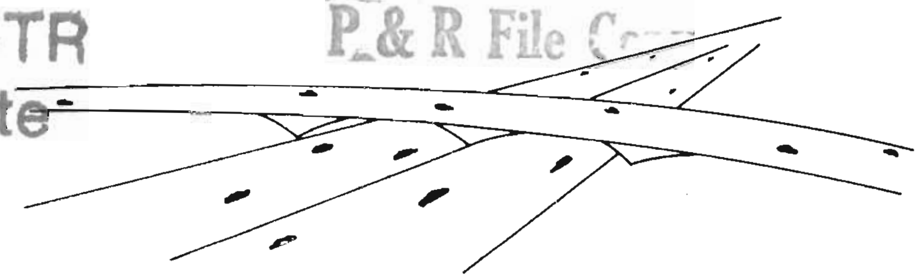


DEPARTMENTAL RESEARCH

Report Number: 63-1

GEOLOGY OF TEXAS HIGHWAY DEPARTMENT DISTRICT 9

TEXAS HIGHWAY DEPARTMENT

GEOLOGY OF TEXAS HIGHWAY DEPARTMENT DISTRICT 9

by

Highway Design Division
Staff Geologists

RESEARCH REPORT No. 63-1

Preparation of Geologic Information for use
in the Texas Highway Department
Research Project 1-8-63-63

Conducted by

Highway Design Division
The Texas Highway Department

In Cooperation with the
U. S. Department of Commerce, Bureau of Public Roads.
The opinions, findings, and conclusions expressed in
this publication are those of the authors and not
necessarily those of the Bureau of Public Roads.

August 1966

TABLE OF CONTENTS

LIST OF FIGURES

GEOLOGY OF TEXAS HIGHWAY DEPARTMENT DISTRICT 9

PART I

INTRODUCTION

The report is submitted as evidence of partial fulfillment of the study objectives as developed under the Cooperative Research Program and conducted by the Texas Highway Department. The report is a summary of published information on the conditions as they are applicable to Highway Engineering in the District. The report is intended to be used as a guide in assisting Engineers and Geologists in better understanding all of the geological processes and features that play such a vital part in the planning and construction of roads. It is not intended to be a detailed account of source areas or physical properties of soils or geological formations, but is to be used as a guide in planning further locations of detailed surveys and highway routes. An extensive bibliography is included at the end of the report and can be used as a source of additional information. Also included is a glossary of geological and pedological terms found in the report.

ACKNOWLEDGMENTS

Generous assistance has been provided by the Bureau of Economic Geology, University of Texas. Dr. Peter T. Flawn and his staff in the Bureau have allowed the use of their extensive reports and publications and have provided valuable personal assistance. Soil descriptions were obtained from the Soil Conservation Service, Department of Agriculture's "Standard Soil Series Descriptions", and published soil surveys of that department and the Texas Agricultural Experiment Station. Thanks go to Mr. Gordon McKee of the Soil Conservation Service for his valuable assistance. Assistance on soils as related to highway engineering in particular was provided by the Materials and Tests Division, Texas Highway Department. Generous assistance and cooperation was also provided by personnel of District 9.

LOCATION AND FEATURES

District 9, Texas Highway Department is located in the central part of the state on the western edge of the Gulf Coastal Plain, approximately 200 miles inland from the Gulf. It encloses the following counties: Bell, Bosque, Coryell, Falls, Hamilton, Hill, Limestone, and McLennan (Figure 1, Location Map). The District covers 7,625 square miles and has elevations that range from 300 feet in Falls County to the southeast to 1600 feet in Hamilton County to the northwest. The average rainfall for the entire District is 35.05 inches and ranges from an average of 30.98 inches for Hamilton County in the northwest to an average of 37.61 inches for Limestone County in the east. The temperature ranges from an average of 46° in January to 85° in July with an average of 66°.

The major river that traverses the District is the Brazos with an average annual runoff at Waco in McLennan County of 1,827,000 acre feet. Other major rivers include the Bosque River in Bosque, Hamilton, and McLennan Counties; the Little River which forms from the junction of the Lampasas and the Leon Rivers in Bell County; and the Leon River which traverses Hamilton, Coryell, and a part of Bell County.

Vegetation in the District includes oak and other hardwoods, pine, cedar, and tall bunch grasses.

PHYSIOGRAPHY

The Gulf Coastal Plain topography of District 9 is characterized by belted topography. This is shown by a series of prominent westward-facing cuestas developed on more resistant strata separated by lowlands. The District is divided from east to west into the following physiographic provinces: The East Texas Timberland, the Blackland Prairies, the East Cross Timbers, the Grand Prairie, and the West Cross Timbers. The land of the East Texas Timberland is generally rolling to undulating and hilly. The Blackland Prairies have gently rolling hills and rounded valleys and are divided into the Eagle Ford, Austin and Taylor Prairies which will be discussed under the geological formations which form each prairie. The East and West Cross Timbers lie to the east and west of the Grand Prairie and are connected further north beyond the District line. They are characterized by sandy soils and the development of stunted forests of oak. The Grand Prairie is characterized by deeply entrenched streams forming flat-floored valleys rising sharply to broad lands of low relief.

This prairie is divided into the Lampasas Cut Plain and the Washita Prairie which will also be discussed individually later in the report.

The boundary between the Blackland Prairies and the Grand Prairie is the Bosque Escarpment which is a west-facing erosional escarpment along the Balcones Fault Zone (See Figure 2, Major Physiographic Feature in Texas).

LOCATION MAP ------DISTRICT 9 -------TEXAS HIGHWAY DEPARTMENT

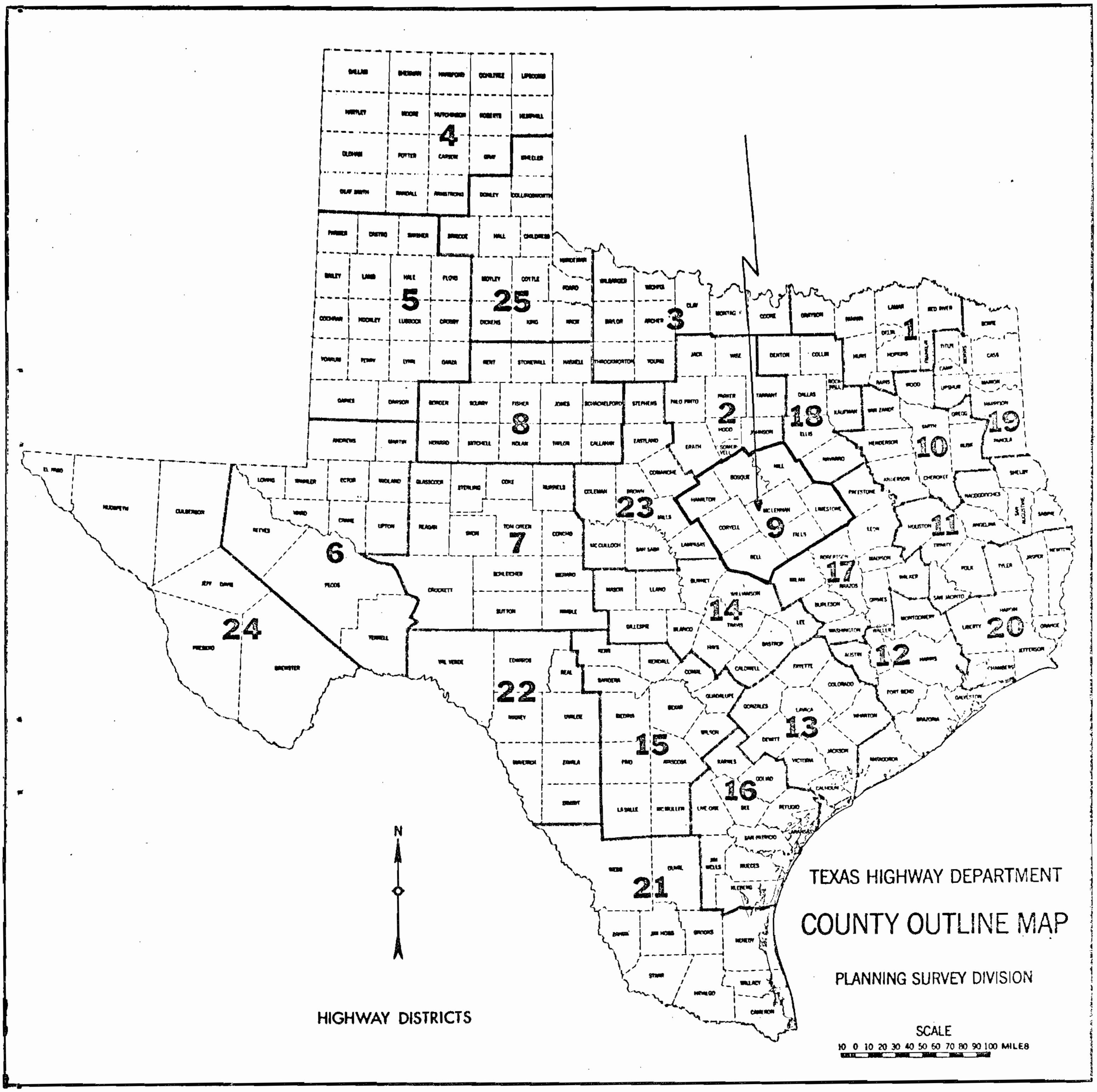
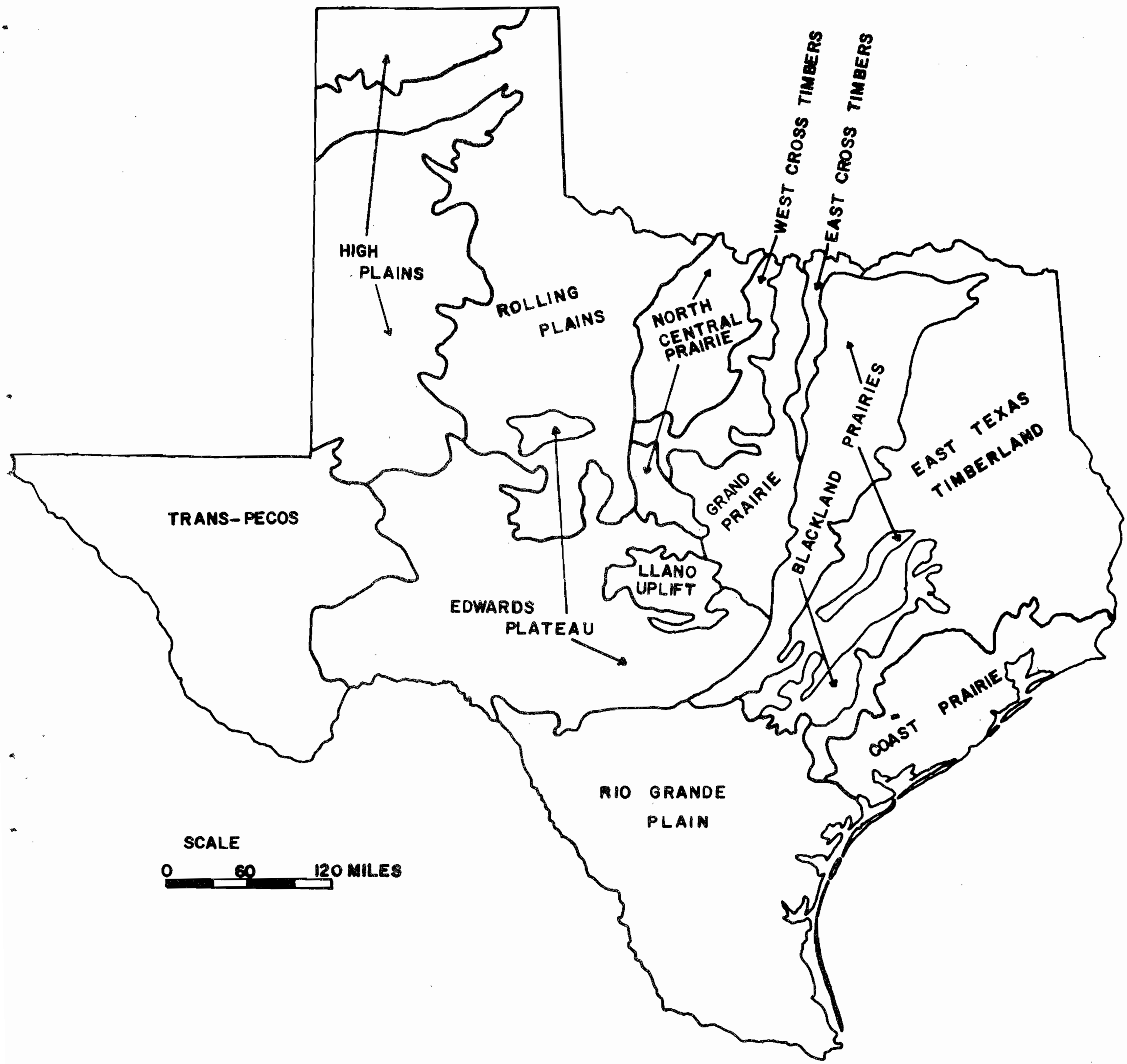


FIGURE 1



Major Physiographic Features In Texas

Figure 2

GENERAL GEOLOGY AND STRUCTURE

PART II

BRIEF HISTORY

The sequence of rocks exposed in District 9 begins with the strata of Lower Cretaceous age that are seen to outcrop in the far western portion of the District. As one proceeds towards the east, he encounters successively younger geologic formations at the surface. Rocks exposed in the District are inclusive of those from the Lower Cretaceous formation to rocks that are still in the process of formation at the present time.

The majority of the rocks exposed in District 9 belong to the Cretaceous period of time and were laid down beginning 135,000,000 years ago by deposition of sediment from waters of a northward advancing sea. These Cretaceous deposits designate the last great epicontinental marine invasion, and all the succeeding rocks of the Tertiary Period of time were restricted to relatively narrow areas along the continental margin. These succeeding Tertiary deposits were laid down during a time of emergence of the land mass and a regression of marine waters interrupted by local transgressions of the sea over the continent.

Covering these older rocks in places, particularly adjacent to the many streams of the Districts, are Pleistocene gravel terraces and recent alluvium deposits (See Figure 3, General Geologic Map).

LITHOLOGY

The Cretaceous deposits of District 9 consist primarily of rocks of two major classes; marginal marine deposits that were formed adjacent to the continental land mass, and off-shore shallow-water deposits. The lowermost group of Cretaceous rocks constitutes the Trinity Group which includes deep water, marginal, reef, and oyster aggregate deposits. Deposits of the Washita Group were laid down and these are characterized by strata that were marginal to the continental land mass, those that were associated with shallow water, and those associated with the formation of reef deposits. Following these deposits of Lower Cretaceous age,

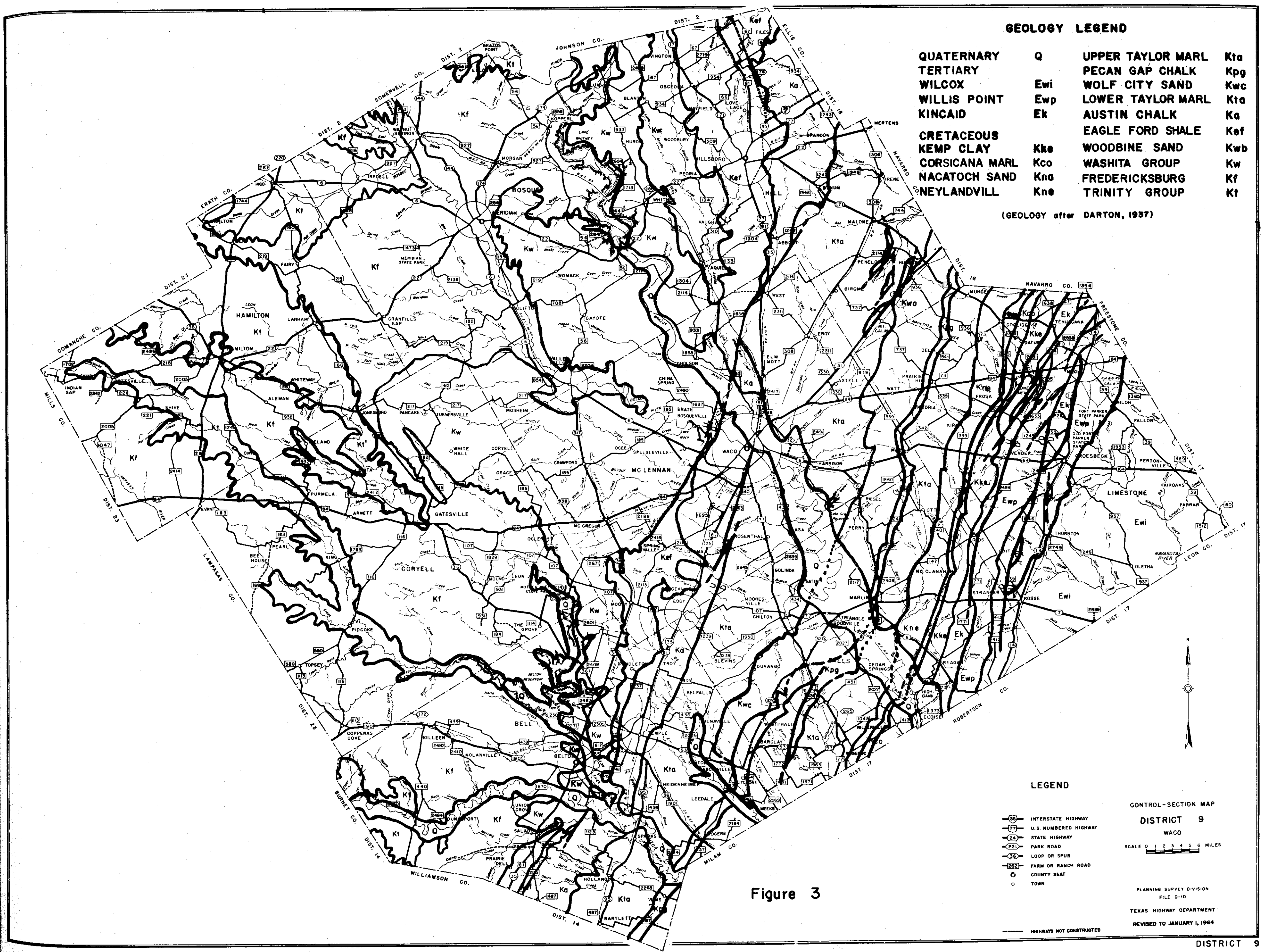

GEOLOGY LEGEND
QUATERNARY Q
TERTIARY
WILCOX Ewi
WILLIS POINT Ewp
KINCAID Ek
CRETACEOUS
KEMP CLAY Kke
CORSICANA MARL Kco
NACATOCH SAND Kna
NEYLANDVILL Kne
UPPER TAYLOR MARL Kta
PECAN GAP CHALK Kpg
WOLF CITY SAND Kwc
LOWER TAYLOR MARL Kta
AUSTIN CHALK Ka
EAGLE FORD SHALE Kef
WOODBINE SAND Kwb
WASHITA GROUP Kw
FREDERICKSBURG Kf
TRINITY GROUP Kt
(GEOLOGY after DARTON, 1937)
LEGEND
INTERSTATE HIGHWAY
U.S. NUMBERED HIGHWAY
STATE HIGHWAY
PARK ROAD
LOOP OR SPUR
FARM OR RANCH ROAD
COUNTY SEAT
TOWN
HIGHWAYS NOT CONSTRUCTED
CONTROL-SECTION MAP
DISTRICT 9
WACO
SCALE 0 1 2 3 4 5 6 MILES
PLANNING SURVEY DIVISION
FILE D-10
TEXAS HIGHWAY DEPARTMENT
REVISED TO JANUARY 1, 1964
HAMILTON
CORYELL
BELL
MC LENNAN
LIMESTONE
BOSQUE
HILL
FALLS

Figure 3

the rocks of the Upper Cretaceous or Gulf Series were laid down and these include deposits of various environments. Most of them consist of near-shore sediments. From the beginning of upper Cretaceous time on, volcanic materials are prominent.

The Tertiary rocks of the District include strata of the Midway and Wilcox Groups. The Midway Group is characterized by an advance of the sea bringing inland a series of marine sedimentary rocks. During the time that the Wilcox Group was being deposited, river-laid sands extended far seaward and continental type deposits became superimposed over the marine strata.

Pleistocene rocks are represented in District 9 by terrace gravels and the recent sediments are characterized by alluvium deposits (See Figures 4&5, Generalized Cross Section, and Geologic Column).

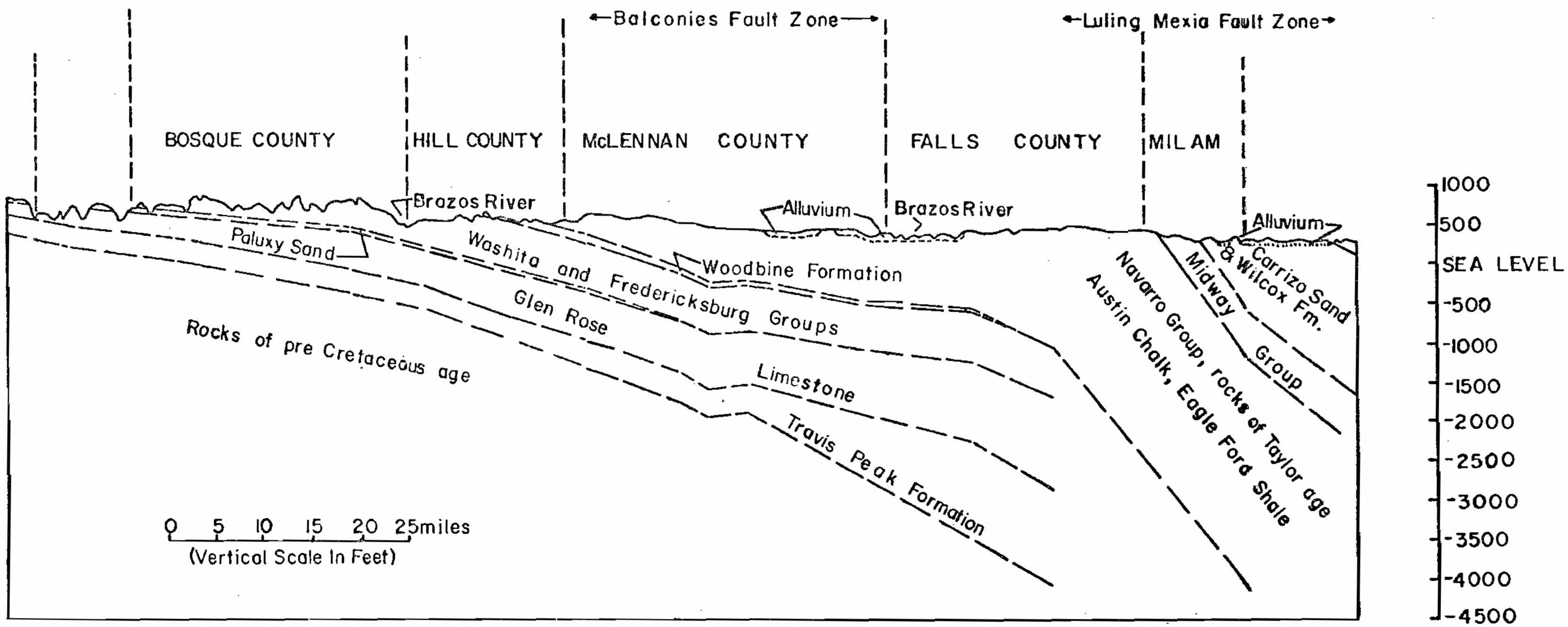
STRUCTURE

The Cretaceous deposits of District 9 dip gently to the east or southeast. Faulting is present. With the exception of this faulting and the mild regional dip, no large structural features are present in the District.

The Balcones Fault Zone extends from Uvalde County to north of Waco in McLennan County as a narrow belt of normal or gravity faults. This zone is not definitely recognized north of McLennan or Hill Counties. However, Bargon reports that he traced a zone (68) of faulting northward from Waco passing near Italy in Ellis County. The Balcones is a prominent topographic feature of which the individual faults are Eocene and do not necessarily parallel the trend of faulting. Displacement can vary from 1000 feet to only a few feet. Most of the faults are down to the east.

The Luling-Mexia-Talco Zone parallels the Balcones in places and extends from the Louisiana line in Bowie and Titus Counties to Medina County in southeast Texas. This zone is represented in District 9 in Limestone and Falls Counties and is characterized by normal or gravity faults. The downthrow side is predominantly to the west and northwest, however, in some instances it is to the east or southeast.

These major zones of faulting form grabens (depressed tracts of land produced by faults), which are 30 to 50 miles wide and which skirt the Llano uplift located southwest of District 9.



GENERALIZED CROSS SECTION DISTRICT 9

(after Cronin, 1963)

FIGURE 4

GEOLOGIC COLUMN DISTRICT 9

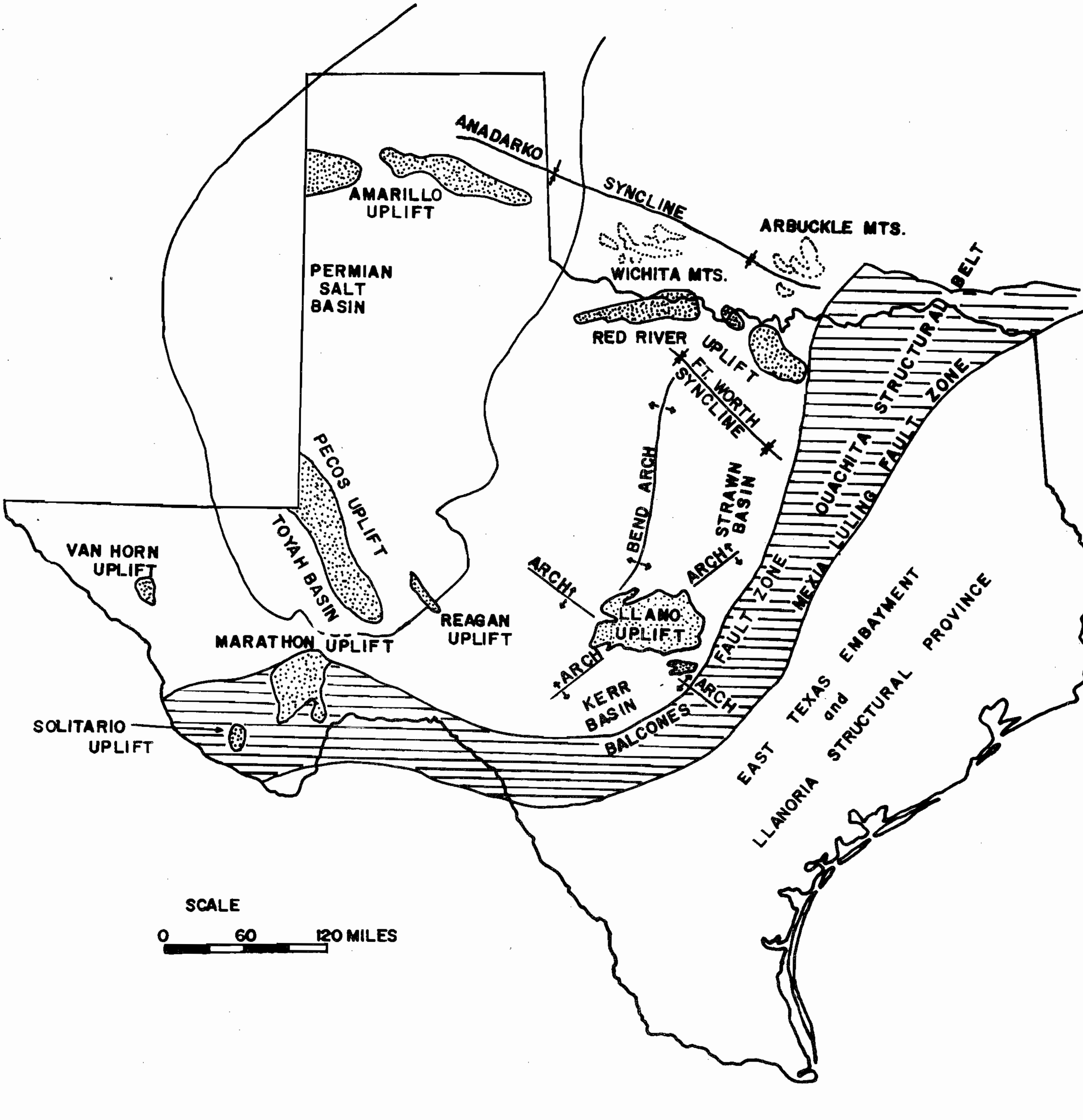
SYSTEM	SERIES	GROUP	FORMATION	MEMBER
QUATERNARY	PLEISTOCENE & RECENT		TERRACE & ALLUVIUM DEPOSITS	
TERTIARY	EOCENE	WILCOX	SABINETOWN	
			ROCKDALE	
			SEGUIN	
		MIDWAY	WILLS POINT	
			KINCAID	TEHUACANA
CRETACEOUS	GULF	NAVARRO	KEMP	
			CORSICANA	
			NACATOCH	
			NEYLANDVILLE	
		TAYLOR	TAYLOR	U. TAYLOR
				PECAN GAP
				WOLFE CITY
				L. TAYLOR
		AUSTIN	AUSTIN UNDIFF.	
		EAGLE FORD	EAGLE FORD UNDIFF.	
		WOODBINE	WOODBINE UNDIFF.	
	COMANCHE	WASHITA	BUDA	
			GRAYSON (DEL RIO)	
			GEORGETOWN	MAIN STREET
				PAWPAW
				WENO
				DENTON
				FORT WORTH
				DUCK CREEK
				KIAMICHI
		FREDERICKSBURG	EDWARDS	
			COMANCHE PEAK	
			WALNUT	
		TRINITY	PALUXY	
			GLEN ROSE	
			TRAVIS PEAK	

FIGURE 5

The Balcones Fault Zone is also significant in that it divides the Central Texas area into two structural provinces; a western province of extremely gentle dip (20 to 25 feet per mile); and an eastern province of somewhat steeper dip (up to 100 feet per mile).[36]

District 9 is underlain in a general NE-SW direction by the rocks of the folded Ouachita Structural Belt. This belt extends from a point in East-Central Mississippi westward and southward along a sinuous course into Mexico.[29] The rocks of this belt include folded and faulted sedimentary and metamorphic rocks of pre-Cretaceous age.

Sandstone dikes have been reported and twenty-one such dikes have been studied in some detail in northern McLennan County.[54] The dikes are located on Elm Creek in North-Central McLennan County. They are nearly vertical, intersecting the direction of the bedding of the strata at almost right angles. They contain well-sorted, subrounded, fine quartz grains which, in general, are not well cemented. In some places the degree of cementation by silica has resulted in a quartzite (See Figure 6, Major Geological Structures in Texas).



Major Geological Structures In Texas

Figure 6

DESCRIPTION OF GEOLOGICAL FORMATIONS

PART III

CRETACEOUS SYSTEM

COMANCHE SERIES

The Comanche Series in Central Texas is composed of the Trinity, Fredericksburg, and Washita Groups which underlie the West Cross Timbers and the Grand Prairie. Differing topographies develop on each of these groups.

TRINITY GROUP

The Trinity Group in District 9 comprises the lowermost Cretaceous sediments exposed and is confined in its outcrop pattern to the western portion of the District including Bell, Bosque, Coryell, and Hamilton Counties. Sediments of this group of rocks were deposited from a sea which, during Trinity time, was changing in depth over the continental land mass. Sands of the Upper Trinity Group underlie most of the Western Cross Timbers. The group consists of the Travis Peak, the Glen Rose and the Paluxy* Formations in District 9.

TRAVIS PEAK FORMATION

This formation is confined to the borders of streams in northwest Hamilton County. At its base the Travis Peak contains packsands, grits, sandy clays, sandstones, conglomerates, and gravels. Above the base section, it consists generally of three sandstone or packsand members each capped by shales and sandy shales. The sands of the formation are white to gray. The shales are black or blue. The significance of this formation is minor in District 9 because of its minimum area coverage.

---

* Recent writers consider the Paluxy Formation to be basal Fredericksburg, however, since it is mapped as Trinity and not differentiated on the enclosed maps, it is considered uppermost Trinity for purposes of this report.

GLEN ROSE FORMATION

This formation crops out in the valleys formed by the more significant streams in Bell, Bosque, Coryell, and Hamilton Counties. Most of the Glen Rose consists of alternating beds of thin to medium-bedded limestone and marl. It is easily recognized on hillsides by its terraced or "staircase topography", consisting of well-bedded resistant limestones forming shelves which are separated by receding layers of soft marl[2] (See Figure 7).

PALUXY FORMATION

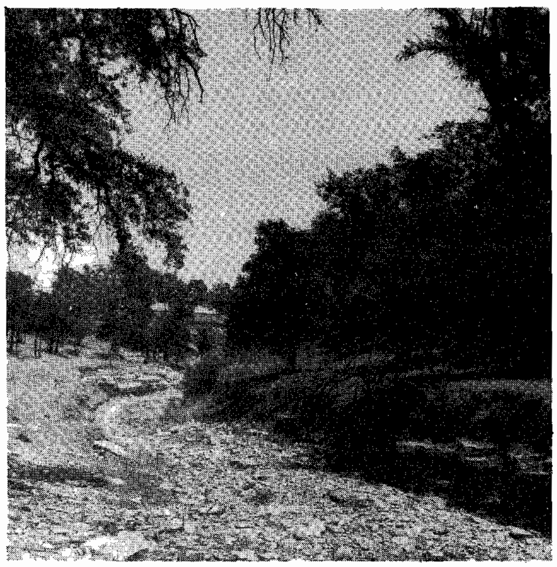
The Paluxy is especially well exposed in Bosque, Hamilton, and Coryell Counties in the District. It crops out in a narrow margin along the western edge of the Lampasas Cut Plain. The area of its outcrop pattern is known as the Paluxy Cross Timbers (Western Cross Timbers) because of the oak trees common to it. The Paluxy is recognized by the red soils which develop on it. It is composed predominantly of homogeneous, fine to very fine-grained, compact quartz sand.[3] Lenses and laminae of dark, impure clays are common. Abundant iron concretions occur along the outcrop at many localities. Grain size of the sands varies and the sand is generally well sorted.

FREDERICKSBURG GROUP

The Fredericksburg Group in Central Texas consists of a complex assortment of various geological formations. The outcrop area of the Frdericksburg Group which includes the Walnut, Comanche Peak, and Edwards Formations underlies the Lampasas Cut Plain. This cut plain is characterized by rugged topography with high flat topped buttes capped by Edwards Limestone, wide flat valleys developed on Walnut Clay, and steep slopes composed of Comanche Peak Limestone.

WALNUT FORMATION

This formation is exposed generally in Bosque, Coryell, Hamilton, and Bell Counties. On the Lampasas Cut Plain it forms the valley floors and part of the slopes. The Walnut is generally divided into two units because of differences in the physical constituents. The upper



Glen Rose Formation exposed along creek bed along new proposed FM location. South of Pearl, Coryell County (Bee House Creek).

Figure 7

portion of this formation consists of hard crystalline limestone beds, chalky limestone, thick calcareous clay beds, and soft marly limestone. The lower portions of the formation consist of alternating beds of thin bedded limestone and gray marls, shell aggregate and thin shale seams. The formation is usually cream to buff colored on exposure at the surface. A good exposure of Walnut which consists of gray to black, calcareous clay with seams of bedded limestone, thicker chalky nodular limestone, and fossiliferous limestone are found on State Highway 36 north of Gatesville (Figure 8).

COMANCHE PEAK FORMATION

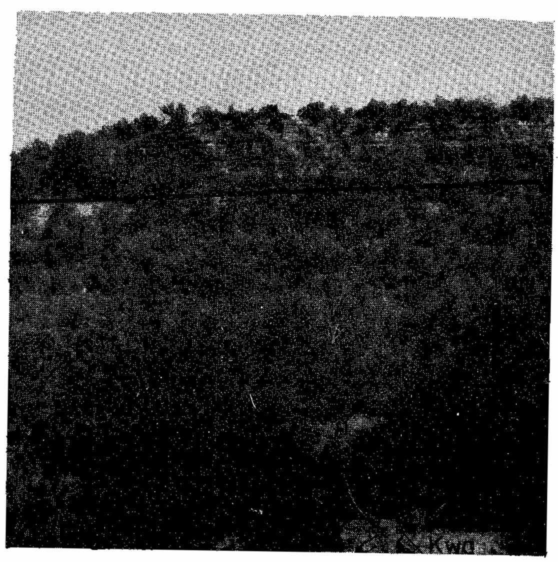
In District 9 the Comanche Peak outcrops throughout the Lampasas Cut Plain beneath the resistant Edwards Limestone above and the soft clay floors of Walnut beneath. Exposures are found in western Hill County and most of Bosque County where complete sections are exposed in the Brazos Bluffs. Other exposures occur in the Bosque River Valley near Valley Mills, and on the east side of the Leon River, where long exposures cross Coryell County and continue into northern Bell County, as well as in much of Hamilton County. Generally this formation is massive and consists of nodular limestone separated by thin marly seams. It seems to have a fractured appearance because of jointing or flaking. In outcrops it is dull white to gray in color and it forms steep slopes. The Comanche Peak is a weak limestone easily eroded in many places by stream action. In general the upper section of the formation is more resistant than the lower. It is recognizable by its characteristic chalky, nodular appearance (Figures 9,10, and 12).

EDWARDS FORMATION

This formation outcrops along a north-south line west of Waco through the District. Good exposures are seen on Farm to Market Road 2280 about 3 miles east of Jonesboro, Coryell County, and in an abandoned quarry approximately 2 miles northwest of Belton, Bell County, and in McLennan County in the valley of the Middle Bosque River. Many other exposures too numerous to mention are found in the outcrop area. In Central Texas the Edwards consists of six principal types of carbonate rock; massive reef limestone, shell debris and

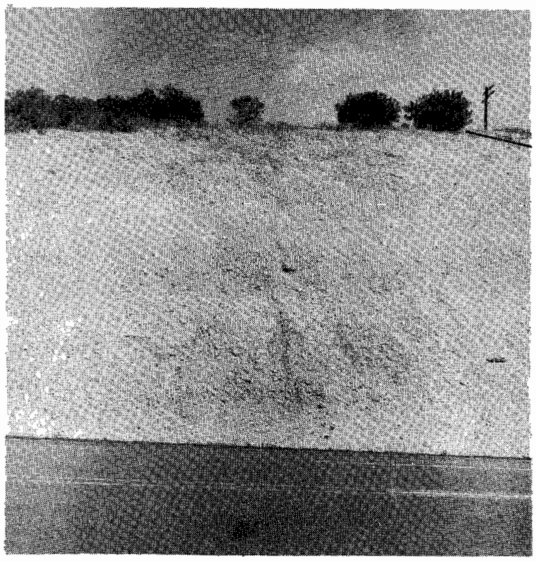
Walnut Limestone beds in Lampasas River
Bed, South of Nolanville, Bell County.

Figure 8



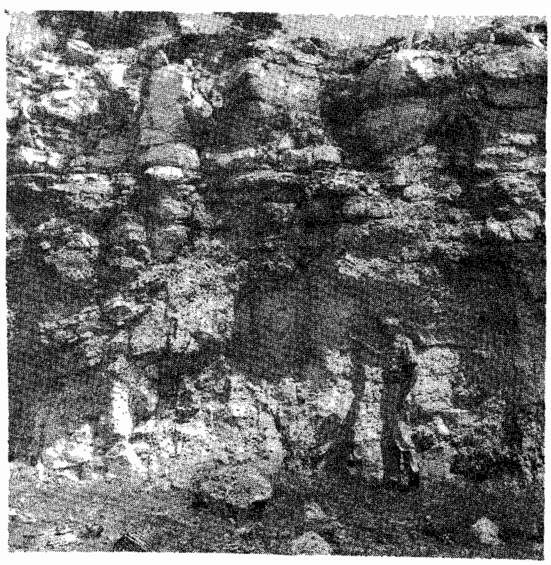
Close up view of Edwards capping butte with
Comanche Peak forming slopes and Walnut
forming valley floor. Location is from FM
1670 on a cut in the Lampasas River, South-
west of Belton, Bell County.

Figure 9



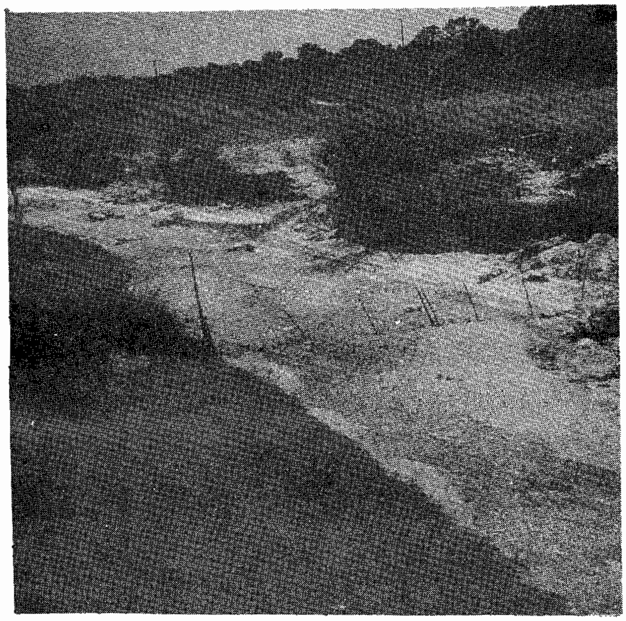
Cut showing the Edwards on top and the Comanche Peak in almost complete exposure. Location is along US 281 in Coryell County, just southwest of Evant.

Figure 10



Exposure of Edwards in a source material pit just north of Evant and west of US 84 in Hamilton County. The material was used on US 84 and US 281. It tested as Class 1 material.

Figure 11



Comanche Peak Formation showing natural weathering. West of Whitney Dam, Bosque County.

Figure 12

Edwards Limestone at Lake Whitney, West end of Dam, Bosque County.

Figure 13

coarse shell fragments and powdered shells in a fine grained matrix, medium to fine-grained limestone, chalk and marl, dolomite, and other types of secondary limestone. All combinations of these occur. In addition chert and silicified carbonate rocks are common in some places.[52] The thickness of the Edwards varies markedly ranging from a minimum of 15 feet north of Gatesville, Coryell County, to a maximum of 124 feet near Moffat in Bell County (Figures 9,11,13, & 14).

WASHITA GROUP

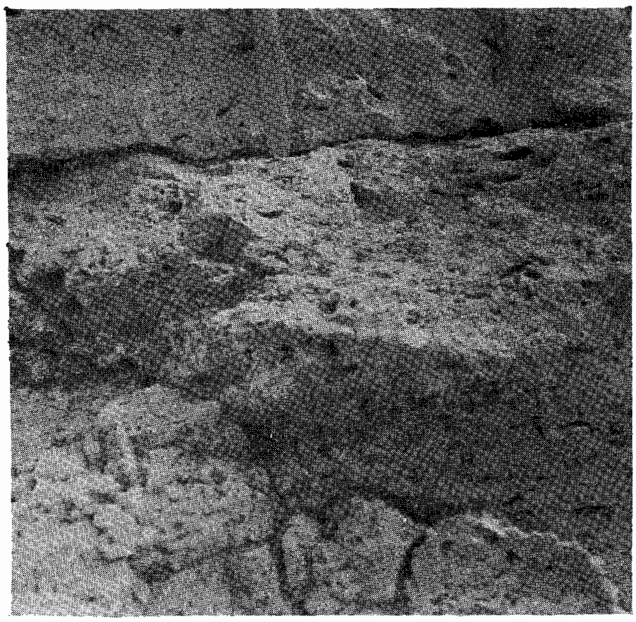
The Washita Prairie is delineated by the outcrop pattern of the Washita Group and forms the eastern portion of the Grand Prairie of Central Texas. The topography is that of gently rolling hills and flat divides separated by steep-walled, level-floored valleys. On the Grand Prairie the drainage pattern is largely controlled by the geologic features and is frequently rectangular in appearance.[24] The Washita Group forms the top of the Comanche Series of the Cretaceous in Texas. It outcrops in Hill, McLennan, Coryell, and Bell Counties in the District.

KIAMICHI CLAY

The Kiamichi is present from the Coryell-Bell County line near Whitson northward and is absent south of this point. Exposures are found in McLennan County on the North Bosque southwest of China Springs, and in the Valley Mills region, on Hogg Creek at Patton, and on the middle Bosque River near Crawford. Numerous exposures are also to be found in Bosque and western Hill County. The formation is composed of calcareous and silty shales, calcareous clay, and thin wavy-bedded and nodular limestones. The lithology of the Kiamichi gradually changes from the bottom to top, but three general lithologic divisions are usually recognized in outcrops. In ascending order they are silty shale, limestone, and calcareous clay.[52] A calcareous clay is usually found at the top of the formation and limestones are more abundant in the upper portions. On exposure at the surface the Kiamichi is generally tan in color because of oxidation of the iron contained in the clay.

GEORGETOWN FORMATION

The eastern portion of the Grand Prairie is supported by the resistant limestones of the Georgetown Formation. The six



Close up showing Edward "Coquina" Limestone, from Smith Pit, 2.0 miles West of Evant, Hamilton County.

Figure 14

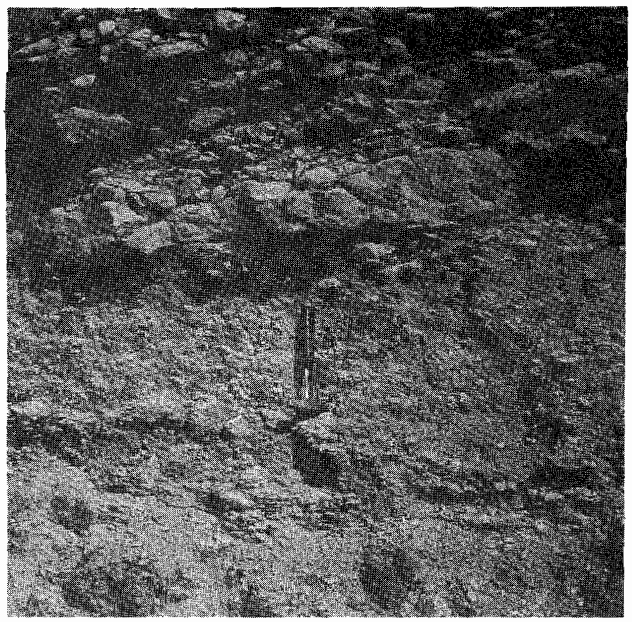
recognized members are as follows:

Duck Creek Limestone Member - Exposures of the Duck Creek are found in McLennan County on Hogg Creek at Patton, in the Middle Bosque River at the crossing 2 miles west of Windson and near Whitson in Bell County, as well as on Cedar Creek, Nolan Creek and the Leon River, east of Belton. This member of the Georgetown formation is a relatively hard limestone, which becomes dark-gray on exposure at the surface. The upper and lower sections are generally more resistant than the middle portion. The member contains shale partings and pyrite nodules. In Bell County it is argillaceous, nodular, and contains subordinate amounts of limey marl (Figure 15).

Fort Worth Limestone Member - This member is exposed in Rock Creek, Childress Creek, the Middle Bosque River and the east bank of the Brazos River in the China Springs Quadrangle, McLennan County. It is also exposed in an abandoned railroad cut south of Nolan Creek about one mile southeast of the courthouse at Belton, Bell County. The limestone is light gray in color on fresh exposures and weathers to a cream color; it is hard, very resistant, medium crystalline and interbedded with marly shale.[30]

Denton Shale Member - The Denton Shale is predominantly a marly shale containing two thin "coquinoid" limestone beds which are separated by about a foot of shelly marl. The member is continuous over a wide area in central Texas because of its position below the resistant Weno member and is not more than about 5 feet thick in the central portion of District 9.

Weno Limestone Member - In McLennan County it crops out in a belt as much as 4 miles wide and forms projecting ledges in streams. Its outcrop is narrower in Bell County. The member consists of well bedded, nodular, argillaceous, gray limestone with limey marl lenses. The bottom section of the Weno is a massive limestone about two feet thick that is generally referred to as the "Ocee Ledge". This bed is hard, resistant to erosion, and supports much of the area of the Grand Prairie.[30]



Duck Creek Limestone, Georgetown Formation,
Del Mar Ranch near Waco, McLennan County.

Figure 15

Pawpaw Shale Member - The Pawpaw member is not present south of north-central McLennan County. It is exposed along the east bank of the Brazos River, and is also present in Hill County. The member is more sandy in the northern portion of the District and gradually becomes marly as it passes toward the south. The marl is soft, thin bedded, and has shale partings. In exposure it usually consists of two shale beds separated by a four-foot soft limestone. Towards the north the member becomes a loosely cemented, ferruginous, red to brown, cross-bedded sandstone, with sandy clays and some ironstone concretions.

Main Street Limestone Member - The Main Street thickens to the north in Hill County and to the south in Bell County;its outcrop width is less than a mile. It outcrops just west of the Del Rio Formation. It is composed of compressed nodular, somewhat argillaceous limestone, which is white on exposure at the surface. The limestone is relatively hard, medium crystalline, and chalky. Pyrite nodules, calcite crystals, and other characteristics of the Georgetown Limestone are present in the Main Street.(30) It caps the divide between the Lampasas River and the City of Belton, in Bell County.

GRAYSON (DEL RIO) FORMATION

The Del Rio formation is exposed throughout McLennan County in a strip running NE to SW, particularly along the Bosque Valley in southern McLennan County. It is also exposed along the Leon River in Bell County and on the east bank of the Lampasas River. There are also many exposures in McLennan County north of Waco. In the District the Del Rio is a marl, or clay, high in lime in many places, with pyrite, gypsum, and hydrated iron oxides. There may rarely be scattered limestone seams, shelly strata, and near the top a few very limey, whitish, nodular thin limestone seams, or thin buff-weathering platy seams of fine sandstone or siltstone. In McLennan County the bulk of the formation is bluish-gray jointed clay. Stain tests indicate bentonitic and illitic clays are present in all parts of the formation.(71) In Bell County it is composed generally of a clay in the upper portions, with siltstone lenses, a greenish-gray clay in the middle portions, and alternating marl and marly limestone in the lower portions.

BUDA FORMATION

This formation has a peculiar intermittent outcrop across McLennan and Bell Counties. Good exposures are seen above the city of Bosqueville in McLennan County, but are few and scattered. The best exposure is in Bell County. The Buda is thin, 1-3½ feet thick, dense to porous limestone. It contains pyrite, and marcasite. On exposure at the surface it is buff or gray in color.

GULF SERIES

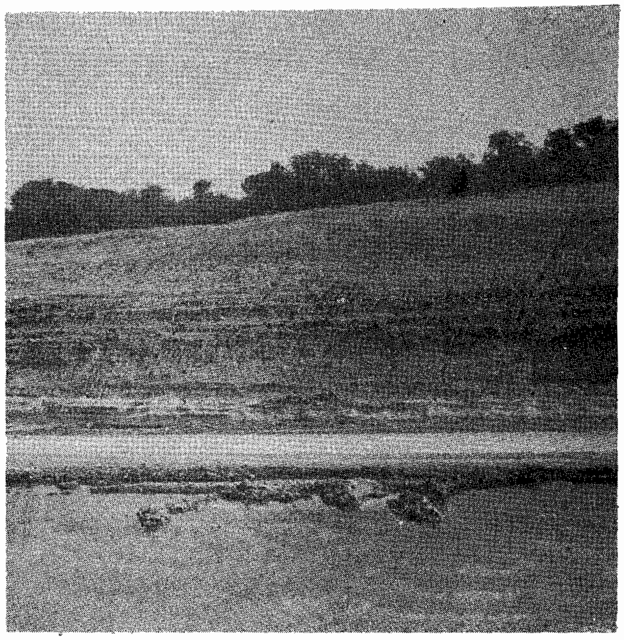
The Gulf or Upper Cretaceous series characteristically develops the Blackland Prairies Physiographic Province of Central Texas. The Blackland Prairies differ from the Grand Prairie in having less relief with rolling hills and rounded valleys. The Blackland Prairies Physiographic Province is divisible into three distinct prairies, each being characteristic of an individual geologic formation and having the same name. North of McLennan County the Grand Prairie is separated from the Blackland Prairie by the Eastern Cross Timbers which develop on the sands of the Woodbine Formation.

WOODBINE GROUP

The Eastern Cross Timbers which develop on the Woodbine were described by Hill in 1887 as a "rolling, hilly country". The area has numerous low rounded hills capped by more resistant sandstone. The Woodbine develops this type of topography only on its northern sandy portion. It consists of porous and crumbly to friable, indurated, ferruginous sandstones which alternate with black, non-calcareous shales. South of Hill County only the Pepper formation is present. The Pepper consists of non-calcareous, non-carbonaceous (with exception), black shale, with pyrite, and the development of gypsum, celestite,siderite, jarosite, and other minerals. In the north the Woodbine is divided into the Lewisville, the upper more calcareous portion, and the Dexter, the lower massive and clean sands of the Woodbine. The Lewisville locally has volcanic material associated with it while the Dexter is relatively free of volcanic ash and sand (Figure 16).

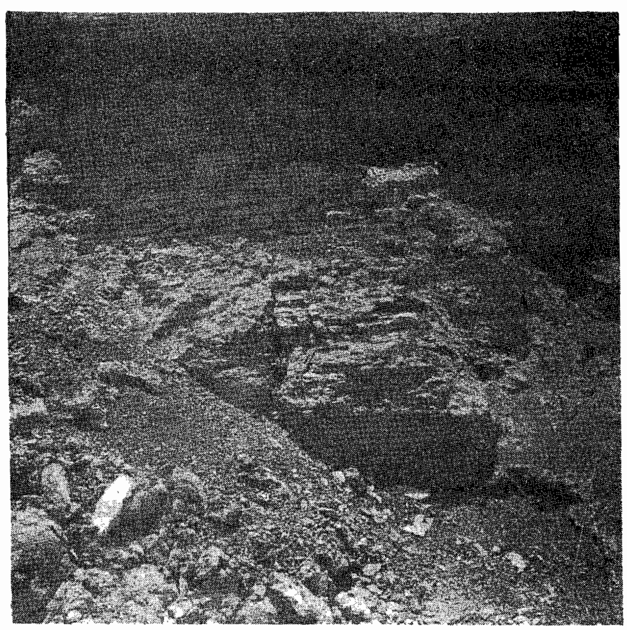
EAGLE FORD GROUP

The Eagle Ford formation forms the westermost prairie of the



Pepper Formation (Southern Extension of the Upper Woodbine), Lake Waco Dam Area, McLennan County.

Figure 16



Eagle Ford Formation exposed at Hillsboro, Hill County.

Figure 17

Blackland Prairies of Central Texas. The topography of the prarie is one of rolling lands and hills which show a rounded appearance except in places where more resistant limestone flags have been undercut by erosion to form steep slopes. Its outcrop pattern is somewhat wider than the Woodbine and parallels it through the District. The Eagle Ford consists mainly of laminated, bentonitic, shale. It includes some layers of thin laminated limestone. The formation is more calcareous to the south. Pyrite nodules are common. In the area south central McLennan County the Eagle Ford is divided as follows (oldest to youngest) (Figure 17).

LAKE WACO FORMATION

This formation consists of grayish-white to brownish wavy-bedded limestones and dark silty shales with bentonite layers. This formation is divided into the following members:

Bluebonnet Member - Composed of limestone flagstones interbedded with calcareous shale and bentonite. The Bluebonnet member averages 15% limestone, 80% shale, and 5% bentonite. Limestone beds are lenticular, black to gray, fine to medium-grained, porous, and weather gray to buff. They are abundant in the lower half of the member, and commonly grade upward from gray medium-grained, clear crystalline calcite-cemented, clastic limestone to dark-gray, fine grained, chalky limestone.[69]

Choice Member - Composed of dark, silty, calcareous shales with subordinate limestone beds.

Bouldin Member - Composed of interbedded grayish white to brownish silty limestones and silty shales with bentonite seams in McLennan County.

SOUTH BOSQUE MARL

This formation consists of the upper 120 feet of clay and marl.

AUSTIN GROUP

The prairie formed on the Austin formation shows greater relief than that of the Eagle Ford, with many more outcrops visible on the surface. The topography can be described as angular. The formation outcrops in general north-south direction through the District. North of Waco the outcrop is removed by faulting; however, it picks up again at West in northern McLennan County and continues northward to the east of Hillsboro. In McLennan County the outcrop pattern is an irregular discontinuous strip, averaging several miles in width. Exposures are found in a quarry of the Universal Atlas Cement Company in McLennan County. The Austin is composed of alternating layers of white chalky limestone and limey marl with some layers of shelly marl near the top. Pyrite and marcasite nodules are common and are found in both the chalk and marl beds.[66] Bentonite clay beds recognizable by their dark-gray to black color and tan to red color on exposure are present in the Austin. The chalk beds of the Austin are of three types; fine-grained microcrystalline calcite, minute particles and spheres of clear sparry calcite, and organic remains. Minor amounts of pyrite, glauconite, aragonite, and phosphatic material and limonite are also present.[66] The Austin is water-tight except in areas of local joints and faults and makes an impervious formation because of extensive recementation.

TAYLOR GROUP

The prairie formed on the Taylor is one of low relief and is the largest prairie of the Blackland Prairies. There are few resistant beds in the Taylor and consequently the streams in this area flow with almost no geologic control. The drainage pattern produced is dendritic. The outcrop pattern of the Taylor is east of the considerably wider Austin. The outcrop pattern for each of the four divisions of the Taylor is designated on the enclosed geologic maps. These divisions include the Lower Taylor Marl, the Wolfe City Sand, the Pecan Gap Chalk, and the Upper Taylor Marl.

LOWER TAYLOR MARL

The Lower Taylor Marl crops out in a wide band from Bartlett on the Bell-Williamson County line northward to Irene close to the Hill-Navarro County line. The Lower Taylor is a massive, uniformly bedded, fine-grained marl. Finely disseminated pyrite and gypsum crystals are present throughout. The marl is approximately 75% clay minerals, silt, and various insolubles, and 25% calcium carbonate and solubles.

The clays of the Lower Taylor are illites and occasional thin seams of bentonite throughout.[9] On weathered outcrops the marl is fissile.

WOLFE CITY SAND

This formation crops out from just north of Seaton in northeastern Bell County to the District line in the north just north of Hubbard in southeastern Hill County. It consists of calcareous sand with numerous lenticular concretions of calcareous sandstone at the base to a sandy marl at the top. Grain size decreases upward from a fine sand to a clay.[9] At the Blacklands Experimental Watershed in McLennan County the Wolfe City Sand is described as consisting of an upper silty marl and a lower sandy marl. The sands of the Wolfe City consist predominantly of quartz with feldspar, mica and chert. Calcium carbonate content ranges from 5 to 15%.[12]

PECAN GAP CHALK

The Pecan Gap in District 9 crops out in a narrow band just east and parallel to the Wolfe City Sand except that in the south it continues on from a point where the Wolfe City is no longer exposed and leaves the District in southeastern Bell County on the eastern edge of the Lower Taylor Marl outcrop. The Pecan Gap is divided into three divisions in Central Texas; a lower chalk which is more massive, a massive chalk, and a median, marly chalk. The carbonate content ranges from 50% in the median portion to 80% and 85% in the upper and lower chalks. Insoluble residues include organic material, clay, and silt.[9] On weathered outcrops the Pecan Gap is white in color. Blank, Stoltenberg, and Emmerich[12] divide the Pecan Gap into a lower chalk, hard and glauconitic; a lower highly calcareous marl; an upper chalk alternating with chalky marl, and an upper highly calcareous marl from studies conducted at the Blackland Experimental Watershed, near Waco.

The Rogers Chalk, named for chalk found in stream cuts just west and south of Rogers in southwestern Bell County is situated between the Lower Taylor Marl and the Wolfe City Sand in age. The Lott Chalk, named for a locality at Lott, Central Falls County, is equivalent in age to the Wolfe City

Sand, and outcrops in southern Falls and eastern Bell Counties with irregular and interrupted exposures. The Marlin Chalk, named for the chalk which underlies the town of Marlin and occurs at the Falls of the Brazos, covers western Limestone, the east corner of McLennan, and north-central Falls Counties. A higher Taylor chalk which is exposed 3 miles northwest of Coolidge is called the Coolidge Chalk and is located between the Pecan Gap and the Upper Taylor Marl in age.

UPPER TAYLOR MARL

The Upper Taylor crops out from Munger in northern Limestone County, to the south of Rosebud in southern Falls County. Its outcrop pattern is affected by faulting as is the outcrop of the Pecan Gap in southern Falls County. The Upper Taylor Marl is fine-grained, banded marl. The primary differences between the Upper Taylor and the Lower Taylor are; the calcium content does not seem as high in the Upper Taylor Marl, the upper marl has slightly higher percent of siderite or pyrite, and the upper marl grades from a calcareous marl at its base to a slightly calcareous marl in the upper portion.(9)

NAVARRO GROUP

The Navarro Group is limited in outcrop pattern to Limestone and Falls Counties in the District. The group underlies the Elgin Prairie, the eastermost prairie forming the Blackland Prairies. This prairie has a surface which is gently undulating or rolling. The prairie is not confined to the Navarro Group, but covers also the formation of the Midway Group. The Navarro Group is divided into the Neylandville, Nacatoch, Corsicana, and Kemp Formations.

NEYLANDVILLE FORMATION

The Neylandville outcrops from just east of Rosebud in southern Falls County to just east of Munger in northern Limestone County. It is exposed in western Limestone County southwestward from a point 4.2 miles east of Prairie Hill, where it consists of sandy marl, recognizable by its calcareous nature and by the presence of dense gray limestone concretions. In Falls County an outcrop occurs northeast of McClanahan which consists of sandy marl with large concretionary limestone lenses weathered white. The formation in general contains gray sandy, calcareous clay or marl.

NACATOCH FORMATION

The outcrop pattern of the Nacatoch formation is restricted to northern Limestone County where it outcrops in a narrow band from southeast of Frosa to where it leaves the District northeast of Coolidge. The formation is composed of massive gray calcareous sand. Some parts of the sand are hard, calcareous, concretionary masses of various sizes up to several feet across. In Limestone County the formation contains,locally,of large partings of shale, most of them 3 to 4 feet thick. The sands of the formation are mostly fine-grained, light gray quartz sands with many grains of glauconite. Beneath the cap rock, the amount of pore space in the sands averages 25.5%.(67)

CORSICANA FORMATION

This formation in District 9 forms a narrow outcrop pattern which generally parallels that of the Neylandville described above except in the north where it is separated from the Neylandville by the Nacatoch formation. The formation is predominantly a chalky marl. The marl is gray or blue-gray on a fresh damp outcrop, but dries to a whitish or light-gray color. The basal 5 to 6 feet are generally more or less sandy and the proportion of clay to calcium carbonate in the main part of the formation varies from place to place. The lower sandy bed contains phosphatic nodules.(72)

KEMP FORMATION

In general the Kemp formation parallels the outcrop pattern of the Corsicana formation from southeastern Falls County to north-central Limestone County through the District. The width of the outcrop is wider and is affected somewhat by faulting in the northern portions. This formation in Limestone County is described as being a compact to finely laminated gray clay, with a marked conchoidal fracture. The clays of this formation become progressively more marly downward, changing into a thin, hard limestone layer which caps the underlying Corsicana formation. The formation varies in character in different places but generally is a dark clay having a low calcium carbonate content. Layers and concretionary masses of gray dense, fine, calcareous sandstone are fairly common, though rather widely spaced, in the formation. Some of the concretions are completely enveloped in a thick earthy layer. Concretions occupying a zone about midway of the formation tend to weather to reddish tints, while those in the upper part weather to orange limonitic tints.[72]

TERITARY SYSTEM

EOCENE SERIES

MIDWAY GROUP

The Midway Group of Texas is divided lithologically in the following units: the Kincaid formation including the Littig Glauconitic member, the Pisgah member, and the Tehuacana member; and the Wills Point formation including the Mexia member, an aragonite bed and the Kerens member.[33] Elgin undulating and rolling prairies overlie the Midway Group.

KINCAID FORMATION

The outcrop area of the Kincaid formation in this District is from the northeast corner of Limestone County, through the town of Tehuacana, and continuing southwest through Limestone County and into Falls County to the Brazos River near Reagan. The width of the outcrop varies from 1 to 2 miles, with a complex pattern of reoccurrance in Limestone County due to extensive faulting.

The Kincaid formation has a marine facies throughout its extent. The basal strata are littoral in origin and record the transgression of the lower Eocene Sea over the Cretaceous bare-leveled plain. The Tehuacana Limestone is a thin lentil and indicates shallow waters at the close of the formation time, at least locally.[67]

The strata of the Kincaid formation consist generally of glauitic sands, soft gypsiferous clays, and hard indurated limestone lentils deposited in the following proportions: limestone 10%, clay and silty clay 50%, and sand 40%.[67]

Three members of the Kincaid formation are now recognized in District 9.

Littig Glauconitic Member - This basal member is a bed of glauconitic sand which is from a few feet up to 15 feet in thickness. The bed consists of greenish-black calcareous glauconite weathering to yellowish-green or buff color and containing phosphate nodules, small pebbles, sharks teeth, casts of fossils, and spherical calcareous concretions. It is a very persistent layer that constitutes a good marker in stratigraphic and structural mapping.

Pisgah Member - The middle member, the Pisgah, was also first used by Plummer in 1932, although at that time it was the upper member and included the Tehuacana Limestone lentil and other lentils as they occur throughout the entire outcrop area. As now accepted and used in this report, the Pisgah is restricted to the clay, glauconitic clay, and sandy calcareous clay underlain conformably by the Littig member and overlain conformably by the Tehuacana member.[33] The name comes from Pisgah Ridge, a prominent topographic feature in Navarro County, 6 miles north of the Limestone County Line. Thickness of the Pisgah member in this District is approximately 80 feet to 120 feet.

Tehuacana Member - the Tehuacana forms a westward facing escarpment in Limestone County. The escarpment is along a line extending from Tehuacana on the north through Big Hill on the south, and on into Falls County. This member is not only significant because of the influence it has on the topography, it is also the only source of road building material in the eastern part of District 9.

The Tehuacana as observed at its type locality on the northwest side of Tehuacana Hill, just west of the town of Tehuacana on S.H. 171, is generally a grayish-white limestone. This member has very irregular bedding, which gives the appearance of imperfectly shaped lenses with earthy material filling the interstices (Bureau of Economic Geology, Circular No. 7, 1936). This member also includes calcareous, glauconitic sands. Some of the sand beds are loosely indurated with calcareous cement. On exposure, the limestone is often stained yellow or brown by water saturated by ferruginous matter. Close examination of the rock reveals a great mass of small and highly fragmental shell material cemented by calcite to form a coquina. Many of the shells are microscopic so that the rock viewed from a distance of a few feet has the appearance of a rather solid and non-fossiliferous ledge or boulders. Viewed under the hand lens, the small fragments comprise a mixture of finely broken shells, small ostracods, minute pelecypods, focaminifera, and other clastic material (Bureau of Economic Geology, Circular No. 7, 1936). At many locations where the top of the Tehuacana is exposed, the very abundant fossil *Venericardia bulla* is present in such vast number as to form a near shell conglomerate cemented by calcite with a large amount of silica sand. The *Venericardia bulla* can be easily recognized as a bi-valved shell with deep ridges in each valve. The shell is about the size of a 50 cent piece, and is often found perfectly preserved with valves attached.

The importance of this rock unit to the road building program of this District cannot be over emphasized. Problems related to exploration, testing, and engineering characteristics will be discussed in a later report, "Engineering Characteristics of the Geology of District 9."

The Kincaid formation is distinguished easily from the adjacent formations by the following criteria:

1. Topography. In many places the outcrop is along the back slopes of a ridge capped by a limestone or by a glauconitic layer. The Upper Cretaceous marls below and the Wills Point formation above have commonly a flat, featureless or gently rolling topography.

2. Soils. The soils are lighter, more silty, and yellower than those of the underlying Cretaceous. Navarro soils are thick, black and waxy. The Kincaid soils, except where they are in close contact with the Cretaceous, are yellowish green at the base and grade upward into black at the surface. They contain more sand and more iron than Navarro soils. They are yellower, darker, and more calcareous than the Wills Point and terrace soils. The Wills Point soils are noncalcareous, silty, grayish-black loams.

3. Phosphatic nodules. Small black nodules streaked with gray lines characterize certain parts of the Kincaid beds and do not occur in adjacent beds.

4. Concretions. The concretions of the Kincaid formation are most commonly large, well-rounded, rough-surfaced forms well cemented by calcium carbonate. Many contain fossils. The concretions of the Navarro are similar in shape but have smoother surfaces, more veins or crystalline calcite, more dendrite, and no fossils. The concretions of the Wills Point formation are of three types: (a) very numerous small ironstone concretions, (b) large flattened concretions with fretted, fine-veined surfaces, and (c) large elongate sandstone boulders from 3 to 15 feet long, which occur in the sandy beds at the top of the formation and in the base of the Wilcox.

5. Fossils. The Kincaid formation contains a very characteristic group of both megascopic and microscopic fossils, which clearly distinguish it from all other formations (Figures 18 and 19).[67]

WILLS POINT FORMATION

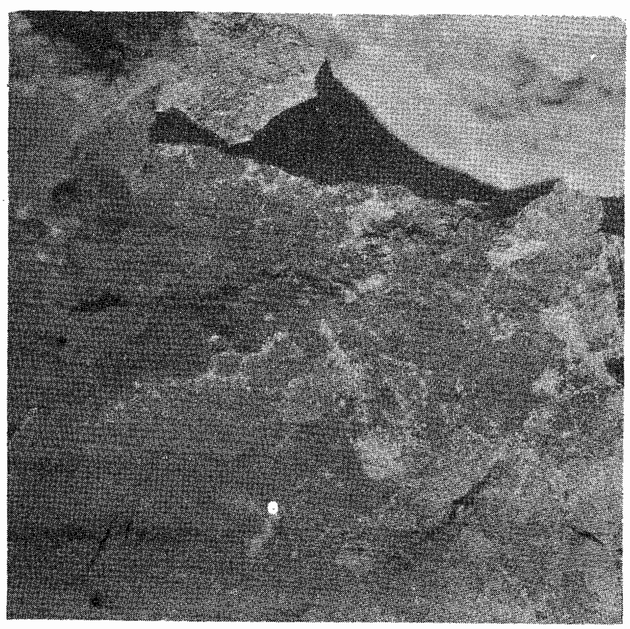
The Wills Point is restricted in outcrop pattern generally to the same general trend as the Kincaid, however, its outcrop pattern is more extensive than the Kincaid. The basal section is exposed in the clay pit of the brick plant in Mexia, Limestone County and the upper section shows on a small northward flowing stream branch of the Tehuacana Creek 4 miles east of Mexia. The formation is made up of a small amount of glauconitic clay at the base, above which is a compact clay, grading upward into silty clay layers. The amount of silt increased upward with the upper 100 feet containing more than 10% silt and in some places as much as 25%. About 90% of the silt grains consist of quartz. The Mexia member contains silts and clays, light gray to blue-gray, some large concretions and much glauconite. Chemical analysis of the Wills Point Clay shows a higher percentage of silica and aluminum, and less lime, manganese oxide, and carbonate than the clays of the Kincaid formation.[67]

WILCOX GROUP

The Wilcox Group, where exposed at the surface, gives rise to

Tehucana Limestone, Kincaid Formation,
North of US 84, 6.0 miles West of Mexia.

Figure 18



Same location as Figure 18 above, Close
up view of Tehuacana Limestone.

Figure 19

sandy soil that is easily eroded and it constitutes a portion of the East Texas Timber Belt.[26] It is represented in outcrop in the District in the eastern tip of Falls County and the eastern half of Limestone County. The strata of the Wilcox comprises a heterogeneous series of sandy, lignitic clays, cross-bedded sands, and stratified silts. The upper layers have a larger proportion of sand. Some massive beds are from 50 to 100 feet thick and consist entirely of medium-grained sands. The subdivision of the Wilcox includes the following formations: Seguin, Rockdale, and Sabinetown.

SEGUIN FORMATION

The Seguin formation consists of 50% fine sand, 30% silt, 19% clay, and 1% carbonaceous matter. The mineral grains are angular and subangular quartz, a few selenite crystals, limonite, considerable altered mica, traces of magnetite, and a little glauconite. All the beds are unconsolidated except the concretions which are large, rough-surfaced, oblate, and firmly cemented with clacite.[67] The formation can be distinguished by a characteristic oyster bed at the top, and by uniformly finely textured and laminated sands containing black flakes or leaf fragments, interbedded with thin layers of black carbonaceous matter. The Wills Point beneath has little or no carbonaceous matter. The Seguin has large, rough, calcareous concretions containing white shell fragments. The concretions in the Rockdale do not contain shell fragments.

ROCKDALE FORMATION

This formation is chiefly lignitic shale and the color varies with weathering and lignite content from black to chocolate brown to reddish brown upon weathering. Sand beds are rare and thin. The strata of the Rockdale is 65% sandy clay, 20% sand, 10% clay, 3% lignite, and 2% large concretions. The sand is fine grained and subangular. The sands are extremely friable and can be crumpled to a fine powder in only a few minutes by rubbing the specimen in the hands. Some diagnostic features include: massive cross-bedded sands, large chunks of petrified wood, lignite lentils, and large, rough-surfaced concretions.

SABINETOWN FORMATION

This formation consists of thinly laminated gray sand, lentils and thin beds of blue sandy clay containing thin partings of impure sand and numerous large iron concretions. The base of the formation is marked by a layer of conglomerate in some places and in other places by a layer of glauconitic sand. These deposits are distinguished from the overlying formation by finer sand grains and smooth iron concretion. The deposits contain less lignite and carbonaceous material than the underlying Rockdale or Seguin formations.

PLEISTOCENE SERIES

PLEISTOCENE RIVER TERRACES

The Uvalde Terrace gravels are the oldest gravels found in the District. They cover broad areas in eastern Bell County, and are also present in southern Bell County, eastern Falls County, and southern McLennan County. These terrace gravels are generally unrelated to present drainage and at a considerably higher elevation. The Uvalde is represented in the District by areas of lag gravel composed of pebbles and cobbles of chert, jasper, quartz, orthoclase granite, and silicified wood in a clay-soil matrix. The pebbles range from 1 to 6 inches in diameter.[27]

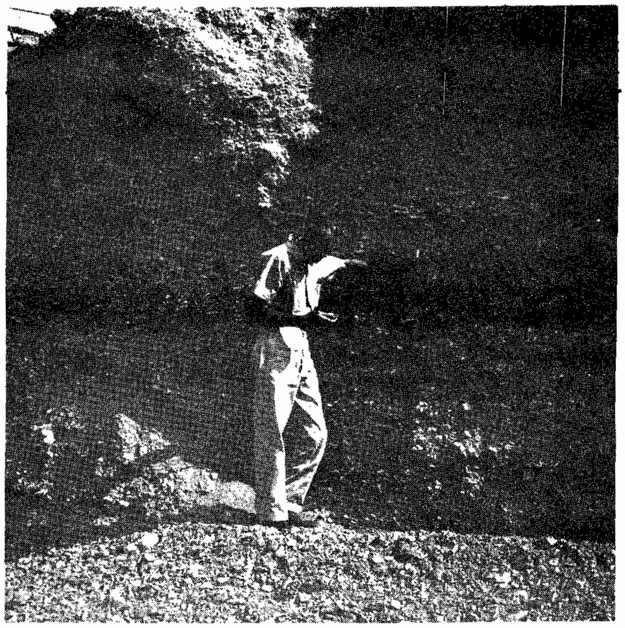
The major streams which traverse District 9 are the Brazos-Bosque system and the Leon-Lampasas Little River system. The Brazos River system of terraces is divided into two groups, each of which is generally considered to consist of two terraces. The lower group lies within the present valley at elevations of 20 to 50 feet above the low water level. The gravels of the Brazos contain well-rounded siliceous pebbles consisting of quartz, quartzite, chert, and jasper. Limestone gravels are found in the lower parts of the lower terraces where the river has cut through the underlying Cretaceous rocks. In Falls County the four terraces formed by the Brazos were described as follows by Hatch:[35] the oldest generally 150 to 200 feet above low water level and consisting of large rounded flint and chert nodules in a matrix of small quartz and chert pebbles, the next youngest is 90 to 100 feet above low water and contains a hard cemented layer at the base with water-worn boulder of sandstone and fossiliferous limestone in the deposits, the next youngest is 40 to 50 feet above low water and the gravel deposits are composed of flat oval-shaped or slightly rounded pebbles up to 6 inches in diameter and rounded iron stained sand, quartz, chert, limestone, and claystone with clay seams 8 to 12 inches in diameter scattered throughout the deposits; the youngest gravel is 25 feet above low water and is similar to the one above without the clay seams.

On Little River in Bell County three terraces are recognized by Nickell.[59] The oldest and highest is composed of flint, is low in limestone, and contains many pebbles of black chert, in three localities; however, the terrace has a high proportion of limestone and reworked fossil shells. The next youngest terrace is predominantly limestone, with some flint, and fossil shells, with black chert present only in small amounts. The youngest appears to be a gravel mixture which has been reworked from the above two terraces.

In Eastern Limestone County only small amounts of gravel are found on the banks of the Navasota River (Figures 20 and 21).

RECENT SERIES

Alluvium, usually black and muddy silt, occupies the beds of streams and in some cases the flood plains in the District. In McLennan County sand and gravel are dredged from the Brazos River. Rapid deposition of fine grained sediments is presently taking place in the Brazos River as well as other major streams of the District.



Terrace Deposits in Bosque River Terrace, Lake Waco area, McLennan County.

Figure 20

Stock pile of Bosque River Terrace Gravel near Waco, McLennan County. Same Material as shown exposed in Figure 20 above.

Figure 21

PEDOLOGY

PART IV

INTRODUCTION

The characteristics of most of the prevalent soil groups are controlled by topography, climate, organic influence, time and parent material. The parent material is considered to be the dominant controlling factor. In general, sandy soils develop on sand parent material and clay and clay loam soils develop from limestone, marl, and clay parent material. The purpose of this portion of the report on District 9 will be to relate, in a general way, the various soils series occurring in the District to the geological formations outcropping at the surface. A second, but no less important aim, will be to supply general descriptions of the various soils encountered along with engineering properties found from observation and tests of these soils.

GENERAL

The major portion of the land area of the District is located in the Blackland and Grand Prairies. The soils of the Blackland Prairies are chiefly of the Houston, Houston Black, Wilson, and Crockett series, although others occur. These soils are dark and are deeply developed from marl and chalk of Upper Cretaceous age with the Crockett soils being transitional into rocks of lowermost Eocene age. The soils have smooth to gently rolling surfaces and drainage, for the most part, is good. The Houston and Houston Black soils are the most extensive of the region.

Soils of the Grand Prairie are mostly of the San Saba, Denton, Crawford, and Brackett series and are chiefly clay and stony clay in texture. They are dark soils developed on the limestones of Lower Cretaceous age.

The East Texas Timberland, which is of minor extent in the District is characterized by the soils of the Edge, Lakeland, Sawyer, and Tabor series. These soils develop on the sands and silts of the Lower Eocene Formations.

The Eastern Cross Timbers which are defined by the outcrop belt of the Woodbine sands north of Waco are characterized by the development of the Edge, Ruston, and Tabor series of soils.

The Western Cross Timbers, which develop on Paluxy sands of Lower Cretaceous age, give rise to soils of the Windthorst and Nimrod series predominantly.

GEOLOGICAL FORMATIONS AND SOILS

COMANCHE SERIES

TRINITY GROUP

TRAVIS PEAK FORMATION

No soil series has been related in origin to the Travis Peak formation in the District because of its minor aerial coverage and lack of sufficient information concerning its outcrop pattern.

GLEN ROSE FORMATION

Brackett, Denton, San Saba, and Tarrant soils are the dominant soils developed on the alternating beds of limestone and marl which make up the Glen Rose Formation. This alternation of limestone and marl is the controlling factor in the soil development of the Glen Rose. Denton series normally occur on gentle sloping areas underlain by marl and clay, while shallow-phase Denton and Denton-Tarrant complex soils commonly develop on the more resistant limestone beds.(15) In Bell County the Brackett stony clay associated with many small areas of San Saba stony clay and Brackett clay are derived from the limestones and marl of the Glen Rose. The Brackett stony clay is a highly calcareous stony clay which is poorly developed and thin and occurs on slopes where erosion is severe. San Saba soils are dark crumbly calcareous clays which are generally mature deep soils that develop on flat, poorly drained areas where soil formation is accelerated. Tarrant soils are extensive shallow associates of the Denton soils. Harbin soils (believed to be equivalent to those soils previously called Denton fine sandy loams) are characteristically developed along the line of contact between the Paluxy sands and the Glen Rose formation. Bushnell and others(17) use the term Denton fine sandy loam in this respect.

PALUXY FORMATION

Harbin, Nimrod, Stephenville, and Windthorst soils are typically developed on the fine quartz sands of the Paluxy Formation. Harbin soils are calcareous equivalents of the Stephenville and are composed predominantly of a surface layer of slightly acid fine sandy loam to loam over a slightly acid sandy clay loam. Nimrod soils develop on smooth flat areas from calcareous sandy parent material. They include a surface of predominantly sand with a slightly permeable subsoil. Stephenville soils consist predominantly of fine sandy loams which develop on steeper slopes than do the Windthorst soils. Windthorst soils occupy rolling surfaces, though the stony types may occupy ridges and somewhat steep slopes of valleys. They consist of slightly acid sandy loams over sandy clays.

FREDERICKSBURG GROUP

Soils of this group include Brackett, Crawford, Denton, San Saba, and Tarrant. In Bosque, Coryell, and Hill Counties the Fredericksburg is undifferentiated as to individual formations on the enclosed maps. In Bell County and in other counties adjoining the District as well as in portions of the above mentioned counties, the individual formations have been delineated and their soils can be described.

WALNUT FORMATION

Soils of this formation are divided into clay-derived soils and limestone-derived soils by Brown.[15] Denton, Brackett, San Saba, and Tarrant soils are all derived from the Walnut. Large areas of the San Saba series are derived from the Walnut and are developed predominantly from the clay beds. Brackett soils develop from the shell agglomerate found in places in the Walnut. Brackett soils occur rarely on steep, marly, limestone slopes capped by limestone beds. Tarrant soils develop from the lower hard crystalline limestone beds of the basal Walnut.[15]

COMANCHE PEAK FORMATION

Brackett, Denton, and San Saba soils are derived from the limestones and marls of the Comanche Peak. Where the Comanche Peak outcrops on the steep slopes of hills capped by Edwards Limestone, the poorly developed Brackett series is the dominant soil developed. This is attributed to the fact that erosion removes much of the weathered rock debris. The calcareous Denton Clay is derived from the Comanche Peak and occurs in flats, slight depressions, and basins about the heads of drainage ways, where the surface is level or very gently sloping.(17) The San Saba clay soils also are derived from the Comanche Peak where the topography is flat to slightly sloping.

EDWARDS FORMATION

Brackett, Crawford, Denton, and San Saba soils are related in origin to the hard limestones of the Edwards Formation. Soils of the Edwards are usually shallow and stony. The Brackett, Denton, and San Saba are derived to some extent from the Edwards. Their positions and relationships are as already mentioned. By far, the most abundant soils developed from the harder limestones of the Edwards are the Crawford soils. Generally, they are stony clays or clay and are, in some cases, mapped with Brackett clay and some rough stony land, with which they are associated. Scattered abundantly throughout these soils are irregular fragments of chert and limestone. Locally this is called "flint land."

WASHITA GROUP

KIAMICHI CLAY

This formation is represented by only 25 feet of material in northern Hill County and it thins and disappears in southern McLennan County along its outcrop. Some Tarrant and Tarrant-Brackett soils are present on the Kiamichi; however, because of its minor extent, they are probably derived in part from the overlying Georgetown Formation.

GEORGETOWN, DEL RIO, AND BUDA FORMATIONS

Brackett, Crawford, Denton, San Saba, and Tarrant soils are developed on the limestones and marls of these formations. Generally, the same manner of development of these soils, as has already been mentioned, is characteristic. Both Tarrant and Brackett soils develop on steep slopes; however, Tarrant soils develop on slopes where the runoff is rapid while Brackett soils develop on the slopes where runoff is very rapid. Crawford soils form on the harder limestones such as the Fort Worth where drainage is slow to medium. The Denton soils develop from interbedded limestone and marl on gently to moderately sloping areas and are associated with the San Saba soils which are darker, flatter, and less permeable. Some portions of the Del Rio and Buda Formations are overlain by Houston and Houston Black soils. These areas may be considered to be a transition zone between the soils of the Grand Prairie and those of the Blackland Prairies.

GULF SERIES

WOODBINE GROUP

In Bell County the outcrop pattern of the Woodbine is narrow and a distinct soil grouping whose origin can be traced to the formation cannot be determined without detailed mapping. However, in Hill and McLennan Counties the soils derived from the ferruginous sandstones and non-calcareous shales of the Woodbine are predominantly the Tabor, Edge, and Ruston soils, which develop on the northern sands and the Houston and Houston Black clays, which develop on the southern calcareous shales. The Edge soils develop on non-calcareous clays and sandy clays and differ from the Tabor soils which tend to have a thicker A horizon and slightly sandier parent material. Ruston soils develop from acid sandy clay loams which contain layers of sand, sandy clay, or loamy sand.

EAGLE FORD GROUP

Ellis, Houston Black, Houston, Austin, Stephen, and Sumpter soils develop on the marls, shales, and limestones of the Eagle Ford. The Ellis soils comprise shallow clayey soils developed on non-calcareous olive colored shales of the Eagle Ford. The Houston clays develop from marl or highly calcareous clays and are very extensive in the Blackland Prairies. The Houston Black soils are developed on calcareous clays or clayey marls and are associated with the Sumpter soils which are formed of the same parent material but on more sloping areas where surface drainage is very rapid.

AUSTIN GROUP

The dominant soils which develop on the Austin Chalk are Austin, Eddy, Houston, Houston Black, Stephen, and Sumpter series soils. Austin soils develop predominantly on chalky marl or chalk and are less plastic and more crumbly than the Houston Black soils. They develop on more sloping surfaces than do Houston or Houston Black soils. Eddy soils occur in small areas associated with those of the Austin and Houston Black series. They develop from chalky marl. The Houston Black soils here are developed on chalky marls and are associated with the Austin and Eddy soils, with the Austin being developed where runoff is medium to rapid and the Eddy where is is very rapid. Houston clays and stony clays are more extensive in the Austin Formation than the Houston Black soils. The Stephen soils, originally classed as a shallow variant of the Austin series, are also developed on chalk of the Austin Formation.

TAYLOR GROUP

The Burleson, Crockett, Houston, Houston Black, Sumpter, and Wilson soils are predominantly developed on the marls, sandy marls, and clays of the Taylor formation. Burleson soils occupy nearly level, slowly-drained areas which are underlain by calcareous clays. From a study of the detailed soil map by Baird, Lauritzen, and others,[83] Blank, Stoltenberg, and Emmerich[12] derived a somewhat definite relationship between the soils in the area of the Blacklands Experimental Watershed near Waco, and their parent material. On portions of the sandy marl of the Wolfe City member, Crockett soils are developed. These soils probably owe their greater degree of leaching to an admixture of sand from ancient alluvium deposits, now almost completely eroded; however, evidence for this is not conclusive. The calcareous Houston and Houston Black series form on the highly calcareous marls of the Pecan Gap and the less calcareous upper and lower Taylor marls. Houston soils are also found on the silty marl of the Wolfe City member in spite of its lower calcium carbonate content - probably because the invisible silt is too fine and the clay content too high to permit much internal leaching.(12) From a close study of the Soil Map of McLennan County, it appears that the Houston Black clays are more extensively developed on the Taylor than on the Austin Formation. The Wilson soils which occur on the Taylor Formation are restricted almost entirely to the sandy clays of the Wolfe City on the flatter uplands where drainage is poor and on parts of the terrace alluvium derived in whole or part from the Wolfe City member.

NAVARRO GROUP

Soils derived from the Navarro group include Burleson, Crockett, Houston, Houston Black, Sumpter, and Wilson. Crockett fine sandy loam is associated with the Wilson soils and is derived from slightly calcareous clays and sandy clays. Other soils included here as being derived from the Navarro group are similar in derivation to that already mentioned.

EOCENE SERIES

MIDWAY GROUP

The limestones, silty clays, clays and sands of the Kincaid Formation and the Wills Point Formation are parent material for the Crockett, Houston, Houston Black, and Sumpter soils. The Midway group forms a transition zone between the soils of the Blackland Prairie underlain by Upper Cretaceous deposits and those of the Eastern Timberland.

WILCOX GROUP

The sandy clays, clays, sands, and silts of the Wilcox group are parent material for the Crockett, Edge, Lakeland, Sawyer, Tabor, and Wilson soils. Clays of the Crockett and Wilson soils are developed to a minor extent on the lignitic clays and non-calcareous clays of the Wilcox. The Lakeland fine sands are derived from thick or moderately thick beds of sands, which in many cases overlie finer textured sediments, while the sandy loams of the Edge and Tabor series are derived from the sands and silts. Lakeland soils develop where the topography is nearly level to gently sloping. Tabor soils develop on nearly level to gently undulating topography, and Edge soils develop on undulating to rolling erosional uplands.

PLEISTOCENE SERIES

The following soils are produced on Pleistocene terraces and gravel deposits: Axtell, Bastrop, Bell, Burleson, Irving, Lewisville, and Travis. Axtell soils are very fine sandy loams developed on calcareous clays and sandy clays in which the dominant clay minerals are montmorillonitic. They develop predominantly on old high dissected stream terraces. Bastrop soils consist of fine sandy loams derived from calcareous moderately sandy old alluvium of the Brazos River. The Bastrop soils occur as dominant soils of old low river terraces. Bell soils consist of clays derived from calcareous clayey alluvium, sometimes with chert or limestone gravel toward the base. They occur on level undissected parts of stream terraces ranging in age from early Pleistocene to recent. Burleson soils consist of slowly permeable clays developed on weakly to moderately calcareous montmorillonitic clays of old alluvium. They occupy undissected stream terraces on erosional uplands. Irving soils are composed of sandy loams to clayey loams derived from alluvial sediments of slightly calcareous clays and occurring on old stream terraces. Lewisville soils consist of well-drained clays very strongly granular which are derived from calcareous alluvial clays. They occupy old stream terraces. The Patrick series, which is associated with the Lewisville, differs in having beds of gravel within three feet of the surface. Lewisville soils are underlain by areas of chalk or limestone. Travis soils are composed of fine sandy loams with sandy clay subsoils derived from old alluvium containing stratified clay, sand, and gravel which is mostly calcareous. They occupy well-drained areas of old high stream terraces.

RECENT SEDIMENTS (FLOOD PLAINS)

The following soils are developed upon recent flood plain sediments: Catalpa, Frio, Gowen, Kaufman, Miller, Navasota, Norwood, Trinity, and Yahola. Catalpa soils consist of calcareous clays or silty clays and are associated with the Trinity soils but are more granular, generally higher in calcium carbonate and better drained. They develop on recent flood plains that are nearly level. Frio soils are well-drained calcareous silty clay loams that develop on nearly level stream bottoms. Gowen soils consist of non-calcareous clay loams that occupy nearly level flood plains subject to occasional or frequent overflow. They resemble Kaufman soils but are less acid and occur in more Western areas. Kaufman soils are slightly acid to alkaline clays which occur in the flood plains of streams draining the Blackland Prairies. Miller soils are composed of calcareous clays that occur in the flood plains of streams like the Brazos which drain areas underlain by red beds to the west. Navasota soils are acid clayey soils occupying level to slightly concave positions in flood plains. They are derived from alluvium which is largely derived from prairies in the Coastal Plain. Norwood soils are calcareous silty loams that develop in the flood plains of streams like the Brazos which carry sediments derived from the western plains and the limestone prairies. Trinity soils are calcareous clays which form from recent stream sediments in the Blackland Prairie areas, and which generally occupy level flood plains. Yahola soils are very fine sandy loams which occupy flood plains in streams like the Brazos which drain the western plains. In general, from west to east, the following soils occur in the District: Frio, Catalpa, and Trinity in the central portion; Miller, Norwood, and Yahola in the Brazos River flood plains; and Gowen, Kaufman, Navasota, and Trinity in the eastern portions of the District.

TABLE OF SOILS CHARACTERISTICS

On the following table, Table I, are listed the physical properties and some of the important engineering characteristics of the more important soils found in the District. This table is not an attempt to list all of the individual types of soils found in the District. It is merely a listing of the soils thought to be most significant from the standpoint of highway construction. For detailed soil descriptions, interested persons are referred to the Soil Survey Bulletin for McLennan County by E. H. Templin; it is accurate and in accord with present day standards. Also, the Soil Survey Bulletins of Bell and Falls Counties by W. T. Carter and M. W. Beck, respectively, in which the soil boundaries are somewhat more generalized and the classification not completely in accord with present day standards.

clays which occur in the flood plains of streams draining the Blackland Prairies. Miller soils are composed of calcareous clays that occur in the flood plains of streams like the Brazos which drain areas underlain by red beds to the west. Navasota soils are acid clayey soils occupying level to slightly concave positions in flood plains. They are derived from alluvium which is largely derived from prairies in the Coastal Plain. Norwood soils are calcareous silty loams that develop in the flood plains of streams like the Brazos which carry sediments derived from the western plains and the limestone prairies. Trinity soils are calcareous clays which form from recent stream sediments in the Blackland Prairie areas, and which generally occupy level flood plains. Yahola soils are very fine sandy loams which occupy flood plains in streams like the Brazos which drain the western plains. In general, from west to east, the following soils occur in the District: Frio, Catalpa, and Trinity in the central portion; Miller, Norwood, and Yahola in the Brazos River flood plains; and Gowen, Kaufman, Navasota, and Trinity in the eastern portions of the District.

TABLE OF SOILS CHARACTERISTICS

On the following table, Table I, are listed the physical properties and some of the important engineering characteristics of the more important soils found in the District. This table is not an attempt to list all of the individual types of soils found in the District. It is merely a listing of the soils thought to be most significant from the standpoint of highway construction. For detailed soil descriptions, interested persons are referred to the Soil Survey Bulletin for McLennan County by E. H. Templin; it is accurate and in accord with present day standards. Also, the Soil Survey Bulletins of Bell and Falls Counties by W. T. Carter and M. W. Beck, respectively, in which the soil boundaries are somewhat more generalized and the classification not completely in accord with present day standards.

TABLE I SOILS CHARACTERISTICS OF DISTRICT 9

SOIL	DESCRIPTION AND REMARKS	DEPTH inches	STRUCTURE	ACIDITY	TOPOGRAPHY	% SLOPES	EXT. DRAINAGE	INT. DRAINAGE	EROSION	ASSOCIATED SOIL
Asa	Brown to dark reddish-brown silt loam, very friable, Alluvium soil, 10 to 18 inches thick.	0-12	mod. to strong med. granular	neutral to mildly alkaline.	Nearly level area in high, rarely inundated parts of flood plains		slow	moderate	Uneroded	Norwood Miller Yahola
	Brown to dark brown heavy silt loam, very friable, 10 to 18 inches thick.	12-30	compound mod. med. subangular blocky and granular.	mildly alkaline and in places calcareous						
	Reddish-yellow or reddish-brown strongly calcareous silt loam, very friable, rather uniform to a depth of 6 to 8 feet where the silty alluvium gives way to stratified sandy, silty and clayey sediments.	30-72	massive but porous	strongly calcareous						
Austin	very dark grayish brown silty clay, very dark brown when moist. 7 to 20 inches, gradual slightly wavey boundary.	0-15	strong med granular and fine subangular blocky	mod. alkaline and calcareous contains some 30% $CaCO_3$ with fine concretions.	Undulating to gently rolling upland	1 to 6%	medium to high	moderately low	moderate to very susceptible.	Lewisville soils are the alluvium-terrace equivalents Houston Black Eddy
	Brown silty clay, dark brown when moist, 7 to 12 inches thick, few to common small hard and soft concretions of $CaCo_3$ 1 to 3 mm in diameter	15-25	same	same						
	Pale brown silty clay, brown when moist, gradual wavey boundary, 7 to 20 inches thick. Crumbly, and slightly plastic.	25-40	moderate fine subangular blocky and granular.	strongly calcareous		* High volume change potential evident				
	Pale yellow unconsolidated chalky marl with finely divided $CaCO_3$ and subordinate montmorillonitic clay, grading into thin bedded platy chalk of alternating soft and hard layers at depth of 60 inches or more.	40-60								
Axtell	grayish brown very fine sandy loam, hard when dry, very friable when moist. 2 to 4 inches thick.	0-3	very weakly granular to massive	slightly acid	nearly, level plane to weakly convex surfaces on old alluvium terraces.	0 to 2%	very slow to rapid	very slow	very little to moderate	Travis Irving
	Light-gray very fine sandy loam, hard when dry, very friable when moist, rests abruptly on underlying claypan. 3 to 6 inches thick.	3-6	massive but permeable.	medium acid						
	Reddish-brown clay mottled with grayish-brown and yellowish brown, very firm and compact when moist, very hard when dry, 10 to 15 inches thick.	6-18	mod. mod. blocky	strongly acid		* The clay fraction is highly expansive and undergoes large volume changes with change in moisture content. During prolonged droughts extensive shrinkage cracks develop in lower horizons.				
	Light olive gray and light yellowish brown compact clay or sandly clay.			weakly calcareous						

TABLE I SOILS CHARACTERISTICS OF DISTRICT 9

SOIL	DESCRIPTION AND REMARKS	DEPTH inches	STRUCTURE	ACIDITY	TOPOGRAPHY	% SLOPES	EXT. DRAINAGE	INT. DRAINAGE	EROSION	ASSOCIATED SOIL
Bastrop	Grayish-brown fine sandy loam, very friable when moist, slightly hard when dry. 10 to 18 inches thick Reddish-brown sandy clay loam, friabel, permeable, porous, 18 to 24 inches thick. Yellowish-red sandy clay loam, friable and freely permeable. 25 to 50 inches thick. Unleached parent material of reddish yellow strongly calcareous sandy clay loam. This is old alluvium 10 to 50 feet thick and has limestone gravel near the base.	0-15 15-30 35-70 70+	weak medium granular very weak subangular blocky	slightly acid about neutral slightly alkaline	Convex to plane	0 to 2%	free	free	none to	
Bell	dark-gray heavy clay, crumbles on wetting and drying; very firm when moist; stick when wet. 10 to 20 inches thick. dark-gray heavy clay; slowly permeable when moist; has few small concretions of $CaCO_3$ below 30 inches. 20 to 30 inches thick. Parent material of pale-yellow calcareous clay mottled with light olive gray. Friable marly clay at depth of 6 or 10 feet.	0-18 18-45 45-70+	moderately granular weak coarse blocky dry, massive moist	calcareous calcareous strongly calcareous	Level undissected parts of stream terraces.	less than 1% * Severe volume change potential	very slow	very slow	none to moderate	terrace analogy of the Houston Black
Brackett	Light brownish-gray clay, with numerous fragments of limestone. 3 to 8 inches thick. pale-yellow clay; friable; contains numerous large fragments of limestone.	0-6 6-12	strongly granular strongly granular	calcareous calcareous	Hilly to gently rolling	5 to 15%	rapid to very rapid	moderate to slow	very active	Denton San Saba Crawford Tarrant
Brazos	Brown silt loam very friable 12 to 25 inches thick. Light reddish-brown loose loamy fine sand stratified with thin seams of silt and clay	0-15 15-50+	moderate medium granular	neutral calcareous	Level to nearly level, convex slope of low terraces and high bottoms.		slow	rapid	not susceptible	Yahola
Brewer	dark grayish-brown, non-calcarous, friable clay loam. very dark-gray to black noncalcareous clay dark grayish-brown calcareous clay light brownish-gray calcareous clay, mottled with brownish yellow and containing some sand. stratified reddish-brown and yellow calcareous silty clay and sand.	0-8 8-45 45-60 60-85 85-110+	granular	neutral	Nearly level low terraces and high flood plains	rarely more than ½%	slow	slow	not susceptible	

TABLE I SOILS CHARACTERISTICS OF DISTRICT 9

SOIL	DESCRIPTION AND REMARKS	DEPTH inches	STRUCTURE	ACIDITY	TOPOGRAPHY	% SLOPES	EXT. DRAINAGE	INT. DRAINAGE	EROSION	ASSOCIATED SOIL
Burleson	very dark gray clay, black when moist, extremely hard, very firm, 20 to 50 inches thick.	0-40	moderately fine irregular blocky, weak blocky below	slightly acid	Level to very gently sloping	0-3%	very slow	very slow	none to slight	Wilson Houston Black Axtell Alluvium equivalent is the Navasota
	dark gray clay, very dark gray when moist, few evident shear planes or slickensides that intersect at 30 to 45° angle, extremely hard, few small concretions of $CaCO_3$, 15 to 30 inches thick.	40-55	massive or coarse irregular blocky	neutral						
	mottled light olive gray and pale yellow weakly calcareous clay with few hard concretions and small soft lumps of $CaCO_3$, very compact and apparently nearly impervious.	55-70+				*Severe volume change potential evident				
Catalpa	grayish-brown light clay or silty clay friable to firm, crumbly, 10 to 30 inches thick.	0-15	strong medium granular		Nearly level flood plains		slow	slow to moderate	not susceptible	Trinity
	grayish-brown, calcareous, crumbly, light clay or silty clay continuing to a depth of a few feet.	15-50+				* Moderate volume change potential evident				
Crawford	dark reddish-brown clay, very hard, 8 to 15 inches thick	0-10	moderate granular to fine blocky	slightly acid	Very gently sloping upland	½-2%	slow to moderate	very slow	mostly slight some moderate	Denton
	dark reddish-brown clay, very firm, very sticky and stiff, extremely hard when dry, 10 to 20 inches thick	10-26	coarse blocky	slightly acid		* Moderate volume change potential evident				
	same as layer above but clay is weakly calcareous and contains few small concretions of $CaCO_3$, and a small fragments of limestone, 3 to 6 inches thick.	26-30								
	hard limestone bedrock or bed of broken limestone fragments over bedrock	30+								
Crockett	grayish brown fine sandy loam, friable, slightly hard dry, 6 to 12 inches thick.	0-10	weakly granular	medium acid	Undulating to gently rolling	2-4% Dominant	rapid	slow	slight to moderate	Wilson
	reddish brown mottled with red and olive yellow clay, thick clayskins, very firm, very sticky and stiff, extremely hard dry, 6 to 10 inches thick.	10-18	strong medium blocky	medium acid						
	mottled red, olive yellow and yellowish brown clay, very firm, extremely hard, 10 to 20 inches thick.	18-34	weak blocky	slightly acid						
	mottled gray and yellowish brown clay, slightly calcareous and has few small concretion of $CaCo_3$ below 40 inches.	34-50+								

TABLE I SOILS CHARACTERISTICS OF DISTRICT 9

SOIL	DESCRIPTION AND REMARKS	DEPTH inches	STRUCTURE	ACIDITY	TOPOGRAPHY	% SLOPES	EXT. DRAINAGE	INT. DRAINAGE	EROSION	ASSOCIATED SOIL
Denton	dark, grayish-brown calcareous clay brown calcareous crumbly clay limestone	0-18 18-30 30-50+	granular	calcareous or neutral, not acid	Undulating to gently rolling	1-4% *Moderately to highly plastic but has shallow profile on shallow phase	rapid	moderate to slow	slight to moderate	associated lighosols Brackett & Tarrant
Eddy	light brownish-gray silty clay, very friable, slightly hard but crumbly when dry, contains few small fragments of chalky limestone, 3 to 15 inches thick. soft or semi-indurated white chalk or chalk fragments containing soft chalky marl over indurated chalk.	0-8 6-30+	strong medium granular	strongly calcareous	MODERATELY uniform slopes	4-8%	rapid	moderately free	very susceptible	humid equivalent of Brackett
Edge	brown fine sandy loams, hard, 2 to 5 inches thick. pale brown fine, light, sandy loam, very friable, hard, 2 to 6 inches thick Red clay, few to common fine distinct mottles of brown, yellowish brown and gray, very fine and compact, very slowly permeable, 3 to 12 inches thick. mottled reddish brown, grayish brown and brownish yellow clay, very firm and compact, 12 to 24 inches thick. light brownish gray clay or sandy clay, few to common coarse mottles of brownish yellow and yellowish red, very firm, 10 to 30 inches thick. very pale brown to light gray slightly shale clay with occasional thin sandy layers.	0-4 4-8 8-12 12-30 30-50 50-80	weak fine granular structureless strongly medium blocky weak medium blocky weak coarse blocky	slightly acid to neutral slightly acid strongly acid strongly acid strongly acid strongly acid	Undulating to rolling erosional upland	1-5%	medium to rapid	very slow		
Ellis	dark yellowish-brown or dark olive brown noncalcareous gummy clay light olive-brown noncalcareous gummy clay light olive-gray noncalcareous shale	0-4 4-20 20-60+		slightly acid	gently to strongly sloping	3-12%	rapid	very slow	very susceptible without vegitation cover.	Wilson Houston Sumpter
Frio	grayish-brown silty clay loam, crumbly and friable, 15 to 25 inches thick. grayish-brown silty clay loam, porous, firm but crumbly, slightly sticky and plastic, grades into stratified gravelly and sandy sediments at depths below 6 feet.	0-20 20-50+	strong medium granular massive	strongly calcareous strongly calcareous	Nearly level stream bottoms		slow	moderate		subhumid equivalent of Catalpa

TABLE I SOILS CHARACTERISTICS OF DISTRICT 9

SOIL	DESCRIPTION AND REMARKS	DEPTH inches	STRUCTURE	ACIDITY	TOPOGRAPHY	% SLOPES	EXT. DRAINAGE	INT. DRAINAGE	EROSION	ASSOCIATED SOIL
Gowen	Dark grayish brown clay loam, friable, 8-16 inches thick. dark gray clay loam, porous, friable hard when dry.	0-12 12-46+	moderately granular massive	neutral slightly acid	Nearly level flood plains		slow	slow		Kaufman Catalpa
Harbin	brown fine sandy loam, friable 4 to 8 inches thick. yellowish-brown fine sandy loam, friable, 1-6 inches thick. Yellowish-red sandy clay, porous friable, sticky and slightly plastic when wet, very hard when dry, 6 to 12 inches thick. Reddish-yellow light sandy clay, porous, friable, with a few small particles of $CaCO_3$ in lower part, 4-12 inches thick. Yellow sandy clay loam, porous 5 to 30 inches thick. Yellow sandy earths or weakly indurated packsand.	0-5 5-10 10-18 18-28 28-38 38-50+	weakly granular very weakly granular massive massive massive	neutral neutral neutral to mildly alkaline mildly alkaline strongly calcareous very strongly calcareous	GENTLY to moderately sloping upland.	1-3%	moderate to rapid	moderate		Stephenville Windthorst Tarrant Brackett
Houston	dark grayish-brown calcareous heavy clay crumbly, very sticky when wet, 6 to 14 inches thick. olive-brown or dark yellowish-brown calcareous heavy clay. yellowish-brown calcareous heavy clay of cloddy breakage, contains few concretions of $CaCO_3$, somewhat more compact than first two layers. light gray and pale yellow, calcareous nearly impervious clay. unweathered light olive-gray shaly marl. unweathered light olive-gray shaly marl	0-10 10-20 20-45 45-150 150-250	granular blocky weak blocky	strongly calcareous strongly calcareous	Gently to moderately sloping upland	4-8%	rapid	slow to very slow	very susceptible	Houston Black Sumpter Austin
						* Moderately to highly plastic causing poor pavement performance, after dry seasons soil is deeply creviced. In late summer months and during prolonged droughts very narrow shrinkage cracks occur to depths of many feet in this expansive soil. Severe volume change potential evident in this soil.				
Houston Black	very dark gray clay, very sticky and plastic when wet; very crumbly when slightly moist, 10 to 20 inches thick. same as above except lower in organic matter, and contains a few concretions of $CaCo_3$ in lower part, 0-30 inches thick olive gray heavy clay of same consistancy and reaction as above, few concretions of $CaCO_3$. 12-30 inches thick. light olive gray strongly calcareous clay, mottled with olive yellow, numerous small concretions of $CaCO_3$. grades into weathered highly calcareous impervious gray or olive-yellow clay at depths from 10 to 20 feet.	0-18 16-40 40-56	medium granular weakly granular to coarse blocky weakly granular to coarse blocky	calcareous calcareous calcareous	nearly level to gently sloping upland	1-4%	slow to rapid	slow to wanting	none to moderate	on chalk they are Austin, Eddy and on clays they are Houston, Wilson, Sumpter
						* highly plastic and undergoes severe volume changes with changes in moisture content. Crevices 3 to 6 inches wide and extending to several feet form during extremely dry seasons. The most outstanding examples of failure due to weak and swelling subgrade in District 9 are found on this material.				

TABLE I SOILS CHARACTERISTICS OF DISTRICT 9

SOIL	DESCRIPTION AND REMARKS	DEPTH inches	STRUCTURE	ACIDITY	TOPOGRAPHY	% SLOPES	EXT. DRAINAGE	INT. DRAINAGE	EROSION	ASSOCIATED SOIL
Irving	dark-gray noncalcareous clay loam, friable when moist, hard dry.	0-10	weakly granular	neutral	Level stream terraces	0-1%	very slow	very slow	none	Axtell terrace equivalent of the Wilson
	very dark-gray noncalcareous clay of cloddy breakage.	10-18		neutral		* Moderate volume change potential, after dry seasons soil developes, very narrow but deep shrinkage cracks				
	dark gray noncalcareous tough clay	18-43								
	gray tough, noncalcareous clay containing few concretions of $CaCO_3$.	43-60								
	light olive-gray, calcareous, tough clay, very slowly pervious	60-70+								
Kaufman	dark grayish-brown noncalcareous clay loam, crumbly, friable, and permeable.	0-48	moderately granular	neutral	Level flood plains	*Moderate volume change potential	very slow	very slow	not susceptible	
Krum	dark grayish-brown clay or silty clay, friable, 8 to 15 inches thick	0-10	strong medium granular	strongly calcareous	Moderately sloping, concave slopes	4-8%	free	free	very susceptible	Lewisville
	grayish brown light clay, very crumbly and friable, 12 to 20 inches thick.	10-25	strong medium granular	strongly calcareous						
	brown silty clay of same consistancy and reaction as above horizon, 20 to 30 inches thick.	25-50	same as above horizon	same as above horizon						
	yellowish brown silty clay, scattered subrounded fragments of limestone and some concretions of $CaCO_3$, permeable, underlain at depths of 3 to 10 feet by marine limestone or marl.	50-70+		same as above horizon						
Lakeland	grayish brown loose fine sand containing some organic matter. 2 to 4 inches thick.	0-3	structureless	strongly acid	Nearly level to gently sloping upland	0-5% dominant	low to high	rapid		
	light yellowish brown loose fine sand, 10 to 40 inches thick.	3-36		strongly to very strongly acid.						
	brownish yellow loose fine sand, 18 inches to several feet thick.	36-60		strongly to very strongly acid						
	mottled yellow, brown and light gray friable fine sandly clay loam, several feet thick.	60+		strongly acid						
Lewisville	dark grayish-brown silty clay or clay, crumbly and friable, very hard when dry, 6 to 14 inches.	0-10	very strong medium granular	strongly calcareous	Nearly level to moderately sloping areas on stream terraces	1-10%	slow to rapid	moderate	none to very susceptible	Patrick Austin is the equivalent of the erosional upland
	brown clay or silty clay, very crumbly and friable, 10 to 20 inches thick	10-26	same as above	same as above		* Moderate volume change potential evident				
	light brown silty clay or clay, very friable, contains a few soft concretions of $CaCO_3$, 10-24 inches thick. This horizon may be missing in places.	26-42	moderate medium granular	slightly calcareous						
	light brown or light yellowish brown friable alluvial marl, continues to many feet or rests on gravel beds from 3 to 15 feet below the surface.	42-70+								

TABLE I SOILS CHARACTERISTICS OF DISTRICT 9

SOIL	DESCRIPTION AND REMARKS	DEPTH inches	STRUCTURE	ACIDITY	TOPOGRAPHY	% SLOPES	EXT. DRAINAGE	INT. DRAINAGE	EROSION	ASSOCIATED SOIL
Milam	dark grayish-brown light fine sandy loam, 3 to 6 inches thick.	0-3	very weak granular	slightly acid	Nearly level old terraces 25 to 100 feet above present floodplains		moderate to rapid	moderate to rapid	none to slightly susceptible	Travis Irving Bastrop
	yellow or very pale-brown light fine sandy loam, 8 to 12 inches thick.	3-13	very weak granular	strongly acid						
	red sandy clay loam, moderately permeable and friable. 20-30" thick.	18-42	massive	slightly to strongly acid						
	yellowish-red fine sandly loam high in clay.	42-66		strongly acid						
	reddish-yellow sandy loam stratified with some white sand and fine gravel.	66-80								
Miller	dark brown calcareous clay or silty clay, crumbly,sticky and plastic when wet	0-20	granular	calcareous	NEARLY level flood plains		very slow	very slow	not susceptible	Norwood Yahola
	reddish-brown clay or silty clay, crumbly and not impervious, underlain at greater depths by sands and silts, very sticky and plastic when wet.	20-60	fine blocky to massive	calcareous		* High volume change potential evident				
Navasota	very dark gray clay mottled with yellowish brown and grayish-brown, crumbly moist, very sticky and plastic when wet, extremely hard dry,	0-8	granular	medium acid	level to slightly concave areas in flood plains		very slow	very slow		Trinity Catalpa Kaufman
	gray clay mottled with yellowish-brown, very firm, extremely hard,	8-38	massive	acid pH6-4.5		* Moderate volume change potential evident				
	gray noncalcareous clayey alluvium, weakly stratified below about 45 inches with layers containing appreciable sand.	38-56+		mildly alkaline						
Nimrod	grayish brown fine sand	0-3	loose	slightly acid to neutral	Undulating to gently rolling upland	1-3% dominant	slow to moderate	slow to very slow		Windthorst Stephenville
	very pale brown fine sand	3-27	loose	'same'						
	mottled yellow and light gray, or yellow, light gray, and red sandy clay, very stiff and slowly permeable.	27-40	massive	moderately to slightly acid						
	noncalcareous sandy earths commonly containing less clay than above.	40+								
Norwood	reddish-brown silt loam, very friable, 9 to 25 inches thick.	0-18	weakly granular	strongly calcareous	Level to nearly level flood plain		slow	moderately rapid	not susceptible	Yahola Miller
	light reddish-brown silt loam, very friable, grades to stratified sandy and silty alluvium at depths of 5 to 8 feet below surface.	18-60	very weakly granular	strongly calcareous						

TABLE I SOILS CHARACTERISTICS DISTRICT 9

SOIL	DESCRIPTION AND REMARKS	DEPTH inches	STRUCTURE	ACIDITY	TOPOGRAPHY	% SLOPES	EXT. DRAINAGE	INT. DRAINAGE	EROSION	ASSOCIATED SOIL
Patrick	dark grayish brown light clay, crumbly and friable, 10 to 20 inches thick brown clay or silty clay, very crumbly and friable, hard when dry, contains few rounded particles of hard $CaCO_3$, 3-24 inches thick. porous bed of waterworn limestone gravel containing small amount of yellowish brown fine earth, weakly to strongly cemented with $CaCO_3$ in the top part.	0-14 14-30 30+	strong medium granular strong medium granular	calcareous strongly calcareous	Nearly level to gently sloping	½-4% nongravelly areas up to 10% in gravelly areas * Moderate volume change potential evident	slow to rapid	moderate to rapid	slight to moderate	Lewisville
Payne	grayish brown clay loam, friable, 5 to 10 inches thick. brown clay, very frim, very sticky and stiff, 8 to 16 inches thick. brown clay, firm 7-15" thick. same as above horizon but faintly mottled with yellowish-red and light brown. yellow friable clay containing scattered concretions of $CaCO_3$.	0-8 8-20 20-30 30-45 45-80+	weakly granular weak coarse granular weak blocky weak coarse blocky	neutral to strongly acid 'same' calcareous strongly calcareous 'same'	VERY gently sloping	½-2% * Moderate volume change potential evident	free but slow	slow	slight to moderate	Lewisville Irving
Ruston	pale brown sandy loam. light yellowish brown moist, yellow dry sandy loam. pale brown moist, yellow sandy loam. yellowish-red moist, reddish yellow dry, friable sandy clay loams. yellowish red moist, reddish yellow dry, friable sandy clay loams, slightly plastic wet. yellowish red moist, reddish yellow dry friable sandy clay loam grading to very friable sandy loams. reddish yellow moist, reddish yellow dry, very friable nearly loose sandy loam or loamy sand, several feet thick.	0-3 3-7 7-12 12-15 15-28 28-32 32+	structureless 'same' medium weak blocky 'same' loose	strongly acid 'same' 'same' 'same' 'same' 'same' 'same'	Level, gently rolling to hilly uplands	0-20%	rapid to slow	moderate		
San Saba	very dark gray clay, crumbly and friable; sticky and very plastic. very dark, gray, very firm, very sticky and plastic, has small subrounded particles of hard $CaCO_3$. Olive-gray clay, has small hard particles of $CaCO_3$. Hard limestone or partly weathered limestone interbedded with thin marly sames, or strongly calcareous clay interbedded with limestone.	0-18 18-40 40-54 54+	medium granular granular 'same'	calcareous strongly calcareous 'same'	Nearly level to gently sloping concave surface	0-2% * Moderate to high volume change potential	slow	very slow	none to slight	Crawford Tarrant Brackett

TABLE I SOILS CHARACTERISTICS OF DISTRICT 9

SOILS	DESCRIPTION AND REMARKS	DEPTH inches	STRUCTURE	ACIDITY	TOPOGRAPHY	% SLOPES	EXT. DRAINAGE	INT. DRAINAGE	EROSION	ASSOCIATED SOIL
Sawyer	grayish-brown light fine sandy loam, friable.	0-3	granular	neutral	Nearly level upland	0-2%	slow to moderate	slow	slight	Tabor
	very pale-brown light fine sandy loam containing a few fine pebbles.	3-15	massive	slightly acid						
	brownish-yellow sandy clay loam.	15-17		mod. acid						
	brownish-yellow sandy clay, heavey, mottled with reddish brown light gray, slowly permeable.	17-25		'same'						
	yellow plastic sandy clay mottled with light gray.	25-40	weak blocky	slightly acid						
	parent material of pale-yellow and light gray sticky sandy clay loam.	40-60+								
Stephen	Dark brown light silty clay containing a few fine fragments of chalk, firm, sticky (not very sticky), 8 to 20 inch thick.	0-14	medium granular	calcareous more than 5% $CaCO_3$	Undulating up to rolling erosional upland	up to 8%	moderate to slow in A horizon	bedrock is not impervious.		Austin, Brackett, Eddy, and Houston Black
	Rubble containing (a) some 5 parts of platy fragments of chalk several inch in diameter and (b) one part of light silty clay occupying interstices between fragments of chalk, 0 to 40 inches thick.	14-24				* Moderate to highly plastic volume change potential is low due to shallow profile of clay unit.				
	White thick-bedded marine chalk consisting of alternating softer and harder beds with a massive, harder bed at the top.	24-40								
Stephenville	dark brown fine sandy loam, very friable, 3 to 6 inches thick.	0-5	weak fine granular	slightly acid	Undulating to gently rolling upland	2-10%	moderate to rapid	moderate		Nimrod Windthorst
	light brown fine sandy loam, porous, very friable, 8 to 12 in	5-15	weak fine granular	slightly acid						
	yellowish red sandy clay loam, friable, plastic when wet, very hard dry, 8 to 15 inches thick.	15-25	weak medium blocky	slightly acid						
	yellowish red light sandy clay loam, more sandy than above horizon, very friable, hard dry, 10-14" thick.	25-36	massive to weak medium blocky	slightly acid						
	yellowish red weakly indurated sandstone banded or laminated with shades of red and yellow.	36-50+		slightly acid						
Sumpter	yellowish-brown calcareous heavy clay, crumbly.	0-3	medium granular	calcareous	moderate to steep	7-15%	very rapid	slow	very susceptible	Houston
	light yellowish-brown or olive-yellow calcareous heavy clay.	3-15	massive	calcareous						
	parent material of pale-olive and yellow raw shaly marl or highly calcareous clay, nearly impervious.	15-50		calcareous	* High to severe volume change potential					

TABLE I SOILS CHARACTERISTICS OF DISTRICT 9

Tabor	Grayish-brown fine sandy loam, friable when moist, 4 to 7 inches thick. very pale brown fine sandy loam, hard, friable, many fine pores, 3-8" thick. brownish-yellow dense sandy clay, few to common fine distinct mottles of grayish-brown and yellowish-red, continuous clay films, few fine pores, very sticky and very plastic, 8-20" thick. mottled brownish yellow and light gray heavy sandy clay with spots of red, extremely hard, very sticky and plastic, 10 to 18 inches thick. compact mottled yellow and gray sandy clay.	0-5 5-12 12-25 25-39 39-60+	weak granular structureless moderate coarse blocky prismatic to medium blocky massive or weakly bedded	medium to slightly acid 'same' strongly acid medium to strongly acid medium acid	Nearly level to gently undulating upland	1-3%	slow to moderately rapid	very slow		Sawyer Axtell Edge Crockett Lakeland
Tarrant	very dark grayish brown clay, very crumbly and friable, has numerous fragments of limestone, 3-8" thick. Broken or partly weathered limestone with small amount of brown clay and chalky marls in crevices, 2-6" thick. Limestone bedrock	0-5 5-12 12+	strong fine or medium granular	strongly calcareous	Undulating to rolling upland	1-20%	free to rapid	free to rapid	slight to rapid	Denton, shallow San Saba, shallow Crawford Brackett
Travis	Brown fine sandy loam, very friable, 3 to 5 inches thick. light brown fine sandy loam, with some fine gravel, very friable, 8 to 15 inches thick. red sandy clay with some fine siliceous gravel, very firm, sticky and stiff, 18 to 35 inches thick. reddish thinly stratified loamy fine sandy, clay loam and sandy clay. bed of waterworn fine gravel, largely of chert, mixed with 30-50% clay.	0-3 3-15 15-40 40-54 54+	weakly granular structureless weakly blocky	neutral to slightly acid slightly acid medium to slightly acid weakly alkaline med. acid	Nearly level to moderately sloping convex surfaces in uplands underlain by old alluvium	1-6%	moderate to rapid	slow	slight to moderate	Milam Axtell
Trinity	dark-gray heavy clay, very plastic and sticky when wet, slowly permeable, grades to olive-gray clay at depths of 5 to 12 feet below surface.	0-50+	weakly blocky	calcareous	LEVEL flood plains * Moderately to highly plastic, moderate volume change potential		very slow	very slow	none	Kaufman Catalpa washed from Houston Black, Houston, Bell
Wilson	gray to dark-gray noncalcareous clay loam, very hard dry, 5-12" thick. dark-gray noncalcareous compact heavy clay, extremely hard and tough dry, claypan, 12 to 26 inches thick. gray calcareous tough clay. light brownish gray calcareous tough clay. parent material of yellow and light gray calcareous compact clay or sandy clay.	0-10 10-35 35-50 50-70 70-100+	weakly granular coarse blocky massive massive massive or shaly	slightly acid medium acid to neutral calcareous calcareous calcareous	Nearly level to gently undulating upland	0-4% * Moderately to highly plastic causing poor pavement performance. In late summer and during droughts shrinkage cracks up to 3" wide and many feet deep occur in this highly expansive soil. Moderate to high volume change potential.	slow to moderate	very slow	none to moderate	Crockett Irving

TABLE I SOILS CHARACTERISTICS OF DISTRICT 9

SOILS	DESCRIPTION AND REMARKS	DEPTH inches	STRUCTURE	ACIDITY	TOPOGRAPHY	% SLOPES	EXT. DRAINAGE	INT. DRAINAGE	EROSION	ASSOCIATED SOIL
Wind-thorst	dark grayish brown fine sandy loam, very friable, 2 to 6 inches thick.	0-4	weakly granular	slightly acid	Gently to moderately sloping upland	1-8%	free	slow	very susceptible to sheet erosion	Stehpenville Nimrod
	light yellowish brown fine sandy loam, very friable, 6 to 10 inches thick.	4-10	'same'	slightly acid to neutral						
	red heavy sandy clay, very firm, very sticky and stiff, 3 to 10 inches thick.	10-18	fine blocky	'same'						
	mottled red heavy sandy clay, very firm, extremely hard, 15 to 20 inches thick.	18-34	coarse blocky	'same'						
	parent material of very firm stratified sandy clay of various colors, with thin strata of weakly indurated reddish-yellow sandstone.	38+	stratified	'same'						
Yahola	reddish-brown light very fine sandy loam, 6 to 30 inches thick.	0-20	granular to massive	noncalcareous but not acid	Level to gently undulating flood plains		medium	rapid to very rapid	none	Miller Norwood
	light reddish-brown very fine sandy loam stratified with fine sand.	20-50	stratified							

REPRESENTATIVE

MEASURED SECTIONS

PART V

Midway between Iredell and Walnut Springs on Farm Road 927, Bosque County:

Paluxy Sand Formation:
Cross-bedded and laminated sands. The cross beds of this outcrop dip NNE at 14 degrees and contrast sharply with almost flat-lying beds in the area . . . . 40'

General Section of the Walnut form various outcrops in Bell County:

Comanche Peak:
Compressed nodular light grayish limestone.

Walnut:
Rounded-oval nodules of soft marly limestone in matrix of dark gray limy marl; abundant fossils . . . . 15'
Gray marl weathering whitish and yellowish, with thin marly limestone flags; abundant fossils . . . . 25'
Shell agglomerate, cemented . . . . 5'
Marl with thin limestone seams . . . . 25'
Prominent limestone seam . . . . 1'
Marl with thin limestone seams, about . . . . 70'
Several thin limy seams with thin marl interbedding . . . 25'

Glen Rose Limestone:[2]

One mile north of Crawford on State Highway 317, McLennan County:

Duck Creek:
Gray, hard, microgranular, fossiliferous, medium-bedded nodular limestone. Exposed . . . . 0-4'

Kiamichi:
Interbedded blue-gray, calcareous shale, brown shale, and light gray nodular limestone; section not measured in detail . . . . 6.3'

Edwards:

White, moderately hard, massive, medium to coarse-grained clastic limestone grading upward into biostromal limestone, limonite concretions and stalactites occur in the lower half of the unit . . . . 7.5'

White to light buff, soft, thickly bedded, fine to coarse-grained clastic limestone containing limonite concretions near the top of the unit; the prominent projecting ledge in the outcrop along Bluff Creek is formed by this unit . . . . 10'

Gray, moderately hard, massive, microgranular to medium-grained, clastic limestone . . . . 6.3'

Gray, soft, shaly, microgranular limestone grading into unit above . . . . 1.5'

Light gray, hard, massive, biostromal limestone . . . . 8.7'

Comanche Peak:

Light gray, moderately hard, very thickly bedded, microgranular, argillaceous, nodular limestone . . . . 12.7'

Similar to unit above . . . . 3.3'

Similar to unit above. Exposed. . . . . 8'

Bluff along ranch road descending into the Lampasas River Valley, 2.1 airline miles due west of U.S. Highway 81, Bell County:

Edwards Formation:

Buff, hard, medium-bedded, microgranular dolomitic limestone. Exposed.. . . . . 3'

Light buff and gray-mottled, hard, massive, microgranular dolomitic limestone . . . . 3'

Gray and buff-mottled, moderately hard, massive, microgranular dolomitic limestone . . . . 4.5'

Gray-brown, soft, finely porous, massive, microcrystalline dolomite containing lenses of hard, gray, microcrystalline limestone; toward the west end of the outcrop, this unit becomes honeycombed to a considerable extent . . . . . 7.5'

Light gray, hard massive, microcrystalline limestone mottled with soft, finely porous dolomite grading upward into similar dolomite. This unit is marked at the top by a nodular chert band and pinches out or grades laterally into the top of the unit below . . 0-4'

Very light gray, hard, massive, biostromal limestone grading upward into light gray, hard, massive, pitted, microcrystalline limestone; this unit and the one below form one massive bed 12 feet thick . . . . 8'

Light brown, moderately hard, massive, finely porous, microcrystalline dolomite gradational into the units above and below . . . . 4'

Comanche Peak:

Gray, moderately hard, massive, microgranular, nodular dolomite; toward the west end of the outcrop, this unit exhibits a sharp contact with the unit above but laterally, toward the east, the nodular character becomes less prominent and the contact becomes obscure. At this point the unit below forms the base of the overhanging cliff. . . . . 3'

Lithologically similar to the unit above at the west end of the outcrop. Exposed. . . . . 3'

North side of bridge over Nolan River, .25 miles north of Blum, Hill County:

Comanche Series
Washita Group
Georgetown Formation

Duck Creek Member:

Limestone, thin bedded . . . . 5'

Limestone, very resistant, massive, shell fragments abundant near the bottom . . . . 11"

Fredericksburg Group

Kiamichi Formation:

Covered; buff-colored shale exposed in a few places and at the top . . . . 5'10"

Shale; buff, poorly exposed . . . . 3'9"

Limestone; resistant, shell fragments abundant, violet on fresh fracture . . . . 3"

Shale; calcareous, buff . . . . 1'2"

Limestone; with interbedded shale, thin shale near the top contains abundant shell debris . . . . 3'7"

Limestone; with shaly partings . . . . 1'3"

Shale; calcareous, buff . . . . 1'4"
Shale; tan, thin limestone bed at top and bottom . . . . 10"
Shale; calcareous, receding . . . . 5"
Limestone; resistant, shell fragments abundant in upper half . . . . 5"
Shale, calcareous, gray . . . . 10"
Limestone; resistant . . . . 3"
Shale; silty, gray and buff . . . . 1'2"
Limestone; resistant, gray when fresh . . . . 3"
Shale; calcareous, gray and buff . . . . 1'3"
Limestone; resistant . . . . 6"
Shale; calcareous, rust and gray . . . . 9"
Limestone; violet on fresh fracture, coquinoid, fossiliferous . . . . 4"
Shale; silty, calcareous, buff, fossiliferous . . . . . 1'3"

Edwards Formation:
Limestone; resistant, massive, gray, iron oxide-stained fucoids or burrows about 1/4 inch in diameter are present at the top . . . . 5'

Approximately 9.4 miles southeast of Valley Mills on Highway 6, turn left approximately 1 mile to Bosque River, McLennan County:

Georgetown Formation:
Weno Member:
Limestone interbedded with shale; limestone is more predominant in upper 20 feet. Limestone is soft to hard, light gray weathering to light cream. It contains pyrite nodules, calcite replacement. Contains numerous filled cavities. The shale is slightly fissile, dark gray weathering to light gray. More predominant in the lower 20 feet. Irregularly bedded conforming to bedding planes of the limestone. It contains fucoids, fossils and calcite crystals of a larger size than in the limestone; pyrite nodules are common . . . . 41'

Denton Member:
Shale dark gray weathering to light gray, soft, marly, non-fissile, non-fossiliferous at top becoming very fossiliferous. Two limestone ledges, very fossiliferous also . . . . 4'

Fort Worth Member:
Limestones and interbedded shales forming less resistant receding zones and resistant ledges. The limestones are fossiliferous and have limonite stains. The shales are thin and marly . . . . 33.5'

Duck Creek Member:
Interbedded limestones and shales. Limestones are resistant to fragmental, nodular bedded, and contain iron stains. Interbedded shales are slightly fissile and marly . 22.5'

Kiamichi Formation:(6)
Shale, dark gray with interfingering limestone lenses; arenaceous, marly, medium grained, weathering light gray to tan. Limestones, soft, argillaceous, coarsely crystalline, containing finely, macerated shell fragments . . . . 4'

State Highway 317, 4 miles south of Moody, or 1.5 miles south of the McLennan County Line in Bell County:

Lake Waco (Lower Eagle Ford)
Cloice Member:
Shale, yellowish-weathered, calcareous, with thin limestone strata, poorly exposed on grassy slope . . . . . 30+'

Bluebonnet Member:
Limestones, ledge-forming, thin-bedded from 0.1 to 1.0 foot thick, with thin bentonite seams interbedded in yellow calcareous shale. Fossils common in the limestone . . . . 11.6'

Pepper Formation:
Shale, purplish-black, weathered, partially exposed beneath the overlying flaggy limestone. Jarosite and selenite common . . . . 36'

Buda Formation:
Limestone, fossiliferous, white, hard, massive, ferruginous stained. Exposed in the Highway shoulder and as blocks in the nearby stock tank excavation . . . . 1'

Del Rio Formation:
Clay, gray, fossiliferous, typical of Del Rio in Bell and McLennan Counties . . . . 5+'

Alligator Creek, 5.5 miles WNW of West, Hill County:

Eagle Ford (Group) Formation:
Limestone, grayish-brown, thin and wavy-bedded with interbedded gray calcareous shale. Oyster fragments abundant . . . . 2+'

Woodbine (Group) Formation:
Sandstone, oil saturated, thin, friable, with abundant fossil molds (cavities) interbedded with blue-gray sandy jarositic shale immediately below the contact; below this section are large concretionary sandstones several feet thick, fucoidal in part, interbedded in friable sandstone and sandy shale . . . . 10'
Interbedded friable and platy white to gray thin sandstones and gray sandy shale (partly concealed) . . . . 17'
Black Pepper-type shale with a few thin sandstone beds; small pyritic fossils . . . . 28.5'
Black Pepper-type shale with ferruginous nodule layers and thin friable white sandstones at the top and bottom . . . . 13.5'
Black Pepper-type shale similar to the unit (28.5') thick above . . . . 16'
Black Pepper-type shale with common ferruginous nodules and thin fossiliferous sandstones at the base . . . . 17'

Del Rio Formation:
Gray, plastic, calcareous shale with chalky and argillaceous nodular limestone. Containing fossils . . . . 7+'

In tributary of Aquilla Creek about 1,000 yards north of county road, about 21 miles south of Hillsboro, and about 11 miles north of Waco, McLennan County:

Eagle Ford (Group) Formation:
Cloice Member (Lake Waco Formation):(6)
covered . . . . 2.3'
Limestone, gray, very thinly laminated, very finely crystalline, argillaceous, weathers tan . . . . 0.2'
Shale, gray to tan, fissile, laminated, calcareous, weathers buff to light gray . . . . 3.0'
Limestone, gray, very thinly laminated, very finely crystalline, argillaceous, some fossil fragments, weathers tan . . . . 0.2'
Shale, gray to tan, fissile, laminated, calcareous, weathers buff to light gray . . . . 3.7'

Bluebonnet Member (Lake Waco Formation):
Calcilutite, yellow, argillaceous, weathers light-tan to reddish-brown . . . . 0.7'

Bentonite, yellow to white, fractured . . . . 0.2'
Shale, gray to tan, fissile, laminated, calcareous, jointed near top, weathers tan to gray . . . . 3.6'
Limestone, tan, thinly laminated, finely crystalline, porous, fossils at base, weathers light tan . . . . 0.2'
Shale, light gray, thinly laminated, calcareous, thin bed of pseudo-aragonite near middle, weathers light gray . . . . 1.0'
Limestone, light gray, thinly laminated, distorted laminae, porous, weathers brownish-gray . . . . 0.2'
Shale, tan to gray, fissile, thinly laminated, calcareous, thin bent-weathering to whitish gray, fissile on weathering . . . . 15'
Marl, more calcareous than unit above, some masses of crystalline gypsum on weathered surface; poorly defined lamination, semi-massive zone, black-brown on fresh exposure, weathering to brownish-gray, some fissility on weathering . . . . 7.9'
Bentonite seam, weathering orange, abundant micro-fissils . . . . 0.1'
Marl, more calcareous than unit above, blackish-brown on fresh exposure, irregular lamination, more massive than unit above weathers to whitish-gray, some fissility on weathering . . . . 4.5'

2-1/3 miles southeast of Perry, McLennan County, just east of Highway 6 by approximately 3/4 mile:

Taylor (Group) Formation:(6)
Pecan Gap Member:
Chalk, calcareous, resistant, gray on fresh exposure, weathers white, somewhat nodular, fossiliferous. Lower portion is more calcareous, more massive, and more fossiliferous. Glauconite present at base . . 5.4'

Wolfe City Member:
Marl, high clay content, silty, much less resistant than chalk unit above, brownish on fresh exposure, weathers yellow . . . . 1.4'

1½ miles (air line) upstream on the Brazos River from the Milam-Falls County Line, west side of river, Falls County:

Midway Group
Kincaid Formation:(33)

Harsh sandy clay showing jointing but very little trace of lamination, dull blue gray when fresh, weathering yellowish brown, abundantly fossiliferous . . . . . . 6.5'

Very dense blue clay, deeper in color and not so sandy as unit above, breaking with a conchoidal fracture and sparsely fossiliferous . . . . 3.5'

Thinly laminated yellowish brown sand with an inconstant layer of partially indurated marl with sandy fossiliferous stringers about it; marl often as thick or thicker than the sand bed . . . . 1.5'

Upper Cretaceous:

Dense dark blue-gray shale breaking with a conchoidal fracture, fossiliferous throughout, and, directly below the top, abundantly so, some fossils present, a 2 inch gypsum seam about midway from the base to the contact with the upper beds . . . . 10'

Northwest side of Tehuacana Hill, just west of Tehuacana of the Tehuacana-Waco Road, Limestone County:

Midway Group
Kincaid Formation:
Tehuacana Member:(67)

Limestone, grayish-white, in places stained yellow and in other spots brown by water saturated by ferruginous matter. The rock is composed of a great mass of small and highly fragmental shell material cemented by calcite to form a coquina . . . . 20'

Sand, greenish-yellow, fine grained, not well exposed . 20'

Limestone, light yellowish-gray, fossiliferous, the lower ledge is fossiliferous . . . . 10'

Pisgah Member:

Sand, grayish-yellow, glauconitic, medium grained, fossiliferous, contains large spherical concretions and in places, lenticular ledges of consolidated sand . . . . 28'

Clay, blue-gray to black, weathering yellowish-gray, very silty, in places sandy and fossiliferous, especially rich in microscopic fossils . . . . 30'

Clay, bluish-gray to black, weathering yellow, contains less silt than overlying strata and breaks with conchoidal fracture. Contains seams and numerous nodules of white, soft, amorphous gypsum. Many fragments of fossils . . . . 25'

Clay, bluish-gray, very soft, in some layers very thinly laminated, in others massively bedded, very fossiliferous . . . . 25'

Littig Member:

Sand, yellowish-gray, very fine, glauconitic in places, contains a few pebbles and black phosphatic nodules . 0.7'

A series of isolated outcrops in sequence along the Mexia-Teague Road from the Limestone-Freestone County Line back to the clay pit in Mexia. Each thickness, expressed below, is from one outcrop beginning with the uppermost just east of the county line:

Wilcox Group

Sequin Formation:

Sand, gray, medim grained, containing thin seams of limonite . . . . 25'

Midway Group

Wills Point Formation:(61)

Sand, light grayish-yellow, silty, thinly and uniformly bedded, soft, micaceous, breaks readily along bedding planes to form small, thin, smooth plates of sand. Exposed in a ditch near the town of Cotton Gin. . . . 18'

Silt or silty clay, grayish black, weathering to yellowish gray, poorly laminated,containing large, rounded, rough-surfaces concretions, and a few poorly preserved fossils. The silty clay grades upward into fine and more evenly bedded sand. Exposed along creek near New Hope near eastern line of Limestone County . . . . 15'

Clay, light gray, stiff, breaks with an uneven and conchoidal fracture, poorly bedded. Partings along the bedding planes shown thin streaks of fine micaceous silt. The silt runs through the clay in uneven wavy bedding lines. Clay weathers to form light sandy soil. Exposed in ditch 1½ miles east of Mexia . . . . 15'

Clay, dark bluish-gray, compact, breaks with conchoidal fracture and contains numerous small egg-shaped limonitic concretions and a layer of rock about a foot thick made up of large number of aragonite crystals. Exposed in ditch on Mexia-Wortham Road . . ?

Clay, dark bluish-gray, breaks with conchoidal fracture and contains poorly preserved shells and shell fragments and a few hard oval-shaped concretions from 8 to 11 inches in thickness. The concretions are greenish-yellow, extremely hard, and break with conchoidal fracture. The fresh broken surfaces shown fine dendritic patches of black manganese. Thickness in Mexia clay pit . . . . 25'

GLOSSARY

ACID SOIL: A soil that gives an acid reaction (precisely, below pH 7.0, practically, below pH 6.6).

ALLUVIAL SOILS: Soils developed from relatively recently deposited materials, transported by flowing water. A great soil group which is composed of azonal soils developed from transported and recently deposited alluvium characterized by a weak modification of the original soil-forming process.

ARAGONITE: A mineral with the same chemical composition as calcite, $CaCO_3$.

ARCH: An anticline. Term applied to strata which dip in opposite directions from a common ridge or axis, like the roof of a house.

ARGILLACEOUS: Applied to all rocks or substances composed of clay, or having a notable proportion of clay in their composition, as roofing slate, shale, etc.

AZONAL SOILS: Soils without well-developed profile characteristics. Many soils on recent alluvial and colluvial deposits are azonal.

BEDDED: Applied to rocks resulting from consolidated sediments, and accordingly, exhibiting planes of separation designated as bedding planes.

CALCAREOUS: An adjective applied to rocks containing calcium carbonate or the carbonate of calcium with less than 5% magnesium. A general term applicable to several grades and types.

CALCITE: A mineral, calcium carbonate, $CaCO_3$.

CALICHE: Gravel, sand, or desert debris cemented by porous calcium carbonate; also the calcium carbonate itself.

CHERT: In minerology a compact, siliceous rock formed of chalcedonic or opaline silica, one or both, and of organic or precipitated origin. Chert occurs distributed in limestone, affording cherty limestone. Flint is a variety of chert.

CELESTITE: A mineral, S_rSO_4.

CLAYPAN: A compact soil horizon or layer rich in clay and separated more or less abruptly from the overlying horizon; hard when dry and plastic or stiff when wet.

CONCRETION: A nodular or irregular concentration of certain constituents of sedimentary rocks and tuffs; developed by the localized deposition of material from solution, generally about a central nucleus, and harder than the surrounding rock.

CRYSTALLINE: Of, or pertaining to, the nature of a crystal, having regular molecular structure.

CROSS BEDDING: The arrangement of laminations of strata transverse or oblique to the main planes of stratification of the strata concerned; inclined, often lenticular beds between the main bedding planes; found only in granular substances.

DOLOMITE: A term applied to those rocks that approximate the mineral dolomite in composition ($CaMg(CO_3)_2$).

EPICONTINENTAL: Situated upon a continental plateau of platform, as an epicontinental sea.

ESCARPMENT: The steep face of a ridge of high land. In gently inclined strata, the abruptly truncated and cliff-like outcrops of the hard beds are called escarpments.

FAULT: A fracture or fracture zone along which there has been displacement of the two sides relative to one another parallel to the fracture. The displacement may be a few inches or many miles.

FERRUGINOUS: Descriptive of rocks of red color but not necessarily abnormal iron content. Containing iron.

FISSILE: Splitting into thin more or less paper sheets.

FORMATION: Any assemblage of rocks which have some character in common, whether of irigin, age, or composition. The ordinary unit of geologic mapping consisting of a large and persistent stratum of some one kind of rock.

FRIABLE: Easily crumbled as would be the case with rocks that are poorly cemented.

GLAUCONITIC: Containing glauconite which is a green mineral, closely related to the micas and essentially a hydrous potassium iron silicate. Commonly occurs in sedimentary rocks of marine origin. Also used as a name for a rock with a high glauconite content.

GRABEN: Depression produced by subsidence of a strip between normal faults. A block, generally long compared to its width, that has been downthrown along faults relative to the rocks on either side.

GROUP: A local or provincial subdivision of a series, based on lithologic features. It is usually less than a standard series and contains two or more formations.

GYPSUM: A mineral $CaSO_4 \cdot 2H_2O$. A common mineral of evaporites.

HETEROGENEOUS: Differing in kind; having unlike qualities; possessed of different characteristics; opposed to homogenous.

HOMOGENEOUS: Of the same kind or nature, consisting of similar parts or elements of a like nature, opposed to heterogeneous.

HORIZON, SOIL: A layer of soil approximately parallel to the land surface with characteristics produced by soil-forming processes.

A_o HORIZON: The A_o horizon is not strictly a part of the A horizon or of the solum; it consists of a layer of partly decomposed or matted plant remains.

A HORIZON: The upper major horizon consisting of one or more surface mineral horizons with maximum organic accumulations; or horizons that have lost clay minerals; or some combination of these conditions. The principal subhorizons are designated as A_1, A_2, A_3.

B HORIZON: A major horizon characterized by an accumulation of clay and oxides of iron or aluminum; or more or less blocky, columnar, or prismatic structure, together with development of stronger red or yellow colors; or some combination of these characteristics. The principal subhorizons are designated as B_1, B_2, B_3.

C HORIZON: The relatively unconsolidated parent material.

D HORIZON: A stratum underlying the C, or the B if the C is not present which is unlike the material from which the soil was formed, or the C horizon.

INDURATED: Rocks that have been hardened not only by heat but also by pressure and cementation.

INTERZONAL SOILS: Any group of soils with well-developed soil characteristics that reflect the dominating influence of some local factor or relief, parent material, or age over normal effect of the climate and vegetation. Often a condition of poor drainage is responsible.

JAROSITE: A mineral, $KFe_3(SO_4)_2(OH)_6$.

JASPER: Red, brown, green, impure slightly translucent cryptocrystalline, quartz with a dull facture. (Cryptocrystalline: Crystalline, but so fine grained that the individual components cannot be seen with a magnifying lens).

LAG GRAVEL: Residual accumulations of coarser particles from which the finer material has been blown away.

LAMINA: Unit layer or sheet of a sediment in which the stratification planes are one centimeter or less apart. Lamina need not be parallel to the bedding.

LENTIL: A lens. A lentil has slight geographic extent. The essential feature of a lentil is that it thins out, presumably in all directions.

LIGNITE: A brownish-black coal in which the lateration of vegetal material has proceeded further than in peat but not as far as sub-bituminous coal.

LIMESTONE: A bedded sedimentary deposit consisting chiefly of calcium carbonate ($CaCO_3$) which yields lime when burned. Limestone is the most important and widely distributed of the carbonate rocks and is the consolidated equivalent of limy mud, calcareous sand, or shell fragments.

LITHOSOLS: Azonal soils having no clearly expressed soil morphology and consisting of a freshly and imperfectly weathered mass of rock fragments; largely confined to steep sloping land.

LITHOLOGY: The physical character of a rock, generally as determined megascopically or with the aid of a low-power magnifier.

LOAM: A soil composed of a mixture of clay, silt, sand, and organic matter. A soil that has roughly equal percentages of sand and silt and a small amount of clay.

MARCASITE: White iron pyrites. A mineral, FeS_2.

MARL: A soft water-deposited material consisting chiefly of calcium carbonate, but containing some sand, clay, organic matter, and other impurities.

MEMBER: A division of a formation, generally of distinct lithologic character or of only local significance.

NODULAR: Having the shape or composition of nodules. A nodule is the general term for a rounded sedimentary body, which can be separated in a discrete mass from the formation in which it occurs.

OUTLIER: Those detached portions of strata which stand out from the main body, and appear to have been separated by the denuding force of water;and resembling those heaps or portions of a bed of earth left by excavators to indicate what has been removed.

PEDOLOGY: The science dealing with the soil as a natural body.

PERMEABILITY: The capacity of a rock to transmit fluid. Degree of permeability depends on the size and shape of the pores, the size and shape of their interconnections and the extent of the latter.

PHYSIOGRAPHY: Physiography has to do primarily with the surface of the lithosphere and with the relations of air and water to it. Used by American writers as synonymous with physical geography.

PLASTIC: Capable of being molded without rupture.

PYRITE: Fool's gold. A mineral FeS_2. Brass yellow in color.

QUARTZ: A mineral, SiO_2.

RELIEF: The elevations or the inequalities, collectively, of a land surface. The difference in elevation between the high and low points of a land surface.

SANDSTONE: A cemented or otherwise compacted transported sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

SANDSTONE DIKE: Tabular shaped bodies composed of sandstone ranging in thickness from a fraction of an inch to several inches, and in length up to several miles, which cut across structure and bedding of the enclosed rock.

SERIES: A term applied to a number of related rocks or minerals arranged, or capable of arrangement, in a natural sequence of succession, composition, or other property. The term is applied to the main subdivisions of systems.

SHALE: A laminated sediment, in which the constituent particles are predominantly of the clay grade.

SIDERITE: A mineral, $FeCO_3$, commonly containing also Mg and Mn.

SILICEOUS: Of, or pertaining to silica, containing silica, or partaking of its nature.

SILTSTONE: A very fine grained clastic (derived from pre-existing rocks) rock composed predominantly of particles of silt grade.

SLOPE, SOIL: Refers to the incline of the surface of the soil area. Slopes may be defined as single or complex. Slope names and the ranges in slope percent as defined in the Soil Survey Manual are as follows:

SLOPE RANGE %	SLOPE NAME	SLOPE TYPE
0-3	level	single or complex
1-8	gently sloping	single
1-8	undulating	complex
5-16	sloping	single
5-16	rolling	complex
10-30	moderately steep	single
10-30	hilly	complex
20-65	steep	single or complex
45-65	very steep	single or complex

SOLUM: That part of the soil profile, above the parent material, in which the processes of soil formation are taking place. In mature soils, this includes the A and B horizons and the character of the material may be greatly unlike that of the parent material.

SPARRY: Resemblying, consisting of, or abounding in spar; spathic. Spar is any transparent or translucent, radily celavable, crystalline mineral having a vitreous (luster of broken glass) luster.

STRATIFIED: Formed or lying in beds, layers, or strata.

STRUCTURE, SOIL: The aggregation of soil particles into clusters of particles, which are separated from adjoining aggregates by surfaces of weakness. The principal types of soil structure are:

BLOCKY: The soil aggregates have a blocky shape, irregularly six-faced, and with the three dimensions nearly equal. The size of these aggregates ranges from a fraction of an inch to 3 or 4 inches.

CRUMB: Small, soft, porous aggregates irregular in shape and rarely larger than 1/3 inch in size.

GRANULAR: Same as Crumb except that the aggregates are relatively nonporous.

MASSIVE: Large uniform masses of cohesive soil, structureless.

PRISMATIC: Elongated column structure with level and clean-cut tops. If tops are rounded, the structure is identified as columnar. Found in B Horizon when present.

TERRACE: A plain of limited extent which has a descending face on one side and a face ascending to the adjacent land on the other side. The term terrace should be used with modifying terms that denote its method of origin, such as alluvial, fluvio-glacial, or deltaic. Other modifying terms identify its character, such as sand, gravel, and bedrock.

ZONAL SOILS: Soils having well-developed characteristics that reflect strong influence of climate and living organisms, mainly vegetation in their formation.

BIBLIOGRAPHY

1. Adkins, W. S., 1923, Geology and Mineral Resources of McLennan County, Univ. Texas Bur. Econ. Geology Bull. 2304, 202 pp., 4 pls.

2. Adkins, W. S., and Arick, W. B., 1930, Geology of Bell County, Texas, Univ. Texas Bur. Econ. Geology Bull. 306, 92 pp., geologic map in color.

3. Atlee, W. A., 1962, The Lower Cretaceous Paluxy Sand in Central Texas, Baylor Geol. Studies Bull. No. 2, 25 pp., 13 figs.

Barnes and Baird, See No. 81 and 83.

4. Bates, Neal, See Baylor Geol. Society, 1958.

5. Baylor Geological Society, 1958, Guide to the MidCretaceous Geology of Central Texas, 19 pls.

6. ------, 1960, Cretaceous Stratigraphy of the Grand and Black Prairies East-Central Texas, 138 pp., 16 pls.

7. ------, 1961, Popular Geology of Central Texas, Bosque County, Vol. 5, 47 pp., 10 pls.

8. ------, 1963, The Hill Country, Popular Geology, Vol. 8, 45 pp., 2 pls.

9. Beall, Arthur, See Baylor Geol. Society, 1960.

10. ------, 1964, Stratigraphy of the Taylor Formation (Upper Cretaceous) East-Central Texas, Baylor Geological Studies, Bull. No. 6.

11. Beck, M. W., (no date), Soil Survey of Falls County, Texas, U. S. Dept. of Agr., Series 1932, No. 7, 40 pp., soil map in color.

12. Blank, H. R., and Stoltenberg, N. L., and Emmerich, H. H., 1952, Geology of the Blacklands Experimental Watershed Near Waco, Texas, Univ. Texas Bur. Econ. Geology, Rept. Inv. No. 12, 46 pp., 1 fig., 4 pls., geologic map.

13. Booth, C. C., 1956, Geology of Chalk Mountain Quadrangle Bosque, Erath, Hamilton and Somervell Counties, Texas, Map 1:47,823, Unpublished Thesis, Univ. Texas.

14. Broman, R. L., 1950, Geology of the Brazos River Terraces in McLennan County Texas, Unpublished Masters Thesis, Univ. Texas, 41 pp., 5 figs., 14 pls.

15. Brown, J. B., 1963, The Role of Geology in a Unified Conservation Program, Flat Top Ranch, Bosque County, Texas, Baylor Geol. Studies, Bull. No. 5, 27 pp., 3 figs., 4 pls., 2 tables.

16. Burket, J. M., Jr., 1961, The Geology of the City of Waco and its Environs, Map 1:24,000, Unpublished Masters Thesis, Baylor Univ.

17. Bushnell, T. M.; Hawker, H. W.; and Pratapas, D. B., 1923, Soil Survey of Erath County, Texas U. S. Dept. of Agr., Bur. of Soils in cooperation with the Texas Agr. Expt. Sta., 37 pp., 1 fig., 6 tables, soil map in color.

18. Bryan, Frank, 1933, Recent Movements on a Fault of the Balconies System, McLennan County, Texas, Am. Association Petrol. Geol. Bull., Vol. 17, No. 4, pp. 439-442.

19. Carter, W. T., 1931, The Soils of Texas, Texas Agr. Expt. Sta. Bull. No. 431, 192 pp., soils map in color.

20. ------, 1938, The Soils of Texas, Texas Agr. Expt. Sta., 19 pp.

21. Carter, W. T.; Lewis, H.G.; and Hawker, H. W., 1918, Soil Survey of Bell County, Texas, U. S. Dept. Agr. Bur. Soils, 46 pp., soil map in color.

22. Colligan, Jack, 1951, Geology of Belton Reservoir Area Leon River, Bell County, Texas, Fondren Science Series No. 4, Southern Methodist Univ. Press, pp. 29-44, 21 pls.

23. Cronin, J. G.; Follett, C. R.; Shafer, G. H.; and Rettman, P. L., 1963, Reconnaissance Investigation of the Ground-Water Resources of the Brazos River Basin, Texas, Texas Water Commission, Bull. 6310, 152 pp., 24 figs., 20 tables, 11 pls. Note: Darton, N. H., See 82.

24. Davis, Asa, See Baylor Geol. Society, 1958.

25. Desha, G. K., 1961, Generalized Soil Map of McLennan County, Texas, Dept. of Agr., Soil Conservation Service and Texas Agr. Expt. Sta.

26. Deussen, Alexander, 1914, Geology and Underground Waters of the Southeastern Part of the Texas Coastal Plain, U. S. Geol. Survey Water-Supply Paper 335, 365 pp., 17 figs., 9 pls.

27. ------, 1924, Geology of the Coastal Plain of Texas West of the Brazos River, U. S. Geol. Survey, Prof. Paper No. 126, 145 pp., 38 figs., 36 pls.

28. Fisher, W. L., 1961, Stratigraphic Names in the Midway and Wilcox Groups of the Coastal Plain, Univ. Texas Bur. Econ. Geology, Rept. Inv. No. 44, 33 pp., 1 fig., 1 chart, Reprinted from the trans. of the Gulf Coast Association of Geological Societies, 1961, Vol. XI, pp. 263-295.

29. Flawn, P. T.; Goldstein, August, Jr.; King, P. B.; and Weaver, C. C., 1961, The Ouachita System, Univ. Texas, Bur. Econ. Geology, Publication 6120, 401 pp., 13 figs., 15 pls., 2 geologic maps in color.

30. Fox, W. J., and Hopkins, O. N., Jr., See Baylor Geol. Society, 1960.

31. Fox, J. W., 1962, Geology of the Crawford and Speegleville Quadrangles, McLennan County, Texas, Map 1:24,000, Masters Thesis, Unpublished, Baylor Univ.

32. Frost, J. G., See Baylor Geol. Society, 1961.

33. Gardner, Julia, 1933, The Midway Group of Texas, Univ. Texas Bur. Econ. Geology Bulletin No. 3301, 403 pp., 4 figs., 28 pls.

34. Grubbs, D. M., 1936, The Edwards Limestone of Bell County, Texas and Surrounding Territory, Univ. of Okla. Bull. 681, new ser. absts. of Thesis Issue, pp. 105-106.

35. Hatch, Jessee, 1936, Report on a River Terrace Investigation as a part of a Mineral Resource Survey in Falls County, Texas, Univ. Texas Bur. Econ. Geology Min. Res. Sur. Circ. 6, 3 pp.

36. Hayward, O. T., 1957, The Structural Significance of the Bosque Escarpment, McLennan County, Texas, Unpublished Doctoral Dissertation, Univ. of Wisconsin.

37. Henningsen, E. R., 1962, Water Diagenesis in Lower Cretaceous Trinity Acquifers of Central Texas, Baylor Geological Studies Bull. No. 3, 37 pp., 17 figs., 1 table.

38. Hill, R. T., 1901 Geography and Geology of the Black and Grand Prairies of Texas, 21st Ann. Repr. of the U. S. Geol. Survey to the Secretary of the Interior.

39. Holloway, Harold D., 1961, The Lower Cretaceous Trinity Acquifers, Mc Lennan County, Texas, Baylor Geological Studies Bull. No. 1, 31 pp., 10 figs., 1 table.

40. Howell, J. V., and Weller, J. M., 1960, Glossary of Geology and Related Science, American Geological Institute, 397 pp.

41. Howman, E. C., and Redfield, R. C., and Stoecker, W. C., 1945, The Industrial Utilization of a Sand-Clay Mixture from Falls and Robertson Counties, Texas, U. S. Bur. Mines Rept. Inv. 3825, 30 pp., illus.

42. Hopkins, O. N., Jr., 1961, The Geology of the Valley Mills and China Springs Quadrangles, Mc Lennan and Bosque Counties, Texas, Map 1:24,000, Masters Thesis, Unpublished, Baylor Univ.

43. Huckabee, J. W., 1960, Generalized Soil Map of Bell County, Texas, Dept. Agr. Soil Conservation Service and Texas Agr. Expt. Sta.

44. ------, 1961, Generalized Soil Map of Falls County, Texas, Dept. Agr. Soil Conservation Service and Texas Agr. Expt. Sta.

45. ------, 1961, Generalized Soil Map of Limestone County, Texas, Dept. Agr. Soil Conservation Service and Texas Agr. Extp. Sta.

46. ------, 1963, Generalized Soil Map of Coryell County, Texas, Dept. Agr. Soil Conservation Service and Texas Agr. Expt. Sta.

47. ------, 1963, Generalized Soil Map of Hamilton County, Texas, Dept. Agr. Soil Conservation Service and Texas Agr. Expt. Sta.

48. Hull, A. M., 1951, Geology of Whitney Reservoir Area, Brazos River, Bosque-Hill Counties, Texas, Fondren Science Series, No. 4, Southern Methodist Univ. Press, pp. 45-63, 16 pls.

49. Ikins, W. C., 1959, Stratigraphy and Paleontology of the Walnut and Comanche Peak Formations, Shreveport Geological Society Guidebook, 17th Annual Field Trip.

50. Lee, H. L., Jr., 1958, Woodbine Strata of Northwest Hill County, Texas, Unpublished Masters Thesis, The University of Texas, 126 pp., 11 pls., 39 figs., 5 tables, geologic map in color.

51. Lozo, F. E., and Perkins, B. F., 1951, The Woodbine and Adjacent Strata of the Waco Area of Central Texas, A Symposium, Fondren Science Series, No. 4, Southern Methodist Univ. Press, 161 pp., with separate papers listed in this bibliography.

52. Lozo, F. E.; Nelson, H. F.; Young, Keith; Shelburne, O. B.; and Sandidge, J.R., 1959, Symposium on the Edwards Limestone in Central Texas, Univ. Texas Bur. Econ. Geology Publication 5905, 234 pp., 23 figs., 40 pls., (1 in color).

53. McLerran, J. H., 1957, Glossary of Pedologic (Soils) and Lanform Terminology for Soils Engineers, Highway Research Board, Special Rept. 25, 32 pp.

54. Monroe, J. M., 1951, Woodbine Sandstone Dikes of Northern McLennan County, Texas, Fondren Science Series No. 4, Southern Methodist Univ. Press, pp. 93-98, 2 figs., 2 pls.

55. Muller, D. A., See Baylor Geol. Society, 1960.

56. Murray, G. E., 1961, Geology of the Atlantic and Gulf Coastal Province of North America, Harper & Brothers, 692 pp.

57. Nash, J. P., 1919, The Road Materials of Texas, Univ. Texas Bur. Econ. Geology Bull. No. 1839, 159 pp., 10 pls.

70. Soil Conservation Service, Dept. Agr., 1961, Generalized Soil Map of Hill County, Texas, in conjunction with Texas Agr. Expt. Sta.. Map compiled by Soil Scientists, SCS and TAES from published soil surveys.

71. Stanford, Jack, See Baylor Geological Society, 1958.

72. Stephenson, L. W., 1941, The Larger Invertebrate Fossils of the Navarro Group of Texas, Univ. Texas Bur. Econ. Geology Bull. No. 4101, 641 pp., 13 figs., 93 pls.

73. ------, 1953, Probable Reklaw Age of a Ferruginous Conglomerate in Eastern Texas, U. S. Geol. Survey Prof. Paper 243-C, 42 pp., 3 pls.

74. Taff, J. A., 1892, Cretaceous Area North of the Colorado River, Texas Geol. Survey, 3rd Annual Rept., pp. 269-379.

75. Templin, E.H., 1958, Soil Survey McLennan County, Texas, U. S. Dept. Agr. Soil Conservation Service, Series 1942, No. 17, 124 pp.,9 tables, soil map in color (4 sheets).

76. Thomas, J. R., 1960, Generalized Soil Map of Bosque County, Texas, Dept. Agr. Soil Conservation Service, and Texas Agr. Expt. Sta.

77. Thompson, S. A., 1935, Fredericksburg Group of the Lower Cretaceous with Special Reference to North-Central Texas, Am. Assoc. Petrol. Geol. Bull., Volume 19, No. 10, pp. 1508-1537.

78. Weeks, A. W., 1945, Balconies, Luling and Mexia Fault Zones in Texas, Am. Assoc. Petrol. Geol. Bull., Volume 29, No. 12, pp. 1733-1737, 1 fig.

79. ------, 1945, Quaternary Deposits of the Texas Coastal Plain between the Brazos River and the Rio Grande River, Am. Assoc, Petrol. Geol.Bull., Volume 29, No. 12, pp. 1693-1720, illus. (Incl. index, geol. maps and aerial photo).

80. Wilmarth, M. G., 1938, Lexicon of Geologic Names of the United States, U. S. Geol. Survey, Bull No. 896, 2396 pp.

58. Nelson, H. F., (no date), High-Calcium Edwards Limestone, Central Texas, Univ. Texas Bur. Econ. Geology Open-File Rept.

59. Nickell, C. O., 1936, Report on River Terraces in Bell County, Texas as a part of a Mineral Resource Survey in Bell County, Univ. Texas Bur. Econ. Geology Min. Res. Survey Circ. 12, 5 pp.

60. Oaks, Henry, and Godfrey, Curtis, and Barton, Jack, (no date), Land Resource Areas of Texas, Texas Agr. Ext. Service, L-400-4 pp.

61. Payne, W. R., 1960. Geologic Report of Mosheim and Clifton Quadrangles, Bosque County, Texas, Map 1:24,000, Unpublished Masters Thesis, Baylor Univ.

62. Rice, C. M., 1949, Dictionary of Geological Terms, Edward Brothers Inc., 461 pp.

63. Rogers, R. W., See Baylor Geological Society, 1960.

64. ------, 1962, Geology of the Glen Rose Limestone, Central Texas, Map 1:25,000, Unpublished Masters Thesis, Baylor Univ.

65. Schock, E. P., 1918, Chemical Analysis of Texas Rocks and Minerals, Univ. Texas Bur. Econ. Geology Bull. No. 1814, 256 pp.

66. Seewald, K. O., See Baylor Geological Society, 1960.

67. Sellards, E. H.; Adkins, W. S.; Plummer, F. B., 1932, The Geology of Texas, Volume 1, Stratigraphy, Univ. Texas Bur. Econ. Geology Bull. No. 3232, 1007 pp., 54 figs., 10 pls., geologic map in color.

68. Sellards, E. H., and Baker, C. L., 1934, The Geology of Texas, Volume 2, Structure and Economic Geology, Univ. Texas Bur. Econ. Geology Bull. No. 3401, 884 pp., 40 figs., 7 pls., structural map in color.

69. Silver, B. A., 1963, The Bluebonnet Member, Lake Waco Formation (Upper Cretaceous), Central Texas, -- A Lagoonal Deposit, Baylor Geol. Studies, Bull. No. 4, 46 pp., 13 figs., 9 pls.

81. Barnes, V. E.; Dawson, R. F.; and Parkinson, G. A., 1942, Building Stones of Central Texas, Univ. Texas Bur. Econ. Geology Bull. No. 4246, 198 pp., 18 figs., 6 pls.

82. Darton, N. H.; Stephenson, L. W.; and Gardner, Julia, 1937, Geologic Map of Texas, U. S. Geol. Survey, Scale 1:500,000.

83. Baird, R. W; Lauritzen, C. W.; and others, 1942, Hydrologic Data: Blacklands Experimental Watershed, Waco, Texas, 1937-1939, U.S. Dept. Agr. Hydrologic Bull. 5, 38 pp.