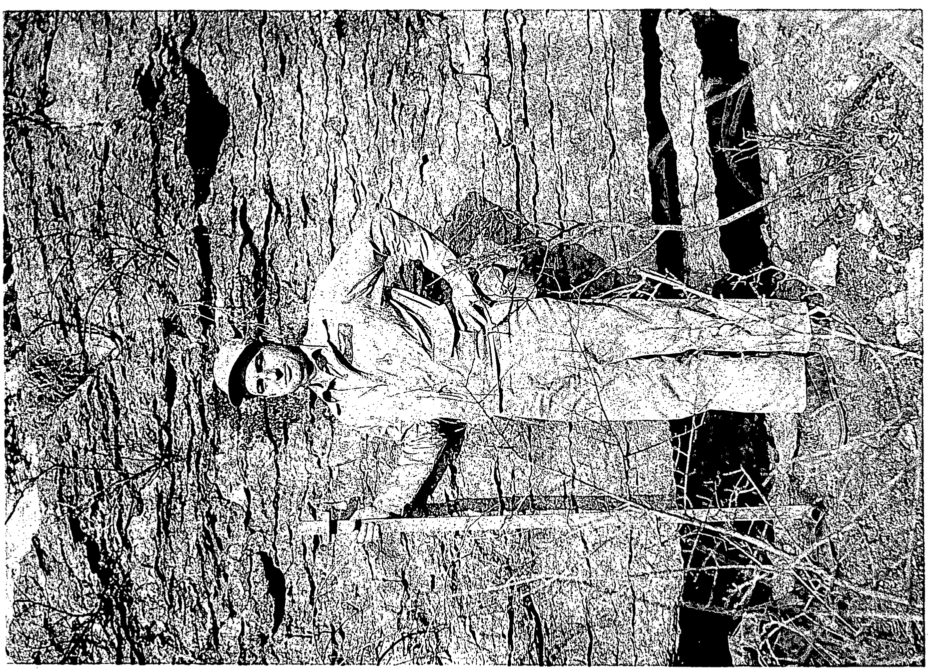
Plates II–VII

A
Limestone in upper Hill Creek beds. Grades laterally into sandstone.

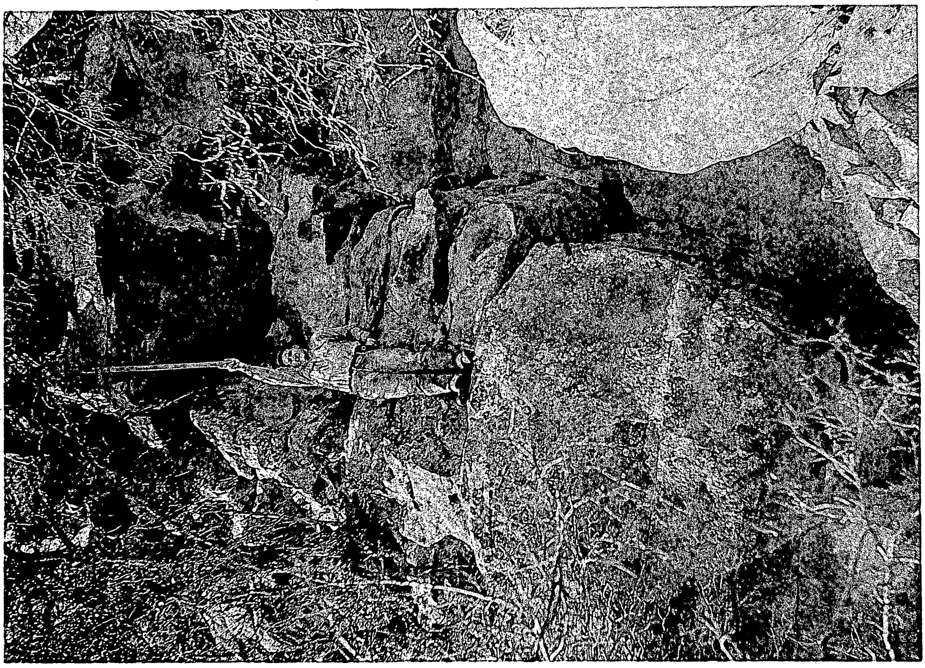
B
Ripple marks in sandstone in upper Hill Creek beds.

LAZY BEND AREA



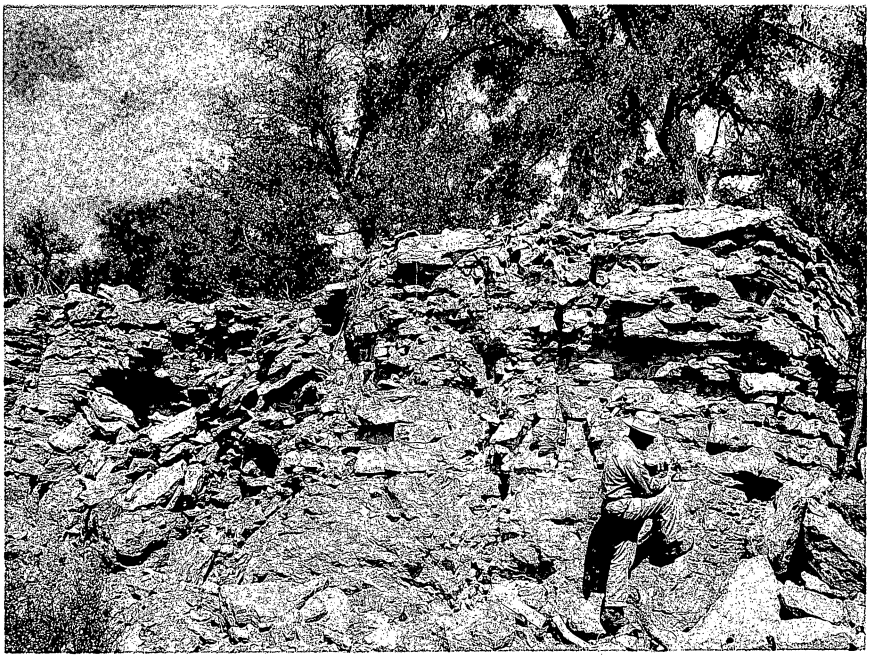
A

Meek Bend limestone one-half mile southwest of Lazy Bend of Brazos River.



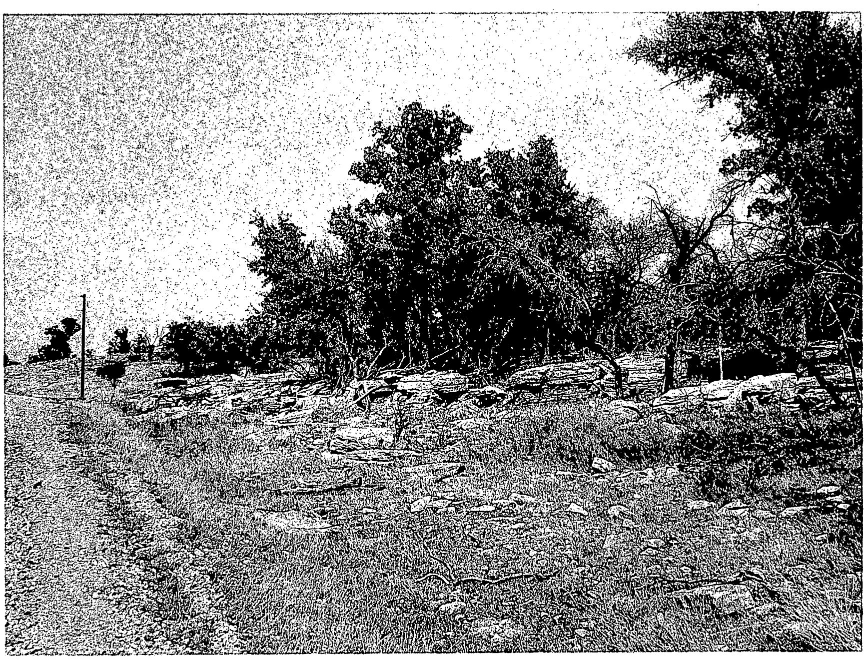
B

Massive sandstone body in uppermost Hill Creek beds, west bluff of Lazy Bend of Brazos River.



A

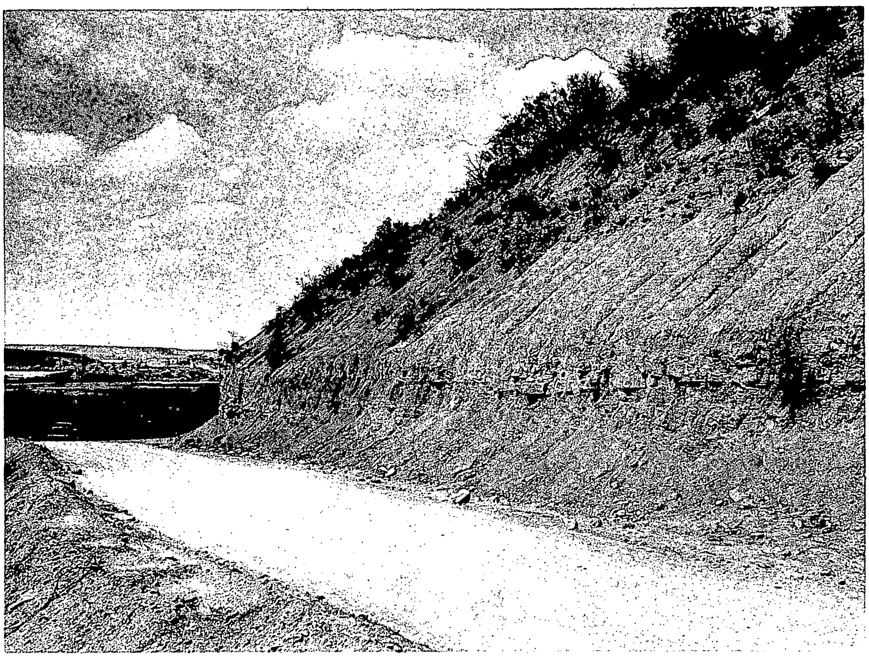
Upper bed. In quarry on west bluff of the Brazos River, 2 miles south of U. S. Highway 80.



B

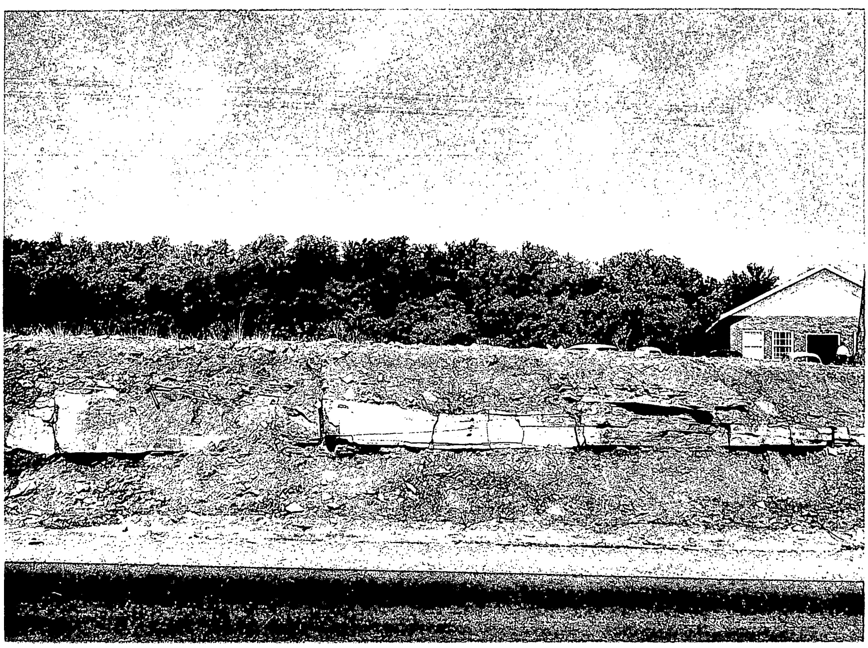
Lower bed. On Steussy Scarp, 2½ miles south of U. S. Highway 80.

BRANNON BRIDGE LIMESTONE



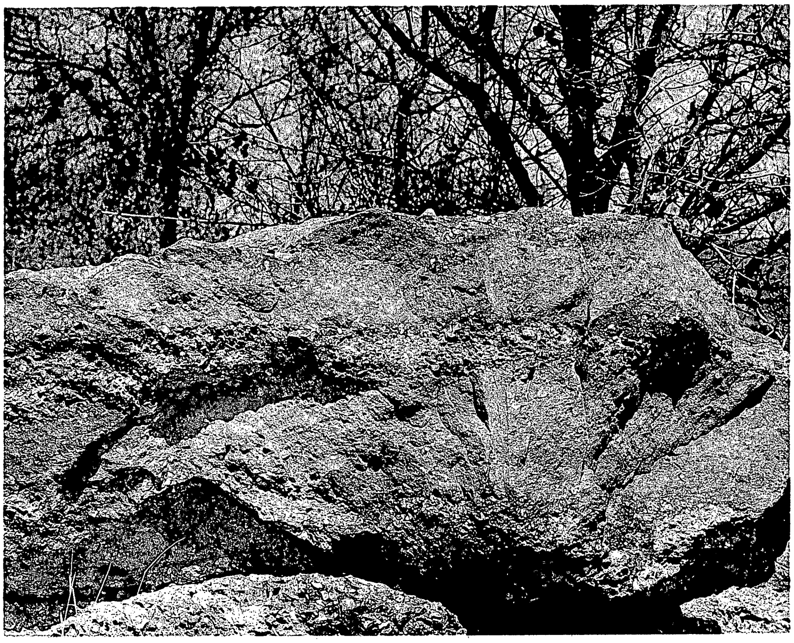
A

Grindstone Creek shale with numerous thin, lensing sandstone layers. One mile southeast of Bennett.



B

Lower Grindstone Creek shale, with rapidly lensing sandstone layer. On U. S. Highway 80, one-half mile east of Brazos River.

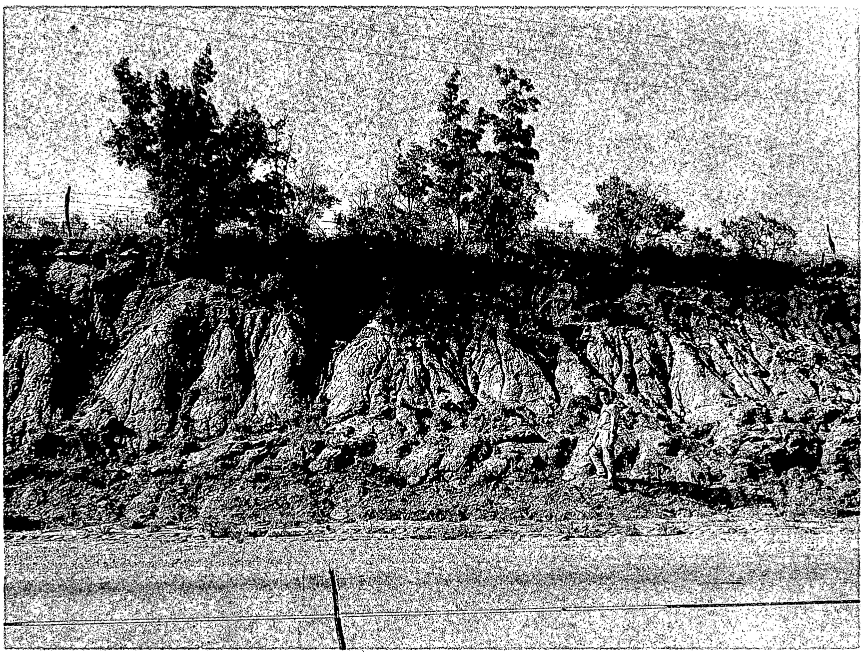


A

Brazos River sandstone and conglomerate, showing interlensing of sandstone and conglomerate; massive bed is 3 feet thick. In scarp on highway 2½ miles of Millsap.

B

Detail of Brazos River conglomerate from same locality.



A

Paluxy sand, showing lensing nature of sand bodies in the sandy clay.

B

Conglomeratic sand in lower Trinity beds, showing complex cross-bedding.

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