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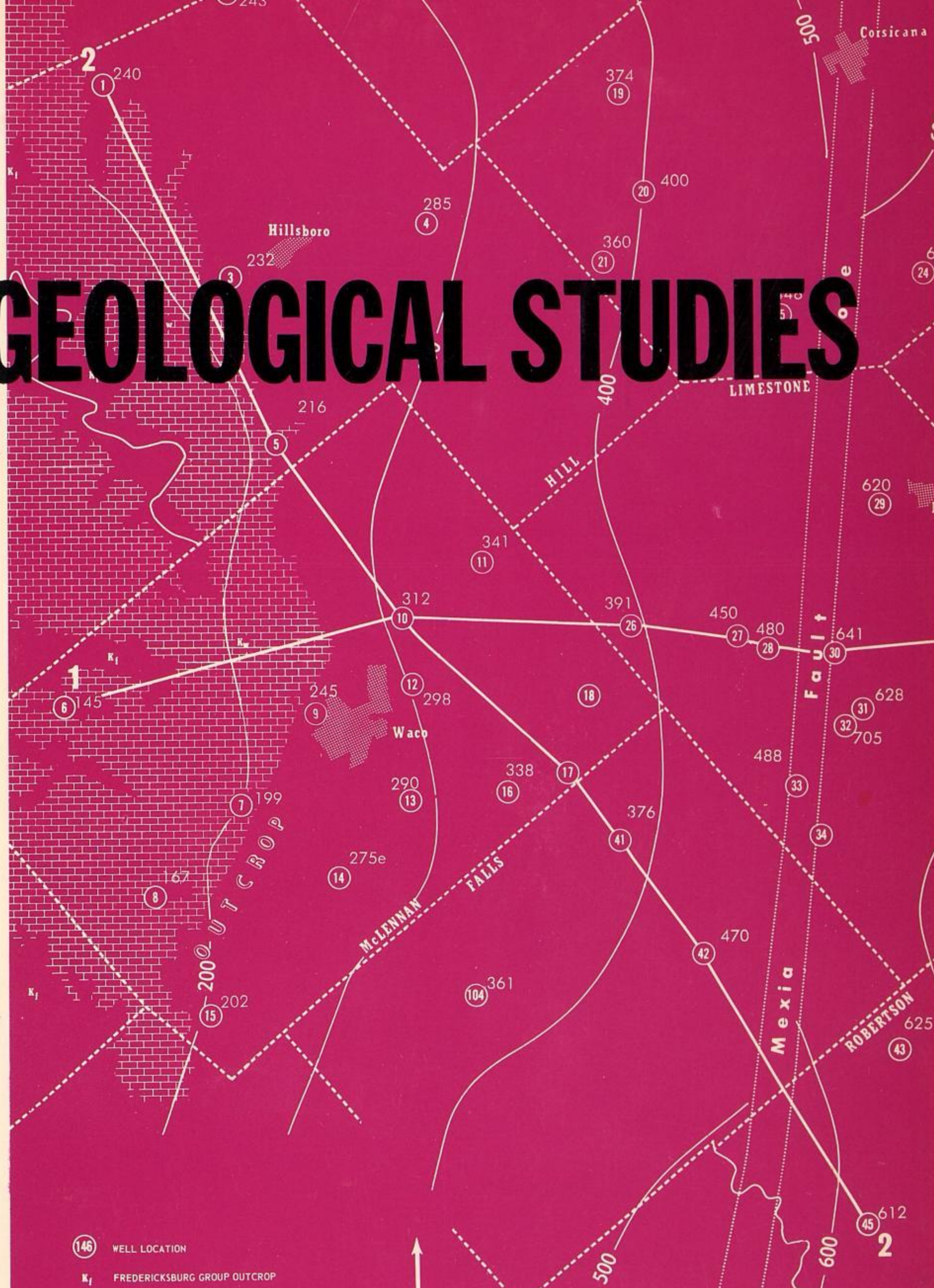

FALL 1970
Bulletin No. 19

BAYLOR UNIVERSITY – WACO, TEXAS
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Subsurface Stratigraphy of the Comanchean Series in East Central Texas

MOICE A. MOSTELLER

"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.

The Baylor University Press
Waco, Texas

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BAYLOR UNIVERSITY
Department of Geology
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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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ABSTRACT

The Comanchean Series in East Central Texas (the study area) is a thick wedge of deltaic clastics and shallow marine limestones and shales which fill the East Texas Basin and lap westward onto the Texas craton (fig. 1). In early Cretaceous time sands and shales of the Travis Peak Formation were deposited in the East Texas Basin by deltaic processes. As deposition continued the deltaic sediments lapped westward onto the Texas craton-Ouachita fold belt area.

After the initial filling and leveling of the basin there was a westward transgression of the sea. Limestones and shales of the lower and upper Glen Rose formations were deposited in a shallow lagoon. Southeast of the lagoon the Stuart City reef separated the lagoonal or back reef province from the fore reef province which was located south of the barrier reefs. The lagoonal area became isolated from the open ancestral Gulf of Mexico and the lagoon water became saturated with salts. During this period the Ferry Lake Anhydrite was precipitated.

A minor marine regression occurred during deposition of the Fredericksburg Group. There was local erosion and truncation of upper Glen Rose limestones in the Texas craton area. Paluxy Sand filled the topographic lows. In the Fredericksburg age lagoon rudistid reefs formed north and west of the Stuart City reef trend. These rudistid reefs, the Edwards Formation, were later exposed to the atmosphere and were eroded.

The Fredericksburg regression was followed by transgression of the sea during Washita Group deposition. The lagoon during this time spread across the study area. Sedimentary conditions were nearly uniform in the lagoon region. This can be seen by the large areas covered by individual Washita formations. At the end of Washita deposition the area was uplifted and tilted gently to the southeast. This caused the truncation of the Maness Shale, Buda Limestone, and Del Rio Clay on the Texas craton.

There were several active tectonic areas during Comanchean time. In the axial area of the East Texas Basin Jurassic salt moved because of the pressures of overburden and increased heat with depth of burial. Anderson County was an area of continuous salt withdrawal and doming. Some of the thickest stratigraphic sections of the study area occur in salt withdrawal areas. Another tectonically active area was along the Mexia fault zone. Movement contemporaneous with deposition caused thicker sections to accumulate on the east side of the zone. A third tectonic element was a hinge line which trended across eastern Hill and McLennan counties. This hinge line separates the area of low thickening rates on the west from the area of high thickening rates on the east.

INTRODUCTION*

PURPOSE

This study is designed (1) to determine the major stratigraphic relationships between Comanchean rocks of the Texas craton and the East Texas Basin in east Central Texas and (2) to interpret the geologic history of these sediments.

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

LOCATION

The area of study is located in Central Texas between the Comanchean outcrop band west of the City of Waco and the Trinity River to the east (fig. 1). This area includes all or part of Anderson, Falls, Freestone, Grimes, Henderson, Hill, Houston, Leon, Limestone, McLennan, Madison, Navarro, Robertson, and Walker counties.

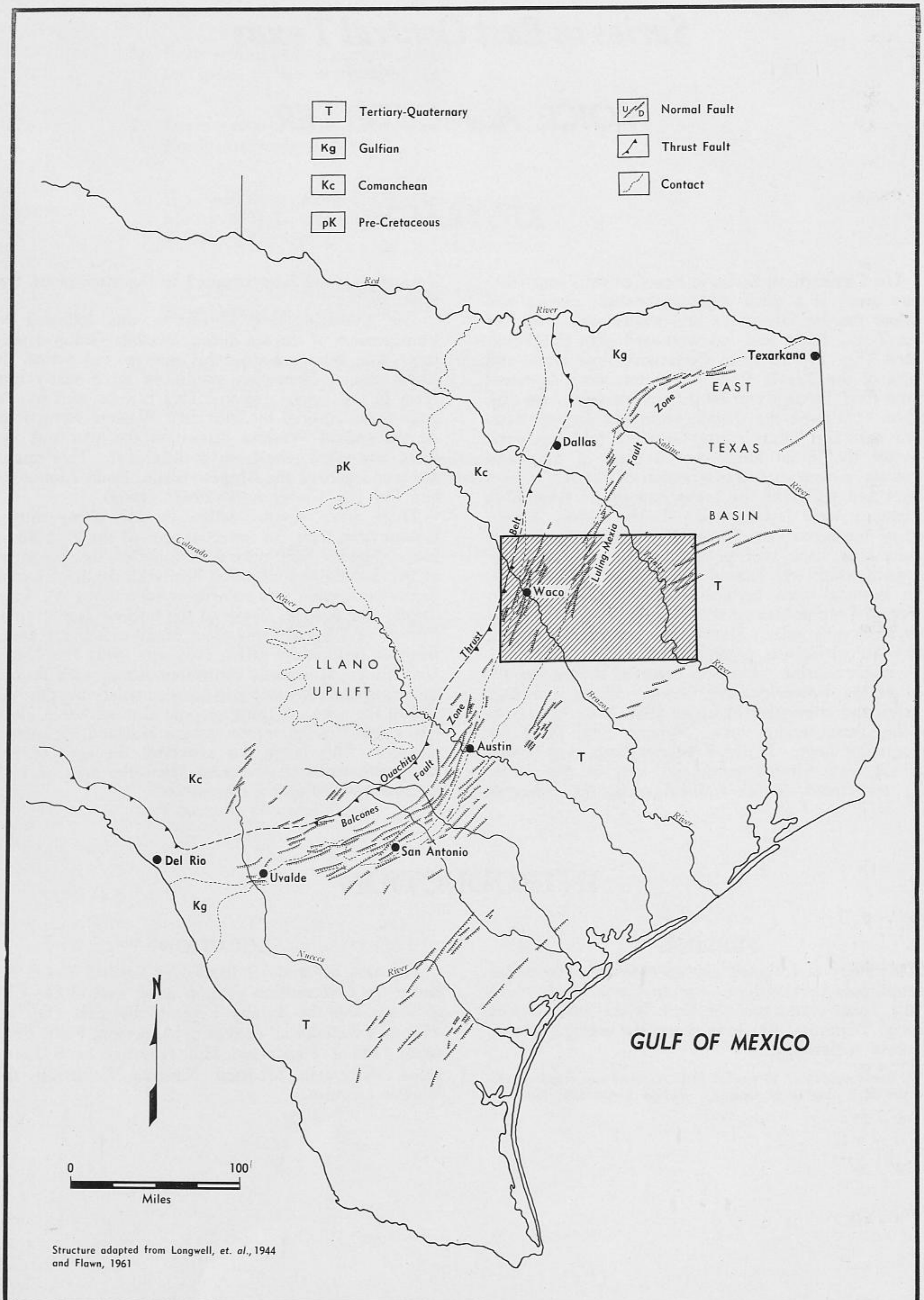

Fig. 1. Index map, showing regional structure and gross surface stratigraphy.

In western Hill and McLennan counties and counties to the west, Comanchean rocks crop out in a broad north-south band across the eastern edge of the Texas craton (fig. 1). From the outcrop these rocks dip gently to the east until they reach the Balcones fault zone in central Hill and McLennan counties. At this point the eastward dip increases and the formations thicken toward the basin axis.

The Balcones fault zone is parallel and coincident to the Ouachita fold belt, a deformed belt of Paleozoic rocks that divides the East Texas Basin from the Texas craton. Comanchean rocks unconformably overlie these metamorphosed Paleozoic sediments.

About twenty miles east of the Balcones fault system is a part of the Mexia fault system which crosses Falls, Limestone, and Navarro counties (fig. 1). East of this fault zone the Comanchean rocks thicken abruptly and increase in dip to the axis of the East Texas Basin. The basin axis trends north-south through eastern Freestone, Leon, and Madison counties and western Anderson, Houston, and Walker counties. From the axial area the rocks thin eastward onto the Sabine uplift.

PROCEDURES

Data for this study were derived from 104 electric well logs, cuttings from eight wells, published material, field observations, and discussions with T. H. Shelby, Jr. and A. C. Raasch, geologists familiar with the area.

The major part of the study involved isopaching genetically related sequences of rocks. This information was correlated with lithologic and environmental data in order to better understand the geologic history of the area. Isopach intervals were correlated using electric well logs. The correlation points used are considered to represent points on a time surface. It is very likely that there is some deviation from a perfect time correlation, however the deviation is small in magnitude relative to the total time represented by the isopached interval.

Published material was used to gather information regarding outcrop stratigraphy, paleontology of different units, tectonic concepts relating to the study area, and ideas concerning the area's sedimentary history.

PREVIOUS INVESTIGATIONS

Investigation of Comanchean rocks in the Oklahoma-Texas area began with brief outcrop observations in the early nineteenth century and has progressed to detailed stratigraphic, lithologic, paleontologic, and economic studies of areas from the outcrop to the deepest parts of the East Texas Basin.

Lower Cretaceous fossils were first collected by Dr. G. Pitcher in 1830 from formations of the Washita division near Fort Towson in the Indian Territory (Oklahoma) (Hill, 1891, p. 516). Dr. Pitcher's fossil collecting is the first known work on the Comanchean Series, but any ideas or observations which he may have had were not recorded.

The first important investigation of Comanchean rocks was made by Ferdinand Roemer, a German geologist who visited Texas from 1845 to 1847. The purpose of his visit was to study the area and make recommendations for possible future German settlement (Reel, 1960). Although some of Roemer's stratigraphic theories about the Fredericksburg division were wrong (Hill, 1887, p. 308), his paleontologic work was of great value to later investigators.

Shortly after Roemer's visit to Texas three other geologists, G. G. Shumard, Jules Marcou, and B. F. Shumard, visited the area. These men catalogued many Lower Cretaceous macrofossils. B. F. Shumard worked out a stratigraphic column which showed correlations from Texas to Alabama and Nebraska (Shumard, 1860, p. 583).

The most important and lasting stratigraphic work on the Comanchean Series was done in the late nineteenth and early twentieth centuries by Robert T. Hill and his colleagues (Hill, 1887, 1891, 1901). Hill's work on the Cretaceous outcrop stratigraphy has remained the standard for geologic work in Texas for the last seventy years. He was the first to divide the Cretaceous into two series, Comanchean and Gulfian, and to separate his lower "Comanche Series" into three "divisions." Many of his formational names are still in use.

In the years following Hill's work investigators made detailed studies of various stratigraphic units and fossils. Among these, those most critical to this study are Atlee (1962), Bishop (1967), Boone (1968), Dixon (1967), Frost (1967), Hayward and Brown (1967), Holloway (1961), Rodgers (1967), and Tucker (1962). Investigation spread into the subsurface as oil companies drilled wells and obtained seismic profiles. The volume of information has continued to grow until today there are numerous maps, published reports, theses, seismic profiles, and well logs. Because of the economic and academic interest in the Comanchean Series, this volume of data will continue to grow at a fast pace.

ACKNOWLEDGMENTS

I would like to extend my deepest appreciation and gratitude to all the people who aided me in this study. Many thanks to my friends at Humble Oil and Refining Company—Buddy Barron, S. R. Bryant, Walter M. Conley, Verne E. Farmer, Jr., R. E. Johnson, Richard Meyers, A. C. Raasch, John S. Reeder, E. J. Reynolds, T. H. Shelby, Jr., and Jack Starr—for their help in locating well cuttings, electric well logs, and for their valuable and useful advice. At Baylor University Gustavo A. Morales, my thesis advisor, guided the work and made many beneficial and time-saving suggestions. I would like to thank J. W. Dixon for use of his library and for critically reading the manuscript. My wife, Jane, helped correct writing errors and typed the original thesis manuscript.

A special note of appreciation is extended to E. A. Wendlandt of Tyler, Texas for carefully reviewing the manuscript.

STRATIGRAPHIC NOMENCLATURE

When Roemer saw the limestones of the New Braunfels area in Texas, he noticed the lithologic and faunal similarity between these and the Cretaceous rocks in southern Europe (Roemer, 1852, p. 25). From his field observations, he divided the Cretaceous rocks into two major units based on faunal difference. The formations (Fredericksburg Group) of the hilly area west of New Braunfels he called the Cretaceous formations of the highlands and placed them stratigraphically above the formations (Gulfian) east of New Braunfels which he called the Cretaceous formations at the foot of the highlands.

Roemer's mistake of placing Fredericksburg rocks stratigraphically above younger Gulfian rocks went undetected by G. G. Shumard, Jules Marcou, and B. F. Shumard who worked out formational correlations in the Texas-Oklahoma area in the 1850's. In 1860 B. F. Shumard, the director of the Texas Geological Survey, published a stratigraphic section of the Cretaceous strata of Texas. Shumard's section divided the Cretaceous rocks into the Upper and Lower Cretaceous divisions. The Upper Cretaceous division included in descending order: the *Caprina* Limestone (Edwards Formation), Comanche Peak Group (Comanche Peak Formation), Austin Limestone (Austin Formation), *Exogyra arietina* Marl (Del Rio Formation), Washita Limestone (Georgetown Formation), Blue Marl (Eagle Ford Group) and the *Caprotina* Limestone (Glen Rose Formation). The Lower Cretaceous division in descending order included: the Arenaceous Group (Woodbine Formation) and the Red River Group (Taylor and Navarro formations).

In 1887 Robert T. Hill published an article in the American Journal of Science placing the Cretaceous rocks in their correct stratigraphic relationships for the first time. He divided the Cretaceous strata into three parts: Upper, Middle, and Lower. The Lower Cretaceous stratum he subdivided into the Washita Division, Fredericksburg Division, and Basal Sands. Hill's publication examined Roemer's and Shumard's incorrect stratigraphic sections, showed where each error occurred, and corrected it.

By 1890, Hill had worked out the basic Comanchean stratigraphic nomenclature (Hill, 1891). He divided the Comanchean Series into three divisions: the Trinity, Fredericksburg, and Washita. The Trinity Division he subdivided into the Trinity Sands and Glen Rose Beds. The Fredericksburg Division was subdivided into Paluxy Sand, Walnut Clay, Comanche Peak Chalk, *Caprina* Limestone, and Goodland Limestone. The Washita Division he subdivided into the Kiamichi Clays, Duck Creek Chalk, Fort Worth Limestone, and Denison Beds. With the exception of the subsurface units of the East Texas Basin, Hill described all of the known Comanchean rocks of Central Texas.

Since Hill's publication in 1891 few changes have been made in his stratigraphic terms and no major errors have been detected. The only change in his work has been the subdivision of some units. The stratigraphic nomenclature which is presently used can be placed in two groups: an East Texas Basin nomenclature and a Texas craton nomenclature (Table 1).

In the East Texas Basin where the Comanchean Series is several thousand feet thick, the rock sequences are not subdivided into thin units as they are in the outcrop area. This is because the rock units on the outcrop have been studied in greater detail and for a longer time than the units in the basin. The study of units in the basin has been primarily related to petroleum exploration, and there has been a tendency to subdivide only productive intervals and mappable units.

In both the East Texas Basin and Texas craton areas, the Comanchean Series is divided into three groups: Trinity (lower), Fredericksburg (middle), and Washita (upper).

TABLE 1. Nomenclature of the East Texas Basin and the Texas Craton.

TEXAS CRATON		EAST TEXAS BASIN	
WASHITA GROUP			
Formation	Member	Formation	Member
		Maness	
Buda		Buda	
Del Rio		Del Rio	
	Main Street		
	Pawpaw		
Georgetown	Weno	Georgetown	
	Denton		
	Fort Worth		
	Duck Creek		
		Kiamichi*	
FREDERICKSBURG GROUP			
Formation	Member	Formation	Member
Edwards			
		Goodland	
Comanche Peak			
Walnut		Walnut	
Paluxy		Paluxy	
TRINITY GROUP			
Formation	Member	Formation	Member
Glen Rose		upper Glen Rose	Ferry Lake Zone
Hensel		lower Glen Rose	Rodessa
Pearsall			Pine Island
			Pettet
Sligo		Travis Peak	
Hosston			

Editor's Note: The Kiamichi Clay is commonly assigned to the Washita Group in the outcrop area of central Texas. In the East Texas Basin, it is traditionally included in the underlying Fredericksburg Group.

In this bulletin the outcrop tradition is honored, since the purpose of the bulletin is to correlate the outcrop section near Waco with the subsurface section in the basin.

EAST TEXAS BASIN NOMENCLATURE

The Trinity Group in the East Texas Basin area is made up of three formations, in ascending order: (1) the Travis Peak, (2) the lower Glen Rose, and (3) the upper Glen Rose (Shelby, 1951, p. 133). The Travis Peak Formation has no members. The lower Glen Rose Formation has three members: the Pettet Limestone, the Pine Island Member, and the Rodessa Limestone (*idem*). The Pine Island Member has three zones: the Pine Island Shale, the James Limestone, and the Bexar Shale. The upper Glen Rose Formation has no members; however, a zone of massive anhydrite known as the Ferry Lake Anhydrite Zone is widely mapped as the base of the upper Glen Rose Formation.

The Fredericksburg Group is divided into two formations in the East Texas Basin area, in ascending order: (1) the Walnut and (2) the Goodland. In some cases the Goodland Formation is subdivided into the Edwards Limestone and the Comanche Peak Limestone.

The Washita Group is composed of five formations which include in ascending order the: (1) Kiamichi, (2) Georgetown (3) Del Rio, (4) Buda, and (5) Maness. Only one of these formations, the Georgetown, is subdivided into members but is rarely subdivided in the basin area.

TEXAS CRATON NOMENCLATURE

There are five formations of the Trinity Group in the Texas craton area: (1) Hosston Sand, (2) Sligo Limestone, (3) Pearsall Formation, (4) Hensel Sand, and (5) Glen Rose Formation (Atlee, 1962, p. 7).

The Fredericksburg Group contains four formations: (1) Paluxy Sand, (2) Walnut Clay, (3) Comanche Peak Limestone, and (4) Edwards Limestone (*idem*).

The three formations of the Washita Group are the Georgetown Limestone, Del Rio Clay, Buda Limestone (*idem*). The Georgetown Limestone is subdivided into seven members: (1) Kiamichi Clay, (2) Duck Creek, (3) Fort Worth, (4) Denton, (5) Weno, (6) Pawpaw, and (7) Main Street.

In addition, there are local names used for facies of certain formations. However, these names will not be used or mentioned in this paper.

BASIN FRAMEWORK

The following statements describe the basin framework of the study area:

(1) The study area is in the back reef province of a major barrier reef trend on the north side of the ancestral Gulf of Mexico (Fisher and Rodda, 1969, p. 55).

(2) During deposition of Comanchean sediments there was a relatively stable area to the west made up of the Texas craton and the Ouachita fold belt.

(3) In Comanchean time, there was an area of instability in the subsiding East Texas Basin caused by the horizontal and vertical movement of Jurassic age salt.

(4) The study area was tilted to the southeast during Comanchean deposition.

(5) The sedimentary pattern in the stable area is characterized by north-south depositional strike and formational thicknesses which change laterally at a low rate.

(6) The sedimentary pattern in the area of salt movement is characterized by a gross north-south depositional strike and formational thicknesses which often change abruptly.

The study area lies in the northwest part of the Gulf Basin (fig. 1). During Comanchean time this part of the basin consisted of two depositional provinces which were separated by the Stuart City reef trend (Tucker, 1962, p. 182). Barrier reefs extended from Mexico to Louisiana. The reef separated the fore reef to the southeast from the back reef on the northwest; the study area lies within the back reef province. Part of the barrier reef crossed the southeast corner of the area. Wells in parts of Grimes, Houston, Madison, and Walker counties extend into the lagoonal side of the reef complex. The Skelly Oil Company No. A-1 Gibbs (location 103) in Walker County encountered more than 2500 feet of reef complex. Three periods of reef growth are found in this well: Pettet-Pine Island period, Rodessa-upper Glen Rose period, and Goodland-Buda period.

Comanchean rocks southeast of the study area were deposited in deep water seaward from the reef trend (Tucker, 1962, p. 184). Rocks in the study area show that the back reef province was a lagoon where formations extended for many miles and had relatively uniform lithologies (*idem*, p. 195).

The study area can be divided into two areas of different tectonic behavior. The Texas craton-Ouachita fold belt area was relatively stable while the East Texas Basin was very unstable.

TEXAS CRATON

The Texas craton (Comanche platform) (Fisher and Rodda, 1969, p. 55) was an area along the northwest edge of the Gulf Basin which has been relatively stable from late Mesozoic time to the present. In the study area, the Texas craton occupies the western parts of Hill and McLennan counties. Cratonic rocks which are found below the Cretaceous System include

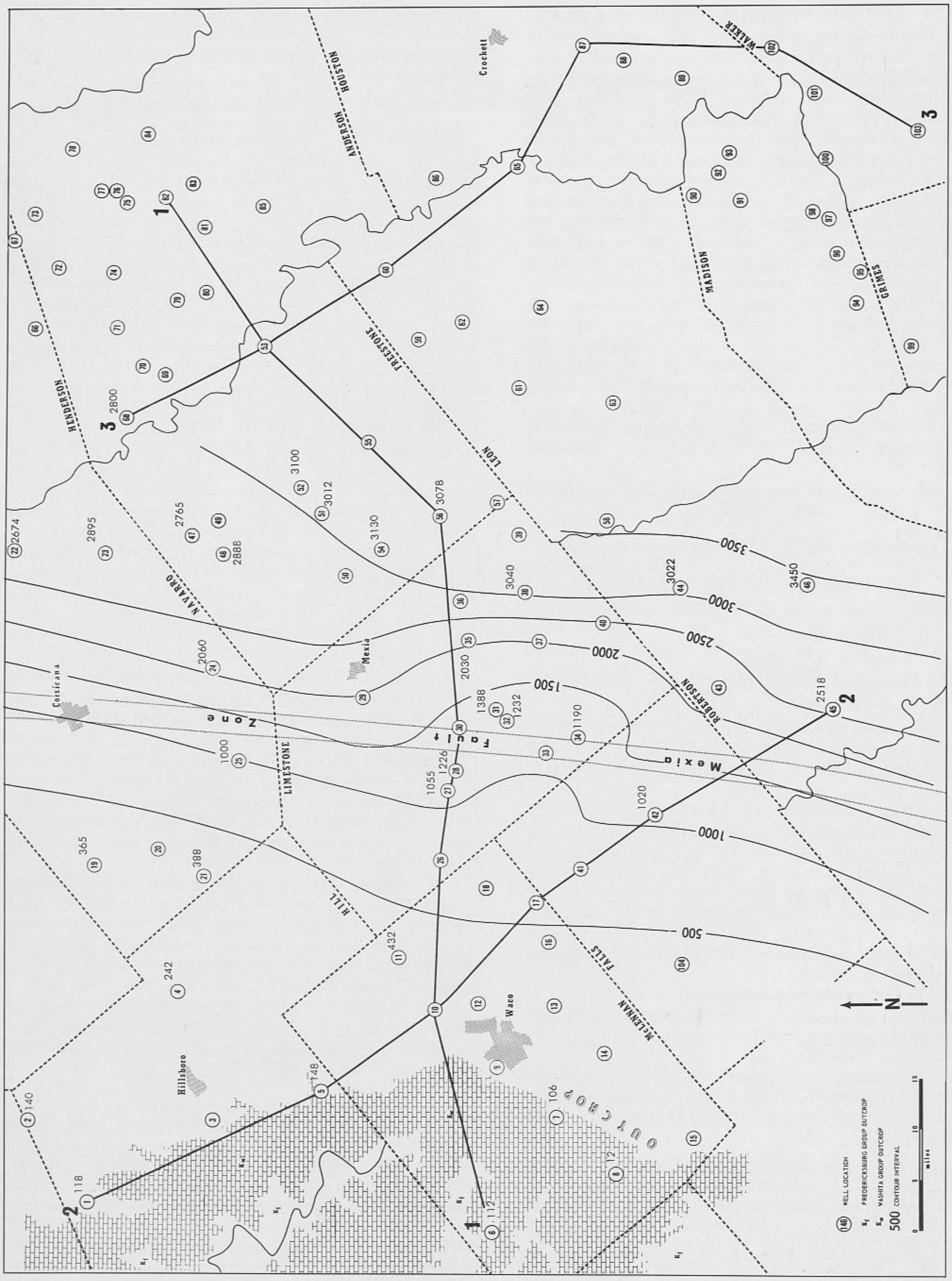

Fig. 2. Isopach map of the subsurface Travis Peak Formation, Central Texas.

sands and shales of the Atoka Formation (Pennsylvanian). In central Hill and McLennan counties Ouachita facies rocks have been thrust over the Atoka beds (Flawn, 1961, Plate 2). This craton area along with the Ouachita fold belt was gently tilted toward the southeast during Comanchean time.

In the outcrop area, Trinity beds onlap topographic features of the eroded Paleozoic surface (Boone, 1968, p. 13). The early Cretaceous sea flooded old drainage systems of the Wichita paleoplain filling them with coarse clastics. Local relief was as much as 100 feet. Typical Pennsylvanian lithologies in this area are red to brown shales, sandstones, conglomerates, sandy mudstones, and siltstones.

OUACHITA FOLD BELT

Between the Texas craton and the East Texas Basin is the north-south band of deformed Paleozoic rocks in the Ouachita fold belt. These rocks do not crop out in the study area. They are present on the outcrop in the Ouachita Mountains of Oklahoma and the Llano Uplift in Texas (Flawn, 1961, p. 3). The fold belt has been divided into two tectonic provinces: the frontal zone to the west and the interior zone to the east.

The interior zone consists of sheared and metamorphosed rocks whose ages often cannot be determined. The frontal zone consists of the folded rocks which have been thrust toward the Texas craton. Ouachita facies rocks penetrated by wells include Bigfork (Ordovician), Stanley (Mississippian), and Bend Series (Pennsylvanian).

Topographic relief on the eroded Ouachita surface is low in the western frontal zone area with a gentle slope toward the east. The slope becomes steep in eastern Hill and McLennan counties.

Isopach maps show that Comanchean depositional strike in the stable Texas craton-Ouachita fold belt area was north-south. There are no abrupt thickness changes in this area. This indicates that there were no major local tectonic movements.

EAST TEXAS BASIN

The East Texas Basin was an area of instability during Comanchean time. The unstable condition of the basin resulted from two tectonic conditions affecting the basin area: regional tilting and salt movement. The rate of regional tilting for the East Texas Basin was greater than that of the stable area to the west. This increased rate of tilting may have been caused by differential compaction between the already compacted Paleozoic sediments of the stable area and the semi-compacted Jurassic sediments of the basin. Another possibility is that the tilting rate may have been the result of a "hinge line" along which basement rocks were warped during Comanchean time. The most important factor causing instability of the basin was movement of salt. Salt moves plastically if rock temperatures exceed 200 degrees centigrade or if there is at least 25,000 feet of overburden (Halbouty, 1967, p. 35). Salt withdrawal from an area causes subsidence. Thick Comanchean sections are encountered in withdrawal areas. Salt moving into dome areas uplifts overlying sediments. Sedimentation over these areas results in abrupt thickness changes over short distances. This condition is common along the axis of the East Texas Basin. Anderson County is an area of salt withdrawal which has several salt domes associated with it. The Bethel salt dome (locations 69 and 70) has penetrated the Comanchean section as a result of salt rising from the Jurassic beds.

Movements along the Mexia fault zone had a strong influence on Comanchean sedimentation. There is abrupt thickening on the east side of this zone and in the fault graben area in many of the formations (figs. 2, 4, 7, 8, 9). This faulting may be the result of tensional stress caused by the basinward movement of the section overlying the Jurassic salt. The updip limit of the salt roughly coincides with the Mexia fault system (Halbouty, 1967, p. 47).

The strike in the East Texas Basin area trends slightly northeast-southwest. There are abrupt changes in formational thicknesses and elevations in this area.

TRINITY GROUP

Robert T. Hill's oldest division of Comanchean rocks is the Trinity Group. This group is a wedge of sediments which helped to fill the East Texas Basin and to drive the ancestral Gulf of Mexico shoreline south to its present position. In the axial area of the East Texas Basin more than 6,000 feet of Trinity rocks were deposited. Over 50 percent of all Comanchean rocks in the study area belong to the Trinity Group.

The Trinity Group is made up of three formations: (1) the Travis Peak Formation, (2) the lower Glen Rose Formation, and (3) the upper Glen Rose Formation.

TRAVIS PEAK FORMATION

The oldest Comanchean sediments in the Central Texas area make up the Travis Peak Formation. This formation is a sandstone and shale sequence which conformably overlies the Schuler Member of the Cotton Valley Formation. These clastics onlap the Paleozoic rocks of the Ouachita fold belt and Texas craton to the west. The formation represents deltaic sedimentation which filled the East Texas Basin during early Comanchean time (T. H. Shelby, Jr., 1969, oral communication).

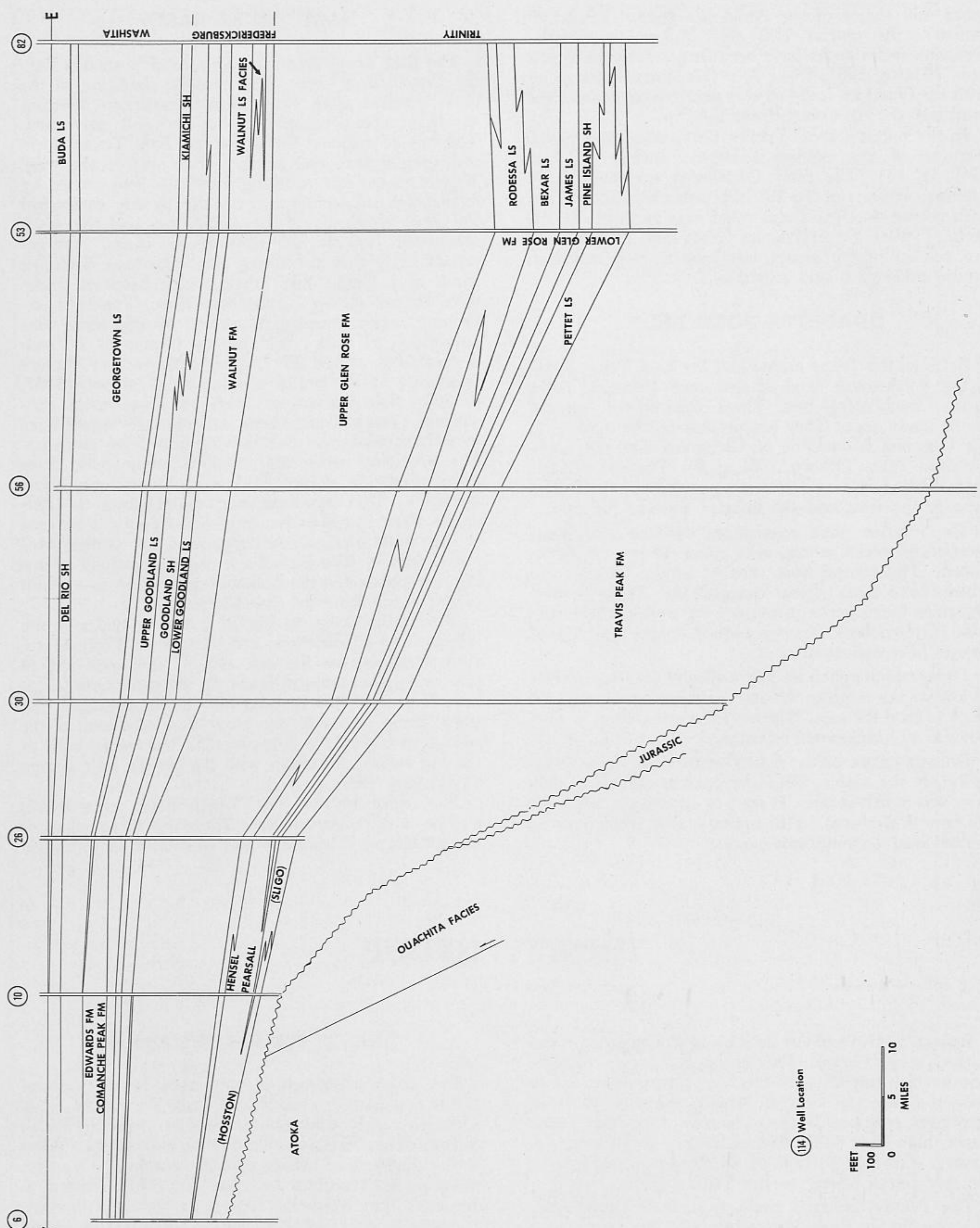

Fig. 3. East-west cross section of Comanchean rocks, northwest McLennan County to central Anderson County.

In the East Texas Basin, Travis Peak clastics overlie Jurassic clastics (Schuler Member). The systemic boundary between Jurassic and Cretaceous is extremely difficult to recognize in this area. Well cuttings from the Travis Peak-Schuler interval show a similar lithology throughout. Electric well logs show no characteristics which would help in segregating the two systems. Lithologically there is no difference between the Travis Peak and the Schuler clastics, and there is no strong evidence for a major unconformity between the two. For these reasons the contact between the Cretaceous and the Jurassic in this study is considered to be conformable. T. H. Shelby, Jr., an authority on the East Texas Basin, believes the contact to be unconformable. Some of the evidence for this is based on the difference in cherts found in the two systems (*idem*).

Lithology of the Travis Peak Formation in the East Texas Basin area is predominantly sandstone and shale (locations 4, 7, 44, 47 and 56 in Appendix II). The sandstones are composed of clean fine-grained quartz. Their colors include pink, red, brown, grey, and white. The lower part of the formation is dominated by the sandstones; the upper part has numerous shale beds separating the sandstone units. Near the top of the formation the sandstones are almost gone and there is a grey calcareous shale facies with calcareous sandstone stringers which has taken their place.

Younger Travis Peak beds lap toward the west onto the Texas craton where they overlie Pennsylvanian sandstones and shales. Valleys in the Paleozoic bedrock were filled by the transgressing Travis Peak sediments as far west as Callahan County. Measured profiles in this area show as much as 60 feet of relief on the paleotopographic surface (Boone, 1968, p. 13).

In the outcrop area the Travis Peak Formation is called the Hosston Sand (Holloway, 1961, p. 16). The lithology consists of fine- to medium-grained orthoquartzites, sandy shales, and conglomerates (Boone, 1968, p. 19). Well cuttings from the Robert C. Smith and Falcon Oil Corporation No. 1 H. G. McKethan (location 7) in McLennan County consist of clean white orthoquartzites, grey shales, shell fragments, lignite, pyrite, red to brown sandstones, and angular chert grains. A similar lithology was observed in well cuttings from the Phillips Petroleum Company No. A-1 Posey (location 4) in Hill County.

The thickness of the Travis Peak Formation was measured from the base of the Pettet Member (lower Glen Rose Formation)* to the top of the underlying Paleozoic rocks in the Texas craton-Ouachita fold belt area (fig. 2). In the East Texas Basin where the Travis Peak is conformable with the Schuler Member, the thickness was measured from the base of the Pettet Member to the top of the youngest Jurassic shale formation.

The isopach map of the Travis Peak Formation shows that the depositional strike was north-south. The area west of Navarro, Limestone, and Falls counties had a gentle east slope on which 12 to 450 feet of Travis Peak clastics were deposited. Local thinning of the formation, like that at location 8, appears to be due to topographic highs on the Paleozoic bedrock which failed to receive sediments until the adjacent valleys were filled. In eastern Hill and McLennan counties the slope steepened sharply and the rate of easterly thickening changed from 8 feet per mile to 100 feet per mile (fig. 3). The Travis Peak-Schuler clastics are over 3000 feet thick in Freestone County. In the axial part of the basin none of the wells used in the study drilled through the Travis Peak section. It can be assumed that the formation in this area is several thousand feet thicker than it is in Freestone or Robertson counties to the west.

Editor's Note: Recent usage puts the Pettet member in the upper Travis Peak Formation.

LOWER GLEN ROSE FORMATION

The lower Glen Rose Formation is a sequence of limestone and shale beds. These rocks record the first Cretaceous marine transgression in the study area where they conformably overlie the deltaic clastics of the Travis Peak Formation.

The lower Glen Rose isopach map (fig. 4) shows the following relationships:

(1) West of the Mexia fault zone was a relatively stable tectonic area.
(2) The Mexia fault zone was active during early Glen Rose time.
(3) The area east of the Mexia fault zone was unstable and abrupt thickness changes occur over short distances.
(4) Maximum thicknesses occur in Anderson County.
(5) Anderson County was the most unstable part of the study area during early Glen Rose time.
(6) Most of Leon County was a positive structural feature.
(7) The Stuart City reef trend is an area of thinning Comanchean rocks.
(8) The gross strike is north-south.
(9) Regional thickening is to the east.

The formation thickens toward the east. In western McLennan County, the lower Glen Rose thickness is 145 feet at location 6. There is a thickening rate of 75 feet per mile eastward to the Mexia fault zone, where the formation is 500 feet thick. Immediately east of this zone the formation is about 650 feet thick. East of this area the rate of thickening is difficult to calculate because of the irregular isopach pattern. The gross increase in thickness is from 600 feet in central Limestone County to over 1600 feet in eastern Anderson County.

West of the Mexia faulting the depositional strike is north-south. This area was relatively stable compared to the basin east of the fault zone. There is a slight north component of thickening from McLennan County to Hill County.

East of the Mexia fault zone the formation thickness was strongly influenced by salt movement. Salt movement in Anderson County caused great differences in the amounts of sediments that localities received. Salt domes and pillars formed adjacent to withdrawal areas. There is as much as 500 feet difference in formational thickness between the areas of accumulation and with-

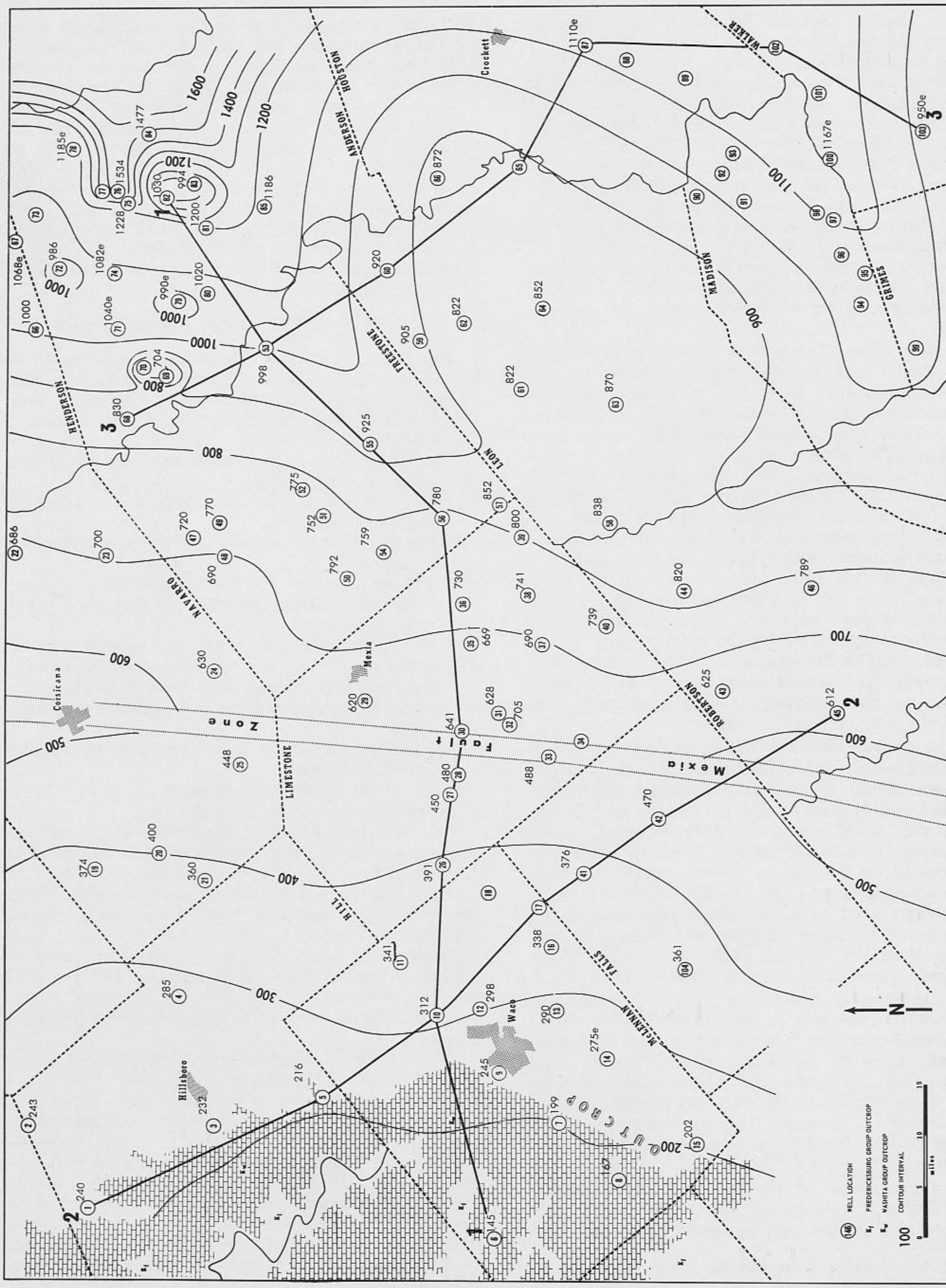

Fig. 4. Isopach map of the subsurface lower Glen Rose Formation, Central Texas.

drawal (location 83 and 84). In Leon County there was a positive area which lay between the Stuart City reef trend to the south and the highly unstable Anderson County withdrawal area. On the lower Glen Rose isopach map the Stuart City reef trend is a thin zone with a thick area just to the north (figs. 4, 6). The lower Glen Rose Formation consists of three members: (1) Pettet, (2) Pine Island, and (3) Rodessa.

Pettet Member

The first major Comanchean limestone unit is the Pettet Member. This sequence of limestones and shales conformably overlies the Travis Peak Formation.

In the Humble Oil and Refining Company No. 1 R. P. McWatters (location 56) in Freestone County the Pettet Member consists of 218 feet of interbedded grey shales and limestone. The limestones are white to light grey, dense, and fossiliferous. The lower limestone beds grade into grey shales toward the east in Anderson and Henderson counties (fig. 3). To the south in Walker and Madison counties the limestone facies is dark grey and dense. In the Skelly Oil Company No. A-1 Gibbs (location 103) about 230 feet of dark grey, dense limestone and shale were observed in well cuttings. In the Stuart City reef trend area many of the limestones are dark in color probably as a result of petroliferous reef material in the sediments.

In Robertson County the Shell Oil Company No. 1 D. J. Hamilton (location 46) encountered white to grey micritic and grey pelmicritic limestone beds along with thin grey shale stringers. The thickness of the Pettet Member at this location is 247 feet.

In Hill and eastern McLennan counties the Pettet Member is called the Sligo Formation. Well cuttings from the Phillips Petroleum Company No. A-1 Posey (location 4) show the lithology to be light grey, dense limestone. Some of the lower sands and shales of the Pearsall Formation at this location are time equivalents of the downdip Pettet limestones.

In central McLennan County the limestone facies of the Pettet Member is gone. Its time equivalent facies is the upper part of the Hosston Formation and lower part of the Pearsall Formation. In the Robert C. Smith and Falcon Oil Company No. 1 H. G. McKethan (location 7) this facies is a white, calcareous sandstone about 18 feet thick.

Pine Island Member

The Pine Island Member conformably overlies the Pettet Member of the lower Glen Rose Formation. In the basin the member consists of the Pine Island Shale (lower shale zone), the James Limestone, and the Bexar Shale (upper shale zone). The total thickness of the member ranges from about 50 feet on the Texas craton to over 500 feet along the basin axis.

In Freestone County the well cuttings in the Humble Oil and Refining Company No. 1 R. P. McWatters (location 56) show the Pine Island Shale to be black and the Bexar Shale to be light to dark grey and calcareous. There are about 80 feet of white to grey micritic James Limestone. The Bexar Shale interfingers with the limestone facies of the overlying Rodessa Member.

The James Limestone is not present to the west along the Texas craton. Wells in McLennan and Hill counties show that the Pine Island and Bexar shales form one unit, the Bexar Shale.

In Anderson County near the axis of the basin, the James Limestone is 130 feet thick. There is thickening of the limestone to the south (fig. 6). In the Skelly Oil Company No. A-1 Gibbs (location 103) the James Limestone is 175 feet thick. Well cuttings show the unit to be a dark grey, dense limestone in this area. The Bexar and Pine Island shales are dark grey to black and dense. The thickening of the James Limestone in this area is at the expense of the encasing shales.

In Robertson County in the Shell Oil Company No. 1 D. J. Hamilton (location 46), the James Limestone is a grey micritic and pelmicritic limestone. The Bexar Shale is grey, fissile, and noncalcareous. The Pine Island shale is similar to the Bexar except it is calcareous. Thickness of the total Pine Island Member is about 260 feet (Bexar—130 feet, James—80 feet, and Pine Island—50 feet). The James Limestone has a middle shale bed and a poorly developed limestone facies.

In McLennan County in the Robert C. Smith Falcon Oil Corporation No. 1 H. G. McKethan (location 7) the Pine Island Member is 40 feet of grey sandy shale.

Rodessa Member

The Rodessa Member is a massive limestone which overlies the Bexar Shale. In McLennan County the facies equivalent is the Hensel Sand and upper part of the Pearsall Formation. Lithology of the Rodessa equivalent in the Robert C. Smith and Falcon Oil Corporation No. 1 H. G. McKethan (location 7) is 68 feet of white calcareous sandstone.

In Hill County the Phillips Petroleum Company No. A-1 Posey (location 4) drilled 120 feet of Rodessa Member. Lithology was white to grey sandy limestone.

A typical basin section was encountered in the Continental Oil Company No. 1 Murphy M. Williams (location 47) which drilled 180 feet of Rodessa limestone. Lithology was grey mottled limestone and grey shale.

In the study area, the Rodessa Member is the oldest limestone in the second phase of growth of the Stuart City reef complex. In the Skelly Oil Company No. A-1 Gibbs (location 103) in Walker County, the second reef buildup begins in the Rodessa and continues essentially uninterrupted until late Glen Rose time (fig. 6). The Rodessa equivalent in the reef complex is 320 feet of dark grey, dense, cryptocrystalline limestone with porous zones of white sparritic limestone.

Well cuttings from the Shell Oil Company No. 1 D. J. Hamilton (location 46) in Robertson County show the Rodessa Member to be a combination of grey pelmicrites, dismicrites, biomicrites, and grey shale. The member thickness is about 290 feet with about 80 feet of this being shale.

UPPER GLEN ROSE FORMATION

The youngest Trinity formation is the upper Glen Rose Formation, a sequence of limestones, shales, and anhydrites. The lower part contains the Ferry Lake

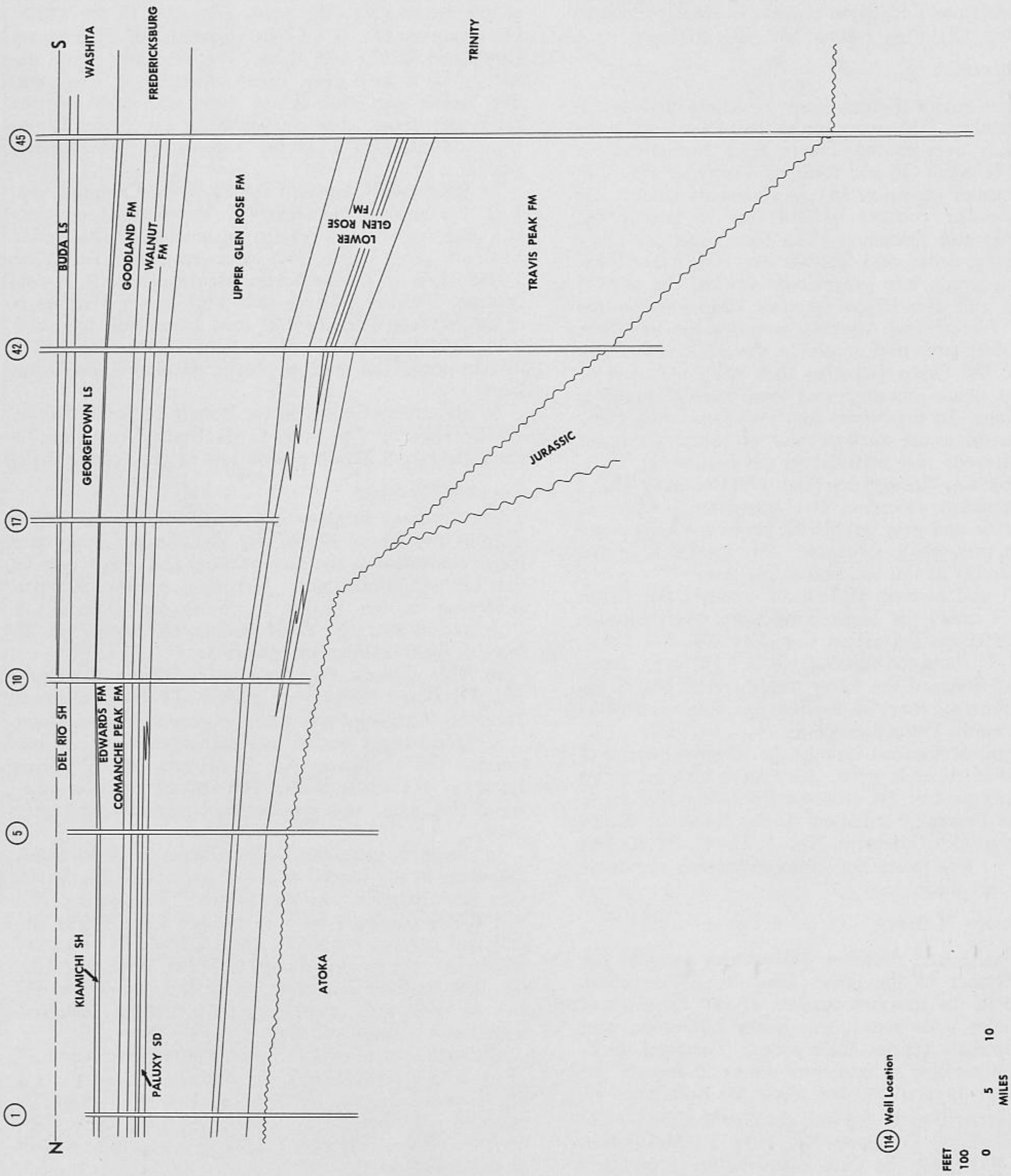

Fig. 5. North-south cross section of Comanchean rocks, northern Hill County to northwest Robertson County.

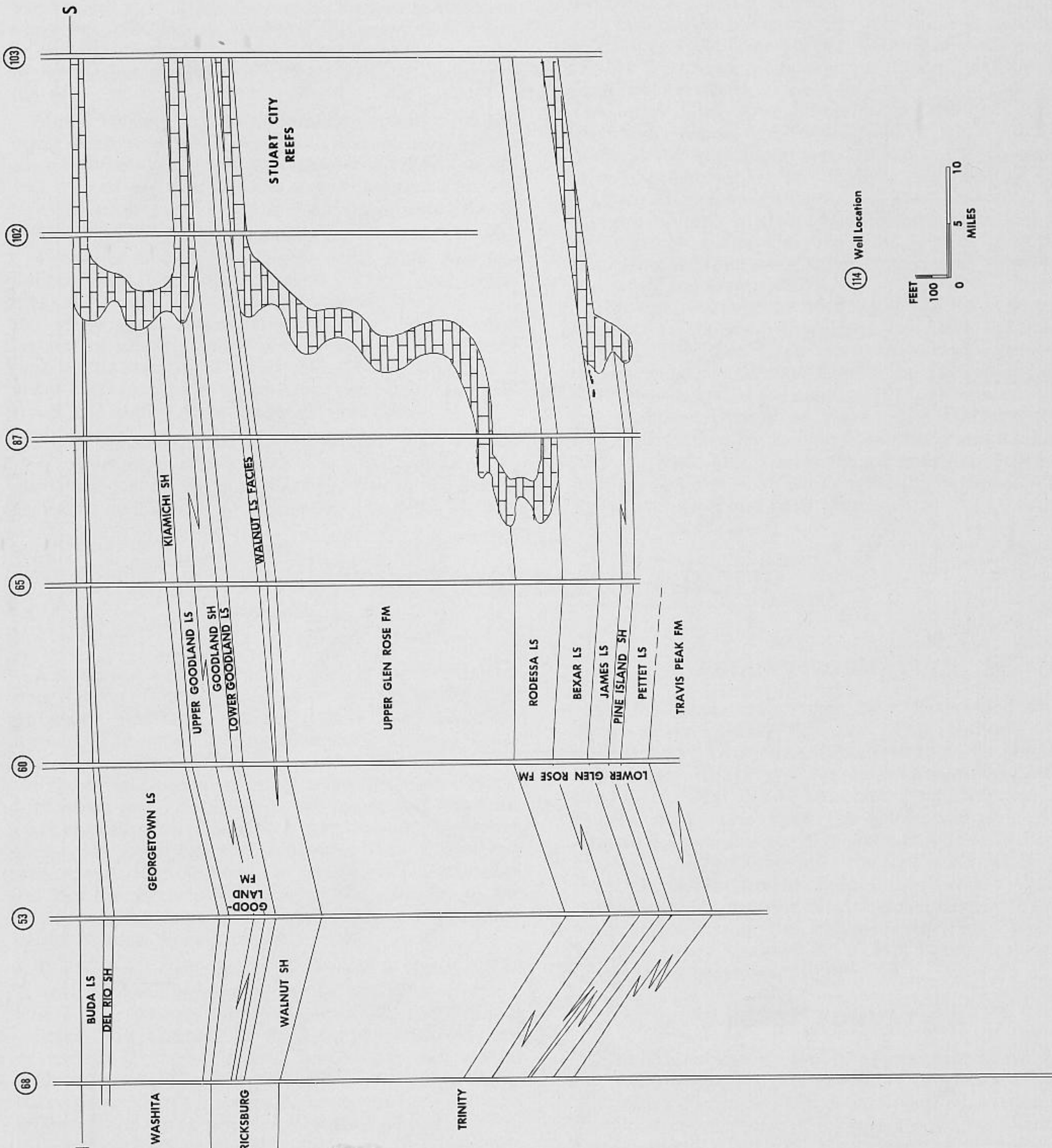

Fig. 6. North-south cross section of Comanchean rocks, northwest Anderson County to northwest Walker County.

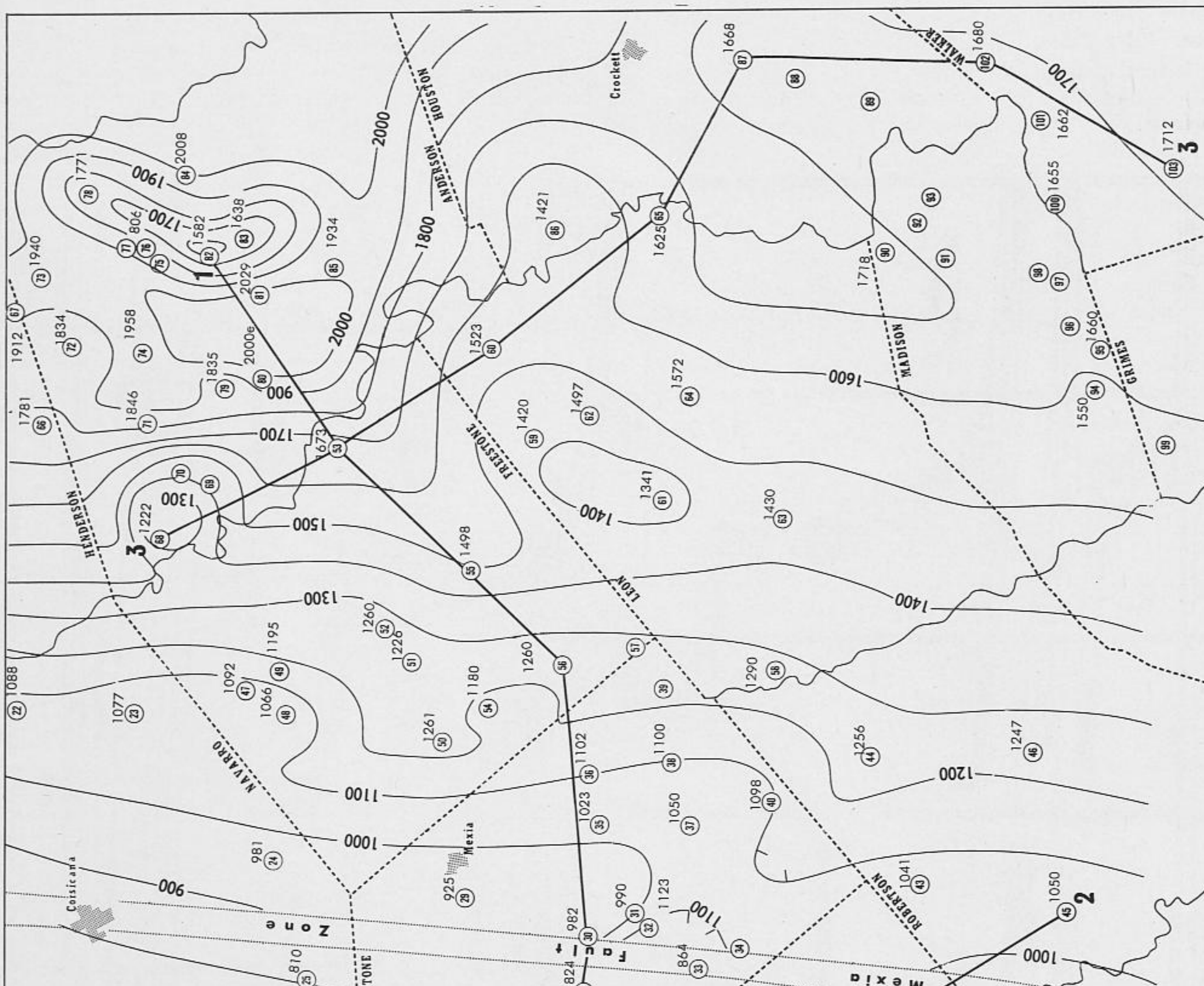

Fig. 7. Isopach map of the subsurface upper Glen Rose Formation, Central Texas.

Anhydrite zone which overlies the Rodessa Member of the lower Glen Rose Formation.

The isopach map of the upper Glen Rose Formation (fig. 7) shows a tectonically stable area west of the Mexia fault zone. Formational thicknesses in this area range from 430 feet in western Hill County to 864 feet in central Limestone County. The depositional strike in this stable area is north-south with thickening to the east.

Mexia faulting was active during deposition of the upper Glen Rose sediments. This can be seen by the abrupt thickening across the fault zone. Location 28 just west of the zone has 824 feet of section. The section thickens to 1123 feet at location 32 immediately east of the faulting.

The area east of the Mexia fault zone was tectonically unstable. Salt movement affected most of the area and caused irregular sedimentary patterns. In the study area, Anderson County had the greatest amount of subsidence and salt flowage. In the eastern part of the county the upper Glen Rose Formation is about 2000 feet thick. South along the Stuart City reef trend, the section thins to about 1650 feet.

In McLennan County the upper Glen Rose Formation ranges in thickness from 470 feet in the west to about 680 feet in the east. Well cuttings in the Robert C. Smith and Falcon Oil Company No. 1 H. G. McKethan (location 7) include white fossiliferous limestone, sparritic limestone, grey shale, shell fragments, white calcareous sandstones, and orange quartz grains. In the lower beds, *Orbitolina texana* and gastropod fragments are quite common.

In Hill County numerous *Orbitolina texana* were seen in cuttings from lower upper Glen Rose beds in the Phillips Petroleum Company A-1 Posey (location 4). Shell fragments and echinoid spines were also observed. The upper Glen Rose limestones in this well range from grey, dense, and fossiliferous to white micritic. Some of the grey limestones are sandy. White anhydrite is present above the Rodessa Member.

Upper Glen Rose cuttings from the Continental Oil Company No. 1 Murphy M. Williams (location 47) in Freestone County include 1092 feet of grey and white mottled limestone, grey shales, and gastropod and pelecypod fragments.

The unit thickens to over 2000 feet in Anderson County. To the south the upper Glen Rose Formation is about 1700 feet thick along the Stuart City reef trend (fig. 6). In Walker County the Skelly Oil Company No. A-1 Gibbs (location 103) penetrated 1712 feet of upper Glen Rose rocks. The lithology from well cuttings is white to light grey, dense micritic limestone to dark grey, dense cryptocrystalline limestone with porous zones of white sparritic limestone. The shales are dense and dark grey.

FREDERICKSBURG GROUP

The second Comanchean division is the Fredericksburg Group. This group consists of two main units: an upper limestone sequence and a lower shale sequence. The upper limestones in north Central Texas and in the East Texas Basin are collectively called the Goodland Formation. In the outcrop area in western McLennan and Hill counties, the upper reef limestone beds are called the Edwards Formation, and the lower limestones are called the Comanche Peak Formation. The lower shale sequence is the Walnut Formation. In McLennan and Hill counties and counties to the west, there is a lower sand facies (Paluxy Formation) in the Walnut Formation.

Depositional strike in the study area is about N 45° E with regional thickening to the southeast (fig. 8). The Fredericksburg Group is about 320 feet thick in western Hill County. It thickens to about 400 feet in eastern Navarro, central Limestone, and central Falls counties. The group thickens across the Mexia fault zone. Fault movement contemporaneous with sedimentation amounted to about 100 feet of vertical displacement. From the fault zone, the section thickens toward the southeast into a linear depocenter which trends from the Anderson County salt withdrawal area south to the back-reef side of the Stuart City trend in Madison County.

The section thins from Madison County south over the reef trend where it is about 550 feet thick.

PALUXY FORMATION

On the Texas craton there is a lower sand facies known as the Paluxy Formation. This sand unit overlies the upper Glen Rose disconformably. In northern Hill County electric well log correlations indicate that the upper Glen Rose beds are truncated and the Paluxy sands have filled the paleotopographic lows. The sand facies thins to the south and east. In northern Hill County (location 1) the unit is about 100 feet thick. It is not present in most of Navarro County nor to the south and east of McLennan County. Paluxy Sand cuttings from the Phillips Petroleum Company No. A-1 Posey (location 4) in Hill County consist of fine-grained quartz sandstone.

WALNUT FORMATION

The Walnut Formation is a grey calcareous shale and marl sequence. It conformably overlies the upper Glen Rose Formation and is conformably overlain by the Goodland Formation. Where the Paluxy Sand is present, the Walnut Clay rests conformably upon Paluxy Sand.

The Walnut Formation interfingers with the underlying Paluxy sands and upper Glen Rose limestones and marls of the overlying Goodland Formation. Walnut shales overlying the Paluxy Formation range in thickness from about 50 feet at location 1 in Hill

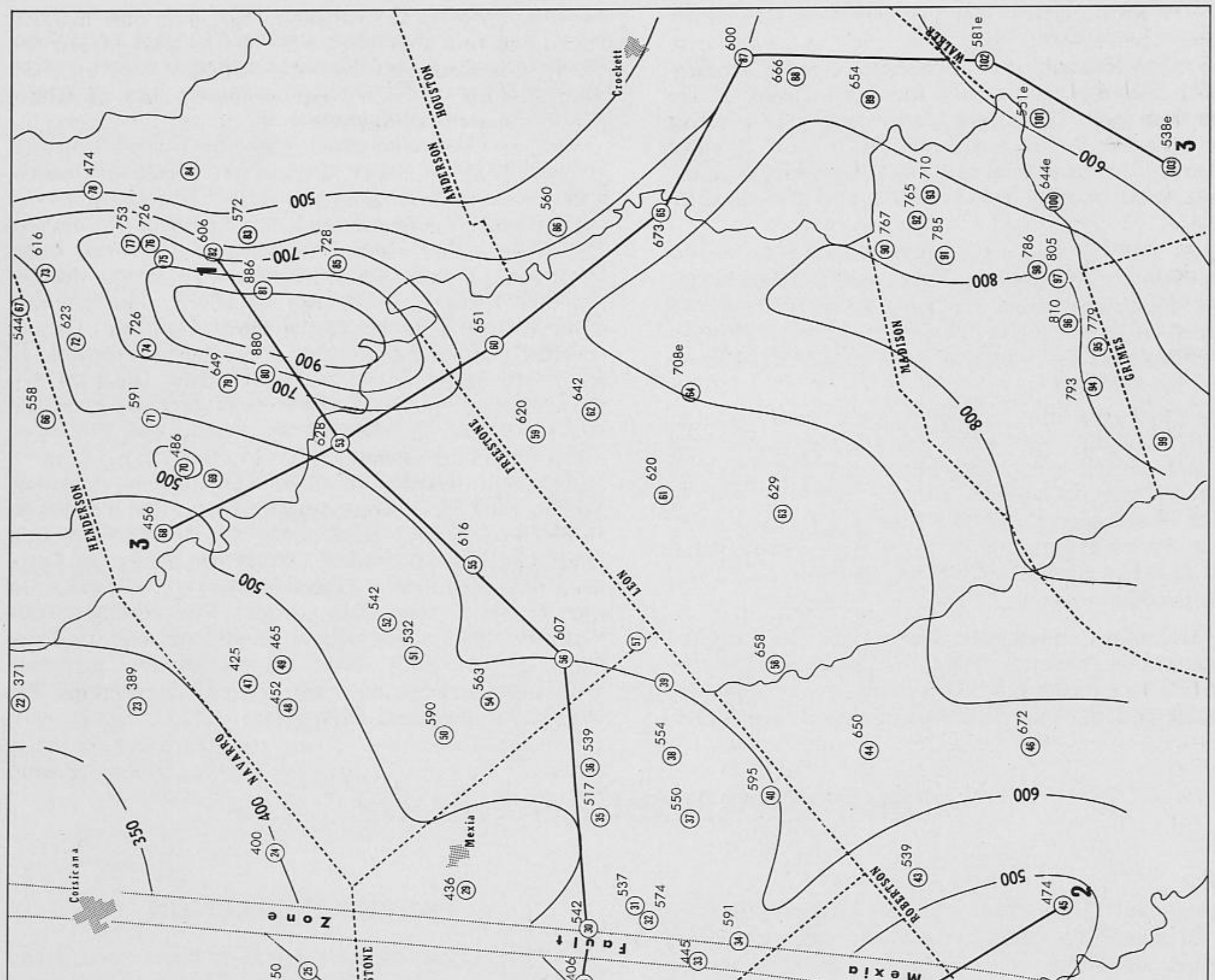

Fig. 8. Isopach map of the subsurface Fredericksburg Group, Central Texas.

County to about 150 feet at location 7 in McLennan County. The Walnut Formation thickens to the east (fig. 3). At location 55 in Freestone County the formation is 260 feet thick; from there it thickens to 320 feet at location 82 near the basin axis in Anderson County. To the south at location 65 in Leon County the formation is about 330 feet thick. From here southward it thins to 230 feet at location 103 in Walker County along the Stuart City reef complex.

In the basin axis area the lower part of the Walnut Formation develops a limestone facies (figs. 3, 6). At location 103 in Walker County this limestone facies is 60 feet thick. Well cuttings from the Glenrose Corporation No. 1 G. E. Kelley (location 87) in Houston County show this facies to be dense, grey limestone, shell fragments, and some fine-grained, grey sandstone. The limestone facies is 55 feet thick in this well. Other wells which show the Walnut limestone facies lie near the basin axis north of the Stuart City reef trend.

GOODLAND FORMATION

The Goodland Formation is a limestone and shale sequence which conformably overlies the Walnut Formation. In the basin area the formation consists of two limestone units divided by a shale or marl unit (fig. 3). In Anderson County at locations 80 and 81 the formation is over 400 feet thick. The unit thins southward toward the Stuart City reef trend where the estimated thickness is about 300 feet. Limestones of the Goodland and Georgetown formations merge into one massive buildup in this area (fig. 6). Well cuttings from the Skelly Oil Company No. A-1 Gibbs (location 103) show that the Goodland equivalent consists of white, porous, sparritic limestone and dense, grey, cryptocrystalline limestones.

There is a regional thinning of the Goodland Formation westward from the basin axis. In eastern Limestone County the formation is 332 feet thick at location 35. The middle shale unit accounts for 150 feet of the formation. In western Limestone County the formation is 280 feet thick. There is no abrupt thinning west of the Mexia fault zone; the interval remains almost constant as far west as location 7 in McLennan County where the formation is 276 feet thick. Most of the thickening in the Fredericksburg Group occurs in the Walnut Formation (fig. 3).

On the Texas craton the Goodland Formation is called the Edwards Limestone (upper unit) and Comanche Peak Limestone (lower unit). The Comanche Peak Formation is a nodular white to buff micritic limestone and marl sequence on the outcrop. It is transitional with the underlying Walnut Formation and time equivalent to parts of the Paluxy, Walnut, and Edwards formations (Hayward and Brown, 1967, p. 43).

In Hill County well cuttings from the Phillips Petroleum Company No. A-1 Posey (location 4) consist of 210 feet of cream to white micrite; grey sandy limestone; white sparritic, fossiliferous limestone; and grey shale.

WASHITA GROUP

The youngest Comanchean division is the Washita Group. This group consists of calcareous shales and marine limestones. There are five major subdivisions of the group: Kiamichi Shale, Georgetown Limestone, Del Rio Clay, Buda Limestone, and Maness Shale. These subdivisions can be correlated throughout the study area except where they have been eroded. Their uniform lithology, excellent character on electric well logs, and lack of major facies changes make them useful as time markers in the upper part of the Comanchean section. The group varies in thickness from about 200 feet in western McLennan County to over 1400 feet in central Anderson County (fig. 9).

The Washita Group thickens regionally toward the northeast. The area of maximum subsidence was in the Anderson County salt withdrawal area. Abrupt thickening across the Mexia fault zone indicates about 150 feet of vertical movement during Washita time. The Stuart City reef trend was a high area. Wells in Walker County have about 450 feet of Washita age reef sediments.

In western McLennan County, the Washita section is about 200 feet thick. Equal thickness contours on the isopach map are oriented in a northwest-southeast-trending arc whose focal point is Anderson County. The gross rate of northeast thickening is about 7 feet per mile.

The Bethel salt dome in Anderson County (locations 69 and 70) was very active during Washita time. The section on this dome is about 400 feet thinner than the section of the surrounding area.

KIAMICHI FORMATION

The Kiamichi Formation is a black, fissile shale which becomes calcareous in the upper beds. West of Waco in the Middle Bosque River valley 4 to 15 inches of the formation crop out. Thickening is to the north and east. At Whitney Dam in Bosque and Hill counties the unit is 11 feet thick (Dixon, 1967, p. 243). In central Anderson County the Kiamichi Shale is over 120 feet thick. This was an area of continuous subsidence during Comanchean time. The formation thins to about 30 feet just north of the Stuart City reef trend in Grimes and Walker counties (fig. 6). Abrupt thickening occurs eastward across the Mexia fault system

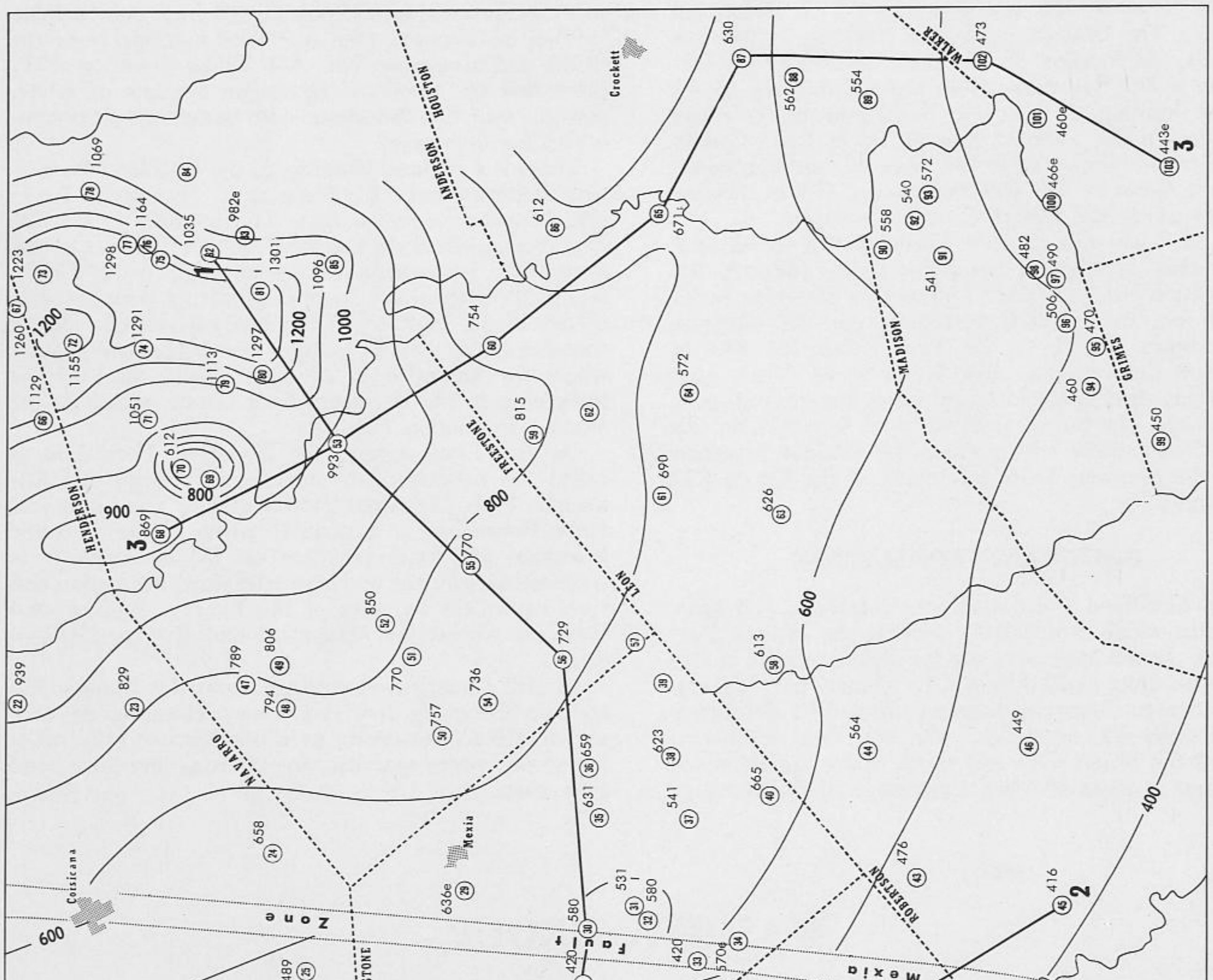

Fig. 9. Isopach map of the subsurface Washita Group, Central Texas.

indicating fault movement during Kiamichi sedimentation.

The lithology in the study area is black shale over the area except where the Kiamichi shales interfinger with Kiamichi age reef limestones in Grimes and Walker counties. Correlation of the unit in the reef complex is difficult to impossible.

The black Kiamichi shales are thought to have been deposited under conditions of restricted water circulation (Bishop, 1967, p. 159). The black shale facies represents a period of water stagnation caused by reef growth along the Stuart City reef trend which closed channels to the open sea. The Edwards Limestone banks were exposed to the air, eroded, bored, leached, and then smothered by black shales in the shallow oxygen-deficient water. The East Texas Basin area must have been relatively stable in relation to sea level during Kiamichi deposition in order to develop such a widespread and thin lithologic unit.

GEORGETOWN FORMATION

The Georgetown Formation conformably overlies the Kiamichi Shale and is made up of interbedded limestones and shales. The limestones are white, chalky in texture, and fossiliferous; the interbedded shales are calcareous, grey in color, and fossiliferous. The formation is divided into six members in the outcrop area: Duck Creek, Fort Worth, Denton, Weno, Pawpaw, and Main Street members. In the subsurface the formation is usually not subdivided, however individual units can be correlated over long distances and the outcrop members can be mapped in the subsurface from electric well logs.

In the outcrop area of western McLennan County the Georgetown Formation is about 130 feet thick (Dixon, 1967, p. 243). In the Layne-Texas Company No. 2 Texas Water Company (location 9) at Waco in McLennan County, the formation is 151 feet thick but thickens to the north. In northern Hill County, the Humble Oil and Refining Company No. 1 Ella Freeman (location 2) penetrated 208 feet of the formation.

From the outcrop the unit gradually thickens across McLennan County and reaches a thickness of 246 feet in the M. M. Miller No. 1 J. C. Rogers (location 27) just west of the Mexia fault zone in central Limestone County. There is abrupt thickening of Georgetown beds across the fault zone. Immediately east of the fault zone, the Pan American Petroleum Corporation No. 1 Elmer Beene (location 30) encountered 368 feet of Georgetown Formation. From central Limestone County the formation continues to thicken to the east where there are about 1000 feet of section in central Anderson County (fig. 3). South from Anderson County the unit thins. The thickness of the unit is about 350 feet just north of the Stuart City reef trend in Madison County (fig. 3). Within the reef complex the Georgetown Formation merges with other Washita formations and the Goodland Formation into a continuous carbonate build-up.

Lithology of the Georgetown Formation in the Stuart City reef area consists of dense, light grey cryptocrystalline limestone; white, porous, sparritic limestone; and dense, dark grey shales (location 103—well cuttings). In Freestone County the Georgetown Formation is made up of white chalky limestone and grey shale (location 47). The white chalky facies is present over most of the study area including Hill County (location 4), Robertson County (location 46), and along the outcrop.

DEL RIO FORMATION

The Del Rio Formation is a shale and marl unit which conformably overlies the Georgetown Formation. Well cuttings of the formation are calcareous grey shales over the entire study area. The formation appears to be a facies of the upper Georgetown Formation. The development of upper Georgetown Limestone beds is at the expense of the Del Rio Shale.

The contact between the Del Rio Formation and the overlying Buda Formation is fairly sharp and may represent a hiatus. The upper Del Rio beds have been truncated in central McLennan County and along strike in Hill County (fig. 3). Gulfian rocks rest directly on Del Rio shales (locations 9, 15, 3, 4, and 2).

The thickness of the Del Rio Formation varies from about 15 feet in Madison County (location 98) to 102 feet in Navarro County (location 19). The formation thickens to the north and west, which is opposite from the behavior of other Comanchean units.

This inverse trend of thickening is probably due to the facies relationships between the Del Rio shales and the Georgetown limestones. The limestone facies becomes more dominant toward the Stuart City reef complex (fig. 6). At location 64 in Leon County the Del Rio Shale is 7 feet thick.

BUDA FORMATION

The Buda Formation is the uppermost Comanchean limestone unit. In the study area west of Freestone County, the Buda unconformably underlies rocks of Gulfian age. In Freestone County and the area to the east, the Buda is overlain by the Maness Shale, the youngest Comanchean formation.

The thickest Buda section for the study area occurs in northeastern Anderson County; wells in this area encountered over 150 feet of the formation. The formation thins to the south and west from Anderson County. South in Madison County, the Buda Formation is about 50 feet thick. Westward thinning terminates in central Hill and McLennan counties where the Buda Formation has been eroded away, and Gulfian rocks occur above the Del Rio Formation (fig. 5). An area of thick Buda Limestone trends from Robertson County northeast to Anderson County.

In the outcrop area, the Buda Formation is a fossiliferous, yellowish, dense, crystalline limestone (Hayward and Brown, 1967, p. 48). In Robertson County well cuttings from the Shell Oil Company No. 1 Murphy M. Williams (location 46) show the Buda Formation to be a dense white micrite. The Buda Limestone is a white micrite in well cuttings over most of the study area (locations 47, 56, and 87). In Walker

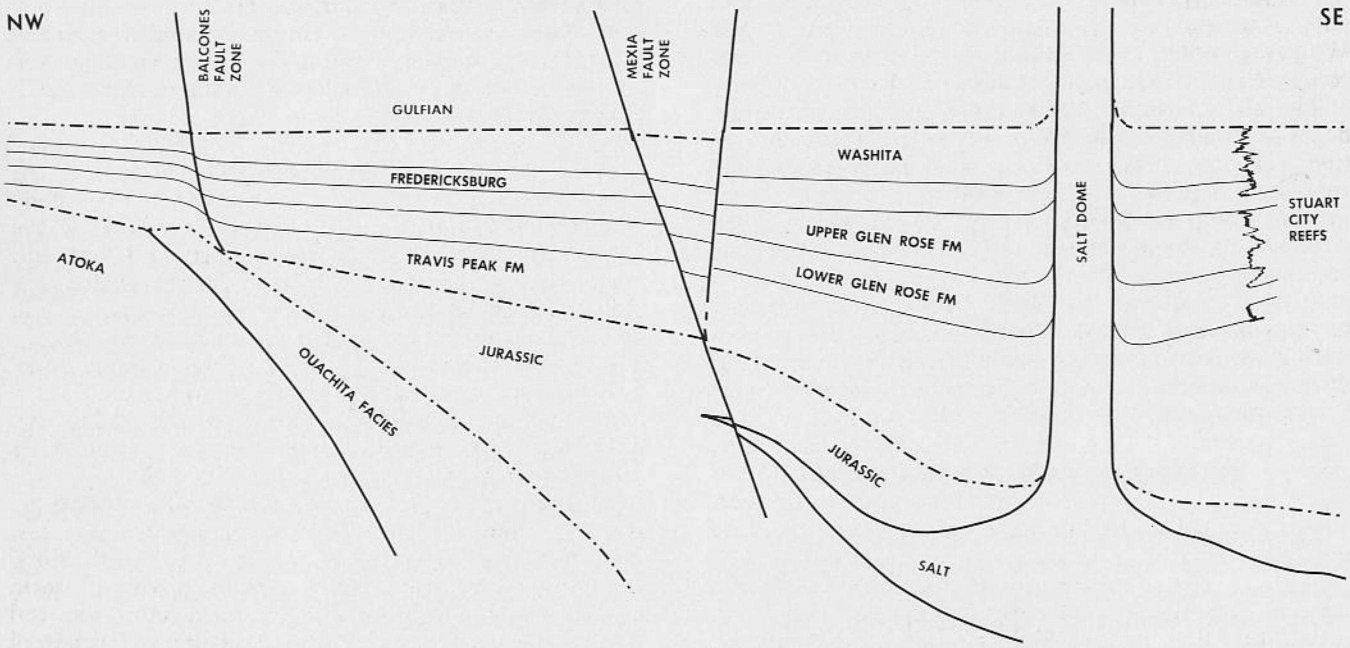

Fig. 10. Diagrammatic northwest-southeast cross section of Comanchean rocks from McLennan County to Houston County.

County along the Stuart City reef trend, the Buda Formation has a grey, dense cryptocrystalline facies as well as a white micrite facies (location 103).

MANESS FORMATION

The Maness Shale is the youngest Comanchean formation. It does not crop out in the study area and is confined to the central part of the East Texas Basin. The unit is named after a well in eastern Cherokee County, Texas—the Shell No. 1 Maness. Lithology of the unit is bronze or copper-colored to dark grey shale. The Maness Formation is recognized in the deep part of the East Texas Basin and as far south as Robertson County. It has also been identified as far west as central Limestone County (Bailey, Evans, and Adkins, 1945). Thickness of the formation ranges from 0 to 200 feet.

Electric log correlation of the Maness Formation is difficult especially where it is overlain by Gulfian shales. Well cuttings in the study area become mixed with younger rocks so that only the copper-colored facies is easy to recognize.

SEDIMENTARY HISTORY

The sedimentary history of the Comanchean Series can be divided into two major periods: (1) the deltaic period and (2) the marine transgression period.

DELTAIC PERIOD

The deltaic period is represented by the sands and shales of the Schuler Member (Jurassic) and the Travis Peak Formation (Cretaceous). In late Jurassic time, the factors controlling deposition of marine shales changed. The marine environment migrated toward the east and a deltaic environment took its place. Sands and shales of the Schuler Member of the Cotton Valley

Formation started filling the deeper parts of the East Texas Basin. As the basin's topographic lows were filled, Schuler sediments began to lap westward onto the eroded surface of the Ouachita fold belt. Sometime during westward onlapping, the age of the deltaic sediments graded from Jurassic to Cretaceous.

The Comanchean deltaic complex, the Travis Peak Formation, continued filling the East Texas Basin and lapping westward (fig. 10). Depositional patterns of Travis Peak clastics were controlled by three factors: (1) the movement of Jurassic salt, (2) a sharp break in slope in the western part of the study area, and (3) the topography of the Texas craton-Ouachita fold belt area.

Movement of Jurassic age salt affected the thickness of local deposits of Travis Peak sediments. Salt withdrawal areas subsided as compared with surrounding areas where there was little or no salt movement or where flowage of the salt moved upward to form salt domes or anticlines. Areas of subsidence have thick sections, and areas of uplift have thin sections. Often the areas of subsidence and uplift were close together. The sedimentary section in such an area has very irregular thickness patterns.

Early Travis Peak deposition was restricted to the eastern part of the study area by a steep east slope which started in eastern Hill and McLennan counties. West of this slope-break the basin floor was gently dipping toward the east. The approximate location of the slope-break can be seen on the isopach map of the Travis Peak Formation (fig. 2). Several thousand feet of sediment were deposited in the basin area before the onlapping Travis Peak clastics reached the slope-break. Once the slope-break was reached Travis Peak sedimentation spread rapidly westward. In covering the old slope-break, the Travis Peak Formation formed a gentle eastward-sloping basin floor. The relatively flatter basin floor condition caused transgressive pulses to affect larger areas than in the past.

Sedimentation across the Texas craton-Ouachita fold belt area was controlled by erosional features on the pre-Cretaceous surface (Boone, 1968, p. 13). Drowned river valleys were filled first, and finally the old divides were covered by the onlapping sediments. In some areas only a thin blanket of Travis Peak clastics cover the paleotopographic highs. Such an area is location 8 in McLennan County which has only 12 feet of Travis Peak (Hosston) Formation.

Near the end of the deltaic period the Travis Peak Formation developed a grey marine shale facies in the basin axis area. This marked the end of the deltaic period and the beginning of the marine transgression period.

MARINE TRANSGRESSION PERIOD

At the end of Travis Peak time, the sea swept westward across the study area and deposited the shales and limestones of the lower Glen Rose Formation. The first units to be deposited were the Pettet Limestone Member and the Pine Island Member which is composed of the Pine Island Shale, James Limestone, and Bexar Shale. This sequence of limestones and shales covered the area east of Hill and McLennan counties. West of that area, shales and calcareous sandstones were deposited in a nearshore environment. These nearshore facies are the Sligo, Pearsall, and Hensel formations in the outcrop area.

In the southeast part of the study area, the Stuart City reef trend was beginning to form in Houston, Grimes, Madison, and Walker counties. The reefs during Pettet and James times were minor and later were covered by the Bexar Shale (fig. 6). The lagoon north of the early reef trend was probably open to the sea at this time. Most of the lime muds in the lagoon were derived from the growing reefs. Currents in the lagoon distributed these carbonates north and westward where they interfingered with land-derived shales.

During early Glen Rose time, the area east of Hill and McLennan counties was tectonically active (fig. 4). There was movement along the Mexia fault zone. Salt was withdrawing from parts of Anderson County and accumulating in other areas. The only stable part of the lagoonal area at this time was a large structurally positive area that included most of Leon County.

The end of early Glen Rose time was marked by the deposition of the Rodessa Limestone Member. This was the beginning of major reef growth along the Stuart City reef trend. Beginning with Rodessa deposition, the reef growth continued until the end of late Glen Rose time when the shales and sands of the Walnut and Paluxy formations covered the area. Figure 6 shows the massive reef zone at locations 102 and 103 in Walker County. The Rodessa Limestone extends into western McLennan County; the position of the Rodessa shoreline was west of the study area.

The maximum marine transgression occurred during deposition of the upper Glen Rose Formation (Rodgers, 1967, p. 130). Marine conditions existed over the entire study area at this time. Early in late Glen Rose time, the water in the lagoon became restricted and the salinity increased. During this period the Ferry Lake Anhydrite was precipitated. The restricted condition of the lagoon was probably caused by closure of the channels which normally allowed circulation through the barrier reef complex (Tucker, 1962, p. 195). This period of high salinity lasted only a short time and the lagoon returned to normal conditions. Limestones and shales of the upper Glen Rose formations extended from the basin axis to the Texas craton area west of Hill and McLennan counties. The lagoon west of the study area was very shallow. This is indicated by ripplemarked and crossbedded limestones, serpulid worm reefs, carbonized wood, and dinosaur tracks found in the outcrop area around Somervell and Erath counties (Rodgers, 1967, p. 119).

Following upper Glen Rose deposition, there was a minor marine regression. In Hill County (locations 1, 2, 3, 4, and 5) the upper limestone beds of the Trinity Group have been truncated and are unconformably overlain by the non-marine Paluxy Sand. Cross-bedded Paluxy channel sands occur in the outcrop area around the city of Walnut Springs in Bosque County (Atlee, 1962, p. 19). The sandy nonmarine formation extends as far east as eastern Hill and McLennan counties. The Fredericksburg regressive period is represented by four facies: Paluxy shoreline sands, Walnut lagoonal shales, Comanche Peak lagoonal carbonate muds, and Edwards rudistid reefs. In the basin there is no surface of erosion separating the Trinity Group from the Fredericksburg Group. The Fredericksburg Group in the basin is made up of the Walnut Shale and the Goodland Formation. Fredericksburg carbonate muds of this area were probably derived from the Stuart City reef trend. The Fredericksburg of the Texas craton is characterized by its reef facies (Edwards Formation). Edwards rudistid reefs migrated eastward with the regressing sea (Frost, 1967, p. 138). These reefs probably contributed much of the carbonate muds which make up the Comanche Peak Limestone. Growth of the Edwards reefs was terminated at the end of the Fredericksburg time by exposure to the atmosphere. Evidence for this is the oxidized and truncated upper surface of the formation (*idem,* p. 146).

Structural movements affected deposition during Fredericksburg time in the eastern part of the study area. The Anderson County salt withdrawal area was active and received over 800 feet of Fredericksburg sediments. Movement along the Mexia faults caused about 100 feet of thickening on the east side of the zone. Thin Fredericksburg sections over the Stuart City reef trend show that this area remained structurally positive.

Marine transgression started again in Washita time. Black shales of the Kiamichi Formation covered the Edwards reefs. As the sea spread further west, limestones of the Georgetown Formation were deposited. Some of the most massive reef growth occurred during this time along the Stuart City trend; lime muds from the trend were spread over the entire lagoon. The widespread transportation of the carbonates can be seen by the large lateral extent of individual units in the Georgetown Formation. Tectonic activity during Washita deposition included salt withdrawal in Anderson County, movement along the Mexia fault zone, and gentle regional tilting. Georgetown deposition was followed by deposition of Del Rio Clay, Buda Limestone, and Maness Shale. These formations represent lagoonal conditions similar to those present during Georgetown time.

The close of Comanchean time was marked by uplift and tilting of the entire study area. This caused truncation of the Maness Shale, Buda Limestone, and part of the Del Rio Clay.

CONCLUSIONS

(1) The Comanchean Series was deposited during two sedimentary periods. The first period was the deposition of the Travis Peak Formation's deltaic sands and shales. During this time the East Texas Basin was filled from east to west across the study area in an onlapping sequence. The second period was the transgression of the sea across the study area. During this period a barrier reef developed to the southeast forming a lagoon or back reef province over most of the study area.

(2) There was vertical movement along the Mexia fault zone during Comanchean time. This movement together with greater subsidence in the basin area east of the zone resulted in the deposition of thick stratigraphic sections as compared with the area to the west of the zone.

(3) Salt movement in the basin axis area caused abrupt lateral thickness variations. Anderson County was an area of major salt withdrawal and doming.

(4) The Texas craton-Ouachita fold belt area was relatively stable. This area was gently tilted toward the east.

(5) The slope on the basin floor became progressively flatter as each sequence of sediments was laid down. Gentlest slopes occurred during Washita time. This is shown by the wide area which individual formations cover and their relative uniform appearance.

(6) The area of major subsidence was from Anderson County southward to just north of the Stuart City reef trend. The Stuart City reef trend behaved as a structurally positive area from as early as Pettet time until deposition of the Buda Formation.

(7) A structural "hinge line" in eastern Hill and McLennan counties persisted through most of Comanchean time. The presence of this hinge line shows up in the thickness patterns on the isopach maps. The area east of the line shows an increased rate of thickening.

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APPENDIX I

WELL LOCATIONS

Location Number

1. Joe A. Humphrey, #1 J. E. Osborne, Hill County, T.D. 8,278 ft. (32° 12' N; 97° 19' W).
2. Humble, #1 Ella Freeman, Hill County, T.D. 11,808 ft. (32° 15' N; 97° 08' W).
3. Layne-Texas Co., #14 City of Hillsboro, Hill County, T.D. 1,684 ft. (32° 01' N; 97° 09' W).
4. Phillips Pet. Co., #A-1 Posey, Hill County, T.D. 6,622 ft. (32° 01' N; 96° 57' W).
5. A. P. Merritt, #1 H. Noris, Hill County, T.D. 3,129 ft. (31° 52' N; 97° 09' W).
6. E. J. Muth, #1 Freeman, McLennan County, T.D. 2,000 ft. (31° 36' N; 97° 28' W).
7. Robert C. Smith & Falcon Oil Corp. #1 H. G. McKethan, McLennan County, T.D. 1,604 ft. (31° 29' N; 97° 17' W).
8. Delta Drilling Co., #1 Horstmann, McLennan County, T.D. 2,250 ft. (31° 25' N; 97° 23' W).
9. Layne-Texas Co., #2 Texas Water Company, McLennan County, T.D. 2,120 ft. (31° 33' N; 97° 14' W).
10. Layne-Texas Co., #3 Connally Air Base, McLennan County, T.D. (D.F.) 470 ft. (31° 39' N; 97° 04' W).
11. Simon Korshoj, #1 R. W. Ferguson, McLennan County, T.D. 3,977 ft. (31° 41' N; 96° 58' W).
12. J. L. Myers & Son, #1 Pardo, McLennan County, T.D. 2,500 ft. (31° 33' N; 97° 04' W).
13. J. L. Myers & Son, #1 Youngblood, McLennan County, T.D. 2,400 ft. (31° 28' N; 97° 06' W).
14. Gray Oil Co., #1 C. B. & H. C. Warren, McLennan County, T.D. 1,702 ft. (31° 25' N; 97° 11' W).
15. J. L. Myers & Son, #2 City of Moody, McLennan County, T.D. 1,494 ft. (31° 19' N; 97° 21' W).
16. Layne-Texas Co., #2 Texas Power and Light, McLennan County, T.D. 2,851 ft. (31° 28' N; 96° 59' W).
17. Riesel Independent School Corp., #1 Riesel Independent School land, McLennan County, T.D. 3,109 ft. (31° 28' N; 96° 56' W).
18. R. J. Caraway, #1 Slaughter, McLennan County, T.D. 2,240 ft. (31° 32' N; 96° 53' W).
19. Larkin & Mauch & Gulf, #1 J. C. Stone, Navarro County, T.D. 3,775 ft. (32° 06' N; 96° 42' W).
20. Coffield & Guthrie, #1 Clark, Navarro County, T.D. 3,757 ft. (32° 00' N; 96° 44' W).
21. George Rahal, #1 Elmer Porter, Navarro County, T.D. 3,632 ft. (31° 51' N; 96° 47' W).
22. Wiggins Bros. Inc., #1 Mrs. Clyde, Navarro County, T.D. 12,345 ft. (32° 07' N; 96° 11' W).
23. Pan American, #1 W. T. Ware, Navarro County, T.D. 12,274 ft. (32° 00' N; 96° 13' W).
24. Humble, #1 Nelle Ruth Adams, Navarro County, T.D. 9,370 ft. (31° 53' N; 96° 25' W).
25. Falcon, #1 J. C. Keitt, Navarro County, T.D. 6,455 ft. (31° 32' N; 96° 35' W).
26. Balcones Oil Co., #1 Jackson, Limestone County, T.D. 3,525 ft. (31° 35' N; 96° 49' W).
27. M. M. Miller, #1 J.C. Rogers, Limestone County, T.D. 6,168 ft. (31° 34' N; 96° 43' W).
28. W. W. Wise Drilling Co., #1 W. T. Lattmer, Limestone County, T.D. 7,105 ft. (31° 32' N; 96° 40' W).
29. Pure Oil Co., #16 Kendricks, Limestone County, T.D. 6,404 ft. (31° 41' N; 96° 31' W).
30. Pan American, #1 Elmer Beene, Limestone County, T.D. 8,612 ft. (31° 31' N; 96° 38' W).
31. W. L. Hernstadt, #1 W. Cannon Barron, Limestone County, T.D. 9,132 ft. (31° 29' N; 96° 36' W).
32. Humble, #1 Hernstadt, Limestone County, (31° 28' N; 96° 37' W).
33. Eugene Talbert & Rotary Drilling Inc., #1 B. B. Barron, Limestone County, T.D. 5,051 ft. (31° 25' N; 96° 40' W).
34. W. H. Foster & Zephyr Oil Co., #1 F. P. Wilson, Limestone County, T.D. 8,394 ft. (31° 22' N; 96° 40' W).
35. Union Producing Co., #1 J. F. Jackson, Limestone County, T.D. 11,325 ft. (31° 30' N; 96° 29' W).
36. Humble, #1 Fallon Gas Unit Well #1, Limestone County, T.D. 8,700 ft. (31° 30' N; 96° 24' W).
37. Ralph Spence, #B-1 C. C. Favors, Limestone County, T.D. 7,529 ft. (31° 25' N; 96° 30' W).
38. Texas, #1 A. W. White, Limestone County, T.D. 13,694 ft. (31° 25' N; 96° 24' W).
39. Harry S. Phillips, #1-A Jacoby and Harris, Limestone County, T.D. 9,192 ft. (31° 25' N; 96° 18' W).
40. Thornton Lomax, Jr. & J. Burns Brown, Limestone County, T.D. 7,507 ft. (31° 19' N; 96° 29' W).
41. John Jackson & Mack Hays, Jr., #1 Herman Weiting, Falls County, T.D. 3,441 ft. (31° 25' N; 96° 53' W).
42. H. C. Cockburn & Zephyr Oil Co., #1 N. D. Buie, Falls County, T.D. 6,822 ft. (31° 16' N; 96° 49' W).
43. K. L. McHenry, #1 George Abraham, Robertson County, T. D. 7,333 ft. (31° 10' N; 96° 37' W).
44. Humble, #1 J. L. Blair, Robertson County, T.D. 15,120 ft. (31° 12' N; 96° 26' W).
45. Nevill G. Penrose, #1 W. H. Ables, Robertson County, T.D. 11,023 ft. (31° 00' N; 96° 42' W).
46. Shell Oil Co., #1 D. J. Hamilton, Robertson County, T.D. 17,747 ft. (31° 01' N; 96° 29' W).
47. Continental Oil Co., #1 Murphy M. Williams, Freestone County, T.D. 12,717 ft. (31° 53' N; 96° 13' W).
48. Tidewater Oil Co., #1 H. B. Steward, Freestone County, T.D. 11,717 ft. (31° 50' N; 96° 15' W).
49. Humble, #1 T. R. Bonner, Freestone County, T.D. 7,916 ft. (31° 50' N; 96° 12' W).
50. Humble, #1 Teague Unit #1, Freestone County, T.D. 8,642 ft. (31° 40' N; 96° 20' W).
51. Texaco, Inc., #1 Ruby Middleton, Freestone County, T.D. 13,904 ft. (31° 42' N; 96° 13' W).
52. Hunt Pet. Corp., #1 F. E. Hill Co., Freestone County, T.D. 14,520 ft. (31° 43' N; 96° 10' W).
53. Continental Oil Co., #1 Emma Hill, Freestone County, T.D. 10,620 ft. (31° 44' N; 95° 55' W).
54. Continental Oil Co., #1 H. C. Brown, Freestone County, T.D. 14,039 ft. (31° 37' N; 96° 17' W).
55. Humble, #1 McAdams, Freestone County, T.D. 9,645 ft. (31° 36' N; 96° 06' W).
56. Humble, #1 R. P. McWatters, Freestone County, T.D. 16,275 ft. (31° 31' N; 96° 15' W).
57. Ralph Spence, #1 Ocie Walker, Freestone County, T.D. 9,124 ft. (31° 26' N; 96° 15' W).
58. Humble, #1 Jewell Martin, Leon County, T.D. 9,549 ft. (31° 17' N; 96° 19' W).
59. Texaco Corp., #1 Keep Gas Unit, Leon County, T.D. 10,707 ft. (31° 30' N; 95° 57' W).
60. Carter-Gragg, #2 Carter, Leon County, T.D. 10,485 ft. (31° 32' N; 95° 49' W).
61. Lone Star Prod. Co., #1 James Donahoe, Leon County, T.D. 10,683 ft. (31° 23' N; 96° 04' W).
62. Lone Star Prod. Co., #7 "A" G. W. Lee, Leon County, T.D. 10,162 ft. (31° 26' N; 95° 56' W).
63. Humble, #1 L. J. Craig, Leon County, T.D. 10,949 ft. (31° 15' N; 96° 06' W).
64. Lone Star Prod. Co., #1 J. L. Beddingfield, Leon County, T.D. 10,389 ft. (31° 20' N; 95° 55' W).
65. Cauble Enterprises, #1 Irva B. Mitchell, Leon County, T.D. 11,347 ft. (31° 19' N; 95° 42' W).
66. Sinclair Oil Co., #1 W. F. Joyce, Henderson County, T.D. 11,186 ft. (32° 03' N; 95° 49' W).
67. Hunt Pet. Corp., #3 Mrs. Stella Miller, Henderson County, T.D. 10,700 ft. (32° 03' N; 95° 40' W).

68. Tidewater Oil Co., #1-D J. A. Campbell, Anderson County, T.D. 11,193 ft. (31° 57' N; 95° 59' W).
69. Texas Co., #1 E. C. Walton, Anderson County, T.D. 9,044 ft. (31° 53' N; 95° 56' W).
70. Texas Co., #1 M. J. Derden, #3 Sidetrack, Anderson County, T.D. 9,654 ft. (31° 54' N; 95° 55' W).
71. Delta Drilling Co., #1 Minnie Russell, Anderson County, T.D. 10,261 ft. (31° 56' N; 95° 50' W).
72. Johnson Cone, #1 T. D. Pierce Estate, Anderson County, T.D. 10,630 ft. (32° 00' N; 95° 43' W).
73. Bonanza Oil Co., #1 Turner Lang Gas Unit, Anderson County, T.D. 10,876 ft. (32° 01' N; 95° 37' W).
74. Delta Drilling Co., #1 Ward, Anderson County, T.D. 10,825 ft. (31° 55' N; 95° 44' W).
75. Fair Oil Co., #1 W. C. Quick, Anderson County, T.D. 11,307 ft. (31° 54' N; 95° 37' W).
76. Humble, #1 Brice N. McDonald, Anderson County, T.D. 11,900 ft. (31° 54' N; 95° 36' W).
77. Humble, #1 R. G. Freeman, Anderson County, T.D. 12,607 ft. (31° 55' N; 95° 36' W).
78. Atlantic Richfield Co., #1 Letha Hurd Et Al, Anderson County, T.D. 11,096 ft. (31° 57' N; 95° 31' W).
79. P. G. Lake, Inc., #1 B. H. Hilton, Anderson County, T.D. 10,300 ft. (31° 50' N; 95° 48' W).
80. W. R. Hughey, #1 Huffman, J.C. & F.W., Anderson County, T.D. 10,405 ft. (31° 48' N; 95° 48' W).
81. Pure Oil Co., #1 City of Palestine, Anderson County, T.D. 11,888 ft. (31° 45' N; 95° 38' W).
82. W. R. Hughey Et El, #1 B. H. Gardner, Anderson County, T.D. 10,872 ft. (31° 50' N; 95° 37' W).
83. Texaco, #1 Rutledge, Anderson County, T.D. 10,842 ft. (31° 47' N; 95° 37' W).
84. Hunt Industries, #1 Royall National Bank, Anderson County, T.D. 11,479 ft. (31° 50' N; 95° 31' W).
85. Secure Trusts, #1 Nelms Gas Unit, Anderson County, T.D. 10,799 ft. (31° 42' N; 95° 40' W).
86. Humble, #3 Nell H. Rhea, Houston County, T.D. 10,574 ft. (31° 27' N; 95° 40' W).
87. Glen Rose Corp., #1 G. E. Kelly, Houston County, T.D. 12,637 ft. (31° 12' N; 95° 30' W).
88. Sunset International Pet. Corp., #1 Earnest L. Knox, Houston County, T.D. 11,210 ft. (31° 09' N; 95° 34' W).
89. Brewster-Bartle Drilling Co. Inc., #1 L. A. Little, Houston County, T.D. 11,255 ft. (31° 04' N; 95° 36' W).
90. Associated Oil & Gas, #1 Wakefield, Madison County, T.D. 12,102 ft. (31° 05' N; 95° 47' W).
91. Chambers & Kennedy, #1 Farris, Madison County, T.D. 11,325 ft. (31° 00' N; 95° 49' W).
92. J. Ray McDermott, #1 J. M. Christian, Madison County, T.D. 11,207 ft. (31° 02' N; 95° 45' W).
93. Roy M. Huffington Inc., #1 W. E. and George Nealy, Madison County, T.D. 11,190 ft. (31° 01' N; 95° 44' W).
94. West Production Co. and Noranda Oil Co., #1 Boring, Madison County, T.D. 12,515 ft. (30° 52' N; 96° 01' W).
95. J. M. West, #1 Heath Gas Unit, Madison County, T.D. 13,086 ft. (30° 52' N; 95° 58' W).
96. Standard Oil Co. of Texas, #1 W. H. Hutchins, Madison County, T.D. 11,500 ft. (30° 54' N; 95° 55' W).
97. George Mitchell & Associates, #1 Garrett, Madison County, T.D. 11,838 ft. (30° 54' N; 95° 52' W).
98. George Mitchell & Associates, #1 J. S. Stewart, Madison County, T.D. 12,240 ft. (PGAC Depth) (30° 55' N; 95° 51' W).
99. Brewster & Bartle Drilling Co., #1 Neville, Grimes County, T.D. 10,600 ft. (30° 48' N; 96° 06' W).
100. Humble, #1 W. D. McAdams, Walker County, T.D. 14,601 ft. (30° 53' N; 95° 46' W).
101. Humble, #1-C Gibbs Brothers & Co., Walker County, T.D. 14,543 ft. (30° 53' N; 95° 39' W).
102. H. L. Hawkins & H. L. Hawkins, Jr., #1 Earl Norris, Walker County, T.D. 14,307 ft. (30° 56' N; 95° 33' W).
103. Skelly Oil Co., #1 Gibbs "A," Walker County, T.D. 15,972 ft. (30° 45' N; 95° 45' W).
104. Chilton Water Well Company, #2 Chilton, Falls County, T.D. 2,874 ft. (31° 17' N; 97° 05' W).

APPENDIX II

SAMPLE DESCRIPTIONS

Location 4, Phillips Petroleum Co.
#A-1 Posey, Hill County

960' - 970' Georgetown Fm	White chalky limestone
1,160' - 170' Kiamichi Shale	Grey calcareous sandstone (cavings?)
1,180' - 190' Goodland Fm	Cream colored micritic limestone; grey sandy limestone
1,190' - 200' Edwards Fm	White micritic limestone; white sparritic fossiliferous limestone
1,210' - 20' Comanche Peak Fm?	White micritic limestone, grey shale
1,390' - 1,400'	Sparritic grey dense (fossiliferous) limestone; shell fragments
1,440' - 450' Paluxy Sand	Clear, clean, fine-grained sandstone; shell fragments and limestone fragments
1,480' - 490'	White, clean, fine-grained sandstone; occasional pyrite
1,500' - 010' Upper Glen Rose Fm	White micritic limestone; echinoid spines; light grey dense limestone
1,990' - 2,000'	White sandy limestone; shell fragments; grey sandy shale; numerous *Orbitolina texana*
2,020' - 030'	White anhydrite; grey sandy shale; grey sandy limestone
2,040' - 050' Ferry Lake zone	White anhydrite (cavings?); grey sandy shale; grey dense fossiliferous sparritic limestone; grey sandy limestone
2,100' - 110' Rodessa Equivalent	Sandy limestone, white lime mud matrix with dark quartz inclusions
2,130' - 140' Rodessa Equivalent	Grey sandy limestone
2,190' - 2,200'	White calcareous fine-grained sandstone; occasional white, pink coarse quartz grains
2,220' - 230'	Same as above except with grey shale
2,230' - 40' Pettet Equivalent?	Light grey dense limestone
2,260' - 270' Travis Peak?	Light grey dense limestone
2,280' - 290' Travis Peak	White clean sandstone; some grey sandy shale
2,310' - 320'	White clean sandstone; some grey sandy shale
2,410' - 420'	Same as above except occasional red, yellow sandstone and lignite
2,530' - 540'	Clean white medium-grained sandstone
2,580' - 590'	Same as above and also red, white, pink cherts and quartz grains; pyrite
2,620' - 30' Stanley Shale	Red and greenish white sandstones
2,740' - 750'	Dark grey phylite or metashale

Location 7, Robert C. Smith and Falcon Oil Co.
#1 H. G. McKethan, McLennan Co.

540' - 550' Upper Glen Rose Fm	White fossiliferous limestone; some sparritic limestone; shell fragments; grey shale
750' - 760' Glen Rose Fm	White micritic limestone; grey limestone
840' - 850' Glen Rose Fm	White micritic and white sparritic limestone
945' - 955'	White fossiliferous micritic limestone; some grey shale
1,015' - 020'	White fossiliferous micritic limestone; orange quartz grains; white calcareous sandstone; gastropods and *Orbitolina texana*
1,040'	White micritic limestone; grey sandstone; white calcareous sandstone
1,050'	Same as above and also grey shale
1,055' - 60' Rodessa Equivalent	White calcareous sandstone; numerous orange and coarse quartz grains
1,070' - 75'	Same as above except more coarse, angular quartz
1,105' - 10'	White, clear, red and pink coarse quartz grains; white sandy limestone, calcareous white fine-grained sandstone
1,130'	Grey sandy shales
1,165'	White calcareous fine-grained sandstone; pelecypod fragments
1,195' - 1,200'	Mostly white clean sandstone; some lignite, pyrite, shell fragments, grey shale
1,240' - 245'	Same as above but also red to brown oxidized sandstone
1,295' - 1,300' Travis Peak Fm	White chalky limestone; grey shale; yellow, brown, red sandstone; some cherts
1,325' - 30' Paleozoic Rocks	Iron-stained (yellow) light grey shales; red shales

Location 44, Humble #1 Blair
Robertson County

8,430' - 40' Pettet	Grey pelmicrite, grey shale
8,690' - 8,700' Travis Peak	Grey shale, grey pelmicrite, white sandstone
8,690' - 8,800'	White sandstone (70%), grey shale (30%)
8,880' - 890'	Red sandstone (fine-grained) (80%) grey shale, white sandstone (5%)
8,990' - 9,000'	Red sandstone (5%), white sandstone (60%), grey shale and siltstone
9,100' - 110'	Red sandstone (45%), white sandstone (50%), grey shale (5%)
9,200' - 10'	Red sandstone (80%), white sandstone (15%), grey shale (5%)
9,290' - 300'	White and pink sandstone (85%), red sandstone (10%), grey shale (5%)
9,400' - 10'	White and pink sandstone (85%), red sandstone (10%), grey shale (5%)
9,500' - 510'	Pink sandstone (60%), red sandstone (35%), grey shale (5%), white sandstone trace
9,600' - 610'	White and pink sandstone (70%), red sandstone (25%), grey shale (5%), trace greenish white sandstone
9,710' - 20'	White sandstone (70%), red sandstone (15%), grey shale (15%)
9,790' - 800'	Pink and white sandstone (60%), red sandstone (20%), grey shale (20%)
9,890' - 9,900'	White sandstone (55%), pink sandstone (5%), red sandstone (20%), grey shale (20%)
9,980' - 990' Travis Peak	White sandstone (25%), pink sandstone (10%), red sandstone (35%), grey shale (30%)
10,110' - 120'	White sandstone (25%), pink sandstone (10%), red sandstone (35%), grey sandstone (30%)
10,200' - 210'	White sandstone (60%), pink sandstone (5%), red sandstone (15%), grey shale (20%)
10,300' - 310'	White sandstone (30%), red sandstone (30%), grey shale (30%), trace green-white sandstone
10,400' - 410'	White sandstone (30%), red sandstone (30%), grey shale (30%), trace green-white sandstone
10,500' - 510'	White sandstone (25%), pink sandstone (25%), red sandstone (30%), grey sandstone (20%)
10,600' - 610'	White sandstone (20%), pink sandstone (20%), red sandstone (30%), grey shale (30%)
10,690' - 700'	White sandstone (30%), pink sandstone (10%), red sandstone (30%), grey shale (30%)
10,790' - 800'	White sandstone (50%), pink sandstone (10%), red sandstone (20%), grey shale (20%)
10,890' - 900'	White sandstone, pink sandstone, red sandstone, grey shale; all equal amounts
10,990' - 11,000'	White sandstone (20%), pink sandstone (20%), red sandstone (30%), grey shale (30%)
11,190' - 200'	Same constituents as above in equal amounts; except very little pink sandstone
11,400' - 410'	Same constituents as above in equal amounts; except very little pink sandstone
11,550' - 560'	Same constituents as above in equal amounts; except majority grey shale
11,700' - 710' Jurassic?	White sandstone, red sandstone, majority dark grey fissile shale

Location 46, Shell #1 Hamilton
Robertson County

6,150' - 60' Buda Fm	White dense micrite
6,210, - 20' Del Rio Fm	Dark grey fissile shale
6,300' - 10' Georgetown Fm	White dense micrite
6,440' - 50' Georgetown Fm	White dense micrite
6,530' - 40' Kiamichi Fm	Black fissile shale
6,560' - 70' Goodland Fm	White to cream micrite
6,570' - 80'	White micrite and dismicrite
6,590 - 00' Goodland Fm	White to cream micrite
6,710' - 20' Goodland Fm	White micrite, grey shale
6,860' - 70' Goodland Fm	White to grey micrite, grey shale
6,900' - 910'	Grey and white micrite, shale
7,070' - 80' Paluxy Fm	Light to dark grey shale
7,320' - 30'	Grey dismicrite, white micrite, micrite, grey shale
7,800' - 810' Upper Glen Rose Fm	Grey micrite, white and grey sparite, grey shale, biosparite
8,170' - 80' Ferry Lake zone	White anhydrite, grey biomicrite, grey shale, grey to white dismicrite
8,510' - 20' Rodessa Fm	Grey pelmicrite, grey dismicrite, biomicrite, grey shale
8,750' - 60' Bexar Shale	Noncalcareous, grey fissile shale
8,870' - 80' James Limestone	Grey pelmicrite, grey micrite, dismicrite, grey shale
9,020' - 30' Pettet Fm	White to grey dense micrite, grey shale
9,440' - 50' Travis Peak Fm	Grey shale (mostly) white sandstone, grey pelmicrite (from Pettet Formation)
9,720' - 30'	White to tan (mostly) quartz (90%); maybe white samples dirty
9,900' - 10'	Tan quartz sandstone (90%); maybe samples dirty
10,010' - 20'	Tan to grey quartz sandstone (90%); maybe samples dirty
10,120' - 30'	Tan to white quartz sandstone (90%)

Location 47, Continental Oil Co.
#1 Murphy M. Williams, Freestone County

4,340' - 350' Buda Limestone	White micrite limestone; grey calcareous shale
4,450' - 460' Del Rio Shale	Grey shale, slightly calcareous
4,720' - 730' Upper Georgetown Fm	White chalky limestone, grey shale
5,010' - 020' Lower Georgetown Fm	White chalky limestone, grey shale
5,100' - 110' Kiamichi Shale	Dark grey to black friable shale
5,320' - 330' Goodland Fm	Light grey dense micrite limestone; light grey silty shale; grey shale
5,420' - 430' Walnut Fm	Grey shales and siltstone, some white limestones
5,680' -690' Upper Glen Rose Fm	Grey and white mottled limestones; grey shales; shell fragments (gastropods and pelecypods)
5,920' - 930'	Similar to above
6,070' - 080'	Same as above
6,410' - 420' Upper Glen Rose Fm	Same as above
6,700' - 710' Rodessa Fm	Grey mottled limestone and grey shale
7,020' - 030' Bexar Shale	Grey shale
7,250' - 260' Pettet Limestone	White and grey mottled limestone—very fossiliferous
7,450' - 460' Upper Travis Peak Fm	Dark grey shales
7,540' - 550' Travis Peak Fm	Dark grey shales and dense grey limestones
7,850' - 860'	Pink sandstone; dark grey shale; red shale; some pyrite
8,120' - 130' Travis Peak Fm	Light grey shale; red shale; light grey sandstone; white clean sandstone
8,270' - 280'	Red fine-grained sandstone; light grey shale; white clean sandstone; red, pink and white coarse quartz grains
8,520' - 530' Travis Peak Fm	Mostly white, clean medium-grained sandstone; some red sandstone and grey shale
8,650' - 660'	Mostly white, clean medium-grained sandstone; little more grey shale than 8,520' - 530' interval
8,800' - 810' Lower Travis Peak Fm	White medium-grained sandstone, red sandstone, and grey silty shale in equal amounts
8,860' - 870' Lower Travis Peak	Red sandstone; chert; quartz fragments; oxidized quartz sands; probably basal Cretaceous sand
9,160' - 170' Jurassic	Grey siltstone; red sandstone; red shale

Location 56, Humble Oil and Refining Co.
#1 R. P. McWatters, Freestone County

5,080' - 100' Buda Fm	White micrite limestone
5,190' - 200' Del Rio Fm	Grey calcareous shale
5,300' - 5,600' Georgetown Fm	White chalky limestone
5,760' - 770'	Black calcareous shale
5,800' - 6,000' Goodland Fm	Dense grey to white sparritic and micritic limestones
6,200' - 230' Walnut Fm	Grey to dark grey shales
6,300' - 330' Paluxy Fm	Grey shale; scattered pelecypod shells; grey silty shales
6,450' - 6,600' Upper Glen Rose Fm	Grey, black, and brown sparritic limestones with occasional shell fragments
7,000' - 7,100' Glen Rose Fm	Dark grey dense micritic limestone; white sparritic limestone; grey shale
7,550' - 70' Ferry Lake zone	White anhydrite; grey shale; grey dense limestone
7,670' - 690' Rodessa Fm	Dark grey dense cryptocrystalline limestone
7,770' - 780' Rodessa Fm	Grey sparritic limestone (calcite replaced shell material)
7,840' - 850' Rodessa Fm	Dense grey cryptocrystalline limestone, grey calcareous shale
7,950' - 980' Bexar Shale	Light to dark grey calcareous shale
8,090' - 8,110' James Limestone	White to grey micritic limestone
8,160' - 170' Pine Island Shale	Black shale
8,200' - 8,220' Pettet Limestone	White to light grey fossiliferous (60% of rock) limestone
8,320' - 8,330' Lower Pettet Limestone	Grey mottled dense limestone; white fossiliferous limestone
8,500' - 8,530' Travis Peak Fm	Grey shale
8,600' - 610'	Fine-grained white to pink sandstone; grey shale; pyrite-filled shells
8,750' - 770' Travis Peak Fm	Red and white sandstone
9,000' - 9,200'	White medium-grained sandstone (95% of sample)
9,400' - 10,100' Travis Peak Fm	White medium-grained sandstone (40% to 60% of sample); grey siltstone (20%), red sandstone (varying amounts)
10,400' - 430' Jurassic?	Grey siltstone (60%); white sandstone (20%); red sandstone (20%)

Location 87, Glenrose Corp.
#1 G. E. Kelley, Houston County

8,680' - 720' Maness Shale	Dark grey silty shale
8,880' - 830' Buda Limestone	White micritic limestone
8,890' - 920' Upper Georgetown Limestone	Grey shale, white micritic limestone
9,070' - 9,100' Upper Georgetown Limestone	Light grey to white micritic limestone
9,220' - 250' Upper Georgetown Limestone	Light grey to white micritic limestone
9,370' - 400' Kiamichi Shale	Dark grey to black friable shales, dense light grey cryptocrystalline limestone
9,430' - 460' Upper Goodland Fm	Light to dark grey cryptocrystalline limestone; dark grey calcareous shale
9,670' - 700' Lower Goodland Fm	Light to dark grey cryptocrystalline limestone; dark grey calcareous shale
9,820' - 850' Walnut Fm	Dark grey calcareous and silty shale with some dense grey limestone, pyrite, and shell fragments
9,940' - 970' Paluxy Equivalent	Same as above except more shell fragments and some grey fine-grained sandstone
10,030' - 060' Upper Glen Rose Fm	Grey calcareous fine-grained sandstone (Paluxy?); dense grey micritic limestone; many shell fragments
10,090' - 120'	Dense grey micritic limestone
10,480' - 510' Upper Glen Rose Fm	Dense grey micritic limestone except grey shale also present
10,960' - 990' Upper Glen Rose Fm	Dense grey micritic limestone except grey shale also present
11,290' - 320' Upper Glen Rose Fm	Dense grey cryptocrystalline limestone; dense grey shale
11,410' - 440'	Dense grey cryptocrystalline limestone; dense grey shale
11,530' - 560' Rodessa Limestone	Dense grey cryptocrystalline limestone; dense grey shale
11,710' - 740' Rodessa Limestone	White micritic limestone; dark grey dense limestone
11,830' - 860' Rodessa Limestone	Dense dark grey limestone; some dark grey shale
12,010' - 040' Lower Rodessa Limestone	Dense dark grey limestone; some dark grey shale
12,220' - 250' Bexar Shale	Dense dark grey shale
12,280' - 310' Bexar Shale	Dense dark grey calcareous and silty shale; dense grey limestone
12,400' - 430' James Limestone	Dense dark grey limestone; dense grey shale
12,580' - 610' Pine Island Shale	Similar to above but more shale than limestone

Location 103, Skelly Oil Co.
"A"-1 Gibbs, Walker County

12,400' - 410' Buda Equivalent	White micritic limestone; grey dense cryptocrystalline limestone; dark grey dense shales
12,530' - 540' Upper Georgetown Equivalent	Dense light grey cryptocrystalline limestone
12,810' - 820' Lower Georgetown or Upper Goodland Equivalent	White sparritic limestone with occasional fossil fragments replaced by calcite crystals; also rare pyrite crystals in limestone and dense dark grey shale
12,840' - 850'	White sparritic limestone and dense dark grey shale
12,910' - 920' Goodland Equivalent	White sparritic limestone and grey dense cryptocrystalline limestone
13,060' - 070' Goodland Equivalent	Grey dense cryptocrystalline limestone
13,210' - 220' Walnut Clay Equivalent	Dark grey dense shales
13,420' - 430' Upper Glen Rose Equivalent	White to light grey, dense micritic limestone, dark grey dense cryptocrystalline limestone
13,730' - 740'	White to light grey, dense micritic limestone, dark grey dense cryptocrystalline limestone
14,090' - 100'	Dark grey dense cryptocrystalline limestone; white sparritic limestone
14,290' - 300' Upper Glen Rose Equivalent	Dark grey dense cryptocrystalline limestone; white sparritic limestone
14,490' - 500' Upper Glen Rose Equivalent	Dark grey dense cryptocrystalline limestone; white dense sparritic limestone
14,930' - 940'	Dark grey dense cryptocrystalline limestone, and dark grey dense shale
15,260' - 270' Rodessa Equivalent	Dark grey dense cryptocrystalline limestone; white dense sparritic limestone
15,550' - 560' Bexar Shale	Dark grey dense shale
15,690' - 700' James Limestone	Dark grey dense shale; dark grey cryptocrystalline limestone
15,800' - 810' Pettet Limestone	Light to dark grey dense limestone

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