THE WILLIS FORMATION OF THE TEXAS GULF COAST

A Thesis
Presented to
The Faculty of the School of Arts and Sciences
The University of Houston

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Geology

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by
L. Bruce Forney
September, 1950

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ABSTRACT

The Willis formation has long been a source of much discussion and confusion among geologists of the Gulf Coast, and today many of the questions concerning it remain unanswered.

The Willis is distinguishable as a coarse gravelly sand, red or reddish-brown in color but grading to pink, yellow, or brown. It is dominantly a coarse sandstone peppered with pebbles and granules of quartz and chert, and the whole cemented with ferruginous clay and limonite.

It outcrops in a belt of dissected ridges and cuestas, typically covered with a dense growth of trees and shrubs, through portions of Newton, Jasper, Tyler, Polk, San Jacinto, Walker, Montgomery, Harris, Waller, Grimes, Austin, Colorado, Lavaca, and Dewitt Counties in Texas. In Dewitt County, it is overlapped by younger formations and disappears to the southwest. On the east, it continues into Louisiana.

No fossils have been reported from the Willis. It is overlain by beds of the Pleistocene and underlain by beds of the Pliocene, so from the superposition of beds, it is Lower Pleistocene in age.

The Willis was deposited by swollen, surging rivers on a broad flat plain near sea level as the rivers discharged their loads carried from a region of greater relief. These river deltas coalesced to form a continuous blanket of material. Erosion has since removed the upstream portion and the Willis now found at the surface is part of the plain developed at a distance from the mouth of the streams.

The gravels of the Willis formation are the chief source of gravel for road surfaces and for concrete aggregate on the Gulf Coast.

Water bearing sands of the Willis formation form the most productive aquifer on the Gulf Coast. It is extensively produced for both public water supplies and industrial purposes and preferred because of its softness and low mineral content.

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INTRODUCTION

The Willis formation has long been a source of considerable discussion among geologists of the Gulf Coast, and many problems concerning it remain unsolved. It outcrops in a belt of dissected ridges and cuestas, often covered with a dense growth of trees and shrubs, in portions of Newton, Jasper, Tyler, Polk, San Jacinto, Montgomery, Walker, Harris, Grimes, Waller, Austin, Colorado, Laveca, and Dewitt Counties. In Dewitt County it pinches out and disappears to the southwest. To the east, it continues into Louisiana. The coarse red sand and gravel of the Willis distinguishes it from the adjacent formations and makes it a mappable unit.

No fossils have been reported from the formation. It is overlain by Pleistocene beds and underlain by Pliocene beds, both unconformably. The Willis is here considered Pleistocene.

The subject of the Willis formation was chosen for several reasons. First, it was the source of much confusion and consternation among geologists of the Gulf Coast as to its age, extent, and correlation. Second, it is very important economically as the principle source of water for Houston and the coastal cities. Lastly, it outcrops in an area near the University of Houston and, such a research project is of more importance to Houston than a study of some distant feature.

Research was undertaken in the summer of 1950. The outcrop was mapped from the Sabine River to Dewitt County where it disappeared. The majority of the reconnaisance was by automobile. Distances were clocked by speedometer and plotted on county road maps, with a scale of 2" equals one mile, obtained from the Texas Highway Department. Careful descriptions were made at all principle exposures, and samples were collected and analyzed whenever practical.

In the preparation of this thesis, the writer is indebted to several persons, without whose help this could never have been written. The writer wishes to acknowledge the invaluable advice and criticism offered by Professor A. A. L. Mathews, his faculty advisor, and that of Dr. George B. Somers, Dr. Paul H. Fan, and Mrs. Louise Herrington of the Geology Department of the University of Houston. The writer also wishes to acknowledge the work done by Miss Susan Calnon in the typing and final preparation of this thesis.

STRATIGRAPHY

UNDERLYING FORMATIONS

MIOCENE SERIES

FLEMING GROUP:

Kennedy[1] first described the clays and thin sandy beds lying between the Catahoula sandstone and what he referred to as the Lafayette sands in East Texas. These he named Fleming after the exposures near Fleming Station (now Hampton) on the Missouri, Kansas, and Texas Railroad in Polk County.

Deussen[2] introduced a new name, the Dewitt formation, for a series of beds in South Texas which occupies about the same stratigraphic position as the Fleming although he himself considered this a facies of the Fleming. Dumble[3] divided the same series of beds into the Oakville, Lapara and Lagarto formations. The Lapara was subsequently shown to be separated from the underlying clay by a prominent unconformity and was placed in the Goliad formation above. The Lagarto was redefined to include the clays lying between the Oakville sand and the Lapara sand. This was rather a drastic change since it put the beds Dumble originally named Lagarto well up in the Goliad formation, above the Lapara. This drastic emendation was deemed justifiable in order to preserve the name Lagarto for the clay above the Oakville since it had enjoyed such wide acceptance and usage.

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[1] Kennedy, W.: A Section from Terrell, Kaufman County to Sabine Pass on Gulf of Mexico. Texas Geol. Survey Annual Report, 1892.

[2] Deussen, Alexander: Geology and Underground Waters of the Southeastern Part of the Texas Coastal Plain. U. S. Geol. Survey, Water Supply Paper 335, 1914

[3] Dumble, E. T.: The Cenozoic Deposits of Texas. Jour. Geol., Vol. 2, 1894.

The name Fleming has been preserved as a group name to include the Oakville and Lagarto formations, since it is considerably difficult to separate the two formations east of the Brazos River.

In East Texas, the Fleming is distinguished by its yellow, gray, greenish or black clays which weather to a black loamy soil. Calcareous nodules are common and occasionally thin limestons ledges may be seen. The basal beds are slightly more sandy than the upper ones, and all are calcareous. Reworked Cretaceous fossils are common, and pyroclastics are rare.

The Fleming group in central and South Texas has been divided into two formations, each of which will be discussed below in stratigraphic order.

OAKVILLE FORMATION:

The Oakville formation was named by Dumble for exposures along the Nueces River near Oakville in Live Oak County. It is in reality a sandy phase of the Lower Fleming and grades laterally and vertically into clay. Dumble originally considered it as restricted to South Texas and correlated it with the Lower Fleming. It has since been shown to outcrop more or less continually from Grimes County southwest through Duval County. From Duval to southern Starr County it is overlapped by Pliocene beds, but outcrops along the Rio Grande in Starr and Hidalgo Counties. Northeast of Grimes County, the sandstone changes to a clay facies and with few exceptions cannot be differentiated from the Lagarto clay. One and a quarter miles north of Cold Spring, San Jacinto County, and near Burkeville, Newton County, are isolated outcrops of a sandstone not unlike the Oakville sandstone

Oakville Outcrop
Near Halletsville, Lavaca County

Oakville Outcrop
1-1/4 Miles North of Coldspring, San Jacinto County

LAGARTO FORMATION:

The Lagarto formation was originally named by Dumble for Lagarto Creek in Live Oak County. Working in this area, he divided the beds between the top of the Oakville and the base of the Pleistocene into two divisions. The upper clay section was named Lagarto and the Lower sandy section, Lapara. Between the Lapara and Oakville is an important clay section five hundred to a thousand feet thick, which also came to be known as the Lagarto since Dumble originally thought the Lapara was present only along the Nueces River and overlapped elsewhere by the Lagarto. Later, the Lapara sand was shown to be continuous and to have a prominent unconformity at its base, and was therefore placed in the Goliad formation. The clay section above the Lapara was emended to the Lagarto Creek clay, while the section below was named the Lagarto formation since that name, though erroneous, had enjoyed such a wide usage and acceptance. The type section for the Lagarto formation was emended to comprise exposures along the Brenham-Houston highway just west of the Brazos River bridge in Washington County.

The Lagarto outcrops in a belt roughly parallel to the present coast line and immediately south of the Oakville outcrop, from the Sabine River to the Rio Grande except where it is obscured by Pleistocene deposits. Down dip it occurs as a marine facies in wells drilled near the coast and it is typically a clay section with occasional lenses of sand.

In outcrop, the Lagarto occurs as a yellow, yellowish brown, reddish, gray-green, or black massive clay which forms a rolling topography and which weathers to a black loamy soil. It is very

Typical Fleming Topography and Vegetation
Grimes County

Lagarto Clay Outcrop, Two Miles South of Hempstead
Waller County

similar to the Oakville except for its greater proportion of clay. Like the Oakville, it is calcareous and contains numerous limy nodules.

The Lagarto contains redeposited Cretaceous fossils, marine and brackish water invertebrate sheels found in cores of deep wells, and bones of land vetebrates found along the outcrop. These faunas indicate a Late Miocene or possibly Early Pliocene age.

PLIOCENE SERIES

GOLIAD FORMATION:

The Goliad formation was named by I. K. Howeth and P. F. Martin for Goliad, Goliad County, where it is typically exposed along the San Antonio River. They included in their original description all the beds between the top of the Lagarto clay (as emended) and the base of the Lissie. In the type section, this division is quite satisfactory, since the Willis is missing here and the Lissie rests unconformably on the Goliad; however, to the northeast, the Willis outcrops between the Goliad and the Lissie.

The Goliad outcrops in a belt roughly parallel to the present coastline in Central and South Texas, except where it is obscured by Pleistocene sands. Northeast of the Colorado River, the formation becomes dominantly a clay and virtually indistinguishable from the Lagarto clay. The Goliad is present northeast of the Colorado River at least as far as the Sabine River and also it is present as an upper member of what is now mapped as Fleming clays. In San Jacinto, Polk, Tyler, Jasper, and Newton Counties, there occurs in the upper portion of the Fleming a series of clays which have the peculiar mottled pink, green, and purple shades that are similar to those found in the Goliad in Lavaca and Dewitt Counties and yet completely different from the dull green, yellow and black of the typical Lagarto. No attempt was made to differentiate between these clays, but rather they were all considered as Fleming.

It must be noted that the considerable thickness of the Pliocene section found in wells near the coast requires a rapid thickening of section in the subsurface not far from the surface outcrop, if such exists. The upper portion of what is now mapped as Fleming, in East Texas, may well be the feather edge of this overlapped Pliocene section. Wells drilled along the south edge of the Willis outcrop encounter pink clays and gumbo and some sands at depths too deep to be Willis, and this may well be part of the Pliocene section[5].

The Goliad formation in central Texas may be divided into three members[6]. The lowermost, the Lapara sand, consists of a coarse sand and conglomerate with cross-bedded sand and limy clay. Color varies from red or pink to white depending upon the composition.

The middle member or Lagarto Creek clay consists of a mottled pinkish-brown and reddish limy clay resembling the Fleming clays, but having a higher lime content and more pastel shades. At the type locality, it is about fifty feet thick.

The uppermost member, the Labahia beds, consist of an upper bed of grayish white, medium to fine grained sandstone which weathers to form bluish-black rough surfaced ledges; a middle bed of greenish-gray, pink or reddish calcareous clay containing white calcareous nodules; and a lower bed of grayish-white,

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[5]Doering, John: Post-Fleming Surface Formations of Coastal Southeast Texas and South Louisiana. Am. Assoc. Petr. Geols., Bull., Vol. 19, pp. 651, 1935.

[6]Plummer, F. B., et al.: The Geology of Texas. Univ. of Texas Bull., 3232, 1932.

medium to coarse grained, calcareous cross-bedded sandstone containing conglomeritic lenses of chert and quartz pebbles and balls of green clay.

There is considerable disagreement among geologists concerning the environment at the time of deposition of the Goliad. Some geologists believe that the deposition of the Goliad resulted from the increased flow of the rivers brought on by the approaching glaciation and its accompanying increase in precipitation. Others point to the presence of caliche, some of which is believed to have formed during Goliad times, as proof of semi-aridity at the time, since as far as we know caliche is produced only under conditions where the rate of evaporation exceeds the rainfall.

Sediments of the Goliad clearly reveal that it was deposited by swollen rivers as a blanket of sand over the coastal plain, since it has all the characteristics of a fluviatile deposit. The lower section contains well rounded pebbles and cobbles and clay balls and have the typical cross-bedding of a river deposit. In late Goliad time, the streams lost much of their transporting power and became more sluggish, spreading their fine sediments over a much broader area.

Paleontological evidence of the age of the Goliad is scarce. Some few vertebrate and invertebrate remains have been found and are regarded as Pliocene in age. Many of these remains are water worn and may have been redeposited from the Lagarto or Oakville formations.

OVERLYING FORMATIONS

PLEISTOCENE SERIES

LISSIE FORMATION:

The Lissie formation was named by Deussen[7] for the town of Lissie, in Wharton County, Texas, where it is typically exposed above the Southern Pacific Railroad right-of-way.

In the earliest reports written on the younger formations they were referred to as "Diluvium", "Northern Drift" or "Orange Sand". In 1891, McGee[8] described the Pleistocene deposits of the Gulf and Atlantic Coast under the Lafayette formation, using Lafayette County, Mississippi, as a type locality. This work was widely read and accepted and the name Lafayette became applied to a great variety of gravel and sand deposits. Lafayette County is located far in the interior of Mississippi and has since been shown to be in an area of Tertiary Wilcox. The name Lafayette has been applied to gravel and sand formations ranging in age from Tertiary to Recent and has therefore lost specific meaning and has been discarded.

Dumble[9] named these coastal sands the "Equus Beds" as a result of the discovery of fossil horse bones in them.

Hayes and Kennedy[10] proposed the name Colombia sand for this formation of fine sands in East Texas, which they borrowed from the Atlantic Coast section.

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[7]Deussen, Alexander: Geology and Underground Waters of the Southeastern Part of the Texas Coastal Plain. U. S. Geol. Survey, Water Supply Paper 335, 1914.

[8]McGee, W. J.: The Lafayette Formation. U. S. Geol. Survey, 12th. Annual Report, Part 1,pp. 384, 1891.

[9]Dumble, E. T.: The Cenozoic Deposits of Texas. Jour. Geol., Vol. 2, 1894.

[10]Hayes, C. W., and Kennedy, W.: Oil Fields of the Texas - Louisiana Gulf Coastal Plain. U.S.G.S., Bull. 212:174, 1903.

Deussen believed the "Equus Beds" might not be the same age as the Columbia sand, and, therefore, proposed the name Lissie for the section above the Pliocene and below the Beaumont clay. This name remains in general use.

Between the Lissie and Goliad lies a bed of sands and gravels that has caused considerable discussion among stratigraphers. It has been variously referred to as Citronelle[11], Lissie[12], "Unnamed Pliocene"[13], Lower Lissie[14], and Willis[15]. The exact age is not known, but has been placed as Pliocene, Pliocene-Pleistocene, and Pleistocene by various authors. This will be discussed in detail elsewhere in this work, but the essential fact at this point is that the formation between the Lissie and the Goliad is a definite mappable unit, separate and distinct from the formations above and below it, and that the base of the Lissie as defined by current usage is taken as the top of this formation.

The Lissie occurs in a broad belt paralleling the coast between the Willis or Goliad outcrops and the Beaumont clay. It is continuous from the Rio Grande to the Sabine River and into Louisiana, in a belt about thirty miles wide, but smaller tongues extend up into the interior through stream gaps cut into the Willis cuesta, and overlap the Willis and Fleming unconformably.

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[11]Matson, G. C.: <u>The Pliocene Citronelle Formation of the Gulf Coastal Plain</u>. U. S. Geol. Survey, Prof. Paper 98, 1916.

[12]Barton, Donald C.: <u>Surface Geology of Coastal Southeast Texas</u>. Am. Assoc. Petr. Geols., Bull., Vol. 15, pp. 1301, 1930.

[13]Plummer, F. B., et al.: <u>The Geology of Texas</u>. Univ. of Texas Bull. 3232, 1932.

[14]Bailey, T. L.: <u>The Geology and Natural Resources of Colorado County</u>. Univ. of Texas Bull. 2333, 1923.

[15]Doering, John: <u>Post-Fleming Surface Formations of Coastal Southeast Texas and South Louisiana</u>. Am. Assoc. Petr. Geols., Bull, Vol. 19, pp. 651, 1935.

The lithology varies widely, but is dominantly a silty sand grading locally into gravel and clay. In the type locality, it is a dirty-buff to ashen-gray silty sand, massive, and very soft and unconsolidated. In Jasper and Newton Counties, and in other areas, particularly near the base, it may be very ferruginuous, containing numerous limonite nodules and having a slightly coarser texture. Near larger streams, such as the Colorado, Brazos, Trinity, Guadalupe, and Sabine Rivers, it is much coarser than in the inter-stream areas. In Colorado County, near the Colorado River, very coarse gravels are quarried from terraces of Lissie age and extensively used for road ballast and construction materials.

The composition of the Lissie varies depending upon the source of the sediments. In East Texas, the sands are considerably more ferruginuous than in other areas due to the deposition of this part of the Lissie by streams draining the ferruginuous Claiborne areas of East Texas and Western Louisiana. Around the Colorado River the sands and gravels contain a high percentage of igneous pebbles and granitic debris derived from the Central Mineral Region which this river drains. In Southwest Texas the sediments are largely derived from the Edwards Plateau and contain a high percentage of limestone pebbles and debris as well as calcareous cementing material.

Sorting is usually poor in the Lissie. Even the coarse sands and gravels contain a large amount of disseminated clay. Bedding is not usually noticeable, although locally the sands may be cross-bedded. Within the Lissie itself, there are numerous unconformities but few of these can be traced far enough to be of any use.

One outstanding feature of the Lissie is its characteristic topography. It forms broad flat, nearly featureless plains, quite distinguishable from that of the underlying formations. These plains are virtually treeless, most of the trees being confined to creek and river bottoms.

Unfortunately for the geologist, outcrops and exposures of the Lissie are scarce and rarely good. Because of the topography and elevation, our principle view of the formation is of the weathered surface. Slope at the top of the Lissie is about five feet per mile while its base, which is the top of the Willis is about twenty feet per mile. This gives a thickening of about fifteen feet per mile toward the coast from which a thickness of about one thousand feet is estimated at the present coast line[16].

Fossils are rare in the Lissie; however, some bones and a few invertebrates have been found and determined. These have established the age as Pleistocene, probably middle or upper-lower.

It is this writer's opinion that the deposition of the Lissie was closely connected with the glaciation that occurred in North America about the same time. Most authors agree that the Lissie is of fluviatile origin, and that it was deposited on a broad plain paralleling the shoreline as the seaward-facing interstream equivalents of the upstream river terraces. It should be obvious

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[16] Doering, John: Post-Fleming Surface Formations of Coastal Southeast Texas and South Louisiana. Am. Assoc. Petr. Geols., Bull., Vol. 19, pp. 651, 1935.

Lissie Plain at Lissie, Wharton County, Showing
Typical Topography and Vegetation

Lissie Plain Near Katy, Waller County
Showing Typical Topography and Vegetation

also that such a large volume of sand and gravels could only have been transported by rivers which were surging torrents and constantly at flood stage.

During the glacial periods, the sea level was lowered due to the ice cap on the land giving the streams a rejuvenescence equivalent to uplift. Presence of the ice sheet obviously made the climate much more humid and greatly increased the precipitation.

These swollen streams poured their burdens out on the broad flat coastal plain to form the broad blanket of sands and silts that remains today.

BEAUMONT CLAY:

The Beaumont clay was named by Hayes and Kennedy[17] for the exposures in the vicinity of Beaumont, Jefferson County, Texas. It had previously been referred to as Port Hudson, and "Coast Clays". Hayes and Kennedy showed the Port Hudson to be of Recent age, and defined the Beaumont clay as the clay deposits between the Port Hudson and the top of what is now the Lissie. The name and description have remained in acceptance since. The type section is given as the shallow wells in and around Beaumont. The surface formations at Beaumont are recent terrace silts from the Neches River, but beneath these are some four hundred feet of clays attributed to the Beaumont.

The Beaumont occurs in a broad belt about fifty miles wide paralleling the coast and extending from Mexico into Louisiana. It

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[17] Hayes, C. W., and Kennedy, W.: Oil Fields of the Texas - Louisiana Gulf Coastal Plain. U.S.G.S., Bull. 212:174, 1903.

overlaps the Lissie unconformably and fingers of the Beaumont extend up the principle streams crossing the Lissie, Willis, Goliad, and Fleming unconformably.

Its seaward edge is overlapped by recent sands and silts. In the Rio Grande Valley, large portions of it are obscured by wind-blown sand deposits, particularly in Hidalgo and Willacy Counties. Excellent exposures may be found in the drainage ditches near Beaumont, Jefferson County, Houston, Harris County, and in the bluff overlooking Corpus Christi Bay at Corpus Christi.

The Beaumont is typically a dark, heavy, waxy, calcareous clay. It is commonly black, blue or gray, and less commonly, red. When wet, it forms a thick, waxey, very sticky gumbo. It commonly contains disseminated particles of lime and occasionally calcareous nodules and particles of decomposed wood. In some localities, it may be quite sandy, and frequently contains lenses of silty sand. It typically forms a broad flat plain, often treeless, with even less relief than the Lissie. Bayous and streams have cut deep narrow channels in it, quite unlike the broad channels found north of the Beaumont. The surface of the Beaumont slopes about two feet per mile, and reaches a maximum thickness of nine hundred feet at the coast.

Fossils in the Beaumont are scarce, but oyster and shell beds have been discovered in a few places, notably Trinity Bay, and around Nueces Bay. Even more rare are a few bones and teeth of vertebrates that have been unearthed. Determination of these fossils leaves little doubt that the Beaumont is Upper Pleistocene in age.

Deposition of the Beaumont was similar to that of the Lissie, except that it was less severe. It was formed by the coalescing deltas and levees of the several streams along the coast as these sluggish streams constantly shifted and changed their mouths. The interior highlands had been eroded down to near their present level by this time, and the Late Pleistocene glaciation was much smaller in extent than before, thus not having as great an effect upon the climate and rainfall. The streams, during Beaumont time, were therefore more sluggish and carried finer particles than previously.

Barton[18] has carefully mapped the soils in Fort Bend, Brazoria, Harris, and Liberty Counties, and proved by his detailed work that the Beaumont in these areas was laid down as the coalescing lagoonal deltas of the Brazos and Trinity Rivers. He has gone so far as to show and map the old channels of the rivers and in some instances show the ancient terraces.

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[18] Barton, Donald C.: Surface Geology of Coastal Southeast Texas. Am. Assoc. Petr. Geols., Bull., Vol. 15, pp. 1301, 1930.

WILLIS FORMATION

Among the earliest descriptions of the sands and gravels of the Willis formation, they are referred to as Diluvium or Northern Drift, since they were thought to be of glacial origin. Harper[19] in 1857 introduced the name Orange Sand, which he borrowed from the geologic section of Tennessee. This name continued in usage for some time although it was necessary to redefine it to preserve harmony among the various authors.

Hopkins[20] first definitely described the material. He distinguished between the older gravels, or "Drift", and a younger clay formation, the "Prairie Diluvium".

By 1891 so many different names had been applied to the gravel beds of the Gulf Coast region that a meeting of eminent geologists of the Gulf Coast was held in San Francisco to establish a suitable name. Selections were made from a group which included such names as "Ferruginuous Sand", "Drift", "Southern Drift", "Diluvium", "Lagrange", "Orange Sand", "Stratified Drift", "Bluff Gravel", "Plateau Gravel", "Columbia", "Appamattox", and "Lafayette".

Because of various objections to all other names, Lafayette was chosen. This name had been introduced by McGee[21] for a type locality in Lafayette County, Mississippi, and quickly gained wide acceptance.

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[19] Harper, L.: Preliminary Report on the Geology and Agriculture of the State of Mississippi. Miss. Geol. Survey, Bull., 1857.

[20] Hopkins, F. V.: Louisiana Geological Survey, First Annual Report for 1869, 1870.

[21] McGee, W. J.: The Lafayette Formation. U. S. Geol. Survey, 12th. Annual Report, Part 1, pp. 384, 1891.

<table>
<tr><th colspan="9">CORRELATION OF AUTHOR'S TERMINOLOGY</th></tr>
<tr><th></th><th>KENNEDY
1903
SE Texas</th><th>DEUSSEN
1924
SW Texas</th><th>BARTON
1930
SE Texas</th><th>HOWE
1933
Louisiana</th><th>PLUMMER
1933
Texas</th><th>WEEKS
1933
SE Texas</th><th>DOERING
1935
SE Tex. & La.</th><th>WEEKS
1945
SW Texas</th></tr>
<tr><td rowspan="3">PLEISTOCENE</td><td>Beaumont</td><td>Beaumont</td><td rowspan="3">Beaumont</td><td rowspan="3">Beaumont
&/or
Port Hudson</td><td>Beaumont</td><td>Beaumont</td><td>Beaumont</td><td>Beaumont</td></tr>
<tr><td rowspan="2">Columbia</td><td rowspan="2">Lissie</td><td rowspan="2">Lissie
(Reynosa)</td><td rowspan="2">Upper
Lissie</td><td rowspan="2">Lissie
(Reynosa)
(Port Hudson)</td><td>Lissie</td></tr>
<tr><td>Willis</td></tr>
<tr><td rowspan="2">PLIOCENE</td><td rowspan="2">Lafayette</td><td rowspan="2">Reynosa</td><td rowspan="2">Lissie</td><td rowspan="2">Citronelle
(?)</td><td>Unnamed
Pliocene
(Citronelle)</td><td>Lower
Lissie</td><td>Willis</td><td rowspan="2">Goliad</td></tr>
<tr><td>Goliad</td><td>Upper
Lagarto</td><td>Goliad</td></tr>
</table>

Lafayette County is far to the interior of Mississippi and has since been shown to be in the area of Eocene Wilcox. The name Lafayette has been applied to formations ranging in age from Eocene to Recent and therefore, lost specific meaning and has been discarded.

In 1916, Matson[22] introduced the name Citronelle for a series of sand and gravel beds which he mapped across Louisiana, Mississippi, Alabama, and Eastern Florida. Type locality for the Citronelle was given as the exposures along the Mobile and Ohio Railroad near the town of Citronelle, in Mobile County, Alabama. His work clarified much of the old confusion of names, and the name Citronelle gained immediate recognition.

Roy[23] has shown that Matson's Citronelle formation in its type locality includes portions of two formations; the overlying sands and gravels, and the underlying shales from which Matson collected Pliocene plant leaves. Because of this and also because of the imperfect description of the type locality, the term Citronelle has been dropped as a formational name, but is still used as a broad inclusive group name in certain areas, particularly Alabama.

The formation herein called the Willis, has been called the "Unnamed Upper Pliocene Sands" by Plummer[24] and the "Lower Lissie"

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[22] Matson, G. C.: The Pliocene Citronelle Formation of the Gulf Coastal Plain. U. S. Geol. Survey, Prof. Paper 98, 1916.

[23] Roy, Chalmer J.: Type Locality of Citronelle Formation, Citronelle, Alabama. Am. Assoc. of Petr. Geols., Bull., Vol. 23, pp. 1553, 1939.

[24] Plummer, F. B., et. al.: The Geology of Texas. Univ. of Texas Bull. 3232, 1932.

by Weeks[25] and Bailey.[26]

The name Willis was proposed by Doering[27] in 1935 to replace the old ambiguous names. The type locality comprises exposures in and around the town of Willis in Montgomery County, Texas.

The term Willis as used in this work, is considered the same as that described by Doering. Doering divides his Willis into three members: The Willis Gravelly Sand or basal member, the Willis Ferruginous Sand, and the Hockley Mound Sand. No division into members is made by this writer.

DISTRIBUTION:

The Willis forms a gravelly sand belt paralleling the coast at a distance of about one hundred miles. Its outcrop is one to twenty miles wide, commonly ten to fifteen, and forms red rolling hills and densely wooded ridges. It occurs as cuestas, deeply eroded by rivers and forms a resistant cap over the softer formations on the divides between streams.

The writer has mapped the formation (in pocket) through portions of Newton, Jasper, Tyler, Polk, San Jacinto, Montgomery, Harris, Grimes, Walker, Waller, Austin, Colorado, Lavaca, and Dewitt Counties and into Louisiana. To the southwest in Dewitt County, it disappears and apparently pinches out over the San Marcos Arch and is overlapped by the Lissie or younger formations.

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[25] Weeks, A. W.: Lissie, Reynosa, and Upland Terrace Deposits of Coastal Plain of Texas Between Brazos River and Rio Grande. Am. Assoc. Petr. Geols., Bull., Vol. 17, 1933.

[26] Bailey, T. L.: The Geology and Natural Resources of Colorado County. Univ. of Texas Bull. 2333, 1923.

[27] Doering, John: Post-Fleming Surface Formations of Coastal Southeast Texas and South Louisiana. Am. Assoc. Petr. Geols., Bull., Vol. 19, pp. 651, 1935.

Contacts are often difficult to locate on the Willis, particularly the upper contact. In Colorado County and in the vicinity of the Colorado and Guadalupe Rivers, the Willis-Lissie contact is especially difficult to determine because of the lithologic similarity of the two formations. In this area, the change in vegetation was especially important since the Willis was characterized by a thick growth of scrub trees, and the Lissie by a treeless plain. In areas of extensive cultivation such as the rice fields of Harris and Waller Counties, where few contacts could be observed, they were interpolated from those available. In some of the densely wooded areas of East Texas, the same procedure was followed.

Scattered throughout Texas between the Balcones Fault Zone and the coast are residual patches of gravel and terrace deposits which may in part be equivalent to the Willis. These are not connected with the main body of the formation, nor with each other and their interrelationships are strictly a matter of conjecture. They cannot be correlated by means of fossil remains, nor because of their very nature can they be correlated on the basis of lithology.

Woodward and Gueno[28] have attempted to correlate the terrace deposits of Louisiana with the Pleistocene glacial and interglacial periods with some degree of success. Weeks[29] has done the same thing with the Colorado River Terraces, and these two conceptions are

[28] Woodward, T. P., and Gueno, A. J.: The Sand and Gravel Deposits of Louisiana. La. Geol. Survey, Bull. 19, 1941.

[29] Weeks, A. W.: Quaternary Deposits of Texas Coastal Plain Between Brazos River and Rio Grande. Am. Assoc. Petr. Geols., Bull., Vol. 29, 1945.

CORRELATION OF PLEISTOCENE TERRACE DEPOSITS

EPOCH	GLACIAL STAGE		INTER-GLACIAL STAGE	FORMATION: TEXAS [1]	FORMATION: LOUISIANA [2]
Recent			Recent	Beaches & River Deposits	
PLEISTOCENE			Ice Retreat	Beaumont Capitol	Prairie
	Wisconsin	Mankato			
			Ice Retreat	Asylum	
		Cary			
			Ice Retreat		
		Tazewell			
			Peorian	Uvalde	
	Iowan				
			Sangamon	Bastrop Park	Montgomery
	Illinoian				
			Yarmouth	Gay Hill	Bentley
	Kansan				
			Aftonian	Willis	Williana
	Nebraskan				

1 after Weeks, A.W.; 1945.

2 after Woodward, T.P. & Gueno, A.J.; 1941.

presented here in the accompanying chart. These are both commendable works, and illustrate a change of reasoning which will undoubtedly expose much additional information on all the Quaternary sediments. Nevertheless, the fact remains, neither were able to prove their point beyond a proposition, and they correlate only generally with each other and with the seaward interstream deposits. It must be remembered that Woodward and Gueno worked on the Mississippi and Red Rivers, while Weeks worked on the Colorado and Brazos Rivers. Much more information must be gained, particularly on other rivers before this method of reasoning can be fully evaluated. In the meanwhile, this author advocates division of the Pleistocene in Texas into Willis, Lissie, and Beaumont as before, since these seaward facing interstream terraces form the bulk of the formation, are easily mapped and correlated, have diagnostic lithologic characteristics, and are far more important economically than their possible upstream fingerings.

LITHOLOGY:

The Willis may be described in general as a red, coarse sand, gravelly in part and slightly indurated. It varies considerably throughout its outcrop, both vertically and laterally, and for this reason no detail sections are given, since they are of little or no value and cannot be correlated for over a few feet.

The color varies somewhat from one locality to another. In Montgomery and San Jacinto Counties, near the type locality, it is a distinctive brick red, or mottled red and white. Color shades vary slightly with size. When separated by graded sieves, each decreasing

Willis Outcrop in Road-Cut Two Miles Southeast of New Ulm, Austin County

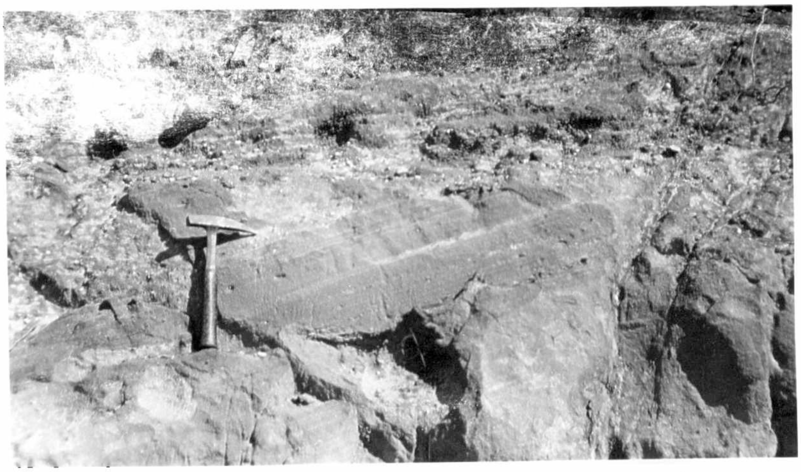
Willis Outcrop on Bank of San Bernard River, Colorado County grain size is a slightly lighter shade of the same color, with the exception of the pebbles, which may be any color.

In Polk, Tyler, Jasper, and Newton Counties, the color is usually more yellowish or brownish yellow, with only occasional brick-red exposures. In Harris, Waller and portions of Austin County, the upper portion of the Willis is characterized by a pink sand. In Colorado County it is a coarse brown gravel.

Composition depends upon the stream which deposited it, and the drainage area of that stream. The Willis sediments in East Texas, being derived in part from the ferruginous Claiborne group of East Texas, are quite ferruginous and show the characteristic red and yellow-brown color of limonite. Much of the cementing material and the bulk volume of the sand is limonite or hematite. Limonite nodules are common throughout the formation, but are usually small, from 1/2" to 1/8". Sand grains and pebbles are composed of quartz, chert, and some silicified wood. It often contains balls of bentonite clay as well.

In Colorado County and in the vicinity of the Colorado River, the Willis formation is a coarse gravel composed of chert, quartz, and igneous pebbles derived from the Central Mineral Region which this river drains.

Size of particles range from cobbles and large pebbles to clay; however, pebbles over two inches are unusual, except locally. Sorting is very poor and inconsistant. Locally sorting may be fairly good as exemplified by the massive sandstone 7.8 miles northeast of Willis on the Coldsprings road, in Montgomery County. In



Willis Outcrop in Road-Cut 1.7 Miles East of Willis, Montgomery County

Willis Outcrop in Road-Cut Southwest of Camilla, San Jacinto County

Willis Outcrop in Road-Cut West of Rose Hill,
Harris County

Willis Outcrop Ten Miles West of Courtney,
Grimes County

Colorado County, the Willis is a coarse gravel with some cobbles over six inches, but principally two and three inch pebbles or smaller, and subordinate amounts of sand and clay. In East Texas it is definitely a sand member peppered with gravel and not simply a gravel bed.

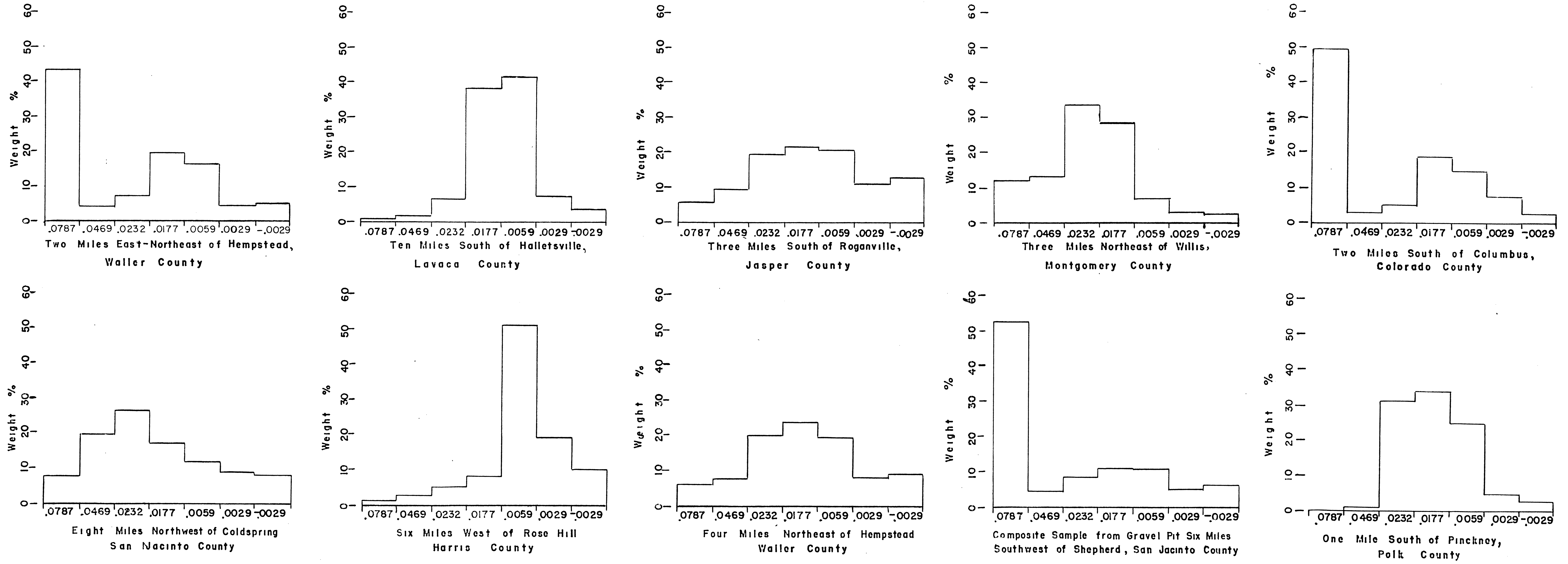
Sorting is very poor and variable within surprisingly short distances both laterally and vertically. A bed of coarse gravel may lense out into a single row of pebbles or even disappear within a few feet. Ordinarily the pebbles constitute a small percentage of the total bed, and these are arranged in attenuated bands or sprinkled indiscriminately throughout the bed.

Numerous samples were collected from exposures throughout the outcrop area, and screen analysis was run on each of them. Because of the vast differences in size and sorting, the results were inconclusive. The accompanying histograms show the erratic patterns formed by some of the various samples. Correlation or identification by histogram or cumulative-frequency curve is obviously inaccurate. In general, the Lissie is not as coarse as the Willis, but locally this may not be true, or they may be virtually indistinguishable by grain size alone. The Willis is always coarser than the beds immediately underlying it, and lower contact may be determined by grain size, among other methods.

Bedding is extremely irregular, cross-bedding and lenticularity being the rule. In addition, the Willis is bounded by an unconformity above and below, therefore reliable dips are nearly always impossible to obtain. On the basis of averages over a broad area,

HISTOGRAMS OF WILLIS FORMATION

GRAIN SIZES IN INCHES



and well logs down dip, the dip has been estimated at 2 to 20 feet per mile to the southeast.

The thickness is variable. It has been measured as 75 feet thick in Colorado County,[30] and pinches out to the southwest in Dewitt County. In his original description of the formation of the formation, Doering[31] gives the thickness as 80 to 85 feet in Southeast Texas and Southwest Louisiana and 120 to 125 feet in Southeast Louisiana. It thickens at the rate of about five feet per mile toward the coast.

Distinguishing Features of the Willis Formation:

1. Texture - usually coarser than formations above or below.
2. Cementation -more indurated than the Lissie or Fleming clays.
3. Topography - forms resistant hills and has been eroded to form ridges and cuestas incised by the major streams. Differs from the flat prairie of the Lissie or the rolling hills of the Fleming.
4. Color - Commonly, reddish or brown sandy soil differing from the black clay soil of the Fleming or the ashen-white or buff colored silt of the Lissie.

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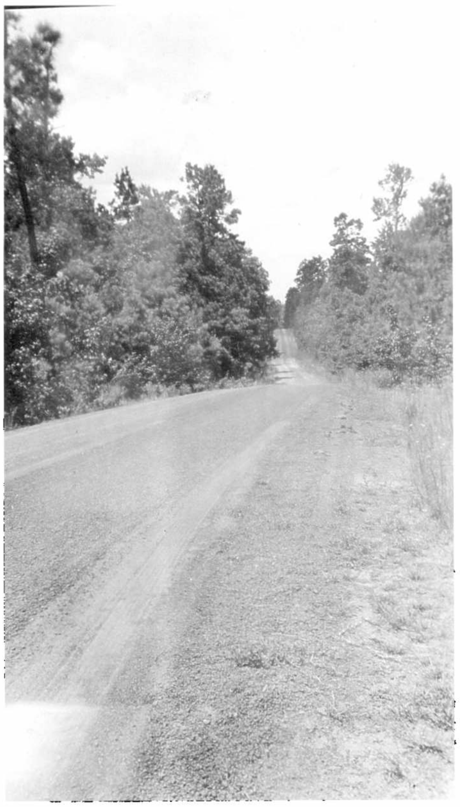
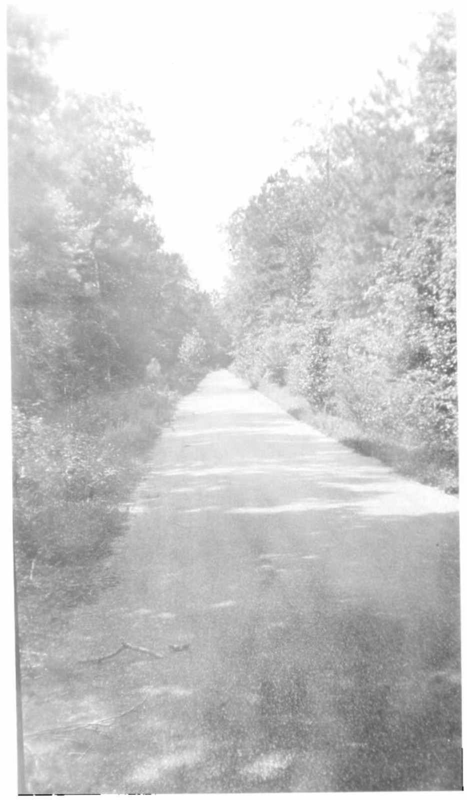
[30] Weeks, A. W.: Quaternary Deposits of Texas Coastal Plain Between Brazos River and Rio Grande. Am. Assoc. Petr. Geols., Bull., Vol. 29, 1945.

[31] Doering, John: Post-Fleming Surface Formations of Coastal Southeast Texas and South Louisiana. Am. Assoc. Petr. Geols., Bull., Vol. 19, pp. 651, 1935.

Typical Willis Vegetation, Polk County



Typical Willis Vegetation and Topography, Polk County



Typical Willis Vegetation Newton County

5. Lime Content:[32]

Average Lapara sand. 41.05%

Average Lagarto Creek sand 38.45%

Average Lissie and Willis. . . . . . . .None

Average Beaumont Clay. 14.71%

6. Vegetation - The Willis is dominantly covered with a thick growth of trees and shrubs, while the Lissie is characteristically a treeless plain, and the Fleming is sparsely dotted with deciduous trees.

AGE:

No fossils have been reported from the Willis. This in itself is a surprising fact since it would seem logical that in the extensive removal of the formation in gravel pits at least some form of life would have been unearthed, but apparently leaching in the formation has been complete enough to destroy any remains.

The Willis is overlain unconformably by the Lissie formation from which Pleistocene vertebrate remains have been reported. These include Bison latifrons (Harlan), Elephas columbi Falconer, Elephas imperator Leidy, Equus excelsus Leidy, Equus francisi Hay, Equus complicatus Leidy, and Equus semiplicatus Cope.

Near the Colorado River, and elsewhere, the Willis rests unconformably on the typical Goliad sandstone. A few vertebrate remains have been recovered from the Goliad, among these, Hipparion ingenum (Leidy) and Teleoceras cf. T. fossiger (Cope). These forms are regarded

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[32] Bailey, T. L.: The Geology and Natural Resources of Colorado County. Univ. of Texas Bull. 2333, 1923.

Willis-Goliad Contact Ten Miles West of Courtney, Grimes County

Willis-Goliad Contact South of Halletsville, Lavaca County as Pliocene in age, consequently, on the basis of faunal evidence and superposition of beds, the Willis is here considered as Lower Pleistocene.

The origin of the Willis is intimately related to the widespread glaciation that was taking place in North America about the same time. Most students of the North American Ice Age believe that the Pliocene included the cooling down of the earth in preparation for the Ice Age, and some believe that glaciation began in that period. Most authorities, however, believe the coming of the ice sheets marked the transition from the Pliocene to the Pleistocene, so that the whole of the Ice Age belongs to the latter. Chamberlin and Salisbury state it as follows:

> "This old surface, this horizon of oxidation, weathering, and erosion; this horizon below which glacially derived materials do not occur, and above which they are present, we hold to be the dividing plane between the Pleistocene and Pre-Pleistocene formations." (Chamberlin and Salisbury, 1891)

During all of the Tertiary preceding the Willis, the sediments deposited on alluvial coastal plains and in the Gulf were characterized by muds. Only occasionally were sands brought into this area. Gravels are even more rare and usually very fine. There are no gravels comparable to the Willis in any of the formations older than the Willis, nor are there any such gravels in the streams today other than those which have caved in from the banks. From this it seems obvious that the deposition of the Willis required special conditions which must have prevailed generally over the Gulf Coast.

It is known that special conditions did exist during the Pleistocene. Vast ice sheets extended south into the mid-western states, and this presence of ice on the land lowered the sea level, thus rejuvenating the streams. Clouds moving north from the Gulf of Mexico contacted the cool air of the glacier, condensed and fell as rain. This increased rainfall couples with the melting of the glacier made surging torrents of the streams and tremendous amounts of material were transported and deposited. On the basis of stratigraphic position and leaching, the Willis period of entrenchment and alluviation has been correlated by Weeks with the Nebraskan Glacial and Aftonian Interglacial ages.[33]

GEOLOGIC HISTORY AND DEPOSITION:

Assuming the Willis to be Pleistocene in age, the sequence of historical events follows:

After the deposition of the Fleming and before the deposition of the Willis, the coast was tilted about 25 feet per mile seaward. A comparatively flat erosional surface was developed on the Fleming, extending back to the cuestas of the first hard formations, the Oakville and Catahoula formations. This stripping of the Fleming probably provided much of the material for the thick Pliocene clay section found near the coast.

The strong development of the Oakville in Central and Southwest Texas provided that area with a source of sandy material which was not available in East Texas and Louisiana.

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[33] Weeks, A. W.: Quaternary Deposits of Texas Coastal Plain Between Brazos River and Rio Grande. Am. Assoc. Petr. Geols., Bull., Vol. 29, 1945.

After the Goliad, the coast was again slightly tilted and erosion attacked the Catahoula and Oakville formations, contributing much coarse sand to the Willis. About the same time the great ice sheet was retreating from the Middle-West, and its melting coupled with the tremendous increase in rainfall, accustomed by the glacier, made surging floods of the rivers and streams.

It is thought that during Willis time, the area now covered by the veneer of gravels was a flat featureless plain close to sea level. The rivers flowing out onto this plain from a region of greater relief would drop their loads to form broad deltas. These channels would be constantly clogged with debris and the streams would be continually changing their channels and flood plains back and forth until these alluvial fans coalesced and formed a more or less continuous alluvial apron, similar to that at the foot of steep mountain ranges today.

The stream gaps through which the Willis was discharged and the interior extension of the formation have now been destroyed by erosion and the Willis now found at the surface is part of the Willis plain developed at a distance from the gaps. The Willis in all probability extended up the principle streams at one time, much as the Lissie and Beaumont do at this time and some of the gravel outliers upstream and on the interior inter-stream areas have been correlated with the Willis. Some of these may be, in fact, equivalent, but they are not continuous with the main body of the formation and the determination of their exact age is difficult. In this paper, the writer has excluded all outliers unless they could be conclusively shown to be Willis.

It seems probable that the Balcones faulting, which cannot be very ancient because its scarp is so well preserved, took place just prior to Willis time. The erosion of this scarp and the elevated area behind it would furnish many of the chert and flint pebbles that are found in the Willis.

The streams which deposited the Willis were the ancestors of our present streams. At this time, they were developing their patterns of drainage. During each succeeding cycle, they retained their drainage pattern, simply depositing new material farther south.

After its deposition, the Willis was probably tilted seaward 10 to 15 feet per mile, thus rejuvenating the streams, first in their lower courses and subsequently upstream. The first action of the streams was to cut trenches in the Willis plain and later the removal of much of the interior extensions of the gravels.

This interior erosion brought down a flood of sediments which formed the Lissie formation. These sands and silts were first deposited at the mouths of the streams, but they eventually coalesced and merged to form a continuous blanket of sediments, with the upstream fingerings, which we find today.

The Lissie cycle was brought to a close by new and smaller flexing of the coast, and the period of erosion and deposition of the Beaumont clays ensued.

ECONOMIC CONSIDERATIONS

AGRICULTURE:

The Willis formation forms the poorest land for agricultural purposes of all the upper formations on the Gulf Coast. Its coarse sandy and gravelly soil forms what is often referred to as the "Post Oak Belt", after the dense growth of scrub trees, particularly Post Oaks (Quercus stellata) and Live Oaks (Quercus virginicus) which characterize the outcrop.

Agriculture is commonly confined to livestock grazing; particularly cattle and hogs, but even these eke out a scanty existence in the dense undergrowth.

In the vicinity of Waller, in Waller County, and Hockley, in Harris County, the Willis forms a broad treeless, gently undulating plain on top of the Hockley Bench, and is extensively planted in rice.

In Northwestern Harris County, the pink sandy soil of the Willis forms an excellent soil for peanuts, and many hundreds of acres are devoted to this crop.

Near Hempstead, watermelons, which require a sandy soil, are widely cultivated.

LUMBER:

Southwest of Magnolia County, the outcrop of the Willis formation supports a dense growth of scrub trees and shrubs whose usefulness is limited to little more than fence posts and firewood. In Magnolia County and to the northeast, the outcrop supports a growth of trees which forms one of the best lumbering areas in Texas. Magnolia, San Jacinto, Polk, Tyler, Jasper, and Newton Counties are literally dotted with saw mills and lumber camps which form the principle industry of these counties. The yellow pine (Pinus palustris) and the loblolly pine (Pinus taeda) form the principle source of lumber, with the oaks and hardwoods subordinate.

Sam Houston National Forest and several small state forests are included, in part, in this outcrop area and both these and the private forests are carefully patrolled and regulated to prevent forest fires and the most modern methods of harvest and reforestration are employed to prevent depletion of this vast natural resource.

GRAVEL:

The Willis formation, being dominantly a coarse sand and gravel formation, furnished an excellent source for gravels throughout its outcrop area.

In any discussion on the merits of a gravel, it is necessary to consider the purposes for which it is to be used. These may be divided into two principle catagories, road gravels and concrete aggregate gravels, each having different characteristics.[34]

Road gravel may be defined as an admixture of tough hard pebbles that contains enough sand to fill in the pore spaces and a sufficient quantity of clay to cement the pebbles and sand grains together to

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[34] Nash, J. P.: Road-Building Materials in Texas. Univ. of Texas Bull. 1839, 1918.

form a hard surface. Pebbles should range between 2 inches and 1/4 inches, with no pebbles over 2 inches. A good road gravel can be used for surfacing roads without having to be mixed with other material, and many such deposits are to be found in the Willis formation. Composition, however, varies. In the vicinity of the Colorado River, the gravels are siliceous and very coarse, being composed principally of chert and quartz pebbles, with a small amount of igneous derivatives. In East Texas, the gravels are composed of chart and quartz pebbles and a large percentage of limonite nodules. In addition, they are usually not as coarse, the pebbles seldom being over 1 inch, and having a larger percentage of sand.

Road gravel is quarried extensively throughout the outcrop area, and the majority of the farm roads are surfaced with gravel from local pits. Roads in Sam Houston and neighboring National forests are surfaced with gravels from numerous pits in the forest itself. These pits are usually shallow, rarely over 5 feet deep, commonly 2 to 3 feet deep and normally covering 1 to 10 acres. The gravels are quarried with bull-dozers or graders and transported by dump-truck.

Colorado County is dotted with extensive quarries and furnishes a very high grade of gravel. These pits are quite extensive, often 30 feet deep and covering several hundred acres. The gravels are removed with drag-lines and streamshovels and transported by railrodd.

The requirements for concrete aggregate gravels differ from road gravels in that they should contain no sand or clay or clay coatings on the pebbles. Having more rigid specifications, concrete

Shallow Gravel Pit for Park Roads, Sam Houston National Forest, San Jacinto County

Shallow Gravel Pit, Polk County

gravels are naturally less plentiful than road gravels; nevertheless, they are quarried extensively in Colorado County and at a few scattered localities elsewhere.

Gravel resources in the Willis formation have scarcely been touched and many very extensive deposits have not been worked at all. It is true that much of the gravel is inferior because of size or sorting of the pebbles, but many millions of cubic yards of high grade gravels are still available. The controlling factor at the present time is the accessibility of the deposits. Most of the sizable quarries must be served by a railroad spur, and the economic feasibility of mining a deposit is dependent upon the distance from rail transportation. This is strictly a matter of economics, and as the more accessible deposits are depleted, it will become possible to profitably work the more remote deposits.

WATER:

The Willis forms the most productive aquifer on the upper Gulf Coast. It yields abundant supplies of water to shallow wells in the outcrop area and in deeper wells wherever it is reached. The city wells of Houston as well as many privately owned industrial wells and rice irrigation wells draw heavily from these sands.

In the outcrop area of the water-bearing beds, the water is generally unconfined, and there is a water table. As these sands become interbedded with clay and silt down dip, waters in the sands become confined and are under artesian pressure. In the early days of Houston, artesian wells could be obtained practically anywhere in the city area, and artesian pressures sufficient to raise the water 15 to 30 feet in the air were common. The artesian head is now over 80 feet below the surface in Houston as a result of the withdrawal of water from the sands faster than it could be replaced by the natural processes.

The Willis sand in its outcrop yields soft waters of low mineral content. A comparative analysis of the hardness of waters from shallow wells in the outcrop areas of the Lagarto, Willis, Lissie, and Beaumont formations is given in the accompanying diagrams. From this it is easily seen that waters from the Willis are by far the softer of the four.

As the waters pass down dip, there is a gradual alteration in chemical character, changing from a calcium bicarbonate, which characterizes the shallow waters to a sodium bicarbonate, which characterizes the deeper waters. This is accompanied by an increase in sodium bicarbonate, the hardness and content of the other constituents remaining about the same.[35] This is better illustrated in the accompanying illustration which shows the variation of mineral content and hardness with depth for a well drilled in Houston. This is a composite of data from numerous wells in the city and the top of the Willis formation varies from 900 - 1300 feet deep.

The Willis yields the softest waters available down dip, and is much in demand for launderies and for use in boilers where mineral content is very critical.

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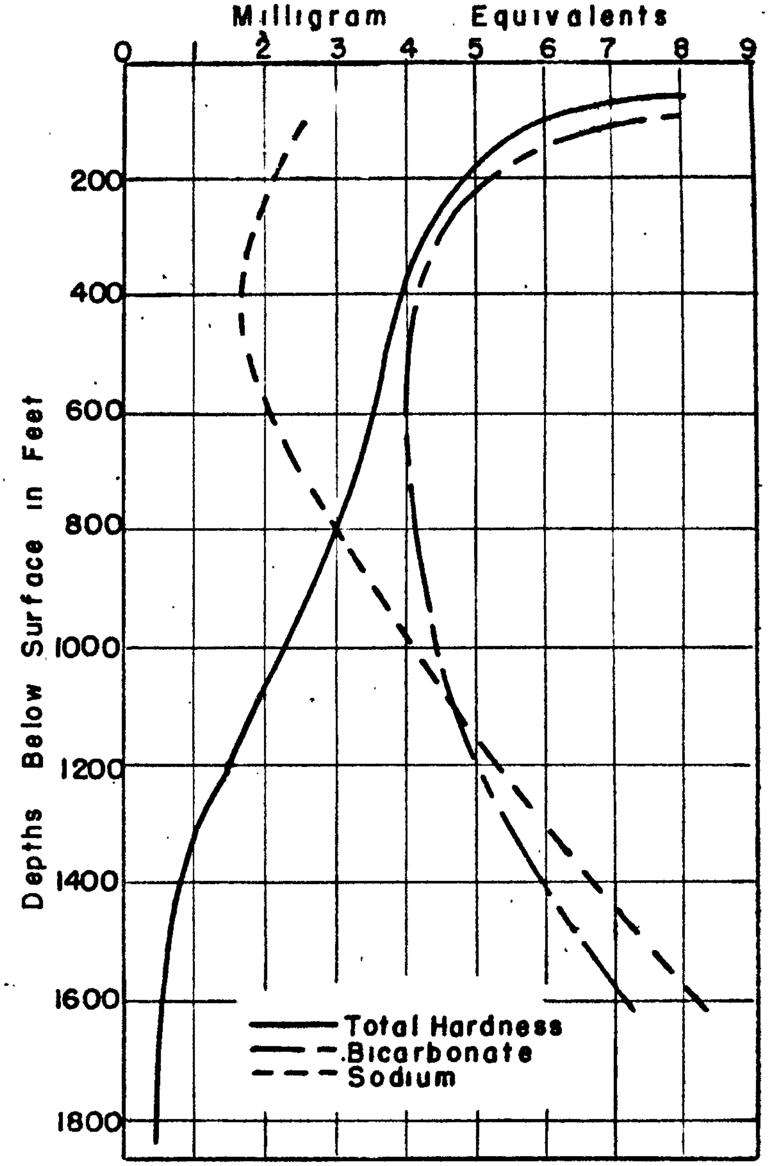
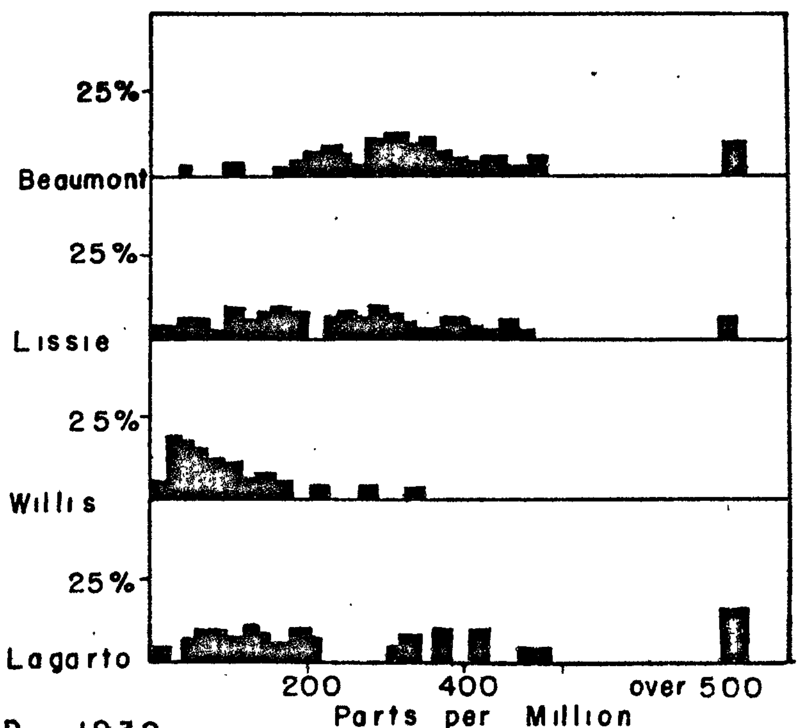
[35] Foster, Margaret D.: Ground Waters of the Houston - Galveston Area. Industrial and Engineering Chemistry, Vol. 31, No. 8, August, 1939.

Sodium and Bicarbonate Content and Hardness of Ground Waters at Differant Depths at Houston [1]



Percentage Distribution of Total Hardness of Waters from Shallow Wells in the Outcrop Areas of the Differant Formations [1].



1 after Foster, Margaret D.; 1939.

OIL:

The Willis formation produces oil around a few shallow salt domes on the Gulf Coast, but is by no means an important oil horizon.

At Spindletop, in Jefferson County, and Humble, in Harris County, are several sands of the Willis-Lissie group at depths of 600 to 1000 feet which produce oil. The oil in these sands has probably accumulated by leakage from the cap rock along small fault or fracture planes. Wells range from 600 to 1000 feet deep, and production is small. Initial production is 40 to 50 barrels per day and total production per well usually below 15,000 barrels.

The Batson Field in Hardin County produces a small amount of oil from sands of Willis age at depths of 189 feet and lower.

The Saratoga Field in Hardin County produces a small amount of oil from sands of Willis age. Some violent blowouts have even been encountered from gas in shallow pockets 200 to 600 feet deep in Willis and other sands.

It is entirely probable that certain of the shallow oil sands in the Goose Creek Field in Harris County are Willis age.

With the exception of Goose Creek,all of the production from the Willis is found in shallow sands above the more shallow salt domes. The oil itself has most likely seeped into these sands from the cap rock, rather than from any of the normal source beds.

GULF COAST CORRELATION CHART

	TEXAS			LOUISIANA		MISSISSIPPI		ALABAMA		FLORIDA
	GRP.	FORMATION	MEMBER	FORMATION	MEMBER	FORMATION	MEMBER	GRP.	FORMATION	FORMATION
PLEISTOCENE	Houston	Beaumont		Pleistocene Terrace Deposits	Prairie	Loess		Citronelle	Pensacola	Melbourne Bone Bed
						Natchez			Hammond	Miami Oolite
									Port Hickey	Anastasia
										Key Largo Lime
									St. Elmo ?	Ft. Thompson
		Lissie			Montgomery					Alachua
					Bentley					Bone Valley Gravel
		Willis			Williana					
PLIOCENE		Goliad	Labahia	No Surface Outcrops		Undifferentiated				Caloosahatchee
			Lagarto Creek							
			Lapara							
MIOCENE	Fleming	Lagarto		Fleming	Blonts Creek	Fleming	Pascagoula	Pascagoula		Choctawhatchee
					Castor Creek					
					Williamson Cr.					
					Dough Hills					
					Carnahan Bayou					
		Oakville			Lena		Hattiesburg	Alum Bluff Group		Alum Bluff Group
		Catahoula	Soledad Tuff	Catahoula		Catahoula		Catahoula		Tampa Marl
			Dunlop Quarry							
			Fant Tuff							
			Chita							

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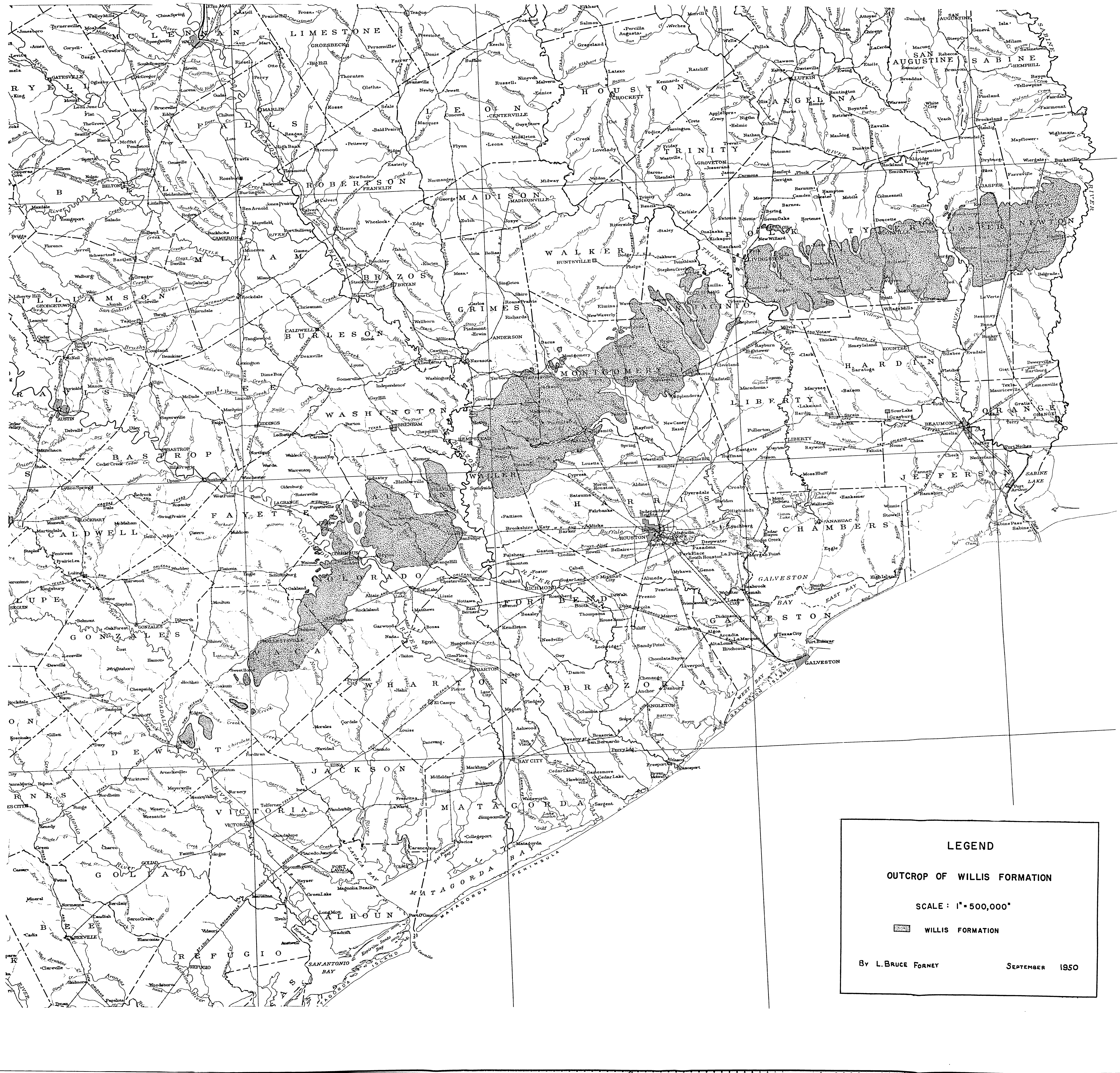
LEGEND
OUTCROP OF WILLIS FORMATION
SCALE : 1" = 500,000"
WILLIS FORMATION
BY L. BRUCE FORNEY
SEPTEMBER 1950