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No. 1931: June 1, 1919

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BUREAU OF ECONOMIC GEOLOGY AND TE
DIVISION OF ECONOMIC GEOLOGY
J. A. UDDEN, Director of the Bureau and Head of

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

Sam Houston

Cultivated mind is the guardian genius of democracy . . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

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THE GEOLOGY OF TARRANT COUNTY

BY W. M. WINTON AND W. S. ADKINS[1]

GENERAL DESCRIPTION OF THE AREA

Tarrant County is in the third tier of counties of the east central province of Texas, and is included within the belt of densest population in the state. The estimated population of the county, January, 1919, is about 148,000, of which 130,000 is concentrated in the city of Fort Worth. This city, like the cities of Dallas, Waco, Austin, and San Antonio, lies on the outcrop of the calcareous formations of the Cretaceous system. Limestone areas have always been the areas of the greatest industrial development and its accompaniment of concentrated population; and of limestone areas those of the Cretaceous have in the past been the most favorable. Many writers have commented on the curious relationship between centers of civilization and the outcrops of Cretaceous rocks. In fact, even today, a map of the world showing the areas of greatest human development would bear a striking resemblance to the map of the world's outcrops of Cretaceous rocks. Many explanations have been attempted of this suggested connection. The simple facts seem ample. Cretaceous limestones furnish an abundant water supply, a firm substratum, break down into rich soil, furnish material for the construction of roads and buildings, and by their mode of weathering furnish a land surface which is a perfect compromise between the level surface most favorable to the development of elaborate transportation, and the rolling surface most favorable for perfect drainage.

Tarrant County epitomizes in a way the agricultural industries of the state. The western part of the county is in the rolling short-grass prairie region of West Texas, which is typical grazing land; while the eastern part of the county is made up of timbered country and bottom lands, including a typical cotton-farming country. In a biological sense the county lies at the junction of the humid and semi-arid divisions of the Lower Austral life zone. Its location implies a great mixture of wild life, both plant and animal; and such a condition exists. Be-

[1] The order of names does not in any way indicate seniority.

Ms. accepted June 1, 1919, published March 1920.

sides this, the county lies at what might be considered the junction of life zones in a north-south distribution; that is, it contains life forms which belong both to the sub-tropical area and to the warmer temperate zones. There is probably no other region in the state which shows such a variety of wild life, especially of plant life, exhibiting a blending of semi-arid with humid forms and temperate with sub-tropical forms.

Tarrant County lies roughly between longitude W. 97° 1.8′ and longitude W. 97° 32.6′, and latitude N. 32° 33.3′ and latitude N. 32° 59.3′, giving it an area of about 903 square miles. The magnetic declination at the station of the United States Coast and Geodetic Survey on the Texas Christian University campus at Fort Worth is 9° 27.4′ east. On the ordinary pocket compass used by hunters, boy scouts, and field geologists, reading to a minimum of two degrees, the declination is ten degrees to the east. That is, when the pocket compass is held so that the needle points to 10° east, the zero or north mark of the compass is pointing to the true north.

The entire county is covered by rocks belonging to a single geological age—the Cretaceous, about equally divided between lower Cretaceous, or more properly Comanchean, and Upper Cretaceous. The underlying rocks dip gently toward the southeast. The rocks are hard chalky limestones, soft limestones, marls, and red sandstones. The dip of the strata gives, in general, long gentle slopes on the southeast side of the uplands, where the surface of the ground approximates the dip of the underlying rocks, and it gives rather abrupt slopes on the northwest side of such uplands, where the successive ledges of the different formations emerge from below the surface. This is the so-called "cuesta" type of topography. Despite its recognizable nature, with the gentle dip plains on one side and steep bluffs on the other side, the fact must be kept in mind that in many cases the "dip plains" are not true dip plains, and the abrupt bluffs are not always the "ends" of formations. This statement is made here because many writers in discussing this feature of North Texas topography have taken rather too literally the proposition that this cuesta type of topography indicates exactly the position, thickness, and attitude of the formations.

PHYSIOGRAPHY AND TOPOGRAPHY

The underlying geological formations, aside from climatic factors, are the most important natural features in determining the configuration of a region, and therefore, also, its possibilities for cultivation and its suitability for a dense population, location of large cities, and other cultural developments.

The area included in Tarrant County illustrates this intimate relation between the geology of a country and its surface features. A complexity of surface features is possible with a combination of alternate hard and soft strata, an even dip, and a well developed drainage. These factors result in a striking diversity of land forms and a pleasing variety of scenery.

The highest point in the county is in the western part, where an elevation of 1050 feet above sea level is reached. The lowest point is where the Trinity River passes out of the county to the east. This latter point has an elevation of 450 feet, giving the entire county a maximum relief of 600 feet. In general this is represented by a gradual slope to the east, broken by the westward facing escarpments. The escarpments are steep and conspicuous, but the much longer and gentler eastern slopes are not so readily noticed. The trip from Fort Worth to Dallas by the automobile pike is decidedly downhill in its entirety, the fall being about 160 feet in a distance of a little more than thirty miles; but because of the several conspicuous escarpments which must be ascended in traveling east, the average individual fancies that he is traveling mostly up hill.

TOPOGRAPHIC DIVISIONS OF TARRANT COUNTY

The area included within Tarrant County consists of four broad belts, two prairie strips alternating with two sandy strips or "cross timber" zones. These are as follows, from east to west: the Black Prairie, the Eastern Cross Timbers, the Grand Prairie, and the Western Cross Timbers.

The Black Prairie has only a small part of the lower and western portion of its great area in Tarrant County. This black land prairie is underlain by the whole Cretaceous series, above the Woodbine sand[1]. Due to the dip of the strata toward the Gulf Coast, this is the lowest of the belts in altitude, but the highest in the geological series. It is a gently rolling slope with a treeless surface. The soil is black, waxy, and carbonaceous. It is deep and of a superior grade. Because of the deep soil, the cuesta topography is not prominent, but even in the soft marly shales, as in the eastern part of Tarrant County, the escarpment and dip plains are recognizable. The Eagleford subdivision of the Black Prairie is separated from the Austin chalk subdivision by the prominent Austin chalk escarpment which extends for hundreds of miles across Texas parallel to the general direction of outcrop of the strata, and is finely exposed in White Cliff on the Fort Worth-Dallas pike, a few miles west of Dallas. This westward-facing escarpment overlooks the successive strips of Eagleford prairie, which arise from under it, and ascending westward divide the prairie by small crests which are themselves miniature escarpments. These correspond to the subdivisions of the Eagleford formation. Approaching Fort Worth from the east, these rise in altitude until just east of Arlington the top of the Woodbine sand emerges from underneath the basal member of the Eagleford shales.

The Eastern Cross Timbers are underlain by a homogeneous strip of red sandstone composing the Woodbine formation; and are heavily timbered with black jack oaks and post oaks. The exposure of the Woodbine formation is an important catchment area for water, as noted by Dr. Hill, furnishing artesian water in areas far to the east of Tarrant County where this sand is deep underground. A conspicuous feature of the rock under the Cross Timbers is its tendency to form large lens-like masses and to show cross bedding. These features should be considered very cautiously by prospective oil drillers and are explained and discussed under the section on the Woodbine formation At the western border of the Cross Timbers where the limestone emerges, an interesting feature is the string of small "islands" or outliers of the red sandstone. These form the numerous "Brushy Knobs", seen in this strip from the Red River to the Brazos. Some of

[1] The formations referred to in this discussion are subsequently more fully described under the section on Geology.

these "knobs" are distinctly peak-like, and are possibly due to lenticular masses in the sandstone.

The Grand Prairie has a surface which is varied corresponding to the diverse groups of rock strata underlying it. The columnar section (fig. 1-6) indicates roughly a series of limestone layers alternating with marl members. The limestones weather out as upland surfaces which are more or less flat, except for the effects of erosion, while the softer marl groups break down more readily under weathering and are exposed as slopes connecting the levels of the limestones above and below. This produces a terrace effect which is one of the features of the region. The limestones do not always or even usually weather out into dip plains whose surfaces are entirely upon a single stratum. This sort of plain is rare, despite frequent reference to such occurrences in the geological literature of this region The most common upland slope is an erosion slope dipping in the direction of the greatest dip of the underlying strata but also slanting off towards the drainage and consequently not lying entirely on one stratum, but including many successive strata. The statement that the cuesta type of topography prevails must be accepted with reserve so far as Tarrant County is concerned.

The Grand Prairie has two areally prominent members, the Mainstreet limestone and the Fort Worth limestone. These together make up 80 per cent of the total area; and the other members of the series form essentially narrow strips connecting these two with the adjoining areas and with each other. For instance, the Grayson marl connects the eastern prairie strip, the Mainstreet limestone, with the Woodbine sand. Although fifty feet thick, the Grayson is an inconspicuous strip areally (exaggerated in mapping) and the formation is very rarely exposed or entirely free from overwash. The Mainstreet with the same thickness forms a broad upland many miles wide. At many places the Denison beds, the Denton, Weno, and Pawpaw formations, form a sharp, even slope connecting the Mainstreet limestone upland of the eastern side with the Fort Worth limestone upland of the western side. Yet the thickness of the Denison beds far exceeds the combined thickness of the Mainstreet and Fort Worth limestones.

The Western Cross Timbers and the adjoining rocks to their east are complicated by the greatly dissected headwaters of the Trinity River. This dissected lowland is likewise composite, and is underlain by three groups of strata in addition to the river alluvium. The three groups are timbered but are very dissimilar in the rock composing them.

The upper and eastern strip is the Walnut formation, which is conspicuous by the great amount of slabs composed entirely of Grypheas, a fossil oyster-like shell. The region is considerably dissected into steep hills, deep laterals of the Trinity River, with frequent waterfalls, cliffs and small rapids. It is well timbered with post-oak, black-jack oak, and water oak. Next underlying it geologically, and farther west, is a strip of Paluxy sand. This weathers into flat bottom lands of dull reddish sand. The Glenrose limestone, which is westward and immediately under the Paluxy sand, is not exposed at the surface in Tarrant County.

Throughout the four great belts of country above described, there are two types of gravel, an upland and a lowland type, and probably several stages of alluvium. These two gravels are recognized commercially as "pit" (upland) and "stream" (lowland). In these gravels are found the few fossils of the Pleistocene age which are known for this region, such as mammoths, and a few others.

DRAINAGE

Tarrant County is drained entirely by the Trinity River. The Clear Fork of the Trinity, arising in Johnson County near the Noland's River divide (Brazos drainage) passes northeast to join at Fort Worth the main branch of the Trinity, the West Fork, which rises in Wise County. These two forks drain the entire western half of the county, and the east half is drained by smaller laterals of the Trinity, such as Sycamore, and Big and Little Fossil creeks. The Trinity descends from an elevation of 1050 feet at the southwest corner of the county to 450 feet at the Tarrant-Dallas County line, giving a drop of 600 feet in 40 miles, or 15 feet per mile. Much of this drop is almost in the strike, for where the river runs directly across the outcrops of the formations near Fort Worth, the rock strata are dipping eastward about ten times as fast as the river. The result is that the river in passing eastward crosses successively younger formations until northeast of Arlington it has passed into the Eagleford shales.

The drop of the Trinity River is rather even across Tarrant County where throughout its course it has a timbered lowland alluvial floodplain, increasing in width to five miles at the eastern border. The floodplain is bordered by Goodland and Duck Creek escarpments capped by Goodland and Fort Worth uplands west of Fort Worth, and east of Fort Worth by Weno and Pawpaw escarpments capped by Mainstreet uplands. In the southwest part of the county the Clear Fork of the Trinity passes through a Goodland floodplain as described, but in the northwest the West Fork cuts down a much dissected headwaters region. To the east the alluvial floodplain is bordered by Cross Timbered Woodbine sands.

The strata of Tarrant County have suffered erosion from the Trinity drainage according to their hardness and other characteristics so that the topography of the areas bordering the river valley shows three general types: (a) Dissected Headwaters; (b) Dissected Uplands; (c) Cross Timbered Bottom Lands. These types have distinct individualities, divide the county into natural regions by producing each a different topography and scenery, and have differing possibilities of development.

Dissected Headwaters of the Trinity:—This is an area of about one-sixth that of the county, on the upper course of the West Fork. The inequalities in hardness and composition of the underlying Walnut clays and shell marl produce a very rough and precipitous headwaters region whose aspect is totally different from that of the uplands. The laterals of the Trinity run mostly in deeply cut narrow valleys which are tortuous and carry swift streams during the rainy season. The hills make indented and irregular ridges converging towards the river valley and to the east capped by Goodland limestone. From the top of the Goodland escarpment are broad vistas of this dissected timbered landscape ascending toward the west and uncovering in its turn the underlying sandy land of the Western Cross Timbers. (See page 26.)

Dissected Uplands:—These strips of upland prairie, mainly underlain by the Fort Worth and Mainstreet limestones (page 51) are topographic units over the whole Cretaceous area in North Central Texas, where their direction of outcrop is a little east of north. It is notable that several railroads approaching Fort Worth from the north and south have found at the same time an even gradient and a firm substratum by running in the strike of these formations.

It has been mentioned that while the outcrops of these upland limestones and their interbedded marl formations conform in general to the cuesta type of topography, it is nearly always with modification due to erosion slope toward the drainage bottoms. The uplands are covered with 'young' stream valleys cutting their way into the original dip plains or their remnants and producing a rolling topography. This upland dissection is active and rapid in Tarrant County, while in the adjoining counties of the Cretaceous strip the exposures seem rarer. As the Trinity cuts across these limestones it produces the conspicuous escarpments which border its valley for over half its course in the county. The city of Fort Worth owes its favorable location to the Fort Worth limestone escarpment as exposed along the south bank of the Trinity and its resulting good drainage and broad outlook over the adjacent valley. Although the Trinity is a small stream at low water there has been considerable lateral swing as evidenced by the comparatively broad valley, the bordering escarpments, the fluviatile shell deposits, and other features.

GEOLOGICAL MAP

Because of the lack of an areal map which is reliable enough to be used as a base for geological mapping, our base map is composite and contains certain errors which affect the exactness of the formation contacts. In general it may be pointed out that the formations most nearly follow the roads as mapped, although even sight compass intersections show the roads to be slightly mislocated in places. In addition an even degree of refinement has been attempted over the whole area, and this has necessitated a simplification of the geology at places where more detail could have been shown. On the map the finest pen line drawn represents a width of 106 feet, and at many places the geology can be mapped more closely than this. It is hoped that there may be produced an areal map on which the known detail of Tarrant County geology can be represented.

Tarrant County has been more worked than any other county in the North Texas Comanchean, except Grayson County. It is the scene of investigations by Hill, Taff, Leverett, and others. Part of the county or all of it is included in the following maps.

1892 *Taff and Leverett: Cretaceous Area North of the Colorado River. 3rd Annual Report, Texas Geological Survey.

1898 *Hill: Black and Grand Prairies of Texas. 21st Annual Report, Part VII, U. S. G. S.

1898 Reconnaissance Map, U. S. G. S., Fort Worth Sheet.

1912 J. B. Hawley, Topographical map of the Lake Worth region.

1913 J. C. Travilla: Road map of Tarrant County.

1916 *Geological Map of Texas; Udden, Baker and Böse. Bureau of Economic Geology and Technology, University of Texas, Bulletin 44. (Third edition, 1919).

—— Missouri, Kansas and Texas Railway of Texas. Contour map of 4 square miles southeast of Fort Worth, Texas.

1918-19 Corps of Engineers, U. S. Army. Progressive Military Map, Advance Sheet 487 N, II & IV.

TYPE LOCALITIES IN TARRANT COUNTY

Within this county are found the type localities of many of the species described by Cragin and Clark. For convenience of reference there is here given a list of these localities, the original terminology being quoted:

Epiaster elegans var. praenuntius Cragin[1] Comanche Peak, Benbrook.

Epiaster hemiasterinus Cragin[1].......... Grayson marl, 6 miles east of Fort Worth.

Heterodiadema ornatum Clark[2].......... Washita group, Fort Worth.

Leptarbacia argutus Clark[2]............. Washita group, Fort Worth.

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*Geological map.

[1] Cragin, 4th Ann. Rept. Tex. Geol. Surv., 1893.

[2] Clark and Twitchell, U. S. G. S., Mon. LIV., 1915.

Ophioglypha texana Clark[3]	Denton marl, 6 miles north of Fort Worth, on the banks of Little Fossil Creeek.
Astarte acuminata Cragin[1]	Weno marl, 3½ miles east of Fort Worth.
Vola bellula Cragin[1]	Half mile above T. P. bridge on Sycamore Creek, near Fort Worth.
Exogyra plexa Cragin[1]	T. P. Ry., 3 miles east of Benbrook, 20 feet below the top of a bed of Exogyra texana.
Stearnsia robbinsi White[3]	Little Fossil Creek, 6 miles north of Fort Worth.
Dalliconcha invaginata White[3]	Same.
Cinulia tarrantensis Cragin[1]	Top of Exogyra Texana bed, T. & P. Ry., 2½ miles east of Benbrook, with Tylostoma mutabilis and Cylindrites formosus.
Cylindrites formosus Cragin[1]	Same.
Trichotropis shumardi Cragin[1]	E. texana beds, 1½ miles east of Benbrook.
Neritopsis tramitensis Cragin[1]	Woodbine sands, top, Bear Creek, Tarrant County, near Dallas County line.

These localities are all still recognizable. The type localities of the Fort Worth limestone (Hill[4]) are practically obliterated by overwash and by street grading.

FOSSILS AS HORIZON MARKERS

It is desirable to place on record here certain observations regarding the range of the fossils found in the formations ex-

[1]Cragin, 4th Ann. Rept. Tex. Geol. Surv., 1893.

[3]Hill, Bull. Geol. Soc. Amer., 5, 1893, p. 328.

[4]Hill, Amer. Jour. Sci., 1888; and 21st Ann. Rept., U. S. G. S., Pt. VII, 1901, pp. 259-61.

posed in this county, and to indicate so far as practicable the relative utility of different species as horizon markers, including the mode of preservation of the fossils, and the possibility of recurrent horizons.

In Tarrant County the limestones and interbedded marls follow each other in alternating beds, so that the whole geological column presents a remarkable uniformity. In the first place, the formations alternate between harder and softer groups of rocks, so that each limestone formation is overlain by a soft marly or clay formation. For example, the Goodland limestone is overlain by the Kiamitia marl; then comes the Duck Creek limestone, overlain by the Duck Creek marl; then the Fort Worth limestone, overlain by the Denton shell marl; then the Weno limestone and marl, overlain by the Pawpaw clay; then the Mainstreet limestone, overlain by the Grayson marl. In the second place, within a formation are alternating lime and marl strata.

With such a confusing similarity of strata some means of locating the exact geological level is necessary other than that of a mere inspection of the rock. This is furnished by certain of the fossils contained in the beds. Of course some fossils run throughout the series or through considerable portions of it, and therefore are worthless as horizon markers. Of these practically nothing will be said in this paper. Certain others are strictly limited in their range and occur only at particular levels. These are key fossils, or horizon markers. If their range of occurrence in Tarrant County is roughly less than ten feet vertically, the range, in this paper, will be called the *zone* of occurrence. If it is two vertical feet or less, it will be referred to as a *restricted zone*. If it is more than ten feet, but of limited range, it will be referred to as a *horizon*. Some fossils have *zones* in which they are particularly abundant, lying within *horizons* in which they occur, but less abundantly. Some fossils appear in *recurrent zones,* that is, zones between which the fossils in question have never been found, even after considerable search, although admittedly they might occur there. It seems likely that many fossils now known only at certain levels will be found more widely distributed; and that the main reliance is to be placed upon their *zones of abundance* as here outlined.

MODE OF PRESERVATION

Fossils in this region have been found in the following modes of preservation:

(a) In the condition of lime compounds, as aragonite, and calcite. This is the most common mode. There are two conditions: The original shell material may be replaced by lime, preserving the original appearance and the material may be either indurated or chalky; or the original shell may be present, sometimes with the nacre and lustre of the living form.

(b) In the condition of iron compounds, as pyrite, hematite, or limonite.

(c) In the condition of silica, as in some fossilized or opalized wood fragments and sandstone fossils.

(d) In the condition of mud casts, consisting of compacted marl, often yellowish, and differing from ordinary shells in appearance, usually casts of the interior of the original shell. These casts are especially prevalent in the Goodland limestone, but are common also in the Washita division. The impressions may be internal, as casts; or external, as moulds.

If the original shell is replaced by iron oxide it is then called an iron pseudomorph. Sometimes, but rarely, calcareous shells are colored pinkish.

POSSIBILITY OF RECURRENT HORIZONS

Certain species which are doubtfully recurrent will be mentioned. The matter of recurrent forms is at present debatable, and we confine ourselves to bare facts. To establish recurrence in a given region, a fossil must occur in certain zones and not between these, and it must be proven that the recurrent zones contain the same species. If these things are true, there was at intervals a presumable migration of the species in and out of the region to one or more "reservoirs" in other regions. In practice it is essential not to confuse fossils from different levels by supposing them to indicate the same level. The chief recurrent forms are:

(a) *Kingena wacoensis* and other species. In Tarrant County, these brachiopods have been found in only four zones: base of the Duck Creek limestone; Lower Kingena zone and upper Kingena zone of the Duck Creek marl; and base of the Mainstreet limestone. Of these, the Kingena zone near the base of the Mainstreet limestone is the Kingena zone of the literature, and is stated to lie at the top of the Georgetown limestone at Georgetown, Austin, and other Central Texas localities. At Blum, in Hill County, near the Brazos River, brachiopods occur near the top of the Gryphea and Ostrea conglomerate of the Denton formation, and at the classic locality on Duck Creek north of Denison and other places on the Red River they occur at the base of the Hamites zone in association with fossils of this zone. The Mainstreet zone extends from the Red River to the Rio Grande, according to Hill. The Duck Creek marl zones extend for miles in every direction from Fort Worth, but have not yet been found at the Red River. We know of no occurrences between the zones above mentioned. For practical purposes, it can be said of the Kingenas, first, that they are not confined to one zone; and second, that there are probably several species of brachiopods in these zones.

(b) *Ostrea carinata* Lamarck. The taxonomy is again confused here and the Texas material requires critical study and comparison with European individuals. This is one of the two or three species still remaining from a large number of species formerly thought to be common to the Texas and European Cretaceous. The zones of recurrence of this species have been so greatly extended that they are only doubtfully recurrent, yet between these zones these forms have not yet been found in the Texas region. In Europe where the species ranges widely in the Cenomanian it is not considered to be recurrent.

(c) *Gervilliopsis invaginata* (White.) The situation is essentially the same as for *Ostrea carinata.*

(d) *Exogyra americana* Marcou. This large conspicuous oyster occurs near the top of the Duck Creek limestone near Denison (Dr. Boese) and persistently in the top of the Fort Worth limestone in Tarrant County and other places. It has so far not been found elsewhere.

UTILITY OF FOSSILS IN INTERPRETING WELL RECORDS

All of the following fossils are of much practical importance, since even from minute fragments such as are found in well drilling, the level may be determined always approximately, and sometimes with exactness. These levels have been carefully checked and their sequence verified in the field in numerous localities and over wide areas. Where there is variation within Tarrant County, this is stated under the discussion of the fossil horizon.

These key fossils will be seen to unequal advantage in well washings. If, as sometimes estimated, the largest compact fragment likely to be found in a standard rotary drill cutting is about 5/8 of an inch, it is evident that some fossils will survive the drilling process intact, while others will be ground to unrecognizable fragments. Fossils will survive because of their small size, as some of the small pyrite fossils mentioned in this paper; or because of their hardness, as certain Gryphcas, or because of both, as Kingena; or because of their abundance, as some of the Grypheas in the shell marls; or for other reasons. With the number of key fossils cited in this paper, it is believed that a sufficient sample of one or a combination of several fossils can be had from practically any level of the Washita division, to determine the level.

To assist in the certainty of these determinations, the value of the fossils for locating specific levels has been designated in the following table of identification values. The list as given in this table is incomplete and subject to revision. As in the European section the ammonites and echinoids are most reliable for determination of stratigraphic level and other fossils are variable in value. Certain associations and zones of abundance are valuable, as has been explained, if recurrences of the same fossil are carefully distinguished from each other. (See page 18). In the following list, the fossils are arranged within each formation, in the order of their occurrence, from top to bottom.[1]

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[1] In this table fossils which are most likely to be found and which have not been found at other levels than those indicated are marked with two asterisks. (**)

Fossils which are less likely to be found, but which identify the level indicated within narrow limits, are marked with one asterisk. (*)

Fossils occurring in zones of abundance or other fossils occurring in zones important for locating stratigraphic levels, are left without asterisk.

TABLE OF IDENTIFICATION VALUES OF COMANCHEAN AND CRETACEOUS FOSSILS[1]

Eagleford:

**Ostrea belliplicata, gastropods, fish teeth and bones.
Schloenbachia sp. P.
*Acanthoceras swallovi (Shumard).

Woodbine:

*Conglomerate of Ostrea soleniscus, Ostrea carica, Barbatia micronema(?), Exoygra sp., Aguilera cumminsi, Cerithium, fish vertebrae and teeth.
Dexter sands: no fossils observed.

Grayson Marl:

*Exogyra sp. 1.
*Gryphea mucronata Gabb.
*Exogyra sp. 2 and Exogyra arietina Roemer.
Pecten subalpina (abundant), Cyphosoma, Hemiaster calvini, etc.

Mainstreet Limestone:

Leiocidaris (highest).
**Turrilites brazoensis Shumard.
**Kingena wacoensis Roemer(?).
Schloenbachia sp. O., aff. inflata.
*Exogyra arietina Roemer.
Ostrea quadriplicata Shumard (highest).
*Holectypus sp., aff. limitis Boese.
Ostrea carinata Lamarck.
Pachymya austinensis Shumard
*Pecten cleburnensis Adkins and Winton (sp. 1).
Pecten sp. 2.

Pawpaw Clay:

Hemiaster sp. 1; Nautilus sp. 1.
**Pyrite fauna: Baculites sp.; Scaphites hilli Adkins and Winton (sp. A); Hamites tenawa Adkins and Winton; Enallaster sp. 1; Salenia sp. 1; Trochosmilia sp. 1; Turrilites worthensis Adkins and Winton (sp. A) and spp.; Mortoniceras sp. A; Acanthoceras sp. A.
*Starfish zone: Metopaster hortensae Adkins and Winton; Comptonia sp.; other starfishes.
Nodosaria texana Conrad.
Fish teeth, vertebrae, plates.
Enallaster sp. 3; aff. bravoensis Boese.

Weno Limestone and Marl:

"Quarry group": Ostrea quadriplicata, Ostrea carinata (abundant). Gryphea washitaensis (abundant), Homomya sp.

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[1] These and other key fossils are described and figured in: Adkins and Winton, Univ. of Texas Bull. 1945.

*Pentagonaster texensis Adkins and Winton (sp. 1).
Schloenbachia spp. L-M.
*Engonoceras sp. 1
*Nodosaria texana Conrad.
Venericardia sp. 1, Corbula spp. 1-2, Turritella sp. 1.
*Gervilliopsis invaginata (White).
*Pecten georgetownensis Kniker (?), Turritella sp. 2, Remondia (?) acuminata Cragin, Hamites sp. B, Cottaldia sp. 1.

Denton Marl:
**Gryphea washitaensis (abundant).
Ostrea carinata (abundant).
Protocardia sp., Trigonia sp.

Fort Worth Limestone:
*Enallaster longisulcus Adkins and Winton (sp. 2).
*Nerinea sp. 1.
*Exogyra americana Marcou.
Ostrea carinata Lamarck.
*Hemiaster elegans Shumard (abundant).
**Pecten bellula Cragin.
*Schloenbachia sp. K (size of austinensis Lasswitz).
**Holaster simplex Shumard (abundant).
*Pecten sp. 3.
Schloenbachia sp. I.

Duck Creek Marl and Limy Marl:
*Upper Kingena zone.
Upper Gastropod zone: Cerithium, Turritella, Pleurotomaria, Gyrodes (?).
Schloenbachia sp. I.
*Pecten wrightii Shumard.
**Lower (Main) Kingena zone.
*Goniophorus sp. I.
*Crania sp. 1.
**Hamites tanima Adkins and Winton; Hamites spp. D-G.
*Pinna sp. 1.
*Scaphites worthensis Adkins and Winton (sp. B).
Lower Gastropod Horizon: Cerithium, Lunatia, Cinulia, Turbo, Nerinea sp. aff. pellucida Cragin, Schloenbachia sp.

Duck Creek Marly Lime and Limestone:
*Schloenbachia sp. H. aff. trinodosa Boese.
*Schloenbachia sp. G.
*Schloenbachia sp. F.
*Desmoceras sp. B ("brazoensis", "graysonense"?).
*Desmoceras sp. A.
*Inoceramus comancheanus, I. munsoni.
**Hamites comanchensis Adkins and Winton (sp. A); H. nokonis.

Adkins and Winton (sp. B); H. fremonti Marcou (sp. C); H. spp. H-J.

Kiamitia Marl:

**Gryphea navia Hall.
Gryphea washitaensis (lowest).
Pholadomya sp.
*Exogyra plexa Cragin (highest).
*Schloenbachia belknapi Marcou (highest).
*Pecten irregularis Boese (highest).
*Schloenbachia acutocarinata Shumard (highest).
*Exogyra texana Roemer (highest).
Cyprimeria sp. 1.

Fredericksburg Division:

Cyprimeria sp. 1.
*Schloenbachia sp. near belknapi.
Schloenbachia acutocarinata Shumard
*Diplopodia taffi Cragin.
**Coral syndrome: Parasmilia sp., Trochosmilia sp.
*Holectypus sp.
*Enallaster texanus Roemer (abundant).
*Hemiaster sp. near whitei Clark.
**Salenia mexicana. Upper level.
Exogyra plexa Cragin (small form).
**Syndrome of Chondrodonta sp. aff. munsoni (Hill), Pecten irregularis (Boese), Cinulia, Lima, Pinna sp. near comancheanus Cragin, etc.
*Engonoceras sp. aff. piedernale von Buch.
*Exogyra plexa Cragin (large form).
**Schloenbachia acutocarinata (Shumard) (abundant).
Pholadomya sancti-sabae Roemer (abundant).
Gryphea marcoui Hill and Vaughan (abundant).
*Schloenbachia sp. A.
*Gryphea marcoui (Upper Conglomerate).
Exogyra texana (Upper Horizon, abundant).
Salenia sp. (lower level).
Protocardia filosa (Conrad).
Cerithium bosquense Shumard.
Natica sp. aff. pedernalis Roemer.

Walnut conglomerate and clay:

*Schloenbachia acutocarinata Shumard (lowest)
Enallaster sp., Turritella sp.
*Gryphea marcoui conglomerate.

Paluxy sands: No fossils noted in Tarrant County.

THE GEOLOGICAL SECTION

The marine formations found in Tarrant County, as already stated, are those of the Cretaceous System. In addition there are alluvial and terrace deposits of the Cenozoic. In the following table these formations are listed in order, the oldest formations being placed at the bottom of the table. In the second column is given the probable equivalence of the terms here used as applied to other sections in Central Texas, as given in Bulletin 44 of the Bureau of Economic Geology. Of the formations here listed, the oldest actually exposed at the surface in Tarrant County is the Paluxy. The older formations, however, are penetrated in well drilling.

TABLE OF GEOLOGIC FORMATIONS OF TARRANT COUNTY[1]

Tarrant County Section.	Central Texas Section.
Cenozoic and Recent	Cenozoic and Recent.
Eagleford	Eagleford
Woodbine	Buda (?).
Grayson Mainstreet	Del Rio.
Pawpaw Weno Denton Fort Worth Duck Creek Kiamitia	Georgetown.
Edwards Comanche Peak Goodland	Edwards. Comanche Peak.
Walnut	Walnut.
Paluxy	Paluxy.
Glenrose	Glenrose.
Trinity	Travis Peak.
Pennsylvanian	

[1]In this tabulated statement of formations the Woodbine of Northern Texas appears as the equivalent of the Buda of Central Texas. Although in accordance with present usage, the authors wish to express reserve with regard to the equivalence of the Woodbine in the Central Texas section.

DESCRIPTION OF FORMATIONS.

PENNSYLVANIAN

Knowledge of the composition and exact horizons of the Pennsylvanian strata beneath Tarrant County is very defective and awaits further drilling and especially a careful and intelligent recording of the well logs. The Tucker's Hill well, drilled in East Fort Worth in 1892, apparently penetrated at 1120 feet a series of alternating clays and sandstones; the 'Polytechnic' well went out of "dark brown shale and sand" at 1200 feet; the record for 1200-1297 feet is missing; 1297-1416 feet is recorded as "blue shale". From logs of other wells it is known that the base of the Trinity is red sandstone and the top of the Pennsylvanian at Fort Worth is bluish to black shales so that the parting between the Comanchean and the Pennsylvanian sediments in the Polytechnic well possibly lay in the gap in the log, summarized above.

DIP OF THE PENNSYLVANIAN ROCKS

A contouring of the basal Trinity does not, of course, give information which determines the attitude of the underlying Paleozoic rocks, since the two systems are unconformable. Well data show an eastward dip of the base of the Trinity sand, and an eastward dip of the underlying Pennsylvanian strata has been assumed. In addition there appears to be a large depression, possibly synclinal, in the Pre-Comanchean strata under Tarrant County. (See page 97).

COMANCHEAN

TRINITY DIVISION[1]

The Trinity Division consists in Tarrant County of the following formations, beginning at the bottom: Trinity (Basement) sands, Glenrose limestone, Paluxy Sands. The Basement sands are underlain by the Pennsylvanian, and the Paluxy

[1]In this paper we follow the terminology of Hill, who established the accepted classification of the Texas Comanchean and named its divisions and formations.

sands are overlain by the Walnut formation of the Fredericksburg Division of the Comanchean.

TRINITY (BASEMENT) SANDS.

The Trinity (Basement) sand, not exposed at the surface in Tarrant County, is an important reservoir for artesian water under the Black and Grand Prairies, as fully explained by Hill. It contains at least three important artesian levels under this area and is probably about 120 feet thick. Underneath Fort Worth it is penetrated at the depths of from 1025 to 1150 feet.

GLENROSE LIMESTONE.

Proceeding southward from southern Oklahoma, the Antlers or basal Cretaceous sand, is described as being split into two sandy formations by an intervening wedge-shaped limestone mass which thus occupies a place between the two sands. It increases in thickness southeastward. This limestone is the Glenrose formation. It is not exposed at the surface in Tarrant County, but has been penetrated by wells at various points in the county. It is stated by Hill to be about 470 feet thick under Fort Worth and to increase in thickness southeastward at the rate of 8 or 9 feet per mile. Underneath Fort Worth it occurs at depths of about 500-1025 feet.

PALUXY SANDS.

This sand, the westernmost outcropping formation in the county, is exposed in the valley of the West Fork, in the northwest corner of the county. It is an artesian water reservoir and consists of alternating layers of rather unconsolidated sands and compact clay, the formation being iron-stained but free from gypsum, and its water of a correspondingly good quality. On exposure the material is seen to be poorly consolidated, and readily disintegrated; it contains rounded concretions and phosphate nodules. The Paluxy sand is about 100 feet thick and contains three principal artesian layers. It is poor in fossils.

FREDERICKSBURG DIVISION.

The Fredericksburg division consists in north-central Texas of four groups of strata: Edwards limestone, Comanche Peak limestone, Goodland limestone, and Walnut shell conglomerate and clays. Since the limits of each of these divisions are still being studied, the formations will be discussed together.

Brief Diagnosis: Underlying the narrow but very easily recognizable outcrop of brownish shelly Kiamitia marl in Tarrant County is 117 feet of white. chalky, rather pure limestone and interbedded whitish marl, which makes the bluffs of the Clear Fork between Fort Worth and Benbrook, and is exposed over a considerable area along the two forks of the Trinity. Beneath this whiter rock is a bluish shell conglomerate which is the top of the Walnut formation. Under the conglomerate is a series of marls, unconsolidated sand and shell conglomerates extending about 100 feet down to the easily recognized Paluxy sand. A characteristic sequence of fossils in these sediments is noted in the following discussion.

Lithology: The upper 16 feet of the Fredericksburg Division at Fort Worth is a hard, resistant, crystalline, rather unfossiliferous limestone which forms a protective cap for the underlying, more chalky limestones. This has been considered the northern attenuated portion of the Edwards and Comanche Peak formations, which thicken rapidly toward the south, forming below the Brazos the substratum of the Lampasas Cut Plain. Taff records from Benbrook a *rudistid* in the upper four feet of the Fredericksburg; these fossils and an abundance of flinty masses characterize the Edwards limestone farther south.

Below the upper 16 feet is a series of softer, chalky limestones and light straw-colored marls extending from a point which will be defined as the top occurrence of *Schloenbachia* sp. aff. *belknapi* Marcou, downward to the top of a prominent blackish-blue, hard shell conglomerate made almost entirely of the oyster *Gryphea marcoui* Hill and Vaughan. This conglomerate lies 117 feet below the base of the Kiamitia marl, the Fredericksburg-Washita contact, which is easily recognized in Tarrant County. The basal part of the limestone above the conglomerate contains considerable yellowish-brown marl. The basal contact is sharply defined. The limestone contains a characteristic sequence of fossils, which is invariable over a wide area. These fossils are, in part, beginning at the top:—

1. Schloenbachia sp. near belknapi (Marcou).
2. Schloenbachia acutocarinata (Shumard).
3. Diplopodia taffi Cragin.
4. Coral syndrome: Paiasmilia, Trochosmilia.
5. Holectypus sp.
6. Enallaster texanus Roemer.
7. Hemiaster sp. near whitei Clark.
8. Salenia mexicana. Upper level.
9. Exogyra plexa Cragin. Small form.
10. Syndrome of Chondrodonta sp. aff. munsoni (Hill), Lima, Pecten irregularis Boese.
11. Engonoceras sp.
12. Schloenbachia acutocarinata (Shumard), abundant.
13. Pholadomya sancti-sabae Roemer, abundant.
14. Gryphea marcoui Hill and Vaughan, abundant.
15. Schloenbachia sp.
16. Schloenbachia sp. (6″).
17. Turritella sp., abundant.
18. Gryphea marcoui. Upper conglomerate.
19. Exogyra texana, Upper horizon, abundant.
20. Salenia sp., Lower level.
21. Protocardia filosa Conrad.
22. Natica pedernalis Roemer.

The foregoing white-limestone portion of the Fredericksburg Division is exposed in a vertical section at the north end of the Lake Worth dam; good exposures occur on the Azle road 9 miles northwest of Fort Worth, where practically the whole thickness is seen underlying a nearly complete section of the Kiamitia marl; on the Stove Foundry road, half way between Fort Worth and Benbrook, where the upper third is well exposed; on the Weatherford, Granbury, and Plover roads; and elsewhere in the area mapped. The formation is very fossiliferous, most of the fossils being mud casts.

The cut in the hill at the north end of the Lake Worth dam sections the upper part of the Fredericksburg division, commonly assigned to the Goodland limestone, and continues downwards to the top of the bluish-gray Walnut shell conglomerate

LAKE WORTH SECTION OF THE FREDERICKSBURG DIVISION

	Feet.	Inches
Duck Creek Limestone	40	
(The lower two feet of this limestone is the Hamites ledge.)		
Kiamitia marl: Brown marl containing Gryphea navia and Exogyra plexa, forming grassy slope above cliff	31	6
Fredricksburg Division:		
9. Chalky limestone, sparsely fossiliferous	26	9
This contains the following strata:		
9h. Massive limestone in 4 layers .... 6 feet.		
9g. Marly fragmented limestone 8		
9f. Blue marl 1		
9e. Three marl layers interbedded with thin limestone layers 3		
9d. Fragmented limestone 4		
9c. Blue marl with 2 limy layers 2		
9b. Chalky limestone. Echinoid zone 2		
9a. Blue marl 0.75		
These strata are rather barren in the upper 16 feet but contain especially in the lower part: Hemiaster whitei, Enallaster texanus, Diplopodia taffi, Schloenbachia sp. aff. belknapi, S. acutocarinata, Cinulia, Lima, Pecten irregularis, Gryphea marcoui, Exogyra texana, Pinna sp. aff. comancheanus, Cyprimeria, Lunatia, Parasmilia, Trochosmilia and many other fossils.		
8. Massive chalky limestone	5	3
This massive and distinct band contains: Hemiaster whitei, Lima wacoensis, Lima sp, Enallaster texanus, Pecten subalpina, P. irregularis, Exogyra texana, E. plexa, Engonoceras, Schloenbachia acutocarinata, S. sp. aff. belknapi, Tylostoma sp.		
7. Blue calcareous marl	5	6
This distinct marl band is conspicuous (Plate 1), and contains: Turritella, Pholadomya, Lima, Trigonia, Cyprimeria, Exogyra plexa, Enallaster texanus.		
6. Massive chalky limestone	13	0
Hemiaster whitei, Hemiaster sp, Gryphea marcoui, Lima wacoensis, Schloenbachia acutocarinata, sheets of celestite.		

		Feet.	Inches.
5.	Blue marl	7	0
	Hemiaster, Lima, Pecten irregularis, Enallaster texanus and many other fossils.		
4.	Chalky limestone	10	0
	The bottom of this layer is about at the level of the approach to the dam.		
3.	Massive impure fragmented chalky limestone, marly at the base	43	0
1.	Massive chalky limestone overlying the Walnut shell conglomerate and seen in the channel below the dam	5	0
	Total	117	0
	Walnut Conglomerate:		
	Massive blue gray shell conglomerate composed mainly of Gryphea marcoui shells	5	0

The Fredericksburg limestone can be studied to advantage on the steep slopes of the valley of the West Fork, just northeast of the Lake Worth dam, where its fossil sequence is excellently displayed. The following series of levels holds for any locality in Tarrant County within narrow limits, and may be used at Lake Worth, Mary's Creek north of Benbrook, Bear Creek southwest of Benbrook, Azle Road sections northwest of Fort Worth, and Stove Foundry Road sections along the Texas and Pacific track between Fort Worth and Benbrook.

DISTANCE OF FREDERICKSBURG FOSSIL HORIZONS AND ZONES OF ABUNDANCE BELOW THE TOP OF THE FREDERICKSBURG LIMESTONE, IN TARRANT COUNTY

	Feet.
Fossils sparse	0-16
Corals: Parasmilia, Trochosmilia	23
Diplopodia	24
Salenia (upper level)	26
Trichotropis shumardi	27
Exogyra plexa	28
Lima (abundant)	28
Ostrea sp. aff. munsoni	28
Schloenbachia belknapi	40
Hemiaster sp. (small)	36
Salenia (lower level)	55
Protocardia filosa	57
Exogyra texana	40-57; 90-100
Natica pedernalis	110

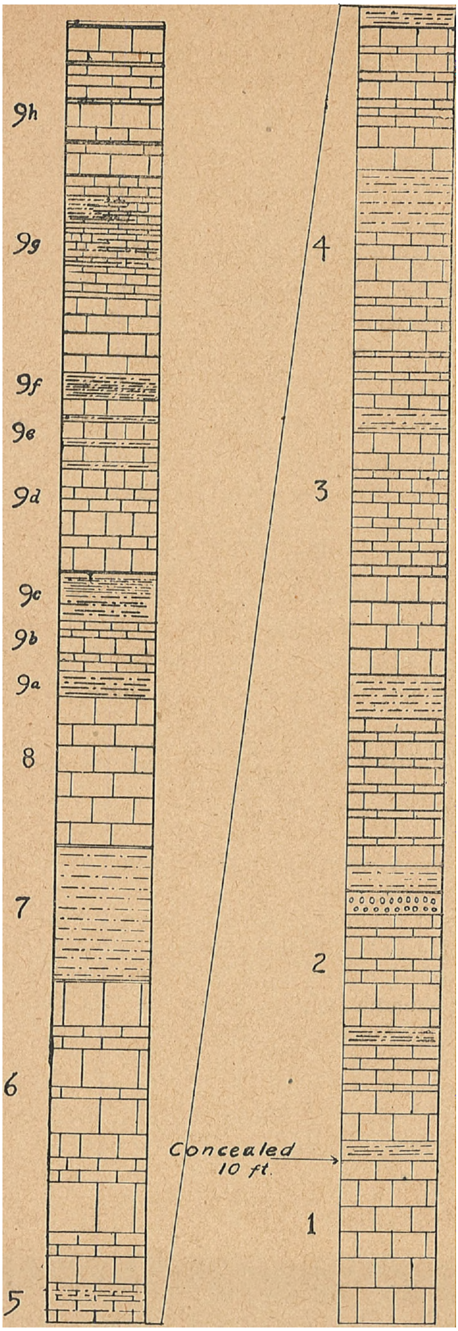

Fig. 1. Columnar section of the Fredericksburg limestone in the valley of the West Fork of the Trinity River near the Lake Worth Dam. The upper half of the section is seen in Plate 1. The numbers refer to corresponding strata described on pp. 29-32. Vertical scale, ⅛ inch=1 foot.

The portion of the Fredericksburg Division lying between the limestone just described and the Paluxy sand below, consists of alternating conglomerate and sand layers totalling about 100 feet in thickness. This series of strata constitutes the prominent escarpment seen below the Fredericksburg limestone on the Azle road, two miles east of Azle, on the Weatherford road near the county line, and elsewhere in the northwest corner of Tarrant County. The topmost impervious conglomerate protects the underlying unconsolidated sands from weathering, and thus gives to the whole escarpment a resistant appearance. In fact the cap conglomerate breaks off and strews the sides of the hills with fossiliferous slabs and debris. This topmost layer sometimes weathers unevenly, and small hard caps remain, forming the Walnut peaks seen near Azle. The shell conglomerate outcrops around Lake Worth, where it is seen at the small exposure just below the dam and for several miles up the river. This basal Fredericksburg belongs to the Walnut formation, but the upper contact will not be defined here.

SECTION OF THE LOWER PORTION OF THE FREDERICKSBURG DIVISION, ON AZLE ROAD, TWO MILES EAST OF AZLE TARRANT COUNTY, TEXAS

	Thickness in feet.
Brown limy marl with Gryphea marcoui, Turritella, Exogyra texana, Enallaster, Natica	20
Blue-black shell conglomerate, containing Gryphea marcoui (in great numbers), Trigonia, Pecten subalpina, Pecten sp., Exogyra texana and spp., Cyprimeria, Turritella, Enallaster texanus, Remondia (?), Lunatia sp.	5
Unconsolidated sand, slightly yellow stained, containing ferruginous fragments. No fossils noted	75
Arenaceous reddish limestone and shell conglomerate, containing Gryphea marcoui, Turritella sp., Enallaster texanus, Exogyra texana	25
Paluxy sand.	

The upper conglomerate of the Walnut, a mass of *Gryphea marcoui* shells, is seen in the east bank of Lake Worth at the Nine-mile bridge, just opposite the bathing beach. It should be especially noted that there is another conglomerate having the same sequence of lithology and of fossils, lying stratigraphically 20 feet above this level and easily confused with it.

FAUNA OF THE GOODLAND LIMESTONE

Hemiaster whitei Clark	Turbo sp.
Hemiaster sp.	Homomya sp.
Enallaster texanus (Roemer)	Pinna sp. aff. comancheanus (Cragin)
Holectypus planatus Roemer	Protocardia texana (Conrad
Salenia mexicana Schlueter	Protocardia filosa (Conrad)
Diplopodia taffi Cragin	Isocardia sp.
Cyphosoma texana	Cyprimeria texana (Roemer)
Goniopygus sp.	Pecten occidentalis ? (Conrad)
Engonoceras sp.	Pecten irregularis (Boese)
Schloenbachia spp.	Pecten subalpina Boese)
Schloenbachia acutocarinata Shumard)	Exogyra texana Roemer
Turritella seriatim-granulosa Roemer	Exogyra plexa Cragin (Boese)
Turritella sp.	Exogyra sp. aff. plexa Boese
Cinulia tarrantensis Cragin	Gryphea marcoui Hill & Vaughan
Trichotropis shumardi Cragin	Pholadomya sancti-sabae Roemer
Cylindrites formosus Cragin	Ostrea sp. aff. johannae Choffat
Cerithium bosquense Shumard	Lima wacoensis Roemer
Tylostoma chihuahuense Boese	Trigonia sp.
Tylostoma tumidum? Shumard	Tapes sp.
Lunatia pedernalis Roemer	Corbula sp.
Nerinea sp.	Schloenbachia sp. aff. belknapi (Marcou)
Neritina sp.	crustacean claws
Rostellaria subfusiformis Conrad	Trochosmilia texana (Conrad)
	Parasmilia austinensis Roemer

FAUNA OF THE WALNUT FORMATION.

Exogyra texana Roemer	Turritella sp.
Exogyra weatherfordensis Cragin	Pecten irregularis (Boese)
Enallaster texanus (Roemer)	Triginia sp.
Remondia ? sp.	Schloenbachia acutocarinata (Shumard)
Gryphea marcoui Hill & Vaughan	Holectypus sp. aff. planatus
Salenia sp. aff. mexicana	

WASHITA DIVISION

The Washita Division of the Comanchean Cretaceous is very fully developed in Tarrant County, and includes the following formations beginning at the base: Kiamitia, Duck Creek, Fort Worth, Denton, Weno, Pawpaw, Mainstreet, Grayson, and Woodbine.[1]

KIAMITIA MARL

Brief Diagnosis: The Kiamitia formation is a brownish yellow, slightly calcareous marl, with scattered limestone, shelly and flaggy bands and abundant deposits of oyster shells, mostly *Gryphea navia*. It is 27 feet thick at Fort Worth. It weathers out usually into a narrow hillside slope which lies above the glaring white Fredericksburg limestone and below the scarp produced by the basal Duck Creek limestone. The outcrops are

[1]The inclusion of the Woodbine in the Washita Division is tentative on the part of the authors.

usually grassy and poorly exposed, and due to their situation are often contaminated by gravel deposits. The limits of the formation are sharply defined in Tarrant County.

Description of Localities: This formation skirts the western edge of the Black Prairie at the foot of its escarpment and forms a narrow sloping strip often less than 50 feet wide. Due to its narrowness and to the close affinities of the formation with the Fredericksburg strata (page 27) it has not been separately mapped; but it may be projected on the map by cutting off a hair-line strip from the east border of the Fredericksburg Division as mapped. The formation decreases in thickness and in shelliness southward. At Shawnee Creek, Denison, it is over 60 feet thick and has prominent bands of hard shell conglomerate distributed through most of its thickness. In Tarrant County the shell bands have disappeared and the shells are present in smaller amounts in the loose limy layers and the interbedded marls. On the Noland's River, southeast of Blum, the formation is 19 feet thick and very similar to its outcrops in Tarrant County. The constant features, from the Red River to the Brazos, according to Hill, are a basal member which is calcareous and argillaceous and contains quantities of shell fragments; the upper part of the formation is a series of calcareous laminated blue clays which turn brownish-black upon weathering, interstratified layers of indurated calcareous clay (e. g., stratum 15 below) and laminated sandstone flags (strata 2, 4, 7, 17). The flags are somewhat calcareous and the whole formation shows iron discoloration. South of the Brazos the formation is attenuated, and near Round Rock is stated to be an "earthy, blue, marly, rather hard limestone" at the base of the Georgetown limestone. (Hill).

In Tarrant County there are two general types of Kiamitia exposure, the hillside and the upland type, of which the latter is very rare and exceptional. If the overlying Duck Creek limestone has been leveled or brought to a very gentle grade over a considerable area, the Kiamitia will form a gentle slope backward from the resistant underlying Fredericksburg rocks and will produce the upland type of exposure. This sort of outcrop is seen at the western edge of Duck Creek uplands, hence its rarity. The best examples are along the Azle road near Lake Worth. On the prevailing hillside outcrops exposures are produced in stream cuttings but they are very inconsecutive. The exposures lying near the main drainage lines are usually partly overlain by terrace gravel deposits. However, the present day lateral drainage is rapidly cutting into the uplands and the headwaters of these valleys show uncontaminated Kiamitia exposures.

Nearly a complete exposure, lacking the upper contact, is seen on the Azle road, about 6 miles northwest of Fort Worth and 2½ miles northeast of Lake Worth, at the point where the road sections the Kiamitia marl and passes down thru the Goodland escarpment.

SECTION OF KIAMITIA MARL, AZLE ROAD, SIX MILES NORTHWEST OF FORT WORTH

		Height from bottom of section		Thickness	
		From	To	Feet	In.
18-19	Brown marl. Gryphea navia	20′	25′	5	
17	Hard shelly limestone..........	19′9″	20′		3
16	Very fossiliferous bluish marl "E. plexa zone"	19′	19′9″		9
15	Fractured limestone, double band with central marl layer...... ..	18′	19′	1	
14	Bluish fossiliferous marl........	16′	18′	2	
13	Hard coarse grained limestone, blue upon fracture	14′4″	16′	1	8
12	Blue marl	14′	15′4″	1	4
11	Hard shelly limestone..........	13′6″	14′		6
10	Blue marl	13′	13′6″		6
9	Blue shaly marl...............	12′10″	13′		2
8	Brownish marl, bluish before weathering	12′	12′10″		10
7	Brown sandy flag.............	11′10″		12	2
5-6	Blue marl, more compressed at top	6′6″	11′10″	5	4
4	Light colored soft sandy flag....	6′4″	6′6″		2
3	Blue marl	5′	6′4″	1	4
2	Light colored soft sandy flag....	4′10″	5′		2
1	Brown laminated clayey marl, blue on fresh exposure........		4′10″	4	10
A′	Fredericksburg limestone.				

(Upper 2 feet of Kiamitia concealed by soil overwash).

These several members in the Azle section may be arranged in three groups that can be distinguished and described as below:

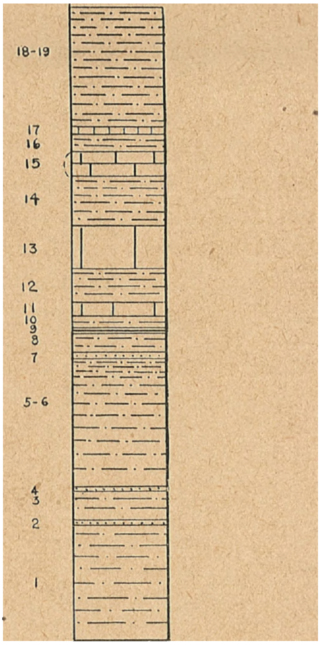

Fig. 2. Columnar section of the Kiamitia formation in cut on Azle road, eight miles northwest of Fort Worth. The numbers refer to corresponding strata described on pp. 35-7. Vertical scale, ⅛ inch = 1 foot.

Basal portion (*strata* 1-6): Approximately the lower half of the formation is a clay-marl which is bluish or bituminous on fresh exposure and extensively laminated; is brown on weathering, breaks into cuboidal chunks, indurates locally in thin layers, and at places is sandy. Hill notes the following features of this portion: It is a dark blue clay resting directly upon the smooth surface of the white Fredericksburg limestone; at a level of 5 feet above the base is a persistent band of gray indurated limy clay (2); at places it is variably arenaceous in the basal portion and some layers very near the base are sandy; near Aledo (Parker County) there is a basal layer of laminated, sandy, very calcareous and argillaceous material which contains large quantities of shell fragments. This argillaceous portion at the Brazos is not more than 5 feet thick.

The Fredericksburg-Kiamitia contact is lithologically the most contrasting and abrupt change in the series. It is seen to advantage at the Marine Creek crossing of the Azle Road. Here the blue, closely laminated, flaky Kiamitia marl lies directly upon the flat but irregular and lumpy surface of the limestone. In stream cuts the marl may be removed exposing the limestone. At localities nearer Fort Worth a finely fragmental shell deposit was noted just over this limestone; and at the Texas Pacific Railroad crossing of the Clear Fork is a six inch slightly shelly, blue marl stratum at the base of the Kiamitia. As noted later the fossils are mainly continuous across this contact.

Middle portion (*strata* 7-17): This limestone portion is topographically and paleontologically the most interesting part of the formation. It consists of six thin limestone layers or flaggy, sandy layers, alternating with blue and brown calcareous, laminated, and in part carbonaceous, clay. Three of these layers (7, 9, 17) are calcareous sandstone flag layers each 2 or 3 inches thick; of the other three layers 13 is a hard, coarse-grained limestone, 11 and 15 are soft marly-chalky limestones. All of the layers are fossiliferous, and the formation, in richness of fossils, is quite the reverse of the description of Taff. The fauna is, however, poor in ammonites and echinoids.

Upper portion (*strata* 18-19): This is a clay marl, brown, non-laminated and sparsely shelly, without the extensive conglomerate sheets which are so prominent in the upper Kiamitia of the Red River section. *Gryphea navia* and *G. corrugata* were noted in this portion.

Palentology: Although the Kiamitia formation has been placed in the Washita division it has strong paleontological affinities with the Fredericksburg, as shown by the following table:

Fossils of the Kiamitia marl, at Fort Worth, Texas.	Formation or formations in which fossil is found, indicated by asterisk in column opposite fossil named.			
	Fredericksburg	Kiamitia	Duck Creek	Washita
Gryphea navia Hall		*		
Avicula leveretti Cragin		*		
Schloenbachia sp. (belknapi?)		*		
Ostrea sp.		*		
Exogyra texana Roemer	*	*		
Pecten irregularis Boese	*	*		
Exogyra plexa Cragin	*	*		
Schloenbachia acutocarinata Shumard	*	*		
Isocardia sp.	*	*		
Homomya sp.	*	*		
Trigonia sp.	*	*		
Pecten subalpina ? Boese	*	*	*	*
Protocardia texana (Conrad)	*	*	*	*
Cyprimeria sp.	*	*	*	*
Gryphea washitaensis Hill		*	*	*
Gryphea corrugata Say		*	*	

Kiamitia Fauna

(Forms known to occur only in the Kiamitia)

	Members of Azle section preceding, in which fossil is found
Pinna sp.	3
Gryphea navia Hall	1-19

The typical *G. navia* is very abundant in the middle third of the formation at Fort Worth, though it forms thick conglomerates in the upper portion on the Red River. It is a massive imbricated shell, usually with a twisted beak.

Schloenbachia acutocarinata, Exogyra plexa (plicate and non-plicate forms), and *Pecten irregularis* were not seen above the stratum 16. *Exogyra plexa* is limited to this layer.

"16" is a very fossiliferous layer. Below it the fossils decrease in number and in the lower third of the formation are rare. *Schloenbachia acutocarinata* and *Exogyra texana* were not observed in the basal Duck Creek limestone as at the Red River.

DUCK CREEK FORMATION.

The Duck Creek formation at Fort Worth is divisible into four lithological and palentological members beginning at the top:

(1) Kingena member—the Duck Creek Marl.

(2) Scaphites member—the Duck Creek Limy Marl.

(3) Schloenbachia sp. (aff. trinodosa) member,—the Duck Creek Marly Lime.

(4) Desmoceras member—the Duck Creek Limestone.

DUCK CREEK MARL AND LIMY MARL

These groups in Tarrant County consist of a series of prevailingly light colored yellowish-gray marls containing thin seams of impure fragmental chalky limestone. The marl is recognizable in the landscape as a gently sloping shelf or terrace lying at the base of the escarpment produced by the overlying Fort Worth limestone and sloping to the outcrop of a limestone layer which lies at the base of the Marl (stratum 17). Below this layer, which in stream cuts forms the edge of the marl shelf, the slope is steep and is continuous with that the the Duck Creek limestone escarpment below. The top of the Duck Creek limestone is a persistent grayish, usually lichen-incrusted band, outcropping below the edge of the shelf in the face of the escarpment. The outcrop of these strata is generally narrow and lies along the rim of the main escarpment as seen near the Texas Christian University at Fort Worth, and therefore its soil value is almost negligible. At places, however, it weathers into a brownish-yellow hillside slope devoid of rock and is then indistinguishable from the Fort Worth upland except for a slight topographic break at their junction. The series is 34½ feet thick near Fort Worth. It is characterized by the following well defined sequence of fossils:

Pleurotomaria austinensis zone
Upper Kingena zone
Pecten wrightii zone
Upper Gastropod horizon..........Globiconcha (?), Turritella,
Diplopodia zone Fusus, Cerithium
Lower (Main) Kingena zone
Goniophorus sp. zone
Crania sp. zone
Limonite fossil (Lower Gasteropod) zone, Scaphites sp B (top)
Gerontic Ammonite zone........Hamites spp.
Pinna sp.

Description of Localities: The Duck Creek Marl and Limy Marl are distinct from the overlying Fort Worth limestone and the underlying Duck Creek limestone, both lithologically and paleontologically, and have as much justification for ranking as a separate formation as either of them. If they are to be placed with either it should be with the Fort Worth limestone, since the faunal changes are very abrupt at the end of the Duck Creek limestone.

The Fort Worth-Duck Creek contact as here described and mapped, following the most frequent usage in the literature, is totally arbitrary. It is debatable if it would not be much better to place this contact below the abundant Kingena zone and the horizon of *Pecten bellula* or lower, so as to partition the ammonites and echinoids more accurately. Such a contact would be as well warranted lithologically and topographically as the present one, and more consistent paleontologically; but since the formations are of only local application, no insistence is placed on this matter of contact. There is a clear and mappable topographic break above the stratum 24, so that the overlying Fort Worth limestone, even if thin, makes a continuous miniature escarpment in the landscape. The only other consistent topographic break is at stratum 17, which is resistent to erosion and caps the underlying Duck Creek escarpment; 17 forms conspicuous horseshoe bend outcrops in runs, while 24 fails to withstand erosion. In this group of strata the limestone beds are soft, chalky and fractured, and the marls are yellowish, water-bearing and very calcareous. Due to the thinness and softness of the limestone bands these degrade rapidly and so produce no conspicuous surface features. Only the Duck Creek stratum 21 is noticeably sandy and flaggy. The limestones and marls grade into each other, and locally there is slight lateral replacement.

The Duck Creek marl is typically exposed in the run above the first turn of the street car track north of Texas Christian University, and in the cut of the military road nearby.

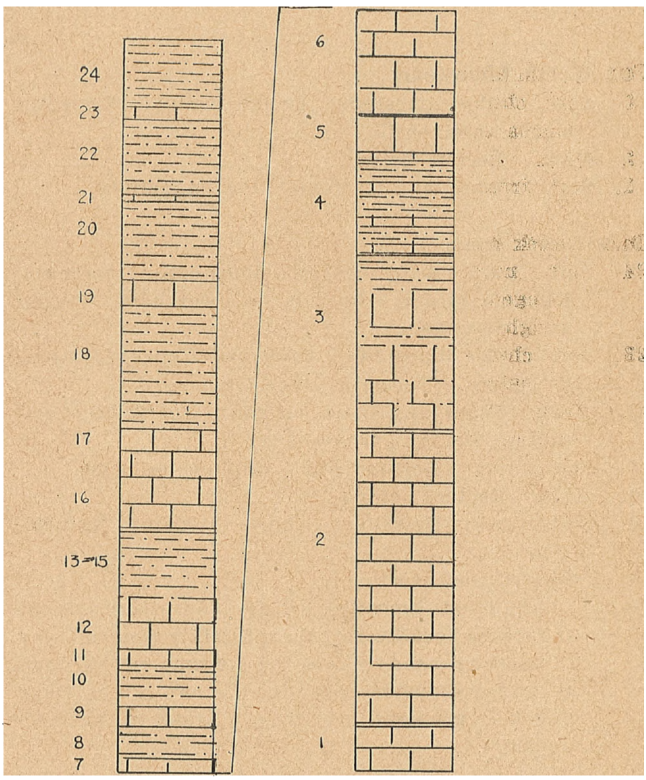

Fig. 3. Columnar section of the Duck Creek formation in cuts near Forest Park, Fort Worth. The numbers refer to corresponding strata described on pp. 42-4. Vertical scale, ⅛ inch = 1 foot.

SECTION OF THE DUCK CREEK MARL, ON BOTH SIDES OF RUN SOUTHEAST OF FIRST TURN OF STREET CAR TRACK, ¼ MILE NORTH OF TEXAS CHRISTIAN UNIVERSITY AND 3½ MILES SOUTHWEST OF FORT WORTH.

Altitude of top of Duck Creek Marl 680 feet.

		Thickness Feet	Thickness Inches
Fort Worth Limestone.			
3.	Soft chalky limestone; Pecten bellula, Pleurotomaria austinensis		6
2.	Marl. Pecten bellula		6
1.	Soft fragmental limestone. Pecten bellula		6
Duck Creek Marl:			
24.	Soft marl with chalky limestone fragments. Kingena (Upper) horizon in lower half. Pecten wrightii zone	3	6
23.	Soft chalky limestone. Kingena (Upper) horizon. P. bellula. Forms a slight terrace		4
22.	Marl. Upper gastropod horizon. Turritella, Cerithium, Fusus, Gyrodes (?)	2	8
21.	Soft sandy limestone flag. Diplopodia zone		3
20.	Marl. Pecten bellula	3	2
19.	Soft chalky limestone. Lower (Main) Kingena zone	1	
18.	Straw colored marl	5	
16-17.	Laminated limestone, gray and iron-stained, indurated locally, rather unfossiliferous, making 'horseshoe' bends where the streams cut through it, and everywhere forming the cap of the Duck Creek escarpment or at least a break in the topography	4	
	(The section is continued in the cut of the military road through the Duck Creek escarpment, ¼ mile north of the University).		
16-17.	Laminated gray indurated limestone, capping the crest of the escarpment. Kingena may usually be found just above it	4	
13-15.	Marl. Gryphea corrugata, Hemiaster elegans, Schloenbachia sp. I, Goniophorus sp	3	
12.	Crumbling, marly limestone. Pinna sp. 1	2	
11.	Limy straw-yellow marl. Limonite fossil horizon (Lower gastropod horizon): Nerinea sp. near pellucida Cragin, Lunatia, Cinulia, Cerithium, Turbo	1	

	Thickness Feet	Inches
9-10. Crumbling chalky very marly limestone Crania sp. 1. Hamites spp.	2	
7.8. Straw colored marl	2	
6. Chalky or bluish impure limestone	2	
Limestones and marls continue downward to the Hamites zone in the bed of the run.		

SECTION OF THE DUCK CREEK FORMATION IN THE RUN FROM SOUTHEAST CORNER OF FOREST PARK TO THE FRISCO SHOPS. LOCALITY, 3 MILES SOUTHWEST OF FORT WORTH AND ½ MILE NORTH EAST OF TEXAS CHRISTIAN UNIVERSITY. Altitude of lower Kingena Zone at second turn of car track, 640 feet.

	Thickness Feet	Inches
Scaphites member (Limy Marl):		
17. Gray indurated Limestone	2	
16. Calcareous marl	2	
13-15. Two equal limy ledges with thin interbedded marl layers	3	
12. Calcareous marl	2	
7-11. Three thin limstone ledges and two thicker marl layers	5	
6. Compacted, closely bedded, impure limestone	4	
Schloenbachia sp. (trinodosa?) Member. (Marly Lime):		
5. Compact limestone	1	6
Calcareous marl		6
4. Compact limestone in four equal layers with interbedded thin marl	4	
3. Compactly bedded, lumpy, in part "fucoidal" limestone mixed with bluish marl	7	
Desmoceras member (Limestone):		
2. Bluish very impure limestone, slightly marly at top, but becoming more compact toward base and usually weathering into smooth cliff faces	12	
1. Harder limestone with iron nodular inclusions. Hamites zone	2	
(The members 1-2 are well exposed along the drive-way in the park near the east entrance).		

Paleontology: Of the fossil zones to be mentioned, the Diplopodia zone (21), the Turrilites zone (19), the Crania zone (10), the Hamites spp. zone (11) and the Pinna zone (6) will be less easily located by the fossils than the others; however, they are easily located by their levels. The other zones are conspicuous. The most dependable fossil, both in the field and in well borings, for locating the Duck Creek Marl is the Lower Kingena (19). The marl above this Kingena zone contains frequent *Pecten bellula*, which in the Fort Worth limestone is sparse. The portion of the marl below the Kingena zone is harder to diagnose; it contains considerable numbers of *Gryphea corrugata* and other undistinctive fossils The most conspicuous associations or syndromes of fossil are the upper and lower gastropod horizons, each containing several genera. It may be mentioned that iron pseudomorphs range considerably in the Duck Creek marl. The fauna of the Duck Creek, marl is essentially a shallow water fauna and has been stated to represent a shallowing and oscillating ocean bottom. The frequent turning of some shells, as *Gryphea washitaensis,* convex side upward is stated to indicate a bottom disturbed by local currents, and there are evidences that some other shells were washed into their place of deposition.

FOSSIL ZONES AND HORIZONS

Upper Kingena Zone: This zone containing many small rounded brachiopods at present referred to the genus Kingena lies in stratum 23 and the lower half of 24, about 7 feet above the main Kingena zone. It is thicker than the main Kingena zone, and the Kingenas are much sparser than in the main zone. Between the two zones no Kingenas have been found in situ, though washed down individuals are abundant to below the indurated ledge 17.

Upper Gastropod Zone: This zone, which contains among other genera *Cerithium, Turritella, Gyrodes* (?), and *Pleurotomaria austinensis,* occurs in stratum 22, where the gastropods are abundant, and in 23-24 where they are sparse. This zone is apparently the lowest range of *Pleurotomaria austinensis* Shumard, of which smooth individuals showing only the first four or five whorls are found. It is a zone of abundance of

Turritella sp., which is also abundant in the lower Kingena zone. The *Gyrodes* (?) sp. has not yet been found elsewhere by us.

Diplopodia Zone: There is a zone of abundance of *Diplopodia* in the arenaceous limy flag layer 21. These slabs also contain plates and fragments of *Hemiaster* and other echinoids, *Pecten subalpina* and *Lima.*

Lower (Main) Kingena Zone: This abundant brachiopod zone, occupying stratum 19, is about a foot thick. The material above and below it does not contain brachiopods. This is a soft chunky, limestone layer which weathers into scattered irregular angular fragments with intervening projecting harder masses. A square meter of area at one locality contained 260 brachiopods of various sizes and shapes and of probably several species. This is one of the most persistent, easily located, and important horizons in the series and has been traced for miles in both directions from Fort Worth. Kingenas occur at the following levels, so far as known to us:

(1) Mainstreet limestone, an extensive horizon near middle. Some of the individuals are much larger than any found at lower levels and are intermingled with those of smaller size and of various shapes, probably referable to several species. This is the horizon most frequently mentioned in the literature.
(2) Denton marl, top: on the Noland's River near Blum. These individuals were mostly of large size.
(3) Duck Creek marl: Upper Kingena zone. Tarrant County.
(4) Duck Creek marl: Lower (Main) Kingena zone, Tarrant County.
(5) Duck Creek Limestone, base. In Grayson County these brachiopods of the smaller size occur within 10 feet of the top of the Kiamitia conglomerate in association with Exogyra plexa Cragin, Schloenbachia belknapi Marcou and in Tarrant County they were found at this level in association with Salenia sp., Plicatula sp. and fish teeth.

Turrilites sp.

A single individual of a vertically ribbed species was found in the lower Kingena zone (19). This is the only turrilite known to us below the base of the Pawpaw in the North Texas section. In the European and Mexican sections Turrilites is well represented in the Vraconien.

Goniophorus sp.

This level is characterized by a very restricted zone of a few inches thickness, containing great numbers of a minute salenid, ⅛ inch in diameter, which has a star-shaped apical system and narrow linear sutures.

Crania sp.

A zone of Crania sp. 1 is contained in stratum 10; the species is distinctive but rare, having yet been found nowhere else in the series.

Hamites spp.

Several small species of Hamites and related genera, quite distinct from the species of large Hamites in the basal Duck Creek limestone, have not been found so far outside stratum 10. These individuals are rather rare.

Pinna sp. 1.

A zone of Pinna sp. with fine concentric and spined imbrications occurs in stratum 6. It is rare and distinctive, but ranges somewhat.

Lower Gastropod Horizon.

This is an aggregation of peculiar small iron stained mud casts and iron pseudomorphs, occurring in strata 9-11. It includes Lunatia, Cinulia, Cerithium, Turbo, Nerinea sp. near pellucida Cragin, Schloenbachia sp., Hamites sp., and Scaphites sp. (top). Most of these fossils are less than 1 cm. in diameter. They are fairly abundant. This limonite fauna occurs at the Red River.

Scaphites sp. B.

This small gerontic ammonite of which usually only the coiled end is preserved, practically characterizes the Duck Creek Limy Marl member. In its upper range it is associated with the iron stained fossils of the lower Gastropod horizon. (Strata 9-11).

The following additional species, which range into the Fort Worth limestone, will also be mentioned here:

Pecten bellula Cragin

This fine ribbed pecten begins near the main Kingena zone (19) and is frequent up to the base of the Fort Worth limestone and present to the top stratum (33) of this formation.

Pleurotomaria austinensis Shumard

This gastropod has not been found by us below the Lower Kingena zone (19) of the Duck Creek Marl; it ranges into the base of the Fort Worth limestone where a fine individual with the body volution and the ornamentation was found. The last two volutions and the markings are usually absent.

Hemiaster elegans Shumard

This echinoid ranges from stratum 12 of the Duck Creek marl to high in the Fort Worth limestone, where it has a zone of abundance in the upper part of the formation.

Holaster simplex Shumard—low individuals

The low flat bottomed Holasters range from the indurated ledge (17) of the Duck Creek Marly Lime to the base of the Fort Worth limestone and are abundant between the two Kingena layers. They are mud casts, rarely with a calcareous test, are usually iron stained and faintly tuberculated.

Holaster simplex Shumard—tall individuals

These tall and top heavy Holasters range from stratum 20 of the Duck Creek marl to near the top of the Fort Worth limestone, being more abundant in a zone near the top of their range.

Pecten wrighti Shumard

This strongly ribbed pecten begins at stratum 22 of the Duck Creek marl and is abundant in 23-24. Thereafter it is sparse and disappears high in the Fort Worth limestone. More than one species may be involved in this range. A similar Pecten occurs in the basal Mainstreet limestone.

Schloenbachia sp. I.

This ammonite begins at the lower Kingena zone and ranges into the base of the Fort Worth limestone.

Gryphea corrugata Say.

This Kiamitia and Duck Creek Gryphea is conspicuous in all the Washita strata below the indurated ledge (17) of the Duck Creek Limy Marl, and is probably absent above that point.

DUCK CREEK MARLY LIME AND LIMESTONE

Brief Diagnosis: The basal part of the Duck Creek formation is a series of compact soft impure limestone strata, thicker bedded than the Fort Worth limestone and with less interbedding. It produces in Tarrant county the steep escarpment at the west edge of the Fort Worth uplands, but almost never itself forms uplands. The series is bounded above by the Duck Creek Limy Marl and below by the Kiamitia marl, and in Tarrant County is 27 feet thick. This portion of the Duck Creek formation is characterized by a remarkable sequence of ammonite zones which locate with exactness the various levels in the formation. The sequence is divisible into four groups, in part overlapping: 1. above, *Schloenbachia* spp. of the *rostrata* type; 2. *Schloenbachia* spp. of the *inflata* type; 3. *Desmoceras* horizon; 4. *Hamites* spp. horizon, at the base of the formation.

Fossils collected by Shumard in the Duck Creek limestone of Grayson county, near Preston on the Red River, were described in 1858 by Marcou, who referred the beds to the Gault. The formation was first named by Hill, who described its lithologic peculiarities, mentioned some of its striking fossils, and defined it so as to include the marly strata lying between the limestone proper and the overlying Fort Worth limestone. The Fort Worth limestone in the old sense as used by Taff and others included the whole Duck Creek formation and at times various other formations.

Descriptions of Localities: Good localities will often be found in stream beds cutting down through the Duck Creek escarpment at the west edge of the Fort Worth uplands. The narrow strip occupied by this member is usually rocky, grassy and marked at the top by isolated clumps of shrubs and trees.

Terrace topography is often present; and in case the Fort Worth limestone scarp is recognized the underlying terrace is the Duck Creek (Kingena) marl; the next underlying scarp is that of the Duck Creek with the limestone at its base; and the terrace beneath is the Kiamitia clay which makes usually a gentle slope downward to the Goodland limestone outcrop.

The Duck Creek limestone is prevailingly an escarpment forming rock; very rarely is a Duck Creek upland present, and then it is of limited area and forms a transitional slope to the underlying Goodland escarpment. Such an upland is seen on the Azle road northeast of the upper lake. More often the limestone forms a divide, but in this case it is usually capped by the harder Fort Worth limestone, as on the Arlington Heights divide. Sections of the Duck Creek escarpment are well exposed in Forest Park.

Several good localities lie near the Azle road about two miles northeast of the upper lake. Northeast of Moslah Temple on this road eight and one-half miles northwest of Fort Worth is an extensive exposure of the ammonite zones of the lower Duck Creek. This portion also forms the rim of an amphitheater-like depression on the headwaters of Marine Creek, Azle road, nine miles northwest of Fort Worth. Three and a half miles southwest of the court-house the formation is well exposed in Forest Park, where complete sections may be seen along a line from the park entrance to the Frisco shops; stream cuts a half mile west of the University also afford good exposures of the basal Duck Creek. The uplands around Plover and Primrose are well exposed. Those southwest of Benbrook are poor. The Duck Creek limestone interbedded with marl forms steep rocky slopes of hard terraced material which for a few miles southwest of Fort Worth makes a conspicuous escarpment bordering the broad alluvial river bottom; this escarpment with the Fort Worth prairies above is seen with striking effect from Benbrook.

SECTION OF DUCK CREEK LIMESTONE IN FOREST PARK NEAR EAST ENTRANCE, EAST SIDE OF DRIVEWAY.

(Cemented Upland Gravel and cross-bedded sand at top of section.)

	Thickness Feet	Inches
3. White limestone mixed with marl, containing Schloenbachia sp. H., Pecten subalpina, Lima, Plicatula, etc.	4	
2. White limestone and interbedded marl, containing Desmoceras sp. and Schloenbachia spp. aff. S. inflata. The Desmoceras is more abundant in the basal strata (B)	12	
1. Harder massive grayish limestone, containing Hamites spp., Plicatula sp., and Pecten subalpina. This stratum is seen along the driveway south of the other locality.	2	

The Kiamitia formation is not clearly exposed at this locality. A similar section is to be seen in the first run west of the University, while in the run from the Frisco shops the whole Duck Creek formation above the middle of the Democeras horizon, and most of the Fort Worth limestone are exposed.

Paleontology: The Duck Creek ammonite series is one of the paleontological landmarks of the Washita division. The Duck Creek limestone is nearly constant in thickness at least from Woodville, Oklahoma, to Georgetown, Texas, and probably farther. The contained ammonite sequence is very widely distributed, possibly world-wide.

A portion of this zonal sequence follows, beginning at top:

Schloenbachia sp. H., aff. trinodosa Boese.
Schloenbachia spp. F-G, inflata group.
Desmoceras sp. B.
Desmoceras sp. A.
Schloenbachia sp. E. aff. elobiense Szajnocha
Schloenbachia belknapi Marcou.
Inoceramus comancheanus Cragin, I. munsoni Cragin.
Hamites spp. and other gerontic ammonites.

FOSSILS OF THE DUCK CREEK FORMATION.

Ostrea subovata (?) Shumard.
Ostrea sp.
Gryphea corrugata Say.
Gryphea washotaensis Hill
Pecten texanus Roemer.
Pecten subalpina Boese.
Pecten bellua Gragin
Pecten wrightii Shumard
Pecten sp.
Pinna sp.
Lima wacoensis Roemer
Inoceramus comancheanus Cragin
Inoceramus munsoni Cragin
Trigonia sp.
Pholadomya sp.
Gyrodes sp. (?)
Turritella sp.
Pleurotomaria austinensis Shumard.
Fusus sp.
Cerithium sp.
Crania sp.
Nerinea sp.
Turbo sp.
Lunatia sp.
Schloenbachia spp.
Schloenbachia belknapi Marcou
Hamites fremonti (?) Marcou.
Hamites spp.
Scaphites sp.
Turrilites sp.
Desmoceras spp.
Kingena wacoensis (?) (Roemer).
Kingena spp.
Diplopodia sp.
Hemiaster whitei Clark
Hemiaster sp.
Holaster simplex Shumard.
Hemiaster elegans Shumard
Salenia sp.
Callianassa sp.
Fish teeth.

FORT WORTH FORMATION.

Brief Diagnosis: The Fort Worth formation includes a series of limestone and marl layers, each less than one foot thick, alternating rather regularly with each other. The limestones are chalky and dead white, or are indurated, bluish interiorly and stained superficially with yellow or brown iron smears. The strata underlie broad stretches of upland grazing and farming country composed of a black soil, and in stream beds weather into small cliff faces with shelf-like projecting limestone layers. The formation is thirty feet thick in Tarrant County. It contains numerous characteristic fossils, such as *Pecten bellula, Holaster simplex, Hemiaster elegans, Exogyra americana, Schloenbachia sp. J*, and may be identified by the following sequence of fossil zones beginning at top:

Enallaster sp.
Ostrea carinata Lamarck.
Exogyra americana Marcou.
Hemiaster elegans Shumard.
Pecten bellula Cragin.
Schloenbachia spp. of inflata type size of austinensis Lasswitz.
Holaster simplex Shumard.
Schloenbachia sp. J.
Pleurotomaria austinensis Shumard.

A nearly complete exposure of the Fort Worth limestone and the overlying Denton Marl is seen on the west bank of Sycamore Creek about 1½ miles above its mouth. The limestone is exposed at several isolated localities, particularly the cliff along the creek at the southwest corner of Glenwood Park, which gives the following section:

		Feet	Inches
33.	Marl, limy at top	3	
32.	Soft impure limestone. Enallaster sp. 2	3	3
31.	Chalky limestone		10
30.	Marl. Nerinea sp		8
29.	Limestone in 4 equal layers with thin marl interbedding	2	
28.	Loose crumbly limestone	1	
27.	Solid, hard, yellow stained limestone	1	8
26.	Marl	1	6
25.	Limestone in 4 equal layers with slight marl interbedding, but the bedding somewhat irregular near base	2	6
24.	Compact coarse grained limestone, iron stained and locally sparingly flinty	1	3
23.	Limestone, concretionary and fucoidal at top, followed by compressed marl (2″), limestone (3″) and compressed marl (2″)	1	3
22.	Coarse limestone, fucoidal at base	1	
20-21.	Coarse grained fucoidal limestone with marl at top	1	5
19.	Lumpy fucoid layer		2
19.	Brown marl		1
17-18.	Chalky limestone with very calcareous coarsely laminated marl at base	1	3
16.	Chalky concretionary limestone		8
15.	Brownish marl		8
14.	Chalky concretionary limestone		5
13.	Brownish marl		5
12	Hard, fine-grained, compact, slightly shelly limestone, semi-crystalline and iron stained at base		7
11.	Blackish marl, brown or weathering. Lima, Holaster, Schloenbachia sp. J		6
10.	Irregular, chalky limestone, Schloenbachia sp J		4
9.	Closely laminated calcareous marl, slaty color, speckled; Holaster simplex, Pecten bellula, Hemiaster elegans		5
8.	Limestone, slightly lumpy or irregularly bedded		7
7.	Laminated marl		3
6.	Limestone, irregularly bedded		8
5.	Laminated marl		6
4.	Limestone, irregularly bedded	1	10
	TOTAL	30	1

The basal layers are not exposed here. The whole Denton marl, showing its usual character, thickness and fossils, is exposed in several places between Belzise Terrace and Sycamore Creek.

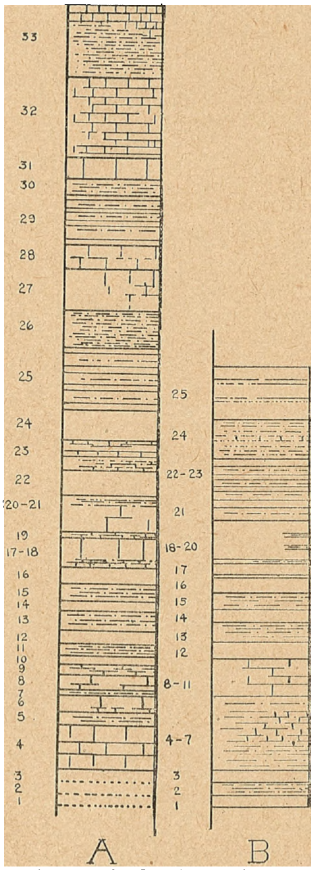

Fig. 4. Columnar sections of the Fort Worth limestone. A. On Sycamore Creek, northwest corner of Glenwood Park, Fort Worth. The Denton marl immediately overlies stratum 33. B. Eastward facing exposure in a run ½ mile east of Texas Christian University and ½ mile south of Forest Park, Fort Worth.

The numbers refer to corresponding strata described on pp. 52-4. Vertical scale, ⅛ inch = 1 foot.

Description of Localities: This formation in the restricted sense adopted by Hill occupies a strip of variable width running through the middle of Tarrant County from north to south. The type localities, ¼ mile east of the Texas & Pacific Railway station, Fort Worth, and on the river bank just north of the Courthouse are now almost obliterated, the former by erosion, the latter by grading and overwash. There has been some variation in the nomenclature of this formation, but as eventually defined, it "consists of a group of impure white limestones, very slightly arenaceous, regularly banded in persistent layers averaging nearly a foot in thickness and alternating very regularly with similar layers of marly clay. The limestones and marls occur in strata 4 or 5 inches to 2 or more feet in thickness. The marly layers alternate with the hard limestones in bands ranging from thin laminae to beds 6 inches or more thick." "Paleontologically the formation may be defined as the horizon of *Ammonites leonensis* and *Epiaster elegans*." With little variation, the following sections may be taken as typical for Tarrant County:

SECTION OF FORT WORTH LIMESTONE, EASTWARD FACING EXPOSURE IN RUN ½ MILE EAST OF TEXAS CHRISTIAN UNIVERSITY, 3 MILES SOUTHWEST OF FORT WORTH, TEXAS. Altitude, top of exposure, 685 feet.

	Feet	Inches
25. Three thin limestone bands with 2 interbedded marl layers	2	2
24. Laminated marl, with a 3″ limy band in center	1	6
22-23. Limestone in 4 equal layers interbedded with thin much compressed limy marl	2	
21. Marl		6
18-20. Limestone in 3 laminated equal layers interbedded with thin, much compressed limy marl	1	3
18. Marl		6
16-17. Limestone		6
Laminated marl		2
Limestone		6
15. Marl		8
14. Limestone		6
13. Marl		10
12. Limestone		8
8-11. Blue marly Limestone	1	6
4- 7. Laminated marl	3	
3. Limestone		5

The basal strata 1-2 are exposed in the bend of the stream just north of this locality.

The formation is thus composed of a series of alternating beds of soft chalky limestone and calcareous marl. It differs from the upper Duck Creek beds in that there is a regular alternation of lime and marl, no bed in general is more than 1 foot thick, and the limestone strata indurate, especially in eastward facing exposures and form projecting ledges, the softer marl having eroded away. The marl layers are compactly laminated and very limy and grade evenly into the limestone, so that the exact limits are undefined even though they appear definite due to the weathering of the marl and the shelf-like projection of the limestone. In addition the hard layers vary slightly in thickness even in the same cliff face due to their being composed of uneven flaky accretions of calcareous material cemented together by limy marl.

The contact of the Fort Worth limestone and the Denton marl is well shown at a point ½ mile south of the Frisco track and 4½ miles southwest of Fort Worth.

Denton Marl		Feet
3.	Shell conglomerate of Gryphea washitaensis, containing Ostrea carinata, Pecten subalpina, etc..	1
2.	Bluish clay with innumerable **Gryphea washitaensis** adults and larvel stages................	16
1.	Brown sandy marl with many sandstone flags....	8
		25

Fort Worth Formation:

33.	Straw-colored calcareous marl with limy fragments. Enallaster sp. E. texanus, Nautilus texanus, Pecten subalpina, Schloenbachia sp. I, Holaster simplex, Hemiaster elegans, Lima sp...........	3
32.	Three limy strata with interbedded thin marl layers	2

The lower Fort Worth strata are excellently exposed along this run.

Essentially the same sequence is seen north of the Frisco track, 3 miles north of Denison and along the Red River in Cooke County and elsewhere.

The base of the Fort Worth limestone is well exposed at the following locality:

FORT WORTH AND DUCK CREEK FORMATIONS AT FIRST TURN OF CAR TRACK ¼ MILE NORTH OF THE UNIVERSITY AND 3½ MILES SOUTHWEST OF FORT WORTH, TEXAS. Elevation at base of Fort Worth limestone, 680 feet.

		Feet	Inches
Fort Worth Formation:			
3	Soft chalky limestone. Pecten bellula Cragin, Pleurotomaria austinensis Shumard...........		6
2.	Marl. Pecten bellula		6
1.	Limestone. Pecten bellula....................		6
Duck Creek Marl:			
24.	Soft straw marl with chalky limestone fragments. Upper Kingena zone in lower half; Pecten wrightii	3	6
23	Soft chalky limestone. Kingena, upper zone. Pecten bellula. Forms a slight terrace........		4
22.	Marl. Gasttopod zone: Globiconcha (?), Turritella, Cerithium, Fusus, Pleurotomaria......	2	8
21.	Soft flaggy arenaceous limestone. Diplopodia zone. Hemiaster plates		3
20.	Marl. Pecten bellula........................	3	2
19.	Soft, chalky limestone. Lower (Main) Kingena zone. Turrilites sp........................	1	
18.	Marl..	5	
16-17.	Laminated gray limestone, ironstained, locally indurated, rather unfossiliferous, making 'horseshoe' bends in streams......................	4	

The rest of the Duck Creek formation is exposed in the run north of this locality.

It is seen that the upper contact of the formation is unmistakeable, and that the lower contact as here placed, leaves the Fort Worth limestone about 30 feet thick in Tarrant County.

Paleontology: The Fort Worth limestone contains certain diagnostic fossil zones, some of which are, beginning at the top:

Zone of Enallaster sp. In the uppermost stratum (33) are two or three species of Enallaster, of which one, an elongated low species occurring at this level at Denison, Fort Worth, Blum and elsewhere has not been seen at any other level.

Exogyra americana Marcou. This large characteristic oyster occurs in a restricted vertical zone (25-27) where it is abundant and easily recognized. It usually fails to weather out cleanly. It occurs at this level from the Red River to the Brazos; Dr. Boese has also found it near the top of the Duck Creek limestone in Grayson County.

Ostrea carinata (?) Lamarck. Fossils ordinarily referred to this species are much more widely distributed in the Texas Comanchean than has been suspected. This species is widely ranging and one of its zones of abundance is in the top of the Fort Worth limestone (28-29). The following occurrences are known to us:

(1) Buda limestone, Austin, Texas (Whitney).
(2) Base of Mainstreet limestone, Fort Worth and Denton, Texas, below the Pachymya zone.
(3) Pawpaw clay, Fort Worth, Texas, and elsewhere.
(4) Quarry limestone, Gainesville and Denton, Texas, abundant.
(5) Top of Weno limestone, Fort Worth, Texas.
(6) Denton marl, top. Conglomerate of Gryphea washitaensis and Ostrea carinata, widespread in north Texas (Hill's member i in 21 Ann Rept. pt. 7, U. S. G. S., pp. 270-71 and elsewhere).
(7) Fort Worth Limestone, top, zone below Exogyra americana, Gainesville, Fort Worth and Krum, Texas, and elsewhere.
(8) Basal Fort Worth Limestone (1) Fort Worth, Texas.

The positive identification of the individuals awaits comparison with European material. It may be mentioned that two cross-sections are prevalent; a triangular one and a semi-elliptical one.

Hemiaster elegans Shumard.

This echinoid begins in stratum 11 of the Duck Creek Marl and ranges upward to the top of the Fort Worth Limestone, with a zone of abundance in strata 22-24. There is considerable variation among individuals referred to this species, some being larger, broader and much flatter than others.

Schloenbachia sp. J.

This species ranges from the base of the Fort Worth Limestone to the top. It is most abundant in a broad zone near the base (1-5).

Holaster simplex Shumard.

Tall, top-heavy individuals referred to this species range from the indurated ledge (17) of the Duck Creek Limy Marl to the top of the Fort Worth, being most abundant near the middle of the limestone (22-24).

Pecten wrighti Shumard.

This peculiar Pecten ranges from the Lower Kingena zone (19) of the Duck Creek Marl to the middle of the Fort Worth and is most abundant just below the base of the Fort Worth limestone.

Pecten bellula Cragin.

This characteristic fine-ribbed Pecten ranges from the lower Kingena zone (19) to the top of the Fort Worth, and is most abundant in the upper part of the marl.

FAUNA OF THE FORT WORTH LIMESTONE

Gryphea washitaensis Hill
Exogyra americana Marcou
Ostrea subovata? Shumard
Ostrea carinata ? Lamarck
Ostrea sp.
Plicatula spp.
Pecten subalpina (Boese)
Pecten wrighti (Shumard)
Pecten bellula (Cragin)
Pinna sp.
Trigonia sp.
Pachymya sp.
Pteria sp.
Remondia ? robbinsi (White)
Tapes sp.
Protocardia texana (Conrad)
Lima wacoensis Roemer
Lima sp.
Pholadomya shattucki Boese
Turritella marnochi White
Turritella seriatim-granulosa ? Roemer
Pleurotomaria austinensis Shumard
Cinulia sp. aff. tarrantensis Cragin

Nautilus texanus Shumard
Schloenbachia spp.

Enallaster sp.
Enallaster texanus (Roemer)
Holaster simplex Shumard
Hemiaster elegans Shumard
Hemiaster sp. aff. whitei Clark
Epiaster aguilerae Boese
Ophioglypha texana Clark

Trochosmilia sp.
Serpula sp.
Lamna sp.
fucoid masses

DENTON MARL

Brief Diagnosis: The Denton marl is a very shelly blue-grayish marl formation, 25 feet thick in Tarrant County, lying between the Fort Worth limestone below and the Weno marl above. It is characterized by a great abundance of the oyster-like shells of *Gryphea washitaensis*, which especially near the top of the marl make a conglomerate containing also shells of *Ostrea carinata*.

Lithology: The Denton shell marl is a shallow water deposit and has the texture and appearance of sediments deposited in modern seashore mud flats. It is excessively shelly, the shells being mainly adults and various young stages of the oyster, *Gryphea washitaensis* Hill.

The mass of the material is a flaky, non-arenaceous, laminated bluish-gray calcareous marl, having considerable plasticity. The basal part of the formation is somewhat sandier, flaggy and less fossiliferous. The top of the marl is a bedded conglomerate of the Gryphea shells, which is usually slabby and breaks off into considerable sheets. The top of the formation is exposed ½ mile southeast of Our Lady of Victory Academy, Fort Worth, between the Missouri, Kansas and Texas Railway and the International and Great Northern Railway tracks; on Sycamore Creek, in the bluff below the Houston and Texas Central Railway bridge and at the waterfall just east of the International and Great Northern Railway track, both localities 4 miles southeast of Fort Worth; at points 1 and 2 miles southeast of Haslet and elsewhere. The top of the formation does not make a conspicuous topographic break as in Grayson County, where it forms a surface shelf at its outcrops. The base of the formation is exposed at a point ½ mile southeast of the Frisco track and 5 miles southwest of Fort Worth, and elsewhere.

SECTION OF DENTON MARL AT BLUFF 100 YARDS NORTH OF THE HOUSTON AND TEXAS CENTRAL RAILWAY BRIDGE ACROSS SYCAMORE CREEK, 4 MILES SOUTHEAST OF FORT WORTH, TEXAS.

	Feet	Inches
Weno:		
3. Limestone	1	
2. Marl	1	6
1. Limestone	1	
Denton:		
3. Unfossiliferous marl above, followed by Gryphea washitaensis Shell Conglomerate, two layers separated by a thin marly stratum and containing Ostrea carinata, Pecten subalpina, Trigonia, Plicatula, etc	5	
2. Blue shelly marl with inconspicuous, scattered conglomerate layers	21	6
1. Brown, sandy marl with a few thin, sandstone flags. Enallaster, Pecten, Plicatula, Lima	1	6

	Feet	Inches
Fort Worth:		
33. Very calcareous marl with Enallaster sp., Nautilus texanus, Hemiaster elegans, Pecten subalpina..	3	
22-32. Alternating limestone and marl layers......	20	
(The lower portion of the Denton and the Fort Worth limestone are seen farther down Sycamore Creek).		

Paleontology: The Denton marl has few restricted fossils and none that are absolutely distinctive, so far as now known. The fauna is marked by the abundance of *Gryphea washitaensis* and by the practical absence of ammonites and echinoids.

(a) Association of *Trigonia, Protocardia, Tapes.* This loose association of pelecypods occurs in the lower, more arenaceous part of the Denton marl stratum. It is an aggregation which is easily recognized, though no one species is limited to this formation.

(b) Association of *Ostrea carinata* and *Gryphea washitaensis.* Succeeding the uppermost strata containing *Hemiaster elegans*—the top of the Fort Worth limestone—are marly strata containing increasing numbers of *Gryphea washitaensis* and scattered individuals of *Ostrea carinata.* In Tarrant County this shelly marl culminates (stratum 3) in two thin slabby layers of shell conglomerate composed almost entirely of Grypheas but containing frequent *Ostrea carinata,* and *Pecten subalpina, Plicatula* sp. and other fossils.

Gryphea washitaensis Hill ranges from the lower Duck Creek limestone to basal Mainstreet limestone. Its zone of greatest abundance is in the upper 10 feet of the Denton marl. Below this point, in both the Denton and the Fort Worth formations, it is scattered but frequent; while in the Weno and Pawpaw it becomes gradually sparser and in Tarrant County has not been found above the basal Mainstreet. *Ostrea carinata* occurs sparsely throughout the upper 10 feet of the Denton; it is locally abundant in the conglomerate slabs at the top of the Denton, though not so abundant as at the Red River. This is the main zone of this oyster always referred to in the literature; the other occurrences have been noted elsewhere (p. 57).

The association of these two species as a persistent shell conglomerate makes a sheet of rock that extends throughout North Central Texas at this horizon, and is a paleontological landmark in the Washita division. As stated it is thicker and more prominent as a topographic factor at the Red River; at Fort Worth the conglomerate is only 1 foot thick and rarely withstands erosion, although it marks the soil along its outcrop with scattered, very easily recognizable shelly slabs. On Noland's River, near Blum, the Denton is much reduced and the conglomerate has entirely lost its slabby character, being only a loose, slightly calcareous and uncemented shell marl containing *Gryphea washitaensis* and a few *Ostrea carinata.* Farther south it is supposed to form a portion of the Georgetown limestone.

FOSSILS OF THE DENTON MARL

Leiocidaris hemigranosus (?) Shumard.
Ostrea carinata (?) Lamarck.
Gryphea washitaensis Hill.
Ostrea marcoui Boese.
Pecten subalpina Boese.
Pecten texanus Roemer.
Nautilus texanus Shumard.
Lima wacoensis Roemer.
Protocardia sp.
Trigonia sp.
Ostrea quadriplicata Shumard.
Plicatula sp.

WENO FORMATION

Brief Diagnosis: The Weno formation consists of a series of limestones and brown or yellow calcareous marls containing seams of limestone or ironstone, lying above the *Gryphea* conglomerate of the top of the Denton marl, and below the Pawpaw clays. It is 67 feet thick on Sycamore Creek near Fort Worth and nearly twice as thick at the Red River. In Tarrant County it is reduced in thickness but it is not in any way "consolidated" (with the adjoining formations) as has been claimed. It is abundantly fossiliferous. The top limit on the Red River is the Quarry Limestone group, but at Fort Worth this group is reduced and is recognizable only with difficulty; the contact in Tarrant County is placed at the junction of the white chalky Weno limestone below and brown sandy clay containing pyrite fossils, are described later (p. 67). The Denison and Gainesville sections of the Weno are essentially similar to each other. As we go south from the Red River the Weno thins, and becomes more calcareous and somewhat less fossiliferous. The nacreous and chalky fossils seen at the Red River and their ironstone casts and molds become rarer in southern Cooke County and are absent in this form at Fort Worth. The separate members of the Weno also seem to thin towards the south.

As noted for the Pawpaw marls (p. 68), the ironstone seams of the Red River section are replaced in Tarrant County, especially north of the Trinity, by great amounts of jasper-like pebbles. The Weno appears prevailingly as a yellow marl with chalky limestone layers.

Description of Localities: On the east bank of the upper half of Sycamore Creek, which runs nearly in the strike, there is exposed for several miles a continuous section, from the Gervilliopsis ledge at the top of the lower third of the Weno, upwards to the base of the Mainstreet limestone. In addition, the pit at the Cobb Brick Yards, an exposure on Sycamore Creek ⅛ mile below the brickyards and two exposures near the Houston & Texas Central Railway bridge across the Sycamore Creek show the basal third of the Weno and most of the Denton marl. These localities are rich in fossils; and the whole landscape reveals the very intimate relations between the topography and the underlying geological structure. The diagrammatic terrace features correspond accurately to the formations beneath them, and represent from bottom to top: (a) the top of the lower half of the Weno limestone, usually an inconspicuous terrace; (b) the top of the Weno limestone producing the first main terrace; (c) the second terrace, composed of the limestone cap over the Pawpaw clay; and (d) an erosion slope, often terrace-like, which represents the Mainstreet limestone capping the hill. In the portion of Sycamore Creek which runs nearly in the strike, the *Gervilliopsis* ledge forms the bed of the creek. South from Sycamore Creek the Weno-Pawpaw strip narrows and follows the edge of the reduced Mainstreet upland, close to the west border of the Cross Timbers, leaving the county west of Burleson. The outcrops are here covered with Woodbine and Mainstreet overwash. Northwards from upper Sycamore Creek the Weno-Pawpaw strip widens to about 3 miles and spreads over the uplands along the tributaries of Sycamore Creek. The cliffs of the two formations, with the Mainstreet upland above, border the river valley near Rivercrest for several miles east of Fort Worth just as the Duck Creek and Goodland escarpments do in the western part

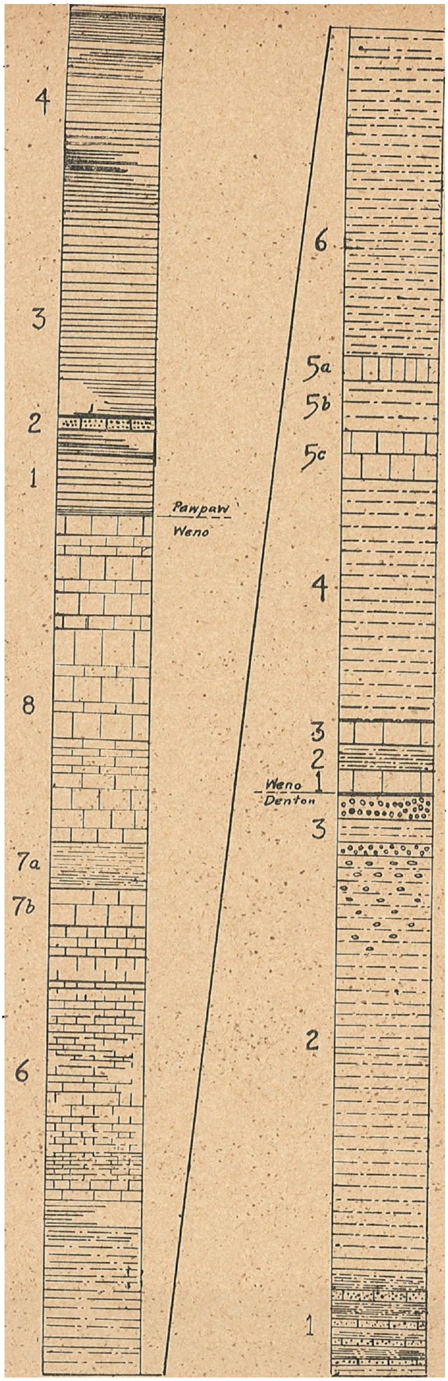

Fig. 5. Columnar section of the Denton, Weno and Pawpaw formations on Sycamore Creek, 3 miles southeast of Fort Worth. The numbers refer to corresponding strata described on pp. 58-69. Vertical scale, ⅛ inch = 1 foot.

of the county. North of the Trinity the strip widens, is gently sloping and, due to overwash, is mapable with difficulty.

Lower Weno: The Weno begins with two layers of chalky limestone separated by a marl layer and lying just above the Denton shell marl. From the base of these two layers to the base of a hard white limestone stratum containing clumps and scattered individuals of *Gervilliopsis invaginata* (White) is a layer of gray-blue or slate-colored, slightly laminated, jointed argillaceous marl, sometimes called a 'pipe clay.' It is rather fossiliferous and contains two fossils which especially distinguish it: a species of *Turritella* and *Pecten* sp. aff. *georgetownensis* Kniker, which differs from that species in having split ribs on only the right valve. This pipe clay is well exposed on the northeast bank of Sycomore Creek, 150 yards north of the Houston and Texas Central Railway bridge, where the upper Denton marl is also seen. The bluish Denton marl becomes less shelly near its top, and is abruptly followed by the two thin ledges, each about 8 inches thick and lying 1 foot apart. The pipe-clay is capped by a thin ledge of fragmented chalky limestone, locally slabby and indurated. The lower Weno is 15 feet thick on Sycamore Creek.

Middle Weno: The *Gervilliopsis* ledge, which is a persistent and reliable stratigraphic marker in the county, forms the bed of Sycamore Creek in its middle portion, where it runs almost in the strike, and elsewhere very consistently forms the resistent shelf of small waterfalls, such as those at the crossing of the Houston & Texas Central and the International & Great Northern tracks and at the crossing of the International & Great Northern track over Sycamore Creek, both about 4 miles southeast of Fort Worth. The ledge is often indurated and fucoidal and is the base of a group of marly limestones which extend upwards for about 34 feet to the top of a chalky limestone layer which often makes a subsidiary terrace. At the brickyards 1¾ miles southeast of Gainesville, the *Gervilliopsis* ledge is a blue-gray loosely compacted marl 1 foot thick, containing great numbers of *Gervilliopsis* and other fossils and lying 39 feet below the top of the Quarry limestone group. In the branch of Duck Creek 1 mile north of the Union Station, Denison, the layer is also well developed.

Upper Weno: The upper 18 feet lies between the subsidiary terrace in the Weno and the base of the Pawpaw marls. It consists of chalky white limestone and its upper limit is distinct, since the overlying brown marl washes away and leaves the top of the Weno limestone as a projecting shelf or terrace.

Paleontology: The following is a brief summary of the Weno fossil sequence:

Pawpaw clay: Pyrite fossil zone (p. 69).

Weno limestone and marl.

8. Nautilus sp., Homomya; Ostrea carinata (abundant). These species and others characterize the uppermost Weno Limestone. Certain of them occur in the basal Mainstreet limestone. The Ostrea carinata is conspicuous and abundant; its other occurrences have been noted (p. 57).

6-7. Nodosaria texana Conrad.
The Weno occurrence of this fossil protozoon is in a narrow zone about 19 feet below the top of the Weno. Nodosaria also occurs in the base of the Pawpaw in North Texas; in the Denison Beds at Cerro de Muleros; and in the Del Rio Clays, in association with Exogyra arietina Roemer in South Texas

5. Gervilliopsis invaginata (White)
The main zone of occurrence of this fossil is at the top of the 'pipeclay'. Its other occurences have been noted.

1-4. Turritella sp., Pecten sp. near georgetownensis, Remondia acuminata Cragin.
These species are frequent in the basal part of the Weno pipeclay, where there exists a considerable fossil sequence that will not be discussed here.

Denton marl: Gryphea washitaensis (abundant) and Ostrea carinata.

FOSSILS OF THE WENO FORMATION IN TARRANT COUNTY (PARTIAL LIST)

	Weno	Pawpaw	Mainstreet	Grayson	Buda
Trochosmilia sp.	*	*			
Hemiaster calvini	*	*	*	*	*
Hemiaster sp.	*	*			
Enallaster bravoensis	*	*			
Enallaster texanus ?	*	*			
Holaster sp.	*	*			
Cottaldia sp.	*				
Leiocidaris hemigranosa	*	*	*		
Nodosaria texana	*	*			
Pentagonaster sp.	*				
Trochosmilia sp.	*	*			
Turritella sp	*				
Cinulia sp.	*				
Anchura sp.	*				
Turbo sp.	*				
Trochus sp.	*				
Schloenbachia sp.	*	*			
Schl. sp. like inflata	*	*	*		
Hamites sp.	*				
Engonoceras sp.	*	*			
Nautilus texanus	*		*	*	*
Homomya sp.	*		*		
Pecten subalpina	*	*	*	*	
Pecten texanus	*				
Plicatula sp.	*				
Corbula sp.	*				
Tapes sp.	*				
Nucula sp.	*				
Astarte acuminata	*	*			
Protocardia sp.	*				
Ostrea quadriplicata	*	*	*		
Ostrea carinata	*	*	*		*
Gryphea washitaensis	*	*			
Trigonia sp.	*				
Gervilliopsis invaginata	*				
Ostrea sp. near marcoui	*				
Lima sp.	*				
Lamna sp.	*				
Oxyrhina sp.	*				

PAWPAW FORMATION

Brief Diagnosis: This formation on Sycamore Creek consists of 23 feet of brown arenaceous clay, lying below the hard, white Mainstreet limestone, and above the softer chalky limestone which forms the cap of the Weno formation. This brown clay contains sandy slabs in its basal half and carries a characteristic assortment of fossils. On account of its totally different color, hardness and composition, it should be easily recognized and separated from the adjoining formation in well drilling. Due to its increment in thickness northwards it is about 27′ thick at the Denton-Tarrant County Line, while at the Tarrant-Johnson County line it is about 12 feet thick. The prevailing texture is sandy, the soil is acidic, the vegetation sparse; the slopes are variable, sometimes gentle but usually steep, making a narrow outcrop and good exposures. There is a sudden and marked increase in the amount of ironstone fragments in the Pawpaw northwards from the Trinity. The prevailing aspect of the formation, aside from this red material, is brown sandy-flaggy. The Pawpaw contains characteristic and unmistakable fossils. At the Pawpaw pit of the Cobb brickyards, Fort Worth, the total section is exposed, and shows a resistant, firm ironstained brown clay with ironstone, bituminous arenaceous and limy seams.

Description of Localities: There are numerous localities in Tarrant County, lying above the terrace formed by the top of the Weno limestone and weathering into a steep barren slope filled with sandy flags and limestone fragments. Such slopes in stream cuttings often recede considerably from the face of the Weno terrace and form extensive amphitheatre-like basins whose sides are continuous exposures of the whole Pawpaw and whose floors along the streamlets contain fine concentrations of the small fossils which occur near the base of the clay. Such localities occur along the middle and upper portions of Sycamore creek especially near the International and Great Northern railway bridge and thence northwards to the river; along the Trinity valley southeast of Riverside; at several localities southeast of Haslet; near Watauga; and near the Cleburne road south of Fort Worth. The localities are just underneath the western border of the Mainstreet limestone and naturally are contaminated with rock and fossils from that formation.

SECTION OF PAWPAW CLAYS ON SYCAMORE CREEK NEAR THE HOUSTON AND TEXAS CENTRAL RAILWAY, 4 MILES SOUTHEAST OF FORT WORTH, TEXAS:

		Feet	Inches
4.	Brown slabby argillaceous thin limestone layers with considerable interbedded marl and scattered jasper pebbles. Nautilus sp. Hemiaster sp., Pecten subalpina; Plicatula sp.	13	
3	Brown clay with scattered flags. Turrilites sp.	6	
2.	Sandy flagstone, fragile, containing Metopaster sp.		4
1.	Brown clay with pyrite and other fossils	3	8
		23	

SECTION EAST OF KELLER ROAD, 1 MILE SOUTH OF HASLET, TEXAS:

		Feet	Inches
	(Mainstreet limestone forms thin cap of hills around amphitheater.)		
3-4.	Brown clay with flaggy and slabby dimension layers and great quantities of ironstone pebbles. Few fossils	22	8
2.	Flaggy layer		4
1.	Brown clay with pyrite fossils	4	
		27	

From these sections the increment in thickness towards the Red River is visible within Tarrant County.

PALEONTOLOGY

3-4. Nautilus sp. and Hemiaster sp.

The upper portion of the formation, especially the upper 5 feet contains a small species of Nautilus and a rotund bulky species of Hemiaster. The middle part of the formation contains Nautilus sp. near texanus, Pecten subalpina, Plicatula, etc.

2. Metopaster sp.

   A thin flaggy stratum about 4 feet above the base of the Pawpaw contains the starfish Metopaster sp., which so far has not been found elsewhere and may prove to be narrowly limited. The zone also contains other species of starfish.

1. 'Pyrite Fossil Zone'.

   Approximately the lower 8 feet of the clay contains an assortment of iron pseudomorphs and other fossils which is distinctive and includes the following:

Turrilites sp.	Enallaster sp.
Schloenbachia sp.	Salenia sp.
Scaphites sp. A.	Fish teeth and vertebrae
Hamites sp.	Baculites sp.
Arca sp.	Flickia sp.
Engonoceras sp.	Acanthoceras sp.
Cinulia sp.	Mortoniceras spp.

The zone is present at this level at all localities in Tarrant County. The Turrilites are distinctive, and none has been found by us below the Pawpaw except a solitary vertically ribbed species in the Main Kingena zone of the Duck Creek marl.

For brevity we call this a pyrite fauna; some fossils are pyrite, some hematite and some limonite.

MAINSTREET FORMATION

Brief Diagnosis: The Mainstreet limestone, the second most important upland forming rock in Tarrant County, underlies a belt of irregular width just west of the Eastern (Woodbine) Cross Timbers. Its outcrop is a dissected dip plain modified by erosional slope towards the stream valleys, and is essentially similar to the Fort Worth limestone prairie. The Grayson marl lies between it and the Woodbine Cross Timbers, and the brown Pawpaw clays underlie it. It is thus sharply limited both above and below and should be recognizable in well drilling. It is characterized by the sequence of fossils listed later. The Mainstreet limestone totals about 50 feet in thickness at Fort Worth.

Lithology: The formation with little variations from top to bottom, is composed of regularly alternating strata of straw-colored marl and chalky, or hard fairly pure limestone. The bands do not usually exceed one foot in thickness and the formation has a deceptive similarity to the Fort Worth limestone.

Description of Localities: This limestone forms conspicuous and extensive uplands. In general appearance these are much like those formed by the Fort Worth limestone. The uplands of the Mainstreet limestone extend from one end of the county to the other in a north south line passing east of Fort Worth. The extensive and gently rolling area between the Burleson and the Cleburne roads in the southern part of the county is underlain by this formation. Good exposures may be seen along Sycamore creek, from the region of the Glen Garden country club southeast; in the stream cuts between Seminary hill and Crowley; along the road from the Burleson pike to Crowley, where almost the entire thickness is passed through; near Keller, and other parts of the county. The lowest strata are well exposed in Sycamore Creek about one half mile north of Crowley. This part of the formation is highly fossiliferous, *Holectypus limitis* (?) and *Pachymya* sp. aff. *austinensis* being especially abundant. *Turrilites brazoensis* which ranges throughout the formation occurs here, but is more abundant higher up, as in the exposures along Deer Creek between Burleson and Crowley.

The upper portions of the formation are well exposed at various places along the Keller road, especially just south of Keller.

The upper portion may be seen also at the crossing of the Mansfield road and the Cleburne-Fort Worth interurban railway.

Paleontology: The Mainstreet limestone can be identified and its levels distinguished by means of the fossil sequence, which in part is as follows:

Leiocidaris sp. Rarely spines of this echinoid are seen high in the Mainstreet formation. **Cyphosoma** and other echinoids are associated with it. It lies nearly at the top under the level of **Exogyra** sp. 2 which occurs in the basal chalky marl of the Grayson formation.

Turrilites brazoensis Shumard. The upper ten feet or so of the

Mainstreet formation is rather barren; below this, **Turrilites** appears and ranges downward as low as the Holectypus zone, which is about eight feet above the base of the formation. The greatest abundance of **Turrilites** is about eighteen feet below the top of the formation. It may be seen in greatest abundance at the Deer Creek crossing of the Cleburne interurban.

Kingena wacoensis? Roemer. This distinctive large brachiopod is not found outside of the Mainstreet limestone except possibly in the Denton marl of the southern section. A zone of great abundance and almost the highest occurence is about 20 feet above the base of the formation; the lower limit is the base of the formation itself.

Schloenbachia sp. O, like inflata. Throughout the Mainstreet.

Exogyra arietina Roemer. This tall spired Exogyra begins about the middle of the Mainstreet limestone and ranges upward into the basal Grayson.

Ostrea quadriplicata Shumard. This characteristic fossil of the Denton, Weno and Pawpaw formations has not been seen above the basal Mainstreet, where it is rare.

Holectypus limitis (?) Boese. Large sized Holectypus are abundant in a zone about eight feet above the base of the Mainstreet formation.

Ostrea carinata Lamarck. One of the numerous but distinctive occurences of this striking oyster is a stratum in the basal Mainstreet limestone. This and the following zone may be seen along the Cleburne road.

Pachymya sp. aff. austinensis Shumard. A narrow zone of this fossil characterizes the base of the Mainstreet, where numerous well preserved individuals occur. We have seen it elsewhere only in the middle of the Weno limestone.

FOSSILS OF THE MAINSTREET FORMATION (PARTIAL LIST)

Ostrea sp., aff. marcoui Boese
Ostrea carinata (?) Lamarck.
Ostrea quadriplicata Shumard
Lopha sp.
Ostrea subovata Shumard.
Exogyra arietina Roemer.
Exogyra sp.
Gryphea sp.
Pecten texanus Roemer
Pecten subalpina Boese
Pecten wrightii Shumard
Pecten roemeri Hill
Pecten spp.
Spondylus cragini Whitney.
Lima wacoensis Roemer.
Protocardia vaughani Shattuck.
Pholadomya shattucki Boese.
Ptychomya ragsdalei Cragin
Pachymya sp. aff. austinensis Shumard
Homomya sp.
Barbatia Simondsi Whitney
Trigonia sp.
Schloenbachia sp. aff. inflata.
Turrilites brazoensis Shumard.
Turrilites sp.
Nautilus texanus Shumard.
Nautilus hilli Shattuck.
Kingena wacoensis (?) Roemer.
Cyphosoma volanum Cragin.
Holectypus limitis (?) Boese.
Enallaster bravoensis Boese.
Enallaster sp.
Hemiaster sp.
Leiocidaris sp. aff. hemigranosus Shumard.

GRAYSON MARL

Brief Diagnonsis: The Grayson marl in Tarrant county is exposed either as a steep narrow marl band lying against the western margin of the Woodbine Cross Timbers or as a gentle slope connecting the Woodbine sands with the Mainstreet upland. In either case it is at nearly all places covered with overwash and vegetation. Exposures are more rare than in any other Comanchean formation. The marl is yellowish-brown and locally contains pyrite seams and fossils, gypsum, and interspersed thin limestone bands. The formation is about 50 feet thick at its outcrops near Fort Worth.

Descriptions of Localities: The best and most accessible localities are a cliff one mile east, and a small divide about two miles southeast of Burleson, just outside of Tarrant county. The slopes of the Woodbine hills just west and northwest of Burleson also bear isolated exposures of the Grayson marl. The Texas and Pacific railway cut one-fourth mile east of Handley exposes the middle portion of the formation, as do small stream cuts one mile west of Handley.

SECTION OF THE GRAYSON MARL, 2 MILES SOUTHEAST OF BURLESON, JOHNSON COUNTY.

		Feet
3.	Yellowish calcareous marl, sparsely fossiliferous	12
2.	Shelly limestone band	1
1.	Yellowish calcareous marl, with gypsum, pyrite and limonite. Gryphea mucronata, Exogyra sp., Pecten subalpina, Hemiaster calvini, Enallaster sp., Turrilites sp., Lima sp., Engonoceras sp., abundant small pyrite fossils	15
	(Top and base of Grayson marl not exposed here).	

No locality clearly showing the Grayson-Woodbine contact has yet come to light in Tarrant county. This contact has been claimed by Taff to be unconformable at the locality on the Red River in Cooke county, which is now much obscured by Woodbine overwash. The Grayson marl locality just east of Burleson is rich in *Pecten subalpina, Lima* sp., *Gryphea mucronata,* and contains *Cyphosoma volanum, Hemiaster calvini, Enallaster bravoensis* and *Engonoceras.*

None of these exposures shows the entire thickness of the Grayson marl. In the cliff east of Burleson about 50 feet is exposed, reaching not quite to the Grayson-Woodbine contact; while between the bottom of the exposure and the Mainstreet limestone near Village Creek there is at least 20 more feet of basal Grayson. Part of these basal strata are seen at the locality 2 miles southeast of Burleson. At Handley likewise, the Grayson is probably about 70 feet thick, and here as usually the upper part is mantled by Woodbine overwash, a sandy, red, timbered soil whose presence everywhere makes the Grayson appear abnormally thin.

Perhaps the completest exposure known is in a tall bluff 3 miles ESE. of the bridge of the Fort Worth-Denton road over Denton Creek, east of Roanoke, Texas. This shows an apparently conformable contact of the Grayson with the overlying Woodbine, and also the contact with the underlying Mainstreet limestone. The Grayson here is 75.2 feet thick.

GRAYSON MARL NEAR ROANOKE, TEXAS

WOODBINE:

Red ledge, forming crown of hill.

Feet

GRAYSON:

Soft gray marl containing eleven limestone ledges, each 3 to 12 inches thick, the uppermost lying in contact and conformable with the base of the Woodbine.

Lima sp., *Protocardia* sp., (same as the Weno sp.), Cidarid spines (very large), zone of *Hemiaster calvini* and *Enallaster bravoensis* (10 feet below top), *Schloenbachia* sp., *Cyprimeria* sp., *Gryphea mucronata* (scarce), *Pecten texanus* (abundant), *Plicatula* (abundant), *Scaphites ?* sp. 37.8

Yellowish limonite stained marl. Rich in *Gryphea mucronata*. Turrilites (small sp.), no other ammonites seen; no echinoids seen. *Pecten texanus*, less abundant than above 15.2

Soft gray marl. Fossils scarce, mostly *Engonoceras* sp., *Gryphea mucronata* and flattened *Exogyra arietina*. A number of red ironstone seams weathering out black 22.2

MAINSTREET LIMESTONE:

Top: *Kingena* sp. very abundant.

This locality is noticeably more calcareous than those farther west.

SEQUENCE OF GRAYSON FOSSILS

The following paleontological sequence is taken from the Burleson, Roanoke and Denison localities:

WOODBINE: Ostrea carica and spp. Seen at Burleson and elsewhere immediately overlying the Grayson.

GRAYSON:

a. Zone of abundance of *Hemiaster calvini* and *Enallaster bravoensis* about 10 feet below top. Associated fossils: *Pecten subalpina*, *Pecten texanus*, *Lima* sp., *Protocardia* sp., *Cyprimeria* sp.

b. Zone of *Acanthoceras* sp. and *Tissotia ?* sp. 20-30 feet below top. Associated fossils: *Cyphosoma volanum*, *Pachymya* sp., *Protocardia texana*, *Turrilites* (small sp., ranges down to Pawpaw).

c. Zone of abundance of *Gryphea mucronata*. Associated fossils: *Pecten texanus*, *P.* sp. aff. *subalpina*, *Inoceramus* sp. 45 feet below top of Grayson.

d. *Exogyra* sp. 1. Associated with *Pectens*, *Gryphea* and *Lima*. 45-55feet below top.

e. *Engonoceras* sp. About 65 feet below top.

f. Association of *Nautilus*, *Enallaster bravoensis*, *Enallaster* sp. near *texanus*, *Holectypus limitis*, *Gryphea mucronata*, a salenid, *Pecten*, *Lima* and other pelecypods.

g. *Exogyra arietina* and sp. This zone lies just beneath the preceding, at the base of the Grayson. *Turrilites* sp. is abundant in both layers. The zone is underlain by Mainstreet limestone containing abundant *Kingena*.

FOSSILS OF THE GRAYSON MARL

Gryphea sp. like corrugata Say.
Gryphea mucronata Gabb.
Exogyra spp. 1-3.
Exogyra arietina Roemer.
Exogyra sp. like texana Roemer.
Pecten subalpina (Boese).
Turrilites spp. 1-2.
Arca sp.
Lima sp.
Cyphosoma volanum Cragin.
Ostrea sp.
Anomia sp.
Plicatula spp.
Protocardia sp.
Tapes sp.
Pholadomya shattucki Boese.
Trigonia sp.
Cerithium sp.
Cinulia pelletti Whitney.
Turritella sp.
Hemiaster calvini Clark.
Enallaster bravoensis Boese.

WOODBINE FORMATION

Brief Diagnosis: The Woodbine formation is a series of sandy, iron stained, argillaceous clay strata and ironstone; which weathers into low rolling hills with open glades and flats of bottom land. The outcrop, which covers roughly the eastern third of Tarrant county, is heavily timbered with black jack oak and post oak, and is known as the Eastern (Upper) Cross Timbers.

The soil is sandy, red, and acidic, and is suitable for special purposes as fruit growing. The outcrop forms the catchment area for the Woodbine artesian reservoir whose water bearing sands dip eastward, underlying at an increasing depth a large area in north central Texas.

The Woodbine has been divided into two divisions, the lower (Dexter) sands and the upper (Lewisville) beds. The latter are locally fossiliferous. The series has been considered about 300 feet thick between Handley and Arlington.

R. T. Hill[1] gives the following excellent description of the Woodbine formation: "The rocks of the Woodbine formation are largely made up of ferruginous, argillaceous sands, characterized by intense brownish discoloration in places, which are accompanied by bituminous laminated clays. These sands, like those of the Trinity division, are unconsolidated in places, but differ from them by containing a greater proportion of iron and other mineral salts, which materially influence the character of the waters derived from them. The sand, which in the unoxidized substructure are usually white and friable contain particles of iron occurring with glauconite and pyrite. These minerals oxidize toward the superficies, and their solutions consolidate the more porous beds of sand into dark brown siliceous iron ore, occuring in immense quantities in certain localities. Other beds of sand break down into deep loose soils. These support a vigorous timber growth."

Description of Localities: The Woodbine sands are poorly exposed in Tarrant county due to the small, inconsecutive sections, the softness of the strata and the consequent very general overwash, and the extensive timbering. The best series of exposures is along the road east of Birdville, and the Rock Island railway cuts east of Tarrant station. The basal contact of the Woodbine was not anywhere seen with clearness, altho localities near Burleson and Handley have the basal part poorly exposed. The upper contact with the Eagle Ford shales is seen in Taff's

[1]Hill, 21st Ann. Rept. U. S. G. S., part 7, p. 294.

locality on Bear Creek, 1/4 of a mile west of the Tarrant-Dallas county line and 2 1/2 miles northeast of Tarrant. A few basal strata are visible in cuts of the Fort Worth-Dallas interurban, 2 miles east of Handley.

An excellent section of part of the Woodbine formation near the base is seen at the pit of the Acme brick yards, Denton, Texas. This section is forty-two feet deep, and is strongly acidic in all of its material. The alternation of argillaceous bands with pure sandstone beds is striking. There is a perceptible stratification, apparently with conformable members, except at the top. Here there is either the end of a lenticular mass or the beds represent the foreset laminae of strong cross bedding. The former is the more likely, especially since about a mile distant and in the plane of the cut, a similar group of beds is shown whose dip is strongly against that of the beds, suggesting the other edge of the lenticular mass.

SECTION IN THE PIT OF THE ACME BRICK YARDS, DENTON, TEXAS:

		Feet
5.	Lenticular mass, four members, overlain by a red sandy clay	15
4.	Light colored limonitic argillaceous member	7
3.	Red sandstone	5
2.	Light colored limonitic argillaceous member	1
1.	Grayish sandy argillaceous member, containing several bands of almost black sandstone	14
		42

A 25 foot boring at this point penetrated the Grayson marl.

SECTION OF WOODBINE EAST OF TARRANT STATION

(The following section is seen south of the railroad below the first bridge west of the county line.)

		Feet	Inches
27.	Sandstone ledge, locally a shell conglomerate, containing Barbatia micronema Meek, Ostrea soleniscus Meek, Ostrea carica Cragin, Ostrea sp., Exogyra sp., and other Lewisville fossils. The upper portion is indurated, laminated and especially fossiliferous. Exposed in three cuts nearest		

		Feet	Inches
	the Tarrant-Dallas County line. This is the top of the Woodbine and is overlain by Eagleford shale. Between the two localities it has locally a dip of 2 1/2° East, but this reduces at most places to about 1/2° East....................	7	
26.	Light yellowish sand with limonitic stain, usually unconsolidated and containing Ostrea sp. (with large attachment scar)......................	5	
25.	Arenaceous yellow-brown shales containing Ostrea sp.	8	
24.	Three ironstone bands interbedded with bluish sandy shale...............................	2	
23.	Thin bedded closely laminated shale with dimension layers of iron stained red shale, and containing gypsum, limonite and oyster shells (O. carica). The lower 10 feet is especially fossiliferous.....	22	
	(The section in the cuts west of this locality exposes all of the foregoing members, and in addition in a deep run about a mile east of Tarrant, the following section is exposed.)		
22.	Bluish red shale with limonite stain and abundant gypsum. Ostrea carica is rare in the top......	20	
21.	Loosely laminated thin bedded brown shale, weathering to a rough faced cliff.............	5	
20.	Compact laminated brown shale forming a smooth cliff face..................................	2	
19.	Three thin red ironstone layers with interbedded compact blue clay..........................	4	
18.	Bluish limonitic shale........................	12	
	(There is a break in the section at this point. A cut of the Rock Island Railway 1/2 mile east of Tarrant exposes the following section.)		
16.	Thin bedded red sandstone, no fossils seen. Minor faulting present. Gypsum present. Dip is 2 degrees east in the west end of the cut, and straightens out to 1 degree in the east end....	10	
15.	Blue shales containing gypsum and lignite seams. No fossils................................	12	

It is doubtful if many of these members are continuous over great areas. There is a break in the section near Tarrant station. There is a middle sandstone member of the Woodbine formation which consists of massive red sandstone, and which seems extensive. Its structure is complicated by lenticular masses and by sharp reversals of dip. About 2 miles west of Tarrant station at the crossing of the Arlington-Grapevine road and the Rock Island railway, is a massive sandstone ledge. A cut of the railway 2 miles west exposes a similar sandstone ledge. Cuts along the first parallel road north of the Rock Island railway, from Birdville to the county line and a few cuts south of the railway expose the lower half of the Woodbine formation. There is locally at least a basal sandstone which forms the resistant cap of certain "Brushy Knobs." For example, on the knob 2 miles northwest of Burleson, the basal strata of the Woodbine are seen to be in part a sandy shale and in part a red sandstone whose massive fragments are scattered over the crest of the hill. At Burleson this stratum is fossiliferous.

The Woodbine formation in the Liggett-Tarrant section thus seems to consist of three red sandstones and two interbedded series of blue shales with various other lithologic features. Extensive cross bedding and some evidence of large lenticular masses were seen in this section. Sharp reversals of dip and rapid tapering of small lenses so as to simulate angular nonconformity within the formation were seen.

Dip and thickness: The apparent local dip of the Woodbine varies greatly, due to two factors, cross bedding and lenticular masses. An estimated thickness between Handley and Arlington of 300 feet has been given by Hill.

This is based on a dip of 40 feet per mile of the overlying and underlying strata, but this estimate is probably too low. The uniform maximum dip of the Washita division east of Fort Worth is 2 degrees southeast, and the measured dip of the Eagle Ford and Austin chalk west of Dallas approximate 1 degree southeast.* From numerous observations Tarrant and

*The minor faulting of the Austin chalk often obscures its general dip, but the following data indicate the mean maximum dip to be about 1 degree near Dallas: White Rock cliff, cut on Fort Worth pike, 5 miles west of Dallas, 1 degree dip, direction 260 degrees from magnetic north. South end of Oak Cliff viaduct, 1 degreen 20 minutes, dip in direction 215 degrees from magnetic north. Missouri, Kansas & Texas Railway cut, 1 mile north of Union Terminal Dallas, 1 degree dip, direction 110 degrees from magnetic north.

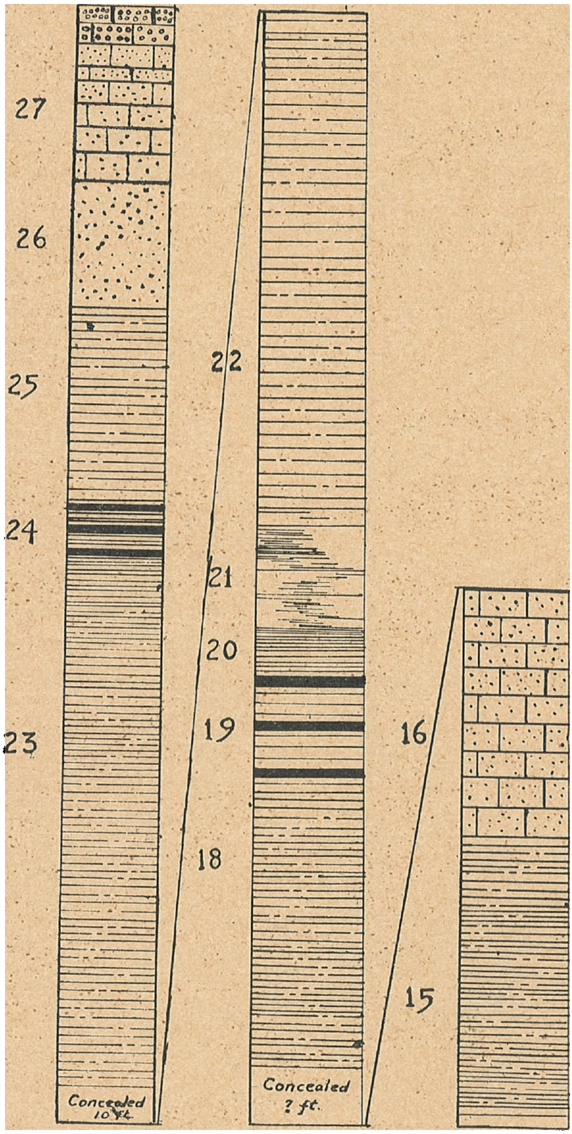

Fig. 6. Columnar section of portion of Woodbine formation in cuts of Rock Island railway between Tarrant station and the Tarrant-Dallas county line. The numbers refer to corresponding strata described on pp. 76-7. Vertical scale, ⅛ inch = 1 foot.

Dallas counties we place the mean maximum dip of the Woodbine at 1½ degrees southeast, which counting reversals of dip would mean a thickness of 350 feet for the formation.

DIPS OF WOODBINE STRATA IN TARRANT AND DALLAS COUNTIES

	Angle of dip °	′	Direction in degrees from magnetic north
1. Road due east from Birdville:			
	3	30	90
	1	20	82
	5		114 (lenticular mass)
	1	30	196
	1		245
2. Rock Island Railway cuts 2 miles east of Tarrant station:	2	30	80
3. Bear creek, 2 miles northwest of Tarrant station:		30	80
4. 1/2 miles southwest of Grapevine:	1-3		110 (with reversals)

Structure: The main relief features of the Woodbine strip of cross timber land are produced by the alternating harder and softer strata. This gives an obscured "cuesta" topography, especially near the outcrops of the middle and upper massive sandstones, both of which make small ridges in the landscape. The outcrop of the latter may be seen along the Rock Island railway between Irving and Tarrant station. Certain harder ironstone ledges cap the summits of numerous "Brushy Knobs" which form outlying strips of islands often parallel to the western border of the main Woodbine formation. Certain notably sharp peaks within the outcrop are likely due to lenticular masses of iron ore.

The cross bedding and consequent divergence of dip is one of the most striking structural features of the Woodbine sands and is purely local in extent and not indicative of underlying disturbances of economic importance. Very striking reversals of dip within short distances are common features of the Woodbine formation. If the contacts of the Woodbine in north Texas are conformable as reported, then these variations of dip within the formation must straighten out at the contacts. Such twisted strata overlain by evenly dipping beds are seen in many places.

Even more deceptive are the numerous steep or gentle lenticular masses which are underlain and may be overlain by evenly dipping strata. These are not to be confused with "domes" and indicate no underlying structure of importance, as detailed in the discussion on possibilities of oil and gas. A lens-shaped mass with its slopes will often closely resemble a dome, especially if the mass is not penertated by a cutting revealing the undisturbed strata beneath. These lenses are of variable size, often many hundred feet across.

Small scale faulting was seen at many places. The shallowness of the deposition is indicated by included masses, as for instance an irregular limestone mass of about two cubic feet surrounded by a sandstone cyst and completely imbedded in the Woodbine formation. Vertical joint planes running in the direction of the strike were seen in the middle sandstone near Tarrant station.

Minerals: The Woodbine sands contain immense quantities of low grade iron oxides which make up the bulk of the strata at certain levels and at others merely impregnate or discolor the sandstone. At a few levels and locally as in the basal argillaceous sand, the iron is extremely low in percentage, but such material burns to a red brick. A nearly stainless stratum outcrops near Mansfield. Gypsum is present as broken sheets and fragments at certain levels, as in the upper third of the formation, and contributes an unpleasant element to the water from this level. Scattered fragments of gypsum are seen at practically all levels of the Woodbine formation which were examined by us. Lignite is present in the blue shale below the middle sandstone, and may be seen in the Rock Island railway cut east of Tarrant station, where there are several seams each less than one inch thick, and of no commercial importance. Wood occurs in three forms, silicified, lignitized, and practically unaltered. So far no other plant remains occur in Tarrant county although they are reported in abundance along the Red River.

Desert varnish is a thin enamel-like incrustation which sometimes forms on the face of sandstone exposures, especially if the sandstone is rich in iron. The conditions necessary are that the sandstone shall contain a large quantity of absorbed water together with a considerable amount or iron (or manganese) salts and that there shall be an uninterrupted arid spell of many weeks. The capilliary movement of the water brings to the surface the dissolved salts of iron and deposits them in a thin crust which is reddish or yellowish if there is little organic matter and increasingly greenish with the increased amounts of organic substances which can reduce the iron oxides. A truly remarkable exhibition of this phenomenon was observed by the writers in an isolated block of Woodbine sandstone two miles southeast of Denton, Texas. Following the very long arid spell of 1918, the "varnish" had formed in an excavated pit about twelve feet across and about seven feet deep. The excavation faced towards the southwest and the entire surface, including furrows and grooves made by the picks, was covered with a thin enameled surface of greenish color, averaging about 1/16 of an inch in thickness. The green color was spotted with darker green and blacks, the whole giving the effect of the rarest Turkish tile.

Fossils of the Woodbine formation: The following fossils were reported by Hill in the 21st Ann. Rept., U. S. G. S., part 17, pages 314-318:

Ostrea soleniscus Meek.
Ostrea carica Cragin.
Exogyra columbella Meek.
Modiola filisculpta Cragin.
Aguilera cumminsi White.
Cytherea leveretti Cragin.
Trigonarca siouxensis H. & M.
Arca gallieni variety tramitensis Cragin.
Barbatia micronema Meek.
Pteria salinensis White.
Turritella coalvillensis Meek.
Turritella renauxiana Cragin.
Cerithium interlineatum Cragin.
Natica tramitensis Cragin.
Nerita sp, Cragin.
Scaphites sp. Hill.
Crab sp.
Plants spp.

UPPER CRETACEOUS

EAGLEFORD SHALES

Brief Diagnosis: The Eagle Ford Shales, the easternmost formation in Tarrant County, outcrops in two small areas which are separated by the alluvial Trinity River valley. The first area extends from near the northeast corner of the county along an irregular line through Grapevine and thence southeast to the Dallas county line near Liggett, where the contact runs nearly south, remaining within Tarrant county and about 1/4 mile west of the county line. The formation outcrops in small runs into the Trinity almost at the point where the Rock Island railway crosses the Tarrant-Dallas county line. The contact likewise runs along a stream, Tradinghouse creek, just east of Arlington. The second area is a roughly triangular strip covering the southeast corner of the county. The formation consists of blackish and bluish shales, with seams of arenaceous and shelly limestone, and weathers into a black, waxy, carbonaceous, treeless, rolling upland soil. The formation is stated to be about 500 feet thick between Arlington and the White Rock escarpment west of Dallas; of this thickness about half occurs in southeastern Tarrant county.

Description of Localities: The Bear Creek locality is stated by Taff and Shuler to show the contact between the Woodbine and the basal Eagleford shales. The contact is excellently exposed in a small run and in railway cuts at the point where the Rock Island railway crosses the Tarrant-Dallas county line. Here the Eagleford is a characteristic laminated blue shale with a few arenaceous thin ledges near the base. *Acanthoceras swallovi* (Shumard) is found in the basal three feet. The Eagleford formation conformably overlies the Woodbine, whose top stratum is a laminated sandstone in most places composed almost entirely of masses of nacreous shells. The upper contact of the Eagleford shales does not occur in Tarrant county but is finely exposed at the White Rock escarpment, 5 miles west of Dallas, and in the hills south of the Arcadia Park stop on the Dallas interurban. At these localities are found many shark teeth and vertebrae, *Schloenbachia* spp., *Ostrea belliplicata* Shumard, *Inoceramus* sp., gastropods and pelecypods.

There are slight variations in dip in the Eagleford shales but it is doubtful if these in Tarrant county indicate any structures of economic importance in the Eagleford or the underlying Woodbine formations; while the slight disturbances farther east may be connected with the local small scale faulting so prevalent in the Austin chalk.

CENOZOIC AND RECENT

The Cenozoic and recent deposits in Tarrant County are made up, as previously noted, of gravels. The gravels are readily divided into the upland deposits and the lowland deposits,—known to the trade as "pit" gravels and "stream" gravels.

The distribution and physical appearance of these is discussed on page 91. Besides the physical appearance, the fossils of the two gravels are of interest. In both cases the fossils originate —except for the rare vertebrate forms,—in older formations. The lowland gravels contain the fossils of the beds through which the streams pass, being predominantly of the upper part of the geological section in the south and east and of the lower part of the section in the west and north. The upland gravels contain fossils which are consistently of the Fredericksburg formations. In both types of gravel certain fossils are readily recognized, the various species of *Gryphea*s and the small sea urchin, *Hemiaster,* being well preserved, although badly worn. The few vertebrate remains which have been found occur in the upland gravels. Among these are the Mammoth (Elephas imperator) of which a splendid tusk and a few teeth are on exhibition in the Carnegie Library at Fort Worth; a mastodon; Elephas, small species, and Megatherium, bothfrom a gravel pit in the river bank one mile east of the Court House, where many Pleistocene fossils have been found; and a small horse, believed to be Equus francisii, of which only the teeth have been found. Shells of clams (Quadrula spp.), snails and other fresh water invertebrates are common just below the Lake Worth dam, on the uplands and elsewhere. The distribution of the upland gravels indicates that they may be older than the Pleistocene, but the authors have not entered into the broad problems connected with these deposits.

ECONOMIC GEOLOGY

The nature of the underlying rocks of Tarrant county determines to a great extent its natural resources and possibilities and indicates its logical line of future development. Geology explains many of the resources and natural advantages of a region, and among them the following:

(1) Resources of location: Substratum, drainage, accessibility, varieties of topography, scenery.

(2) Resources of soil: Adaptability to different kinds of use; farm land, grazing land, etc.

(3) Resources of native or importable plant and animal life.

(4) Resources of crude material: Building material, road material, minerals, oil and gas, artesian water.

RESOURCES OF LOCATION

Excavation and foundations. The question of the safety hardness, resistance, and thickness of the underlying rocks bears directly upon excavation for deep foundations of large buildings, or for pipe lines, drainage lines, sewers, cuts, dams, bridges and other structural works.

This question is of significance where, as under Fort Worth, a rather thin cap rock is succeeded by a marl member which not only is soft but is water bearing and caves readily. The solid Fort Worth limestone under the business district of the city averages about 25 feet in thickness. If this is not mostly excavated out for basements and sub-basements, it of course affords a firm substratum for buildings up to a certain size, depending upon the amount of the excavation. When this 25 feet of limestone is penetrated a marl mixed with insecure thin limy ledges and extending downward for about 15 feet is encountered. This level may be instantly recognized by the abundant brachiopod, *Kingena*, which the excavation will reveal.

Then comes a limy ledge about 7 feet thick with considerable marl material intermixed. This ledge has firmness enough for many building purposes.

Underneath is a series of limy and marl layers of increasing firmness and compactness, which after 11 feet below the ledge are quite compact and afford an excellent foundation. The section may be seen in Plate 6, and is exposed at several places near the court house.

The marlier layers have a certain water content which will depend somewhat on whether their outcrops west and north of the site of excavation have a favorable catchment area or not. If they are narrow or built over or paved, or slope sharply to the west, less water will seep under the foundation.

The foundations of numerous buildings in Fort Worth have penetrated these strata to different depths. An example is the foundation of the W. T. Waggoner office building whose excavation (May 1919) sectioned at Eighth and Houston streets about two feet of soil, then penetrated the typical thin bedded Fort Worth limestone, which towards the base was bluish, calcareous and very hard. The interbedding was a hard calcareous marl. The excavation for concrete piles was continued to stratum 1 which lay at a distance of 28 feet below the level of the sidewalk. In general it is inadvisable to base heavy buildings on marl.

Roads and railroads. Roads in many parts of the county have a naturally firm sub-stratum, as over portions of the Fort Worth and Mainstreet uplands. The Woodbine roads often have a natural base, and along the eastern border the Eagle Ford overwash forms a clay binder for the sand and makes an excellent natural roadbed.

The railroads running in the strike of the Comanchean formations often lie on limestone strata, as the Frisco on the mineralized ledge (17) of the Duck Creek formation, southwest of Fort Worth. The Misouri, Kansas and Texas and the International and Great Northern run successively on the Fort Worth limestone, the Weno limestone and the Mainstreet limestone south of Fort Worth. The Santa Fe south of Fort Worth in Tarrant County runs on the Mainstreet limestone. Railroad cuttings across the strike follow more or less the "cuesta" slopes, as the Texas and Pacific to the west and the Interurban to Dallas.

Drainage. The streams have cut back the softer materials from the adjoining harder formations producing small and poor exposures of the marly material. This is especially true of the Grayson marl, where good exposures are rarely found, and which only exceptionally weathers as a divide, such as that southeast of Burleson, or in stream cuts descending from the Woodbine formation. The softer nature of the Grayson marl is attested by the disproportionate number of graveyards scattered throughout its outcrop across Tarrant county.

Certain railroads run on drainage divides, as the Fort Worth and Denver City Railway, which north of Fort Worth follows the divide between the West Fork and the Denton Fork of the Trinity.

Slumping and side-slip of strata on the edge of uplands result in virtual reversals of dip and in two known places blocks of Fort Worth limestone have been undermined by the Trinity.

RESOURCES OF SOIL

No soil map of Tarrant county has appeared, but analagous conditions resulting from the same types of geology may be seen in the maps of Grayson and Travis counties. The county contains soil areas which follow closely the outcrop of the geological formations as mapped here, and these may be roughly divided as follows:

(1) *Uplands*: The Fort Worth and Mainstreet uplands have been stated to possess such shallow soil that they are suitable only for grazing. However over great stretches, notably the dip plain area north of Fort Worth, which Hill calls the type of the Black Prairie, the soil and subsoil are deep and are used for large scale farming. The exposures of the Fort Worth limestone southwest of the city are extensively used for grazing. These uplands drain quickly, even after heavy rains, and in general artificial water basins must be constructed if a permanent water supply is desired. This portion of the county is dissected by streams cutting down to the Trinity, especially near the western prairie border, and is rolling or slightly hilly and almost treeless. Practically the same conditions hold for the Mainstreet upland except that near its eastern border there is a considerable mixture of red sandy soil from Woodbine overwash. The two uplands are at many places connected by a fairly even grassy slope obscuring the intervening formation and making the two areas practically one topographic unit.

(2) *River Bottom.* The untimbered portion of the alluvial Trinity River valley is wide enough in many places to permit

of considerable cultivation and in the central and western part of the county is not subject to serious overflow. In the eastern part of the county a system of levees exists. The river alluvium is deep and has at many places a gravel and sand foundation which is exploited commercially, as at the Rock Island pits near Birdville. This material is transported by the stream for considerable distances as seen by the Fredericksburg fossils occurring in gravel deposits near Dallas. The numerous *Exogyra texana* and *Gryphea marcoui* in these gravels come mostly from strata below and outcropping west of the white Goodland limestone. As the river cuts thru the Woodbine cross timbers the soil deposits gather sandy acidic components, so that this portion of the bottom land like the Woodbine is used for fruit growing.

(3) *Woodbine Cross Timbers*: This strip of red sandy acidic soil is still densely timbered with black jack and post oak, but contains natural glades and artificially cleared areas. The soil is suitable for many purposes, especially fruit growing, peaches, peanuts, and to a less extent cotton, corn and tobacco. However its limitations should be clearly noticed if loss is to be avoided in the selection of crops. The Fort Worth region has been agriculturally, first a cattle raising country, and second a grain and cotton country. Without doubt its diverse soils are suited to a variety of profitable special products whose exploitation is only a matter of study and experiment. The main cotton belt at present is the outcrop of Eagle Ford (and to a less extent the Woodbine also) in the eastern part of the county.

RESOURCES OF NATIVE OR IMPORTABLE PLANT AND ANIMAL LIFE

As already stated the county lies at the junction of the humid (eastern) and the semi-arid (western) divisions of the Lower Austral Zone, and it has accordingly a mixture of temperate and subtropical wild life. This is seen clearly in the mammals, birds, insects, and in the plants. Subtropical and temperate zone birds live side by side in the upper Trinity valley, as noted by Bendire. The county lies on the northern range of certain subtropical insects and other invertebrates. Finally the same situation is true of other vertebrates.

A plant zone map of Texas as indeed of most of the United States will correspond broadly to a map of the underlying geological systems. Hill and others have recognized that the various divisions of the Texas Comanchean and Cretaceous carry their own peculiar or at least prevailing flora; and the phenomenon of timber belts which characterize certain formations has long been known. This correspondence extends for some plants to the minute subdivisions of geological formations.

There are certain plants which occur either largely or exclusively upon certain types of topography regardless of the underlying geological formation.

(1) UPLAND PLANTS

Centaurea americana.
Helianthus annuus.
Helianthus maximiliani.
Lindheimera texana.
Castilleja purpurea.
Linum lewisii.
Linum arkansana.
Polygala alba.
Croton texensis.
Euphorbia marginata.
Baptisia bracteata.
Psoralea hypogaea.
Callirhoe digitata.
Megapterium missouriense.
Phellopterus macrorhizus.
Eustoma russellanium.
Amsonia texana.
Quamasia hyacinthea.
Cooperia drummondi.
Sisyrhinchium amoenum.
Lesquerella gracilis.
Draba cuneifolia.
Neptunia lutea.

(2) ESCARPMENT PLANTS

Yucca arkansana (mainly on Fredericksburg limestone).
Androstephium ceruleum (mainly on Duck Creek limestone).
Erythronium albidum coloratum (mainly on Duck Creek limestone).
Aragallus lamberti.

(3) LOWLAND PLANTS

Smilax bona-nox.
Clematis simsii.
Cnidosculus texanus.
Viola obliqua.
Viola rafinesquii
Craetegus mollis.

(4) PLANTS OF THE WOODBINE SANDSTONE BELT

Quercus marylandicus the "Black Jack" oak is the characteristic tree of the "lower cross timbers."
Pentstemon australis.
Houstonia minima.

RESOURCES OF CRUDE MATERIAL

LIMESTONE INDUSTRIES.

When mention is made of the resources suggested by the geology of a region, the average layman assumes at once that reference is made to mining possibilities and to oil and other so-called mineral resources. Often a region has undeveloped resources in its rocks which are of more permanent value than even fairly rich mineral deposits in the popular sense.

Limestone industries are many, and much depends on the various factors of the quality of the limestone, the presence or absence of other substances besides the calcium carbonate which makes up the bulk of all limestone, transportation facilities, accessibility to a market, fuel, labor, etc. Examples of limestone industries are: quarries, cement plants, carbon-dioxide gas plants, rock crushers and lime kilns.

The limestones in Tarrant county which offer possibilities in the opinion of the writers are as follows: the Mainstreet limestone, which is fifty feet thick; the Weno limestone, which is twenty feet thick; the Duck Creek limestone, which is thirty feet thick; and the Goodland limestone which is a little more than one hundred feet thick. The areal extent of each of these at the surface can be seen on the map.

Unfortunately very little exploitation of these various limestones has been carried beyond the experimental stage. Even in the simple matter of crushed rock for road metal, the writers lack any practical data based on industrial experience, as Tarrant county has the crushed rock for its roads shipped from another county.

The following considerations govern the limestones of the county: Only one, the Weno limestone offers possibilities for the establishment of quarries. This excellent material is rather limited. The rock, however, seems to cleave well and should be adapted to exploitation as a good grade of building stone. It is white in color, fine grained in texture, does not contain enough iron to be likely to develop wall stains, and as noted above cleaves well, with the cleavage planes clean and parallel. Blocks to a maximum thickness of eighteen inches should be readily obtained and with a length of six feet and a breadth of three feet. As this limestone is in many places covered with other formations or otherwise in a condition to make a quarry impracticable, the following localities are suggested to prospectors: the area north of Polytechnic especially in the region near the Texas and Pacific tracks, the bluffs along Sycamore creek especially in the neighborhood of the crossing of the loop road about a mile after it leaves the Burleson road. A considerable area of this limestone is exposed along the Keller road about four miles north of Fort Worth, but much of the exposure is overlain by a thick blanket of soil.

The Mainstreet limestone is the best exposed over a large area, but is massive, breaking into angular fragments and considerably iron stained. In the opinion of the writers, however, this limestone should be entirely satisfactory for crushed rock. It is remarkably uniform through a considerable thickness, and this is a quality desirable in crushed rock. The Fort Worth limestone and the Duck Creek limestone contain much marl in the form of beds alternating with the limestone. In the present stage of development of the limestone industries these two limestones are not likely to be worth exploiting as long as there is such a large supply of much higher grade material.

The Goodland limestone offers, apparently, more possibilities. The map indicates the great area covered by this formation. The region around Benbrook is especially rich in good exposures of this limestone. The most conspicuous single exposure of this limestone is in the bluff at the north end of the Lake Worth dam. In fact the use of this limestone in connection with the construction of this dam seems to be the only extensive experiment which has been made in its exploitation.

The Goodland limestone is almost pure calcium carbonate, and offers possibilities for exploitation in many ways: lime kilns, carbon dioxide plants, cement plants (using the Kiamitia clays immediately overlying the Goodland limestone). For practical purposes the supply may be considered as inexhaustible and many excellent exposures occur near the city of Fort Worth.

GRAVEL AND SAND

There are two types of gravel in Tarrant county:

(a) River gravel, lowland, rounded, clean, little cementing or adhering of sand or clay.

(b) Pit gravel, upland, angular, cemented with matrix of poorly assorted particles of sand, clay, rock materials, etc., of various sizes.

The lowland gravel occurs at or near the present level of the drainage at many places even up the small laterals. The upland gravel is widely distributed and is worked commercially. There are considerable deposits along the whole course of the Trinity particularly the Clear Fork, on the south side of the Arlington Heights divide, on the hills around the Texas Christian University, on the Rock Island railway south of Birdville, and along Sycamore Creek, Big and Little Bear Creeks and Big and Little Fossil Creeks.

SAND: The river sands are impure, being mixed with clay, gravel and calcareous particles and fragments. The purest sands are probably in the upper part of the Woodbine near Mansfield. This is a round-grained sand, and has some iron stain. Extensive sands occur in the Walnut and Paluxy formations west and northwest of Fort Worth.

MINERALS: The following have been found in Tarrant County: Calcite, aragonite; pyrite, hematite, limonite; celestite; gypsum; radiolarian ooze; desert varnish. In addition gilsonite in the Trinity sand, and lignite in the Woodbine occur in non-workable amounts. Apparently none is of economic importance.

CLAY INDUSTRIES

Probably the purest clays in the county are those of the Pawpaw and Woodbine formations; which, so far as known, have not been tested except for brick. There are also clay members in the Paluxy sand. These clays are iron stained and somewhat impure, but should be suitable for tile, crockery, earthenware, and certain other clay products. The Athens Pottery Company at Fort Worth ships in its clay. The availability of clay for commercial use depends somewhat upon the price of fuel and the conditions of transportation. Factories will locate in a great rail center like Fort Worth and ship in their raw material. Hence it is extremely desirable to use all possible local raw material, and to make special investigations to find which are suitable. There has apparently been little testing and no exploitation in Tarrant county but the favorable combination of materials found here makes a greater future development of certain clay industries seem very probable.

BRICK

The general requirements for the location of a brickyard are accessibility to transportation, to fuel, to suitable market, to water, and to crude material as described. The crude material should be present in large quantities; should be accessible without great amounts of excavation; should be free from overlying soil or undesirable rock formations which would require removal; should be capable of proper drainage; and should be of a certain quality or purity, especially as regards shell material or other calcareous inclusions.

Evidently several formations exposed in Tarrant county fit these conditions, especially the following: Eagle Ford shales, Woodbine sands (basal part), Pawpaw clays, Weno marl, Kiamitia marl, Paluxy sands, Walnut clays. These are exploited so far at only five places in Tarrant county, but it will be useful to refer to the nearly similar conditions found in the same formations in adjoining counties. In this connection attention is called to the interesting geological possibilities of brick yards to students or others doing paleontological work, since in brickyards marl formations, otherwise poorly exposed, are well sectioned.

As the pits deepen the question of drainage becomes more pressing. Many pits are pumped, a proceedure involving expense and often delay. It might be practicable in some pits to resort to the drainage device used at times by the American Expeditionary Forces in France, in which a lower lying dry sand was reached by boring and the drainage emptied automatically into this sand. In the Washita divisions, certain levels of the Paluxy sand might be drilled to; and above the Washita, certain of the Woodbine sands.

CLAYS OF THE WOODBINE SANDS

Acme Brick yards, one mile south of Denton, Texas: The material used is mainly a whitish arenaceous clay layer whose base lies within 25 feet of the bottom of the Woodbine formation. This layer is nearly 30 feet thick and is overlain by a lenticular mass of red sandstone which is dragged back from the top preceding excavation of the material. This whitish material is semi-consolidated in places and weathers nearly white with little iron stain. The "red clay" burnt alone gives a non-spotted building brick; the white material alone gives a cream colored brick; while the two mixed give a spotted de luxe brick which is sorted.

Johnson Station, Tarrant County: This brick yard uses material from the lower third of the Woodbine sands.

Kennedale, Tarrant county: two brickyards use the middle part of the Woodbine sands.

Brambleton, Tarrant county: this brickyard uses middle Woodbine material.

CLAYS OF THE PAWPAW AND WENO FORMATIONS

The Cobb Brick yards, Fort Worth, use two sources of supply, the basal Weno marl and the Pawpaw clay. The pit in the Weno near Sycamore Creek exposes nearly the basal third of the marl, including the *Gervilliopsis* layer. The marl after weathering, is grayish-blue, putty colored and is only slightly shelly. The few *Gryphea, Gervilliopsis* and other shells present after screening are burned with the mixture and reduce to insignificant friable limy spots. This Weno marl burns at about 1700°F to a variety of red bricks, which are sorted. The upper Pawpaw marl east of Sycamore Creek is used to produce a red building brick which burns at about 1700°F. The clays of the Pawpaw formation in Tarrant County offer many advantages for brickmaking. They are particularly free from shells, obviating screening, as is necessary in certain clays of the Weno deposits. The formation has in the basal portion small pyrite fossils whose contained sulphur might be a disadvantage, but the total amount of this material is small.

The Pawpaw formation is a homogeneous clay or shale practically free from calcareous shells, about 23-27 feet thick. It is capped at most places by Mainstreet limestone which would have to be blasted or stripped back. This Mainstreet cap at places disintegrates so that the stripping is easier; however, at such places it contaminates by percolation the underlying clay to a depth of 3 feet or more. The drainage of Pawpaw localities is almost invariably good, since they lie on hillsides. For the same reason a gravity haul to a plant located so as to utilize also the underlying Weno marl is practicable. The amount of material is unlimited, since it is necessary only to follow the line of outcrop. This 23-27 feet of Pawpaw is underlaid by an amount of Weno limestone which it would be impracticable to remove, in order to expose the underlying Weno marl. It should be noted that north of the Trinity, the Pawpaw contains immense amounts of siliceous fragments resembling jasper, which will probably require screening; this material is absent south of the Trinity. Finally, in Tarrant County the formation is accessible to railroads.

BRICKYARDS 1¾ MILES SOUTHEAST OF GAINESVILLE, TEXAS

The pit of the Gainesville Brick Co. exposes the Weno formation from the Quarry limestone group, which is well developed on the south rim of the pit down to the basal third of the formation, about 20 feet below the Gervilliopsis layer. The Weno is about 75 feet thick and the depth of the pit practically the same. A water well nearby penetrated the Denton marl and the Fort Worth limestone.

A "buff marl" layer, free from shells and lying about 2 feet below the *Gervilliopsis* layer burns to a clear buff brick and is much favored. If the material is excessively shelly it is discarded. Much material from the upper part of the pit also was discarded on account of the abundant ironstone. The burning temperatures vary from 1700°F. to 1800°F., and the bricks are sorted. The plant uses the dry moulding process, is equipped to burn lignite and coal, and has a capacity of 40,000 bricks per day.

CLAYS OF THE PALUXY SANDS

One brickyard north of the Texas & Pacific Railway on the White Settlement road 15 miles west of Fort Worth, uses the material from the upper part of the Paluxy formation, which burns to a red building brick.

POSSIBILITIES OF OIL AND GAS

A bulletin on the geology of any of the counties of North Texas would be incomplete and unsatisfactory without a discussion of the possibilities of petroleum. Mr. E. W. Shaw, of the U. S. Geological Survey, included Tarrant County in his study of the natural gas resources of parts of North Texas, (U. S. G. S. Bulletin 629), including a structural map of the outcrop of certain limestone ledges in the area south and west of Benbrook. It was his opinion that notwithstanding the fact that oil and gas showings in water wells of the southern part of Tarrant County are frequent it is likely that the accumulations of petroleum products in the rocks underlying this county has escaped. The writers of this bulletin are inclined to agree with this general view. We do not pretend to have thoroughly investigated all the structural possibilities in the county, and it is of course possible that structures favorable for the concentration and retention of oil or gas may exist. However, we have seen no such structures, and the probable occurrence of a large syncline in the Paleozoic rocks in this region is especially unfavorable.

In Tarrant County, as in many other counties of North Texas, considerable exploratory drilling has been carried on in the area covered by the Woodbine formation. The red sandstone which makes up the formation, is extremely interesting and complex. Its exact thickness is not known, and a complete recorded section does not exist. It is much cross bedded and its dip changes with frequent and startling suddenness. Above all else, it has extremely deceptive structural features in the shape of lens-like masses. Some of these are quite extensive, and might very well be mistaken for "domes" suggesting a corresponding structure in the underlying rocks and, of course, the possibility of concentration of petroleum. A careful study of one of these bodies has been made by the writers. Unfortunately this body does not occur in Tarrant County, but it is so perfectly exposed and the arguments of the writers are so well illustrated that attention is called to one of these bodies in the Acme Brick Yards at Denton, Texas. In the westward facing out of the pit, a little more than forty feet of the Woodbine formation is exposed. The upper fifteen feet is made up of a lens-like mass containing four members. The lens shape is due to sharply dipping members in the bed. The dip here is mainly south. About a thousand yards north of the pit in the cut of the Missouri, Kansas and Texas Railway is an exposure of the rocks in the plane of the pit, in which the members dip in the opposite direction. In both cases, the underlying rocks are horizontal. This pseudo "dome" then is estimated to have had an original depth of from sixty to seventy feet and a diameter of nearly a mile, and without the underlying horizontal beds so well exposed, this "dome" might have been discovered and exploited by some inexperienced person.

The Bend and the Ellenburger formations, if present underneath Tarrant County, are deeply buried. The Bend has not been reached in the Polytechnic well at 4380 feet according to Dr. Udden. A sample said to be from this well from "below 4,000 feet" (depth not stated, possibly near 4,600 feet) is a hard black shale lacking fossils; and a sample claimed to be from "about 4,600 feet" is likewise black shale, probably not Bend, but resembles somewhat the black shale above the Bend, in the opinion of Dr. Udden. Comparison of wells at Georgetown, Gatesville, Myra, and Muenster with those in Tarrant County would appear to indicate a considerable depression, possibly synclinal, of the Trinity, and the Bend and Ellenburger if present, under the Fort Worth region; there is also a feeble reflection of this depression in the overlying Comanchean formations.

The following table gives approximate data for contouring the base of the Trinity sand in Tarrant County; it indicates that the base of the Trinity here dips almost east at the rate of about 48 feet per mile.

WELL	Altitude of well	BASE OF TRINITY Depth	BASE OF TRINITY Altitude	See page
Tucker's Hill Well	650	1120	− 495	25
Polytechnic Well	650	1250?	− 600?	25,107
Mansfield Well	600	1678	−1078	115
Grapevine Well	600	1720?	−1120?	

WATER RESOURCES

The water supply of Tarrant County is derived from (a) streams, (b) artesian wells, (c) dug wells and (d) seepage springs; of these the first two named produce the greater part of the supply. The various city reservoirs on the two forks of the Trinity, especially the Lake Worth reservoir, have been widely discussed and will not be treated here. The problem of impounded water is in Tarrant County mainly an engineering problem, since a supply is assured. Much water is still derived from artesian sources, mainly by pumping. The principal artesian reservoirs under Tarrant County are the Woodbine, which is a shallow source of water underlying the strip of country east of Handley; the Paluxy reservoirs, which underly the whole County except a small area in the northwest corner; and the Trinity reservoir, which underlies the whole county. Since all these reservoirs dip to the southeast they increase in depth, and the pressure of their waters increases, going either south or east. Accordingly, as younger strata come in on top of them towards the east border of the county they will be overlain at increasing depths, as seen in the following table of approximate depths.

This table gives the approximate depths at which the various artesian water reservoirs occur in Tarrant County. The points taken to illustrate these depths to the various water reservoirs are Mansfield, Texas, the Texas and Pacific Railway Station at Arlington, Texas (elevation 616 feet), the Central Fire Station, Fort Worth, Texas (elevation 620 feet), The Polytechnic and the Tucker's Hill wells, East Fort Worth (elevation 650 feet). The figures are only approximate. The notation of Dr. R. T. Hill is used, the shallowest horizon in each formation being listed first and the deepest last. Trinity 1 is the main Trinity reservoir.

	Mansfield	Arlington	Tucker's Hill	Polytechnic	Fort Worth Central Fire Station
ELEVATION OF SURFACE, in feet:	575	616	650	650	620
DEPTH TO:					
Woodbine 2		70			
Woodbine 1		235			
Woodbine-Washita contact	150	300			
Goodland-Washita contact	500	659	124	257	122
Walnut				360	244
Paluxy 2	670	750?	300	476	378
Paluxy 1	740		425		503
Glenrose	950			893	
	1042			963	
Trinity 3	1454	1480?	895	1100	875
Trinity 2	1480		1035		1015
Trinity 1	1533		1120?	1280?	1100?
Paleozoic contact	1550	1580?	1120?	1297?	

The Woodbine contains at least two reservoirs, varying somewhat but at places in Tarrant County about 100 feet apart. These are shallow and feebly developed over the Woodbine outcrop in Tarrant County, and are available at moderate depths under the Eagle Ford prairies. There is a water bearing stratum in the base of the Fredericksburg limestone, possibly formed by the shell conglomerate 20 feet above the base, as already mentioned.

The basal hard rock and shell conglomerate of the Walnut clays encloses the topmost Paluxy water bed, as may be seen in numerous exposures in the western part of the county. The Paluxy contains clay seams interstratified with the red sand layers, and these clays act to retain the Paluxy water in the water sands.

The Glenrose limestone, which is invariably arenaceous in parts, contains one or more artesian water beds. The most important and purest artesian water in the county comes from the Trinity reservoir which consists of three main sands. These are interstratified mainly by impermeable, water-tight clays, and lie at approximately the depths indicated. (See also well logs, pp. 107 ff.)

DIP, ALTITUDES, ETC.

DIP

The dip of the formations is for mast parts of the county very nearly 2° southeast. The influence of this amount of dip in the formation of parallel outcrops has been mentioned in connection with the decreased altitude of the geological younger outcrops, which lie toward the east. (p. 9).

Thickness of beds for Dip of 2°, in directions of various angles to the dip.

This table will apply to most outcrops in Tarrant County. The angles given are azimuths read in a clockwise direction from the magnetic north, which is here taken as being 10° east of the true north.

Magnetic Azimuth	Slope for 2° Dip Ft. per 100	Slope for 2° Dip Ft. per mile	
5°	+1.75	+ 92.4	
20	.87	45.9	
35	0.00	00.0	STRIKE
50	−0.87	− 45.9	
65	−1.75	− 92.4	
80	−2.62	−138.3	
95	−2.91	−153.6	
110	−3.20	−169.0	
125	−3.49	−184.3	DIP
140	−3.20	−169.0	TO SOUTHEAST
155	−2.91	−153.6	
170	−2.62	−138.3	
185	−1.75	− 92.4	
200	−0.87	− 45.9	
215	0.00	00.0	STRIKE
230	+0.87	+ 45.9	
245	1.75	92.4	
260	2.62	138.3	
275	2.91	153.6	
290	3.20	169.0	
305	3.49	184.3	DIP
320	3.20	169.0	
335	2.91	153.6	
350	2.62	138.3	

The last two columns give the amount to be added to or subtracted from the elevation of a station to find the elevation of the same stratigraphic level at another station which is the given distance and direction away.

The following is a list of altitudes within the county, all of which are from the records established by the United States Geological Survey and by the City Engineer's Office, Fort Worth:

ALTITUDES IN TARRANT COUNTY

620.0 Bench mark, U. S. G. S., brass plug in ledge above sidewalk, northeast corner Fire Department, Throckmorton and 8th streets, Fort Worth.
619.0 BM, U. S. G. S., base of Jennings Avenue viaduct.
670.0 BM, U. S. G. S. Weather Bureau, Fort Worth.

614.0 Track, T. & P. Ry. station, Fort Worth.
602.0 Track, Santa Fe station, Fort Worth.
594.0 Top of spillway, Lake Worth dam.
692.93 Northeast curb, corner College and Capps avenues.
558.0 Santa Fe station at Stock Yards, North Fort Worth.
627.18 Spike on pole, northeast corner Forest Ave. and Edwin St.
618.19 Concrete bridge, south end Forest Park, 2-inch iron pipe in northeast corner pier.
631.72 Spike in light pole, northwest corner Forest Park.
672.62 Spike in telephone pole, northwest corner Gibson Ave. and Forest Park Blvd.
582.52 Culvert under car line near southeast corner Forest Park, top southwest corner of culvert.
616.3 H. & T. C. rail at crossing of H. & T. C. under I. & G. N. track, near Sycamore creek, 3 miles southeast of courthouse.
616.0 Arlington, T. & P. Ry. track.
845.0 Avondale, F. W. & D. Ry. track at station.
658.0 Benbrook, T. & P. Ry. station.
694.0 Bethel, M. K. & T. track.
535.0 Grapevine, St. L. S. W. track.
590.0 Handley, T. & P. track.
700.0 Haslet, Santa Fe track.
704.0 Keller, M. K. & T. track.
603.0 Kennedale, H. & T. C. track.
580.0 Mansfield, H. & T. C. track.
773.0 Primrose, Frisco track.
724.0 Saginaw, Santa Fe track.
606.0 Watauga, M. K. & T. track.

934.0	Webb.
558.0	Fort Worth, crossing of St. L. S. W. Ry.
606.0	BM at crossing of Ft. W. & D. C. Ry. and Ft. W. & D. electric line.
533.0	North Fort Worth, St. L. S. W. station.
627.0	Hodge, St. L. S. W.
606.0	Hodge, M. K. & T.
606.0	Hodge, crossing of M. K. & T. and St. L. S. W.
618.0	Arlington, BM on Citizens' National Bank.
579.0	Handley, BM on Power House of N. T. T. Co.

PRECISE LEVELS IN TARRANT COUNTY AND A FEW NEARBY POINTS[1]

Feet	Meters		
841.255	256.415	O	Avondale, Tarrant County, Texas, 6 feet south of the third telegraph pole south of and across the tracks from railroad station, and 30 feet from the tracks, in line with the telegraph poles. Bottom of a square hole cut in the top of a Texas limestone post lettered US BM.
751.311	229.000	P	1¼ miles north of Saginaw, Tarrant County, Texas, on an arched concrete abutment of the Chicago, Rock Island and Pacific Railway, four telegraph poles north of mile pole 10 of the Fort Worth and Denver City Railway, on the east side of the abutment, in the northeast corner, 9 inches from either edge. Intersection of two lines cut in end of half-inch copper bolt.
628.168	191.466	Q	About 1½ miles north of the Trinity River crossing at Fort Worth, Tarrant County, Texas, in the northwest corner of the west side of an arched concrete culvert at mile post 608 (Chicago, Rock Island and Pacific Railway track) 8

[1] Bowie and Avers; Fourth general adjustment of the precise level net in the United States and the resulting standard elevations. U. S. Coast and Geodetic Survey, Special Publication 18, 1914, pp. 108, 120, 151, 235-6.

Hayford: Precise leveling in the United States 1900-1903 with a readjustment of the level net and resulting elevations. U. S. Coast and Geodetic Survey, Appendix No. 3, Report for 1903 Washington, 1917, pp. 782-3.

Feet	Meters		
			inches from the north and 4 inches from the west edge. Intersection of two lines cut in end of half-inch copper bolt.
537.640	163.873	R	About 3 miles north of Union Station at Fort Worth, Texas, on a large stone pier (the first from the north bank of Trinity River) of the Chicago, Rock Island and Pacific Railway bridge No. 3306, on the northwest corner of the west side, 8 inches from either edge. Bottom of square hole cut in stone.
530.380	161.660	S	About 2 miles north of Union Station at Fort Worth, Texas, on the south end of the west pier supporting the Missouri, Kansas and Texas track (over the Chicago, Rock Island and Pacific Railway track) at the north end of the freight yards of the Chicago, Rock Island and Pacific Railway, on the lowest step at the southeast corner, 6 inches from either edge. Bottom of square hole cut in stone.
569.467	173.574	T	A mile north of Union Station at Fort Worth, Texas, on the northwest corner of the large block forming the lowest step to the west side of the south abutment supporting the Fort Worth and Denver City Railway track (over the Chicago, Rock Island and Pacific track), 4 inches from the adjacent edges of the stone and 3½ feet from the ground. Bottom of square hole cut in stone.
605.865	184.668	U	Fort Worth, Texas, at the west side of the south abutment where the railroad tracks pass over the Fort Worth and Dallas Electric Line tracks (2 blocks east of Union station) on the second step from the top, 6 inches from the adjacent edges of stone. Bottom of square hole cut in stone.
619.254	188.749	V	Fort Worth, Texas, at the northeast corner of the city fire department building (central station) on Throckmorton street, between Eighth and Ninth, near the center of the east face of a block of stone in

Feet	Meters		
			the fourth tier and about 4 feet from the ground, 15 inches from the corner of the building, 13 inches from a window. Cross on a half-inch copper bolt. (This is the same station as the first elevation given).
578.391	176.294	W	Handley, Tarrant County, Texas, in the center of the middle pilaster on the northeast side of the power house of the Northern Texas Traction Company, about 4 feet from the ground. Cross on half-inch copper bolt.
617.935	188.347	X	Arlington, Tarrant County, Texas, at the east side of the north face of the Citizens' National Bank Building, in the middle brick of the eastern brick column, about 4½ feet from the ground. Cross in half-inch copper bolt.
618.749	188.595	M^3	Fort Worth, Texas, on top of the stone base to one of the iron supports to the viaduct over the tracks, one-fourth mile west of Texas and Pacific Railway station. The mark is on the base under the second support east in second row north of main track, at southeast corner, 3½ inches from south and east edges. Bottom of square hole cut in stone.
654.884	199.609	N^3	A mile east of Belt Junction, Tarrant County, Texas, 15 paces from the eighth telegraph pole west of milepost 3 on Fort Worth and Rio Grande Railroad, on the southwest corner of the west abutment of a culvert. Bottom of square hole cut in stone.
770.773	234.932	O^3	Primrose, Tarrant County, Texas, five poles west of the station sign, six telegraph poles east of milepost 12, in an angle of the right-of-way fence, on the Fort Worth and Rio Grande Railroad, 16 paces north of the track. Bottom of square hole cut in top of limestone post, lettered US BM.
944.585	287.910	P^3	Virgile, Tarrant County, Texas, 10 feet north of the third pole west of the station sign, in an angle of the right-of-way

Feet	Meters		
			fence on the Fort Worth and Rio Grande Railway, 15 paces north of the track. Bottom of square hole cut in top of limestone post, lettered US BM.
1045.109	318.550	Q^{8}	In Parker County, Texas, just across the county line from Cresson. Tarrant County, Texas, 50 paces east of the station, 5 paces east of mile post 25, and 20 paces north of the track of the Fort Worth and Rio Grande Railroad. Bottom of square hole in top of limestone post, lettered US BM.
682.328.	207.974	T^{8}	One-half mile north of the siding at Bethel, Tarrant County, Texas, 50 feet west of the railroad track, in the right-of-way of the Missouri, Kansas and Texas main line, 3 feet east of telegraph pole opposite mile post 764. Bottom of square hole in top of limestone post, marked US BM.
715.064	217.952	U^{3}	Burleson, Johnson County, Texas, in the brick building used as the postoffice, in the east front, 4½ feet above the sidewalk, in a panel north of the northernmost window. Cross in top of copper bolt.
624.392	190.315	C_{10}.	At Fort Worth, Tarrant County, Texas, on the Hill Street concrete viaduct, over the Texas & Pacific and the Frisco Line Railway tracks, 1.1 miles west of the Union Passenger station, on the east face of the north side of the arch over the main-line track of the Texas & Pacific Railway, 1.45 meters above the ground and 0.36 meter from the south edge of the face of the arch.
557.262	169.854	D_{10}.	2.1 miles west of Fort Worth, Tarrant County, Texas, on the highway bridge carrying the Fort Worth and Weatherford road over the Clear Fork of the Trinity River, on the top of the south wing wall of the east concrete abutment, about 0.20 meter from the footplate of the truss. This bridge is about 35 meters north of the Texas & Pacific Railway bridge 249-A over the same stream.

Feet	Meters		
576.160	175.614	E_{10}.	About 4.5 miles west of Fort Worth, Tarrant County, Texas, and midway between the Texas & Pacific Railway track and the center of the Fort Worth and Weatherford highway, 0.5 meter inside and south of the railroad's right-of-way fence and 1.5 meters inside and east of the fence of the first by-road that crosses the track west of the siding for the Fort Worth waterworks pumping station.
623.290	189.979	F_{10}.	About 1.4 miles east of Benbrook, Tarrant County, Texas, on the middle pier of the Texas & Pacific Railway plate-girder bridge 254-C over Marys Creek, on the top of the coping of the north end of the pier, and approximately in the center of the stone.
662.669	201.982	G_{10}.	At Benbrook, Tarrant County, Texas, on land belonging to Mr. C. W. Carpenter, at the turn of the Fort Worth and Weatherford highway, just across the road and south of the Texas & Pacific Railway stock pens, about 50 meters south of the main-line track, and 0.75 meter south and 0.75 meter west of the highway fence.
787.285	239.965	H_{10}.	About 2.8 miles west of Benbrook, Tarrant County, Texas, on the Texas & Pacific Railway plate-girder bridge 258-B over Walnut Creek, on top of the north end of the east masonry abutment.
980.303	298.797	I_{10}.	At Iona, Parker County, Texas, about 130 meters west of the section house, 15 meters south of the west end of the siding, and 1 meter north of the fence between the railroad right-of-way and the county road.
888.049	270.678	J_{10}.	At Aledo, Parker County, Texas, on land belonging to Mr. J. J. Sears and in use as a public park, about midway of the south side of the park, and 1 meter north of the boundary fence.
892.032	271.892	K_{10}.	At Aledo, Parker County, Texas, on the west side of the entrance of the stone building owned by Mr. J. J. Sears, and occupied by his general merchandise store, and 2 meters above the sidewalk.

DESCRIPTION OF NEW MAGNETIC STATION

United States Coast and Geodetic Survey Magnetic Station on the grounds of Texas Christian University, Fort Worth, Texas. In the southwest part of the grounds of Texas Christian University, 4 miles southwest of the old (1888) station and about 3¾ miles southwest of the Courthouse, 800 feet west of the steps of Brite Bible College and 51.4 feet east of the west fence about the University grounds, and about 85 feet west southwest of the banks of a ditch through this part of the grounds. Marked by a limestone post 5″x7″x30″, projecting 2″.

Bronze disk dated 1918, set in top.

Declination	9°27.4′ East
Dip	62°35.3′
Longitude	97°22.0′
Latitude	32°42.4′

True bearings: Chimney near middle of (Rivercrest) Country Club: 25°18.3′ West of North. Wooden water tank, 1 mile distant: 46°58.9′ East of South.

LOG OF WELL AT POLYTECHNIC, TEXAS

Kind of Material	Color	Hardness	Feet From	Feet To	Thickness	Formations
Shaley soil	Light		0	25	25	Main street, Pawpaw, Weno, and Denton
Shale, blue	Blue		25	118	93	
Shale	Gray	Hard	118	128	10	
Shale	Blue		128	165	37	Fort Worth
Mud	Blue		165	206	41	Duck Creek, Kiamitia, and Goodland
Shale	Gray		206	210	4	
Shale	White		210	291	80	
Shale	Brown		291	297	6	
Shale	Gray		297	345	48	
Shale	Brown		345	360	15	
Water sand			360	400	40	Walnut
Shale	Light gray		400	319	19	
Water sand			419	455	34	
Shale	Gray		455	476	21	
Water sand			476	492	16	Paluxy
Shale	Light gray		492	510	18	
Lime	Gray		510	518	8	
Shale	Gray	Soft	518	526	8	
Lime	Gray		526	553	27	
Lime shell		Hard	553	563	10	Glenrose
Shale	Gray		563	585	22	
Shale	Blue		585	615	30	
Lime	Gray		615	644	29	
Shale	Blue		644	650	6	
Lime	White		650	705	55	
Shale	Blue		705	709	[illegible]	

Kind of Material	Color	Hardness	Feet From	Feet To	Thickness	Formations
Lime	Gray		709	715	6	
Shale	Blue		715	717	2	
Lime	Gray		717	756	39	
Shale	Gray		756	790	34	
Lime	Blue		790	796	6	
Lime and shale	Gray		796	822	26	
Sandy shale			822	824	2	
Lime	White		824	830	6	
Shale	Dark blue	Soft	830	843	13	
Shale and shells	Gray		843	857	14	
Water sand			857	885	28	
Shale	Blue		885	893	8	
Water sand			893	913		
Shale	Gray		913	935	22	
Water sand			935	950	15	
Shale	Blue		950	956	6	
Shale	White	Sandy	956	963	7	
Water sand			963	995	32	
Shale	Red		995	1000	5	
Sand rock			1000	1005	5	
Shale	Red		995	1000	5	
Sand rock			1000	1005	5	
Conglomerate of green, dark blue, white and red putty, light shale			1015	1025	10	
Red shale and white rock			1015	1025	10	
Sand stone			1025	1030	5	Trinity
Shale	Red		1030	1047	17	
Sand rock			1047	1057	10	
Shale	Dark blue		1057	1070	13	
Shale	Dark blue		1070	1074	4	
Shale	Red		1074	1100	26	
Water sand			1100	1125	25	
Shale	Green and dark blue		1125	1132	7	
Putty	White and and red		1132	1150	18	
White rock and sandstone			1150	1180	30	
Sand with particles of coal			1180	1190	10	
Shale and sand	Dark brown		1190	1200	10	
MISSING			1200	1297	97	
Shale	Blue		1297	1416	119	Pennsylvanian
Limestone	White		1416	1430	14	
Shale	Blue		1430	1468	38	
Lime		Hard	1468	1475	7	
Shale	Blue		1475	1490	15	
Lime		Hard	1490	1505	15	
Shale	Blue		1505	1530	25	
Sand		Hard	1530	1550	20	
Shale	Blue		1550	1565	15	
Lime		Hard	1565	1570	5	
Shale	White		1570	1590	20	
Lime		Hard	1590	1630	40	
Shale	Blue		1630	1638	8	
Lime		Hard	1638	1646	8	
Shale	Blue		1646	1670	24	
Lime		Hard	1670	1700	30	
Shale	Brown		1700	1715	15	
Sand broken with shale			1715	1740	25	
Lime and shale			1740	1775	35	
Slate	Blue		1775	1800	25	
Lime	White		1800	1825	25	
Shale	Blue		1825	1840	15	
Limestone			1840	1845	5	
Shale	Blue		1845	1860	15	

Kind of Material	Color	Hardness	From (Feet)	To (Feet)	Thickness	Formations
Lime		Hard	1860	1880	20	
Shale	Blue		1880	1890	10	
Sand			1890	1915	25	
Shale	Blue		1915	1925	10	
Sand			1925	1935	10	
Shale	Blue		1935	1990	55	
Lime		Hard	1990	2005	15	
Shale	Blue		2005	2020	15	
Slate	Black	Soft	2020	2040	20	
Lime			2040	2048	8	
Shale	Blue		2048	2070	22	
Lime		Hard	2070	2080	10	
Shale	Blue		2080	2120	40	
Limestone			2120	2135	15	
Shale	Blue		2135	2170	35	
Lime		Hard	2170	2180	10	
Shale	Brown		2180	2235	55	
Chalk rock			2235	2255	20	
Shale	Blue		2255	2270	15	
Sand			2270	2280	10	
Shale	Blue		2280	2320	40	
Lime	Gray		2320	2340	20	
Sand	Brown		2340	2360	20	
Shale	Blue		2360	2375	15	
Lime	Gray		2375	2395	20	
Sand rock	Gray		2395	2415	20	
Shale	Black		2415	2500	85	
Shell rock			2500	2550	50	
Salt water and sand with gas and shale	Blue		2550	2615	65	
Lime rock shale	Blue		2695	2725	30	
Shale rock and salt water shale	Gray		2725	2780	55	
Lime and shale	Black		2825	2900	75	
Shale and lime rock, black sand, sand contained oil; at 3000 ft. a flow of salt water	Black and brown		2900	3000	100	
MISSING			3900	3962		
Shale	Dark blue		3962	4071	109	
Shells of slate and lime, with 9 ft. shale between	Gray	Hard	4071	4083	12	
Shale with frequent shells of lime formation	Dark gray		4083	4141	58	
Lime, sharp	Dark gray	Hard	4141	4151	10	
Slate	Black		4151	4154	3	
Lime shell	Black		4154	4159	5	
Sandy lime	Black	Sharp	4159	4214	55	
Lime	Black	Very hard	4214	4217	3	
Shale	Light gray		4217	4295	78	
Lime shell	Black	Hard	4295	4298	3	
Shale with shells of lime	Dark gray		4298	4333	35	
Lime	Black	Medium	4333	4339	6	
Lime	Black	Very hard	4339	4342	3	
Sand (no water)	Gray	Hard, sharp	4342	4352	10	
Sand	Gray	Coarse	4352	4355	3	
Shale	Dark		4355	4363	8	
Shale	Black		4363	4371	8	
Shale with shells of lime	Black		4371	4409	35	
Shale, with frequent hard shells of lime	Black		4409	4470	61	

DESCRIPTION OF SAMPLES FROM THE POLYTECHNIC WELL BETWEEN THE DEPTHS OF 2,495 FEET AND 4,380 FEET, BY DR. J. A. UDDEN:

Dark, almost black shale of fine texture, and considerable hardness. Very little silt present. On heating in tube, faint fumes of sulphur and exceptionally strong fumes of ammonia were noted. Shale no doubt Pennsylvanian . . . . 2495 ft.

Dark shale with some fragments of exceedingly fine sandstone, both showing very minute scales of mica. Pennsylvanian in aspect. No fossils noted . . . . 2500 ft.

Dark, almost black, shale which shows a few scattered minute fragments of black carbonaceous material. No fossils noted. Heated in closed tube it gives off very strong fumes of ammonia, and in-distinct fumes of bitumen and sulphur. Aspect Pennsylvanian . . . . 2520 ft.

Dark gray shale, with a trace of very fine-grained sand and some very small mica scales. On heating in closed tube, it gives strong fumes of ammonia, and darkens. No fossils noted. Pennsylvanian in aspect . . . . 2540 ft.

Dark gray indurated shale, with a few fragments of red shale and some white calcareous small fragments. Gives strong fumes of ammonia when heated. The calcareous fragments may have fallen in from above. Pennsylvanian . . . . 2560 ft.

Very dark bluish gray shale of hackly fracture. On heating it gives weak fumes of sulphur and very strong fumes of ammonia. Some fragments of white limestone noted, evidently from above. No fossils noted of any kind. Pennsylvanian . . . . 2570 ft.

Dark gray stony shale, non-calcareous, very slightly micaceous, and gives weak fumes of sulphur and strong fumes of ammonia. No fossils noted. Pennsylvanian . 2575 ft.

Very dark gray shale, somewhat indurated, slightly micaceous with streaks of silt, which are more micaceous than the finer and darker shale. Strong fumes of ammonia noted on heating. No fossils found. Non-calcareous. Pennsylvanian . . . . 2588 ft.

Mostly dark gray sandy silt with some sandstone. The sandstone is cemented by calcareous material. Some mica present in shiny particles. Ammonia noted on heating in closed tube. No foraminifera present . . . . 2600 ft.

Bluish dark gray sandy shale. Strong ammonia smell given off from sample when heated in closed tube. Sand grains plentiful. No foraminifera noted . . . . 2640 ft

A hard, dark blue shale with lumps of brownish-pink clay. Ammonia noted when heated in closed tube. No foraminifera noted. Some sand grains present. Typical Pennsylvanian ....2685 ft.

Gray, non-calcareous shale, of fine texture, bluish when wet. When heated in closed tube, the sample gives off strong ammonia fumes and bitiminous fumes. Fragments decrepitate in flame. One piece of brownish, hard, non-calcareous clay noted................2706 ft.

Gray, non-calcareous shale of fine texture. Heated in tube, the samples gives off strong fumes of ammonia and some bituminous fumes. There are some angular grains. Fragments decrepitate in flame..........2730 ft.

Bluish gray, non-calcareous shale of fine texture. When heated in closed tube, the sample throws off decided fumes of ammonia, but bituminous fumes are absent. Decrepitation marked ....2760-2770 ft.

Bluish gray non-calcareous shale of fine texture, with a few pieces of brownish, hard, non-calcareous clay. Heated in tube the sample gives strong ammonia fumes 2760-2770 ft.

Gray shale, non-calcareous. The sample contains considerable sand. No pyrite or mica noticed. Heated in closed tube it gives strong fumes of ammonia, but no bituminous fumes. Fragments decrepitate in flame....

Very dark and hard shale of uniform texture with a few fragments of clay-iron-stone. In closed tube it gives off strong fumes of ammonia and faint fumes of sulphur. No fossils noted ....2830 ft.

Very hard dark shale with some fragments of concretionary non-calcareous indurated material. Heated in closed tube gives off strong fumes of ammonia and sulphur fumes. No fossils noted ....2835 ft.

Dark blue hard shale. Heated in closed tube sample gives off fumes of sulphur and ammonia...............2890 ft.

Dark, almost black, hard shale and light gray sandstone of fine texture cemented by calcareous material. Pyrite noted. Bituminous fumes and strong fumes of ammonia given off in closed tube. Crinoid stems and a crinoid spine noted ....2895 ft.

Light gray sandstone of fine texture and dark shale. Bituminous fumes and fumes of ammonia given when heated in tube. No fossils noted.................2905 ft.

Dark shale and light gray sandstone. The sandstone is fine grained, and with interstices partly open and partly filled with calcareous material. Faint fumes of bitumen and ammonia. No fossils ....2915 ft.

Dark shale and sandstone. Heated in open tube gives bituminous fumes and slight ammonia fumes. The sandstone is very slightly infiltrated with lime. No fossils noted ....2920 ft.

Dark hard shale. Heated in tube the sample gives very Strong fumes of ammonia. No fossils............2980 ft.

Light gray sand and some fragments of blue shale, and calcareous material. The sand has a dirty yellow color. Heated in a closed tube, the sample gives off bituminous fumes and fumes of ammonia. No fossils noted. Near ....3000 ft.

Sample consists of about 3-4 dark shale and 1-4 light gray sandstone. Description:

1. Dark, non-calcareous indurated shale. Faint bituminous fumes and strong fumes of ammonia given off in closed tube. Some small cylindric bodies about 1-8 mm. in diameter. 2. Very light gray, non-calcareous sandstone of fine texture. The grains are angular and range from 1-4 to 1-16 mm. in diameter. Strong bituminous fumes and deposits of oil are shown in closed tube, with slight fumes of ammonia. No fossils present ....3000 ft.

Dirty, yellowish gray sand, mostly from 1-4 to 1-8 mm. in diameter. On heating it turns dark and gives weak fumes of sulphur and bitumen. Some fragments of black and some of greenish gray shale are present. A few mica scales were noted.....................3005 ft.

Gray sandstone and dark shale. The sand grains are mostly about 2 mm. in diameter ....3006 ft.

Dark hard shale with some fine-grained sandstone. Heated in closed tube, it gives bituminous odor and strong ammonia fumes. No fossils noted. Some exceedingly fine mica present.............................3010 ft.

Gray sandstone and some dark shale. Heated in closed tube, gives bituminous odor, sulphur coat, and fumes of ammonia. The sandstone is slightly calcareous, the sand grains are mostly 1-4 mm. in diameter......3012 ft.

Dark, almost black shale, and fine-grained sandstone......3019 ft

Gray sandstone and some dark shale. Heated in clased tube, gives bituminous odor and ammonia fumes. The sandstone if fine grained, the grains being about ⅛ mm. in diameter, and they lie in a matrix of black, probably bituminous, material. All sand grains are sharply angular. The sandstone is slightly micaceous ....3026 ft.

Hard bluish-gray shale with some fine-grained gray sandstone. Heated in closed tube gives bituminous and sulphur odors and strong ammonia fumes. In thin section the sand grains are seen to be all sharply angular ....3030 ft.

Gray sandstone and some black shale. Heated in closed tube, gives bituminous odor and ammonia fumes. The sand grains mostly measure from one-fourth to one-sixteenth mm. in diameter........................3080 ft.

Gray sandstone and some black shale. Heated in closed tube gives sulphur odor and ammonia fumes. Grains in sandstone below one-fourth mm. in diameter........3095 ft.

Bluish black shale. Heated in closed tube, it gives bituminous odor and ammonia fumes. Shale contains a few very small mica scales ....3200 ft.

Bluish black shale. Heated in closed tube, gives very strong ammonia fumes ....3235 ft.

Hard bluish gray shale and gray sandstone. Heated in closed tube, gives bituminous odor and strong ammonia fumes. The sandstone is fine grained, hard, slightly calcareous, and somewhat micaceous; quartz grains angular ....3370 ft.

Bluish-gray shale and gray sandstone. The sandstone is very fine-grained, grains measure ⅛ mm. or less, with a calcareous matrix.......................3380 ft.

Very dark shale with some fine-grained grayish sandstone. Heated in closed tube, gives bituminous odor and ammonia fumes ....3385 ft.

Hard gray sandstone and hard dark shale................3565 ft.

Hard, dark blue shale and some gray shale. Heated in closed tube, gives bituminous odor and strong ammonia fumes. The sand grains are all angular, nearly all below ⅛ mm. in diameter ....3575 ft.

Hard, grayish-blue shale and a few fragments of fine-grained gray sandstone ....3610 ft.

Hard, grayish-blue shale. Heated in closed tube, gives bituminous odor and ammonia fumes................3615 ft.

Hard, bluish-black shale and a little gray sandstone. Heated in closed tube, gives bituminous odor and strong ammonia fumes. In thin section the shale is seen to have scattered grains of quartz, all angular........3775 ft.

Bluish black shale. A few buff colored fragments of limestone present. Fumes of ammonia and sulphur noted on heating. In thin sections this limestone is seen to be of compact texture in one fragment. Two other sections show many imbedded organic fragments, mostly of small size. Some of these were tubular, some others resembled fragments of ostracod shells..3800 ft.

Black shale. Heated in closed tube gives very strong ammonia fumes and slight sulphur odor. Ammodiscus noted ....4060-4131 ft.

Hard black shale and hard gray sandstone. Heated in closed tube gives very strong ammonia fumes. Some rounded quartz grains with a diameter of one half mm. noted ....4131-4141 ft.

Hard black shale and some hard dark gray to black fine grained sandstone. Some rounded quartz grains about one half mm. in diameter noted. Heated in closed tube give strong bituminous odor and strong ammonia fumes ....4141-4147 ft.

Hard grayish black shale. Some rounded quartz grains present. The largest of these measure ½ mm. in diameter. Most of the quartz sand is about one eight mm. and less in diameter. Heated inclosed tube gives faint bituminous odor and faint ammonia fumes and strong odor of sulphur............4160-3214 ft.

Hard black shale. Some quartz, sand grains about ½ mm. in diameter noted. Heated in closed tube gives strong ammonia fumes and bituminous odor........4295-4298 ft.

Hard grayish black sandy shale. Heated in closed tube gives strong bituminous odor and strong ammonia fumes ....4333-4339 ft.

Grayish white sandstone and some black shale. The sandstone consists of rounded and angular quartz grains. They are mostly about one-eighth mm. and less in diameter. A few are one quarter mm. in diameter ....4342-4352 ft.

Hard grayish black shale and gray sandstone ....4371-4380 ft.

Black hard shale. Some slightly calcareous small fragments are present in fine washed material. No pyrite nor fossils were seen. In closed tube, fumes of ammonia and sulphur were noted. Exast depth not known.
One sample said to be........................4000+ ft.
Another larger similar sample said to be..........4600 ft.

LOG OF WELL NEAR MANSFIELD, TEXAS

Kind of Material	Feet From	To	Thickness	Formation
Yellow Clay	0	45	45	
Sand	45	60	15	Woodbine
Water (50-60)				
Black shale	60	85	25	
Sand	85	95	10	
Water				
Dark shale	95	115	20	
Sand	115	125	10	
Dark shale	125	140	15	
Sand	140	145	5	
Light shale	145	158	13	
Brown sand	158	164	6	
Light showing oil at 160				
Dark shale	164	175	11	
Water sand	175	190	15	
Light shale	190	225	35	Grayson
Broken lime	225	255	30	
Hard lime	255	270	15	Mainstreet
Black slate	270	292	22	
Lime stone	292	320	28	
Dark shale	320	340	20	Pawpaw
Broken lime	340	350	10	Weno
Light shale	350	375	25	
Lime stone	375	400	25	
White slate	400	410	10	Denton, Fort Worth,
Soft lime	410	470	60	Duck Creek
Brown shale	470	500	30	Kiamitia
White lime	500	575	75	Fredricksburg
Black Slate	575	580	5	
Lime	580	600	20	
Black slate	600	612	12	
Broken lime	612	632	20	
Black slate	632	640	8	
Hard lime	640	648	8	
Brown shale	648	670	22	
Sand	670	674	4	
Water, 4 bailers per hour				
White shale	674	688	14	

Kind of Material	Feet From	To	Thickness	Formation
Red shale	688	694	6	
White shale	694	740	46	Paluxy
Sand	740	806	66	
Water				
Light shale	806	814	8	
Hard lime	814	854	40	
White slate	854	862	8	Glenrose
Limestone	862	905	43	
Dark shale	905	912	7	
Limestone	912	950	38	
Sand	950	960	10	
Water				
Light shale	960	975	15	
Broken lime	975	1030	55	
Hard lime	1030	1040	10	
Sand	1040	1052	12	
Artesian water	1042			
Hard lime	1052	1095	43	
Dark slate	1095	1100	5	
Broken lime	1100	1156	56	
Water				
Hard line	1156	1165	9	
Light shale	1165	1215	50	
Hole full of water at 1218				
Lime and sand	1215	1226	11	
Blue shale	1226	1258	32	
Water sand	1258	1270	12	
Shale	1270	1275	5	
Water sand	1275	1288	13	
White shale	1288	1295	7	
Water sand	1295	1305	10	
Slate and shell	1305	1340	35	
Red shale	1340	1359	19	
Water sand	1359	1400	41	
Brown shale	1400	1422	22	
Red rock	1422	1454	32	Trinity sand
Water sand	1454	1649	15	
Red rock	1469	1480	11	
Water sand	1480	1505	25	
Showing oil at 1482				
Red rock	1505	1517	12	
Sand	1517	1530	13	
Water at 1522				

	Feet			
Kind of Material	From	To	Thickness	Formation
White shale	1530	1532	2	
White sand	1532	1550	18	
Strong water at 1533				
Red shale	1550	1620	70	Pennsylvanian
Hard sand	1620	1632	12	
Red shale	1632	1648	16	
Dark shale	1648	1665	17	
Red shale	1665	1670	5	
Sand	1670	1678	8	
White slate	1678	1690	12	
Dark slate	1690	1722	32	
Limy sand, hard	1722	1736	14	
Dark slate	1736	1795	59	
Hard lime	1795	1809	14	
Dark shale	1809	1840	31	
Hard lime	1840	1846	6	
White slate	1846	1875	29	
Hard sand	1875	1890	15	
Red shale	1890	1892	2	
Hard sand	1892	1909	17	
Sandy very close, but nice showing of oil from 1895 to 1900				
Dark shale	1909	1920	11	
Lime shell	1920	1926	6	
Light shale	1926	2015	89	
Dark shale	2015	2072	57	
Sand shell	2072	2075	3	
Dark shale	2075	2150	75	
Lime shell	2150	2155	5	
Dark shale	2155	2175	20	
Limey sand	2175	2190	15	
Slate, dark	2190	2205	15	

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EXPLANATION OF MAP SHOWING GEOLOGICAL HORIZONS AND LOCALITIES IN THE FOREST PARK-TEXAS CHRISTIAN UNIVERSITY AREA.

In the accompanying large scale map of this area, four square miles in extent, there are shown a few typical and easily recogized horizons and a few unusually good collecting localities. This region is reached by a short street car ride from Fort Worth (Forest Park car), and is an excellent one in which to make studies of many of the formations discussed in this paper. All the Comanchean formations from the Goodland to the Mainstreet are exposed in this area. The Goodland limestone (Fredericksburg) is exposed in the northwest corner of this area, but for only a few vertical feet at the top of the formation. The Lake Worth and Benbrook sections are much better for this formation. This small area is especially rich in fossiliferous exposures of the Duck Creek and Fort Worth formations. For complete succession lists of the fossils of the various formations, see the text for the formations in question.

ABBREVIATIONS USED ON THE MAP

*	Good fossil locality.
..T..	Turrilites brazoensis: Mainstreet limestone, middle.[1]
P	Pyrite fossils, Arca, Turrilites: Pawpaw clay, base.
N	Nodosaria texana: Weno limestone, middle.
E	Exogyra americana: Fort Worth limestone, middle.
S	Schloenbachia small sp.: Fort Worth limestone, base.
Hol	Holaster simplex: Duck Creek marl, top.
..K..	Main Kingena zone: Duck Creek marl, top.[1]
..H..	Hamites zone: Duck Creek limestone, base. Just above and parallel to this zone is the striking Desmoceras horizon of the Duck Creek limestone.[1]
D	Desmoceras horizon: Duck Creek limestone, base.
G	Gryphea navia: Kiamitia marl, thruout.

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[1]The three continuous dotted lines on the opposite map lettered H, K and T, indicate the outcrop of the Hamites zone, the Main Kingena zone and the Turrilites brazoensis zone respectively, as mentioned in the above list of abbreviations. The other letters refer to good localities for the corresponding fossils, as listed above.

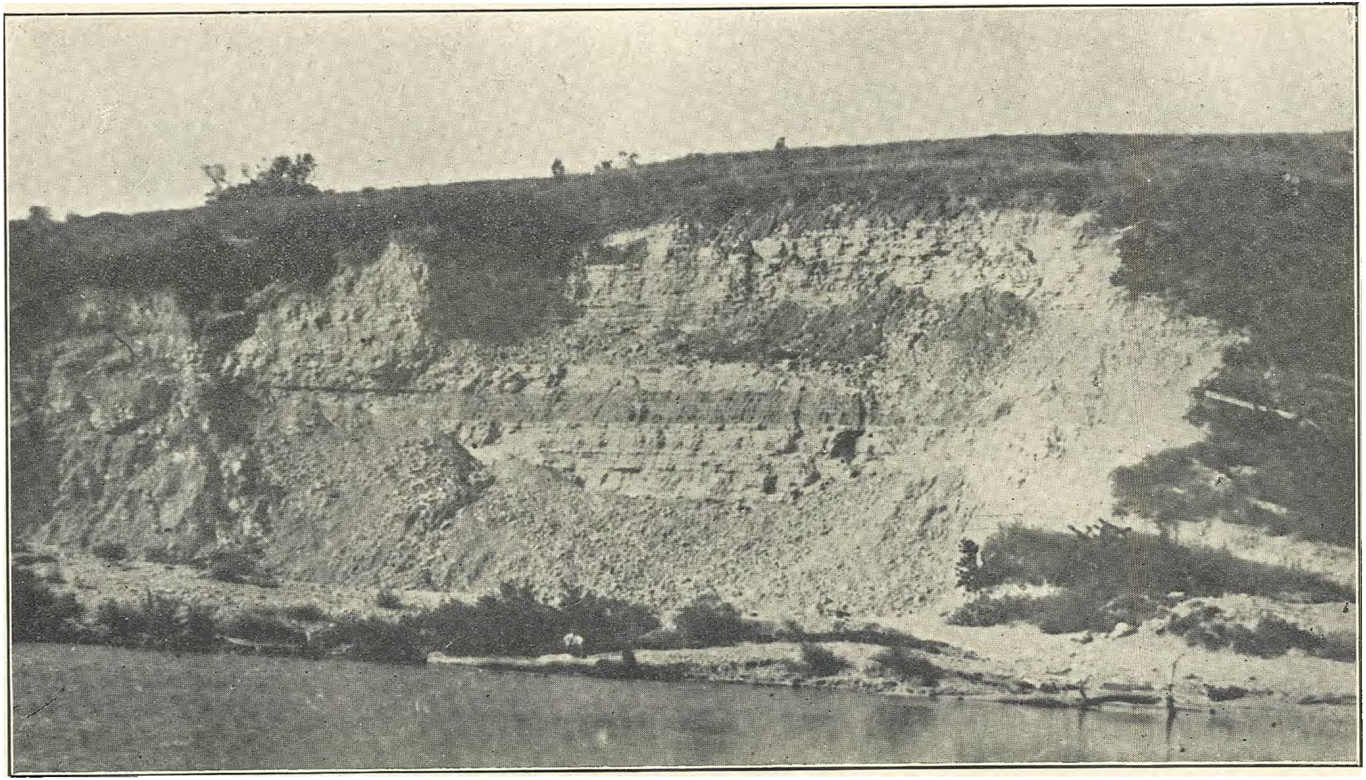


Plate 1. Goodland limestone (top of Fredericksburg division) at the Lake Worth Dam, 8 miles northwest of Fort Worth.

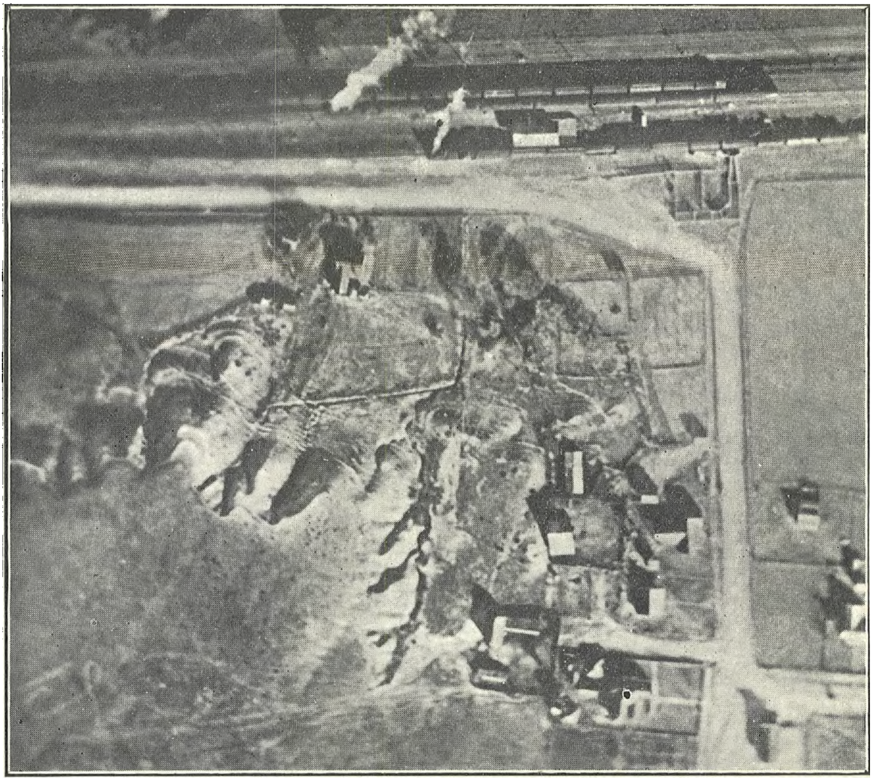


Plate 2. Fig. 1. Airplane view of top of Goodland limestone, Benbrook, Texas. (Locality described by Taff.)

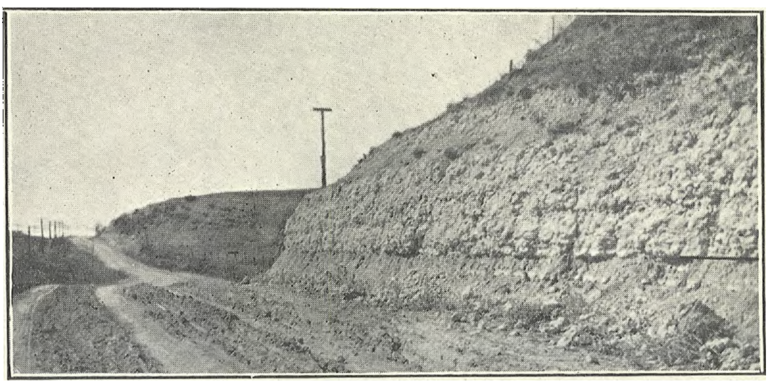


Plate 2. Fig 2. Goodland limestone, Stove Founday Road, 4 miles west of Fort Worth. The base of the telephone pole is the Upper Salenia horizon.

Plate 3. Fig. 1. Top of Goodland (Fredericksburg) limestone, looking east from near Benbrook.

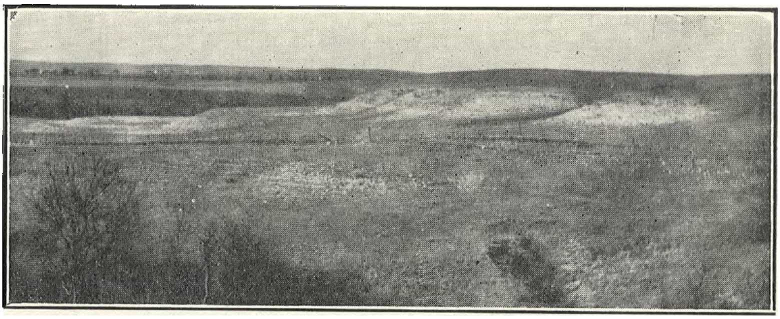


Plate 3. Fig. 2. Terrace in the Fredericksburg division. The top terrace is the top of the Goodland.

Plate 3. Fig. 3. Terraces in the basal Washita Division. The bottom terrace is the top of the Goodland limestone, and the top two are the Duck Creek limestone and marl.

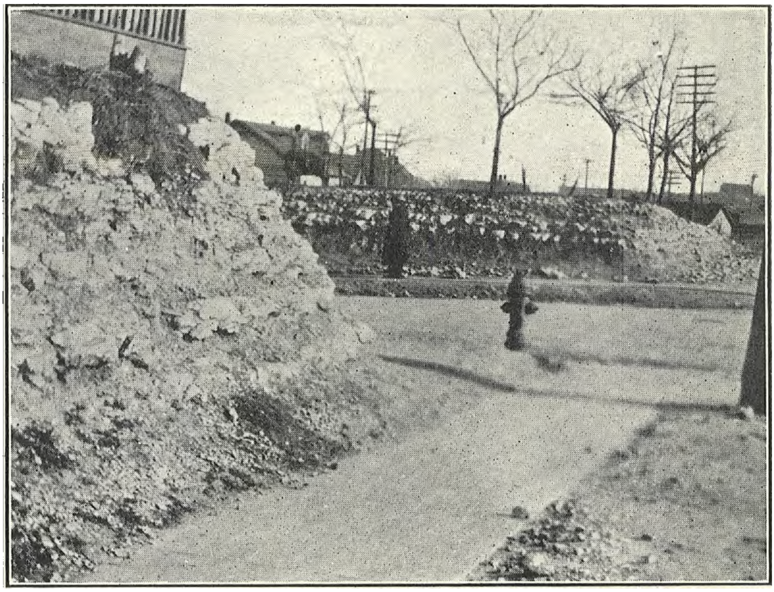


Plate 4. Fig. 1. Base of Fort Worth limestone, which underlies the business section of the City of Fort Worth. On Main Street, the base of the limestone is about 30 feet underground. The limestone is underlain by the less resistant Duck Creek marl.

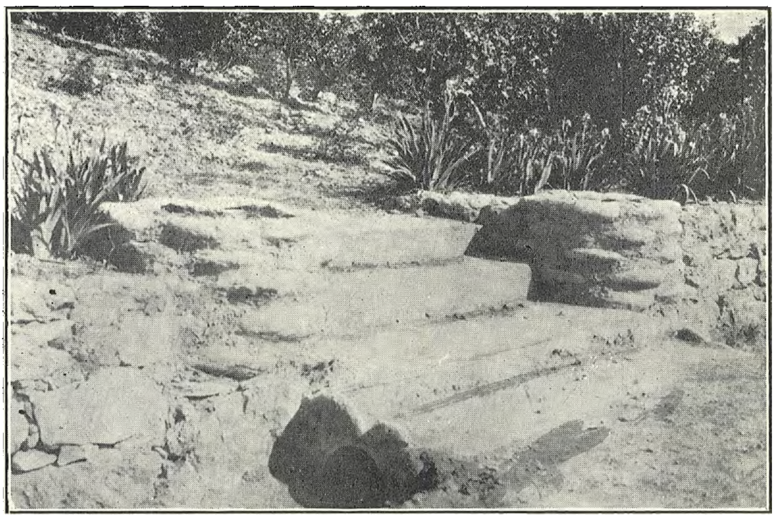


Plate 4. Fig. 2. Gate posts and flower beds in Forest Park, built of the large ammonite, Desmoceras brazoense.

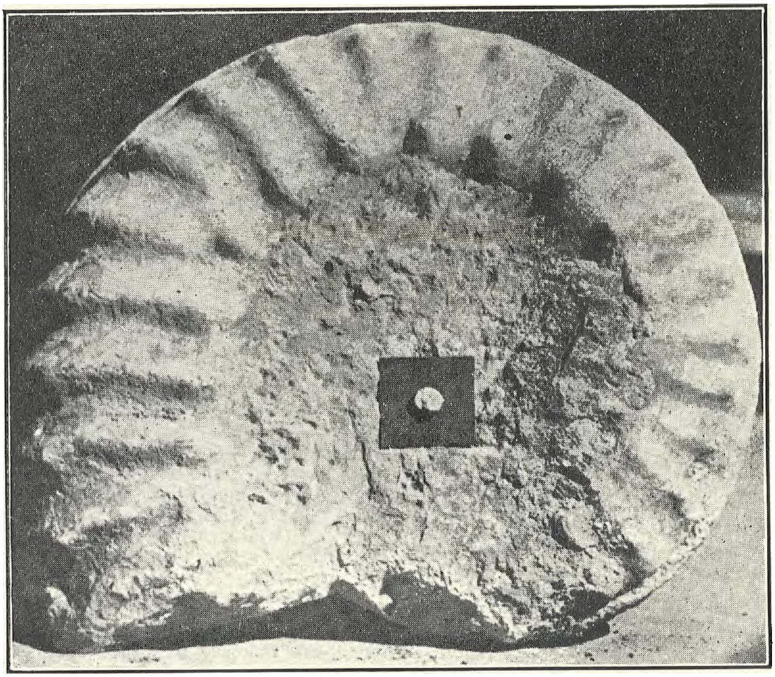


Plate 5. Fig. 1. The large ammonite, Schloenbachia sp. J., which characterizes the Fort Worth limestone.

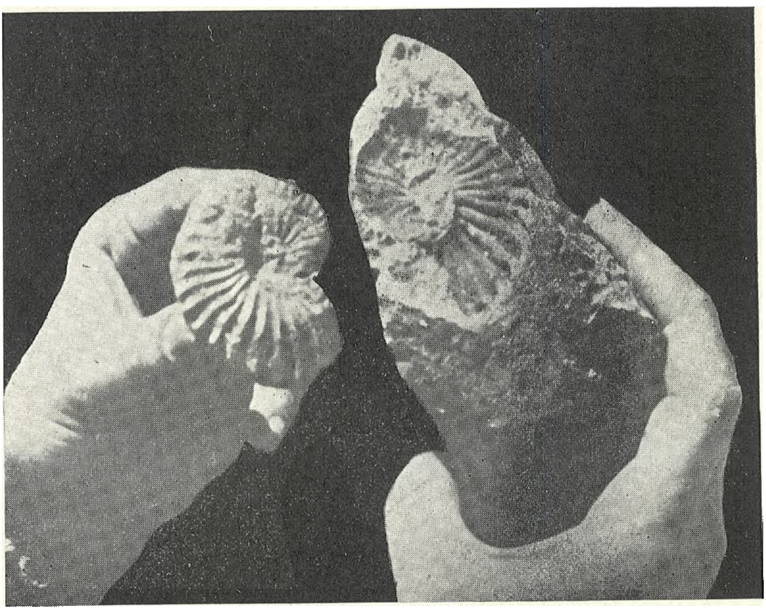


Plate 5. Fig. 2. Illustration of the terms "cast" (left) and "mold" (right).

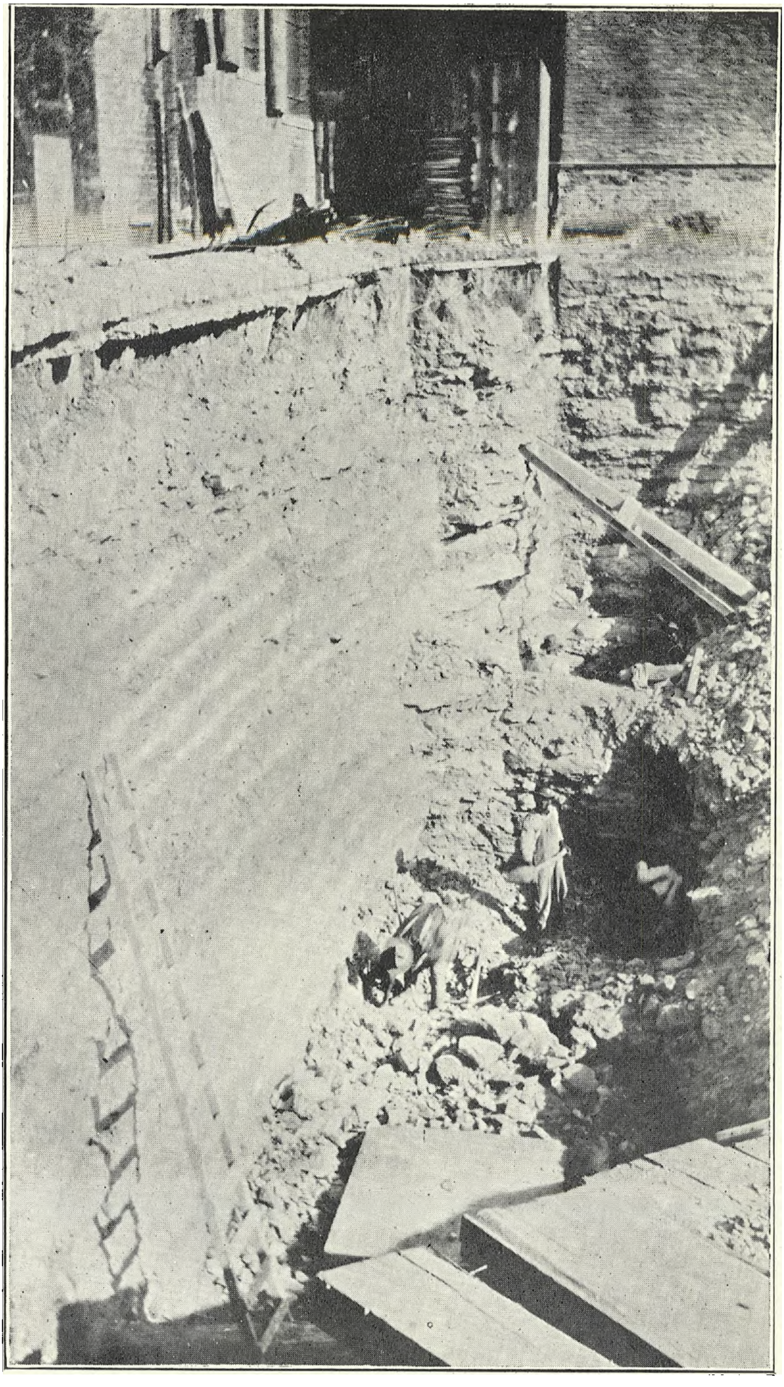
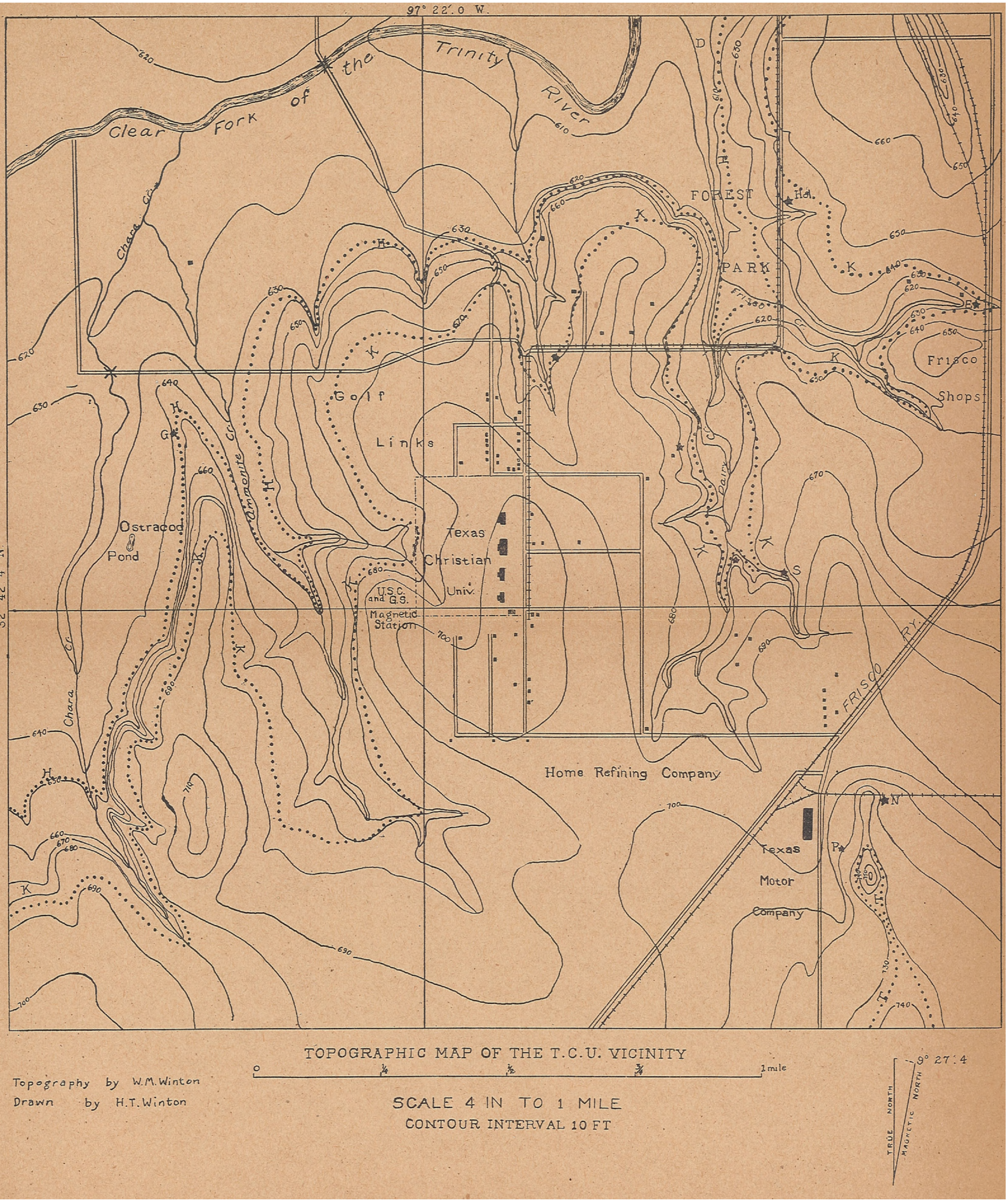


Plate 6. Fort Worth limestone, in excavation at northwest corner of 8th and Houston sts., Fort Worth. Excavations for buildings in the main business district pass into or entirely through the Fort Worth limestone.

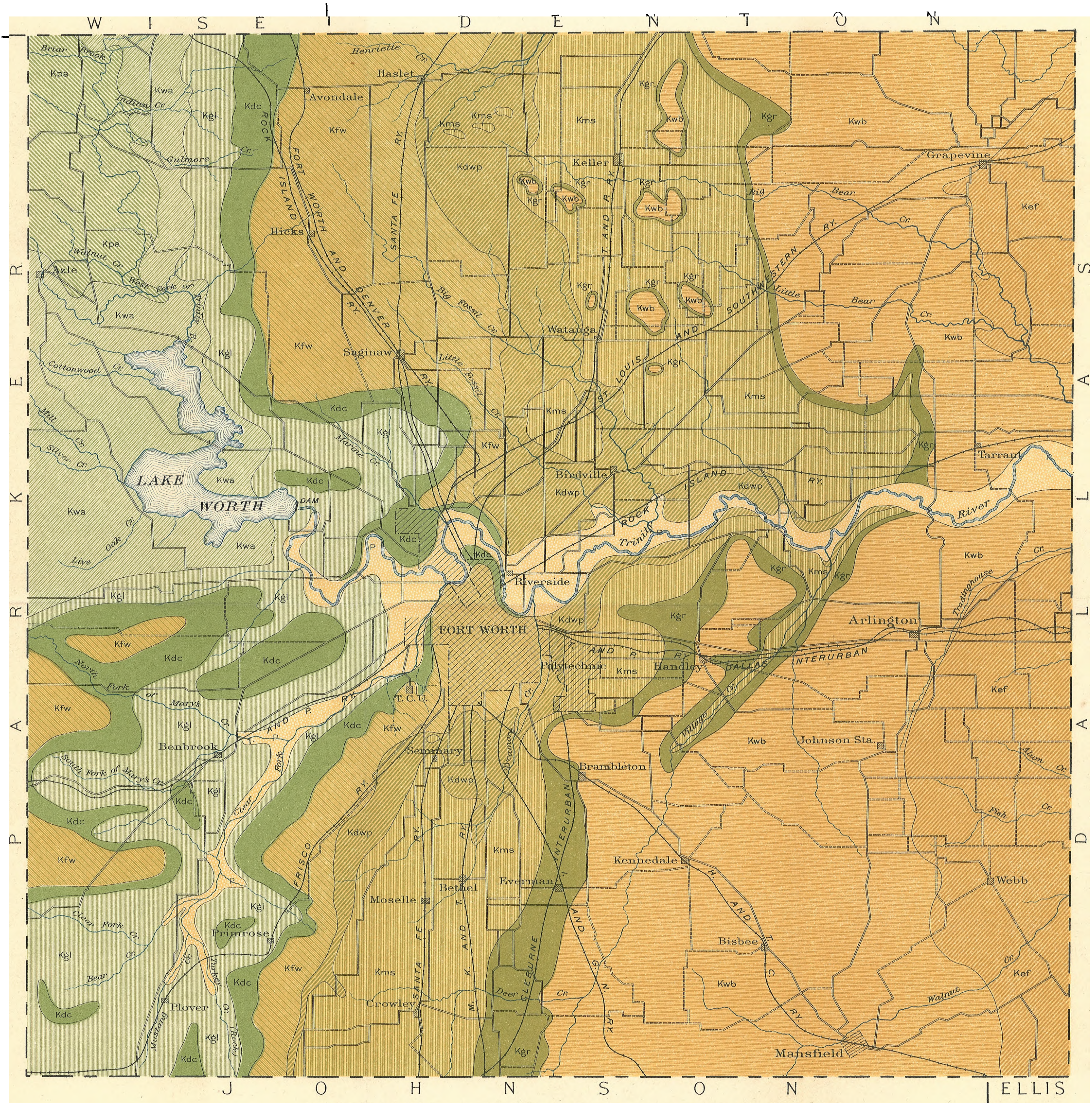


TOPOGRAPHIC MAP OF THE T.C.U. VICINITY

0 ¼ ½ ¾ 1 mile

Topography by W. M. Winton
Drawn by H. T. Winton

SCALE 4 IN TO 1 MILE
CONTOUR INTERVAL 10 FT



GEOLOGICAL MAP OF TARRANT COUNTY, TEXAS

GEOLOGY BY W. M. WINTON AND W. S. ADKINS

DRAWN BY H. T. WINTON

Scale

0 1 2 3 4 5 6 Miles

LEGEND

P	Pleistocene
Kef	Eagleford
Kwb	Woodbine
Kgr	Grayson
Kms	Main Street
Kdwp	Denton-Weno-Pawpaw
Kfw	Fort Worth
Kdc	Duck Creek
Kgl	Goodland-Comanche Peak-Edwards
Kpa	Paluxy
Kwa	Walnut