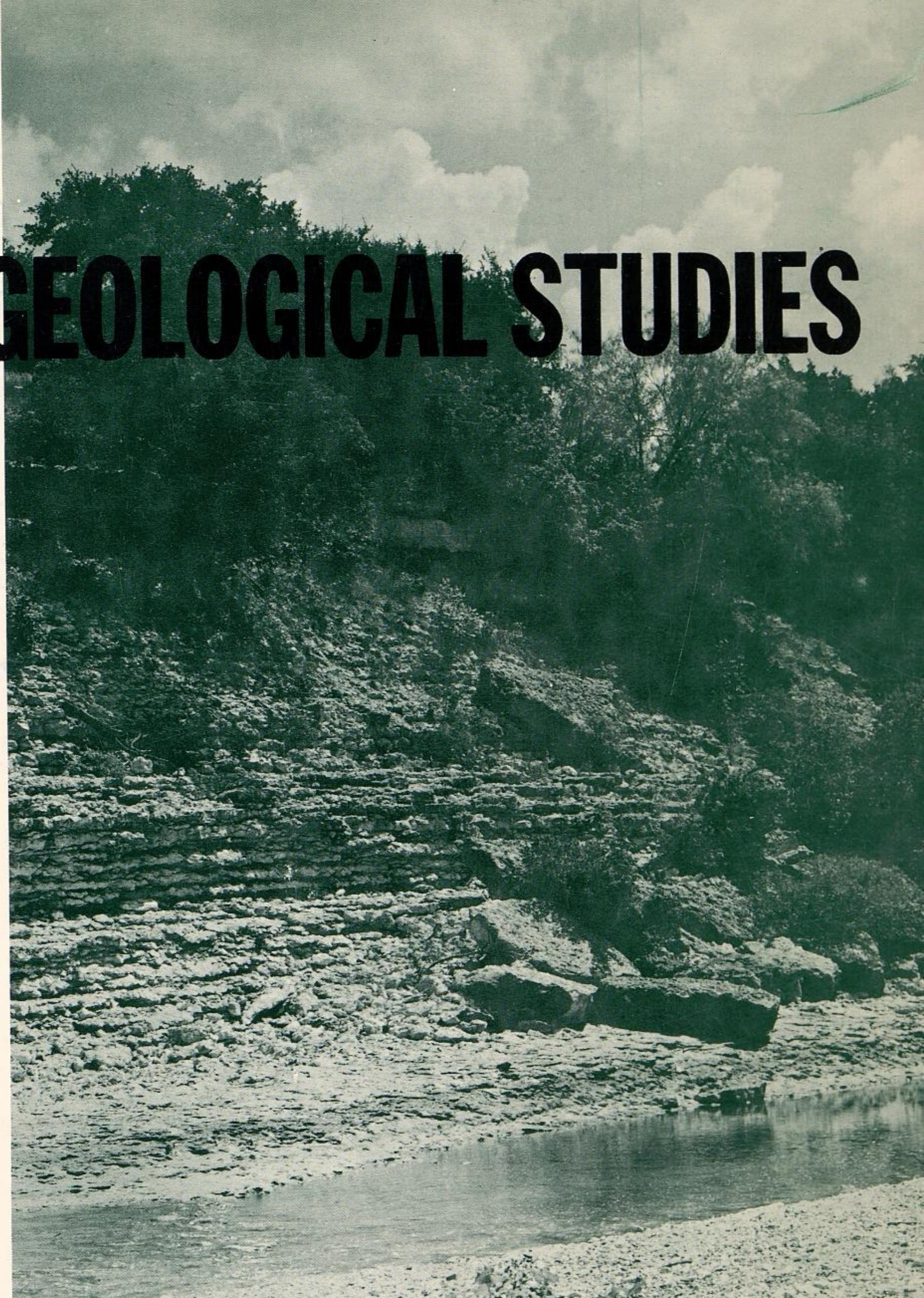
BAYLOR GEOLOGICAL STUDIES



FALL 1971

Bulletin No. 21

BAYLOR UNIVERSITY – WACO, TEXAS
FOUNDED PRO ECCLESIA PRO TEXANA 1845

Stratigraphy of the Washita Group in Central Texas

THOMAS E. BROWN

"Creative thinking is more important than elaborate equipment--"

FRANK CARNEY, PH.D.
PROFESSOR OF GEOLOGY
BAYLOR UNIVERSITY
1929-1934

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The training of a geologist in a university covers but a few years; his education continues throughout his active life. The purposes of training geologists at Baylor University are to provide a sound basis of understanding and to foster a truly geological point of view, both of which are essential for continued professional growth. The staff considers geology to be unique among sciences since it is primarily a field science. All geologic research including that done in laboratories must be firmly supported by field observations. The student is encouraged to develop an inquiring objective attitude and to examine critically all geological concepts and principles. The development of a mature and professional attitude toward geology and geological research is a principal concern of the department.

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THOMAS E. BROWN

BAYLOR UNIVERSITY
Department of Geology
Waco, Texas
Fall, 1971

Baylor Geological Studies

The Baylor Geological Studies Bulletin is published semi-annually, Spring and Fall, by the Department of Geology at Baylor University. The Bulletin is specifically dedicated to the dissemination of geologic knowledge for the benefit of the people of Texas. The publication is designed to present the results of both pure and applied research which will ultimately be important in the economic and cultural growth of the State.

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Cover illustration by O. T. Hayward,
Department of Geology, Baylor University.

Stratigraphy of the Washita Group in Central Texas

THOMAS E. BROWN

ABSTRACT

The Washita Group in central Texas is the uppermost group of the Comanche Series, and consists of three formations, in descending order: the Buda Formation, the Del Rio Formation, and the Georgetown Formation. Each formation has a lithology distinctly different from the others. In addition, there is a lateral change in lithology in the Georgetown Formation.

In central Texas the Buda Formation is a hard, dense, fossiliferous limestone found only in scattered outcrops in the southern half of the study area. On the outcrop the Buda Formation has the most consistent lithology and paleontology of any formation of the Washita Group within the area of study. In the subsurface the Buda Formation uniformly thickens southeastward, reaching a thickness of 70 feet in Falls County.

The Del Rio Formation in central Texas is almost entirely dark gray, blocky clay interlaminated with a few thin beds of ocherous hematite, limestone, and thin-bedded, calcareous siltstones. These slight variations in lithology are localized in nature, and individual beds cannot be correlated over distances of a few hundred yards.

The most prominent characteristic of the Del Rio Formation in central Texas is its nearly uniform thickness, both on the outcrop and in the subsurface. It also has both faunal and lithologic continuity throughout the study area.

Thickest of the three formations of the Washita Group is the Georgetown Formation. It is about 150 feet thick in the northern part of the study area. From the middle of McLennan County northward, the Georgetown Formation consists of seven members, in descending order: the Main Street, Pawpaw, Weno, Denton, Fort Worth, Duck Creek, and Kiamichi members. Southward into Bell County, the Georgetown Formation thins to about 80 feet and can be separated into five members only with great difficulty.

Lithologic changes in the Georgetown Formation are the result of either the presence or absence of fine clastic deposits mainly in the form of calcareous shales. The irregularly bedded limestone beds of the formation, while thinning southward, are remarkably similar throughout the study area. There is a definite reduction in the amount of calcareous shales southward through McLennan County and those members of the Georgetown Formation containing the largest percentage of calcareous shales exhibit the greatest lithologic changes. The Pawpaw and Kiamichi members are composed almost entirely of calcareous shales, therefore they gradually lose their lithologic identity southward and apparently have no Bell County equivalents in the Georgetown Formation.

There appears to be no major faunal variation in the Georgetown Formation except the vertical variation characteristic of the individual members.

Taken as a whole, the Washita Group exhibits a definite faunal similarity which can best be shown by the microfaunal assemblage. The most characteristic megafossils of the Washita Group are *Pecten georgetownensis* and *Gryphaea washitaensis*. Microfossils are abundant, especially in the Del Rio Formation, and the most characteristic of the group are *Globigerina washitensis, Ammobaculites goodlandensis, Textularia rioensis, Acruliammina longa, Lenticulina gaultina,* and *Anomalina plummerae.*

Only one stratigraphic unit possesses a fauna which is not typically "Washita" in aspect. The Kiamichi Member of the Georgetown Formation often contains many species usually associated with the Fredericksburg Group.

Early in the depositional history of the Georgetown Formation, there were two, possibly three, reasons for variable sedimentation. The first two were the existence of the "Belton High" to the south and the location of the source area for fine clastics in the calcareous shales to the north. The third, of which there is only limited evidence, was the presence of reefs in the underlying Edwards Formation. The effects of all three apparently lessened with the passage of time and the continued accumulation of sediments, for the lithology of the Main Street Member, along with the Del Rio and Buda Formations, has lateral continuity in the study area. The general trend of the entire group was toward uniformity of sedimentation over a wide area.

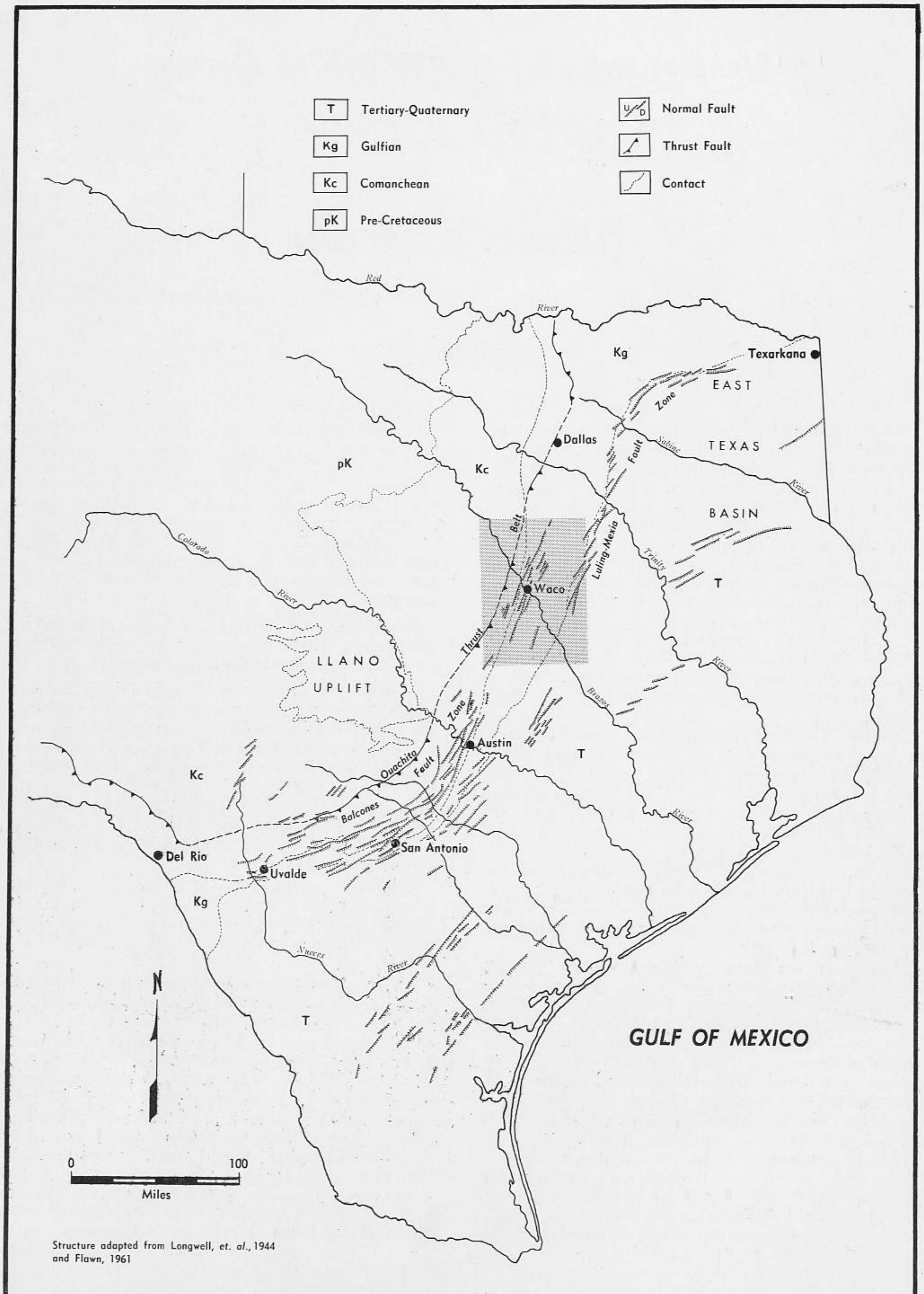

Fig. 1. Index map. Location of study area in shaded pattern.

INTRODUCTION*

The Washita Group in central Texas, which consists of three formations, is represented by a vertical section of variable lithology. In addition, a lateral change in lithology is present, especially in the lowermost formation, the Georgetown Limestone. Although extensive investigations have been conducted in this area, lithologic variations of the Washita Group still present many problems.

LOCATION

The area of study includes portions of Bosque, Hill, McLennan, Coryell, and Bell counties, Texas. It is about 15 miles wide in the north and narrows to about 1 mile in the south. The Washita Group was studied from its occurrence on the north side of Lake Whitney to about 8 miles south of Belton, Texas (fig. 1). Subsurface study of the Washita Group also includes portions of Falls and Limestone counties.

PURPOSE

Purposes of this study are: (1) to determine the nature of lithologic changes in the Washita Group, (2) to ascertain if there are any corresponding faunal variations, (3) to assess the environmental significance of these changes in order to relate the depositional history of the area, during the Washita interval, and (4) to unite the information obtained by several writers with that obtained in this study into one coherent work, thus providing a larger overall view of a significant stratigraphic unit in central Texas.

PREVIOUS WORKS

The earliest work on the Lower Cretaceous rocks of central Texas, including the Washita Group, consisted of general statements (Roemer, 1852) and observations in passing (B. F. Shumard, 1852; Marcou, 1858; G. G. Shumard, 1856-66).

The first work significant to this immediate study was by R. T. Hill, in 1887. In "The Topography and Geology of the Cross Timbers and surrounding regions in North Texas," Hill (1887a) gave the "Washita fossils" a place in the Lower Cretaceous. Hill said that the Comanche series "is one of unbroken sedimentation and faunal continuity from base to top" (p. 298). He did not place the "Dinosaur sand" (Trinity Sands) in the series but just below; other subdivisions were designated by horizons of prominent fossils. Upper or Washita Division beds were subdivided by Hill (1887a, p. 298) as follows:

1. "Lower Cretaceous"		Upper Denison fauna
2. "Washita Limestone"		(*Cidaris hemigranosus* and *Toxaster elegans*)
3. "Indurated Blue Marl"		(*Exogyra arietina*)
4. "Washita Limestone"	A.	(*Gryphaea Pitcheri* with *Ostrea carinata*)
	B.	(*Ammonites vespertinus*)
5.		*Exogyra forniculata*

Later in 1887, R. T. Hill, in his "Texas Section of American Cretaceous," included the "basal sands" (Trinity Sands) with the Washita and Fredericksburg divisions in the Comanche Series. In the same article, Hill presented a list of 79 fossils of the Washita "division." These were notable mainly because of the large number of species previously described by B. F. Shumard and Ferdinand Roemer.

By 1889, Hill had traced the Washita division from Fort Washita in the Indian Territory to south of San Antonio. In the *First Annual Report of the Texas Geological Survey*—1889 (E. T. Dumble, state geologist), Hill gave a brief description of Cretaceous rocks and their economic uses. Hill divided the upper or Washita division of the Comanche Series into five beds as follows:

1. "Shoal Creek limestone"	(Buda Limestone)
2. "Exogyra Arietina clays"	(Del Rio Clay)
3. "Washita or Fort Worth limestone"	(Georgetown Limestone)
4. "Upper Caprotina limestone"	(Edwards Limestone)
5. "Limestone flags"	

By the time of the second, or 1890, annual report of the Texas Geological Survey (1891), other writers began to mention the Washita division. However, they appeared to have trouble agreeing upon the upper and lower contacts of the "division." Part of the trouble was due to the varied appearance of the "division" in the different areas in which they worked. In the second annual report of the Texas Geological Survey—1890 (1891, p. 719-721), J. A. Taff, who worked in southwest Texas, subdivided the Washita division as follows:

1. "Malone Bed" (folded, metamorphosed beds, no northern and eastern equivalents)
2. "Second Caprotina Bed" (Buda Limestone?)
3. "Arietina Bed" (Del Rio Clay)
4. "First Caprotina Bed" (upper Edwards)

In the same year (1891), R. T. Hill added the Kiamitia clays or Schloenbachia Beds to the base of the Washita division. Hill proposed in this paper that the name "Duck Creek Chalk" be given to the "crumbling white chalky limestone" above the Kiamitia clay. The Duck Creek Chalk was named for its occurrence on the southern slope of Duck Creek north of Denison. Hill also proposed that the "Washita limestone" of his earlier work be formally named the "Fort Worth limestone" and to the "Arietina clays" of the Red River district he gave the name "Denison Beds" due to their exposure under Main Street in Denison. Hill adds that

*A thesis submitted in partial fulfillment of the requirements for the M.S. degree in Geology, Baylor University, 1970.

these same Denison Beds are "represented by marly clays (the *Exogyra arietina* clays of my previous classification)" at Del Rio on the Rio Grande.

In September 1892, Taff, in his "Report of the Cretaceous Area North of the Colorado River," grouped the beds of the Washita division as follows:

1. "Vola limestone" (Buda Limestone)
2. "Arietina clay" (Del Rio Clay)
3. "Denison bed"
4. "Fort Worth limestone" (Georgetown Limestone)

Taff also placed the Kiamitia clay (Kiamichi Clay) as the uppermost bed of the Fredericksburg division.

In 1893, R. T. Hill compared the Washita division in two localities, Austin and Denison. In the paper, which was read before the Geological Society of America (later published in 1894), Hill said, "The term 'division', . . . has the equivalency of the word 'group'." Several new "members" were added to the newly subdivided group. Hill still believed that the *Exogyra arietina* beds of Austin were equivalent to the upper "Denison beds" of the Denison area. Hill's (1894, p. 317) "area section" of the Washita Group was as follows:

AUSTIN	DENISON	
"Shoal Creek limestone"		
"*Exogyra arietina* beds"	Denison beds	Main street PawPaw N. Denison Marietta
"Fort Worth limestones"	Fort Worth limestones	
	Preston beds	Duck Creek chalk Kiamitia clays

During the middle 1890's, R. T. Hill was joined by T. W. Vaughan in a series of exhaustive studies for the United States Geological Survey. In a lengthy paper in the *Eighteenth Annual Report of the United States Geological Survey* (1896-97), Hill and Vaughan added little in the way of new subdivisions, but the name Del Rio clays is applied to the *Exogyra arietina* beds of the Austin area. The name is again used by Hill and Vaughan in the Nueces Folio of the United States Geological Survey (1898).

In 1900, T. W. Vaughan substituted the name "Buda limestone" for the "Shoal Creek limestone." Vaughan, in Bulletin 164 of the United States Geological Survey, bestowed the name at the suggestion of R. T. Hill for its occurrence near Buda in Hays County. Vaughan (1900), applying names suggested by R. T. Hill, uses the name "Georgetown limestone." Vaughan said, "This formation named by Mr. R. T. Hill from its occurrence at Georgetown, Williamson County, Texas, is equal in part to the limestone formerly called the Fort Worth limestone" (*idem*, p. 1).

R. T. Hill, in 1901 in the *Twenty-First Annual Report of the United States Geological Survey*, part 7, presented his study, "The Geology and Geography of the Black and Grand Prairies, Texas." The paper, of 666 pages, is one of the most complete works ever published on Texas Cretaceous geology. Forty plates illustrated the section on the Washita Group and numerous outcrop sections were described. Hill decided that most changes that occurred in the Washita Group, from Denison to Austin, happened in the vicinity of the Brazos River. The Denison beds were subdivided into five units: Denton, Weno, Pawpaw, Mainstreet, and Grayson (1901, p. 244). At this time the Washita Group was defined almost as it is today. Hill's correlation (1901, p. 245) of the Washita Group north of the Brazos River (Denison area) and the Washita Group south of the Brazos River (Austin area) was as follows:

AUSTIN	DENISON	
Buda		
Del Rio	Grayson Main Street	
Georgetown	Pawpaw Weno Denton	Denison beds
	Fort Worth	
	Duck Creek Kiamitia	Preston beds

W. S. Adkins (1918) made an extensive study of the Weno and Pawpaw "formations" which he traced through several lithological changes south of the Brazos River.

During the 1920's knowledge of the Washita Group was expanded by various investigators. The group received extensive consideration in a study of McLennan County geology by Lula Pace (1921). A year later in 1922, W. M. Winton and Gayle Scott studied the geology of Johnson County and cleared many of the problems of correlation by their work on the Grayson-Del Rio relationship (Winton and Scott, 1922). A later study of the geology of McLennan County by W. S. Adkins (1923) described the Washita section in central Texas much as it is described today. In 1929, R. H. Cuyler reviewed Hill's 1901 correlation of the Georgetown Formation in central Texas with its northern equivalents in Grayson, Denton, and Tarrant counties (Cuyler, 1929); he added little new information but followed Taff in placing the Kiamichi in the Fredericksburg Group (Adkins, 1930, p. 80).

Later studies added additional information about the Washita section. W. S. Adkins and Frank E. Lozo (1951) described sections containing the upper part of the Del Rio Formation and the Buda Formation in the Waco area. The central Texas section of the Georgetown Formation was described by J. W. Dixon, Jr. (1955) who correlated the individual members in McLennan County with their stratigraphic equivalents in northcentral Texas.* Stratigraphy of the Buda Limestone in central Texas was studied by Johnny R. Ray of Baylor University in 1963.

Recently the Baylor Geological Society has published several guidebooks containing descriptions of rocks of the Washita Group within the area of study.

PROCEDURES

A stratigraphic study of the Washita Group was con-

**Editor's note*: Wilbert (1963 thesis, 1967) conducted a similar Georgetown study from northern Bell County south into Travis County. Wilbert, W. P. (1967) Stratigraphy of the Georgetown Formation, Central Texas *in* Comanchean (Lower Cretaceous) Stratigraphy and Paleontology of Texas, Leo Hendricks, *ed.*, Permian Basin Section SEPM pub. no. 67-8, p. 256-285.

ducted using both field and laboratory investigations. A review of available literature preceded the field investigation.

Field investigation included location and measuring of sections, sampling and mapping (fig. 2). Individual members of the Georgetown Limestone were mapped in the field where possible although, due to the small scale of the map (1:250,000), certain small outliers of the Duck Creek and Kiamichi members in Hill, Coryell, and Bosque counties were omitted.

Laboratory investigation consisted of two parts. The first was the examination of the limestone samples. Samples were then selected for acetate peels (Appendix III) and pertographic thin sections. The second part of the laboratory work involved the examination of the marl and clay samples. These were processed for sand-silt-clay ratios (Appendix III) and for abundance and distribution of microfossils (Appendix II).

In addition to the studies above, well logs were examined for subsurface control and isopach maps were prepared of the Washita Group and of each formation within the group (figs. 3-6).

It was not the intention to duplicate work of certain previous studies involving the formations of the Washita Group. Many needless hours of field and laboratory investigations were saved by the use of the studies by Dixon (1955) and Ray (1963). Much of their work is accepted at face value and with little or no change in this study.

ACKNOWLEDGEMENTS

The writer expresses his appreciation to Professors O. T. Hayward, G. A. Morales, and W. T. Huang of the Department of Geology, Baylor University, for guidance and assistance in the completion of this study. Professor J. W. Dixon, Jr., Department of Geology, Baylor University, gave his field notes and offered many helpful suggestions concerning the stratigraphy of the Georgetown Formation. Charles F. Johnson (1964) provided field and laboratory information on the Del Rio Clay. Especially useful were his outcrop map, x-ray-diffraction analysis, and study of faunal zonation within the Del Rio Formation. Professor O. T. Lind, Department of Biology, Baylor University, offered guidance on water chemistry and environments. The writer's wife Sandra gave assistance, both in the field and in the typing of the manuscript. Appreciation is also extended to Dr. Frank E. Lozo of Houston, Texas for his helpful review of the manuscript before publication.

TOPOGRAPHY

The Washita Group in central Texas crops out in a triangular pattern with the base of the triangle in the north in Bosque and Hill counties and the apex in the south in Bell County. For ease of discussion the topography can be separated into a northern and southern area. The northern area extends from Lake Whitney to about 5 miles north of the junction of McLennan, Coryell, and Bell counties (fig. 2). The southern area extends from the same tri-county junction to the Lampasas River. Both areas, although joined, have different topographical characteristics.

NORTHERN AREA

In the northern area, the area of outcrop is controlled by the thickness and resistance of the individual stratigraphic units. The topographical expression of the Washita Group in the northern area is influenced by the existence of the underlying Edwards Formation in the west and by stream dissection on the eastern margin.

In the eastern portion of the northern area the Brazos and North Bosque rivers have left extensive terrace gravels covering the outcrop areas of the softer units of the Washita Group. This is especially true near Waco. To a lesser degree, Childress Creek, Hog Creek, and the Middle Bosque River do much the same. All of the streams, for a long distance, flow southeast on the resistant Edwards Formation. The nearby stream banks and small tributaries are formed mostly in the Duck Creek and Kiamichi members of the Georgetown Formation. The valley slopes and larger tributaries are usually formed in the Fort Worth, Denton, and Weno members of the Georgetown Formation. The Denton Member, because of its thickness of 5 feet or less, has little effect on topography. The Denton Member is almost never found exposed except where protected by a resistant limestone ledge at the base of the Weno Member. The hilltops and much of the gently sloping "uplands" are in the Main Street Member of the Georgetown Formation. The Pawpaw Member like the Denton Member has a very limited area of surface exposure. The Pawpaw Member is never found exposed except where overlain and protected from erosion by the Main Street Member.

The Del Rio Formation, which is less resistant than the Georgetown Formation, usually occupies the higher areas of low relief between streams. River terraces frequently cover a large portion of Del Rio outcrops and almost every exposed section of Del Rio Clay is capped by terrace gravels.

The Buda Formation has no appreciable effect on the topography except in the area between Lake Waco and China Spring, Texas where a few small hills are capped and protected from erosion by outliers of the thin but resistant limestone.

In the western part of the northern area, the controlling factor in topography is the massive and resistant Edwards Formation. Here the topography changes from the gently rolling Washita Prairie to the steep bluffs of the Lampasas Cut Plain. The Kiamichi and Duck Creek members of the Georgetown Formation

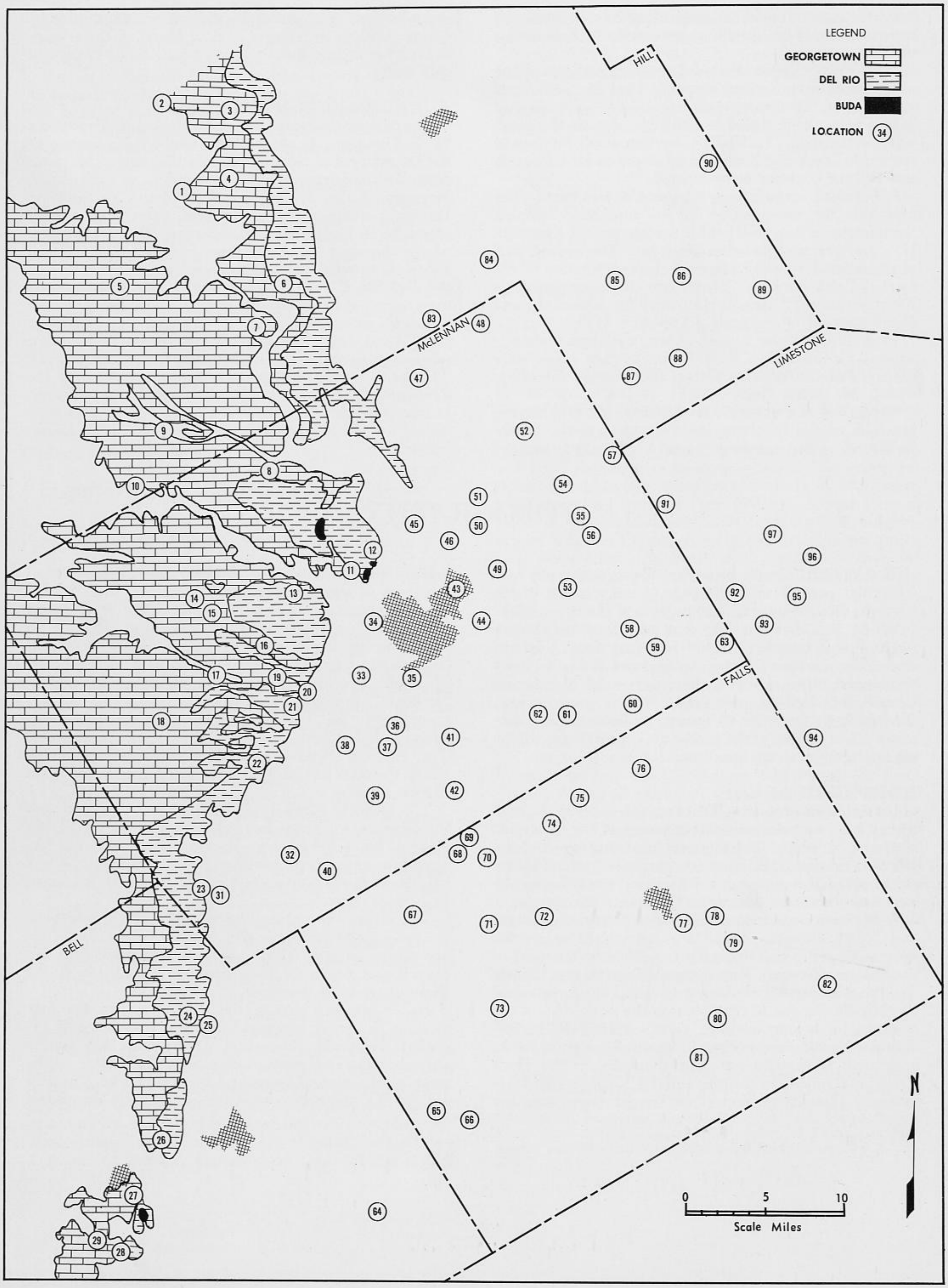

Fig. 2. Locality map showing areas of outcrop, localities of measured sections, and wells.

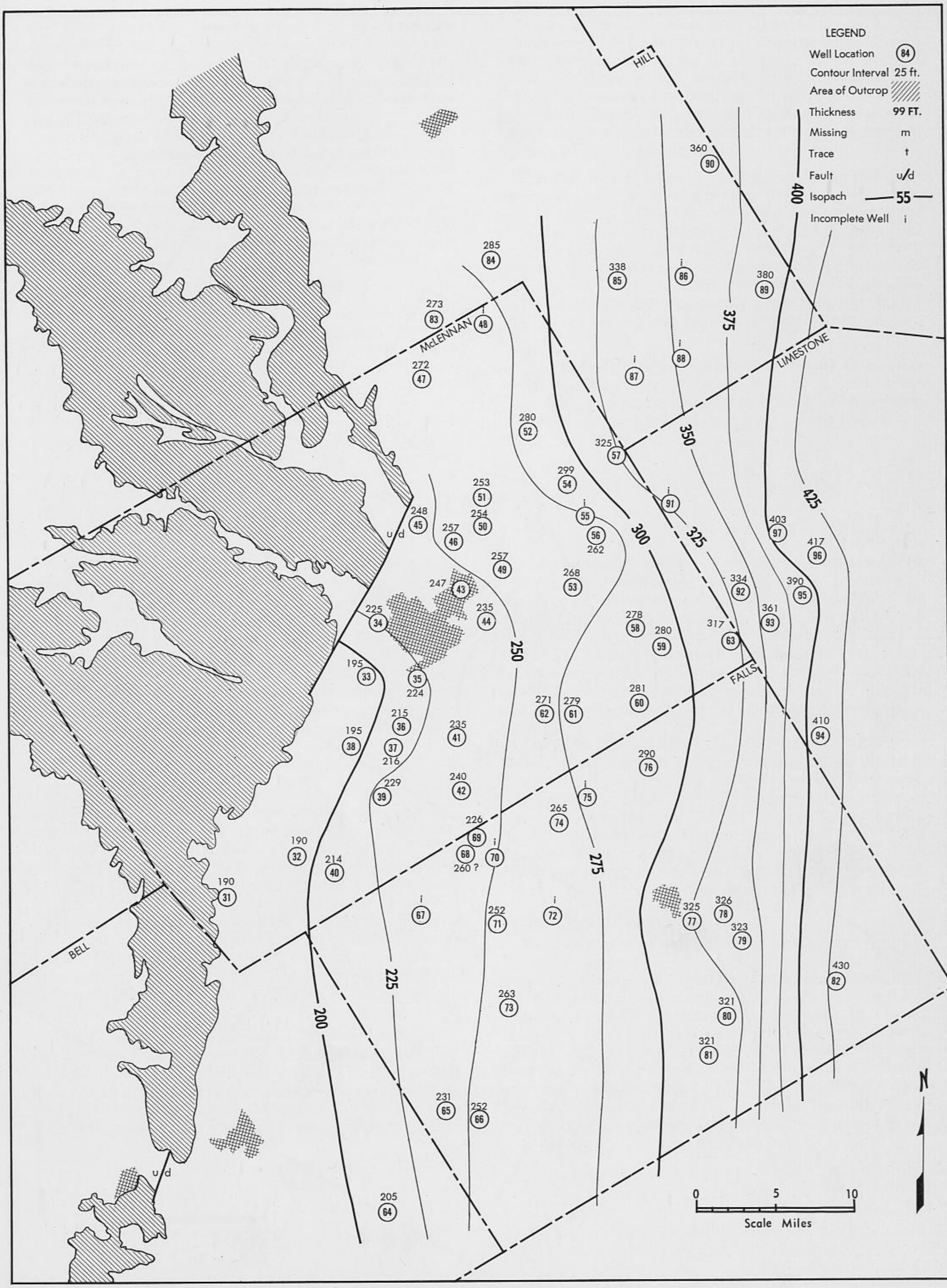

Fig. 3. Isopach map of the Washita Group. Striped pattern, area of Washita outcrop.

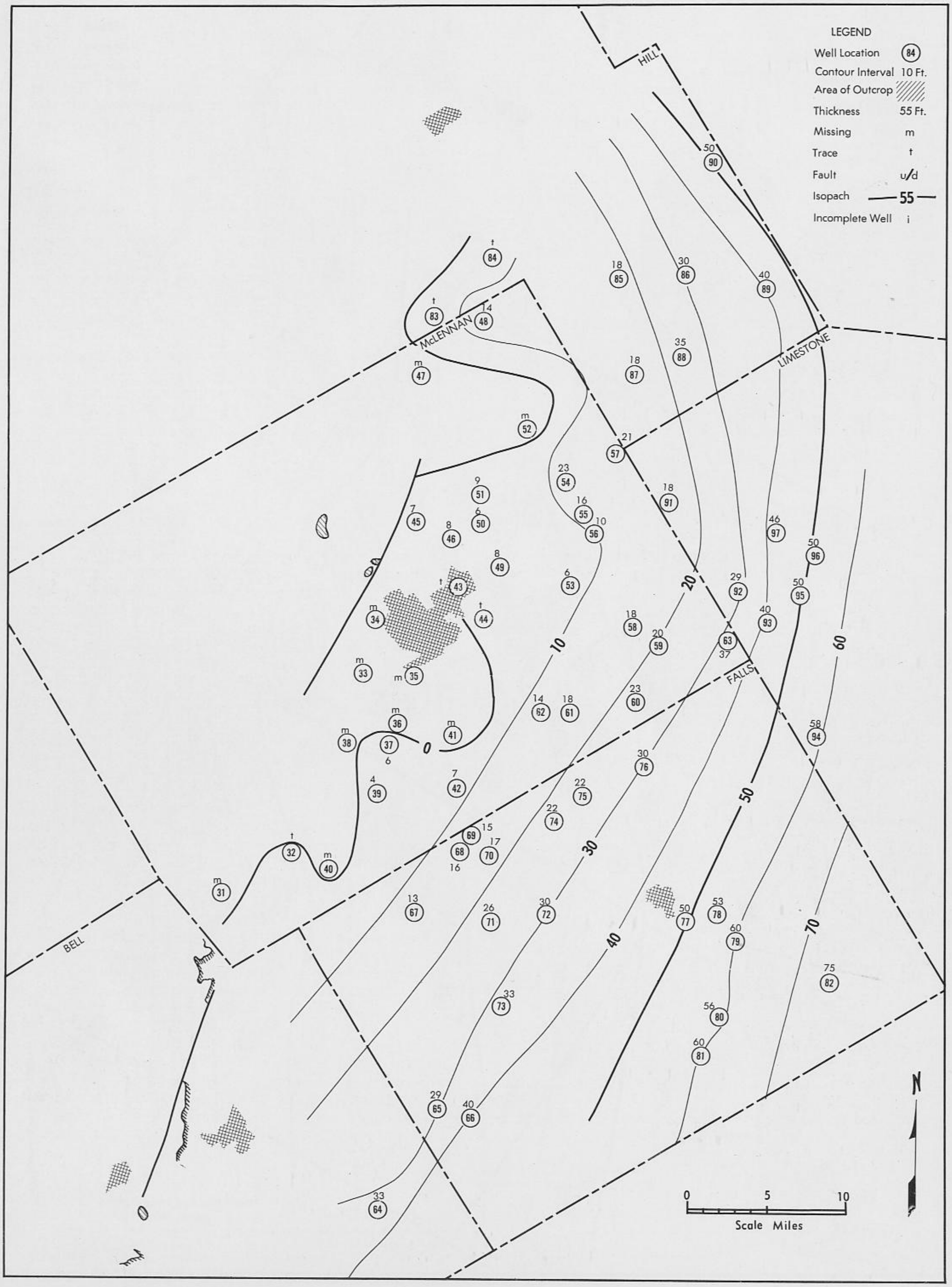

Fig. 4. Isopach map of the Buda Formation. Small areas of shaded pattern, Buda outcrops.

are found above the Edwards Formation in continuous outcrop near the edge of the Lampasas Cut Plain. Farther west in the cut plain, the Kiamichi and Duck Creek members can be found as outliers for 15 miles west of the most westerly continuous outcrop of the Georgetown Formation.

Development of ranch land on the Georgetown Formation and farm land on the Del Rio Formation is very noticeable in the northern area. The contact between the Georgetown and Del Rio formations also may be noted for the change in vegetation which occurs near the contact. Mesquite trees are common on the Del Rio soils while juniper trees characteristically grow upon the poor, rocky soils of the Georgetown Formation.

SOUTHERN AREA

In the southern area, the Washita outcrop is controlled by the thickness of the group, which is less than in the north, and by the Balcones fault system. Here the Washita Prairie is nearly "squeezed out" between the Austin Chalk Escarpment to the east and the Lampasas Cut Plain to the west. In the southern area, the Washita Group crops out in a narrow area of low relief between the two regional highs.

Most of the difference in thickness occurs in the Georgetown Formation. Lack of calcareous shale units and slight thinning in the limestone beds, results in a reduced thickness of the Georgetown Formation in Bell County to about half of that found in Hill County farther north. Except for a few bluffs along the Lampasas River, the topography developed upon this formation consists of gently rolling land.

The Del Rio Formation, which has about the same thickness as in the northern area, has nearly the same area of outcrop. This formation has less surface relief than the Georgetown Formation and usually crops out in the lowest ground. Because of its rapid soil development, the outcrop area of the Del Rio Formation is typically farm land. Outcrop areas of both the Del Rio and Buda formations are partially controlled by faults. The main effect of the faults is to narrow the outcrop area.

The Buda Formation is more continuous in outcrop in the southern area, although because it is thin the Buda has little topographical expression. The outcrop is usually noted as a small bench and scarp around the top of low hills.

STRATIGRAPHY

The Washita Group in central Texas is the uppermost group of the Comanche Series. It is unconformably overlain by the Pepper Formation of the Gulf Series and unconformably overlies the Edwards Formation of the Fredericksburg Group. The Washita Group consists of three formations; from top to bottom, they are: the Buda Formation, the Del Rio Formation, and the Georgetown Formation. The contacts between the formations are conformable and the contact between the Del Rio Formation and Georgetown Formation is transitional (Table p. 19).

BUDA FORMATION

The Buda Formation is found only in scattered outcrops in the southern half of the study area and is missing entirely in localities north of China Spring, Texas. In localities where the Buda Formation is missing, the Del Rio Formation is in contact with the overlying Pepper Formation. The Buda Formation is only 2 feet thick in outliers in the Waco area but thickens rapidly in Bell County where it reaches a thickness of 7 feet. In the subsurface, the Buda thickens uniformly in a southeastern direction. The wedge-shaped Buda sediments reach a thickness of 70 feet in the subsurface of Falls County (fig. 4).

The Buda Formation in central Texas is hard, dense, fossiliferous limestone and can be easily recognized by its orange color and dark red spots. The Buda often contains an abundance of microfossils along with numerous shell fragments, mainly those of *Gryphaea*. The dark red spots, which give the Buda a mottled appearance, are due to nodules of weathered hematite. The nodules often encircle *Gryphaea* and they weather so rapidly that on outcrop the Buda is commonly quite porous. On a fresh surface, the Buda Formation was found to have a crystalline calcite matrix. While the Buda is composed almost entirely of calcium carbonate, some fine quartz sand is present, especially in outliers north of Waco. Glauconite is present in all localities and apparently replaced fossils before lithification (Ray, 1963, p. 7).

The Buda Formation lacks well defined bedding or layers, which adds to the great resistance of the unit. The massive and resistant character of the Buda contrasts with the softer layered limestones and siltstones often found in the Del Rio and lower Pepper formations. One calcareous siltstone bed at the base of the Pepper Formation is frequently found in localities where the Buda is absent and might be easily mistaken for the Buda except for its well defined layering.

DEL RIO FORMATION

The most prominent characteristic of the Del Rio Formation in central Texas is its nearly uniform thickness. Except in Bell County where in certain localities the thickness has been reduced by faults, the Del Rio remains a nearly constant 75 to 80 feet. In certain areas in the subsurface, notably the center of Falls County (fig. 5), the formation thins slightly, but even here the Del Rio Formation exhibits a tendency toward uniformity of thickness. Unlike the Georgetown Formation below, the Del Rio Formation has both faunal and lithologic continuity throughout the study area.

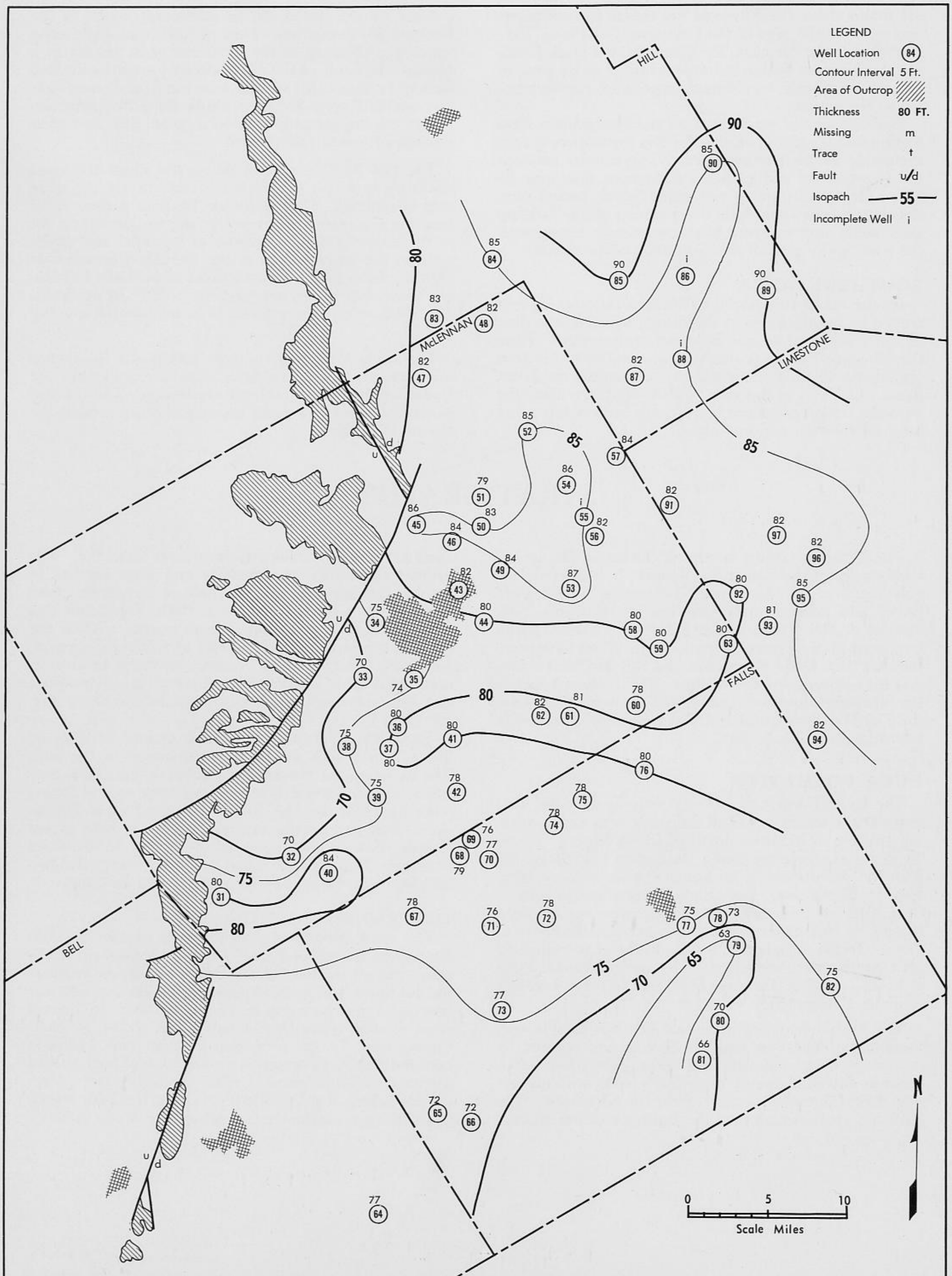

Fig. 5. Isopach map of the Del Rio Formation. Striped pattern, area of Del Rio outcrop.

The Del Rio Formation is composed almost entirely of dark gray, blocky clay in the central Texas area, but other lithologies are present in limited amounts. Near the middle of the Del Rio Formation is a zone about 20 feet thick which contains thin beds of ocherous hematite. These are not continuous and usually extend only a few feet laterally. On a fresh surface these beds are gray in color and difficult to separate from the surrounding clays. However, on a weathered surface they appear carmine red. The weathered surface is also criss-crossed with what appear to be fragments of an aquatic plant. The "plant fragments" do not change color when oxidized as does the carmine red, enclosing hematite.

Throughout the Del Rio Formation occur lenticular beds of dense, fossiliferous limestone usually less than 10 inches thick. Most of the limestone beds contain abundant *Gryphaea graysonana* and the upper surface of one thick limestone bed near the base of the formation is covered by filled burrows.

Not confined to the lower 10 feet but more numerous there, are thin-bedded calcareous siltstones. The siltstones are not as common south of Waco as they are northward. The unusual occurrence of layered pyrite in beds ½ to ¾ inch thick can be found in the barrow pit east of the Lake Waco dam.

The variations in lithology described above are local in nature and cannot be correlated over distances of more than a few hundred yards. The variable lithology of the Del Rio Clay causes a corresponding variation in color on a weathered surface. Yellow and tan are the most common colors, but occasionally red and dark gray may also be present. In southwestern Hill County the degree of dissection and variety of color of the weathered Del Rio impart a "badland" appearance to the local topography.

A fresh sample of Del Rio Clay from McLennan County commonly contains 90 to 95 percent clay-sized particles as opposed to only 5 to 10 percent silt and sand-sized particles (Appendix II). A fresh sample taken from either Hill County in the north or Bell County in the south usually contains a slightly lower percentage of clay-sized particles. Samples taken from a weathered surface or from zones containing an abundance of selenite have as little as 35 percent clay-sized particles. The low clay percentage in highly weathered zones is due in part to the difficulty in taking a fresh sample where the Del Rio is overlain by sand and gravel terraces. Slumping is common in the Del Rio, and terrace materials become mixed with the weathered clays. Selenite is a secondary deposit found only where the Del Rio is overlain by the Pepper Formation. The selenite actually replaces the clay along joints or porous beds, therefore, samples taken from zones containing selenite will have a low clay percentage.

The contact between the Del Rio and Buda formations is conformable as indicated by faunal continuity (see paleontology), despite the sharp contrast in lithology of the two units.

The contact between the Del Rio Formation and the underlying Main Street Member of the Georgetown Formation is transitional. A soft, shaly limestone unit is present at the contact and it is more shaly at the top and more resistant at the bottom where it overlies a unit containing typical Georgetown lithology. Dixon, (1967, p. 250) on the basis of lithology, placed the contact at the top of this shaly limestone unit. The writer concurs, even though the unit contains fossils common to both the Georgetown and Del Rio formations. This same unit may be traced throughout the study area, but thins from 4 feet to 4 inches near Whitney to 10 inches near Belton.

GEORGETOWN FORMATION

The Georgetown Formation, with a thickness of about 150 feet in the northern part of the study area, is the thickest of the three formations of the Washita Group. From the middle of McLennan County northward, the Georgetown Formation consists of seven members; from top to bottom, they are the: Main Street, Pawpaw, Weno, Denton, Fort Worth, Duck Creek, and Kiamichi members. Southward into Bell County* the Georgetown Formation thins to about 80 feet and can be separated into five members only with great difficulty. In Bell County, the Main Street, Weno, Denton, Fort Worth, and Duck Creek members, lacking the sharper defined lithological characteristics of farther north, are usually collectively mapped as the Georgetown Formation. The Main Street, Weno, Fort Worth, and Duck Creek members are predominantly limestone and the Pawpaw, Denton, and Kiamichi members are predominantly calcareous shales.

MAIN STREET MEMBER

The Main Street Member is one of the most resistant members of the Georgetown Formation. In nearly any vertical section of more than 30 feet, the Main Street will be the uppermost member because the other members will not support a steep bluff. Also the Main Street, which is 35 to 40 feet thick in central Texas, is one of the thickest members of the Georgetown Formation and has nearly uniform lithology from base to top.

The Main Street Member consists of irregular-bedded limestone with thin, calcareous shale beds interlaminated every 2 to 3 feet. The shale beds are usually less than one inch thick, but near the center of the Main Street there are several prominent shale beds which are 3 inches to nearly one foot thick. The shale beds are very good points of reference since many are continuous over much of the study area.

It is the Main Street Member which is best described by the term "typical Georgetown lithology" used by Dixon (1967, p. 243). This characteristic appearance of the Georgetown Formation is due to the irregularity of the horizontal bedding planes. Relief on the bedding planes varies as much as 4 inches, which causes the bedding to appear quite irregular upon close view. However, when observed from a greater distance the bedding planes are distinct and can be easily traced along the length of any exposed section. There is no sharp lithological distinction between members as is true farther north because the Pawpaw Member is absent in Bell County. In Bell County the Main Street Member is in contact with the Weno Member forming

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*See editor's note, p. 8. (Wilbert, 1967)—*Ed.*

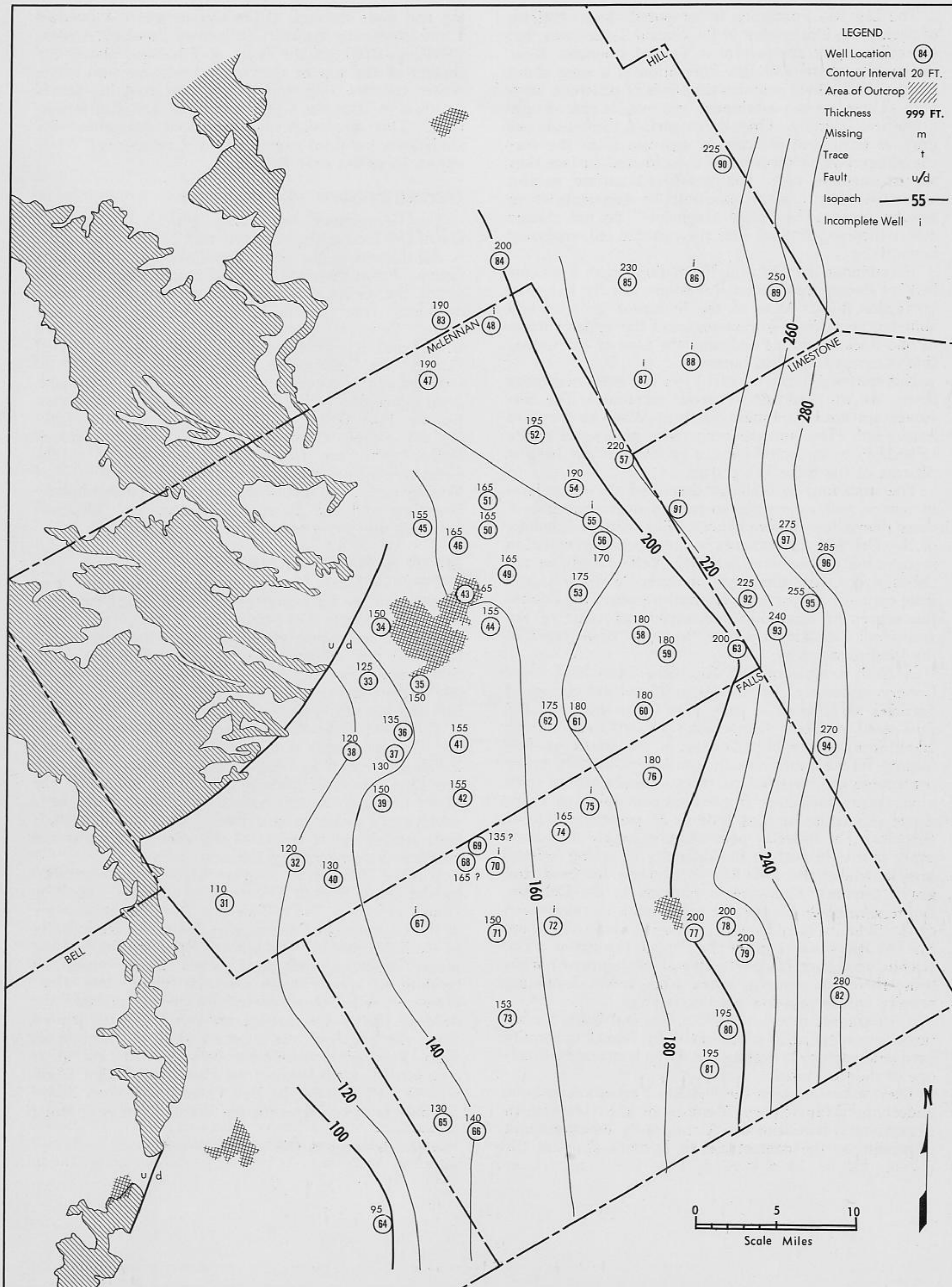

Fig. 6. Isopach map of the Georgetown Formation. Striped pattern, area of Georgetown outcrop.

a continuous section of similar lithology. Thus the "upper Georgetown Formation" in Bell County has about the same lithology as the Main Street Member in McLennan County. The nearly uniform lithology of the Main Street Member is suggested by electric logs from Bell County wells where the formation is about 80 feet thick. Therefore, there probably was lateral continuity of sedimentation during the latter part of the Georgetown interval of time. The writer has placed the contact between the Main Street and Weno members at the first major break in the nearly uniform lithology of the upper Georgetown Formation. The first major break in lithology in Bell County occurs approximately 29 feet below the contact with the overlying Del Rio Formation.

PAWPAW MEMBER

The Pawpaw Member is one of the thinner, predominantly shale, members of the Georgetown Formation. The Pawpaw Member occurs immediately below the thick, resistant, lower unit of the Main Street Member. The Pawpaw Shale is 6 feet 6 inches to 9 feet thick in the northern half of the study area and occurs between two more resistant members. Thus the Pawpaw Member forms a notable receding zone in exposures of the upper Georgetown Formation. The size of this receding zone increases in a northerly direction, with an increase in the percentage of shale within the unit.

In central Texas the Pawpaw Member usually consists of three units: a receding upper and lower shale and a slightly projecting middle unit of shaly limestone. The lower shale thins and the middle unit becomes harder and thicker southward through McLennan County, which makes the member increasingly more difficult to recognize in section. This trend probably continues into Bell County with the result that the Pawpaw interval can no longer be identified.

WENO MEMBER

The Weno Member is the thickest and most variable member of the Georgetown Formation. The upper half of the Weno Member consists largely of irregular-bedded limestones of "typical Georgetown lithology." The upper part of the Weno Member is similar in lithology to the lower part of the Main Street Member, except that it is not as uniform in bedding. The irregular-bedded limestones of the upper Weno Member project from interbedded shales giving a noticeable layered appearance. The limestone units, about 5 feet thick, are separated by shales which vary from 6 inches to one foot in thickness.

The lower half consists largely of calcareous shales which are weakly resistant. Often this part of the Weno Member is found as a covered portion of a larger section. However, it is this lower half of the Weno Member which contains the most resistant limestone ledges in the Georgetown Formation. These limestone ledges unlike most Georgetown Limestone beds are typified by smooth, regular bedding planes. One of these ledges forms the base of the Weno Member and can be easily traced, because of its resistance, throughout most of the study area. The 2-foot thick ledge is referred to informally as the "Ocee ledge" (see section 5, unit F) by Dixon for its occurrence in Hog Creek near Ocee, Texas. The other ledges are not so easily traced and their distance above the "Ocee ledge" may vary somewhat at each locality. These thinner limestone ledges occur in varying numbers at different localities.

The Weno Member has a maximum thickness of about 40 feet in the study area. It is slightly thicker in the Hill-Bosque County area than in the Waco area. There is little of the lower shaly part of the member in Bell County, where the middle Georgetown Formation resembles the harder, upper part of the Weno. However, the resistant limestone ledges of the lower Weno Member are present in the southern part of McLennan County and the northern part of Bell County. Because of southward thinning of the calcareous shale units of the lower Weno, the thickness of the member is greatly reduced in Bell County. The lower contact of the member is placed just above a *Gryphaea* bed which occurs in the center of the Georgetown Formation. The *Gryphaea* bed closely resembles the *Gryphaea* beds of the Denton Member farther north. In Bell County the Weno Member is about 20 feet thick.

DENTON MEMBER

The Denton Member is one of the thinnest and most easily recognized members of the Georgetown Formation within the study area. The Denton, which is usually about 5 feet thick, consists mainly of dark shale and coquinoid limestone. The Denton Member is always found just below the overhanging "Ocee ledge" of the Weno Member. Although the Denton has few species of fossils, the ones present are there in abundance.

Like the other predominantly shale members, the Denton Member is not well represented in Bell County. However, there are several *Gryphaea* beds in Bell County similar in appearance and stratigraphic position to those in the Denton Member in the northern part of the study area. In Bell County the *Gryphaea* beds are thinner and the Denton Member consists of 3 feet of coquinoid limestone.

FORT WORTH MEMBER

The Fort Worth Member, like the other predominantly limestone members, has the "typical Georgetown lithology." The Fort Worth Member is so similar to the Duck Creek Member that the two are difficult to separate in small outcrops exposing both. In any large outcrop the differences between the two are more easily seen. The Fort Worth Member is less resistant, tends to recede, contains more interbedded thin shales, and contains fewer fossils than the Duck Creek Member. The Fort Worth Member is also thinner than the Duck Creek Member. Because of its limited resistance to weathering, the Fort Worth member develops soils more rapidly than adjacent units and this results in covered intervals over that part of the outcrop containing the unit. However, Dixon (1967, p. 246) pieced together several sections and arrived at a thickness of 20 feet for the central Texas area. Close examination of well logs in northern McLennan County gives a thickness of 20 to 25 feet in the subsurface near the outcrop. This thickness compares with that farther north in Johnson County and an interval of similar lithology southward in Bell County. This suggests that

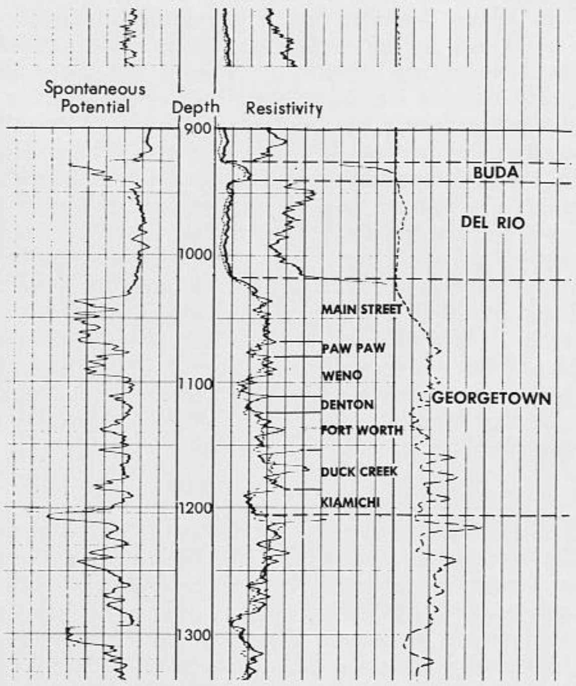

Fig. 7. Electric well log of Georgtown section, Central Texas.

the Fort Worth Member probably possesses the greatest lateral continuity of any individual member of the Georgetown Formation in the study area.

DUCK CREEK MEMBER

Much of the description of the other three limestone members would be applicable to the Duck Creek Member of the Georgetown Formation. The Duck Creek is similar in appearance to the Fort Worth Member. Limestones of the Duck Creek are very resistant to weathering and several limestone ledges near the base of the member resemble those in the lower part of the Weno Member. Because of its resistance and close stratigraphic relationship with the Edwards Formation, the Duck Creek has the largest area of outcrop of any member of the Georgetown Formation.

The Duck Creek Member thins slightly in a southerly direction. On the north side of Lake Whitney (Section 1), it is 32 feet thick. At Section 5 just south of Lake Whitney, it is 30 feet thick (Dixon, 1967, p. 244). Southward into Bell County the thickness is difficult to determine because the contact between the Duck Creek and Fort Worth members is increasingly difficult to identify in Bell County; the Fort Worth Member is 20 feet thick and the Duck Creek Member is 23 feet thick. In the study area the Duck Creek Member is between 25 and 35 feet thick.

The Duck Creek Member is the most fossiliferous of the limestone members, both in abundance and number of species. This is particularly true of the shale intervals near the contact with the overlying Fort Worth Member.

The base of the Georgetown Formation in Bell County does not closely resemble the Duck Creek Member farther north in Bell County. The lower Georgetown Formation is softer with more interbedded shales and more closely resembles the Fort Worth Member. In the southern part of the study area, the Kiamichi Member is missing and the Duck Creek Member is in contact with the underlying Edwards Formation. Although both the Edwards Formation and Duck Creek Member are limestones, there is a marked contrast in lithology at the contact. The Duck Creek Member is softer and receding while the Edwards Formation consists of thin-bedded limestone or massive protruding ledges.

Examination of electric well logs in this area reveals a southward thinning of the Georgetown Formation near the outcrop but a uniform, eastward, down-dip thickening. Thickness of the Georgetown Formation reaches minimum of about 80 feet just south of Belton.

KIAMICHI MEMBER

The proper stratigraphic relationship of the Kiamichi Member is one of the outstanding problems yet to be solved in central Texas geology. Some writers have placed the Kiamichi at the top of the Fredericksburg Group (Adkins and Lozo, 1951, p. 112), while others have noted its similarity to the Washita Group (Cuyler, 1929, p. 1293). Variation of opinion has arisen mainly because of the diverse paleontology of the Kiamichi Member. The unit contains fossils which are characteristic of both Fredericksburg and Washita groups. The Kiamichi Member probably has the most complex sedimentary history of any Washita unit. Dixon (1967, p. 245) suggested that the contact between the Fredericksburg and Washita groups occurred within the Kiamichi Member. He observed the abundance of *Kingena wacoensis* in the upper part of the Kiamichi and noted that they varied in shape from those found widely scattered through the lower part. The present study supports this view. In the course of examining the coarse fraction of the washed microfaunal samples, differences were found between samples collected from upper and lower parts of the member. Samples from the lower part of the member produced few microfossils and conspicuous amounts of shell hash and limestone fragments. Those samples from the upper part more closely resembled the calcareous shales found in the Duck Creek Member.

The Kiamichi Member is present only in the northern half of the study area and rapidly thickens northward and to a lesser extent westward. From zero feet near Moody, Texas it thickens to 17 feet at the northern shore of Lake Whitney.

The Kiamichi Member is composed mainly of calcareous shale with a few thin, nodular limestone beds, especially in the lower half. *Gryphaea* beds appear to be more numerous north and west of McLennan County.

The Kiamichi Member forms a prominent receding zone below the Duck Creek Member and above the Edwards Formation. The unit can be observed to thin over Edwards bioherms which are partially exposed in both the Middle Bosque River and Childress Creek. Thinning over bioherms evidently continues in the subsurface, for the Kiamichi Member has a highly variable thickness down dip.

The Kiamichi clay occurs on outliers above the Edwards Formation in the Lampasas Cut Plain. The fauna found in these outliers is characteristic of the Fredericksburg Group.

Sedimentary Characteristics of the Washita Group in Central Texas

Formation or Member	Thickness (Feet) Hill	McLennan	Bell	Lithology	Fossils
Buda Formation	0	2	6	Limestone—hard, dense, crystalline, resistant, fossiliferous. Weathered surface is orange, porous, contains nodules of hematite. Occasionally glauconite and fine quartz sand.	Most common: *Pecten, Gryphaea, Exogyra.* Less common: *Pinna, Protocardia, Trigonia, Budaiceras* and *Mantellicreas* (ammonite). Numerous specimens, but few species of foraminifera.
Del Rio Formation	80	80	75	Clay—dark and blocky on fresh surface, non-resistant. Contains pyrite, ocherous hematite, scattered coquinoid limestones, thin-bedded calcareous siltstones may contain selenite where overlain by Pepper Formation.	Most common: *Exogyra, Gryphaea, Pecten.* Less common: *Turrilites, Scaphites, Submantelliceras.* Corals, brittle stars, several species of echinoids. Great abundance of foraminifera. Most common are *Globigerina, Anomalina, Lenticulina* and *Textularia.*
Georgetown Formation Main Street Member	42	37	26-29	Limestone—irregular bedded to massive, thin calcareous shales. Iron stains and weathered pyrite nodules common in lower part. Nearly uniform lithology in basal 18 feet.	Most common: *Kingena wacoensis, Alectryonia, Gryphaea,* and *Pecten.* Less common: *Turrilites brazoensis* (upper part), *Holectypus, Cymatoceras, Mantelliceras,* and *Pervinquieria* (southward). Most common foraminifera are *Globigerina, Reophax,* and *Acruliammina.* Other less common are *Lenticulina, Anomalina,* and *Ammobaculites.*
Pawpaw Member	10	6.5	0	Shale—calcareous with thin soft nodular limestones. Shale units thicken northward. Whole member forms prominent receding zone.	Most common: *Pecten, Gryphaea.* Less common: *Pleurotomaria, Holaster simplex.* Most common foraminifera are *Acruliammina, Ammobaculites, Anomalina,* and *Globigerina.*
Weno Member	43	39	17-21	Limestone—irregular bedded, similar to Main Street in upper half but more closely bedded. More shale in lower half. Several resistant limestone ledges in lower half. Basal unit, 24-inch limestone, known locally as "Ocee ledge."	Most common: *Pervinquieria, Pecten, Gryphaea,* and *Hemiaster* (lower part). Less common: *Holaster simplex,* and *Macraster obesus.* Foraminifera more abundant in lower part of unit. Most common are *Globigerina, Acruliammina, Lagena* (lower part), and *Lenticulina.*
Denton Member	10	5	3?	Shale—with soft coquinoid limestones. Darker than members above and below. Whole unit forms receding zone.	Most common: *Gryphaea, washitaensis* and *Kingena wacoensis.* Most common foraminifera are *Globigerina, Ammobaculites,* and *Textularia.*
Fort Worth Member	20	20	20	Limestone—irregular bedded soft, marly. Closely interbedded with thin shales in middle of unit. Several thin *Gryphaea* beds weakly resistant, outcrop often covered.	Most common: *Gryphaea, Pecten, Alectryonia,* and *Hemiaster.* Less common: *Pleurotomaria, Ostrea,* and *Pervinquieria.* Most common foraminifera are *Globigerina, Textularia, Ammobaculites, Lenticulina* and *Anomalina.*
Duck Creek Member	30	27	23?	Limestone—similar to Fort Worth only more resistant, thicker beds, less shale. Very fossiliferous in certain zones. Several 1-foot thick resistant ledges in lower part. Close bedding in lower part gives flaggy appearance in highly weathered section.	Most Common: *Gryphaea washitensis, Kingena wacoensis* and *Pervinquieria.* Less common: *Desmoceras, Hamites, Pleurotomaria,* and *Inoceramus.* Foraminifera nearly same as Fort Worth except more palmate forms.
Kiamichi Member	17	4	0	Shale—calcareous with thin nodular limestones, several thin coquinoid limestones near the base. Very clastic with shell hash and limestone particles in lower part.	Most common: *Kingena wacoensis* (upper part), *Exogyra texana* (lower part), *Oxytropidoceras, Gryphaea.* Less common: *Enallaster, Cyprimeria.* Very sparse assemblage of foraminifera, mainly agglutinated species such as *Acruliammina, Ammobaculites,* and *Reophax.*

PALEONTOLOGY

The paleontology of the Washita Group in central Texas may appear quite varied when one formation is examined independently of the others. However, taken as a whole, the Washita Group exhibits a definite faunal similarity throughout. This similarity includes both the megafauna and microfauna. Only one unit possesses a fauna which is not characteristic of the Washita Group; the Kiamichi Member of the Georgetown Formation often contains many species usually associated with the Fredericksburg Group.

BUDA FORMATION

The Buda Formation is a thin, fossiliferous limestone in the central Texas area. The most common fossils are *Pecten, Exogyra,* and *Gryphaea. Gryphaea* appears to be the most common of the three and is usually found in the lower part of the section (Ray, 1963, p. 12). Others less common but reported from the central Texas area, are *Pinna, Protocardia, Cardium, Trigonia, Isocardia,* and *Turritella.* Ammonite fauna of the Buda Formation is small but characteristic and consists of *Budaiceras mexicanum, Mantelliceras mantelli, Mantelliceras laticlavium,* and *Euhystrichoceras remolinese* (*idem,* p. 13).

The Buda Formation is a hard, dense limestone throughout the central Texas area and examination for microfossils has been restricted to polished sections and acetate peels. Microfossils are numerous in the Buda, but few species can be accurately identified in cross section. The most common microfossils are *Anomalina, Globigerina, Citharina, Lenticulina,* and *Textularia. Valvulineria* and *Dentalina* are less common. There appear to be others, but they may be fragments or only partial cross sections.

DEL RIO FORMATION

The Del Rio Formation has a more varied faunal assemblage than the other formations of the Washita Group. The most common fossil of the Del Rio Formation is *Exogyra arietina. Exogyra arietina* is found in great abundance in certain zones and may be found scattered throughout any horizon in the formation. From Waco northward, large adult specimens of *Exogyra arietina* are far less numerous in the lower 5 feet of the formation and the upper 30 feet. Southward in the Belton area *Exogyra arietina* specimens are abundant in the upper 30 feet with many adult forms present. In the transition zone between the Main Street Member and the Del Rio Formation, all specimens of *Exogyra arietina* are juvenile forms.

Pecten (several species) and *Gryphaea graysonanna* are more common in the upper half of the formation. *Gryphaea mucronata* may be found throughout the formation. Several species of *Ostrea* can be found from Waco southward to the Belton area.

Although pyritic micromorphs may be found in nearly any horizon within the Del Rio Formation, they are particularly abundant about 35 feet above the base of the formation. Pyritized fossils are usually coiled forms such as ammonites and gastropods. The most common micromorphs within this zone are *Turrilites bosquensis* and *Scaphites subevolutus.* Many *Exogyra arietina* in this zone are pyritized, but appear to be juvenile specimens rather than dwarfs. Also common throughout the Del Rio Formation are echinoids, brittle stars, shark teeth and bony parts of fish.

Zonation within the Del Rio Formation is not precise. In the central Texas area, the zones appear to overlap (Adkins and Lozo, 1951, p. 153).

Zonation in the Del Rio Formation*

Lithic Unit		Zonation
DEL RIO	(7)	*Exogyra cartledgei.* Widespread; sparse in central Texas, abundant in Trans-Pecos Texas.
	(6)	*Euhystrichoceras n. sp.* Known from north-central Texas, but probably widespread.
	(5)	*Gryphea graysonana.* Widespread. Zone of abundance (= acme) in Upper Grayson, very sparse in Lower Grayson.
	(4)	*Exogyra arietina.* Widespread. Acme in Middle to Lower Grayson, sparse above.
	(3)	*Pyritic micromorph zone.* Partly overlaps No. 4, widespread, particularly in synclines. Contains: *Turrilites bosquensis, Scaphites subevolutus* + spp., *Adkinsia* (several spp.), *Submantelliceras* spp.
	(2)	*Pseudananchys supernus* (echinoid). North - central Texas, west Texas, Coahuila, probably widespread.
GEORGETOWN (Main Street)	(1)	*Graysonites-Mantelliceras zone.* Widespread. Zone of *Turrilites brazoensis, Kingena, Pervinquieria* (highest), *Alectryonia quadriplicata* (highest), etc.

Foraminifera of the Del Rio Clay are characterized by great abundance and a large number of species. D. L. Frizzell (1954) lists 101 species occurring in the Grayson Marl and equivalent Del Rio Clay. Within the area of study the writer identified 55 species. Others were probably present, but the condition of the tests made accurate identification very difficult.

The microfaunal assemblage, although similar over most of the study area, was not found to be constant from one locality to another. Variation occurred primarily in the relative abundance of the various species. Samples taken in a vertical sequence from one locality were found to have less variation than samples collected from the same stratigraphic horizon at two widely separated localities. Loss or gain in number of species from one locality to another was less noticeable than the relative abundance of individual species. However, there appeared to be a gradual loss in number of agglutinated species southward in a north-south sequence of localities.

Within most measured sections, certain narrow zones (3 to 6 inches) were found to be deficient both in relative abundance and number of species. This condition was especially notable in zones which contained

*Adkins and Lozo, 1951, p. 153.

selenite layers and were near the contact with the overlying Pepper Shale. Frequently these zones contained large numbers of the pelecypod, *Exogyra arietina.* The poor condition of the foraminifera tests from these zones suggests that many were destroyed by percolating acids along joints and pores so common along zones containing selenite.

The most abundant species was the planktonic *Globigerina infracretacea* (Appendix II). This species made up at least 30 percent of the foraminifera population in the Belton area and 20 percent of the total in the northern or Whitney area.

The next two most abundant species, *Anomalina plummerae* and *Lenticulina gaultina* were usually found to be about 10 percent of the total foraminifera population. *Spiroplectammina nuda* was present in nearly every sample and made up a large proportion of the agglutinated species northward from Waco. There were, apparently, no coarse arenaceous foraminifera within the study area. Tests of coarsely agglutinated foraminifera were made of broken pelecypod shells, usually *Gryphaea.*

In certain samples, many *Globigerina* were found to be stained red, even though other species were unaffected. There was no apparent correlation between the stained *Globigerina* and the zones of ocherous hematite, because they were found above and below the zones. One species, *Massilina planoconvexa,* often contained pyrite in the samples collected in Hill County.

GEORGETOWN FORMATION

Although *Kingena wacoensis* is the diagnostic fossil of the Georgetown Formation, it is found in certain horizons and may be missing in any isolated part of the section. The same thing could be said of *Turrilites brazoensis.* The most common fossil of the Georgetown Formation is *Gryphaea washitaensis,* which can be found throughout the formation. *Pecten* can be found at any horizon in the formation but is not as numerous as *Gryphaea.* The ammonite *Pervinquieria* can be found in nearly every member but is more common in some zones than others.

The relative abundance of zonation of the Georgetown fauna was described by Dixon (1967, p. 245-250). There appears to be lateral faunal continuity in the Georgetown Formation in the study area. However, the loss of key stratigraphic markers in the southern part of this study area has made the zonation there difficult.

Georgetown microfauna was not examined with the detailed care given to that of the Del Rio Formation. The poor condition of the microfossils, due to a carbonate "crust," made identification difficult. In addition, because of lithologic variation, a large number of samples would have been needed to examine thoroughly the seven members. The loss of shale units and members southward made inter-member correlation difficult. Finally, the shale units from which the samples were taken represented a very small percentage of the total Georgetown interval. However, 53 samples in the formation were examined in order to determine the most common microfossils of the members in the study area. Only the 15 most common genera were selected for study even though others were present in lesser quantity (Appendix II).

There was little variation in the foraminiferal assemblage from member to member. Variation occurred mainly in the relative abundance of certain genera. Even samples taken from very thin shale beds had virtually the same assemblage as those taken from larger shale intervals. This suggests a microfaunal continuity through the Georgetown Formation regardless of type of lithology.

Many "tooth like" particles were observed in nearly every Georgetown sample. These were later identified as skeletal support for fish fins (pterygyophores). Common in the upper Georgetown members, but rare in the lower members, are sponge spicules. Other common inclusions are pyritized gastropods, echinoid plates, pieces of hematite and shell "hash," especially in the Kiamichi Member.

In the Main Street Member, like most of the Georgetown Formation, various agglutinated genera made up a large percentage of the total foraminiferal population. However, the most common genus was the planktonic genus *Globigerina.* Also common was the attached foraminifer *Acruliammina.* Broken bits of *Gryphaea* shells are common and many have attached foraminifera. *Reophax* could be found in nearly every Main Street sample. *Lenticulina* was common, but individual specimens were not as large as those in the overlying Del Rio Formation and almost every specimen was broken.

Lenticulina was common in the Pawpaw Member and as in the Main Street Member most of the specimens were broken. *Globigerina* was less common than in the Main Street but still formed a large percentage of the foraminiferal population. The Pawpaw Member was notable mainly for the absence of *Frondicularia, Gyroidina,* and *Nodosaria* in the samples examined.

More samples from the Weno Member were examined than any other member. Likewise there was more variation from sample to sample. Some samples were noticeably deficient in many genera even though they did contain the most common genera of the member. Most common genera are *Globigerina, Lenticulina, Acruliammina,* and in the lower part of the member, *Lagena.*

The Denton Member had a large amount of shell "hash" and this was probably due to the abundance of *Gryphaea.* The most common genus in the Denton was *Ammobaculites* which makes its test of shell "hash." Other common genera include *Globigerina, Lenticulina,* and *Textularia.*

The Fort Worth Member is characterized by the great abundance of *Globigerina.* In most of the Fort Worth samples *Globigerina* is about 30 percent of the total foraminiferal population. Other common genera in the Fort Worth Member are *Ammobaculites* and *Textularia. Lenticulina, Spiroplectammina,* and *Anomalina* were found in every sample but were not noticeably abundant. *Gyroidina* and *Frondicularia* are absent in the Fort Worth samples.

The Duck Creek Member has more genera and a greater abundance of microfossils than any other member. *Globigerina* is not so common as in other members,

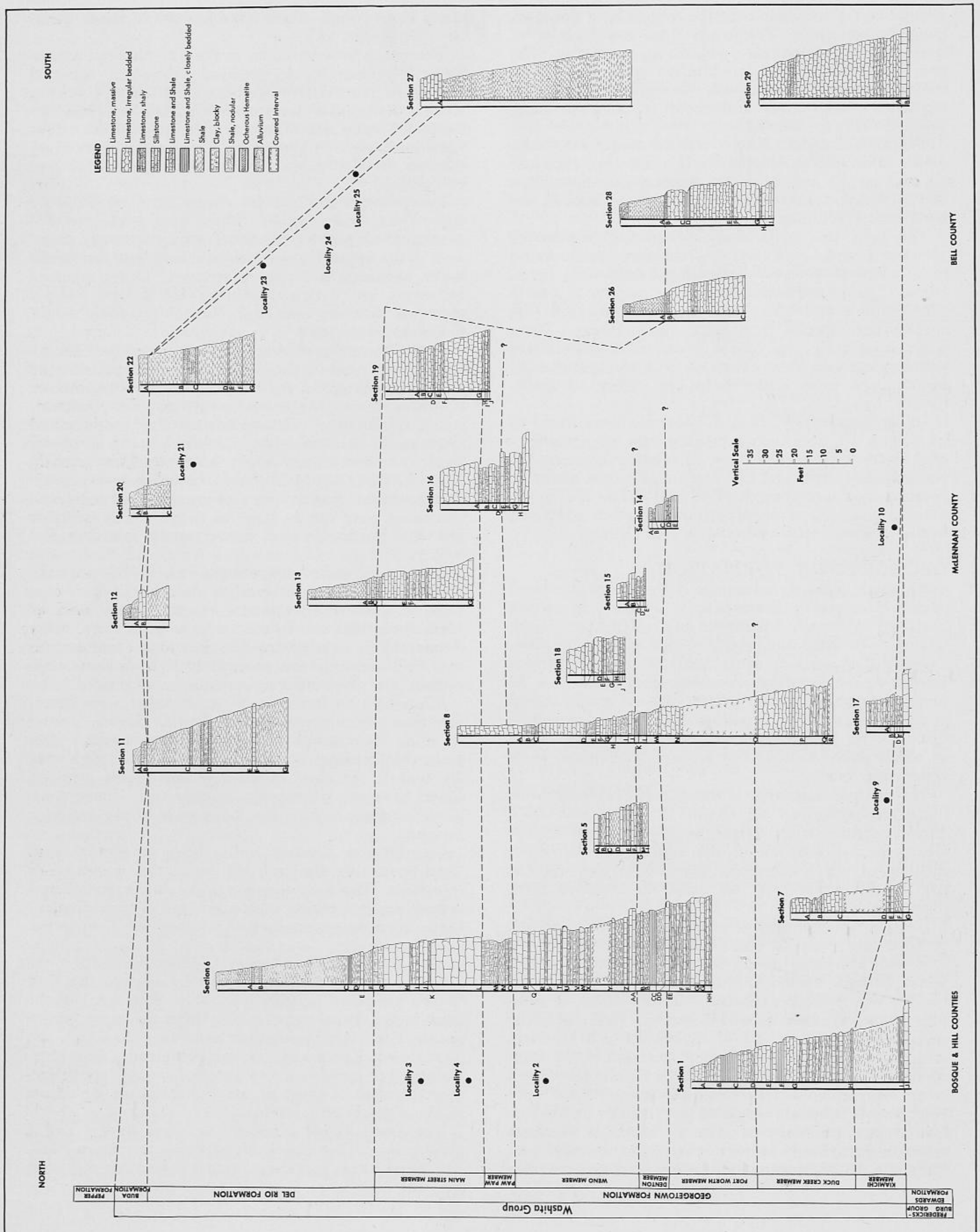

Fig. 8. Outcrop correlations, Washita Group, Central Texas. For location of sections see Figure 2 and Appendix I.

but most genera are well represented. *Frondicularia,* although not abundant, was found in every sample. Except for greater abundance and the presence of *Frondicularia,* the Duck Creek samples resemble those of the Fort Worth Member.

Samples of the Kiamichi Member had the most bulk after preparation and washing, but there were few foraminifers. Kiamichi samples consisted of great amounts of shell "hash" and limestone fragments. In some samples there were more ostracodes than foraminifers possibly due to the greater durability of ostracode shells. Only agglutinated genera were present in the samples examined. Six genera were identified and two of those were identified only with difficulty because of the poor condition of their tests. The most common genus was *Cribratina.* The reason for the abundance of *Cribratina* may be in the construction of the test. *Cribratina* has a labyrinthic interior and a rounded exterior which should add great durability to the test. Others found in most samples included *Reophax, Acruliammina, Textularia* and *Ammobaculites.*

DEPOSITIONAL ENVIRONMENT

Lithology and fauna of the Washita Group are both indicative of a warm, open marine environment. Despite the lithologic changes which occurred during the passage of time, that environment did not greatly change. During the Washita interval of time, only two anomalous episodes had any major influence on the depositional environment. The first of these was the regression of the warm Cretaceous seas which allowed the deposition of the calcareous muds and clays of the Del Rio sediments. This regression created a situation where temporary localized changes could occur in an otherwise stable environment. The second episode, the transgression of the sea during the Buda interval, was more gradual and resulted in the uniform lithology of the Buda Formation.

The initiation of Washita "time" is still somewhat questionable. The stratigraphic significance of the Kiamichi Member of the Georgetown Formation is not clear (see Stratigraphy). From the condition of the microfossils and the large amount of shell "hash" present in the lower Kiamichi, it is concluded that the depositional environment was one of high energy early in the Georgetown interval. The amount of shell "hash," however, decreases near the contact with the overlying Duck Creek Member. This early trend to a low energy, stable environment continued on through Georgetown deposition. The lower shale units of the Duck Creek Member have less shell "hash" than the Kiamichi Member and they also contain sponge spicules and fish remains (see Paleontology) as do the other Georgetown members.

The introduction of fine clastic sediments occurred at irregular intervals. These interruptions of what is normally a limestone sequence, provide the lithologic differences by which the members are identified in central Texas. The calcareous shale intervals do not appear to be the result of great changes in the environment, although the concentration of oysters in certain shales may indicate current or depth changes. There is definite faunal continuity through these shale intervals. Foraminiferal assemblages from two different shale units, separated by several feet of limestone, do not differ greatly. In the southern part of the study area, the shale units are thin and probably reflect only minute changes in the sedimentary environment of this area. Therefore, the entire Georgetown interval could be said to have nearly uniform depositional environment.

Using microfossils as indicators, the depth of water during the Georgetown interval was probably between 100 and 600 feet (Phleger, 1960, p. 59-67). The microfaunal assemblage is typical of that found in the middle and outer neritic zones. The salinity was apparently normal and the temperature of the seas was probably typical of that found in warm temperate regions.

Maximum variations in sedimentary environment occurred during the Del Rio interval of time when regression of the Cretaceous seas brought a change in water chemistry. The varied lithology and fauna of the Del Rio Formation are indicative of a near shore environment, such as that of a bay, large estuary, or lagoon. Salinities of lagoons, estuaries, and bays are highly variable, ranging from brackish to marine to hypersaline condition from season to season. Oxygen content and pH also vary greatly in such an environment. There is likewsie a variation with depth, so it is possible to have one environment near the surface and a completely different one at the depositional interface. The highly variable water chemistry possible under such conditions contributed greatly to the diverse fauna of the Del Rio Formation, especially the benthonic fauna.

An open connection to the sea was probably maintained at all times, for the planktonic *Globigerina* is the most common foraminifer at all horizons within the formation. This suggests that the surface conditions did not vary as much as the bottom conditions and there is some evidence that the bottom conditions were nearly toxic at times. Toxic bottom conditions were probably responsible for the failure of certain ammonites and gastropods to reach full size. There are also certain zones within the Del Rio Formation where all the *Exogyra arietina* are juvenile specimens. However, whether this is due to competition or water chemistry is still undecided. There are pyritic micromorphs in the Del Rio Formation and an analysis of other cases of dwarf fauna clearly shows an association with iron-rich sediments. Further study of the depositional conditions of iron-rich sediments reveals that most are deposited in humid restricted environments of a reducing nature. The principal attributes of sediments formed in humid restricted areas are their dark color, their high organic content, the common association of pyrite, and their generally depauperate faunas. Most of the attributes mentioned above are found in the Del Rio Clay. Therefore, the sediments of the Del Rio Clay represent a distinct chemical environment. It is a chemical environment isolated from the atmosphere and also partially from normal sea water. The area probably was periodically invaded by fresh water, as is indicated by the abrupt changes in sediment types. However, the area was probably calm as opposed to the high energy of a beach area since tests of the varied microfauna of the Del Rio are well preserved.

The Del Rio Formation contains little coarse clastic materials, therefore the nearby land mass was of low relief.

Environmental conditions during deposition of the Buda Limestone were more stable than those during deposition of the Del Rio Formation. The rock suggests a return to a more open marine environment, interpreted as a gradual transgression of a shallow, warm Cretaceous sea.

The Buda Formation is fossiliferous indicating favorable environmental conditions for growth and reproduction of both the megafauna and microfauna. J. R. Ray (1963, p. 17) noted the large size of the oysters and suggested that the salinity was between brackish and normal marine.

Subsurface study reveals that Buda outcrops in the study area are at the feather edge of the area of Buda deposition. This may indicate the sediments found in the outcrop were near shore. Further evidence for this is found in the quartz sand in Buda samples collected in the Waco area where the Buda Formation is thinnest. Other than the slight difference indicated by the quartz sand, the Buda Formation had a stable environment of deposition.

CONCLUSIONS

The major lithologic changes in the Washita Group in central Texas, occur in the Georgetown Formation. Vertical lithologic changes in the Del Rio Formation are few and horizontal changes are even less conspicuous. The Buda Formation is the most consistent formation of the Washita Group in the study area in both lithology and paleontology.

The vertical lithologic variation in the Del Rio Formation was mainly the result of chemical changes in the sedimentary environment. The chemical changes allowed intermittent deposition of coquinoid limestones and ocherous hematite in what usually was a clay sequence. Chemical changes were very localized because the ocherous hematite and coquinoid limestones are not traceable over several hundred yards. There appears to be little faunal variation in the Del Rio Formation in the study area. Except for that noted in the coquinoid limestones the faunal variations are unrelated to lithologic changes and are apparently more closely related to small, horizontal, environmental factors such as salinity, depth, temperature, etc., which affect the distribution of certain species. The overall lateral continuity of the Del Rio Formation, both in outcrop and subsurface, testifies to the environmental stability of the central Texas area during the Del Rio interval of time.

Lithologic changes in the Georgetown Formation are the result of either the presence or absence of fine clastic deposition mainly in the form of calcareous shales. The irregular-bedded limestones of the formation, while thinning southward, are remarkably similar throughout the study area. There is a definite reduction in the amount of calcareous shales southward through McLennan County. Therefore, those members of the Georgetown Formation containing the largest percentage of calcareous shales exhibit the greatest lithologic changes. The Pawpaw and Kiamichi members are composed almost entirely of calcareous shales, therefore, they gradually lose their lithologic identity southward and apparently have no Bell County equivalents in the Georgetown Formation. The Weno and Denton members contain a large percentage of calcareous shale in the northern part of the study area and gradual loss of these shales results in a major reduction of thickness southward into Bell County. The Main Street, Fort Worth, and Duck Creek members, which contain mostly limestones, thin only slightly southward.

There appears to be no major faunal variation in the Georgetown Formation except the vertical variation characteristic of the individual members.

The environmental significance of the lithologic changes mentioned above can be better assessed if the information obtained in a subsurface study of the Washita Group and individual formations is added to the surface investigation. The entire group generally trends toward uniformity of sedimentation over a wide area. Early in the depositional history of the Georgetown Formation when the lower members were being deposited, there were two, possibly three, reasons for variable sedimentation. The first was the "Belton High" which partially separated the Georgetown sediments of the study area from those farther south. The second, by implication, was the location of the source area for the fine clastics in a northern direction, which resulted in the deposition of more calcareous shale northward. The third, of which there is only limited evidence, was the presence of prominent biohermal reefs in the underlying Edwards Formation. These reefs caused thinning of the Kiamichi and lower Duck Creek members in certain areas of the subsurface. The effects of all three apparently lessened with the passage of time and the continued accumulation of sediments, for the lithology of the Main Street Member, along with the Del Rio and Buda formations, has lateral continuity in the study area.

There is a difference in the characteristic lithology of each formation in the Washita Group. A regression of the warm Cretaceous seas, which had deposited the limestones and calcareous shales of the Georgetown Formation, allowed deposition of the muds and clays of the Del Rio Formation. A gradual but limited transgression of the seas followed the Del Rio interval of time. The chemical and biological changes thus introduced resulted in deposition of the fossiliferous Buda Limestone.

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APPENDIX I

MEASURED SECTIONS AND LOCALITIES*

Measured Section 1

Section on railroad cut by abandoned railroad bridge on north end of Lake Whitney, Hill County.

Georgetown Formation**

Fort Worth Member	Thickness (feet)
A. Limestone: nodular, soft, weathers white, lower portion characterized by a one-foot thick receding shale bed, unit is badly weathered and is slumping in most places, overlain in part by quartzite gravels.	5.2
B. Shale and limestone: very soft, recedes from beds below, nodular throughout.	4.7
C. Limestone and shale: nodular irregular bedded limestones interbedded with 3-inch shale beds, unit contains more shale and is darker in color than unit A above, middle portion has strongly projecting limestone bed 9 inches thick.	6.25
D. Shale and limestone: slightly receding zones, interbedded thin nodular limestones.	5.7
Duck Creek Member	
E. Limestone: very hard and projecting, irregular bedded, weathers dark.	5.5
F. Shale and limestone: very fossiliferous, one hard 14-inch limestone in center of unit.	5.4
G. Limestone: hard projecting, irregular bedded, iron-stained, similar to unit E above, weathers dark.	4.5
H. Limestone and shale: mostly a limestone unit with some thin interbedded shales, upper 12 feet consists of irregular bedded limestones with 3-inch shales, upper portion is very weathered and lighter in color than units above and below, lower portion is characterized by three one-foot thick projecting limestones and more shale.	18.1
Kiamichi Member	
I. Shale: calcareous and silty in lower part, scattered nodules of limestone occur throughout unit, weathers brown contrasting with white color of Edwards Limestone below.	17.1
Fredericksburg Group	
Edwards Formation	
J. Limestone: hard massive.	20

Locality 2

Section on Bear Creek, 2.4 miles west of Farm Road 933, 2 miles east of Lake Whitney, Hill County.

Approximately 30 feet of highly weathered limestone and shale (Weno Member). Three samples taken, two of shales and one of a hard resistant limestone.

Locality 3

Section along unnamed creek 5.1 miles north of Whitney, Texas on Farm Road 933, Hill County.

Approximately 16 feet of limestone (Main Street Member). Two samples taken.

Locality 4

Section in dump grounds, one-fourth mile west of Whitney, Texas on Farm Road 1244, Hill County.

Approximately 12 feet of limestone (Main Street Member). One sample taken.

Measured Section 5***

Section on road cut, 0.4 mile south of intersection of State Highway 22 and Farm Road 219, Bosque County.

Georgetown Formation

Weno Member	
A. Limestone: projecting, fine-grained, shaly parting in middle of unit.	1.5
B. Shale: weak shaly limestone beds near the top, small echinoids, large specimens of *Macraster obesus* and *Pecten* occur in this unit.	2.75
C. Limestone: projecting, typical Georgetown lithology.	0.5
D. Shale: with two or three laterally variable limestones that project in places.	4.0
E. Limestone and shale: hard and coarse-grained, limestone, variable thickness, projecting, shale is receding, poorly exposed due to wash from above, hard fine-grained limestone bed 10 inches thick occurs near the base of this unit.	3.50
F. Limestone: very hard, fine-grained, large brown-stained borings, projecting, most prominent unit in exposure. (=Ocee ledge of Dixon)	1.84
Denton Member	
G. Shale: poorly exposed, less fossiliferous than beds immediately below.	1.16
H. Limestone: soft and slightly projecting, coquinoidal with *Gryphaea washitaensis.*	0.58
I. Shale: filled with *Gryphaea,* and fragments of *Gryphaea,* and scattered specimens of *Kingena* of large size.	2.33

Measured Section 6†

Section along White Rock Creek, 4 miles west of Aquilla, Texas, Hill County.

Del Rio Formation	
A. Clay: highly weathered, contains numerous *Exogyra arietina,* several slumping zones covered by quartzite gravels.	16
B. Clay and ocherous hematite: iron rich zone, contains scattered *Exogyra arietina,* weathers red contrasting with pale yellow color of clays above and below.	4.1
C. Clay: highly weathered, yellow-brown color, this unit and unit below contribute badland look to topography.	22.92
D. Clay: numerous *Exogyra arietina,* several silty layers near upper part, weathers light in color.	4.16
E. Limestone: hard and projecting, fossiliferous.	0.5
F. Shale: calcareous, blue-gray color, numerous *Exogyra arietina,* can be distinguished from unit D above by greater resistance and darker color.	3.42
Georgetown Formation	
Main Street Member	
G. Limestone and shale: thin, irregular bedded limestone beds with 1- to 2-inch shale partings, weathered iron nodules, scattered juvenile specimens of *Exogyra arietina,* contains *Turrilites brazoensis.*	4.33
H. Limestone: beds 4 to 8 inches thick, irregular bedded, upper surface where exposed is very uneven and pitted, pyrite nodules common, weathers dark.	9.25
I. Limestone and shaly limestone: receding, more shaly at top and bottom, slightly projecting in middle.	3.16
J. Limestone: hard and projecting, well bedded with irregular bedding planes.	3.33
K. Shale: deeply receding.	0.66
L. Limestone: 4- to 6-inch beds with uneven bedding planes, shaly partings every 18 to 24 inches.	17.58
Pawpaw Member	
M. Limestone: soft and shaly, two thin shale beds near middle, recedes deeply from beds above but less than bed below.	5.58

*For exact map locations, see fig. 2.

**All measured sections and localities are in Comanche Series, Washita Group, except where designated.

***After Dixon, 1955

†Units F through AA adapted from Dixon, 1955.

N.	Shale: deeply receding.	2.5
O.	Shale; calcareous and shaly limestone: not as deeply receding as unit above.	2.66
Weno Member		
P.	Limestone: hard and projecting beds at top, tend to be massive and are more resistant than beds below.	5.5
Q.	Shale: receding.	0.16
R.	Limestone: typical Georgetown lithology, projecting.	5.16
S.	Shale: receding.	1.0
T.	Limestone: typical Georgetown lithology projecting, with 6-inch band of shale at base of unit.	5.16
U.	Limestone: hard and projecting.	3.33
V.	Receding section made up of 6.5 inches of soft limestone, 12 inches of shale, 12.5 inches of gritty nodular limestone, 15.5 inches of shale, and 5 inches soft limestone.	4.26
W.	Limestone: hard, some brown-stained borings.	0.92
X.	Limestone: soft and marly, merges with unit above in places, 1-foot shale at base.	2.67
Y.	Covered interval.	7.33
Z.	Shale and limestone: mostly shale with 7-inch limestone at top and 15-inch massive limestone near base of unit, whole unit recedes from bed below.	5.74
AA.	Limestone: very hard, fine-grained, large borings filled with brown-stained limestone, single massive bed. (=Ocee ledge of Dixon)	2.0
Denton Member		
BB.	Shale: receding, weathers yellow, upper part fissile, middle part contains hard projecting 7-inch *Gryphaea* ledge, lower part consists of numerous *Gryphaea* in a receding shale.	5.00
CC.	Limestone: thin-bedded, thin shale partings, *Gryphaea* ledge in middle, flaggy appearance.	1.92
DD.	Shale and nodular limestone: shale is fissile (unlike beds below) whole unit is receding, highly weathered.	3.92
Fort Worth Member		
EE.	Limestone: projecting, hard, borings, blocky appearance, uniform thickness contrasts with units above and below.	0.66
FF.	Limestone and shale: irregular bedded, nodular limestone and shale in 3- to 4-inch beds, *Gryphaea* numerous in shale beds, also scattered echinoids. *Pecten* numerous in limestones, entire unit somewhat receding, less iron stains and more shale than in unit below.	7.16
GG.	Limestone: 3- to 5-inch beds with interbedded shales, iron stains common, soft beds contain *Gryphaea,* shale beds are several inches thick on upper one-third of unit, each limestone bed projects slightly.	4.75
HH.	Shale and limestone: upper 12 inches is a shale with limestone nodules.	2.25

Measured Section 7

Section on Mills Creek, 1.4 miles south of Smith Bend, Texas, Thomas Farm, Bosque County.

Georgetown Formation		
Duck Creek Member		
A.	Limestone: irregular bedded, softer than unit C below, weathers white, thin shale partings.	6.92
B.	Shale and nodular limestone: upper and lower part of unit is receding, middle part of unit contains nodular limestone in a calcareous shale.	3.84
C.	Limestone and clay: lower part nearly massive irregular bedded, but not nodular, resistant, forms small waterfall, contains numerous ammonites, clay weathers light gray, receding.	8.16
D.	Covered interval.	14.32
Kiamichi Member		
E.	Shale and limestone: shale is lighter in color than in units above, limestone has numerous *Gryphaea,* limestones are slightly projecting, shale is receding, fissile and weathers light tan.	2.08
F.	Shale: black, fissile, not densely fossiliferous, limestone nodules not continuous, but layered, numerous fine limestone fragments and broken shells.	3.66
Fredericksburg Group		
Edwards Formation		
G.	Limestone: hard and projecting, massive.	8

Measured Section 8

Section on Childress Creek at bridge on Farm Road 2490, Wortham Bend area, McLennan County.

Georgetown Formation		
Main Street and Pawpaw members		
A.	Limestone: highly weathered, forms numerous nodules on surface, contains several soft beds which have more dense vegetation, unit is more continuous near lower surface.	22.33
Weno Member		
B.	Limestone: very shaly, uniform slope with unit above.	3.84
C.	Shale: weakly resistant, receding, numerous iron stains.	1.33
D.	Limestone: nearly same as limestone unit A above, with narrow layers of marl and some projecting ledges of massive limestone.	16.0
E.	Shale: fissile for upper 25 inches, thin limestone nodules in lower 15 inches.	3.33
F.	Limestone: resistant, projecting, fine grained, vertical jointing.	0.84
G.	Limestone: nodular, weakly resistant, some intermittent shale.	4.5
H.	Limestone: hard resistant, weathers light red.	0.92
I.	Shale: middle 14 inches is fissile, upper 16 inches has limestone nodules, lower 23 inches has more limestone.	4.42
J.	Limestone: hard and projecting, forms ledge.	2.0
Denton Member		
K.	Shale: receding, contains numerous small *Gryphaea.*	1.42
L.	Limestone and shale: *Gryphaea* beds form ledges, numerous shells.	2.84
M.	Shale: slightly receding.	3.49
Fort Worth Member		
N.	Limestone and shale: alternating nodular limestone and 3-inch shale beds.	6.5
O.	Covered interval: nearly all in Fort Worth Member.	24.92
Duck Creek Member		
P.	Limestone: irregular bedded, contains numerous *Gryphaea* in certain beds, very soft and shaly in middle and lower part of unit.	16.08
Q.	Limestone and shale: contains several hard projecting limestones separated by thin irregular-bedded shales, form several ledges near river surface.	8.64
R.	Shale: mixed with river gravels, difficult to determine exact thickness.	

Locality 9

Section on Childress Creek, ½ mile upstream from its junction with Willow Creek, Bosque County.
Approximately 12 feet of limestone and shale. Edwards Limestone in creek bed and Kiamichi and Duck Creek members on embankment along the creek. One sample taken of Kiamichi Member.

Locality 10

Section along Farm Road 2704, 1.8 miles east of junction with Farm Road 56, Bosque County.
Approximately 26 feet of Duck Creek and Kiamichi members on a large Fredericksburg section. Three samples taken.

Measured Section 11

Section in stream, 200 yards east of spillway of Lake Waco Dam, McLennan County.

Gulf Series		
Pepper Formation		
A.	Shale: soft, receding, fissile, contains jarosite.	3
B.	Siltstone: thin bedded, reddish-brown, projecting	1.33

highly weathered and fractured, some layers harder than others.
Comanche Series
Washita Group
Del Rio Formation
C. Shale: blocky, dark gray, numerous *Exogyra arietina,* several zones of thin-layered pyrite, broken shells throughout unit. 15.1
D. Shale and ocherous hematite: scattered lens of ocherous hematite in blocky clay, "shell hash" throughout whole unit. 7.16
E. Clay: blocky dark gray, similar to shale unit above, not as highly weathered, numerous *Exogyra arietina* in horizontal zones, whole unit very fossiliferous. 14.3
F. Limestone: very resistant, projecting, contains many *Gryphaea washitaensis,* recrystallized, very uneven upper surface, weathers red, cannot be traced for any distance horizontally. 1.16
G. Shale: very dark and blocky, few fossils except for scattered juvenile forms of *Exogyra arietina,* forms base of stream. 12.0

Measured Section 12

Section Keyes Branch, next to cemetery in Bosqueville, McLennan County.
Gulf Series
Pepper Formation
A. Shale: highly weathered, dark, receding and covered by limestone gravel. 2
Buda Formation
B. Limestone: hard and durable, projecting, very dense reddish brown, joints appear perpendicular to bedding planes causing square cornered blocks, contains numerous fossils in places, mostly *Pecten* and *Gryphaea.* 2.33
Del Rio Formation
C. Shale: blocky, highly weathered, except just under limestone ledge, where blue gray in color, weathered surface is yellow-brown, lower surface covered by muds and gravels of stream bed. 8.0

Measured Section 13

Section by Lake Waco, in Speegleville Park, 2 miles north of Speegleville near Old DeHay's Crossing, McLennan County.
Del Rio Formation
A. Clay: yellow to buff, highly weathered upper surface covered in places by limestone gravels, occasional siltstones 1 to 2 inches thick, numerous *Exogyra arietina* especially near lower surface. 20
B. Siltstone: calcareous, thin bedded. 1.16
C. Limestone: highly fossiliferous, hard and resistant, upper surface irregular "patterned," contains *Gryphaea* and *Exogyra.* .84
Georgetown Formation
Main Street Member
D. Limestone and shale: thin bedded, contains scattered *Exogyra arietina* and *Pecten.* 2.5
E. Limestone: beds 6 to 8 inches thick, blocky near middle of unit, irregular bedded near upper 4 feet, very little vertical jointing, occasional marly partings in upper portion of unit. 10.5
F. Shale: noticeably receding, calcareous. 1.25
G. Limestone: irregular bedded, especially in lower 10 feet, where unit becomes nodular with interbedded calcareous shales. 17.33

Measured Section 14*

Section on Hog Creek, ¾ mile upstream from Ocee, McLennan County.
Georgetown Formation
Denton Member
A. Limestone: abundant specimens of *Gryphaea.* 0.42
B. Limestone: soft and shaly, *Gryphaea* common. 0.58
C. Limestone and shale: thin bedded, alternating. 3.67
Fort Worth Member
D. Limestone and shale: two beds with 1 and 0.5 inches of shale between, fossiliferous with *Pecten,* echinoids, and small ammonites, holds up small waterfall, base of unit contains calcareous shale and nodular limestone. 2.02
E. Shale and limestone: thin bedded, receding, many large echinoids and ammonites. 2.33

Measured Section 15*

Section of Hog Creek, 0.25 mile upstream from Ocee, McLennan County.
Georgetown Formation
Weno Member
A. Limestone and shale: unit contains coarse-grained projecting limestones separated by highly weathered receding shales. 5.68
B. Limestone: hard and blocky, brown-stained borings, holds up waterfall.
Denton Member
C. Shale: receding. 0.84
D. Limestone: many *Gryphaea* and *Pecten,* large specimens of *Kingena* at base of this member. 1.16
E. Shale: receding, literally filled with *Gryphaea washitaensis,* large specimens of *Kingena* at top. 1.16
F. Limestone: forms creek bed at base of small falls, a coquina of *Gryphaea.* 0.42

Measured Section 16*

Section on Hog Creek, by bridge on Speegleville Road, 0.25 mile southwest of Speegleville, McLennan County.
Georgetown Formation
Main Street Member
A. Limestone: hard, beds 4 to 6 inches thick, shaly partings every 18 to 24 inches. 13.0
Pawpaw Member
B. Limestone: soft and marly, receding, more shaly and more deeply receding at top. 3.42
C. Limestone: 4- to 8-inch beds with shaly partings, slightly projecting. 2.5
D. Shale and shaly limestone: contains limestone nodules, deeply receding. This unit is part of a prominent receding zone made up of units B, C, and D. 1.33
Weno Member
E. Limestone: massive and hard, conspicuous borings, iron stains common. 1.59
F. Limestone: soft and shaly, *Alectryonia carinata, Pecten,* receding.
G. Limestone: hard and projecting, tendency to be massive but splits into beds on weathering, borings common and stained brown. 3.66
H. Shale: calcareous, receding. 0.33
I. Limestone: hard and projecting, bedding planes uneven and 4 to 8 inches apart, forms bed of stream. 2.0

Measured Section 17*

Section on Middle Bosque River, 250 yards downstream from bridge, 2 miles west of Windsor, McLennan County.
Georgetown Formation
Duck Creek Member
A. Limestone and shale: mainly a limestone unit with 1- to 2-foot limestones separated by 2- to 4-inch calcareous shales, uniform bedding except where unit rises over Edwards bioherm. 8.15
B. Limestone: almost coquinoid in places with *Kingena,* and *Idionamites,* very hard and projecting. 1.33
Kiamichi Member
C. Shale with limestone: calcareous shale and nodular limestone, echinoids, *Kingena, Gryphaea, Exogyra,* and *Oxytropidoceras,* many shell fragments. 1.99
D. Limestone: impure, grades into unit below. 0.25
E. Shale: noncalcareous. 0.33

*After Dixon, 1955

Fredericksburg Group
Edwards Formation
F. Limestone: rudistid reef, forming river bed.

Measured Section 18

Section on road cut on Farm Road 317, 2 miles north of McGregor, McLennan County.
Georgetown Formation
Weno Member

A.	Limestone: nodular, no definite bedding planes, irregular surface, weathered surface dark.	6.33
B.	Limestone: irregular bedding, resistant, protruding, second most prominent ledge, weathers black.	2.33
C.	Shale: receding, limestone nodules.	0.75
D.	Limestone: nearly massive, somewhat wavy exterior surface, projecting, resistant, weathers lighter than beds above, iron stains common.	2.66
E.	Shale: receding, very noticeable, even though thin.	0.25
F.	Limestone: irregular upper and lower surface, in places nearly "squeezed out" by shale units above and below.	0.66
G.	Shale and limestone: numerous nodules of limestone, somewhat receding.	3.08
H.	Limestone: nearly massive white, projecting, resistant.	1.33
I.	Shale: receding, much like unit C, limestone nodules.	0.5
J.	Limestone: weakly persistent, similar to unit F, irregular upper and lower surface.	0.33
K.	Shale: calcareous, highly weathered, limestone nodules.	1.33

Measured Section 19*

Section on Middle Bosque River, 0.5 mile upstream from its junction with South Bosque River, McLennan County.
Georgetown Formation
Main Street Member

A.	Limestone: uneven bed 3 to 4 inches thick in upper 6 feet, middle of unit massive in places, lower 3 feet of unit is similar to upper portion.	11.74
B.	Shale and nodular limestone: prominent receding unit, shale is fissile, middle of unit projects slightly.	2.08
C.	Limestone: forming a sloping shelf, beds 6 to 8 inches thick, bedding indistinct in lower part.	2.84
D.	Shale: deeply receding.	0.33
E.	Limestone: beds 3 to 6 inches thick, uneven planes, forms a sloping shelf.	1.25
F.	Shale: wavy bedding.	0.08
G.	Limestone: irregular-bedded limestone with occasional thin calcareous shale partings, a fossiliferous zone occurs in the upper 4 feet of unit, some of the fossils are pyritized.	12.92

Pawpaw Member

H.	Limestone: projecting.	0.33
I.	Shale: calcareous.	0.16
J.	Limestone: in bed of creek.	

Measured Section 20

Section 3/8 mile downstream from junction of Middle and South Bosque rivers, McLennan County.
Gulf Series
Pepper Formation

A.	Shale: dark on fresh surface, yellow brown on weathered surface, fissile, abundant jarosite and selenite.	30
B.	Siltstone: with interbedded silty shale, two 1-inch flagstones separated by 1 inch of shale forms lower portion, 6 inches of silty shale in upper portion.	0.84

Comanche Series
Washita Group
Del Rio Formation

C.	Shale: blue-gray on fresh surface, light gray on weathered surface, contrasts with somewhat darker appearance of Pepper above, very blocky on fresh surface but fissile on weathered surface, not as fissile as Pepper, lower part covered by river.	8.0

*After Dixon, 1955

Locality 21

Section on south side of bridge over South Bosque River on Highway 84, McLennan County.
Approximately 16 feet of Del Rio Formation. Two samples taken, one near lowest visible surface, the other near uppermost surface.

Measured Section 22

Section on South Bosque River, 100 yards east of bridge on Farm Road 2416, 2.1 miles north of Spring Valley, McLennan County.
Gulf Series
Pepper Formation

A.	Shale: fissile, highly weathered, abundant selenite, yellow-brown color.	12

Comanche Series
Washita Group
Del Rio Formation

B.	Clay: badly weathered though not as weathered as overlying Pepper, light gray in color with numerous brown stains, this unit grades into unit below, abundant selenite crystals.	12.0
C.	Ocherous hematite: brown clay zone with red streaks.	4.0
D.	Clay: very much like unit B, though less weathered and more gray in color, units B, C, D total 26 feet in thickness, internal boundaries are gradational.	10.0
E.	Clay: reddish-brown, very soft, numerous *Exogyra arietina,* less selenite than base of unit below.	0.5
F.	Shale: dark, blocky, less dense than unit G. Although similar to unit G, unit appears to have more fossils. On weathered surface jointing is prominent with brown staining in the joints, contrasting with dark gray of shale. *Exogyra arietina* are of adult size, lower 3 inches very dense with *Exogyra arietina* and weathers white.	4.5
G.	Shale: dark, blocky, somewhat more resistant than unit F although similar in appearance, unit has numerous juvenile specimens of *Exogyra arietina,* but very few other fossils are present, lower 1-foot forms river bed and breaks in slabs giving stairstep effect.	4.0

Locality 23

Section along road cut on Farm Road 107, 0.9 miles west of Moody, McLennan County.
Approximately 32 feet of section with lower portion highly weathered. Buda Limestone and Del Rio Clay exposed, two samples taken, one of Buda and one of Del Rio.

Locality 24

Section on tributary of Cedar Creek, 1.6 miles west of Santa Fe Railroad crossing on Farm Road 1237, Bell County.
Approximately 6 feet of highly weathered Del Rio Clay on stream bank. One sample taken.

Locality 25

Section on hill above Shine Branch, 0.9 mile west of Santa Fe Railroad crossing on Farm Road 1237, Bell County.
Approximately 9 feet of Buda Limestone and Del Rio Clay on hill. One sample taken of Buda Limestone.

Measured Section 26

Section on Pepper Creek and along hillside, 0.7 mile north of Santa Fe overpass on Farm Road 817, Bell County.
Del Rio Formation

A.	Clay: badly weathered on upper surface, partially covered by Leon River gravels, light colored on weathered surface, several thin limestone lenses near middle of unit, numerous *Exogyra arietina* in upper 6 feet, somewhat gradational into unit below.	11.0

Georgetown Formation
- B. Limestone: soft and marly, contains juvenile specimens of *Exogyra arietina.* 1.5
- C. Limestone: nodular near upper surface and in certain softer zones, very hard in places, irregular bedded, weathered pyrite stains more noticeable in upper 10 feet, *Kingena wacoensis* more abundant in zone about 3 feet from upper surface, a few very calcareous shales in lower portion. 26.25

Measured Section 27

Section on hill above Leon River, 2,000 feet north of junction of Farm Road 436 and Farm Road 1123, Bell County.

Buda Formation
- A. Limestone: very hard and resistant, caps hill, fossiliferous, yellow to red color, massive, projects over beds below. 7.66

Del Rio Formation
- B. Clay: highly weathered, yellow-brown color. Lower portion partially covered by Leon River terrace. Whole slope contains fragments from Buda. Great abundance of *Exogyra arietina* in zone 30 feet below Buda. Same zone has abundance of ocherous hematite. Only the total Del Rio interval can be measured because of indistinct bedding. 78

Georgetown Formation

Main Street Member
- C. Limestone: soft, shaly, highly weathered. Contains *Turrilites brazoensis,* becomes more resistant below contact with Del Rio. 3

Measured Section 28

Section on Lampasas River, 200 yards west of Elm Grove Church on Elm Grove Road, Bell County.

Del Rio Formation
- A. Clay: badly weathered, covered in part by river gravels, numerous *Exogyra arietina,* several hard layers on lower surface, grades into beds below, much lighter in upper portion than in lower. 12.5

Georgetown Formation

Main Street Member
- B. Limestone: soft and marly, contains juvenile forms of *Exogyra arietina.* 0.84
- C. Limestone: irregular bedded near upper surface, somewhat massive near lower surface, marly partings, between 6- to 8-inch beds, slightly projecting. 6.84
- D. Limestone and marls: prominent receding zone of 3-inch limestones separated by marls. 1.75
- E. Limestone: projecting, most resistant unit of section, irregular bedded, iron stains, a few very narrow interbedded marls. 14.16

Weno Member
- F. Marl: receding. 0.33
- G. Limestone: projecting, irregular bedded, more interbedded marls than unit E. 9.33
- H. Marl: highly weathered, deeply receding. 0.66
- I. Limestone: irregular bedded, partly covered by slumping material from above. 4.0

Measured Section 29

Section on Lampasas River and up hill along dirt road 3/8 mile of Interstate 35, 2.4 miles south of Belton city limits, Bell County.

Georgetown Formation
- A. Limestone: irregular bedded, marly and nodular in places, only total interval available, section measured along roadside, very difficult to determine various resistance of beds. 52.0
- B. Edwards Formation: rudist reef. 15.0

APPENDIX II

MICROFAUNAL DATA

Del Rio Formation

Sections and units are keyed to figure 8. The percentage of clay was determined by volume. The percentage of calcium carbonate was determined by weight. See Appendix III for methods. Explanation of terms:

Rare—less than 5 per 50 cm^2*

Common—more than 5 per 50 cm^2

Abundant—more than 50 per 50 cm^2

*Area of tray with washed sample sprinkled on loosely for ease in picking and mounting specimens.

Georgetown Formation

Microfaunal abundance is listed by member. The first number of the sample number refers to section, the second to units. Sections and units are keyed to figure 8. Terms same as that for Del Rio Formation.

SAMPLE NUMBER VI—B-1

Section number: 6

Stratigraphic unit and location of sample: Del Rio Clay, unit B

Percentage of clay: 90%, Percentage of calcium carbonate: 25%

Coarse fraction inclusions: weathered iron, quartz sand, and pyritized gastropods

Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan		X	
Bullopora laevis (Sollas)	X		
Cribratina texana (Conrad)	X		
Dentalina communis (d'Orbigny)	X		
Gaudryina sp	X		
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Globulina lacrima (Reuss)	X		
Gyroidina loetterlei Tappan	X		
Lagena hispida Reuss var	X		
Lagena striatifera Tappan	X		
Lagenammina pyriformis Tappan	X		
Lenticulina gaultina (Berthelin)			X
Massilina planoconvexa Tappan		X	
Paleopolymorphina ozawai Tappan	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina cylindroides (Roemer)	X		
Pyrulina longa Tappan	X		
Reophax deckeri Tappan	X		
Spiroplectammina nuda Lalicker	X		
Textularia rioensis Carsey	X		
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER VI—C-1

Section number: 6

Stratigraphic unit and location of sample: Del Rio Clay, unit C

Percentage of clay: 90%, Percentage of calcium carbonate: 46%
Coarse fraction inclusions: weathered pyrite, "shell hash," scattered quartz sand
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan		X	
Dentalina communis (d' Orbigny)	X		
Gaudryina sp	X		
Gaudryinella delrioensis Plummer			X
Globigerina infracretacea Glaessner		X	
Globigerina plainspira Tappan	X		
Globigerina washitensis Carsey	X		
Gyroidina loetterlei Tappan		X	
Lenticulina gaultina (Berthelin)		X	
Massilina planoconvexa Tappan		X	
Nodosaria chapmani Tappan	X		
Paleopolymorphia ozawai Tappan	X		
Spiroplectammina nuda Lalicker		X	
Textulara rioensis Carsey	X		
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER VI—C-2

Section number: 6
Stratigraphic unit and location of sample: Del Rio Clay, unit C
Percentage of clay: 95%, Percentage of calcium carbonate: 41%
Coarse fraction inclusions: scattered quartz sand, pyrite and gypsum
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites goodlandensis Cushman & Alexander		X	
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan			X
Bullopora laevis (Sollas)	X		
Cribratina texana (Conrad)	X		
Dentalina communis (d'Orbigny)	X		
Gaudryina sp		X	
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Globulina lacrima (Reuss)	X		
Gyroidina loetterlei Tappan		X	
Lagena hispida Reuss var	X		
Lagena stratifera Tappan		X	
Lenticulina gaultina (Berthelin)			X
Massilina planoconvexa Tappan		X	
Nodosaria chapmani Tappan	X		
Paleopolymorphina ozawai Tappan	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina cylindroides (Roemer)	X		
Pyrulina longa Tappan	X		
Reophax deckeri Tappan	X		
Spiroplectammina nuda Lalicker			X
Textularia rioensis Carsey	X		
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER VI—C-3

Section number: 6
Stratigraphic unit and location of sample: Del Rio Clay, unit C
Percentage of clay: 90%, Percentage of calcium carbonate: 37%
Coarse fraction inclusions: pyrite, quartz sand and gypsum
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites goodlandensis Cushman & Alexander		X	
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan			X
Bullopora laevis (Sollas)	X		
Cribratina texana (Conrad)	X		
Dentalina communis (d'Orbigny)	X		
Gaudryina sp			X
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Globulina lacrima (Reuss)	X		
Gyroidina loetterlei Tappan			X
Lagena hispida Reuss var	X		
Lagena striatifera Tappan	X		
Lagenammina pyriformis Tappan		X	
Lenticulina gaultina (Berthelin)			X
Massilina planoconvexa Tappan		X	
Nodosaria chapmani Tappan	X		
Nodosaria obscura Reuss	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina longa Tappan	X		
Spiroplectammina nuda Lalicker			X
Textularia rioensis Carsey	X		
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER VI—C-4

Section number: 6
Stratigraphic unit and location of sample: Del Rio Clay, unit C
Percentage of clay: 90%, Percentage of calcium carbonate: 37%
Coarse fraction inclusions: scattered quartz sand and large amount of weathered iron
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites goodlandensis Cushman & Alexander		X	
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan			X
Bullopora laevis (Sollas)	X		
Cribratina texana (Conrad)	X		
Dentalina communis (d'Orbigny)	X		
Gaudryina sp		X	
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Globulina lacrima (Reuss)	X		
Gyroidina loetterlei Tappan			X
Lagena hispida Reuss var	X		
Lagena striatifera Tappan	X		
Lagenammina pyriformis Tappan		X	
Lenticulina gaultina (Berthelin)			X
Massilina planoconvexa Tappan		X	
Nodosaria chapmani Tappan	X		
Paleopolymorphina ozawai Tappan	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina cylindroides (Roemer)	X		
Pyrulina longa Tappan	X		
Spiroplectammina nuda Lalicker			X
Textularia rioensis Carsey	X		
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER VI—D-1

Section number: 6
Stratigraphic unit and location of sample: Del Rio Clay, unit D
Percentage of clay: 60%, Percentage of calcium carbonate: 36%
Coarse fraction inclusions: scattered quartz sand, pyrite and large amount of "shell hash"
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammobaculites sp	X		

Ammodiscus cretaceus (Reuss)	X		
Bullopora laevis (Sollas)	X		
Cribratina texana (Conrad)	X		
Dentalina communis (d'Orbigny)	X		
Gaudryina sp	X		
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Gyroidina loetterlei Tappan		X	
Lagena hispida Reuss var	X		
Lagena striatifera Tappan	X		
Massilina planoconvexa Tappan	X		
Nodosaria obscura Reuss	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina cylindroides (Roemer)	X		
Spiroplectammina nuda Lalicker		X	
Textularia rioensis Carsey		X	
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER VI—D-2

SECTION NUMBER: 6
Stratigraphic unit and location of sample: Del Rio Clay, unit D
Percentage of clay: 35%, Percentage of calcium carbonate: 31%
Coarse fraction inclusions: quartz sand, pyrite and "shell hash"
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Bullopora laevis (Sollas)	X		
Cribratina texana (Conrad)	X		
Dentalina communis (d'Orbigny)	X		
Gaudryina sp	X		
Gaudryinella delrioensis Plummer		X	
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Gyroidina loetterlei Tappan	X		
Lagena hispida Reuss var	X		
Lagena striatifera Tappan	X		
Massilina planoconvexa Tappan	X		
Nodosaria obscura Reuss	X		
Paleopolymorphina ozawai Tappan	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina cylindroides (Roemer)	X		
Pyrulina longa Tappan	X		
Spiroplectammina nuda Lalicker		X	
Textularia rioensis Carsey	X		
Tristix tricarinatum (Reuss)		X	
Vaginulina geisendorferi Franke	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER VI—F-1

SECTION NUMBER: 6
Stratigraphic unit and location of sample: Del Rio Clay, unit F
Percentage of clay: 40%, Percentage of calcium carbonate: 18%
Coarse fraction inclusions: pyrite and large amount of shell fragments
Foraminifera:

Species	Rare	Common	Abundant
Anomalina plummerae Tappan			X
Cribratina texana (Conrad)	X		
Globigerina infracretacea Glaessner	X		
Lenticulina gaultina (Berthelin)	X		
Spiroplectammina nuda Lalicker	X		
Textularia rioensis Carsey	X		

SAMPLE NUMBER VI—F-2

SECTION NUMBER: 6
Stratigraphic unit and location of sample: Del Rio Clay, unit F
Percentage of clay: 70%, Percentage of calcium carbonate: 46%
Coarse fraction inclusions: pyrite, numerous shell fragments
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan			X
Bullopora laevis (Sollas)	X		
Cribratina texana (Conrad)	X		
Dentalina communis (d'Orbigny)	X		
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner		X	
Globigerina washitensis Carsey	X		
Globulina lacrima (Reuss)	X		
Lagena striatifera Tappan	X		
Lenticulina gaultina (Berthelin)	X		
Massilina planoconvexa Tappan	X		
Spiroplectammina nuda Lalicker	X		
Textularia rioensis Carsey	X		
Tristix tricarinatum (Reuss)	X		

SAMPLE NUMBER XI—C-1

SECTION NUMBER: 11
Stratigraphic unit and location of sample: Del Rio Clay, unit C
Percentage of clay: 95%, Percentage of calcium carbonate: 13%
Coarse fraction inclusions: pyritized gastropods and ammonites
Foraminifera:

Species	Rare	Common	Abundant
Acruliammina longa (Tappan)	X		
Ammobaculites goodlandensis Cushman & Alexander		X	
Ammobaculites sp	X		
Anomalina plummerae Tappan	X		
Citharina tripleura (Reuss)	X		
Dentalina communis (d'Orbigny)			X
Dentalina hammensis (Franke)	X		
Dentalina sp	X		
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan			X
Globulina lacrima (Reuss)	X		
Gyroidina loetterlei Tappan			X
Lagena hispida Reuss var	X		
Lagena striatifera Tappan	X		
Lagenammina pyriformis Tappan	X		
Lenticulina gaultina (Berthelin)		X	
Marginulina tenuissima Reuss	X		
Massilina planoconvexa Tappan	X		
Nodosaria obscura Reuss	X		
Paleopolymorphina ozawai Tappan	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina cylindroides (Roemer)	X		
Pyrulina longa Tappan	X		
Reophax deckeri Tappan	X		
Schackoina primitiva Tappan	X		
Spiroplectammina nuda Lalicker			X
Textularia rioensis Carsey	X		
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina geisendorferi Franke	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XI—E-1

SECTION NUMBER: 11
Stratigraphic unit and location of sample: Del Rio Clay, unit E
Percentage of clay: 90%, Percentage of calcium carbonate: 16%
Coarse fraction inclusions: pyritized gastropods and ammonites
Foraminifera:

Species	Rare	Common	Abundant
Acruliammina sp	X		
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammobaculites sp	X		
Anomalina plummerae Tappan	X		
Bullopora laevis (Sollas)	X		
Citharina tripleura (Reuss)	X		
Dentalina communis (d'Orbigny)	X		
Dentalina sp	X		
Gaudryinella delrioensis Carsey	X		

Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Gyroidina loetterlei Tappan	X		
Lagena hispida Reuss var	X		
Lagenammina pyriformis Tappan	X		
Lenticulina gaultina (Berthelin)			X
Lenticulina sp	X		
Marginulina tenuissima Reuss	X		
Massilina planoconvexa Tappan	X		
Nodosaria chapmani Tappan	X		
Nodosaria obscura Reuss	X		
Paleopolymorphina ozawai Tappan	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina longa Tappan	X		
Reophax deckeri Tappan	X		
Schackoina primitiva Tappan	X		
Spiroplectammina nuda Lalicker			X
Tristix märtensi (Reuss)	X		
Vaginulina kochii Roemer	X		

SAMPLE NUMBER XI—G-1

SECTION NUMBER: 11
Stratigraphic unit and location of sample: Del Rio Clay, unit G
Percentage of clay: 90%, Percentage of calcium carbonate: 17%
Coarse fraction inclusions: pyritized gastropods and ammonites
Foraminifera:

Species	Rare	Common	Abundant
Acruliammina sp	X		
Ammobaculites goodlandensis Cushman & Alexander		X	
Ammobaculites sp	X		
Anomalina plummerae Tappan			X
Bullopora laevis (Sollas)	X		
Citharina tripleura (Reuss)	X		
Cribratina texana (Conrad)	X		
Dentalina communis (d'Orbigny)			X
Dentalina debilis (Berthelin)	X		
Dentalina hammensis (Franke)	X		
Dentalina sp	X		
Gaudryina sp		X	
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina palnispira Tappan	X		
Globigerina washitensis Carsey	X		
Gyroidina loetterlei Tappan	X		
Lagena hispida Reuss var	X		
Lagenammina pyriformis Tappan		X	
Lenticulina gaultina (Berthelin)			X
Lenticulina sp	X		
Marginulina tenuissima Reuss	X		
Massilina planoconvexa Tappan			X
Nodosaria chapmani Tappan	X		
Nodosaria obscura Reuss	X		
Paleopolymorphina ozawai Tappan	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina longa Tappan	X		
Reophax deckeri Tappan	X		
Schackoina primitiva Tappan	X		
Spiroplectammina nuda Lalicker			X
Textularia rioensis Carsey		X	
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		
Valvulineria asterigerinoides Plummer	X		

SAMPLE NUMBER XII—C-1

SECTION NUMBER: 12
Stratigraphic unit and location of sample: Del Rio Clay, unit C
Percentage of clay: 80%, Percentage of calcium carbonate: 44%
Coarse fraction inclusions: calcite, "shell hash," and scattered well rounded quartz sand
Foraminifera:

Species	Rare	Common	Abundant
Acruliammina longa (Tappan)	X		
Acruliammina sp	X		
Ammobaculites goodlandensis Cushman & Alexander		X	
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan	X		
Dentalina communis (d'Orbigny)	X		
Dentalina sp	X		
Gaudryina sp	X		
Globigerina infracretacea Glaessner			X
Globulina lacrima (Reuss)	X		
Gyroidina loetterlei Tappan	X		
Lagena hispida Reuss var	X		
Lagenammina pyriformis Tappan	X		
Lenticulina gaultina (Berthelin)	X		
Nodosaria chapmani Tappan	X		
Nodosaria obscura Reuss	X		
Paleopolymorphina ozawai Tappan	X		
Pyrulina longa Tappan	X		
Spiroplectammina nuda Lalicker		X	
Textularia rioensis Carsey		X	
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XIII—A-1

SECTION NUMBER: 13
Stratigraphic unit and location of sample: Del Rio Clay, unit A
Percentage of clay: 90%, Percentage of calcium carbonate: 46%
Coarse fraction inclusions: shell fragments
Foraminifera:

Species	Rare	Common	Abundant
Acruliammina longa (Tappan)	X		
Acruliammina sp	X		
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan		X	
Bullopora laevis Tappan	X		
Citharina tripleura (Reuss)	X		
Dentalina communis (d' Orbigny)		X	
Dentalina hammensis (Franke)	X		
Dentalina sp	X		
Gaudryina sp	X		
Gaudryinella delrioensis Plummer		X	
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan		X	
Globigerina washitensis Carsey			X
Globulina lacrima (Reuss)	X		
Gyroidina loetterlei Tappan			X
Lagena hispida Reuss var	X		
Lagena striatifera Tappan	X		
Lagenammina pyriformis Tappan	X		
Lenticulina gaultina (Berthelin)		X	
Lenticulina sp	X		
Massilina planoconvexa Tappan	X		
Nodosaria obscura Reuss	X		
Paleopolymorphina ozawai Tappan	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina longa Tappan	X		
Quinqueloculina moremani Cushman	X		
Schackoina primitiva Tappan	X		
Spiroplectammina nuda Lalicker			X
Textularia rioensis Carsey		X	
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss		X	

SAMPLE NUMBER XIII—A-2

SECTION NUMBER: 13
Stratigraphic unit and location of sample: Del Rio Clay, unit A
Percentage of clay: 95%, Percentage of calcium carbonate: 37%
Coarse fraction inclusions: ocherous hematite, pyrite, and shell fragments
Foraminifera:

Species	Rare	Common	Abundant
Acruliammina longa (Tappan)	X		
Acruliammina sp	X		
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan			X
Citharina tripleura (Reuss)	X		
Dentalina communis (d'Orbigny)	X		
Dentalina hammensis (Franke)	X		
Gaudryina sp		X	
Gaudryinella delrioensis Plummer			X
Globigerina infracretacea Carsey			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey			X
Globulina lacrima (Reuss)	X		
Gyroidina loetterlei Tappan		X	
Lagena hispida Reuss var	X		
Lagena striatifera Tappan	X		
Lagenammina pyriformis Tappan	X		
Lenticulina gaultina (Berthelin)			X
Lenticulina sp	X		
Marginulina tenuissima Reuss	X		
Massilina planoconvexa Tappan	X		
Nodosaria chapmani Tappan	X		
Nodosaria obscura Reuss	X		
Paleopolymorphina ozawai Tappan	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina cylindroides (Roemer)	X		
Pyrulina longa Tappan	X		
Reophax deckeri Tappan	X		
Spiroplectammina nuda Lalicker			X
Textularia rioensis Carsey	X		
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XIII—A-3

SECTION NUMBER: 13
Stratigraphic unit and location of sample: Del Rio Clay, unit A
Percentage of clay: 85%, Percentage of calcium carbonate: 41%
Coarse fraction inclusions: pyrite and shell fragments
Foraminifera:

Species	Rare	Common	Abundant
Acruliammina sp	X		
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan			X
Citharina tripleura (Reuss)	X		
Dentalina communis (d'Orbigny)	X		
Gaudryina sp			X
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina plainspira Tappan	X		
Globigerina washitensis Carsey	X		
Globulina lacrima (Reuss)	X		
Gyroidina loetterlei Tappan		X	
Lagena hispida Reuss var	X		
Lagena striatifera Tappan	X		
Lagenammina pyriformis Tappan	X		
Lenticulina gaultina (Berthelin)			X
Lenticulina sp	X		
Massilina planoconvexa Tappan	X		
Nodosaria obscura Reuss	X		
Paleopolymorphina ozawai Tappan	X		
Pyrulina cylindroides (Roemer)	X		
Pyrulina longa Tappan	X		
Ramulina sp	X		
Schackoina primitiva Tappan	X		
Spiroplectammina nuda Lalicker		X	
Textularia rioensis Carsey		X	
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina recta (Reuss)	X		

SAMPLE NUMBER XX—C-1

SECTION NUMBER: 20
Stratigraphic unit and location of sample: Del Rio Clay, unit C
Percenatge of clay: 95%, Percentage of calcium carbonate: 15%
Coarse fraction inclusions: pyrite and large amount of selenite
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammobaculites sp	X		
Anomalina plummerae Tappan	X		
Dentalina communis (d'Orbigny)	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Gyroidina loetterlei Tappan	X		
Lenticulina gaultina (Berthelin)			X
Lenticulina sp	X		
Nodosaria obscura (Reuss)	X		
Spiroplectammina nuda Lalicker	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XXII—B-1

SECTION NUMBER: 22
Stratigraphic unit and location of sample: Del Rio Clay, unit B
Percentage of clay: 90%, Percentage of calcium carbonate: 22%
Coarse fraction inclusions: pyritized ammonites and gastropods, weathered iron and numerous shell fragments
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Dentalina communis (d'Orbigny)	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan		X	
Gyroidina loetterlei Tappan			X
Lagena hispida Reuss var	X		
Lagena striatifera Tappan	X		
Lenticulina gaultina (Berthelin)		X	
Nodosaria obscura Reuss	X		
Paleopolymorphina ozawai Tappan	X		
Pyrulina longa Tappan	X		
Reophax deckeri Tappan	X		
Spiroplectammina nuda Lalicker	X		
Textularia rioensis Carsey	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XXII—F-1

SECTION NUMBER: 22
Stratigraphic unit and location of sample: Del Rio Clay, unit F
Percentage of clay: 45%, Percentage of calcium carbonate: 77%
Coarse fraction inclusions: selenite and juvenile specimens of *Exogyra arietina*
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites sp	X		
Dentalina communis (d'Orbigny)	X		
Dentalina sp	X		
Globigerina infracretacea Glaessner		X	
Gyroidina loetterlei Tappan		X	
Lagena striatifera Tappan	X		
Lenticulina gaultina (Berthelin)	X		
Nodosaria obscura Reuss	X		
Spiroplectammina nuda Lalicker	X		

SAMPLE NUMBER XXII—F-2

SECTION NUMBER: 22
Stratigraphic unit and location of sample: Del Rio Clay, unit F
Percentage of clay: 95%, Percentage of calcium carbonate: 23%
Coarse fraction inclusions: pyrite and selenite
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammobaculites sp	X		

Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan	X		
Bullopora laevis (Sollas)	X		
Citharina tripleura (Reuss)	X		
Dentalina communis (d'Orbigny)	X		
Dentalina hammensis (Franke)	X		
Dentalina sp	X		
Gaudryina sp	X		
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Globulina lacrima (Reuss)	X		
Gyroidina loetterlei Tappan			X
Lagena hispida Reuss var	X		
Lagena striatifera Tappan	X		
Lagenammina pyriformis Tappan	X		
Lenticulina gaultina (Berthelin)			X
Marginulina tenuissima Reuss	X		
Massilina planoconvexa Tappan			X
Nodosaria obscura Reuss	X		
Paleopolymorphina ozawai Tappan	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina cylindroides (Roemer)	X		
Pyrulina longa Tappan	X		
Reophax deckeri Tappan	X		
Schackoina primitiva Tappan	X		
Spiroplectammina nuda Lalicker	X		
Textularia rioensis Carsey	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XXII—G-1

Section number: 22
Stratigraphic unit and location of sample: Del Rio Clay, unit G
Percentage of clay: 90%, Percentage of calcium carbonate: 27%
Coarse fraction inclusions: pyritized gastropods and ammonites, weathered iron, and selenite
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan		X	
Bullopora laevis (Sollas)	X		
Dentalina communis (d' Orbigny)		X	
Dentalina hammensis (Franke)	X		
Dentalina sp	X		
Gaudryina sp	X		
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Globulina lacrima (Reuss)	X		
Gyroidina loetterlei Tappan			X
Lagena hispida Reuss var	X		
Lagena striatifera Tappan	X		
Lagenammina pyriformis Tappan		X	
Lenticulina gaultina (Berthelin)			X
Massilina planoconvexa Tappan		X	
Nodosaria amphioxys Reuss	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina cylindroides (Roemer)	X		
Pyrulina longa Tappan	X		
Reophax deckeri Tappan	X		
Spiroplectammina nuda Lalicker			X
Textularia rioensis Carsey		X	
Tristix tricarinatum (Reuss)	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XXVI—A-1

Section number: 26
Stratigraphic unit and location of sample: Del Rio Clay, unit A
Percentage of clay: 80%, Percentage of calcium carbonate: 67%
Coarse fraction inclusions: shell fragments
Foraminifera:

Species	Rare	Common	Abundant
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan	X		
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner	X		
Globigerina washitensis Carsey	X		
Gyroidina loetterlei Tappan	X		
Lenticulina gaultina (Berthelin)	X		
Nodosaria chapmani Tappan	X		
Nodosaria obscura Reuss	X		
Spiroplectammina nuda Lalicker	X		
Textularia rioensis Carsey	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XXVI—A-3

Section number: 26
Stratigraphic unit and location of sample: Del Rio Clay, unit A
Percentage of clay: 85%, Percentage of calcium carbonate: 54%
Coarse fraction inclusions: shell fragments
Foraminifera:

Species	Rare	Common	Abundant
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan			X
Cribratina texana (Conrad)	X		
Dentalina communis (d'Orbigny)	X		
Dentalina hammensis (Franke)	X		
Dentalina sp	X		
Gaudryina sp		X	
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Globulina lacrima (Reuss)	X		
Gyroidina loetterlei Tappan		X	
Lagena hispida Reuss var	X		
Lagena striatifera Tappan		X	
Lenticulina gaultina (Berthelin)		X	
Massilina planoconvexa Tappan	X		
Nodosaria obscura Reuss	X		
Pyrulina longa Tappan	X		
Spiroplectammina nuda Lalicker	X		
Textularia rioensis Carsey	X		

SAMPLE NUMBER XXVII—B-1

Section number: 27
Stratigraphic unit and location of sample: Del Rio Clay, unit B
Percentage of clay: 80%, Percentage of calcium carbonate: 41%
Coarse fraction inclusions: pyrite and shell fragments
Foraminifera:

Species	Rare	Common	Abundant
Acruliammina sp	X		
Ammobaculites goodlandensis Cushman & Alexander	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan			X
Dentalina communis (d'Orbigny)	X		
Dentalina hammensis (Franke)	X		
Dentalina sp	X		
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Lagena hispida Reuss	X		
Lagena striatifera Tappan	X		
Lenticulina gaultina (Berthelin)			X
Lenticulina sp	X		
Marginulina teniussima Reuss	X		
Massilina planoconvexa Tappan	X		
Pyrulina cylindroides (Roemer)	X		
Pyrulina longa Tappan	X		
Quinqueloculina moremani Cushman	X		
Spiroplectammina nuda Lalicker			X
Textularia rioensis Carsey		X	
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina geisendorferi Franke	X		

Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XXVII—B-2

SECTION NUMBER: 27
Stratigraphic unit and location of sample: Del Rio Clay, unit B
Percentage of clay: 85%, Percentage of calcium carbonate: 30%
Coarse fraction inclusions: weathered iron and shell fragments
Foraminifera:

Species	Rare	Common	Abundant
Acruliammina longa (Tappan)	X		
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan			X
Cribratina texana (Conrad)	X		
Dentalina communis (d'Orbigny)	X		
Dentalina debilis (Berthelin)	X		
Dentalina sp	X		
Gaudryina sp	X		
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Gyroidina loetterlei Tappan		X	
Lagena hispida Reuss	X		
Lagena striatifera Tappan	X		
Lenticulina gaultina (Berthelin)		X	
Lenticulina sp	X		
Marginulina tenuissima Reuss	X		
Massilina planoconvexa Tappan	X		
Nodosaria amphioxys Reuss	X		
Nodosaria obscura Reuss	X		
Pyrulina cylindroides (Roemer)	X		
Pyrulina longa Tappan	X		
Quinqueloculina moremani Cushman	X		
Spiroplectammina nuda Lalicker			X
Textularia rioensis Carsey	X		
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina geisendorferi Franke	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XXVII—B-3

SECTION NUMBER: 27
Stratigraphic unit and location of sample: Del Rio Clay, unit B
Percentage of clay: 74%, Percentage of calcium carbonate: 44%
Coarse fraction inclusions: pyrite, shell fragments, and scattered quartz sand
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan			X
Dentalina communis (d'Orbigny)	X		
Dentalina debilis (Berthelin)	X		
Dentalina sp	X		
Gaudryina sp	X		
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey	X		
Gyroidina loetterlei Tappan	X		
Lagena hispida Reuss	X		
Lagena striatifera Tappan	X		
Lenticulina gaultina (Berthelin)		X	
Marginulina tenuissima Reuss	X		
Massilina planoconvexa Tappan	X		
Nodosaria amphioxys Reuss	X		
Nodosaria obscura Reuss	X		
Pseudopolymorphina roanokensis Tappan	X		
Pyrulina longa Tappan	X		
Schackoina primitiva Tappan	X		
Spiroplectammina nuda Lalicker	X		
Textularia rioensis Carsey		X	
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		

Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XXVII—B-4

SECTION NUMBER: 27
Stratigraphic unit and location of sample: Del Rio Clay, unit B
Percentage of clay: 56%, Percentage of calcium carbonate: 49%
Coarse fraction inclusions: pyrite and quartz sand
Foraminifera:

Species	Rare	Common	Abundant
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan		X	
Dentalina communis (d'Orbigny)	X		
Dentalina hammensis (Franke)	X		
Dentalina sp	X		
Gaudryinella delrioensis Plummer	X		
Globigerina delrioensis Carsey		X	
Globigerina washitensis Carsey	X		
Gyroidina loetterlei Tappan	X		
Lagena striatifera Tappan	X		
Lenticulina gaultina (Berthelin)	X		
Marginulina tenuissima Reuss	X		
Massilina planoconvexa Tappan	X		
Paleopolymorphina ozawai Tappan	X		
Pyrulina longa Tappan	X		
Spiroplectammina nuda Lalicker	X		
Textularia rioensis Carsey	X		
Tristix märtensi (Reuss)	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XXVIII—A-2

SECTION NUMBER: 28
Stratigraphic unit and location of sample: Del Rio Clay, unit A
Percentage of clay: 70%, Percentage of calcium carbonate: 28%
Coarse fraction inclusions: weathered pyrite, shell fragments and glauconite(?)
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculites sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan	X		
Cribratina texana (Conrad)	X		
Dentalina communis (d'Orbigny)	X		
Globigerina infracretacea Glaessner		X	
Globigerina washitensis Carsey	X		
Gyroidina loetterlei Tappan	X		
Lagena hispida Reuss	X		
Lagena striatifera Tappan	X		
Lenticulina gaultina (Berthelin)	X		
Lenticulina sp	X		
Massilina planoconvexa Tappan	X		
Paleopolymorphina ozawai Tappan	X		
Spiroplectammina nuda Lalicker	X		
Textularia rioensis Carsey	X		
Tristix tricarinatum (Reuss)	X		
Vaginulina kochii Roemer	X		
Vaginulina recta Reuss	X		

SAMPLE NUMBER XXVIII—A-4

SECTION NUMBER: 28
Stratigraphic unit and location of sample: Del Rio Clay, unit A
Percentage of clay: 95%, Percentage of calcium carbonate: 37%
Coarse fraction inclusions: pyrite and shell fragments
Foraminifera:

Species	Rare	Common	Abundant
Ammobaculties goodlandensis Cushman & Alexander	X		
Ammobaculties sp	X		
Ammodiscus cretaceus (Reuss)	X		
Anomalina plummerae Tappan		X	
Dentalina communis (d'Orbigny)	X		
Gaudryinella delrioensis Plummer	X		
Globigerina infracretacea Glaessner			X
Globigerina planispira Tappan	X		
Globigerina washitensis Carsey		X	
Gyroidina loetterlei Tappan	X		
Lagena striatifera Tappan	X		

Lenticulina gaultina (Berthelin)------------X
Lenticulina sp --------------------X
Massilina planoconvexa Tappan---X
Pyrulina cylindroides (Roemer)---X
Spiroplectammina nuda Lalicker-------------X
Textularia rioensis Carsey----------------------------X
Tristix tricarinatum (Reuss)------X
Vaginulina kochii Roemer--------X
Vaginulina recta Reuss---------X

MICROPALEONTOLOGY OF THE MAIN STREET MEMBER

Sample Number (Section)—(Unit)—(Number)

Genus	6—I—1	6—K—1	13—F—1	19—B—1	19—D—1	28—D—1
Acruliammina	R*	R	C**	R	R	R
Ammobaculites	R	R	C	C	C	R
Anomalina	R	R	—	R	R	R
Cribratina	R	R	C	R	R	C
Dentalina	—	—	—	—	—	R
Frondicularia	R	—	—	—	R	R
Globigerina	C	R	R	C	C	C
Gyroidina	—	R	—	—	—	R
Lagena	—	R	R	R	—	—
Lenticulina	R	R	R	R	R	R
Nodosaria	—	R	—	—	R	—
Reophax	R	R	R	—	R	R
Spiroplectammina	R	R	C	R	R	—
Textularia	R	C	C	R	R	C
Vaginulina	R	—	—	R	—	—

MICROPALEONTOLOGY OF THE PAWPAW MEMBER

Sample Number (Section)—(Unit)—(Number)

Genus	6—M—1	6—N—1	16—B—1	16—D—1
Acruliammina	R	R	R	R
Ammobaculites	R	R	—	R
Anomalina	C	C	C	R
Cribratina	C	C	C	R
Dentalina	R	R	R	R
Frondicularia	—	—	—	—
Globigerina	C	R	C	C
Gyroidina	—	—	—	—
Lagena	R	—	—	—
Lenticulina	C	C	C	C
Nodosaria	—	—	—	—
Reophax	—	C	R	R
Spiroplectammina	R	R	R	R
Textularia	R	R	R	R
Vaginulina	R	R	R	—

*R—Rare

**C—Common (for exact quantitative definition see Title page of Appendix II)

MICROPALEONTOLOGY OF THE WENO MEMBER

Sample Number (Section)—(Unit)—(Number)

Genus	5—B—1	6—S—1	6—Z—1	8—C—1	8—E—1	8—G—1	18—C—1	18—E—1	18—G—1	18—I—1	18—K—1	28—F—1	28—H—1
Acruliammina	C	R	R	C	C	C	C	R	C	C	R	C	C
Ammobaculties	R	—	R	R	—	—	—	R	—	—	—	—	—
Anomalina	R	R	R	R	R	R	R	R	R	R	—	R	R
Cribratina	R	R	—	R	R	R	R	C	R	R	—	C	R
Dentalina	R	R	—	—	—	—	—	R	—	—	—	—	—
Frondicularia	R	—	—	—	—	—	—	R	—	—	—	R	—
Globigerina	C	R	R	C	C	C	C	C	R	C	R	C	C
Gyroidina	—	—	—	—	—	—	—	R	—	—	—	—	—
Lagena	R	—	—	R	R	—	R	R	R	C	R	R	R
Lenticulina	C	R	—	C	C	C	C	C	C	C	R	C	C
Nodosaria	R	—	—	R	—	—	R	R	R	—	—	R	—
Reophax	—	R	R	R	—	—	R	R	R	R	—	R	—
Spiroplectammina	R	R	R	R	—	—	—	—	—	—	—	R	—
Textularia	C	—	—	R	R	R	R	C	R	R	—	R	R
Vaginulina	R	—	—	R	R	R	R	R	—	—	—	—	R

MICROPALEONTOLOGY OF THE DENTON MEMBER

Sample Number (Section)—(Unit)—(Number)

Genus	5—G—1	6—BB—1	6—BB—2	6—DD—1	8—K—1	8—M—1	14—B—1	15—C—1	15—E—1
Acruliammina	—	—	R	—	R	—	C	—	—
Ammobaculites	C	C	C	C	C	C	R	C	C
Anomalina	—	—	—	R	R	—	R	—	R
Cribratina	—	—	—	—	—	—	C	R	C
Dentalina	R	R	R	C	R	C	R	—	R
Frondicularia	—	—	R	—	—	—	—	—	—
Globigerina	C	C	C	R	C	C	C	C	R
Gyroidina	—	—	—	—	—	—	R	—	—
Lagena	R	R	R	R	R	—	—	R	—
Lenticulina	C	C	R	C	C	R	C	C	C
Nodosaria	—	—	—	—	—	—	—	R	—
Reophax	—	—	—	R	R	R	R	—	—
Spiroplectammina	R	R	—	R	—	R	R	R	R
Textularia	R	R	R	R	R	R	R	R	R
Vaginulina	R	—	—	—	—	—	R	—	—

MICROPALEONTOLOGY OF THE FORT WORTH MEMBER

Sample Number (Section)—(Unit)—(Number)

Genus	1—B—1	1—C—1	1—D—1	6—FF—1	6—HH—1	14—E—1
Acruliammina	R	R	—	R	R	R
Ammobaculites	R	C	C	R	R	R
Anomalina	R	R	R	R	R	R
Cribratina	R	R	R	—	R	C
Dentalina	—	—	—	—	R	R
Frondicularia	—	—	—	—	—	—
Globigerina	C	C	C	C	C	C
Gyroidina	—	—	—	—	—	—
Lagena	R	R	—	R	R	R
Lenticulina	R	C	C	R	R	R
Nodosaria	R	R	R	—	—	—
Reophax	R	R	R	—	—	R
Spiroplectammina	R	R	R	R	R	R
Textularia	C	C	R	R	R	C
Vaginulina	—	—	—	R	—	R

MICROPALEONTOLOGY OF THE DUCK CREEK MEMBER

Genus	Sample Number (Number) (Unit) (Section) 1—F—1	1—F—2	1—F—3	1—H—1	7—B—1	7—B—2	17—A—1	17—A—2
Acruliammina	C	R	R	R	R	—	C	C
Ammobaculites	C	C	C	C	R	R	R	R
Anomalina	R	R	C	C	R	R	R	—
Cribratina	R	R	R	R	—	—	C	C
Dentalina	R	R	R	R	—	R	—	—
Frondicularia	R	R	R	R	R	R	R	R
Globigerina	R	C	R	R	R	R	—	—
Gyroidina	—	R	R	R	R	R	—	—
Lagena	—	—	—	—	—	—	R	—
Lenticulina	R	R	R	R	C	R	R	R
Nodosaria	—	—	—	—	—	—	R	R
Reophax	R	R	—	R	R	R	—	—
Spiroplectammina	R	R	R	R	R	R	R	R
Textularia	R	R	R	R	C	R	R	R
Vaginulina	—	—	—	—	R	—	—	—

MICROPALEONTOLOGY OF THE KIAMICHI MEMBER

Genus	Sample Number (Number) (Unit) (Section) 1—I—1	1—I—2	1—I—3	1—I—4	7—E—1	7—F—1	18—C—1
Acruliammina	R	C	—	R	—	R	R
Ammobaculites	—	—	R	—	R	R	R
Anomalina	—	—	—	—	—	—	—
Cribratina	R	C	R	R	C	—	—
Dentalina	—	—	—	—	—	—	—
Frondicularia	—	—	—	—	—	—	—
Globigerina	—	—	—	—	—	—	—
Gyroidina	—	—	—	—	—	—	—
Lagena	—	—	—	—	—	—	—
Lenticulina	—	—	—	—	—	—	—
Nodosaria	—	—	—	—	—	—	—
Reophax	R	R	R	R	R	—	R
Spiroplectammina	—	C	—	—	R	—	—
Textularia	R	R	—	R	R	R	R
Vaginulina	—	—	—	—	—	—	—

APPENDIX III

PREPARATION OF SAMPLES

ACETATE PEELS*

1. Rock slabs of appropriate size (2½" to 3" square) are sawed.
2. One of the surfaces is ground with 240 grade silicon carbide powder. A final polish is carefully applied with a 600 grade abrasive.
3. The polished surface is carefully washed.
4. The prepared surface is etched with diluted (1.2N) hydrochloric acid. Recommended etching time is 25 to 30 seconds.
5. Etching is stopped by washing with water, after which a final washing with distilled water is given, taking care not to touch the polished and etched surface.
6. After drying, the etched surface is immersed in acetone for 2 to 3 seconds. A piece of acetate sheet (2" x 2")and 0.005 or 0.010 inch thick is immediately placed on the etched surface. The film is pressed firmly and evenly with the fingers without sliding it over the smooth surface. No air bubbles should remain under the acetate.
7. After the edges of the acetate begin to curl, the acetate film is carefully removed and placed between two thin glass plates (2" x 2"). The edges are bound with binding tape (Kodak, ⅜") and the sample number is placed on the tape.

MICROFAUNAL PREPARATION AND SAND, SILT-CLAY RATIOS

1. Approximately 1.0 liter of the sample is crumbled with the hands. Most of the hard pieces such as fossils or bits of limestone are removed. The remainder of the sample is placed in a clean container (1 lb. coffee cans are usually sufficient).
2. The sample is allowed to dry for at least 48 hours at room temperature (75° F) or may be heated with a low heat source (electric hot plate) for rapid drying. Too rapid drying will result in undesirable hardening of the sample.
3. Kerosene is added to the container until the sample is completely covered. The sample is allowed to soak at least 24 hours or until completely saturated with kerosene.
4. The kerosene is poured off and the container is immediately filled with water until the sample is covered. The sample is allowed to soak for 24 hours or until completely soft.
5. One hundred milliliters of softened sample and 700 milliliters of water are placed in an electric blender. The blender is then turned on for 60 seconds.
6. The resulting solution is poured into 1000 milliliter graduated cylinder and 300 milliliters of water are added to wash all solids into the cylinder.
7. After two minutes, the sand and silt sized particles will settle to the bottom and can be measured. The difference between the original 100 milliliter and the milliliter of solids is the amount of clay-sized particles remaining in suspension.
8. The solution in the graduated cylinder is then washed through a screen (120 mesh) with the remainder of the sample in order to obtain the microfossils.
9. After washing, the sample is slowly dried and then placed in a clean container, ready for microfaunal examination.

PERCENTAGE OF CALCITE IN SOFT SAMPLES

1. Approximately 10 grams of sample was crumbled into five pieces (.2 cm).
2. The sample was then weighed and placed in a 100-milliliter beaker.
3. Dilute hydrochloric acid (12N) was very slowly added until beaker was one-half full.
4. After 15 minutes, the sample was stirred and the beaker was then filled with the dilute hydrochloric acid.
5. The sample was allowed to remain in the beaker for 24 hours.
6. Filter paper (6") was weighed, folded, and placed in a glass funnel (3") and then set in an Erhlermeyer flask.
7. The sample was filtered then washed with 100 milliliters of distilled water.
8. After filtering, the sample was allowed to dry for 48 hours.
9. The completely dry sample and filter paper were weighed and the amount of calcite was determined by the following equation: Original Sample — (Residue - Filter Paper) = Amount of Calcite.

*Adapted from Katz and Friedman, 1965.

APPENDIX IV

SUBSURFACE CONTROL

Well No.	Buda	Thickness in Feet Del Rio	Georgetown
31. City of Moody, Water Well No. 2, McLennan Co. (31°19'N; 97°21'W)	M*	80	110
32. Jet Oil Company, Willis No. 1, McLennan Co. (31°22'N; 97°15'W)	T**	70	120
33. J. L. Meyers, Midway Indep. School Dist. No. 1, McLennan Co. (31°29'N; 97°13'W)	M	70	125
34. Texas Water Company, Texas Water Co. No. 3, McLennan Co. (31°33'N; 97°10'W)	M	75	150
35. Joe Thompson, Paul Shelby No. 1, McLennan Co. (31°31'N; 97°09'W)	M	74	150
36. J. L. Meyers, Waco Memorial Park No. 1, McLennan Co. (31°28'N; 97°09'W)	M	80	135
37. Chapel Hill Water Company, Water Well No. 1, McLennan Co. (31°27'N; 97°10'W)	6	80	130
38. Beacon Oil Company, Trice No. 1, McLennan Co. (31°26'N; 97°14'W)	M	75	120
39. Gray Oil Company, Warren No. 1, McLennan Co. (31°24'N; 97°12'W)	4	75	150
40. Paine, Eubank No. 1, McLennan Co. (31°20'N; 97°13'W)	M	84	130
41. J. L. Meyers, Youngblood No. 1, McLennan Co. (31°28'N; 97°06'W)	M	80	155
42. Rosenthal Water Company, O'Dowd No. 1, McLennan Co. (31°25'N; 97°06'W)	7	78	155
43. Layne Texas Company, Water District No. 1, McLennan Co. (31°35'N; 97°97'W)	T	82	165
44. J. L. Meyers, Waco Water District 4, Well No. 2, McLennan Co. (31°34'N; 97°05'W)	T	80	155
45. Chalk Bluff Water Supply, Chalk Bluff No. 1, McLennan Co. (31°40'N; 97°08'W)	4-7	86	155
46. Lake-View Water Co., J. E. Passmore No. 1, McLennan Co. (31°39'N; 97°07'W)	8-10	84	165
47. C. P. Quinlan, Prause No. 1, McLennan Co. (31°41'N; 97°04'W)	M	82	190
48. C. R. Porter, E. D. Mazanec No. 1, McLennan Co. (31°50'N; 97°05'W)	14	82	I***(155)
49. J. L. Meyers, Tiery No. 1, McLennan Co. (31°36'N; 97°04'W)	8	84	165
50. Layne-Texas Company, Connally Air Base No. 3, McLennan Co. (31°39'N; 97°05'W)	6	83	165
51. C. R. Porter, Kophal No. 1, McLennan Co. (31°41'N; 97°04'W)	9	79	165
52. Layne-Texas, Leroy-Tours-Gerald No. 1, McLennan Co. (31°44'N; 97°01'W)	M	85	195
53. Mt. Carmel Center, Mt. Carmel Center No. 1, McLennan Co. (31°35'N; 96°59'W)	6	87	175
54. Simon Kershoj, R. W. Ferguson No. 1, McLennan Co. (31°41'N; 96°58'W)	23	86	190

M* Missing
T** Trace
I*** Incomplete log, figure in parenthesis is thickness present on log.

Well No.	Thickness in Feet Buda	Del Rio	Georgetown
55. J. H. Snowden et al, Eubanks No. 1, McLennan Co. (31°40'N; 97°58'W)	16-17	I*	I
56. William H. Winn, James L. Morrow No. 1, McLennan Co. (31°39'N; 96°57'W)	10	82	170
57. S. H. Riggs, Grindstaff No. 1, McLennan Co. (30°42'N; 96°56'W)	21	84	220
58. J. L. Meyers, City of Mart No. 1, McLennan Co. 31°34'N; 96°55'W)	18	80	180
59. R. J. Caraway, Slaughter No. 1, McLennan Co. (31°32'N; 96°53'W)	20	80	180
60. Riesel Ind. School Corp., Riesel Ind. School Water Well No. 1, McLennan Co. (31°28'N; 96°56'W)	23	77-78	180
61. Layne Texas Company, Texas Power and Light Co. No. 2, McLennan Co. (31°28'N; 96°59'W)	18	81	180
62. Max McCotter, Wardlaw No. 1, McLennan Co. (31°29'N; 97°00'W)	14	82	175
63. Mae Belcher, Smyth No. 1, McLennan Co. (30°32'N; 96°50'W)	37	77-80	200
64. A. R. P. Oil Company, John P. Mascheck No. 1, Bell Co. (31°01'N; 97°06'W)	33	77	95
65. A. Delcambre, D. V. Doskocil No. 1, Falls Co. (31°07'N; 97°07'W)	29	72	130
66. Humble Oil & Refining Company, Eleanor Carrol No. 1, Falls Co. (31°06'N; 97°05'W)	40	72	140
67. P. W. Curry, Newman Oil No. 1, Falls Co. (31°17'N; 97°09'W)	13	78	I (50)
68. Hamilton and Torrance, Guderian Est. No. 1, Falls Co. (31°21'N; 97°06'W)	16	79	165
69. Golinda Cooporation, Water Well No. 1, Falls Co. (31°32'N; 97°05'W)	15	76	135
70. Abshier and Jones, Avery No. 1, Falls Co. (31°22'N; 97°05'W)	17	77	I (95)
71. Chilton Water Well, Chilton No. 2, (Approx. Location, Chilton) Falls Co. (31°17'N; 97°04'W)	26	76	150
72. Ace Oil Co. & Ray Holbert, Harrison No. 1, Falls Co. (31°16'N; 97°01'W)	30	78	I (30)
73. Layne-Texas, City of Lott No. 1, (Approx. Location, Lott) Falls Co. (31°12'N; 97°02'W)	33	77	153
74. Midstate Oil Corporation, B. E. Mitchell No. 1, Falls Co. (31°23'N; 97°00'W)	22	78	165
75. J. E. Banks, Kerr No. 1, Falls Co. (31°23'N; 97°58'W)	22	78	I (130)
76. A. R. Sheaf, Pavelka No. 1, Falls Co. (31°25'N; 96°54'W)	30	80	180
77. Bailey and Obermeyer, Warren Allen No. 1, Falls Co. (31°16'N; 96°53'W)	50	75	200
78. L. E. Miers and Dr. C. A. Greenwalt, O. R. Gilliam No. 1, Falls Co. (31°16'N; 96°49'W)	53	73	200
79. H. C. Cockburn and Zephyr Oil Company, N. D. Buie, No. 1, Falls Co. (31°15'N; 96°49'W)	60	63	200
80. Dail Goodson, J. B. Barganier No. 1, Falls Co. (31°13'N; 96°51'W)	56	70	195

Well No.	Thickness in Feet: Buda	Del Rio	Georgetown
81. Marlin Petroleum Company, Joe LaBarbeca No. 1, Falls Co. (31°10′N; 96°51′W)	60	66	195
82. Seaboard Oil Co. No. 1 Green (Approx. Location, 5 mi. SW Kosse) Falls Co. (31°15′N; 96°11′W)	75	75	280
83. Bass, Gerek No. 1, Hill Co. (31°50′N; 97°08′W)	T	83	190
84. J. L. Meyers, City of Abbot No. 1, Hill Co. (31°53′N; 97°08′W)	T	85	200
85. J. L. Meyers, Penelope Water Well No. 1, Hill Co. (31°52′N; 96°55′W)	18	90	230
86. R. J. McMurrey, Joe F. Janek No. 1, Hill Co. (31°52′N; 96°52′W)	30	I (30)	I
87. Camtex Oil Corporation, Cartwright No. 1, Hill Co. (31°47′N; 96°54′W)	18	82	I (160)
88. Eureka Tool Company, Daugherty No. 1, Hill Co. (31°38′N; 96°51′W)	35	I (85)	I
89. J. L. Meyes, City of Hubbard No. 1, Hill Co. (31°51′N; 96°47′W)	40	90	250
90. George Rahal, Lewis Martin No. 1, Hill Co. (31°58′N 96°50′W)	50	85	225
91. Hodle et al., Weiss No. 1, Limestone Co. (31°42′N; 96°53′W)	18	82	I (100)
92. Balcones Oil Company, Jackson No. 1, Limestone Co. (31°35′N; 96°49′W)	29	80	225
93. Farrell Drilling Company, J. R. Gilliam No. 1, Limestone Co. (31°33′N; 96°47′W)	40	81	240
94. Lone Star Gas Production Company, Criswell No. 1, Limestone Co. (31°25′N; 96°42′W)	58	82	270
95. M. M. Miller, J. C. Rogers No. 1, Limestone Co. (31°34′N; 96°43′W)	50	85	255
96. O. W. Killiam, Stone No. 1, Limestone Co. (31°37′N; 96°42′W)	50	82	285
97. Hunt Oil Company, Union Central Life Ins. Co., Limestone Co. (31°40′N; 96°45′W)	46	82	275

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