1943

The Physiography of Beauregard and Allen Parishes.

Wilbur Charles Holland

Louisiana State University and Agricultural & Mechanical College

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THE PHYSIOGRAPHY OF BEAUREGARD AND ALLEN PARISHES

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The School of Geology

by

Wilbur Charles Holland
B.A., Marietta College, 1931
M.S., University of Pittsburgh, 1933
June, 1943
ACKNOWLEDGMENTS

Field work was started in Beauregard and Allen Parishes in the summer of 1940 at the instigation of Dr. H. E. Fisk, Associate Professor of Geology, Louisiana State University. The summer of 1941 was also spent in the field.

The writer wishes to express his appreciation to Dr. Fisk for invaluable assistance in the mapping and interpretation of the terraces. Dr. R. J. Russell, Professor of Physical Geography, Louisiana State University, offered valuable suggestions with respect to the preparation of the manuscript. The writer is grateful to Dr. Russell for checking the field work also and for numerous consultations regarding various problems arising from this work.

The writer wishes to acknowledge the work done by the following field assistants: Mr. William J. Hendy, Jr., Mr. Alec Oaanik, Mr. Albert Melsheimer, and Mr. John T. Lockridge, Jr.

Lastly, the writer wishes to express his appreciation to his wife, Ada Morehead Holland, for proof reading and typing the manuscript.
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ABSTRACT

The area covered by this report is located in southwest Louisiana, in a section whose only surface sediments are Pleistocene sands, silts, clays, and gravel. Three distinct formations outcrop at the surface in the form of terraces, namely: the Bentley formation of Yarmouth age, the Montgomery formation of Sangamon age, and the Prairie formation of Peorian age. These were apparently deposited in response to eustatic changes in sea level as a result of glaciation; deposition took place during rising sea level accompanying waning glaciation, and erosion took place during lowering sea level accompanying waxing glaciation. Each older terrace surface is tilted more steeply than the next younger one, apparently as a result of isostatic adjustments to load at the deltaic centers.

All of the terrace formations are similar, in that they are composed of essentially the same type of material and were formed as portions of a deltaic plain. They differ chiefly in degree of slope and in the amount of dissection that they have undergone. Utilization of the following factors served to differentiate these surfaces: (1) amount of dissection, (2) percentage of regional slope, (3) presence of scarps and rim-swamp streams, (4) drainage and drainage patterns, and (5) elevation.
This paper includes a brief resume of the underlying Tertiary stratigraphy. The principles of deposition of the Tertiary sediments are stressed rather than a detailed description of these rocks. All of them are deltaic in origin. The difficulties attendant with the delimitation of stratigraphic formations within a deltaic mass are discussed.

Pimple mounds, one of the most common physiographic phenomena of this area, are considered in some detail. A fairly complete abstract of the literature on pimple mounds is included. Some twenty-five different theories for the formation of pimple mounds have been proposed. The theory adhered to in this paper is that they are erosional in origin.

Occurring on the terrace surfaces are shallow depressions, averaging about two feet in depth and about one-fifth of a mile in diameter. These depressions, typically, have a flat bottom and, being somewhat swampy, contain a dense growth of deciduous trees and shrubs that contrast sharply with the surrounding, cut-over, long leaf yellow pine areas. For this type of depression the writer proposes the term "bagol", the term that is applied locally to these features. Bagols are relict from channels of former streams that alluviated these surfaces during the Pleistocene.
INTRODUCTION

Location and Size

Beauregard and Allen, adjoining parishes, lie in the long leaf yellow pine section of the mid-southwestern part of Louisiana. (See Figure 1.) Beauregard, the larger and westernmost of the two, comprising an area of 1172 square miles, has as its western border the Sabine River, which here divides Louisiana from Texas. Directly to the north of Beauregard Parish lies Vernon Parish and to the south is located Calcasieu Parish. It is bordered on the east mostly by Allen Parish, although it has, for approximately one and one-half miles on the southern end of its eastern boundary, a common boundary with Jefferson Davis Parish.

Allen Parish lies directly east of Beauregard Parish, with its southeastern tip dipping into the great rice growing section of southern Louisiana. Its southern boundary is with Jefferson Davis Parish, its eastern boundary with Evangeline Parish, and its northern boundary with Rapides and Vernon Parishes. Allen Parish has an area of 663 square miles.
Figure 1. Index Map showing location of Beauregard and Allen Parishes.
Prehistory

The earliest known inhabitants of these two parishes were the Attakapas, a savage tribe of Indians with a reputation for eating their prisoners of war. The name "Attakapas" means "man eater". So troublesome was this tribe of Indians to the surrounding tribes that, shortly before white man came to Louisiana, several other tribes got together and fought a decisive battle with the Attakapas. The land that is now Allen and Beauregard Parishes, as well as quite a bit of the surrounding territory, was allotted to the Opelousas Indians, one of the victorious tribes. This region came to be known by the earlier settlers as the Opelousas district.

The Opelousas Indians and other smaller groups located in this area were apparently rather peaceful, because there is no account of conflict between them and the early white settlers. They mingled rather freely with these colonists, and early accounts state that in some white settlements there were actually more Indians than whites.

The sites of five Indian villages are known to some of the older inhabitants of this section. One of the better known is in Allen Parish along the banks of the Calcasieu River, about nine miles southwest of Kinder, at a place known at the present time as Indian Village.
In Beauregard Parish there were four Indian village sites located as follows: (Fraser, 1933, p. 18).

a. Six or seven miles south of Sugartown on Indian Branch near the home of J. J. Young.

b. Just north of the W. B. Welborn home on Bundicks Creek.

c. Near the mouth of Anacoco Creek.

d. Merryville, on the Frazier farm where the High School now stands.

Early Settlement

Chiefly because of the unfavorable geographic location, no early attempts were made at colonization of the area that is now Allen and Beauregard Parishes. These parishes lie in what was called the "neutral strip", a true "no-man's land", separating Spanish Mexico from French Louisiana. Because it was claimed by both governments, the laws of neither were obeyed. Thus, this area became a refuge for all kinds of outlaws, but attracted few permanent settlers. Its remoteness discouraged settlers; all early trade routes converged toward Natchitoches, well to the north.

After Louisiana was ceded to Spain, in 1763, efforts were made to get colonists into this region. Each emigrant was given a square league of land, a certain amount of provisions, farming implements, and cattle. As a result, the population of the Opelousas District jumped from 409 persons in 1769 to 1,985 in 1788. It is probable that
many Acadians, who arrived in Louisiana between 1765 and 1790, found their way into this section. Other grantees were of French, Spanish, and English origin. A few larger grants of land were made, mostly later. Notable among these larger grants was one in 1797 to Jose M. More, who was granted a large tract of land between the Río Hondo (the Calcasieu River) and the Sabine River.

Many of these grants were not recorded. Although this caused no trouble during the Spanish period, it caused no end of controversy after the United States bought Louisiana in 1803. It was not until 1819 that Mexico relinquished her claim to the "neutral strip" by treaty with the United States. One of the provisions of this treaty, however, was that the United States agree to recognize the Spanish grants wherever proof of ownership could be established. In 1823 Congress passed an act providing for the execution of the title to the land in the "neutral strip", and agreed to take, in default of any authentic data, the testimony of reliable witnesses.

Following the acquisition of this section by the United States most of the "desperadoes, outlaws, and filibusters" moved out but some "remained and reformed". The first really permanent settlers began to come into this territory about 1816. It is to be noted that, during these early years, the French and Acadians settled largely in the southern part of Allen Parish in the prairie section,
mostly east of the Calcasieu River, where, even today, their descendants are quite numerous. People of the Anglo-Saxon stock settled in the northern part of Allen Parish and in Beauregard Parish. The earlier Anglo-Saxon peoples came for the most part from the southeastern states, particularly South Carolina, Georgia, Mississippi and Florida. These were followed later by people from the mid-west and a few from New England.

In Beauregard Parish, Sugartown is credited with being the first white settlement, and also with having the first school, the Sugartown Male and Female Academy which started in 1879 and was operated for two years. To this settlement also goes the honor of having the first cotton gin in southwest Louisiana. Dry Creek and Big Woods, also white settlements, followed soon after Sugartown. There were several other settlements, chiefly lumber mill towns; typical of these are Merryville, De-Ridder, and Longville.

In Allen Parish, Kinder and Oakdale were established after the Kansas City and Gulf Railway was surveyed. Oberlin was founded by residents of Oberlin, Ohio, and was originally intended to be a college town. Elizabeth started as a lumber mill town.
On June 8, 1807, the parish of St. Landry was established as one of the original nineteen civil parishes of Louisiana. This parish covered much of the southwestern part of the state. On March 24, 1840, Calcasieu Parish was created from a part of old St. Landry, and, in 1870, Cameron Parish was carved from Calcasieu. Calcasieu Parish, then covering an area of about 3,600 square miles, included what are now Calcasieu, Jefferson Davis, Allen, and Beauregard Parishes. Between 1870 and 1912 it was the largest parish in the state and, for this reason, was called Imperial Calcasieu. In 1912 it was divided into four separate parishes.

In meetings, held in June, 1911, at Oakdale and in August, 1911, at Lake Charles, attended by representatives from various parts of the parish, it was agreed to divide the parish. Delegates selected by an election held in October, 1911, chose parish division lines. Their findings were presented to the State Legislature in May, 1912. The three parishes, Jefferson Davis, Allen, and Beauregard, that separated from Calcasieu were officially recognized as of January 1, 1913.
Until quite recently a virgin forest of long leaf yellow pine covered all of Beauregard and a large part of Allen Parish; the southeastern portion of Allen Parish was a prairie. This pine forest was open, broken only by dense growths of deciduous trees and shrubs along the flood plains of all the streams. Lumbering, naturally, was one of the first important industries. The cultivation of rice is the most important industry in the southern part of Allen Parish.

Several of the communities which first started as lumber mill towns are the parishes' most important civic centers of today; others, so started, are now but ghost towns.

Between 1910 and 1920 both Beauregard and Allen Parishes showed a population increase of between twenty-five and fifty per cent. This influx of people was due to the lumbering industry which was at its peak about 1915-1920. Between 1920 and 1930, after the timber of this area had been largely cut over, both of these parishes showed a population decline. The 1930 census showed that Beauregard Parish had lost thirty per cent of its 1920 population and that Allen Parish, which is not quite so dependent upon the lumbering industry, had lost seventeen per cent. By 1940 both parishes showed an increase in
population over that of 1930, largely as a result of people moving in to pursue agricultural vocations. The 1940 population of the two parishes, as well as that of the larger towns, is shown in the tabulation which follows. (1940, 16th Census, U.S.)

<table>
<thead>
<tr>
<th>Parish</th>
<th>Population</th>
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<tbody>
<tr>
<td>Allen Parish</td>
<td>17,540</td>
</tr>
<tr>
<td>Oberlin</td>
<td>962</td>
</tr>
<tr>
<td>Oakdale</td>
<td>3,933</td>
</tr>
<tr>
<td>Reeves</td>
<td>120</td>
</tr>
<tr>
<td>Kinder</td>
<td>1,415</td>
</tr>
<tr>
<td>Beauregard Parish</td>
<td>14,847</td>
</tr>
<tr>
<td>DeRidder</td>
<td>3,750</td>
</tr>
<tr>
<td>Merryville</td>
<td>1,216</td>
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</table>

While the importance of the lumbering industry was gradually decreasing, the agricultural pursuits were gradually increasing in prominence. There has been a continual and gradual increase in the number of farms; also during the last decade the number of full owners increased while the number of tenant farmers decreased. The majority of the farms are between 10 and 100 acres in size, and, in the two parishes together, there are but seven farms of over 1000 acres each.

With the exception of the rice growing center of southeastern Allen Parish, there still is a relatively small percentage of the area under cultivation. The cut-over timber land is, for the larger part, open range; grazing is one of the more important agricultural pursuits. Reforestation, which is just getting well started, is most advanced in Allen Parish.
There are three lumber mills and one paper pulp mill in Allen Parish. Beauregard Parish has one lumber mill. More timber is brought to these mills from areas outside of these two parishes than is produced locally. To the south of Beauregard Parish, at DeQuincy, is a wood distillate plant which derives most of its raw material (pine stumps) from Beauregard and Allen Parishes.

There are several railway lines serving these two parishes. The Missouri Pacific line runs across their southern edge, passing through the towns of Kinder, Reeves, and through DeQuincy which lies just south of Beauregard Parish. Another branch of the Missouri Pacific, running from Lake Charles to Alexandria, passes through Kinder, Oberlin, and Oakdale. A branch of the Southern Pacific runs north-south through Beauregard Parish, passing through Longville and DeRidder. Another north-south railroad in this parish is the Kansas City Southern, which passes through DeQuincy, Singer, and DeRidder. The Gulf, Colorado and Sante Fe Railroad runs from Oakdale in Allen Parish to Elizabeth, thence into Vernon Parish and then enters Beauregard Parish near DeRidder and continues to Texas by way of Merryville.

The area is served by a fairly good network of roads. There is one paved road running east-west across the southern part of the two parishes, and a paved road bisects each parish in a north-south direction.
tion there is a hard surfaced road from DeRidder to Kerryville. Several gravel roads transverse these parishes. Within recent years, through cooperation with the Civilians Conservation Corps, a considerable number of secondary roads have been built.
Maps

United States Geological Survey planimetric maps are available for all of Beauregard and Allen Parishes. These maps, which are deficient in that they are not contoured, are constructed on a scale of 1/31,680, or two inches to the mile, and were compiled from aerial photographs. Following is a list of these maps covering the two parishes:

### Allen Parish

<table>
<thead>
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<th>Place</th>
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<td>Steep Gulley</td>
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<td>Bayou Blue</td>
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<td>1935</td>
</tr>
<tr>
<td>Glennmore</td>
<td>1935</td>
<td>LeBlanc</td>
<td>1935</td>
</tr>
<tr>
<td>Beaver</td>
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<td>Oakdale</td>
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<td>Elizabeth</td>
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<td>Kittie</td>
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### Beauregard Parish

<table>
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In addition to the preceding maps, the ones prepared by the Louisiana Geodetic Survey for the Louisiana Highway Commission were also very useful. These are advance maps on a scale of 1/62,500 and are not contoured, but they show the location of all bench marks and their elevations. The following maps cover both parishes, with the exception of the southeast corner of Allen Parish.

Beauregard and Allen Parishes

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<th>Year</th>
<th>No.</th>
<th>Name</th>
<th>Year</th>
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Other useful maps available include:


Louisiana Highway Commission
Allen Parish Map, scale 1/63,360
Beauregard Parish Map, scale 1/63,360
STRATIGRAPHY

General

A consideration of the physiography of a region involves a knowledge of the nature of the underlying sediments. Although only those sediments immediately underlying the surface are of primary interest to the geomorphologist, the entire Tertiary column of this area will be briefly considered, because the conditions prevailing throughout the Cenozoic were not greatly dissimilar to those prevailing at the time of deposition of the surface sediments.

There is no outcrop of Tertiary or older rock in either Beauregard or Allen Parish. The entire surface is blanketed by three Pleistocene terrace formations, the Bentley formation of Yarmouth age, the Montgomery formation of Sangamon age, and the Prairie formation of Peorian age, which are, themselves, locally obscured by deposits of recent alluvium along the streams. None of the Pleistocene formations are indurated in this area. Individually, they consist of interbedded sands, silts, and clays with, locally, some gravel.

The Tertiary formations are known only from wells that have penetrated them. In Beauregard Parish there are two oil fields, the Neale field and the Bancroft field,
both in the western side of the parish. The North Elton field in the southeastern part of Allen Parish is that parish's only field. In addition to these three fields there are 36 wild cat wells scattered over the two parishes. Data obtained from the electrical logs, driller's logs, well samples, cores and paleontology reports of these borings (where available) present a fairly comprehensive picture of the subsurface stratigraphy of this area.

The Tertiary in this area consists of deltaic sediments, chiefly sands, shales, and brackish-water marls, with some marine sediments. These alternate in a somewhat orderly sequence. The contact between any two types is never sharp. These sediments are intertongued. Their thickness is not constant but varies within rather wide limits. With the exception of the Claiborne, they increase or decrease in thickness toward either the southeast or southwest.

A great deal has been written about the Tertiary sediments of the Gulf Coast, and various theories have been offered for their origin. Any theory presented must be in agreement with several observable facts. The alternation of marine, brackish-water, and continental sediments within limited vertical and horizontal ranges is a major factor to be considered. The predominance of continental and brackish-water sediments and the limitation of true marine beds to but a few places in the
column is quite significant. The intertonguing of sediments, transitional formational contacts, and the absence of any but very minor unconformities is of prime importance. The last fact which must be explained by any theory is the localization of great thicknesses of several of the formations and their rapid thinning in all directions away from these centers.

Continuous sedimentation on a subsiding deltaic area is the thesis adhered to in this report for the mode of accumulation of the Tertiary sediments. The entire Gulf Coast area from Texas to Florida received sediments from the beginning of the Tertiary through the Miocene. At any particular time sediments accumulated more rapidly under the positions of the deltas proper, and at any one particular time there may have been several main deltas in this region. The inter-delta areas received brackish-water, or even marine, sediments at the same time that continental sediments accumulated on the delta proper. Major shifts in the positions of the deltaic distributaries, and even of the delta itself, took place many times. This entire area is characterized by both vertical and horizontal transitions from continental through brackish-water to true marine sediments.

When considered as a whole, this deltaic area has subsided at a relatively rapid rate. The movement has
been progressively downward; the only upward movement has been landward beyond the hinge line of the subsiding area. Subsidence is assumed to have been rather uniform for the area as a whole but characterized by more rapid sinking under the positions of the deltas proper. Transgressions and regressions of the sea, resulting in the intertonguing of continental, brackish-water, and marine sediments is not the result of the rate of subsidence; it is, rather, the result of the shifting of the positions of the deltaic centers and, thus, locally, of the amount of sedimentation.

When a stream enters a body of standing water it is forced to drop its load as a result of a checking of its velocity. The coarsest material is dropped first and the finest material is carried out some distance from this point. The deltaic deposit thus formed grows both laterally and vertically. The deltaic distributaries keep one or more channels open into deeper water by the confinement of the channels between natural levees which are maintained above sea level for a distance out in front of the deltaic marshes. As more sediments are deposited, these distributaries extend themselves seaward, and the interdistributary area gradually becomes silted up. Thus the delta grows seaward and the sea regresses. Regressive continental sand and silt deposits accumulate over older brackish-water and marine sediments. It must be remembered,
however, that at the same time these regressive sands are accumulating brackish-water and marine clays and marls are being deposited contemporaneously out in front of and on both sides of the delta.

The weight of the accumulated sediments is eventually sufficient to initiate subsidence. There is a lag between the accumulation of sediments and the actual sinking; a considerable volume of sediments must accumulate before subsidence starts (since the subsidence is assumed to be the result of the weight of the sediments), and, after sedimentation has ceased locally, subsidence continues until an equilibrium is reached. Undoubtedly this subsidence is a result, in part, but not completely, of continued compaction of the sediments under load.

As the natural levees of both the main stream and the distributaries continue to build upward, the level of the channels is built up higher than the surrounding marshes. During times of flood, both major and minor changes in the positions of the stream may take place. Although active sedimentation may cease at any one place on the delta, subsidence continues. Inasmuch as the area is already practically at sea level, subsidence allows the sea to transgress, thus producing brackish-water or even marine deposits over the older regressive sands. Major changes in the position of the delta, as have taken place in recent times in the course of the
Mississippi River (Russell, 1940, pp. 1201-1211), may allow a great portion of the delta to become covered with transgressive deposits.

Transgressions by the sea may also take place as a result of a decrease in the volume of sediments being carried to it by streams, and, conversely, a rapidly regressing sea may result from an increase in the volume of sediments being transported. It is assumed, however, that, although locally important, this factor was of minor importance for the region as a whole. The general trend throughout Tertiary time was toward the formation of regressive deposits with the sea being shoved farther and farther back. The major and minor regressions and transgressions of the sea resulted in the complex inter-tonguing exhibited by Tertiary sediments of the Gulf Coast.

As a result of subsidence, the thickness of the deltaic sediments assumed great proportions. Under the position of most active sedimentation, the thickness of sediments may reach several thousands of feet. The great accumulation of sediments resulted in the formation of bowl shaped masses underlying the deltas, with handle-like extensions up the main contributory streams, a shape which in recent deposits has been described as being like a ladle (Russell, 1940, p. 1213). (1)

(1) Although Russell (1940) was the first to apply the term "ladle" to the shape of these deltaic sediments, their outlines had been previously delineated by Frink (1939, Master's Thesis, L.S.U.), by means of isopach lines. This work was published by Frink in 1941.
In this conception of the mode of accumulation of the Tertiary sediments, time lines do not follow lithologic breaks. Brackish-water clays and lignitic silts were being deposited in the marshy interdistributary and marginal lagoons at the same time that continental deposits were accumulating on the delta, while, off shore, marine marls and sands were being laid down. Thus, formations which are typically established on lithology are not necessarily to be considered as being of the same age in different localities. A major transgression of the sea will allow brackish-water clays to accumulate over continental sands. The same, much thicker, brackish-water clay unit in an adjacent locality must not be considered to be younger than the intertongued, and locally underlying, sand. For the larger part, they were deposited contemporaneously; time lines cross from one into the other and do not follow the lithologic break.

Marker fossils, likewise, must not be considered as exact time indicies. In thick marine sediments, such as the Eocene of Florida, where environmental conditions remained uniform over a great length of time, correlation lines drawn on diagnostic species may be considered essentially as time lines. Environment in such an area plays a relatively unimportant role in the development of new forms. However, in an area such as Louisiana, where ecological conditions have been continually changing, this factor is of prime importance in evolution.
Within limited areas, as within one oil field, the
telzones of index fossils may be used for correlation
purposes with the assurance that such correlation lines
will lie essentially parallel to time lines. On the
other hand, where correlation is done over a larger area
on the basis of the telzones of marker fossils cogni-
sance must be taken of the fact that that particular
marker fossil may have lived in one area at about the
beginning of its existence as a distinct species and at
another area at about the end of its existence. Corre-
lation lines thus drawn cross time lines, and the greater
the heme of that particular species, the greater the
possibility of error in correlation.

The apparent stratigraphic range of a species when
observed at a number of localities may be quite small,
while, in reality, its biozone may be quite large.
Correlation work done on the basis of biozones is
accurate and such correlation lines will lie parallel
to actual time lines. The difficulties attendant with
the delimitation of the biozone of a marker fossil is
herein recognized and it is merely recommended that
cognizance be taken of the fact that correlation lines
drawn on the telzones of such forms do not necessarily
 correspond to time lines. The presence of a particular
fossil in about the same position lithologically in the
section may be merely a reflection of similar environ-
mental conditions rather than of a limited stratigraphic
range.
The Tertiary sediments of the Beauregard-Allen area, being deltaic in origin, record many major and minor transgressions and regressions of the sea by their very complex intertonguing. For the larger part, the movements have been regressive; that is, the coast line has retreated farther and farther seaward. Within the Tertiary section, however, there are many brackish-water and even marine sediments, indicative of both major and minor transgressive movements.

Because of the complex intertonguing of sediments, it is very difficult to establish formational boundary lines. The formations were first established at type localities and may be traced along their strike to outcrops in the parishes to the north of Beauregard and Allen Parishes. At these surface outcrops they have a distinctive lithology as well as, in most cases, a distinctive faunal content. When these same formations are encountered in wells down dip from their outcrops, the lithology may be quite different. The faunal content also typically changes as different environments of deposition are encountered. Under these conditions, the correlation of formations on the basis of lithology alone is subject to considerable error. Even when lithology is used in conjunction with marker fossils, it must be realized that units in widely separated areas are not exact time equivalents merely because their lithology and faunal content are the same.
Although recognizing that a formation in one part of the parish may not be the time equivalent of a formation in some other part, the writer retains the accepted nomenclature for the Tertiary units of the Gulf Coast. This is in conformity with most subsurface correlation work in this area. Hereafter, the word formation as used in this bulletin implies a stratigraphic unit having at different places a comparable lithology and a similar fauna. It does not imply that they were deposited contemporaneously.

Each formation in these two parishes is a wedge-shaped unit whose thickness generally increases down-dip. If the complete picture were available over the entire Gulf Coast, it would be seen that these formations have a wedge shape only locally. In their entirety their shapes are that of large, bowl-shaped masses underlying the deltaic centers of accumulation and whose thicknesses decrease away from their centers in all directions.

The oldest formation encountered by deep borings is the "Wilcox" of lower Eocene age. (1) This formation,

(1) A recent well in the Neals field, the Atlantic-Hawkins unit 1 well, may have penetrated to about 600 feet below the bottom of the "Wilcox". Incomplete information is available at the time of writing, but that available indicates that the bottom of the sands is at about 12,000 feet, below which is about 300 feet of sandy shales and below that another 300 foot unit of shales. This 600 foot unit may represent, in part, or in its entirety, the Midway group.
consisting chiefly of non-marine sands with minor shale breaks, overlies the Midway brackish-water or marine shales which in these two parishes is so deep that no wells have penetrated to it. The Wilcox represents, in general, the encroachment of non-marine deltaic sediments over the marine Midway.

Overlying the Wilcox is the Claiborne group, consisting of the Cane River, Sparta, Cook Mountain, and Cockfield formations. The two oldest Claiborne formations, the Cane River and Sparta, are similar to the Midway-Wilcox, in that the Cane River is composed of brackish-water and marine shales and marls deposited by a transgressing sea and the Sparta is chiefly a sand deposited as a deltaic accumulation near the margin of a regressing sea. The Cook Mountain and Cockfield formations overlying the Cane River and Sparta are a similar sequence, the Cook Mountain representing the transgressive phase and the Cockfield the regressive sands. In this area the entire Claiborne group is relatively far removed from the seat of active deposition of the Sparta and Cockfield deltas. The down dip equivalent of the Claiborne is entirely shale in the Rumble-Edgewood well number B-1 in southern Beauregard Parish.

Overlying the Cockfield is the Jackson group of upper Eocene age and above the Jackson is the Vicksburg
group of Oligocene age. These two groups are inseparable lithologically, but distinct faunally, and consist primarily of brackish-water and marine sandy shales and marls.

The youngest formations of Tertiary age in this area are the Catahoula and Fleming formations of Miocene age. Both consist of sands with minor shale breaks and locally some few small tongues of brackish-water shale and marine marls. These two formations are indistinguishable on electrical logs but may be separated where samples are available in that the Catahoula contains some volcanic ash. They are also separable faunally.

The Pleistocene formations overlying the Miocene sands, and outcropping on the surface in Beauregard and Allen Parishes, represent a departure from the more or less orderly sequence of intertonguing. This departure is the result of oscillations of sea level during Pleistocene glaciation. It resulted in the peculiar set of conditions as outlined in the section on physiography.

In addition to the major formational intertonguing, minor intertonguing within the formations, and particularly along formational boundaries, is very common. This presents a very complex picture which makes the separation of lithologic units into formations very difficult.
With the possible exception of one well, no boring in either Beauregard or Allen Parish has, as yet, penetrated to the Midway group. This exception is the Atlantic-Hawkins Unit 1 well in the Neale field, which, after penetrating 3650 feet of typical Wilcox sands, went through 300 feet of shale with but little sand and 300 feet of even less sandy shale. This lower 600 feet may represent the Midway, although no cores or cuttings are available to the writer. With the limited data on hand, it cannot be stated definitely that this lower 600 feet of material is the Midway; it may be shaley Wilcox sediments.

In addition to wells in the Neale and Bancroft fields, nine wildcard wells have been drilled into the Wilcox formation in these two parishes. Although the thickness of the Wilcox is not known in this area, it probably does not exceed 3800 feet in these two parishes. Likewise, nothing definite is known of its lower contact here. Available evidence from the Atlantic-Hawkins Unit 1 well in the Neale field indicates that its lower contact is transitional over a relatively thick zone.

(1) In spite of the probable invalidity of the term "Wilcox", it is being retained in this report in preference to the more appropriate term "Sabine". This is in conformance with common usage.
The Midway and Wilcox are thought to be essentially contemporaneous, the Midway representing the marine and brackish-water phase and the Wilcox the dominantly continental phase. There were two deltas during Midway-Wilcox time in this vicinity. One was located northward from the Beauregard-Allen area, near the Texas-Louisiana line, and the other far to the east in Mississippi. The Beauregard-Allen area, being fairly near and seaward from the westernmost of these two deltas, shows a great amount of interfingering of thin shale stringers into the typical Wilcox sands. Underlying the Wilcox delta proper there are thick units of channel sands. The absence of these thick channel sands, as indicated on electrical logs of the wells, and the presence of alternating thin shale and thin sand units, called "blanket sands" by Meyers (1939, p. 153) is, in itself, sufficient indication of the fact that these sediments accumulated on the seaward portion of a delta. Farther to the south and to the east there should be still greater interfingering of shale. It is possible to tell, on an electrical log, the approximate position of the well with respect to the delta by the nature of these winnowed sands.

It is probable that, in this area, the contact of the Wilcox with the underlying Midway is transitional. In a seaward, near-delta area, it is to be expected that this transition zone would be quite thick, with shale lenses
occurring well up into the sands and sands well down into
the shales. If the lower sediments in the Atlantic-
Hawkins Unit 1 well in the Neale field are Midway, then,
in this case, the transition zone is somewhat over one
hundred feet thick.

The upper contact of the Wilcox, on the other hand,
is relatively sharp. This contact between the dominantly
sand section of the Wilcox and the dominantly shale
section of the lower Claiborne can be easily determined
to within a few feet on electrical logs. In well samples
the appearance of lignitic sands marks the top of the
Wilcox. Although this contact is comparatively sharp, it
is transitional within a relatively short stratigraphic
range. There is no evidence in either Beauregard or
Allen Parish that an unconformity separates these two
formations. Deposition was apparently continuous from
Wilcox through Claiborne time, and the sharp break in
lithology represents merely a rather quick change in the
rate of sedimentation, probably a major shift in the
position of the deltaic center, which allowed subsidence
to continue until the Claiborne seas began to transgress
over the formerly active delta. Cessation of active
deposition of non-marine sands in this area probably did
not take place at the same time throughout the entire
area, and so this lithologic break should not be thought
of as a time line.
The Wilcox is dominantly a non-marine, deltaic sand of relatively coarse texture (implying rather rapid deposition). There are many shale lenses, some of which are brackish-water and marine shales, but all are of comparatively small magnitude, both vertically and horizontally. The sand has a relatively high porosity in most places. The shale lenses are not continuous over any large area; even within a single field it is impossible to correlate between wells on the basis of these lenses. Typically, the Wilcox contains lignitic materials and, locally, even thin beds of lignite.

The lenses of brackish-water and marine shales within the section were apparently deposited when there were minor transgressive movements of the sea in response to a change in the rate of supply of sediments to that area. With a slowing down of the accumulation of sediments locally, probably as a result of shifting of the deltaic distributaries, the lag in sinking of the delta approached an equilibrium with the rate of supply, and brackish-water invaded the former deltaic land mass. Within these thin brackish-water shales of the Wilcox are some brackish-water fossils. No foraminifera that are of specific value for correlation purposes have been described from these tongues. In the Ville Platte field in Evangeline Parish, lying just to the east of Allen Parish, an undetermined species of *Discocyclina*, occurring 200 feet
below the top of the Wilcox, is locally used for correlation. However, it has not been reported in any other part of the state (Culbertson, 1940, p. 1916).

Claiborne

In southeastern Beauregard Parish and southern Allen Parish, the Claiborne sediments are entirely shales. In the northern part of these parishes the Claiborne is represented by four formations: two sand units and two shale units. These formations, from oldest to youngest, are the Cane River, Sparta, Cook Mountain and Cockfield.

All sediments of the Claiborne in the Beauregard and Allen Parish area accumulated on the seaward, down-dip side of two relatively small deltas. This area was probably southeast of the main Cockfield delta and southwest of the Sparta delta. Both the Cockfield and the Sparta formations thicken northward from this area and both are entirely shale in southern Beauregard and Allen Parishes.

The thickness of the Claiborne as a unit increases from about 2500 feet in the northern part of Beauregard Parish to about 3000 feet in the southern part of that parish; no greater thickness is known in Allen Parish. This increase comes about entirely within the shale section because both sand units decrease in thickness and completely wedge out southward.
Cane River. The Cane River formation is a brackish-water and marine clay and marl. It contains very little sand but does contain considerable glauconite.

The lithologic contact of the Cane River with the underlying Wilcox is quite sharp. In the northern part of the parishes its contact with the overlying Sparta formation is sharp also, but toward the south there is no such lithologic distinction between the Cane River and Sparta formations.

Because of the difficulties attendant with the delimitation of the upper formational boundary line in the southern part of this area, no exact figures can be given for the thickness of the Cane River formation in these parishes. In the northern part of the parishes, however, its thickness varies between 300 feet and 675 feet, the increase in thickness being down dip.

Sparta. The Sparta formation consists chiefly of sands with interbedded shales. Both the sand and shale units are thick. Up dip, in the northern part of Beauregard Parish, the sand units are thicker and the shale units thinner; down dip the shale units are thicker, the sand units thinner, and, in the Humble-Edgewood Well number 3-1, the Sparta has completely wedged out. Within the central part of the area the sand units are rather massive and within local areas they are persistent enough to be used for correlation purposes.
The sand of the Sparta in the sand tongues is typically less coarse than that of the Wilcox, although, locally, the Sparta contains rather coarse sands. Some lignitic materials are present with these sands.

It is not possible to state the thickness of the Sparta in this area with any degree of exactness. The thickness which one assigns to this formation will be dependent upon whether or not one includes the shale units occupying the equivalent stratigraphic position down dip. "Marker fossils" would be of little value in making such a decision because of the different environment of deposition encountered. It is the writer's opinion that the term "Sparta" should include only the sand units and the shale units within the typical Sparta sands. As such, the thickness of the Sparta would range from nothing up to a maximum thickness of approximately 400 feet, the increase being toward the north.

Cook Mountain. The Cook Mountain in the subsurface of Beauregard and Allen Parishes is dominantly a brackish-water and marine deposit. This formation consists essentially of clays and glauconitic marls. Between 100 and 150 feet from the bottom of the Cook Mountain there is a prominent, indurated glauconitic marl which serves as a basis for correlation. This marl is known to drillers as the "Sparta Lime". Attention must be called, however, to the fact that it does not belong to the Sparta
formation but to the Cook Mountain. Although dominantly a brackish-water formation, there are several marine zones within the section, recording transgressions of deeper water over the area. This is particularly true of the down-dip and lower part of the formation. Within the upper part of the Cook Mountain, especially in northwestern Beauregard Parish, there are some sands which represent the beginnings of regressive movements of the sea which culminated in late Claiborne time with the deposition of the Cockfield.

The thickness of the Cook Mountain varies less than that of the other Claiborne formations. Its average thickness in these two parishes is about 800 feet.

The presence in the Cook Mountain formation of the brackish-water Foraminifera Ceratobulimina exigua serves to distinguish this formation from the overlying Cockfield. This foraminifera, which occurs within the upper 50 feet of the Cook Mountain, is of especial value where the overlying Cockfield formation also consists essentially of shales. The only other foraminifera commonly recognized in economic work is Operculinoides sabinensis which, by its abundance, serves as a marker for the so-called "Sparta Lime".

Cockfield. The Cockfield formation consists of lignitic silty clays, silts, and sands. In the northern part of the parishes this formation consists essentially of sands
with thin shale partings. Down dip these shale lenses are thicker and the sands thinner. In the Humble-Edgewood Well number B-1 in southern Beauregard Parish, the sands have entirely disappeared and this stratigraphic position is represented entirely by shales. Since the sands are more common on the western side of the parish also, it is probable that the main Cockfield delta was located to the northwest in Texas.

Within the shale lenses of the Cockfield are brackish-water foraminifers. The appearance of *Nonionella cockfieldensis* within the upper 50 feet of the Cockfield formation is characteristic of this unit throughout these two parishes. Also occurring near the top of the Cockfield, but stratigraphically below *Nonionella cockfieldensis*, are *Discorbis yeguaensis* and *Eponides yeguaensis*. All three may be considered as index fossils for the upper Cockfield.

**Jackson-Vicksburg**

The Jackson group of upper Eocene age and the Vicksburg group of Oligocene age are herein considered as a stratigraphic unit, because they are similar lithologically and can be separated only on the basis of the fauna that they contain. At their surface outcrops they are separable and have been divided into formations on the
basis of lithology as well as faunal content. On electrical
logs in the subsurface of Beauregard and Allen Parishes,
however, separate formations, with the exception of the
Moody's Branch marl at the base of the Jackson, are not
easily recognizable. In this paper no separate formations,
with the exception of the Moody's Branch marl, are recog-
nized.

The Jackson-Vicksburg unit thickens down dip from
1100 feet to 1800 feet south and eastward across these
two parishes. The Jackson and Vicksburg are about equal
in thickness.

The Jackson and Vicksburg groups are dominantly
brackish-water deposits consisting of clays and marls.
In the upper part of the Jackson and in the lower part
of the Vicksburg are some marine marls. In its upper part
the Vicksburg is somewhat sandy.

Moody's Branch Marl. The Moody's Branch marl at the base
of the Jackson is an easily recognizable formation on
practically all electrical logs. This formation is an
indurated glauconitic marl with a thickness of not over
50 feet. It is very persistent throughout these two
parishes, as it is throughout the adjacent area. Oper-
culina vaughani is commonly recognized in most paleon-
tology reports on wells as characterizing the Moody's
Branch marl and therefore indicating that the well is
near the Cockfield.
The Jackson group may be separated from the overlying Vicksburg by the presence of *Kassilina pratti* in the uppermost portion of the Jackson. The presence of this foraminifera is indicative of a marine environment. However, it is reported in the paleontology reports of only a few wells in this locality. Either this marine invasion at the close of Jackson time was not widespread (which is highly probable), or it is not considered of economic importance to separate these two groups in the subsurface. Both *Textularia dibollensis* and *Textularia hockleyensis* extend from the base of the Jackson well up into the section and both are typical brackish-water forms. About the only species of stratigraphic importance commonly recognised in the Vicksburg is *Textularia warreni* which occurs very near the top of the section.

Catahoula-Fleming

Both the Catahoula and Fleming formations of Miocene age consist of sands with interbedded shales. At the surface in west-central Louisiana, the Catahoula consists of lignitic silts and sands with some volcanic ash. At its outcrop, the Fleming formation contains no volcanic ash but does contain several tongues of calcareous sediments. Down dip into the subsurface of Beauregard and Allen Parishes these two formations
thicken greatly and are more shaley. Locally, they may contain a brackish-water or even a limited marine fauna.

The contact between the Miocene sands and the underlying Oligocene is always transitional. On an electrical log, the approximate contact between the Catahoula and the Vicksburg may be determined on the basis of lithology. Faunally, however, this determination can not be verified. On the basis of fauna the top of the Vicksburg often is placed a few tens of feet up into the sands.

In economic reports the presence of the Frio sands is quite often noted. In Texas, these sands are lower Miocene and upper Oligocene in age. It is apparent that those sands called the Frio in southwest Louisiana are merely the lower, more massive portion of the Catahoula, and, as it is not definitely the equivalent of those called the Frio in Texas, that name is not applied in this report.

It is not possible, on electrical logs, to distinguish between the Catahoula and the Fleming. Paleontological evidence, likewise, does not offer a sharp line of demarkation. The contact is some place between the base of the abundant Rotalia beccarii and the top of the Discorbis zone. This distinction is commonly not made in economic work.

Environmental conditions at the time of the deposition of the Miocene were essentially that of a regressing
sea, resulting in the deposition of thick fluviatile sands, but marked by several transgressive stages, permitting the deposition of brackish-water deposits and some marine muds. Down dip, the brackish-water and marine tongues become thicker and the fluviatile sands thinner, although the fluviatile sands still predominate in the Beauregard and Allen Parish area.

If the Fleming formation is of Miocene age and the terrace formations of Pleistocene age, then, a time break of major proportions occurred following the deposition of the Fleming. On the basis of available date in this area, no such hiatus can be recognized; only thick basal gravels of the Pleistocene suggest an unconformity. It is probable, however, that some of the Fleming has been removed through erosion. For this reason it is impossible to give the complete thickness of the Miocene sands. These formations have a maximum thickness in the Beauregard-Allen Parish area of about 6000 feet.

Within the Catahoula formation two transgressive marine phases are commonly recognized in most paleontological reports. These are the Heterostegina zone and, above that, the Discorbis zone. No zones are recognized in the overlying Fleming formation, although the presence of the small brackish-water gastropod, Potamides matsoni, is sometimes reported.
The Pleistocene Terrace Formations

Four distinct Pleistocene formations outcrop in Louisiana in the form of terraces. The oldest of these, the Williams, is not exposed at the surface in Beauregard and Allen Parishes. The other three, the Bentley, Montgomery and Prairie, outcrop in both parishes. These formations were deposited in response to eustatic changes in sea level; a formation was deposited during waning glacial stages and erosion took place during waxing glacial stages. Consequently, they have an unconformable relationship to each other; they are probably also unconformable on the underlying Miocene formations. All of the Quaternary deposits in these two parishes are fluviatile in origin.

There are several difficulties attendant with determining the thickness of any of these formations. Lithologically, they are very similar to the underlying Miocene sands. Even where both are exposed to the surface, as in the parishes to the north, and where the basal gravels are absent, it is very difficult to establish a definite plane of contact between them. Electrical logs commonly do not start near enough to the surface to make them usable as a tool in picking the subsurface bases of the separate terrace formations. Driller's logs have to be relied upon almost exclusively for determining their character and thickness. Although each terrace formation
typically has a gravel at its base, in many cases they do not. When gravels are not reported it is impossible to tell from the driller's logs where one terrace stops and the next terrace or the underlying Fleming starts. An added complication is the fact that gravels are not limited to terrace bases but commonly may occur well up into the formation as a result of local conditions. It is, likewise, impossible to determine the thickness of these Pleistocene formations from surface outcrops because of the lack of sufficient relief, as well as because of the limited amount of erosion that each has undergone.

The Williana formation. The Williana formation is not exposed at the surface anywhere in either Beauregard or Allen Parish. It outcrops a few miles north of DeRidder in Vernon Parish as isolated cappings on hills. It also extends nearly to the Allen Parish line in Rapides Parish.

The Williana formation may be locally absent in the northern part of Beauregard and Allen Parishes. If absent at all, it is probably absent only locally as a result of erosion during the Kansan-Mindel glacial stage.

This formation is the most graveliferous of the four Pleistocene formations. It consists of relatively coarse sand containing many lenses of gravel, not only at its base but throughout its thickness. It is probable that erosion of the Williana in the parishes to the north supplied most of the gravel found in the younger formations.
The Williana delta was probably located in Texas, north of Jasper. Another main delta of Williana time probably was located near Brookhaven in Mississippi. It is impossible to determine the thickness of the Williana formation in Beauregard and Allen Parishes with the data now available.

The Bentley formation. The Bentley formation is exposed at the surface over much of Beauregard Parish and part of Allen Parish. It consists mostly of silts with some clays, sands, and locally some gravel. The prevalence of sands and silts on the surface is probably just the reflection of normal soil forming processes whereby the clay particles are carried down into the soil or carried away over the surface as a result of the action of rain water. Clay within the formation occurs as lenses; the individual lenses are usually quite small but the total volume within the formation may be large. Associated with the clay lenses, and occurring on the surface as a result of weathering, are small ferruginous concretions. Gravel deposits within the Bentley formation are highly localized.

The environmental conditions at the time of formation of the Bentley were that of a deltaic plain. The clays are typical of back-swamp deposition, and the formation of "buckshot" concretions upon the weathering of these clays seems to be diagnostic of this particular type of
environment and perhaps may be used as a criterion for this type of deposition. The sands and silts are typically fluvial deposits. The gravel deposits within the Bentley, particularly those at the base, are thought to be local fan deposits, derived largely from the older Williana.

The thickness of the Bentley formation in this area varies from a minimum of a few hundred feet along the northern margin of Beauregard Parish to a maximum of about 1500 feet on the western side of this parish.

Because of the extremely variable conditions of deposition, no sequence of deposits can be described as typical, except that, in general, the formation ranges from gravel near its base up through finer and finer material. For this reason no sections are given.

The Montgomery formation. No major distinction can be made between the lithology of the Bentley and Montgomery formations. Almost the only possible lithologic distinction is that the Bentley contains more gravel than does the Montgomery.

The Montgomery outcrop area in Allen Parish is herein considered to be typically a back-swamp deposit. There are no gravel deposits at all in this area; enough clay is present near the surface to retard sub-surface drainage, so that flat areas tend to be swampy.
The outcrop of the Montgomery in southern Beauregard Parish is herein considered as a coastwise terrace. Lithologically, it most nearly resembles the Bentley formation.

The Montgomery formation is relatively thin in southern Beauregard Parish because it is very near the northern limit of its coastwise outcrop. In this area it probably does not exceed 300 or 400 feet in thickness. In Allen Parish the Montgomery is also relatively thin, being the outer edge of an outcrop of fluviatile deposits.

The Prairie formation. Of the four Pleistocene formations, the Prairie is composed of the finest material. It contains a much higher percentage of clay than any of the other terrace formations. This higher clay content may be demonstrated by the ability of the surface to retain water when flooded for rice crops in eastern Allen Parish. There is sand and silt present in the Prairie, although, here again, its volume may be less than its surface outcrop would seem to indicate. There are no gravel deposits near the surface in the Prairie formation in Allen Parish. However, local gravel deposits occur in the Prairie, along the Sabine River in Beauregard Parish, probably as local alluvial fans.

The thickness of the Prairie formation can not be determined exactly with the limited data available, but it probably does not exceed 500 feet in these parishes.
Recent Alluvium

Recent alluvial deposits occur along most of the major and minor streams in these two parishes. This recent alluvium is all flood plain deposits. This material consists primarily of fine sand and silts, although locally, along some of the large streams such as the Sabine and the Calcasieu, some clay is present. None of the streams has sufficient gradient to build up any extensive deposits of gravel.

In this area the thickness of the alluvium along the streams is dependent almost entirely upon the size of the stream; the larger the stream, the thicker are the alluvial deposits. Recent alluvium of the Calcasieu River at Oberlin is 52 feet thick, and this thickness probably increases down stream. The thickness of the alluvium along the Sabine River should exceed 100 feet.
PHYSIOGRAPHY

General

The physiography of Beauregard and Allen Parishes is controlled entirely by the nature of the Pleistocene sediments; the surface configuration of this area is a reflection both of the mode of accumulation of the terrace deposits and of the subsequent changes that they have undergone. These Pleistocene sediments were laid down as terrace deposits, apparently in response to eustatic changes in sea level during the ice age. Each terrace deposit was laid down as part of a deltaic coastal plain at a time when the sea stood at about its present level. Deposition occurred during interglacial stages of the Pleistocene. Each interglacial system of deltaic coastal plains extended far coastwise, with inland fingers extending up drowned valleys and estuaries. Periods of erosion occurred when sea level was lowering during waxing glacial stages. The entrenchment of the old deltaic coastal plains left them as terraces, and continued erosion widened valleys for subsequent alluviation.

Upward movement and tilting of this entire section was going on contemporaneous with the deposition and erosion of Quaternary sediments, and is still going on
today. This upward movement appears to be an isostatic response to the overloading of the Gulf Coast area in the vicinity of the various Pleistocene deltas. It provided the means whereby each terrace became tilted more steeply toward the Gulf than the one next younger.

Elevations in these two parishes range from 210 feet on the Bentley terrace near DeRidder, in the northern part of Beauregard Parish, to an elevation of 30 feet on the Prairie terrace in the southern part of the same parish.

Drainage - General

Both Beauregard and Allen Parishes are drained by south flowing streams. The master streams are the Sabine River on the west side of Beauregard Parish and the Calcasieu River which flows south-southwestward across Allen Parish.

The next most important streams are Whiskey Chitto Creek and Bundicks Creek, which flow southeast across the northeast corner of Beauregard and thence into Allen Parish in more or less parallel courses. In Allen Parish Bundicks Creek turns in a southerly direction and flows into the Whiskey Chitto which, in turn, flows into the Calcasieu River.
Bayou Anacoco flows into the Sabine River at the northwestern corner of Beauregard Parish after having followed the Vernon-Beauregard Parish line for twelve to fifteen miles. Bayou Nesque parallels the southeastern boundary between Evangeline and Allen Parishes for about eight or ten miles.

Other streams in these two parishes are minor, tributaries of those already mentioned. Among these is Bayou Blue, which wanders over much of southeastern Allen Parish on the Prairie terrace before flowing into the Nesque. Other streams of this size in Allen Parish are Ten Mile and Six Mile Creeks which flow southward into Bundicks Creek. In Beauregard Parish Barnes Creek, Hickory Branch, and Beckwith Creek are three south-flowing streams which eventually join the Calcasieu River in the next parish to the south. Bearhead Creek flows in a southwesterly direction toward the Sabine River, but, after getting into Calcasieu Parish to the south, it turns east and flows into the Calcasieu River. The Sabine River has only short, minor tributaries in Beauregard Parish.

The typical stream pattern on the Bentley terrace is dendritic, and this same stream pattern may be found in places on the two younger terraces. On the Montgomery terrace there are, in Allen Parish, two areas of a swamp network drainage where the streams exhibit a
large scale network pattern. On the Prairie terrace, which is very flat in many places, there is no well defined drainage system.

In general, all of these terraces have enough slope so that they have well integrated drainage throughout. There are only local areas of poor drainage, notably along the flood plains of the major streams and two areas in northern Allen Parish, West Bay and East Bay.

Locally, however, the terrace surfaces are flat enough to retard drainage sufficiently to allow water to stand on the surface after a rainfall. This does not occur on a large scale.

Pleistocene Terraces

General

Pleistocene and Recent alluvial deposits cover the entire surface of Beauregard and Allen Parishes. They form a thick blanket of unconsolidated sediments overlying all Tertiary bed rock; the latter is known only from wells that have penetrated the Quaternary.

In general, the composition of each terrace deposit ranges from gravel near its base, up through sands and silts, to clay near its top. This is true only in the broadest sense, however, because gravel is not present
everywhere at the base of each deposit, nor do all of them have clay present near their upper surfaces. Silt and sand, the dominant types of sediments, are present in the shape of lenses, either large or small, depending upon the conditions locally prevalent at the time of their deposition. The gravel that is present is mostly very local in extent; it was deposited as alluvial fans at the mouths of relatively small streams. The gravel in the Bentley, Montgomery and Prairie formations of Beauregard and Allen Parishes was derived mostly by erosion of the older Williana to the north.

Typically, the surfaces of the terraces show sand or silt at the top. Since most of the streams have rather low gradients throughout this area, erosion has resulted in the removal of a considerable quantity of the constituent clay particles. This leaves behind a higher concentration of silt and sand, thus giving the impression that they were originally composed of more sand and silt that was actually the case. That there is a high percentage of clay present is shown in road cuts, by the ability of the surface to hold water after rainfall, and by the ease with which water is retained on rice fields on the Prairie terrace in southern Allen Parish.

The topography of this area is essentially that of a youthful plain sloping seaward. In Beauregard and
Allen Parishes there are three distinct, step-like levels of this plain, which are called terraces. Coastward, each terrace is somewhat lower, flatter and less dissected than the next terrace inland. The youngest of the three terraces, the Prairie, occupies the most southerly position. Next inland is the Montgomery, and farthest inland is the Bentley, which is oldest in age. These are the coastwise equivalents of the fluvial terrace that were first named by Fisk (1938, pp. 51-63) in Grant and LaSalle Parishes. Each coastwise terrace has fluvial extensions up the larger streams and, quite typically, also up the larger tributary streams. The innermost margin of each coastwise terrace is somewhat crenulated for the reason that there is a slight erosional break between the deposition of one terrace formation and that of the succeeding formation. The valleys cut during these minor erosional intervals were normally drowned by alluviation during the next depositional stages.

History of Literature on Terraces

A great deal has been written concerning the alluvial sediments of the Gulf Coast. They have been assigned to ages ranging anywhere from the Cretaceous to Recent. They have been called by different formational names in the same region, and the same formational name has been
used to include different stratigraphic units. All this has resulted in a great deal of confusion in the literature. Several papers have appeared within recent years in which an attempted correlation of this terminology is given. The latest correlation to appear was that by Woodward and Gueno (1941, following p. 28) in which the terminology of 57 articles on the Quaternary of the Gulf Coast is integrated in chart form.

The earlier writers, such as Hilgard, Safford, and others, recognized that all the Quaternary sediments of the Gulf Coast area were not deposited contemporaneously. Some two-fold and even four-fold divisions were made of these sediments. Local formational names were given to them and these same formational names were often applied by other writers to entirely different sections, both geographic and stratigraphic.

One of the most important among the earlier papers was one by Deussen (1914, pp. 77-83) who recognized four fluviatile lithologic units in the Gulf Coast area of Texas, the oldest of which, the Uvalde, he considered Pliocene. The three Pleistocene terraces were generally unnamed. The oldest of these he called the "highest Pleistocene terrace" and correlated it with the Asylum terrace of the Colorado River. The "middle Pleistocene terrace" he correlated with the Capitol terrace of the Colorado River and considered it to be the equivalent of
the basal portion of the Lissie gravel. The "lowest Pleistocene terrace" was correlated with the Depot group of terraces along the Colorado and considered to be the time equivalent of the upper part of the Lissie gravel and the whole of the Beaumont clay along the coast. As will be noticed, he recognized both fluvial and coastwise terraces but he did not apply the same formational names to both.

With regard to the mode of formation of the coastwise terraces, Deussen recognized that a change in the elevation of the land with respect to sea level was an important factor. The Lissie formation, which is essentially gravel, was deposited in the form of coalescing alluvial fans. This was followed by uplift of the land and subsequent erosion. Still later, depression of the land with transgression of the sea allowed still more gravel to be deposited unconformably upon the older gravel. This gravel graded upward through sand and silt to a thick clay deposit. In spite of the fact that the gravels were separated by an unconformity, Deussen considered them both to be the Lissie and the overlying clay to be the Beaumont.

In a later paper, Deussen (1924, pp. 4-6, 108-119) recognized five seaward facing terraces which he assigned to the Pleistocene and Recent. These terraces were described as topographic entities and named, from older to
younger, the Torrecillas, Realitos, Alice, Beaumont, and Recent. Stratigraphically, however, he correlated them with his Lissie and Beaumont formations.

Barton (1930-a, pp. 1301-1320), in writing on the geology of coastal southeast Texas, recognized the presence of the Lissie, Beaumont, and Recent terrace deposits and also two or possibly three Recent terrace deposits up the streams. He considered the Beaumont probably to have been laid down contemporaneous with the deposition of the Lissie. He also stated that the coastal terraces in that section were essentially coalesced Pleistocene deltas of the Trinity and Brazos Rivers.

Still later in the same year Barton (1930-b, pp. 350-382) was the author of the most significant article that had appeared up to that time. In this he did not attempt to differentiate any of the Pleistocene formations but devoted his paper to the mode of origin of these deposits. He believed the terraces to be a deltaic coastal plain and had several lines of evidence to support his contention. Stream patterns of a deltaic coastal plain and those of a normal marine plain differ widely. He showed how this area had a typical deltaic stream pattern with abandoned natural levees and also how soil types substantiated this theory.

Howe and Moresi (1933, pp. 13-27), in a report on the geology of Lafayette and St. Martin Parishes, Louisiana,
recognised more than one terrace surface in that area. They were among the first to utilise profiles as a means of locating escarpments. They were also among the first to demonstrate terrace slopes by means of contours.

Boering (1935, pp. 651-688) subdivided the coastal terraces of Louisiana and southeast Texas into four formations, named, from older to younger, the Willis, Lissie, Beaumont, and Recent. He considered the Willis to be Pliocene in age rather than Pleistocene. He recognized intermittent uplift of the coastal plain as an important factor in their formation but did not consider them as being deltaic in origin. He thought they had been formed by coalescing alluvial fans which had been built where small streams cut gaps through the scarps produced by the uplift of the region.

In a later paper, Barton (1936, abstract, pp. 63-64) recognized five series of plains. These plains were called by him as follows: (1) the Beaumont plain, deltaic in origin, (2) the Oakdale plain, a pre-Beaumont Mississippi Valley terrace, (3) the Lissie plain, non-deltaic, (4) an inner belt of plains called by several local names, and (5) the transgressive aeolian plains, also called by several local names.

Plisk (1938, pp. 51-66, 149-173) in an area in central Louisiana, recognized a series of four fluvialite terraces which he predicted could be correlated with the
coastwise deltaic plains. These terraces he named, from older to younger, the Williana, Bentley, Montgomery, and Prairie; younger than the Prairie he recognized the Recent flood plain and other flat areas toward the coast. In that paper a theory for the origin of these terraces was proposed that is widely accepted at the present time.

Later work by Fisk (1939, pp. 181-200 and 1940, pp. 53-113, 175-183), Russell (1940, pp. 1199-1234) and Frink (1941, pp. 364-410) further developed this idea. The mode of formation advanced by Fisk appears to square with observational facts and is adopted here as being most suited for explaining the terrace surfaces in the parishes under discussion.

Means of Differentiating the Terraces

The differentiating of terrace deposits in this area presents a problem not commonly encountered in mapping older deposits. In composition, there is no type of sediment that is characteristic of any particular terrace. No lithological distinction can be made between them because each is composed of large and small lenses of gravel, sand, silt, and clay in no particular sequence, except that, in general, the coarsest deposits are nearest the base of the terrace.
Grain size of the sediments composing the terraces can be used within certain limits. In general, the sediments of the Prairie are finer grained than those of the Montgomery or the Bentley. This as a criterion, however, can be applied only in a very general way; there are large areas of the two older surfaces which have equally fine grained sediments underlying them. Also, in the Prairie there are some coarser sediments.

The occurrence of finer materials in the Prairie is due not only to its original composition but also to the fact that not as much elutriation has taken place here as in the older terraces. Also, since both the Bentley and the Montgomery terraces have been exposed to erosional agencies for a greater length of time, a greater percentage of the finer clay particles has been removed from their surfaces through erosion than from the Prairie surface.

There is no observable difference in constituent materials of these terraces. They are composed primarily of quartz and clay minerals which must have been derived from essentially the same localities throughout the Quaternary.

Locally, paleontologic evidence cannot be used to separate these formations. Neither the coastwise nor the fluviatile terraces are fossiliferous in this area.
Theoretically, it should be possible to differentiate terraces on the basis of the amount of weathering that they have undergone. This is based on the assumption that the older terraces should be more deeply weathered than the younger ones. Nevertheless, as a means of mapping, this is not actually practical. The fact that these formations contain such a small amount of lime means that leaching is not a very important factor in weathering. Their composition is variable from place to place, both horizontally and vertically, which makes this factor very hard to apply. Because the depth of weathering is dependent to a certain extent upon sub-surface drainage, the variations in percentage of slope is an added difficulty toward applying this criterion. Locally, erosion has but recently removed the younger sediments from the surface of these terraces, leaving the present surface exposed to weathering agencies for a comparatively short time. Therefore, weathering as a means of differentiating the terraces can be applied only with caution.

In any attempt at differentiating the terraces, cognizance should be taken of the fact that, although younger sediments overlie the older in conformance with Hutton's law, the older formations occupy a higher topographic position than the younger formations. This is due to the fact that these deltaic sediments were
laid down contemporaneously with a sinking of the Mississippi
delta region and a consequent isostatic uplift of
the region farther inland, so that each younger formation
was laid down as an overlapping alluvial blanket that
succeeded in reaching progressively shorter average
distances inland.

One of the main criteria used in differentiating
terraces, at least those of any large extent, is the
altitude of the terrace. Because of the slow, but con­
tinuous, tilting that has taken place in this section,
the older terraces slope more steeply than the younger
ones. The slope of the Bentley terrace in Beauregard
Parish is approximately five feet per mile, that of the
Montgomery three feet per mile, and that of the Prairie
in Allen Parish two feet per mile, all toward the south.

Another very important criterion is the topography
of the terrace. Although all three terraces should be
thought of as having a youthful topography, the older
terraces have a more mature topography than the younger
ones. This is due to the fact that the older ones have
been exposed to erosion and weathering agencies longer
than the younger ones. The Prairie terrace, in general,
is quite flat. It is rather poorly drained, with but
few streams. Large areas of it are somewhat swampy.
This surface does not have as well an integrated system
of streams as do the older terraces. In addition, it is
nearer base level than the older terraces, which means that erosion is not quite so active. The flatness of this terrace makes possible, by the construction of quite low dikes, the inundation of large areas for rice growing. The Montgomery surface might be spoken of as slightly rolling. Most of the area is in slope although, particularly in Allen Parish, there are flatter areas with poor drainage. Typically, it has a well developed dendritic drainage pattern with the streams and their tributaries well incised. The Bentley surface is the most mature of all. For the larger part it is all in slope although there are some relatively flat areas, representing fragments of the original surface, left on some of the divides. The relief of this terrace is much greater than that of either of the other two. Therefore, by just observing the amount of dissection on a particular surface, it is almost possible to ascertain which terrace it is, although, here too, this criterion cannot be used by itself.

A third criterion which may be used is that of drainage and drainage patterns. This, as a means of differentiating the terraces, is very closely related to the topography as the surface configuration of any terrace is dependent upon the amount of erosion to which it has been subjected by streams. Streams start out on each terrace as consequent streams and, as the shoreline
gradually recedes, become extended consequents. There is no structural control of the streams in this area, with the exception of a small section of Allen Parish, other than the more or less uniform seaward tilting of the entire surface. The drainage pattern, therefore, is dendritic. The older the terrace, the better developed is this drainage pattern. Streams tend to work headward to a terrace escarpment (or perhaps to have started at an escarpment and to have grown as extended consequents) and there to stop, as sufficient time has not elapsed for them to have removed the much greater quantity of material that they would have to erode if they should cut through the escarpment. On a good map it is ordinarily possible to locate the escarpment between two terraces merely by noting where the smaller tributary streams head. Each terrace tends to have its own stream branchworks, with only master streams and larger tributaries crossing from one terrace to the next.

In the case of fluviatile terraces there may be rim-swamp streams present. When a stream is actively aggrading it tends to build natural levees along its course which, combined with the fact that deposition is also going on in its bed, raises the level of the stream above its flood plain. The land surface, therefore, slopes from the natural levee back toward the valley wall. This back-swamp area is quite commonly
drained by a stream which is located along the lowest points, namely, parallel to and against the valley wall. This is a rim-swamp stream. When this flood plain becomes a terrace, following a later period of erosion, the rim-swamp stream will remain, marking the line separating an older terrace (the former valley wall) from the younger terrace (the former flood plain).

Escarlements, if present, are very useful in locating the boundary between two terraces. They are usually present along the major streams but tend to be lower upstream and up the tributaries, until eventually the younger terrace feathers out against the older. Coastwise terraces are sometimes separated by scarps, although occasionally these scarps may be erosional as a result of slight local differences in composition; in other cases there are no scarps separating them.

Still another criterion that may be used, but one that must be used with extreme caution, is that of elevation. The lower terraces are younger than the higher ones. In differentiating by means of elevation, cognizance must be taken of the location that is being mapped, the general elevation of each terrace in that section, and also the direction that the mapping is proceeding with regard to the regional slope. For example, in Beauregard Parish at Merryville the elevation of the Prairie is about 100 feet, while in southern
Allen Parish the same terrace has an elevation of less than 50 feet; in northern Beauregard Parish the Bentley terrace has an elevation of about 210 feet while near Hollingsworth its elevation is only a little over 100 feet.

In the mapping of Beauregard and Allen Parishes all the criteria were applied, or at least as many as the local conditions allowed. Profiles were made along all the good roads by means of a Paulin Surveying Altimeter. These profiles were made on a scale of one mile to the inch and had a vertical exaggeration of 50X, so that they very clearly demonstrated the percentage of slope as well as the amount of dissection. Mapping was usually done contemporaneous with the running of the profiles in order that all criteria could be utilized at the same time.

The value of good altimeter profiles as almost a necessary aid to the mapping of terrace surfaces cannot be over-emphasized. In the mapping of Beauregard and Allen Parishes more than 700 miles of profiles were run, along all of the main roads and a great number of secondary roads. Profiles proved especially helpful in locating boundaries between terraces where no scarps were present.

As to the method of procedure, profiles were first made along roads connecting points of known elevation such as United States Geological Survey bench marks,
Louisiana Geodetic Survey bench marks, etc. If, on arriving at the second known elevation, the altimeter was reading either too high or too low, it was corrected and the profile adjusted accordingly. When making such a profile, elevations of side roads, bridges, or other easily recognized landmarks were determined, in order to have tie-in points for subsequent profiles. Where there was only one point of known elevation in a given area, a closed traverse was made, usually over a short period of time. Side traverses were then made from this primary traverse to other points of known elevation or back to other points along this same traverse. By this means, the elevations of a great number of points throughout the parishes were determined.

By recognizing certain inherent characteristics of an altimeter, quite accurate results can be obtained. One of the most important corrections to be made is that relating to temperature, as temperature directly affects air density. If an altimeter is kept at one elevation throughout the day and frequent readings taken, it will be noticed that there is an apparent rise in elevation from morning until late afternoon, after which time the elevations gradually drop. This variation, which is due partly to temperature and partly to the characteristic diurnal low pressure at four o'clock, can be expressed as a curve, and appropriate corrections can be made on
the profile, if the time at which each reading was taken is known. There are other facts to be considered, largely climatic, so that much better results are obtained by frequently resetting the altimeter to the correct elevation at points of known elevation and distributing the error back to the last known point.

An automobile served as the means of transportation while constructing the profiles, and the altimeter was kept in the car. This introduced a second factor which had to be taken into consideration. That is, the lag or interval of time which is required for the altimeter to become adjusted from a position of motion to a position of rest. During such an interval the altimeter drops very rapidly. Consequently, when a point of known elevation is approached by car, the car stopped, and the altimeter set to the correct elevation, this same interval of time, between the stopping of the car and reading of the elevation, should elapse at each point where an elevation is taken. Also, the speed of the car should be kept as nearly uniform as possible between all points where elevations are read. Otherwise, a serious factual error will be introduced.

A third factor which is somewhat troublesome is the weather. Satisfactory profiles cannot be run when atmospheric conditions are not stable. Usually sudden changes resulting from this factor can be noticed. The best time
to run profiles is in the early morning or on a day when the sky is uniformly overcast.

By taking into consideration the first two factors, and by constructing the profiles only when weather conditions are satisfactory, very good results were obtained.

Such profiles enable the mapper to visualize the topography and to notice any changes in general surfaces level which may be indicative of the presence of a lower or higher terrace. Then, too, the slope can be determined from these profiles. As before indicated, in Beauregard and Allen Parishes, the slope of the Bentley terrace is approximately five feet per mile, that of the Montgomery three feet per mile, and that of the Prairie two feet per mile.

Mechanics of Formation

Fisk (1938), in a geologic report on Grant and La-Salle Parishes, first clearly demonstrated the mechanics of formation of the Pleistocene terraces of the Gulf Coast region. Later, Fisk (1939) presented a regional paper on terraces and, still later, (Fisk, 1940) a bulletin on Avoyelles and Rapides Parishes, in both of which his ideas are further outlined. Russell (1940), in a paper on the Quaternary history of Louisiana, agreed with the conclusions of Fisk and presented some additional information.
Field work by the author in Beauregard and Allen Parishes, where three of these terraces—the Bentley, Montgomery, and Prairie—are better developed than in any other place in the state, further substantiates their theories.

The widespread terraces of the Gulf Coast area owe their origin to two factors. The first is eustatic changes in sea level accompanying glaciation and the second is the downward sinking of the Mississippi River deltaic region, as a result of active sedimentation, and the corresponding isostatic uplift of the region farther inland. No other tenable explanation has been offered to explain the cyclic alternation between periods of active erosion and periods of active sedimentation. No theory other than uplift can explain the occurrence of the Williana terrace up to elevations of nearly 600 feet in the region to the northwest of these parishes in Texas and to the northeast in Mississippi.

Each of the four major ice advances during the Pleistocene covered some four million square miles of the northern part of North America. Other parts of the world, particularly Europe, supported large glaciers at this time also. Between the periods of ice advance there were interglacial epochs when the world was even more free of ice than it is now. During periods of glaciation sea level was greatly lowered as a result of so much water
being locked up as ice on the land, and with deglaciation the seas possibly rose even higher than they now are. The interconnection of the seas made the extent of this phenomenon world wide.

The Gulf Coast area reflects this oscillation in sea level. In the first place, during the glacial stages when sea level was low, the base level of all streams was correspondingly low. As all streams tend to approach and maintain a graded condition, these streams began a period of active erosion, first starting at the mouths of streams emptying into the Gulf and gradually working headward and up the tributary streams. Then, with the melting of the ice following the period of maximum glaciation, and during the ensuing interglacial epoch, these streams alluviated their valleys as they again attempted to approach a graded condition.

It has long been recognized that sea level varied with respect to the land during the Pleistocene. Spencer (1890, pp. 208-213) attributed the deep Mississippi Valley, which is today largely filled with alluvium, the submarine canyons of the Pacific Coast and off the St. Lawrence River, and the depth of the Great Lakes and Hudson Bay to erosion during the Pleistocene, at a time when the continents stood much higher than they now are. He did not recognize a change in the elevation of the sea with respect to the land, but, rather, a variation
in the elevation of the land with respect to sea level. Upham (1890, pp. 492-497) thought that North America was possibly 3000 feet higher during the Pliocene than it is today. His evidence for this was the presence of submarine canyons and fjords, "the absence of all Pliocene formations along both the Atlantic and Pacific coasts", and the tilting of old beach lines along inland lakes. He postulated that this higher elevation of the land during the Pliocene brought on glaciation during the Pleistocene and that there was submergence of the continent to near its present elevation during the Pleistocene. Yeateh (1903, pp. 762-766), in writing on the geologic history of Long Island, recognized a 450 foot fluctuation of the land with respect to sea level as being responsible for the glacial features which he described. Later, Yeateh (Yeateh & Smith, 1939, pp. 1-101) recognized fluctuations in sea level, rather than in elevations of the land, as being the important factor responsible for the formation of such features. No attempt will be made here to summarize the recent work on the topography of the continental shelf areas by means of echo soundings. The work of Shepard (1931, pp. 1-171) off the California coast should be cited, however, as almost sufficient proof in itself of the fluctuations of sea level during the Pleistocene.
Various estimates have been given for the amount of lowering of sea level that would result from glaciation (Daly, 1925, p. 285; Antevs, 1928, p. 81; Dubois, 1931) but most writers agree that it must have been about 300 feet lower during glacial stages of the Pleistocene than it is now. This figure agrees very closely with the amount of alluvial fill in Louisiana valleys (Russell, 1940, p. 1819). Today, there are large ice caps over the Antarctic and over Greenland. If these ice caps should all melt, sea level throughout the world would be raised at least 100 feet, and probably over 160 feet. (Daly, 1925).

This 400 foot fluctuation in sea level has left its mark in many places in the world in the form of terraces, wave cut cliffs, etc. In southern Europe there are four terraces comparable to those of Louisiana. These four terraces are called, from the older to the younger, the Silicienne, Milazzienne, Tyrrhenienne, and the Monastrienne. These are probably equivalent to the Williana, Bentley, Montgomery, and Prairie of the Gulf Coast area. The assumed correlation of the American and European glacial and interglacial terminology with the terrace deposits of Louisiana and southern Europe is shown in Figure 2.

Deposits of glacial debris in the region covered by an ice sheet, as well as in that region immediately
<table>
<thead>
<tr>
<th>Glacial stages</th>
<th>American Glacial Terminology</th>
<th>Louisiana Terraces</th>
<th>European Glacial Terminology</th>
<th>Southern European Terraces</th>
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<tr>
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<td>Recent</td>
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<td>Warm</td>
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<td>Glacial sub-stage</td>
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<tr>
<td>Third inter-glacial stage</td>
<td>Sangamon</td>
<td>Montgomery</td>
<td>Tyrrhenienne</td>
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<tr>
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<td>Illincian</td>
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<td>Ries</td>
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<td>Yarmouth</td>
<td>Bentley</td>
<td>Milassienne</td>
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<td>Kansan</td>
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<td>Mindel</td>
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<td>Williana</td>
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<td>First glacial stage</td>
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Figure 2. Chart showing assumed correlation of Louisiana and southern European terraces with glacial and inter-glacial stages.
in front of the ice, were formed contemporaneous with the existence of the glacier, as a result of its melting. This material may be either morainic or glaciofluvial in origin. Formerly it was considered that all terrace deposits, such as those of the Gulf Coast, were formed at the time of an ice advance and thus they were correlated with the glacial stages. That this is not true of the Louisiana terraces, and that they were formed during the interglacial stages, has been proved by Fisk (1938).

That isostatic adjustments are taking place around the present day Mississippi River delta has been proved by several men, using entirely different methods of approach. It is a matter of observation that the Gulf Coast south of Beauregard and Allen Parishes is sinking. Howe, Russell, et. al. (1935, pp. 51-68), in a report on Cameron and Vermilion Parishes, which lie along the coast south of Beauregard and Allen Parishes, discussed several lines of evidence supporting the belief that this shore line is sinking. Among these were were the drowned river valleys such as the Sabine and the Calcasieu. In this area, also, the salt marshes are encroaching on the land as evidenced by dead cypress stumps which have been killed by the saline waters. Indian mounds in this section, which were built on the highest land possible, are today below sea level. In addition, two unpublished maps of a portion of Grand Lake show that, during a
sixty-year interval, the shore line, in one place, had transgressed a distance of 7500 feet.

The work on the Mississippi River delta by Russell, Howe, et. al. (1936, pp. 162-174) clearly proves that subsidence is an active force in the Gulf Coast area. The main volumetric growth of a large deltaic mass is downward rather than horizontal (Russell, 1938, p. 407). The work of Frink (1941, pp. 404-407) on the basal Quaternary gravels of Louisiana has demonstrated that the thickness of the Recent deposits near the delta is about 3000 feet and that of the Prairie is also 3000 feet, under their centers of maximum accumulation. Thicknesses of 1250 and 1000 feet, respectively, have been measured for the Montgomery and Bentley, although the maximum thickness of these two terraces is unknown. It is obvious that the Gulf was not that deep at the time of deposition of these sediments, especially as they are all deltaic and non-marine. The deposits have pressed down and formed the basins they occupy. Still more evidence is offered by the deltaward dip of these formations. For example, the basal gravels of the Recent, which were laid down essentially horizontally, in places now dip at 130 feet per mile (Russell, 1940, p. 1229).

When some portion of the earth's crust is overloaded, such as the Mississippi River delta, and subsidence is initiated, some adjacent portion rises as isostatic
equilibrium is again reestablished. There is a lag in the upward movement; elevation of the land does not correspond in magnitude to the subsidence. The Williana has a maximum elevation of almost 600 feet near both Brookhaven, Mississippi, and Jasper, Texas. Since this formation was laid down at about sea level, and assuming these elevations to be at or near the top surface of the formation, this would be a measure of the maximum isostatic uplift of this general region from the end of the Aftonian interglacial epoch to the present time. However, one must take into consideration the possibility that sea level might have been about 100 feet higher during the Aftonian than it is now.

As sea level was gradually lowered at the start of the Nebraskan-Guns glacial stage, streams existing on the Tertiary surface of Louisiana gradually deepened their valleys. Probably this erosion more or less kept pace with the lowering base level, so that the gradients of the streams were not at any time excessive. With the waning of the ice sheets, following the period of maximum glaciation and continuing on into the Aftonian interglacial epoch, these streams alluviated their valleys. The area that is now Beauregard and Allen Parishes was at that time much lower than it is now, and so a thick blanket of alluvial sediments was laid down over the entire region, covering the valleys as well as the divides, to a thickness of at least two or three hundred feet.
At the start of the Kansan-Mindel glacial epoch these sands, silts, and clays were dry land, topographically a deltaic plain. Probably the original slope of this surface was slight, but, combined with the seaward tilting resulting from the much heavier sedimentation to the south, it was sufficient to initiate consequent streams. As sea level was gradually lowered during this glacial epoch, these consequent streams were extended seaward. Since these sediments were all unconsolidated, fairly rapid erosion resulted and eventually there may have been developed a deeply eroded area with well incised streams. In some cases, these streams may have cut through the Williana sediments into the older Tertiary below.

With the waning of the Kansan glacial sheets, sea level was again raised and the larger valleys began to be alluviated. This deposition continued until, by the close of the Yarmouth interglacial stage, the entire surface of Beauregard and Allen Parishes was again covered with a thick layer of sediments, which later became the Bentley terrace.

As ice accumulated again during the Illinoian-Riss glacial epoch, drainage channels were again initiated. These streams were entirely independent of any streams that previously existed in this same area on the Williana terrace.
As sea level rose again during the Sangamon interglacial stage, these valleys were again filled, and gradually the deltaic sediments of the Montgomery terrace began to cover more and more of the southern part of these parishes. However, due to the weight of the Williana and Bentley terrace materials, which were much thicker toward the south, Beauregard and Allen Parishes were elevated sufficiently so that the coastwise terrace materials could cover only the southern one-third of Beauregard and extend as an embayment to cover the southeastern five-sixths of Allen Parish. Fluviatile deposition took place up the drowned streams from this coastwise belt.

Terrace deposits, in general, do not reflect minor oscillations in glaciation. It is doubtlessly true that during each ice advance and each ice retreat there were minor fluctuations of sufficient magnitude to affect sea level, but these variations are not recorded in the terraces. However, during the Wisconsin glacial stage, there was at least one time when the continents were sufficiently free from ice to leave a world-wide record of higher sea levels. This interglacial period, the Peorian, is considered by some to be of sufficient magnitude to warrant the division of the Wisconsin ice advance into an earlier Iowan stage and a later Wisconsin stage. By others, the Iowan is considered as a substage of the
Wisconsin. In any event, there is a distinct terrace in the Gulf Coast area as a record of the higher seas of the Peorian.

Following the deposition of the Montgomery formation during the Sangamon, the ice again advanced thus lowering sea level and renewing erosion over the Beauregard-Allen area. Streams were rejuvenated in that part of the parishes that was not blanketed with Montgomery sediments, and thus started to deepen their valleys or, in the case of those streams that had been drowned, to cut valleys with a V-shaped transverse profile in the Montgomery alluvium with which they were filled. As the shoreline gradually receded, streams were formed over the new Montgomery surface, in part by the extensions of the Bentley streams to the north, and in part by the development of entirely new courses.

As the Iowan glacier gradually melted and seas again rose, deposition of the Prairie formation was started. Owing to still higher elevations of the land, the coastwise Prairie terrace did not extend quite as far north as Beauregard Parish; the only Prairie deposits to be found in this parish are the fluvialite sediments which were laid down in the drowned valleys. However, the coastwise Prairie covers the southern half of Allen Parish and there are numerous fluvialite extensions up the main valleys.
The waxing of the Wisconsin glacier again initiated a period of erosion which allowed the major streams to deepen their valleys. With the partial melting of this glacier (remnants of it still exist as the ice caps over the Antarctic and Greenland), streams again began to alluviate their valleys. This is the material of which the recent flood plains of today are composed. This alluviation is continuing at the present time.

The structural relationship between any two terrace formations is that of a wedge-shaped mass of material consisting of gravel, sand, silt, and clay, rapidly thickening toward the Gulf, overlapping onto an older wedge-shaped terrace. The older formation dips more steeply than the younger because the younger, by its weight, apparently as a result of isostasy, has tilted the older terrace so that the dip of its surface is much greater than its original slope.

To consider each terrace formation as a wedge-shaped mass of debris, however, is misleading. Each terrace formation, as well as the Recent deposits, has a shape like that of a huge ladle, with a basin-like bowl underlying the position of heaviest deposition and with a handle or handles extending up the main valleys. (Russell, 1940, p. 1213). Dips of the basal gravel increase greatly as the center of maximum deposition is approached.
Within recent geologic times the Mississippi River has had several separate deltas located at points scattered over a full one-half of the southeastern part of Louisiana. During the Pleistocene most of the deltas were farther west than the recent one of the Mississippi River. The location of these Pleistocene deltas has been worked out by Frink (1941, pp. 402-409), using subsurface data obtained from well logs as his basis. The location of the Prairie delta was some distance west of the recent delta and that of the Montgomery to the northwest of the Prairie. There were two Bentley deltas, one on either side of the state of Louisiana.

Figure 3 is a schematic drawing to show the structural and profile relationships between the terraces. The terminology is adopted after Fisk (1939, p. 192). This diagram shows, first, the Prairie formation as it was deposited; second, the slight tilting of its surface; third, the deposition of flood plain materials; and last, the present day relationship resulting from the further tilting of this surface. The hinge line marks the line of separation between the zone of active uplift and erosion from the zone of active subsidence and deposition. (On a profile this contact would be termed a hinge point). Obviously, with sediments, there can be no sharp line separating two such zones. Furthermore, this hinge line does not remain in any one place for any
Prairie formation as it was first deposited. Notice deltaward thickening and very slight dip.

Prairie formation near close of time of deposition. Notice increased deltaward dip.

Prairie formation following deposition of recent sediments. Notice slight downdrag of surface under recent deposits.

Present day relationship between Prairie formation and recent sediments. Notice subsidence under load and warping of Prairie surface.

Figure 3. Schematic terrace profile and structural relationships.
length of time. As the volume of water in the oceans increases, this line moves farther inland; as the sea level is lowered, this line moves seaward. At any particular time, it is located at that position marking the contact between the farthestmost inland place of deposition of any coastwise sediments then being deposited and the next older terrace or the next older underlying sediment.

**Bentley Terrace**

**Outcrop Area**

Originally, the Bentley terrace covered all of what is now Beauregard and Allen Parishes. Owing to the deposition of later sediments—the Montgomery, Prairie, and Recent flood plain deposits—its outcrop area has been greatly diminished in size. The Bentley now outcrops over the northern three-fourths of Beauregard Parish and the northwestern one-eighth of Allen Parish. Its outcrop area has been further reduced in size by erosion and subsequent deposition of younger sediments along most of the main streams.

In Beauregard Parish the outcrop area of the Bentley formation is bounded on the west by the younger sediments along the Sabine River. Here it adjoins the Mont-
gometry or Prairie at different locations. It even lies adjacent to the Recent flood plain in some places where the Montgomery and Prairie have been cut out by lateral erosion of the Sabine River.

The outcrop area of the Bentley has its widest extent along the northern boundary of Beauregard and Allen Parishes, where it extends from the Sabine River on the west all the way across Beauregard Parish and into Allen Parish as far as three miles beyond Elizabeth.

The southeastern boundary extends from near Elizabeth in Allen Parish to Reeves, also in Allen Parish. There is an inlier of the Bentley, completely surrounded by Montgomery, somewhat east of this line in Allen Parish, between the Whiskey Chitto Creek and the Calcasieu River in T5S, R5W. This area, although topographically higher than the surrounding country, is technically an inlier rather than an outlier because it is completely surrounded by a younger sediment. It comprises about three square miles.

The southern margin of the Bentley outcrop area extends roughly westward from Reeves to the Sabine River.

Elevation and Slope

In general, the Bentley terrace slopes southward from a maximum elevation of about 215 feet along the northern
Plate II. Map showing slope of the Bentley surface in Beauregard and Allen Parishes.
margin to about 100 feet along its southern margin. The slope of the terrace, then, is about five feet per mile toward the south. These figures are based on the assumption that the broad, flat, inter-stream divide areas represent more or less original surface. This older terrace is considerably dissected, so that, in general, it presents a somewhat rolling surface with but few typically flat divides. It is inconceivable that there is actually any "original surface" left. Undoubtedly, some material has been removed through erosion from all of the surface and a considerable quantity of material from most of the surface.

Figure 4. Typical Bentley topography.
There is an eastward component to the direction of slope, as well as the southward component. The eastward component, which is relatively slight as compared to the southward component, is due to the fact that the more recent deltas were located to the southeast and, thus, tilted the terrace in that direction. The Bentley surface slopes south-southeastward at the rate of about five feet per mile.

The highest elevations on the Bentley terrace are to the northwest of DeRidder, along the parish line, where elevations on the inter-stream areas are about 210-215 feet. Directly to the east along the parish line elevations gradually decrease as the eastern margin of the Bentley outcrop area is approached until, north of Elizabeth in Allen Parish, the maximum elevation is only 185 feet. The lowest elevations to be found on this terrace are along the southern margin, where elevations on divides are between 95 and 100 feet. Plate 2 shows generalized contours drawn on elevations of the flatter Bentley divide areas. As will be noticed, the contour lines are closer together near the southern margin; this probably represents the zone of isostatic down-drag.
Drainage

The Bentley terrace surface is the best drained of all surfaces in these two parishes. Since it is the oldest, streams have had a longer time during which to develop an integrated drainage system. As a result, practically all the area is in slope. Some of it is almost flat, but even those surfaces, which to the eye appear to be flat have some slope.

There are, however, local areas where surface drainage is not so good. For the larger part these areas of poor drainage occur on divides in certain rather small depressions known locally as bagols and, occasionally, in depressions between pimple mounds. Pimple mounds, in general, are formed where there is some original slope, even though slight, so that, typically, such areas have a highly developed dendritic drainage system. Bagols, on the other hand, seldom are completely drained. These depressions, which are more or less circular, average about 1000 feet in diameter and usually have sufficient closure so that, after rains, water stands in them to a depth of from a few inches to almost a foot. Neither pimple mounds nor bagols are confined to any particular terrace. They are discussed more fully in a later part of this report.
All of the streams on the Bentley surface had their inception after the beginning of the Illinoian-Riss glacial stage as consequent streams. They were able to erode at a continually increasing rate of speed as this terrace surface was gradually tilted seaward. Headward erosion by these streams and their tributaries resulted in the development of a typical dendritic drainage pattern on the Bentley surface.

Barring local exceptions, the direction taken by the major streams in this area is parallel to the direction of maximum slope of the original surface. The entire terrace surface, when first subjected to erosion, was quite flat and had a slope measured only in inches per mile. Consequently, headward-eroding streams and gullies could very easily be deflected from a course that was parallel to the direction of maximum slope. Slopes, however, were gradually increased even while this terrace was being deposited, but this latter factor was of no major importance in determining stream directions. The main stream courses represent approximately the direction of maximum slope of this original surface.

The courses of streams which originate on the Bentley surface are essentially east of south. If, during the time when these streams were growing by headward erosion, there had been a change in the direction of maximum slope, this should have been reflected by a
change in the direction of the streams near their headwaters, or of their tributaries. No such deflection of streams is noticeable in these parishes. It is therefore probable that the direction of maximum slope of the Bentley surface is today essentially the same as it was at the time of its formation.

In making generalizations such as the one above, only those streams which originate on the Bentley surface can be considered. Major streams which originate on older surfaces have developed their courses across the Bentley as extended consequents. Such streams (the Sabine River is typical of these) would, themselves, be building deltas and, as sea level was gradually lowered, would trench those deltas as the deltas grew seaward. Numerous deflections of the streams' courses would result, and so the courses of such streams would indicate only in a very general way the direction of original slope.

It is true also that even the smaller streams which originate on the Bentley surface would grow mouthward as sea level was lowered and would build deltas or alluvial fans. However, the volume of water in these streams would be relatively small and thus their deposits would not be large enough to deflect their courses appreciably.

Typical streams in Beauregard Parish which reflect original surface slope are Barnes Creek, Hickory Branch,
Wild Cow Creek, Cole Creek, and Beckwith Creek in its upper course. All these streams flow a little east of south in more or less parallel courses. Dry Creek, whose original location was eastward to Bundicks Creek, in its upper section turns northwestward so that this part of its course parallels the original slope.

In the western part of Beauregard Parish, Beckwith Creek in T5S and T6S and Bearhead Creek in T5S and T6S both turn southwestward for a short distance before again turning southward. This deflection of their courses may be the result of a slight westward tilting of the surface as a result of a Sabine River delta.

Figure 5. Bentley scarp along Sabine River near Merryville, Sec. 35, T2S, R11W. Photograph by R. J. Russell.
In most places there is a distinct scarp separating the Bentley from the Montgomery terrace. Where this scarp is absent, the best criterion for separating these terraces is that of degree of slope; the older terrace slopes more steeply than the younger.

The line separating the fluvialite Montgomery terrace from the Bentley is, in most places, marked by a prominent scarp. The scarp separating these two terraces south and east of Elizabeth in Allen Parish is quite distinct, since the Montgomery in this area is not a coastwise surface but a stream deposit closely tied in with some former Mississippi River course.

The line separating the Bentley from the coastwise Montgomery in southern Beauregard Parish is typically a low scarp, although, toward the west, this scarp gets lower and lower until it is scarcely noticeable near the Sabine River.

Some of the best terrace scarps in the entire area are to be found along the Sabine River. Here the fluvialite Montgomery is separated from the Bentley by a good scarp. During Prairie time the river had cut out some of the Montgomery terrace through lateral erosion and so, in places the Prairie abuts against the Bentley. The Sabine River, during Recent times, has even cut out all
the Prairie and Montgomery in places, allowing Recent flood plain deposits to lie adjacent to the Bentley. In each case there is a successively higher scarp formed.

Montgomery Terrace

Outcrop Area

The coastwise Montgomery is present as a belt six to eight miles wide across the southern end of Beauregard Parish and extends for a few miles into the southwest corner of Allen Parish. This belt is the only coastwise Montgomery in the two parishes. It is reduced in area somewhat by numerous tongues of fluvial Prairie terrace materials extending up the streams.

A large area of fluvial Montgomery terrace surface is present on either side of the Calcasieu River in northern Allen Parish. Here, nearly one-third of the area of Allen Parish is surfaced with Montgomery terrace materials. On the south this outcrop area extends west of the Calcasieu River as a prong between that river and the Whiskey Chitto Creek, and to the east of the Calcasieu it extends to the Evangeline Parish line in about the latitude of Oberlin. On the east side this outcrop area extends into Evangeline Parish, and on the north it continues just north of the parish line into Rapides
Parish. On the northwest side the boundary extends from the Vernon Parish line southwestward to Whiskey Chitto Creek and then parallel to that creek on southward.

Upstream from the belt of coastwise Montgomery terrace, extended fluviatile belts of Montgomery parallel most of the streams. In the case of the larger streams the terraces are wider and extend upstream farther. Bearhead Creek, Beckwith Creek, Hickory Branch, and Barnes Creek all have prominent fluviatile Montgomery terraces. The Sabine River has widespread terraces of Montgomery age in places; in other places these terraces have been cut out. Bundicks Creek and Whiskey Chitto Creek both have well developed Montgomery terrace remnants.

Elevation and Slope

The elevation of the coastwise Montgomery varies from 90 feet near its northern margin to almost 60 feet near its southern margin. There are, of course, many elevations on the Montgomery lower than this but they are mostly in valleys.

Elevations along the large area of fluviatile Montgomery in northern Allen Parish range from about 90 feet north of Oberlin to about 125 feet near the Rapides Parish line. There is no appreciable difference in elevation east and west across this area.
Fluvialite remnants of the Montgomery along present-day streams in Beauregard and Allen Parishes may range in elevation up to more than 160 feet. These higher elevations are due in part to deposition during the earlier part of Montgomery time and in part to greater uplift farther to the north.

The slope of the coastwise Montgomery in Beauregard Parish is about three feet per mile toward the south. The large fluvialite Montgomery terrace remnant in Allen Parish slopes at the rate of about three feet per mile, also. Slopes of the Montgomery terrace along the smaller streams within the Bentley outcrop area are usually much steeper than this. The slope of these fluvialite terraces is dependent to a certain extent upon the gradient of the stream along which they occur.

Drainage

In discussing the drainage of the Montgomery terrace a clear distinction must be made between the three different types of outcrop areas. These are first, the coastwise terrace in southern Beauregard Parish; second, the large fluvialite Montgomery area in northern Allen Parish; and third, the smaller fluvialite remnants along streams within the Bentley outcrop area. Each of these three is characterized by different types of drainage.
Coastwise Montgomery: Streams on the coastwise Montgomery terrace surface are well integrated, with a good dendritic drainage pattern. Because this outcrop area is rather narrow, the direction of stream courses as a means of determining the direction of original slope cannot be applied with accuracy. In a distance of forty miles, in an east-west direction, this surface is cut through by six streams which originate on the older surface to the north. Since most, if not all, of these streams originated in pre-Montgomery time, they merely extended their courses across the Montgomery surface as the seas receded during the Iowan glacial stage. They cut channels across the Montgomery and, as erosion proceeded, the land surface which resulted sloped toward these master streams. Streams which originate on this surface are all tributary to the master streams and have a course whose direction is a component of the southward tilting of the original Montgomery surface and of the slope toward the master streams which is the result of subsequent erosion.

Minor streams, in general, tend to head near the Bentley scarp which, as before mentioned, is higher toward the east. Those streams which, at the present time, have their headwaters farther to the south of this escarpment are tending to erode headward toward the scarp. Very few, if any, minor streams have cut headward across the escarpment.
Of the major streams which cross this Montgomery outcrop area, Beckwith Creek and Hickory Branch both flow in essentially southward courses. Bearhead Creek flows parallel to the scarp for a distance of about eight miles. It may have been a tributary to the Sabine River during Montgomery time. On the west side of R12W its course is southward from the scarp and then, in Calcasieu Parish to the south, eastward. This southward and eastward direction of its course is probably the result of a deflection of the stream during Montgomery time, when the Sabine River was building a delta in that section. Barnes Creek flows southeastward across this surface in a course whose direction was determined by the lower elevations to the eastward along what is now the Calcasieu River.

Large Fluvial Montgomery Area in Northern Allen Parish:
Drainage on this Montgomery outcrop area differs in almost every respect from the drainage on the coastwise surface. Here the surface is more nearly flat (in this respect resembling the Prairie surface to be discussed later) and large areas of it are even somewhat swampy. This area is bisected by the Calcasieu River which flows southwestwardly across it. Drainage on the west side of the Calcasieu is tributary to that river; that on the east side of the river flows mostly into the Bayou Nezpique.

It is recognized locally that this area is somewhat different from any of the rest of the surrounding region.
It is spoken of as a "bay", that on the west side of the Calcasieu being known as West Bay and that on the east side as East Bay.

Typically, both of these areas are very flat. Streams here are rather numerous and are not deeply incised. In fact, except for a few streams, they are not incised deeply enough to carry off the water after heavy rainfalls, and so it is not at all uncommon to have widespread areas inundated after prolonged precipitation. Both bays have such poor drainage that the vegetation is entirely different from that of the coastwise Montgomery or the Bentley. Here, oaks, magnolias and similar types of trees are found in abundance, along with a dense undergrowth of shrubs and bushes. It is only rarely that a portion has sufficient drainage to support the growth of pine trees. Only very small sections of this area have been cleared for cultivation. It is still very largely covered with forests.

The drainage pattern in both East Bay and West Bay is that of a swamp network. This pattern is best developed in East Bay. Streams do not have separate channels that are distinct from those of contiguous streams but might be spoken of as anastomosing on a very large scale. Water in the headwater of any particular stream often has a choice of two or even three channels----often separated by two or more miles----through which it can flow. In
Figure 6. Map showing swamp network drainage in East Bay, Allen Parish.
East Bay these streams nearly all flow as tributaries into Castor Creek and eventually into Bayou Nezpique. Those in West Bay are almost all tributary to Mill Creek which flows into the Calcasieu River.

The "bay" area continues with much the same characteristics into Evangeline Parish on the east. This Montgomery outcrop area is thought to represent a portion of the fluviatile terrace along the Mississippi River during Montgomery time. As such, it would have been the flood plain of the Mississippi River at that time. Consequently, it would have had very poor drainage, with but slight southward slope. This area was also very near the active Montgomery delta, because the coastwise Montgomery occurs but a short distance southwest of these bays.

With uplift of this region to its present elevation, the incipient drainage channels on this flood plain began to incise themselves, first starting at the mouth and then working headward. As the bay area is relatively near the headwaters of smaller streams it has not been greatly reduced by erosion as yet. Consequently, the original flatness of this plain has been more or less preserved.

Montgomery Fluviatile Remnants within the Bentley Terrace: Most of the major streams within the Bentley outcrop area, as well as the minor streams on the Montgomery whose headwaters extend into the Bentley, have fluviatile Montgomery
terraces flanking their courses. Near the junction of these streams with the major Montgomery outcrop area, there is usually an embayment extending upstream from the Montgomery outcrop proper. This embayment may be quite wide in some instances and rather small in others.

The width of the Montgomery terrace along streams is dependent almost entirely upon the size of the stream. The maximum width of this terrace along the Sabine River is about two and one-half to three miles; along Bundicks Creek and Whiskey Chitto Creek the maximum width is about one mile; while along creeks such as Bearhead, Beckwith, and Barnes it seldom exceeds one-fourth to one-half mile. These fluviatile remnants are by no means continuous along any stream. By the shifting of the stream, these terraces are quite often cut out completely. Also, as a result of stream meandering, they might lie on the right side of the creek, on the left side, or on both sides. Typically, these terraces extend up the tributaries as well as along the main stream.

Junction with Lower Surfaces

At the junction of the Montgomery terrace with that of the Prairie or the flood plain, in most places is a scarp. This is particularly true along streams. Sometimes this scarp is low and sometimes quite high and
distinct. At many places there is a rim-swamp stream present at the base of the escarpment. This is due to the fact that these fluviatile sediments (the Prairie or the Recent alluvium) were laid down in every case as flood plains and, consequently, usually slope away from the stream to the valley walls, leaving a low line separating the two deposits, along which minor drainage channels may develop as rim-swamp streams.

The best Montgomery terrace scarp in either parish are to be found along the Sabine River near Merryville. Here this scarp is about twenty feet high and quite noticeable topographically.

In southern Allen Parish the junction of the Montgomery with the Prairie is not distinct. The Prairie here seems to grade almost imperceptibly into the Montgomery. However, by constructing profiles it was possible to localize this line on the basis of degree of slope, as well as on amount of dissection. The surface configuration of the land a mile or more on either side of this line is quite distinctive.

**Prairie Terrace**

**Outcrop Area**

The outcrop area of the coastwise Prairie formation lies entirely within the southern half of Allen Parish.
This area extends northward to about the latitude of Oberlin and westward to near Reeves. Southward and eastward, it extends to the parish line. In this report this outcrop area will be spoken of as the coastwise Prairie, although it must be recognized that it is not a true coastwise terrace in the sense that the Bentley is a coastwise terrace. It was formed near the very crenulated, innermost margin of the Prairie terrace belt and, as such, represents the result of deposition in that region where the coastwise and the fluvial environments merge. It could just as well be spoken of as the southernmost portion of a remnant of a large fluvial terrace. It was formed in an embayment extending a slight distance upstream along the Calcasieu River in Allen Parish and some other streams in Evangeline Parish.

Fluvial terrace remnants are found along many streams within the coastwise Montgomery outcrop area. All of the major streams and most of their tributaries have remnants of the Prairie terrace along their courses. It is a peculiar fact that very few such terrace remnants are to be found along the streams in the large area of fluvial Montgomery in northern Allen Parish. Such surfaces are found only along the Calcasieu River and Whiskey Chitto Creek and a few smaller streams near the margin. Within the Bentley outcrop area, fluvial Prairie is found only along the larger streams. In
particular, Whiskey Chitto Creek has well developed Prairie terrace remnants throughout its course in Beauregard and Allen Parishes; Bundicks Creek has good outcrops of the Prairie surface southeast of DeRidder. The best fluviatile Prairie surfaces of all are to be found along the Sabine River, between six miles south of Merryville and the Vernon Parish line.

Elevations and Slope

Elevations of the coastwise Prairie terrace belt range from a maximum of seventy feet near Oberlin to about thirty feet along the Jefferson Davis Parish line. There is but a slight east-west slope to this surface. Elevations on the fluviatile Prairie terrace remnants have a much greater range. The lower limits of these surfaces are no lower—a minimum of about thirty feet has been noted in southern Beauregard Parish—, but the upper limits are much greater. The highest elevations on this surface are found upstream, at positions most removed from the coastwise belt. In Beauregard Parish, along Bundicks Creek north of DeRidder, the Prairie surface reaches an elevation of 165 feet, which is its highest in these two parishes. Widespread Prairie terrace remnants along the Sabine River north of Merryville have an elevation of about 100 feet.
Plate IV. Map showing slope of the Prairie surface in Beauregard and Allen Parishes.
The slope of the coastwise Prairie terrace in Allen Parish is about two feet per mile, which is somewhat greater than the slope of this terrace farther south in Calcasieu Parish or Jefferson Davis Parish. This greater degree of slope is due to the fact that the area which is herein spoken of as the coastwise Prairie is in reality, partly, at least, fluviatile terrace and, as such, has a steeper slope.

Drainage

Of the three terrace surfaces represented in Beauregard and Allen Parishes, the Prairie has the poorest drainage. This surface has been subjected to erosion for a much shorter length of time and, consequently, is less dissected than either of the other two. It is also much flatter than the Montgomery or Bentley surface, an important factor contributing to its poor drainage.

The Prairie surface in southern Allen Parish may be divided into two distinct drainage basins. On the west is the Calcasieu River with its tributaries, chief among which are the Whiskey Chitto, Bunchy, and Bear Creeks. All major tributaries of the Calcasieu River in Allen Parish enter from the west side; there are no streams of any importance entering from the east. The eastern side of this Prairie surface is drained by Bayou Blue and its tributaries.
The pattern presented by these two drainage basins is entirely different. The drainage pattern of the main tributaries of the Calcasieu River is, in general, typically dendritic. Some variations are presented by the smaller tributaries whose courses have been controlled to a certain extent by the presence of channel scars on this surface, particularly channel scars of the Whiskey Chitto Creek. The development of a dendritic drainage pattern in this area is apparently due to the incision of the Calcasieu River, which lowered the base level of all its tributaries, with a corresponding increase in gradient and increase in power to erode headward.

The eastern part of this area, which is drained by Bayou Blue, presents a rather complicated drainage pattern which has undoubtedly been developed as a result, in part, of stream capture. The drainage in this area presents, in a very general way, a rectangular pattern. Streams, to which southeast flowing tributaries join, flow southwest in part and northeast in other parts of their courses. There are very few northwest flowing tributaries.

The very slight slope of this area during Prairie time was probably to the southwest. This would have been the result of a component away from the Mississippi River and a component toward the coast. During Prairie time there were probably southwestward flowing distributaries.
from the Mississippi River crossing this region. One of these old channels is still observable in Allen Parish. It is, in part, occupied by present-day streams—Meadow Creek, Bayou Blue and the Calcasieu River—but in part of this channel there are no streams. It is assumed that from Prairie time until the Present there has been a gradual southeastward tilting of this surface. Gradients of southwest flowing streams gradually became less, until, eventually, the component of the slope toward the northeast was equal to, or greater than, the component toward the southwest. This northeast-southwest direction, however, was normal to the direction of maximum slope, so that consequent streams working headward up slope could very easily capture northeast or southwest flowing streams. Bayou Blue and its tributaries, which drain the Prairie portion of the southeastern part of Allen Parish, present such a pattern, resulting from stream capture.

The history of the drainage in this section is assumed to be essentially as follows. During Prairie time there was a southwest flowing distributary of the Mississippi River crossing this area. Because of the volume of water which this stream was carrying it was able to maintain its course toward the southwest in spite of the change toward the northeast in the direction of slope of the surface. This stream was captured first near the Allen-Evangeline Parish line by Castor Creek.
Figure 7. Map showing drainage of southeastern Allen Parish.
(see Figure 7), a southeastward flowing tributary to Bayou Mespique. This diverted the water from the distributary, leaving only a small stream occupying the channel. Tributaries to this stream had developed on the northwest side as consequent streams, parallel to the direction of maximum slope. No tributaries developed on the southeast side; drainage on this side was southeastward. To the southeast of, and parallel to, this old distributary channel was another stream, Bayou Blue, which flowed northeast into Bayou Mespique. It should be noted that this stream flowed in a direction opposite to that of the old distributary channel. It is flowing in a direction normal to the present-day slope of the surface and opposite to the original direction of the slope. Although there is no evidence one way or another, it is probable that its course was originally also a distributary channel which had been abandoned. Near the headwaters of this stream, a tributary working headward up slope again captured the old distributary channel to the northwest in Section 15, T6S, R4W. Thus this stream, Bayou Blue, received most of the drainage of the Prairie section of Allen Parish east of the Calcasieu River.

This method of stream piracy, whereby streams flowing parallel to the direction of maximum slope capture streams flowing normal to the slope, is well exemplified today by an unnamed tributary of Bayou Blue in Sections 6,
10, and 18, T63, R3W. This stream is within a few hundred feet of capturing a tributary of Meadow Creek which at the present time occupies a part of the old distributary channel.

Bayou Blue, in its lower portion near Bayou Nezpique, does not now parallel the distributary channel to the north; it has an arcuate course which is convex toward the north. This deflection of the stream’s course is probably the result of a slight doming of the underlying strata in southeastern Allen Parish. Bayou Nezpique encircles this dome on the east, and tributaries of both Bayou Blue and Bayou Nezpique almost complete the encirclement on the south and southwest. Tributary streams radiate from the center of the dome to the encircling streams. The North Elton oil field is located within this area.

Along the Allen Parish side of Bayou Nezpique, from the mouth of Bayou Blue northward to Castor Creek and northward along it to the old distributary channel previously mentioned, there is a sub-Prairie level about thirty feet below the level of the Prairie surface in that area. It also lies about ten feet higher than the present-day flood plain level. During recent times both Castor Creek and Bayou Nezpique have incised themselves below this level, as a result of the uplift that the region has undergone.
Drainage on the smaller Prairie terrace remnants, along streams in the outcrop area of older terraces, is somewhat different from that just described. On such surfaces there is generally a component of the slope down the stream, and the other component is either away from the stream or toward the stream. This surface slopes away from the stream if it has not undergone much erosion since its time of deposition. On the other hand, if it has undergone much erosion, it slopes toward the stream along which it lies. In the cases where the slope is away from the main stream, a rim-swamp stream usually lies along the outer valley wall, where the Prairie terrace abuts against the older terrace.

Junction with Lower Surfaces

The Prairie terrace adjoins the Recent flood plains along all major streams and most of the smaller ones. In some places the Prairie surface is separated from the flood plain by a rather steep scarp, especially along main streams. In other cases there is no such sharp line of demarkation. It is very difficult to determine, in the case of the smaller streams, that line where the flood plain and the Prairie join. This is particularly true in southern Allen Parish, where the drainage has been to a great extent artificially modified.
for agricultural purposes. Quite often, small dams constructed for flooding rice fields result in widespread inundation following heavy rains. In such cases, it is very difficult to separate the natural flood plain boundaries from the artificial ones.

Recent Flood Plains

Outcrop Area

Recent flood plain deposits lie along practically every stream in Beauregard and Allen Parishes. These flood plain surfaces are found only along streams in this area; farther south they merge into the marsh deposits along the coast. The width of the flood plains along the streams is entirely a function of the size and gradient of the stream. For example, the width of the flood plain along the Sabine River is much greater than that along Barnes Creek because the river is larger and has a lesser gradient than the creek.

Flood plain deposits in a region with such flat surfaces as Beauregard and Allen Parishes extend practically to the headwaters of all the tributary streams. Near the headwaters of streams it is very difficult to distinguish between true flood plain deposits and slope wash, because, under these conditions, both result in essentially the same transverse profile.
Flood plain deposits in Beauregard and Allen Parishes range from very narrow belts along small streams up to a maximum width of three miles on the Beauregard side of the Sabine River.

Elevations and Slope

Elevations of the flood plain surfaces range from those that are just under the elevation of the highest terraces down to elevations lower than that of the lowest terrace surface. In general, it can be said that elevations range from about 200 feet down to about 25 feet.

The slope of the flood plains is dependent upon the gradient of the stream which formed them. An expression of the slope of flood plain surfaces, then, would mean nothing in a regional picture. Slopes range from those that are quite steep along upper courses of smaller streams to very slight slopes along major streams.

Drainage

The flood plain surface is the most poorly drained of all surfaces in these parishes. Typically, this surface is very swampy. It is usually quite difficult to travel across it. Because of its flatness it is, if not actually swampy, a great deal more moist than the
surrounding region. This wetness of the soil is very well expressed by the vegetation. Plant growth on the flood plains is quite different from that on the better drained surfaces. On the flood plains there are usually found such trees as the oak, gum, and magnolia, with a very dense undergrowth of smaller shrubs and briars. It is quite often easy to determine the boundaries of the flood plain from an aerial photograph, merely on the basis of the difference in vegetation.

Near the larger streams, quite often rim-swamp streams are present where the flood plain joins the older surfaces. Abandoned channel scars are also typical along the flood plains of larger streams. About the only relief offered is that difference between the bottoms of abandoned channels and the tops of old natural levees. The drainage on such surfaces is typically that of a swamp network pattern.

High-Level Flood Plains

Along major streams throughout Louisiana there are to be found certain surfaces which are higher than the recent flood plains but lower than the lowest terrace. In Beauregard Parish, north of Merryville, along the Sabine River, such a surface may be found. Here this surface, which hereafter will be spoken of as a "high-
level flood plain*, lies at least ten feet higher than the highest high-water level of the Sabine River. It is about ten feet lower than the Prairie terrace level in that region and is separated from the surfaces both above and below it by well defined scarps. Its outcrop area is quite irregular in outline, and it often occurs as isolated remnants surrounded by lower levels on all sides.

Such surfaces might originate in several different ways. If it were another terrace surface, resulting from the same conditions as were responsible for the formation of the older terraces, it should be reflected along all the major streams. It should also be present coastwise as a separate level between the Recent marsh deposits and the Prairie surface. This is not the case; this high-level flood plain surface is found only locally along some of the major streams.

It is assumed that uplift of the entire area involved was a process that was going on continuously, at a more or less uniform rate, throughout Quaternary time. However, if this uplift was intermittent and one such upward movement took place after Prairie time and before Recent time, this would rejuvenate streams and cause them to again start to erode downward, thus isolating their former flood plains as higher level surfaces above their present-day flood plains. That this was not the case is again proved by the fact that these surfaces are only
local in extent. Even had the uplift affected only a very small area, as, for example, around a salt dome, these levels should be present, not only along the main streams, but also along each of the tributary streams contiguous to the main streams. It is difficult to visualize an uplift that would affect only a main stream valley and not the adjacent tributaries.

Other conditions that would disturb the condition of grade maintained by a stream, such as an increase in the volume of water or a decrease in its load, would cause rejuvenation. Thus, former flood plains might be isolated as high-level flood plains as a result of the renewed erosional activity of the stream. Such high-level flood plain surfaces should be found along all the stream, as well as along its tributary streams whose base level would be lowered. Again, this is not the case.

A surface, such as the high-level flood plain surface, could be formed through erosion by a degrading stream removing material down to a harder layer of rock, eventually cutting through this harder layer but leaving remnants of it near the valley as isolated terraces. Surfaces formed in this way would have an underlying stratum of harder material. The material under these surfaces is similar to that of the surrounding surfaces, except for a somewhat higher percentage of gravel locally, and this surface obviously could not have been formed as a cut terrace.
Discontinuous terrace levels may be left at different levels on opposite sides of a stream valley as a result of lateral erosion by the stream. If a stream is on one side of its valley and is cutting downward as well as laterally, it will tend to move to the opposite side of its valley while, at the same time, cutting downward. It will then move toward the other valley wall and continue this lateral shifting. The surface formed by the stream during any one transgression of the valley will be a sloping surface from one valley wall toward the other. Remnants of this surface may be isolated at any time, but in no case will these remnants be at the same level on opposite sides of the valley. The various levels along the Sabine River in Beauregard Parish were not formed through erosion; they are depositional surfaces. There is no reason to believe that the high-level flood plain surface should be any different from the other surfaces. It has essentially the same characteristics as those levels above it and that one below it.

The only explanation, seemingly consistent with all the facts, for the high-level flood plain surface in Beauregard Parish is that it represents a portion of an alluvial fan built on the flood plain of the Sabine River at the mouth of Anacoco Creek. This explanation requires that the stream building the fan have a higher gradient than that stream into which it empties. It implies the
deposition of somewhat coarser material than that being deposited by the main stream. Both of these are consistent with the facts. Anacoco Creek has its headwaters in the Williana terrace of Vernon Parish and, having a rather high gradient, picks up and transports quite a bit of gravel. The Sabine River was unable to remove this material as it was being deposited, and, consequently, an alluvial fan was built at the mouth of Anacoco Creek on the flood plain of the Sabine River. This fan, which was being continually enlarged, particularly during flood stages of the Anacoco, pushed the Sabine River westward toward its other bank. Anacoco Creek maintained a channel across the fan which, as gradual uplift of the region continued, it was forced to cut deeper and deeper. Eventually the place was reached where, even during flood stages, it could not overflow onto the fan, and so, it could deposit no more material on this surface. In the meantime the gradient of the stream became less; consequently its carrying power decreased until, at the present time, the Sabine River is able to move all material deposited in it by Anacoco Creek. Remnants of this surface were isolated on the Sabine flood plain by subsequent erosion.
Other Surface Features

Pimple Mounds

General

Pimple mounds (also called "prairie mounds", "natural mounds" and "residual soil hillocks") are a very common physiographic phenomenon of the Gulf Coastal Plain of Louisiana west of the Mississippi River. They occur, too, in the adjoining states of Texas, Oklahoma and Arkansas as well as Missouri and Kansas, but they have never been reported east of the Mississippi River. They are common on the west coast and in places there are referred to as "hog wallows", a term applied to the low spaces between the mounds. They are also reported to occur in Mexico and Argentina. Apparently not restricted to any particular type of rock, they are most common in the Gulf Coast area on the dominantly sandy or silty Pleistocene terraces, but they also occur on flood plains and on Tertiary rock outcrops. Elsewhere, they occur on basalts of the Columbia River Plateau and on Paleozoic rocks. It is quite apparent that all features referred to as pimple mounds were not formed by the same geologic agent.
These mounds are low, rounded hillocks, varying in shape from nearly circular to elliptical, with the typical one appearing to be almost circular. In height they range from those that are scarcely perceptible up to about five or six feet and in diameter up to nearly one hundred feet. The average one in northwest Louisiana, where they are very well developed, is about fifty feet in diameter and two or three feet high.

Figure 8. Pimple mounds in a rice field on the Prairie terrace, one and one-half miles north of Oberlin, Allen Parish. View looking west from U. S. highway 165. Sec. 2, T5S, R7W.
History of Literature on Pimple Mounds

The Caddo Indians had a legend concerning the origin of the pimple mounds that is perhaps as acceptable as some of the hypotheses that have been offered for their formation. This legend, quoted from Veatch (1900), states that: (pp. 192-193)

"...many, many years ago the country was inhabited by a race of giants. For some reason, which the legend did not state, the giants were carrying dirt in their aprons; when the dinner
horn sounded they dropped the dirt where they stood and hurried away to a dinner from which they never returned.

These low mounds, occurring literally by the millions, have attracted the attention of observers for well over a century. Charles Wilkes (1843, vol. 4), in his report on the United States exploring expedition during the years 1838-1842, was one of the first to mention them in print. He observed the mounds on the Columbia Plateau where they are composed mostly of drift. He thought them to be arranged in a definite pattern, although later workers could see no such symmetry. He thought that they might be burial mounds of the Indians, but, upon digging into some, he could find no bones nor artifacts. The only thing suggestive of a human agency was a pavement of round stones at the base. In spite of his negative results, and in spite of the fact that the Indians in that region had no legend concerning them, he considered them to be artificial and to have been made by the medicine men.

Owen (1860), in a reconnaissance report on a part of Arkansas, noticed these low mounds and ascribed their formation to differential weathering. (p. 112)

"Where chert materials prevail, harder and more durable than the rest of the formation, they have resisted decomposition for a longer period of time than the surrounding parts, and give rise to those isolated mounds which rise conspicuously, in all directions, out of the prairie, when viewed from some elevated position in the neighboring hills."
Thomassy (1860), in a book on "Geologie Pratique de la Louisiane", observed the mounds in the marshes of southern Louisiana and considered them to be either ancient mud lumps or to have been formed by water under hydrostatic pressure depositing sand where it comes to the surface. (p. 83)

"Ne sont-ce donc pas là d'anciens Mud-lumps, remontant à l'époque où le fleuve débouchait vers ces parages, où plutôt datant de la commotion qui disloqua le sous-sol et en fit jaillir des eaux boneuses?"

Some years later J. D. Whitney (1865) published his "Geology of California" in which he speaks of the mounds near Thomas' Mill on King's River. He offers no theory as to their origin but says that they are composed of a hard, clayey soil, thrown up into alternate hillocks and hollows, popularly known as 'hog wallows', the origin of which is hard to explain. They resemble the hillocks left by the gradual decay of trees uprooted by the wind in our eastern forests, and the depressions between them contain water in the rainy season."

In a prediction that Louisiana would be found to contain the "richest deposit of oil in the world", Robertson (1867) used as one of his lines of evidence the abundance of pimple mounds, stating that (p. 16)

"I am confident that the whole area covered by these tumuli contains basins of oil, and that the mounds are of comparatively recent origin, and were thrown up by the eruptive force of the gas generated by the oil below."
Three years later Lockett (1870), in reporting on the topography of Louisiana, said (p. 66)

"There is one feature observed in these prairies, quite peculiar and striking, namely, a great number of small isolated mounds. They are thought by the inhabitants to be Indian mounds, and some of them have been excavated and Indian relics found."

Lockett was not inclined to believe them to be artificial, in view of the fact that there were so many of them, and stated (p. 66)

"...it is hardly possible that so many tumuli, so irregularly scattered over so large a scope of country can all be the result of human labor, but rather of natural origin and then subsequently used as burying grounds for the aborigines."

Hopkins (1870) described the pimple mounds in the marshes of southern Louisiana as follows: (pp. 80-81)

"Now the marsh is dotted in every direction with mounds generally circular, and of from 30 to 50 feet in diameter and from three to five feet in height. Their appearance is singular, and is rendered yet more effective by the fact that while nothing but marsh grass can grow between them, they are covered with luxuriant clumps of timber trees, whose grouping could not be excelled by the best landscape gardner."

As to their mode of origin, he thought they were mud lumps, formed at a time when the Mississippi River was actively depositing material in that section, and that sedimentation by the river had progressed on beyond this area and left the mud lumps as pimple mounds, rising above the marshes.

Featherman (1872), in a report on the Botany of southwestern Louisiana, diverged long enough to propose a novel
theory for the origin of these mounds. He thought that

(p. 107)

"...it would be almost as reasonable to suppose
that these mounds were formed by whirlwinds like
snow drifts or mountain-like waves, and were
afterwards fixed in their position by the vege­
tation which subsequently sprang up, which bound

Gibbs (1872) gave a very good discussion of the
mound prairies of Washington. He described them as
being (p. 304)

"...composed of a light soil, with interspersed
gravel, being perfectly homogeneous through the
whole mass....There was no appearance of strati­
fication. The soil and gravel were intermixed
throughout. This prairie is of generally uni­
form level, though with some swales running
across it, and the intervals between the mounds
are, as it were, paved with boulder stones; the
appearance presented being as if the superficial
soil, down to this bed, had been shoveled up
into piles."

Gibbs did not concede them to be of human origin because
they were too numerous, too uniform in size, contained
no bones or relics of any kind, and exhibited no evi­
dence of fire. He was unable to find any integration
of drainage channels among them and thus did not think
that they were erosional in origin. He stated that
they (p. 307)

"...have been attributed to the pushing up of
the soil by the roots of the wild cucumber vine
(Negarrhiza oregona), which frequently reach
the size of half a barrel, and are very commonly
found in them, or that these have at least formed
a nucleus about which the soil has collected."
He thought, however, that the vine had just found enough soil to grow in here and had not been responsible for the formation of the mounds. He also discarded the theories that they were the remains of a burned or over-turned forest, that they were the work of burrowing animals, and that they were formed by springs in the bottoms of lakes. He credited Mr. Agassiz with the (p. 307)

"...only explanation consistent with all the facts."

stating that, (pp. 307-308)

"On exhibiting to him the drawings and descriptions of the mounds, he unhesitatingly declared them to be the work of fish of the sucker family, accumulated in successive years during the lake period, for the protection of their eggs. A similar process, he states, is going on in Jamaica Pond and other little lakes around Boston, and that on a scale which causes no wonder at the size of those of Washington Territory."

Hilgard (1873), in describing the pimple mounds of Louisiana, stated that (p. 11)

"They do not show in their internal structure any vestige of their mode of origin; or rather, being totally devoid of structure of any kind, they merely prove by their material that there has been a mixing up of the surface soil with from two to four feet of the subsoil."

Because of the heterogeneous nature of the material, and because he was undoubtedly influenced by published accounts of the large ant hills of South America, such as Robertsons (1839) which stated (pp. 270-274)

"...thousands of conical masses of earth to the height of eight and ten feet, having a base of nearly five in diameter."
and Parish’s (1852) statement to the effect that (p. 252)

"...Corrientes and Paraguay, where whole plains
are covered with their dome-like and conical
edifices, rising five and six feet in height."

he concluded that the pimple mounds were ant hills. Many
later workers came to this same conclusion with regard to
the mounds on the Gulf Coastal Plain; however, to those
who described the mounds on the west coast, this conclu-
sion was not tenable because of the large percentage of
gravel in their make-up.

Poster (1873), in a book on the prehistoric races
of the United States, concluded that the mounds (p. 121)

"...west of the Mississippi delta to the
Colorado and from the Gulf to Arkansas"

were not of human origin. He did not offer any theory
to explain them but said (p. 122)

"In utter desperation I cease to trouble my-
sel about their origin and call them 'inex-
plicable mounds'."

LeConte offered an explanation of the mounds in
Washington that is still widely accepted, with slight
modifications. He expounded his theory in two articles
under the same title in 1873 and 1874. He recognized
the fact that (1874, p. 367)

"...a phenomena so widespread must be attri-
buted to the action of a wide spread agent."

and so ascribed their formation to surface erosion. His
explanation follows: (1874, p. 366)
"I long ago arrived at the conclusion that they were the result of surface erosion under peculiar conditions.... These conditions are a treeless country and a drift soil, consisting of two layers, a finer and more moveable one above and a coarser and less moveable one below. Surface erosion cuts through the fine superficial layer into the pebbly layer beneath, leaving, however, portions of the superficial layer as mounds. The size of the mounds depends upon the thickness of the superficial layer; the shape of the mounds depends much upon the slope of the surface. The process, once started, small shrubs and weeds take possession of the mounds as the better soil, and hold them by their roots, and thus increase their size by preventing or retarding erosion in these spots."

The role of vegetation was better described in his first paper. (1873, pp. 214-220)

"The process once commenced, weeds, shrubs and ferns take possession of these spots as the better soil, or sometimes the drier soil, and hold them, and by their roots retard erosion there. In some cases a departing vegetation—a vegetation gradually destroyed by an increasing dryness of climate—is an important condition."

Wallace (1877-a) wrote a short article for Nature, in which he described some "hog wallows" at the foot of the Sierra Nevada in California. He, himself, had not seen these mounds, but had been told about them through a letter from his brother. His conclusions regarding their origin was that they were (p. 274)

"...due to the retreat of the broad foot of the glaciers leaving behind it a layer of debris or morain-matter, which has become arranged in its present form by the innumerable rills that issued from the retiring sheet of ice."
Because of the fact that his description of the mounds was quite general, there followed a whole series of short articles and letters in Nature about similar phenomena, mostly by people who had never seen the mounds.

During the same year Kinahan (1877-a, p. 379) described some morainic drift, which he thought fitted the description of Wallace's "hog wallows", but which, obviously, was not the same thing.

Still later in that year Wallace's (1877-b) attention was called to LeConte's explanation of the prairie mounds, and in another article in Nature for that same year he questioned whether LeConte meant fluvial erosion or aerial erosion or both combined. He also stated that (p. 438)

"...more explanation is needed to account for the removal of the eroded material over a surface 30 miles wide without producing any continuous ravines or other water channels."

LeConte (1877, pp. 530-531) explained his theory as stated in previous papers and stated that submergence was not necessary to produce the prairie mounds. He also reviewed theories that had been offered to date, among which was the one that Gilbert offered to explain mounds in Arizona which he thought were the ruined habitations of prairie dogs and the one popularly supported in California where they were supposed to be due to burrowing squirrels.
Williams (1877, pp. 6-7) described some morainic deposits in England which he thought to be comparable to the bog wallows of California, only to be told later by Durham (1877, p. 24) that his glacial morainic deposits were probably "sahares and kames".

Kinnahan (1877-b) in another article recognized that LeConte's prairie mounds and his drift mounds were not the same thing and said that, from LeConte's description, the prairie mounds would (p.7)

"...seem to be somewhat similar and to have the same origin as a tussocky bog or mountain."

which is formed as follows: (p.7)

"...very hot weather cracks the peaty upper soil forming deep fissures; while subsequent weathering changes the portion between the fissure into small hills."

Still later Gabb (1877, pp. 183-184) described some sand dunes in Nevada and assumed them to be the same as the prairie mounds.

Barnes (1879) was one of the first to offer a tenable hypothesis in which plants played an important part. In expounding his theory, with reference to mounds near San Diego, he stated that (p. 566-568)

"Each mound marks a spot where formerly grew a shrub or cluster of shrubbery, which served to fix its location and which exercised an important influence in the successive stages of its development. The shrubs which seem to have been chiefly instrumental in these results are the Rhus laurina, the Simmondsia calendula, and the Isomeria arborea; the former undoubtedly have been principally instrumental in the creation of the more
recent as well, perhaps, as the most ancient ones in this vicinity. These plants are fitted for the office they perform by the nature of their growth, which is in compact groups or clusters, with many stems starting from the earth near together, the branches and foliage forming a dense mass resting closely upon the ground, and with beds of massive roots; while the distribution of the groups is strikingly similar to that of the mounds in their typical form and arrangement.

"Dust set in motion and borne along by the winds is arrested by the shrub and, together with its fallen leaves, accumulate within and around it, and, as is seen in thousands of instances in this vicinity, an elevation of many inches is produced in this manner alone, in many cases covering the lower branches, and in case of the Simmondia, especially, nearly enveloping the whole plant. The gopher, subsisting upon roots and preferring for its operations the loose soil about them, is, in exceptional cases, an adjunct of the wind in heaping up material about the plant." ........ "While the loose earth of which the deposit is composed is protected by the branches and foliage of the plant, the more solid earth beneath is also protected from the wash of rain by its massive roots, while all around erosion goes slowly on, facilitated by the peculiar susceptibility of the soil to wash............... "In the course of time the plant dies— is smothered by the dirt which nearly covers it, or is destroyed by the fires which annually sweep over extensive tracts of country. Thus deprived of its protection, the winds in turn, and the rains which fall upon it wear down the top of the loose deposit, and to some extent widen its base. While this is going on the surrounding earth, or inter-spaces, are being continually lowered by the action of water. The wash always being greater at the base than at its summit, its tendency is to perpetually maintain or increase the prominences."

Although a glacial origin had been assigned to the mounds on the west coast before, Rogers (1893, pp. 393-399) gave the first clear explanation of how they might be formed through glaciation. After reviewing and finding fallacies
in most of the previous theories that had been offered, he suggested that the region had been covered by stagnant ice of the piedmont glacier type and that, in holes in the ice, gravel, sand, and other debris accumulated. After the ice melted, this material was left as mounds.

Nadaillac (1895) in a book on prehistoric America told of two other theories for the mounds of the Gulf Coast. (p. 182)

"Between the Red River and the Ouachita they (the mounds) can be counted by the thousands. According to Forshey, who described them to the New Orleans Academy of Science, these embankments cannot have served as the foundations for homes of men. Other Archaeologists are more positive; they consider that these embankments were used for nothing but cultivation, and that they are intended to counteract the humidity of the soil, still the greatest obstacle with which the tillers of the soil of the plains of the Mississippi Valley have to content."

Turner (1896), in a report on the Sierra Nevada, called attention to low mounds occurring on the slopes of the east side of the San Joaquin and Sacramento valleys. He referred to these as "hog-wallow mounds", and he observed that they appeared to be made of the soil formed directly from the underlying pre-Cretaceous shistose rocks. Other mounds, occurring on an andesite-breccia area of the Sonora region, are composed of finer material, and of these he stated (pp. 631-632)

"It is not likely that these have had an origin similar to those in the lower foothills and on the plains. To one who has seen the little
mounds made by ground squirrels in the Coast Ranges the resemblance of the mounds shown in the illustration (Plate 33) will be at once apparent. In many cases squirrels are now living in these little mounds of the plains region and foothills of the Sierra Nevada, but many of them show no traces of former burrows."

.... "While the evidence is not sufficient to warrant assigning to squirrels or other rodents the making of the hillocks, it is thought that this origin should be considered."

Clendennin (1896), reporting on southwest Louisiana, described the mounds and called attention to their greatest development around and near the sulfur mines in Calcasieu Parish and their decrease in abundance in all directions away from this center until, after 25 to 75 miles, they cease to be sufficiently developed to attract attention. He ascribed to the view expressed by Hopkins somewhat earlier, that they are a pressure phenomenon similar to mud lumps. His conclusions are (p. 182)

"Now, however close the analogy in origin of these mounds to that of the mud lumps at the mouth of the Mississippi, their composition and structure both point to a force acting from below, and similarity of the underlying deposits of those of the Cretaceous ridge which terminates southward in Belle Isle, where undoubted disturbance has occurred, suggests that here, too earthshocks are produced, with more or less fracturing of the strata. Such fractures would radiate and rebranch from a central region, and along the radial and branching fractures the gases would find an easy passage, and above them, around the vents through which they reached the surface, mounds would be produced.

"This would account for the zonal and linear arrangement of these mounds, and likewise for their structure and composition, the excess of sand coming from the underlying Lafayette."
Branner (1900, pp. 151-153) published an article in the Journal of Geology concerning ants as agents of weathering in the tropics. In this paper he described ant hills in Minas Geraes, Brazil, which are from three to fourteen feet high and have a diameter of ten to thirty feet at the base. He also stated that the old ones tended to become rounded and flattened. This paper has been quoted quite a bit by later workers, as well as by Branner himself, who considered that ants were responsible for the formation of the mounds on the Gulf Coast.

Veatch (1900), in a report on the Shreveport area, discussed the mounds of the Gulf Coast and concluded that (p. 194)

"The theory of the gas origin of the mounds seems to be more nearly supported by the observed facts than any other theory yet advanced. But the exact relation between the water and the gas, which issue from the mounds now forming, has never been fully worked out. It may be that the gas merely accompanies the water instead of the water accompanying the gas."

Upham (1904), in writing on drift deposits near Seattle, Tacoma, and Olympia, accepted Rogers' theory that they were of glacial origin. (p. 212)

"The gradation of forms from round mounds to interlocking ridges and mounds, like small reticulated kames, debars the reference to aboriginal mound building, or to mounds of any burrowing animals, which at the first view are suggested by these very unusual drift deposits. Their true explanation has been well stated by Rogers, referring them to the accumulations in little hollows of
of the finally very thin margin of the ice fields when they at last melted back from this outermost tract of terminal moraine belt."

Shepard (1905), in describing the New Madrid earthquake, noted some mounds which he thought to be formed by earthquakes. (p. 52)

"Another peculiar feature of the country which should be mentioned is the presence of 'sandblows' - low mounds of fine white sand mixed with small pieces of lignite. These mounds are three or four feet high, with a diameter of 20 to 100 feet, and are frequently slightly hollowed in the center. They are scattered over the whole district, and the sand is so pure that it will not support vegetation, and consequently barren patches mark their site."

He assumed the cause of the whole thing to be artesian water removing sand from underneath of clay beds, thus disturbing the equilibrium so that a minor earthquake resulted. This method of formation of mounds in this section was seized upon by later workers to explain the formation of all the mounds of the Gulf Coast.

Piper (1905, pp. 324-325) in describing mounds on the Columbia Plateau stated that, for the larger part, they occurred around high, tower-like or crag-like pinnacles. He thought they were the result of differential weathering of these more resistant points.

Veatch (1905, pp. 350-351), in an article in Science, revived the whole question as to the origin of these mounds, particularly the ones on the Gulf Coast. After listing the various theories, he considered only three of them to be worthy of more thought. The first, the spring
and gas vent theory, he thought, was substantiated by the fact that similar cones being built today and by the fact that there is artesian water below these surface beds, but his objections were that similar cones are found today on highly inclined Carboniferous shales and sandstones in Indian Territory. They were too uniform in size and occurred over too large an area to have been formed by the wind and, further, there were no indisputable dunes or lines of dunes present among them. His conclusion was that they were ant hills, either the work of Atta, or leaf-cutting ants, or of a mound building variety of white ants (the termites). This theory is substantiated by the fact that in West Texas atta hills are said to reach a diameter of 40 to 50 feet and a height of from one to two feet, while in Cuba these hills are 10 to 12 feet high with a diameter several times as great. He goes even further to state that if these mounds are the work of termites, this suggests a former moister and warmer climate.

Brammer (1905), previously referred to as the author of an article on ants as agents of weathering, published an article on the mounds of the west coast. He noted that they occurred in places where the underlying rock ranged from Pleistocene gravel to granite and schist to folded Paleozoics. He also stated that they were never found in sandy river bottoms. He stated, with regard to
their composition, that in California they were (p. 515)

"....compact, clayey hard-pan, in places so hard
that it is difficult to plow."

After reviewing the various theories, he stated that the
ant hill theory seemed most plausible. He offered the
idea that they might be concretionary in origin, stating
that (p. 516)

"....in soils of certain kinds, long exposed
to weathering agencies, chemical reaction possibly
takes place around centers that result in the
transfer of minerals in solution to and the
precipitation in nuclei that are now repre­
sented by the position of the mounds, while the
withdrawal of these minerals from the intervening
areas cause the depressions around the mounds."

Hilgard (1905, pp. 551-552) again entered into the
discussion with the statement that he had dug into the
mounds on the Opelousas and Calcasieu prairie where he
first thought them to be similar to the mud lumps of
the Mississippi delta but that the absence of any onion-
like structure eliminated this idea. The total absence
of any structure eliminated the ideas that they were of
either aeolian origin or water erosion. He considered
them to be ant hills, as he had in his previous paper,
concluding that the ants had been destroyed by climatic
changes. He compared them to similar mounds that he had
seen in Yellowstone Valley in which the ants were still
living. He recognized that the mounds of the west coast
and those of the Gulf Coast were different, and said that
the mounds of California were of wind origin and those of
Oregon erosional.
Spillman (1905, p. 632) described some mounds in Lawrence County, Missouri, where they occur on both prairie and timber country. In this section the mounds are on Mississippian limestone, in which is an abundance of flint nodules. When the limestone is weathered into soil the flint merely tends to break up and fall apart. He ascribed the formation of the mounds to places where there was a greater concentration of flint or larger flint nodules. His proof of this theory was that, when dug into, the mounds contained an abundance of flint.

Pardue (1905, pp. 323-824) described the mounds along the Tertiary area in the northeastern part of Arkansas. He as able to find something wrong with all the theories thus far presented. He noted that they always occurred on residual clay soil where the drainage was poor, and concluded, as did Branner, that the action of ground water in segregating mineral matter was probably important.

Bushnell (1905, pp. 712-714) recognized that all mounds were not formed by the same agency and stated that most of the theories were not acceptable. He concluded that the ones in Dallas County, Missouri, were built by man, probably to serve as elevated sites for habitations.

Penneeman (1906) in a bulletin on the Gulf Coast oil fields did not attempt to explain the origin of the mounds but cautioned about connecting them with oil deposits. (p. 124)
"A phenomenon which has carried far more weight than justly belongs to it is found in the so-called 'gas mounds'. These are low rounded mounds averaging perhaps 2 feet in height and several rods in diameter. In view of their vast numbers on the flat Coastal Plain, they show remarkable uniformity in size and shape. They are popularly supposed to be connected with the escape of gases from the soil. Whatever be their origin, there is as yet no evidence that they are in any way related to oil bodies. Even were such a relation assumed, these mounds are so widely distributed over the flat Coastal Plain, that as guides to drilling they are of no value whatever."

Farnsworth (1906, pp. 583-584), in the same year, concluded that the mounds were the result of uprooted trees.

Veatch (1906-a) in a United States Geological Survey Professional Paper again discussed pimple mounds. This discussion was essentially the same as his previous paper in 1905. After listing and finding fallacies in most of the previous theories, he again concluded that ants were responsible for these mounds (p. 59)

"In conclusion, it may be said that these mounds are clearly due to causes not now in operation in this region, and no theory of origin yet suggested is entirely satisfactory. The dune and ant hill theories are, perhaps, the best supported. On either of these hypotheses the mounds are indicators of important climatic changes in recent times, and so offer a line of investigation which may develop very important and far reaching results."

Veatch (1906-b, pp. 34-36), in yet another article, discussed the possibility of pimple mounds being of human origin. As had been suggested by previous authors, they might have been built either for elevated sites for Indian
huts or for cultivation. He did not think they could have been of human origin because (a) they were not in favorable locations, (b) some were in locations that were already elevated, (c) they were entirely too numerous, and (d) some occurred in the poorest soil.

Hill (1906), after discussing various theories for the origin of pimple mounds, concluded that they (p. 705)

"...are natural products of certain types, climatic and geologic conditions."

This being the case, he stated the geologic set up—that they always occur in areas of poorly drained sub-level surfaces where there is plenty of rainfall and that they are always underlain by unconsolidated alluvial sands and clays upon which the rainfall stands until evaporated. He then proposed that these materials would have different capacities for absorption, which would result in unequal settling and thus the formation of pimple mounds.

Udden (1906, pp. 849-851) noted the presence of sunken pits and live ant hills on the mounds in the Gulf Coast country. He stated that these sunken pits, which were exhibited on one-fifth of the mounds, increased in frequency with an increase in size of the mounds and that live ant hills decreased in frequency with decrease in size. He also observed that when such land was inundated for rice crops, the water sank very rapidly through the sand of the mounds so that, if the mounds were too numerous,
the land could not be used for this purpose. Because of the above observations, he considered the mounds to be ant hills.

Campbell (1906) was the author of a very good review of the entire subject of pimple mounds. He considered that, from their wide spread distribution, they must have had a common mode of origin. With this in mind, he was able to discard a great number of the theories which had previously been proposed. He discussed a few of the theories in considerable detail. He had noticed one mound in Arkansas where the material of the mound was different from the material underneath and therefore concluded that the mounds were constructional. His final conclusions were: (pp. 703-717)

"This disposes of all the hypotheses, except that which ascribes their origin to the action of burrowing animals; but whether the mounds are due to ants or to small rodents, the writer is unable to say. Personally he inclines to the ant-hill hypotheses, but there is little or no evidence to determine which is correct. No burrows or chambers of any kind have been discovered in the mounds, and in the case observed by the writer no differences were observed in the character of the underlying clay, which would indicate the former presence of chambers, even though they are now filled. No excavations were noted in the neighborhood which could have supplied outside material for the mound, and consequently, it is assumed that this material must have come from a long distance underground, and the minute channels through which it was transported have been closed by material falling in from above or carried in by water in suspension."

Hobbs (1907, pp. 245-256) concluded that pimple mounds were formed as a result of crustal movement, by
gases, and by water bringing sand to the surface where it was deposited in the form of mounds. He also thought that they were related to deep-seated fissure systems under the Coastal Plain. As proof of his hypothesis he cited examples of mud lumps, craterlets, small sand mounds, etc., being formed at the present time in numerous regions of crustal instability.

Begun (1907), after discussing the possibility that the mounds of the lower Mississippi River-Texas region were of Indian origin, offered the theory that they were due to "soil creep" and pressure. (pp. 99-100)

"If on an impervious bottom at the time the region in question was being formed, there was a semi-fluid layer reaching any distance inland, as the shore line advanced or receded, and this was being covered with another layer faster than it could creep seaward, whether the superficial layer was brought there by wind or water, mud lumps would certainly have been pushed up in all the spots where the latter layer was thin or wanting. This, when dried, would become mounds."

Bretz (1913), in a report on the glaciation of the Puget Sound region, devoted a chapter to the mounds occurring in the Bashar outwash plain south of Tacoma. He divided these mounds into two types, which he named the "Mima type" and the "Ford type". The Mima type appears to be comparable to the mounds under discussion. The Ford type is quite different and shows no relation to the pimple mounds occurring in the Gulf Coast region.

The Mima type mound is composed of both silt and gravel, with, in many cases, an intermound area thickly
covered with gravel and boulders up to two feet in diameter. They never occur on surfaces other than those of glacial gravel. After disposing of various suggested hypotheses for their origin, including that of erosion, he concluded that (pp. 105-106)

"It may be suggested tentatively that if a sheet of ice several feet thick could be formed over the surface of an outwash gravel plain and could subsequently be flooded so that stream-carried debris would be deposited on its surface, it might, on melting, develop pits into which the surficial debris would gravitate. Since water is densest at 39°F., the lower interstices of the gravel in the pits of the postulated sheet of ice would become filled with water at this temperature. Since such water would be 7° warmer than the adjacent ice, it would cause deepening and enlarging of the pits after the earthy accumulation had become so thick that warming of the gravel by the sun ceased to be a direct factor in formation of the pits. Sliding and washing of the surface debris into these pits would expose interpit areas, and the melting of such areas would then proceed more slowly than when rock fragments strewed it, and absorbed the sun's heat.

"Some such set of conditions might give rise, on final melting of the ice, to mounds; these being without structure, without assortment, and superposed on current-bedded gravels as are the Mima type mounds."

He assumes that the Ford type of mound, which is extremely irregular in both size and shape, is the result of deposition between stranded blocks of ice; the area between the blocks of ice, being built up high, formed the mounds and the ice, on melting, formed the depressions between the mounds.

Freeman (1926) described some mounds which occur on top of shallow depressions in the bare basaltic rock of
the Columbia Plateau region. These depressions were described as sometimes being shallow with a lens-like cross section, and in other cases having steep sides like a pot hole. He concluded that the material of which they were composed (p. 451)

"...appears to be brought from elsewhere and deposited by the wind."

He further concluded that the sediment accumulated first in the depression, vegetation started growing on this material (the depression underneath acting as a reservoir for water) and that this vegetation served as an aid in retaining other wind blown material until the mound was formed.

Hannemann (1928), in an article, in German, on the Gulf Coastal plain, believed there to be a connection between salt domes and pimple mounds in the Texas and Louisiana Coastal Plain. He also believed that there was a direct relationship between the occurrence of pimple mounds on the surface of the ground and reservoirs of gas below. He went even further to state that a study of pimple mounds might lead to a method of locating new gas fields. (p. 224)

"Es ist aber meines Erachtens nicht zweifelhaft, dass auch in anderen Staaten der Union die Gastheorie die einwandfreiste und ungewogenste Lösung dieses Problems bietet. Eine systematische und vergleichende Untersuchung der Pimples und pimpleähnlichen Formen in verschiedenen wäre daher sehr erwünscht, und es werden sich sicher noch interessante und wichtige Beziehungen erkennen lassen,
welche vorläufig nur als Vermutungen ausgesprochen werden können. Eine solche Untersuchung hat nicht allein eine wissenschaftliche, sondern auch eine praktische Bedeutung." ....... "Die Pimples andererseits können wertvolle Leitformen werden für die Erschließung neuer Gasfelder."

In an article on the mounds of the Columbia River Plateau, Waters and Flagler (1929) came to the same conclusion as LeConte had reached much earlier——that is, that they were the result of water erosion. Their conclusions and observations are listed below:

1. They are made up of fine volcanic ash and rest directly on weathered basalt.
2. Mounds are polygenic but the ones on the Columbia Plateau have had a common origin.
3. Mounds here are erosional remnants of a once continuous layer of volcanic ash.
4. Mounds developed only where ash rests directly on basalt.
5. Basic condition that subsoil be less moveable than upper soil.
6. Must be enough slope present to permit run-off.
7. Mounds are elongate in the direction of slope.
8. Amount of elongation is a function of the steepness of the slope.
9. Local irregularities produce odd and irregular shaped mounds.
10. If the ash is of uniform thickness, a mound area generally passes with decrease of slope into an area that is completely mantled by the ash; with increase in slope it passes into an area from which the ash has been completely removed.
11. The height of the mound is equal to, or less than, the thickness of the adjacent ash blanket.
12. Mounds are not found where the ash is more than seven feet thick.
13. Drainage between mounds definitely integrated and minutely adjusted.
14. Symmetrical development of drainage system may be influenced by the columnar jointing of the ash.
15. Mounds do not indicate a climatic change.
Welton (1989-a), in a paper presented before the Geological Society of America, stated that mounds (p. 135)

"...owe their origin to gullying by small streams and rivulets in a very weak, sandy soil."

He suggested that the term "residual soil hillocks" be used to replace the term "natural mounds."

Welton (1989-b) described the natural mounds of the Gulf Coast area in Louisiana and Texas in one of the most comprehensive articles that has as yet appeared. He reviewed the literature and classified into fourteen groups all hypotheses for the origin of the mounds. After discussing each of the fourteen hypotheses he concluded that only five of them were valid and worthy of further consideration. These five possibilities were (1) concretionary hypothesis, (2) spring and gas vent hypothesis, (3) sand dune hypothesis, (4) uprooted trees, and (5) stream erosion.

As a result of chemical analysis of composite surface soil and sub-soil samples taken at different places on the mounds and in the inter-mound area, he found that there was no evidence to support the belief that they were the result of large-scale concretionary deposition of mineral matter by ground water. His conclusions were (p. 123)

"...that neither of the compounds (CaCO₃ or Fe₂O₃) which might act as cementing agents vary enough from the mound to the inter-mound areas to cause the concretionary effect postulated."
Furthermore the percentage of Fe₂O₃ is greater by 1.2% between the mounds than it is beneath them. The CaCO₃ is present in such small quantities that it could hardly be supposed to act as a concretionary matrix between the grains of sand. Also, the greatest percentage of CaCO₃ is found between the mounds instead of beneath them, just as in the case of the Fe₂O₃.

The spring and gas vent hypothesis, likewise, was discarded because there was no evidence in the field of any "sand-pipes" or vertical joints filled with sand. Also, there was no evidence of craters or craterlets. The gradation from surface soil to the sub-soil and the absence of any fissures or joints through which the water and gas could have circulated were further evidence against this hypothesis. He admitted, however, that, locally at least, some mounds might have been built by this method.

The sand dune hypothesis was rejected for the following reasons: (p. 126)

"(1) There is no source of sand adequate for the demands of such widespread features.
(2) No cross-bedding of any kind was seen by the writer in the soil of the mounds.
(3) The surface soil of the mounds grades downward uniformly and completely into the sub-soil—-it is definitely 'in place'."

The hypothesis that these mounds might be the result of the uprooting of trees was rejected, largely because of the distribution of trees and also because of the number and size of the trees that would be required to form such a widespread phenomenon.
Thus, by a process of elimination, he arrived at the conclusion that the mounds were the result of stream erosion, and he substantiated his conclusion with several lines of evidence. His theory for their origin was that (p. 128)

"...it is necessary to suppose that in these relatively unindurated sandy strata weathering has produced a weak sandy soil several feet in depth. Slight rejuvenation of the main streams has started an episode of rapid gullying in these soils. The sides of the gullies being too weak to stand vertically for long, have rounded off by rain wash and slumping. Where these mounds are found on geologic formations that are well indurated and fairly resistant, one must assume a longer time of relatively slow erosion in the recent past with consequent deep weathering and the production of a weak porous soil. Slight increase in the activity of the streams would rapidly remove the soil. During removal, such mounds as we now see would be found."

He assumed the relatively flat, inter-mound area to be the result of the difference in resistance between the surface soil and the sub-soil. One of the more important lines of evidence supporting his conclusion that the mounds were erosional in origin was derived from aerial photographs.

Rich (1934) approached the problem from an entirely different angle. In a flight on a regular passenger plant from Dallas, Texas, to Texarkana, Arkansas, he observed and photographed mounds. He concluded that (p. 578)

"The pattern of the mounds differs so radically from normal stream or gully patterns that Melton's
explanation is difficult to accept, but in a modified form in which clump vegetation is assigned an important place it receives partial confirmation."

He suggested the possibility that (p. 578)

"...protection of the areas beneath the trees from the direct beating of the rain might in time leave them standing slightly higher than the exposed places between."

The effect of wind in controlling tree distribution is also mentioned as an explanation for some mounds whose shapes are suggestive of wind influence. His main thesis in the paper is that bunch vegetation was an important factor in guiding the development of the mounds.

As an answer to Rich's paper, Melton (1935) presented some additional aerial photographs and stated that, although vegetation played an important part in guiding headward elongation of rivulets, plant growth clearly followed and did not precede the formation of residual ridges between gullies. He further stated that the effect of insolation, wind and sheet-wash was important.

Fisk (1938) mentioned mounds as being characteristic of the terrace formations in Grant and LaSalle Parishes. He described the mounds in that area but made no definite conclusions as to their origin.

Newcomb (1940), in an article on mounds in Washington, considered them to have been formed by the expansive force of ice in large polygonal mud cracks. According to this theory, during cold weather accompanying glaciation
the frozen surface layer of silt cracked into large polygons, 40 to 60 feet across. Water entered these cracks, froze, expanded and bulged the center of the polygon. Repeated freezing and thawing, and finally melting of the inter-mound ice, left the mounds as they are today.

Delquest and Scheffer (1942), in a recent article, ascribed the formation of the Mima mounds in Washington to the work of gophers. (p. 76)

"We deduce that the Mima mounds have been formed by the localized activity of pocket gophers (T. talpoides) over thousands of years."

According to them, the necessary conditions for the formation of the mounds are (p. 76)

"(1) presence of gophers, (2) a prairie area consisting of a thin layer of silt overlying a dense layer of gravel unfavorable to the growth of plant roots."

In summary, the various theories for the formation of pimple mounds are listed below in tabular form.

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<tr>
<td>Normal erosion</td>
</tr>
</tbody>
</table>
Glaciofluvial erosion
Shrinkage of upper soil
Clump vegetation catching wind deposits
Clump vegetation plus erosion
Trees protecting areas from impact of rain drops
Deposits accumulated in holes in stagnant ice
Concretionary
Differential compaction
Soil creep
Water freezing in soil cracks

Discussion

It is apparent from the foregoing synopsis of the literature on pimple mounds that no single hypothesis can explain the origin of all of these small hillocks. Doubtless, the growth of some of the mounds in California was aided by the wind; some of the mounds in Arkansas were probably the result of differential weathering; some mounds are definitely Indian mounds; and some mounds are the result of the deposition of material around the outlets for underground water. On the other hand, the mounds of the Gulf Coast area, particularly those mounds in Beauregard and Allen Parishes, must be assigned to still another cause.

A discussion of the validity of each of the many hypotheses that have been offered in explanation of pimple mounds is beyond the scope of this paper. The literature already contains a considerable amount of discussion upon this particular topic.
Observational facts support the thesis that pimple mounds are the result of erosion. The minutely adjusted, well integrated drainage patterns exhibited by pimple mound areas and the relationship of the mounds to these streams is almost proof in itself that they were formed through erosion. Mounds occur on areas where the slope is very slight. If there is no slope they have not developed, and if the slope increases those that have developed are destroyed. Near the headwaters of small, intermittent streams the mounds are low and poorly developed. Usually, each individual mound is surrounded on all sides by small drainage channels. Farther down the slope these mounds are higher and better developed; contiguous mounds down slope tend to merge, becoming connected by a low saddle. Farther down stream, or where the slope is steeper, mounds no longer are present but are replaced by elongate ridges. This is due to the greater erosive power of rivulets running parallel to the slope. These rivulets cut down more rapidly than the transverse rivulets and, eventually, as relief is increased, the stage is reached where transverse streams no longer connect the main consequent streams. Thus the mounds, which existed as isolated elevations at first, gradually become connected with adjacent mounds down slope and finally cease to exist as separate mounds but, rather, become a continuous ridge on the divide between two closely spaced streams.
The inter-mound areas tend to be flat or only slightly concave. It may be that, locally, the height of the mounds is controlled by the depth to the "B" horizon of the soil. These small streams can very easily remove the loose, friable soils of the "A" horizon, but erosion is more difficult in the underlying "B" horizon. Consequently, when the streams cut down to this more compact soil, they tend to widen their valleys, thus producing the flat bottoms so characteristic of such streams.

It is quite apparent that some other factor must have entered in to initiate the formation of mounds. Erosion could not, by itself, produce such features. Once differential erosion was started, however, normal degradational processes would tend to accentuate the initial differences. Some type of clump vegetation may very well have played the dominant role in protecting certain areas from the more direct effects of erosion. Even larger trees could have protected the areas beneath them from the direct impact of rain drops and thus caused initial differences in relief which later became pimple mounds.

If the soil were granular, the impact of raindrops would tend to break up and disperse the granules and thus produce a tight, less pervious surface that would be even less easy to erode than the soil of the protected
areas. The soil in the pimple mounds areas, however, is a sandy silt that consists primarily of individual grains. The impact of rain drops on this soil, where it is not protected by vegetation, thus tends to facilitate erosion.

The particular type of vegetation responsible for the starting of differential erosion is not known. It must have been limited eastward by the Mississippi River because no pimple mounds occur east of this line.

Thus, according to the hypothesis presented in this paper (which is not new but was presented in its essential form as far back as 1874 by LeConte), the following combination of factors is responsible for the formation of pimple mounds: (1) a sandy or silty soil with a low percentage of colloidal clay, (2) an initial surface of very low relief, (3) sufficient rainfall to cause erosion, and (4) some type of vegetation peculiar to the pimple mound areas.

Figure 10 Is a tracing from an aerial photograph of some pimple mounds in the headwaters of a small drainage basin on the Bentley surface in Beauregard Parish. The zone of pimple mounds here is about 400 feet wide and extends over an arc of about 1500 feet. Within this zone, but not shown on the map, drainage channels encircle the individual mounds on all sides in an anastomosing pattern; only rarely, on the southeastern side of
Figure 10. Tracing from an aerial photograph of a pimple mound area. These mounds are on a relatively flat surface and grade, down slope, through a transition zone of joined pimple mounds into a zone of elongate ridges. Sec. 31, T25S, R7W, Sugartown Quadrangle, Beauregard Parish.
this zone, are the mounds joined. Within the transition zone the mounds typically are joined to the next adjacent mound down slope by a low saddle. This junction is the result of the deeper incision of those rivulets running parallel to the slope and the abandonment of the cross-flowing rivulets of the network. Farther down stream, where the slope is steeper, the mounds are entirely absent. On the aerial photograph tracing this is termed the zone of elongate ridges.

Plate V is a contour map of a pimple mound area in sections 28 and 29, T3S, R5W, on the Grant Quadrangle in Allen Parish. Here the pimple mounds are developed on a relatively flat Prairie surface remnant near the Montgomery escarpment. The drainage from this area is southwest to a major stream (not shown) which flows south-east. In the mapping of this section the elevations of about 300 different points were determined to the tenth of a foot. The pimple mounds in this area are nearly all of the transition type. The mound area is limited by the Montgomery escarpment. Sufficient erosion has taken place from the foot of this escarpment southwestward to the major stream to have resulted in the incision of those drainage channels running parallel to the slope. Thus, the mounds in this area are, for the larger part, united with adjacent mounds down slope; very few mounds exist as isolated features as they probably once did.
Depressions

There are two main types of depressions present on the terrace surfaces of Beauregard and Allen Parishes. The most common of these is channel scars on the flood plains and on the Prairie surface along many of the larger streams. The other, and most difficult to explain, is small, more or less circular, flat-bottomed depressions locally called "bagols". A third, but relatively unimportant, type of depression may be found in pimple mound areas where drainage is locally obstructed; this type seldom exceeds a few inches in depth.

Any one of these depressions may contain water and form a small pond after rains. Typically, they dry up by evaporation and infiltration shortly thereafter; it is only the most recent channel scars along the Sabine River that are true lakes. The others, because of their high percentage of soil moisture, often support a swamp vegetation that contrasts sharply with the surrounding region. This is particularly true of the bagols.

Channel scars on the younger terrace surfaces are quite definitely related to the streams near which they occur. There are very few definite channel scars on these surfaces that are relict from streams no longer present. From their proximity to main streams, as well as from the magnitude of the radii of these scars, it is
Plate V. Contour map of a pimple mound area on the Prairie surface, secs. 28 and 29, T3S, R5W, Allen Parish.
quite definite that they were formed by the streams present today in the same region. These scars were unquestionably formed by normal stream aggradational and erosional processes.

The word "bagol" is an abbreviated form of the words "Bay Gall". Hilgard (1873), in writing on the back-swamp Montgomery area in Allen Parish, today known as East Bay and West Bay, stated that (p. 13)

"Frequently there is a dense growth of Candleberry (Myrica cerifera and Carliniendra), Bay Galls (Laurus Carolinensis), and a variety of Whortleberries (Voleinitium) and where these prevail exclusively, we have impenetrable thickets, popularly designated as 'Bay Galls', the undisputed resort of the bear, panther and wild cat."

Although this word originally had a botanical connotation and referred to a different geographic feature, it is herein recommended that, in conformance with local usage, the term in its abbreviated form, "bagol", be applied to these peculiar physiographic phenomena herein described.

Thomassy (1860, p. 83) referred to these depressions as "lacs ronds". Although he was referring primarily to round lakes in the marshes along the coast, he apparently included bagols in the same category. His explanation for these "lacs ronds" was that they were the product of gaseous explosions. Russell (1936, pp. 116-121) discussed these same round lakes in the marshes of southern Louisiana at which place they owe their origin to factors not now operative in the region under dis-
The round lakes in the marshes and bagols are not to be considered as having had a common origin.

Clandennin (1896) suggested another mode of origin for bagols, which he referred to as "natural ponds". He thought them to be comparable to the "Buffalo Wallows" of the Great Plains and to have been formed by buffalo.

(p. 183)

"Into these the cattle wade to escape the troublesome flies, and upon leaving, carry away with them an appreciable amount of mud. This suggests their origin.

"The region, naturally flat and poorly drained, had originally an irregular surface upon which water stood in pools. The region was once the pasturing ground for enormous numbers of buffalo. These, seeking the pools in which water remained longest, would wallow in them in order to cover themselves with a protecting coat of mud against pestiferous insects such as flies, gnats and mosquitoes. This process repeated day after day for century upon century resulted at last in these "natural ponds", which in all respects resemble the 'buffalo wallows' of the Great Western prairies."

Fisk (1940, pp. 75-79) described some elongate and round depressions in Avoyelles Parish which he referred to as "pocks" or "pock marks". He recognized a connection between channel scars on the low lands and these rounded depressions. He considered the pocks to be merely a more advanced stage of alluviation of the channel scars on the flood plains.

The typical bagol has a diameter of about one-fifth of a mile, although they range in size from about one hundred feet up to nearly one-half mile in diameter. They are usually about two feet lower than the level of
the surrounding land and ordinarily have a flat bottom. The sides are normally quite steep. In some cases they are entirely enclosed so that, after heavy rains, water may stand in them to a depth of one foot or more. In most cases, however, they are open at one end, and quite often they are open at opposite ends, so that water stands in them to a depth of only a few inches.

There is no apparent difference in composition between the underlying material of the bagols and that of the surrounding region. In spite of the fact that these depressions are typically moist enough to support a swamp flora, they do not contain any peat. Observations from bore holes in a number of different bagols showed only a thin layer of humus at the top, below which were clays and silts.

Bagols are most common on the Bentley surface in Beauregard Parish. The vegetation in these consists primarily of deciduous trees such as the gum, oak, and magnolia, as well as a thick underbrush of shrubs and briars. The surrounding region originally supported an open forest of long-leaf yellow pine. When this area was timbered the trees in the bagols were not cut. Today they stand out like islands on a surface whose only other conspicuous landmarks are the lines of deciduous trees along the streams.

These bagols occur in a belt completely across the Bentley surface in Beauregard Parish. They are present
only on the more or less flat divides on what must be considered as practically original surface remnants. For that reason, they should be thought of as original depositional features rather than as erosional features.

Although most common on the Bentley surface, true bagols are not restricted to it; they also occur on the Montgomery and Prairie surfaces. Observable on the Prairie surface are channel scars in which both ends have been more or less silted up and only the central portion remains swampy. This central portion supports a growth of deciduous trees while both ends support only grasses. From a distance such features look exactly like
the bagols on the Bentley surface. Their origin is clearly betrayed by their relationship to the channel scar. On the Bentley surface those bagols which are open at both ends are but slightly more advanced than the ones on the Prairie surface just described, and those which are open on only one end are still more advanced; those that are completely closed are most advanced of all.

It is believed that these bagols of the Bentley surface of Beauregard Parish date back to channel scars left by some major stream of Bentley time. Partial filling of the channel scars took place during high-water stages of the river during Bentley time. Elevation of the region following Bentley time left these scars as distinctive features still traceable to an old stream pattern and only partly alluviated.

It is believed that small rivulets flowing over the adjacent, nearly flat surfaces have been picking up and transporting some of the surface silt into these depressions, while at the same time eroding this surface into a pimple mound topography. Bagols, thus, are those portions of channel scars that have not been completely alluviated. They owe their shape to the stage of alluviation attained before uplift; subsequent filling did little to modify this shape.

Plate VI is a contour map of a bagol in section 25, T22S, R10W, on the DeRidder Quadrangle, Beauregard Parish. This bagol is one of the northernmost in a group which
extends southwestward in a wide belt across the Bentley surface in this parish. In the mapping of this area, elevations were carried to the tenth of a foot and the elevations of about 200 different points were determined. The elevation of the bench mark from which mapping proceeded was established by means of a Paulin surveying altimeter. This bagol is open at both ends, and only the portion shaded on the map is wooded; the ends are marshy. As will be noticed, there is a difference in elevation of but a few tenths of a foot from one end of the bagol to the other. The surrounding region has been dissected into a pimple mound topography.

Conclusion

The most interesting physiographic problem considered in this report is the origin of pimple mounds. The only explanation seemingly consistent with observable facts is that these mounds are erosional in nature. On the other hand, it is difficult to conceive how erosion alone could produce such phenomena. Some other factor must have entered in to initiate their development. In this paper it is assumed that this other factor was some type of vegetation which was limited eastward by the Mississippi River. The question of the origin of pimple mounds, however, will not be solved until the various
agents involved and their relative importance are known and the mechanics of their formation demonstrated.

Likewise, the question of the origin of bagols is quite perplexing. It is apparent that they are closely connected with ancient channel scars. Whether they are the result of partial alluviation of old channel thalwegs, the thesis adhered to in this report, or whether they may be connected in some other way with relict drainage patterns is not known. Field work and study of aerial photographs in an area such as Beauregard Parish, where bagols are especially well developed, and comparative study along some major stream such as the Mississippi River should shed much light upon the origin of these features.
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Wilbur Charles Holland was born at Cohoes, New York, November 1, 1909. He attended various elementary schools in Ohio and West Virginia, graduating from Williamstown, West Virginia, High School in 1927 with a two years' scholarship to Marietta College, Marietta, Ohio.

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From 1935 to 1941 Mr. Holland was Assistant Professor of Geology at Furman University, Greenville, South Carolina. While on leave of absence from that school he did further graduate work in geology at Louisiana State University during the school year of 1941-1942. The following year he accepted a position as Instructor in Geology at Louisiana State University.
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Major Field: Geology

Title of Thesis: The Physiography of Beauregard and Allen Parishes

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Date of Examination:

April 27, 1943