

STRATIGRAPHY AND THE GEOLOGY OF THE PORT BARRE SALT DOME

ST. LANDRY PARISH, LOUISIANA

by

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A. B., University of Kansas, 1941

Submitted to the Department of  
Geology and the Faculty of the  
Graduate School of the University  
of Kansas in partial fulfillment  
of the requirements for the degree  
of Master of Arts.

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For the department

April, 1947



*Frontispiece*— Aerial View of Port Barre Field

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# STRATIGRAPHY AND THE GEOLOGY OF THE PORT BARRE SALT DOME

ST. LANDRY PARISH, LOUISIANA

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## INTRODUCTION

The subsurface structure of the Port Barre field is that of a relatively shallow piercement-type salt dome. The dome lies within the Red River fault zone of the lower Mississippi alluvial valley. Subsurface investigations and aerial photograph studies of the surface reveal the structural relationships of the salt dome to the regional fault systems. First field developments presented difficult problems in correlation and structural interpretations because of complex fault patterns and the nature of compacted sediments encountered.

Stratigraphic terminology used in this report is based upon a review of literature and is considered to be of current usage. Each unit is described historically which concerns their designations, usages, distribution, lithology and correlation. The information gained from the review of stratigraphy has enabled the writer to apply correct terminology to strata encountered in the Port Barre field.

Surface studies for the Port Barre area, previously, have been ignored because of its relatively featureless surface. The writer, however, found that a careful study of aerial photographs shows various physiographic features that

are not readily discernible from the ground. The writer concludes that several features observed in the photograph study show relationship to the intrusion of the salt.

Previously, no comprehensive report on the geology of the Port Barre field has been published. However, tabulated data on development, production, and scattered bits of geologic information have appeared in various publications. Sufficient information has been unavailable heretofore, for a comprehensive study of the subsurface stratigraphical and structural relationships of sediments to the salt mass.

The writer became interested in the geology of the Port Barre field in 1938 while he was employed by the Pan American Production Company. Through the following period of years much time was spent in collecting information for a master's thesis. The writer was fortunate in obtaining information pertaining to nearly all wells in the area. Also, he was able to obtain first-hand information concerning problems affecting the development of the field which were taken into consideration in this study. The investigation was postponed necessarily, in the early part of 1943 when the writer went into the service during the war.

During the earlier periods of development, the difficulty of interpreting the geology was partially due to the lack of advanced geological knowledge and to methods used in obtaining the data. Difficulty also resulted from erroneous location descriptions, erroneous geological data, and the economic policies involved in collecting data from the many different operators in the field.

Many of the available drillers' logs are of little value since the driller was concerned in drilling a hole as fast as possible and commonly recorded inaccurate information on a log. Exceptions are found in certain cases in which the companies concerned carried out controlled coring procedures.

Recently, wells drilled on the flanks of the dome have penetrated Oligocene and upper Eocene sediments. These wells provide considerable information used in the interpretations in this report. Evidence derived from the improved methods now in use and the accumulation of information which now gives nearly complete coverage of the field permits a more exact and complete study of the structural and stratigraphical relationships.

The purpose of this paper is to introduce an interpretation of the geology pertaining to the Port Barre dome. It is intended to show the relationships of the physiography of the area to the subsurface structure, and that surface manifestations of deeper faulting may be used in delineating favorable areas for production drill-tests. The report is offered in an attempt to attain a more proper usage of stratigraphic terminology within the region as well as the field.

The interpretations given in this report may result in revisions of previous conceptions derived from localized interpretations or a less complete assemblage of data. The writer hopes this paper may furnish a guide for further development and study of the many problems remaining unsolved in this and other fields of the same type.

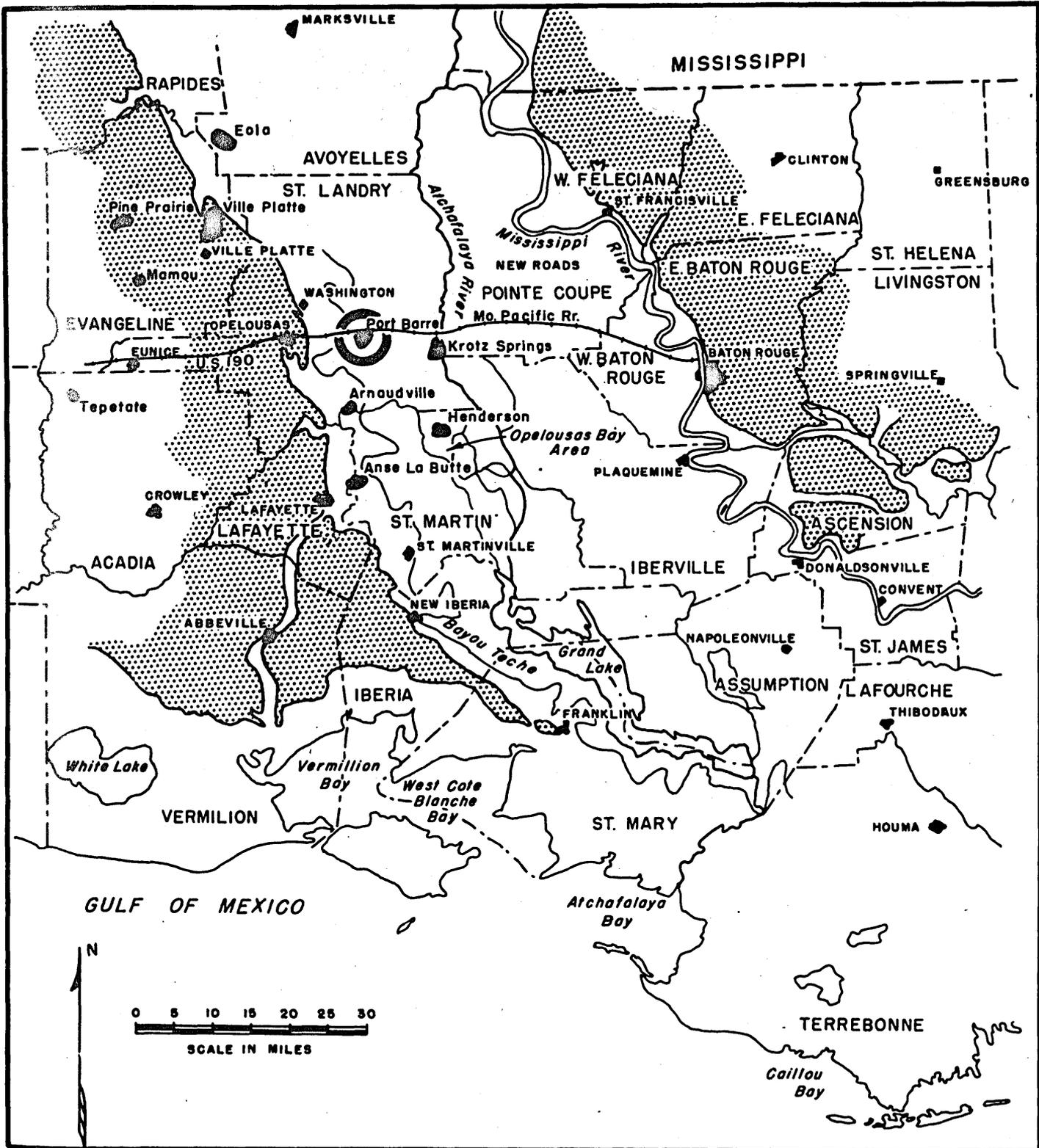
## Acknowledgments

The writer is indebted to G. W. Schneider, Division Geologist, The Texas Company, New Orleans, Louisiana, who made location and base maps available, many electrical surveys, drillers' logs, coring data, paleontological data and much other information. His decision to release such data has been one which has allowed the writer to continue the investigation.

The continued assistance given by John M. Vetter, Chief Geologist and Superintendent of the Geological and Land Department, Pan American Production Company, Houston, Texas, has been most encouraging to the writer when continuation of the project seemed futile because of the lack of information. Thanks are given for the liberties he has extended to the writer. Mr. Vetter has made available electrical surveys, paleontological reports, and samples from the Pan American wells. His influence with other organizations in obtaining necessary information has been valuable.

Acknowledgment is due to John Huner, Jr., State Geological Survey, Baton Rouge, Louisiana, for his assistance in selection of well samples and cores for the investigation.

Appreciation for assistance in assembling data is extended to all men in the field with the Gulf Refining Company, The Texas Company, Pan American Production Company, Wm. Helis Oil Company, McDannald Oil Company, Danciger Oil and Refining Company, Maurice T. Grubb of the Grubb and



**Fig. No.1.** Location map. A portion of Mississippi Alluvial Valley, including Atchafalaya Basin, in Southern Louisiana.

Hawkins Company, and many others.

The writer also wishes to acknowledge the assistance and useful criticisms on stratigraphic and structural problems by Raymond C. Moore, State Geological Survey, Lawrence, Kansas; Lowell R. Laudon, Chairman of Department of Geology, University of Kansas; Harold T. U. Smith, Assistant Professor in Department of Geology, University of Kansas; and M. L. Thompson, Department of Geology, University of Wisconsin, Madison, Wisconsin.

#### LOCATION

The Port Barre dome is in south-central St. Landry Parish, Louisiana. Its regional geographic location is shown on the map of southern Louisiana. (Fig. No. 1)

U. S. Highway No. 190 crosses the structure from east to west, paralleling the Missouri Pacific railroad. The field is ten miles east of Opelousas and two miles southeast of Port Barre. The structure underlies parts of Sections 7, 18, and 19 in Township 6 South; Range 6 East.

#### PHYSIOGRAPHY

The Port Barre dome lies in the Mississippi alluvial valley between the Atchafalaya River and Bayou Teche. From a regional aspect, the dome is related only to the Teche Ridge, Atchafalaya Ridge and the Atchafalaya Basin in that the structural development and the location of the Port Barre dome suggests its influence in the geologic history of the alluvial valley.

The Teche Ridge is a well-defined but abandoned meander belt ridge of the Mississippi River named for Bayou Teche which occupies it from Port Barre to Morgan City. The part occupied by the Teche initially developed as the Mississippi River meanderbelt. Subsequent to its abandonment by the Mississippi River it was followed by the Red River. (Fisk, 1944, p. 31.)

Two sets of natural levees flank Bayou Teche. The outer set, broad and gently sloping, was formed by the Mississippi River and has characteristic black and gray soils. The inner, narrower, and steeper set formed by the Red River has red and brown soils. The Teche meander belt is flanked by many old Mississippi River cut-off meanders similar to those of the present Mississippi River. Bayou Courtableau which follows old Red River courses is a cut-off which breaks across the Teche Ridge at Port Barre and flows into the Atchafalaya Basin. (Fisk, 1944, p. 31.)

The Atchafalaya Ridge which is the natural levee of the Atchafalaya River, the most important distributary of the Mississippi River, bisects the upper end of the Atchafalaya Basin. The ridge is broadest and highest above adjacent basins at its northern end. It tapers and loses its significance about  $10\frac{1}{2}$  miles south of Krotz Springs near the center of the basin where the river divides and the levees of its various branches become less prominent as the river loses its identity in the swamp network. (Fisk, 1944, p. 32.)

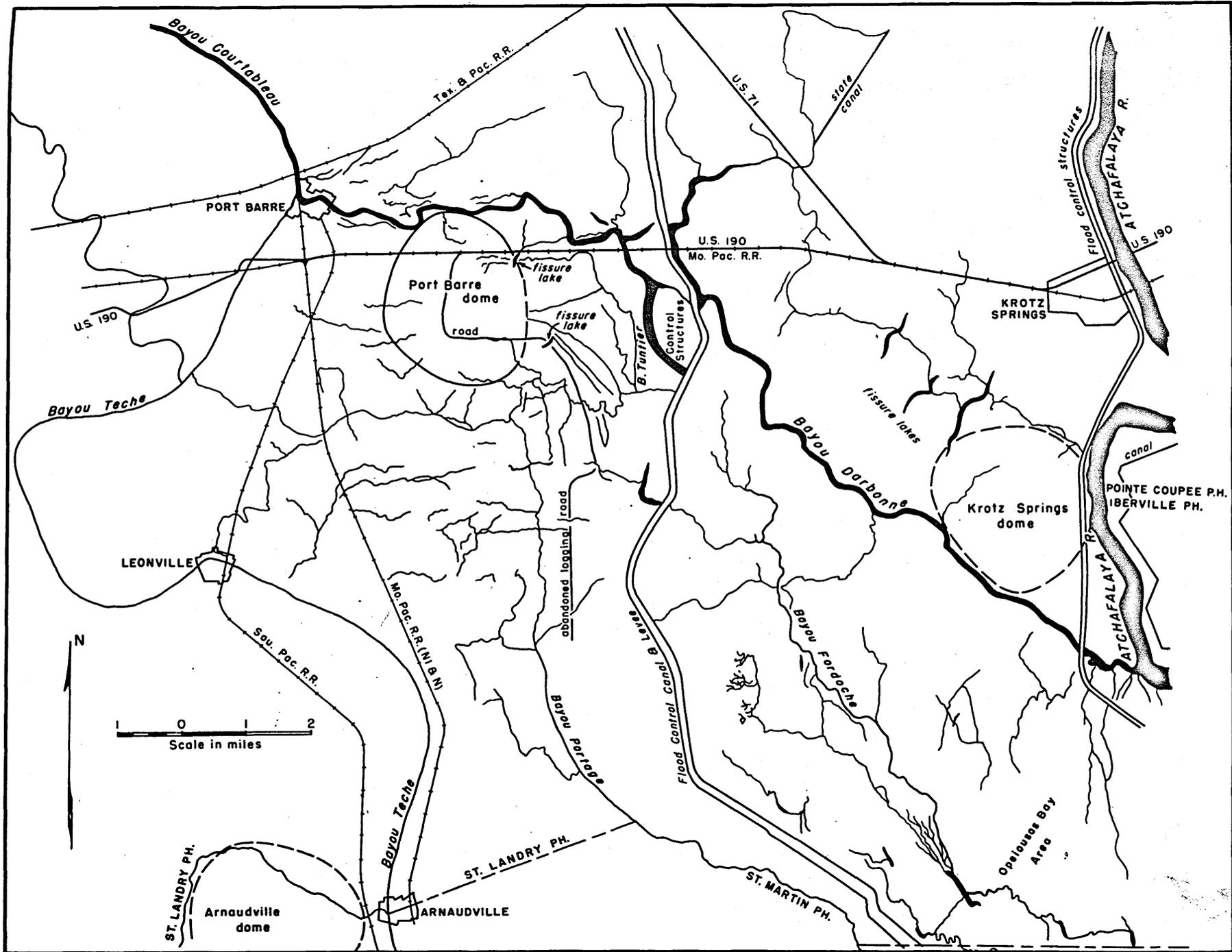


Fig. No. 2— Showing drainage in vicinity of the Port Barre dome

The Atchafalaya Basin receives water from the Atchafalaya and various crevasse and distributary channels of the Mississippi and Red River. The central part of the basin is a plexus of interconnecting streams which distribute the Atchafalaya waters through swamp that ultimately drain into a system of lakes occupying the lower end of the Basin. (Fisk, 1944, p. 32.)

The Prairie terrace, a part of the Mississippi alluvial escarpment, lies about seven miles west of the field and attains a height of 83 feet at Opelousas. The Port Barre area has a general elevation of about 20 feet.

About two-thirds of the field is covered by wooded swamp. Cultivation of the land is restricted to the northern part of the field along the low alluvial ridges of Bayou Courtableau which flows east and west along an abnormal course around the northern edge of the underlying structure.

#### GEOMORPHOLOGY

Regional: The courses of the streams within the Central Gulf Coastal Plain are parallel to the principal fault systems in many places and western tributaries of the Mississippi maintain a common alignment parallel to the fault zones. One of the main zones of the NW-SE faulting is the Red River fault zone. (Fisk, 1944, p. 66.) The Teche Ridge on the western edge of the Atchafalaya Basin trends in the same direction as the regional Red River Fault Zone. In most of the alluvial valley, faults

not indicated by measurable displacement on the surface are manifested in ill-defined elongate topographical sags. (Fisk, 1944, p. 66.)

In a report concerning the Mississippi alluvial valley, Fisk (1944, p. 38) states that stream shifts accompanying alluviation resulted primarily from alluvial fan aggradation, but the location of each shift and trend of each new course were in places determined by faults of the regional system.

In the same report, Fisk (1944, p. 66) discusses physiographic features of the deltaic plain and presents their relationships to the alluvial sediments as adjustments to deep-seated movement along subsurface fault planes. The settlement in the alluvium was accomplished through the development of a multitude of minor fractures, each of which exhibits only a small amount of displacement.

Many other faults are known to exist within the Central Gulf Coastal Plain in addition to the faults delineated by Fisk. He has directed attention to a few isolated NS and EW faults which are related to another fault system not well-defined in the region.

Fisk (1944, p. 55) concluded that inasmuch as the pattern of the regional fault zone reflects the structural grain of the continent, it is believed that the faults originate at great depth in the basement rocks. He also concludes that structural movements in the region have been active concurrently with the subsidence of the coastal

margin under the great weight of the accumulating deltaic masses. (Fisk, 1944, p. 64.)

Local: In the Port Barre area, the effects of structural movement upon the drainage of the alluvial valley and the recency of some movements is illustrated in the rectangular pattern of minor streams and lakes. The abrupt changes in the courses of the major drainage systems along the outer limits of the Port Barre dome, Krotz Spring dome, and the Arnaudville dome (Fig. No. 2) reflect the influence of subsurface salt dome structures.

Surface Features Relative to Local Structure: The drainage pattern as shown in Fig. No. 2 was taken from an aerial photograph index composite and supplemented by a more intensive study of stereoscopic pairs of photographs covering the area. At the outer limit of the dome on the eastern side, there are two small shallow lakes. (Frontispiece) They are estimated to be about 1000 feet long and 50 to 100 feet wide. The nature and proximity of the lakes to the structure and the fault, determined in wells near the northernmost lake, suggest they are small sags as a result of deeper faulting.

The term, fissure lake, is introduced for use in identification and discussion. This physiographic feature is not to be confused with trellis-like, fault-line drainage. The width of the lake is considerably larger than the drainage stream which is connected with it. A cross-section and profile of this feature differs in magnitude and level

and is independent of the cross-section and drainage profile of the connecting stream. Bogs on the southeastern edge of the salt dome appear to be ancient fissure lakes, subsequently filled with sediment and rank vegetation. Another example of fissure lakes is near the Krotz Spring dome which indicates local surface expression of the subsurface faulting.

Concentric drainage patterns are evident around the Port Barre dome and more or less fix the outer limits of this salt dome. The radial drainage over the domal area is perhaps, in most cases, an adjustment to the surface reflection of the dome. Some of the drainage follows a remarkably straight course which is readily observed in aerial photographic studies.

Relationship of Local Surface Features to Subsurface: In two different places on the eastern side of the dome, the soil differences and the remarkably straight courses of drainage indicate surface expressions of subsurface faults. These manifestations are referred to as surface leads. The identities of both surface leads are lost at the outer margin of the dome near the edge of the fissure lakes.

A salt water pit is located near the center of the dome near the Gulf No. 12, Wilson-Cochran well. (Frontispiece) The drainage appears to follow a fault-line that extends from near the middle of the dome to the southern tip of the northern fissure lake. (Fig. No. 2) Accidental drainage of salt water from the pit has denuded vegeta-

tion along its course. Subsurface correlation in wells drilled at the outer limits of the dome along this drainage pattern show faulting of about 300 feet. (Fig. No. 8.)

An alignment of this fault-line drainage away from the dome extends for more than two and one-half miles and trends N. 72° E. (Frontispiece; Fig. No. 2.) Along this alignment about one mile from the edge of the dome, Bayou Courtableau makes an abrupt right-angle turn toward the east and follows the fault-line drainage trend for about three-quarters of a mile. It then abruptly makes another right angle turn toward the south following the original regional drainage trend. The inference is that drainage has adjusted itself to surface expressions of deeper faulting and that other radial drainage can be expected to do likewise.

A study of aerial photographs reveals surface indications of fault-line drainage southeast of the salt dome. (Frontispiece, Fig. No. 2.) A regional alignment, disregarding local disturbances relative to the intrusion of the salt mass, trends approximately N. 45° W.

Along this alignment evidences of stream adjustment to probable deeper faulting is indicated by the "S" shaped course of Bayou Courtableau at the northwestern extremities of the salt dome. A continuation of the alignment lies parallel to the course of Bayou Courtableau northwest of the town of Port Barre. (Fig. No. 2.)

Relationship of Salt Dome to Region: The Port Barre

salt dome lies within the area of the regional Red River fault zone as delineated by Fisk. (1944, Fig. No. 6.)

The surface lead trending N. 72° E. is considered to be evidence of deeper faulting and is supported by subsurface data on the outer extremities of the dome. The surface lead trending N. 45° W., although not supported by subsurface data, is probably a surface manifestation of deeper faulting.

The intersection of the alignments of the two surface leads trending N. 45° W. and N. 72° E. lies over the top of the dome and the writer concludes that they are surface manifestations of deeper faulting related to the regional fault system. It appears that the zone of weakness which would be produced by the intersection of the two faults has been primarily the factor controlling the location of the salt dome.

Attention is directed to the uniform distances between the several salt domes in the region. These domes occur approximately nine miles apart. Their existence may be closely associated with the juncture of faults which could be a part of the regional fault system. Their positions in the area also suggest relationship to the rim of a local basin in which Bayou Portage is a surface feature marking its middle. The apparent quiescence in the growth of the salt stocks appear to be a result of the depletion of their source material. The structure of the basin may have resulted from the downward adjustment

of sediments to the possible outward migration of the underlying salt-bearing strata.

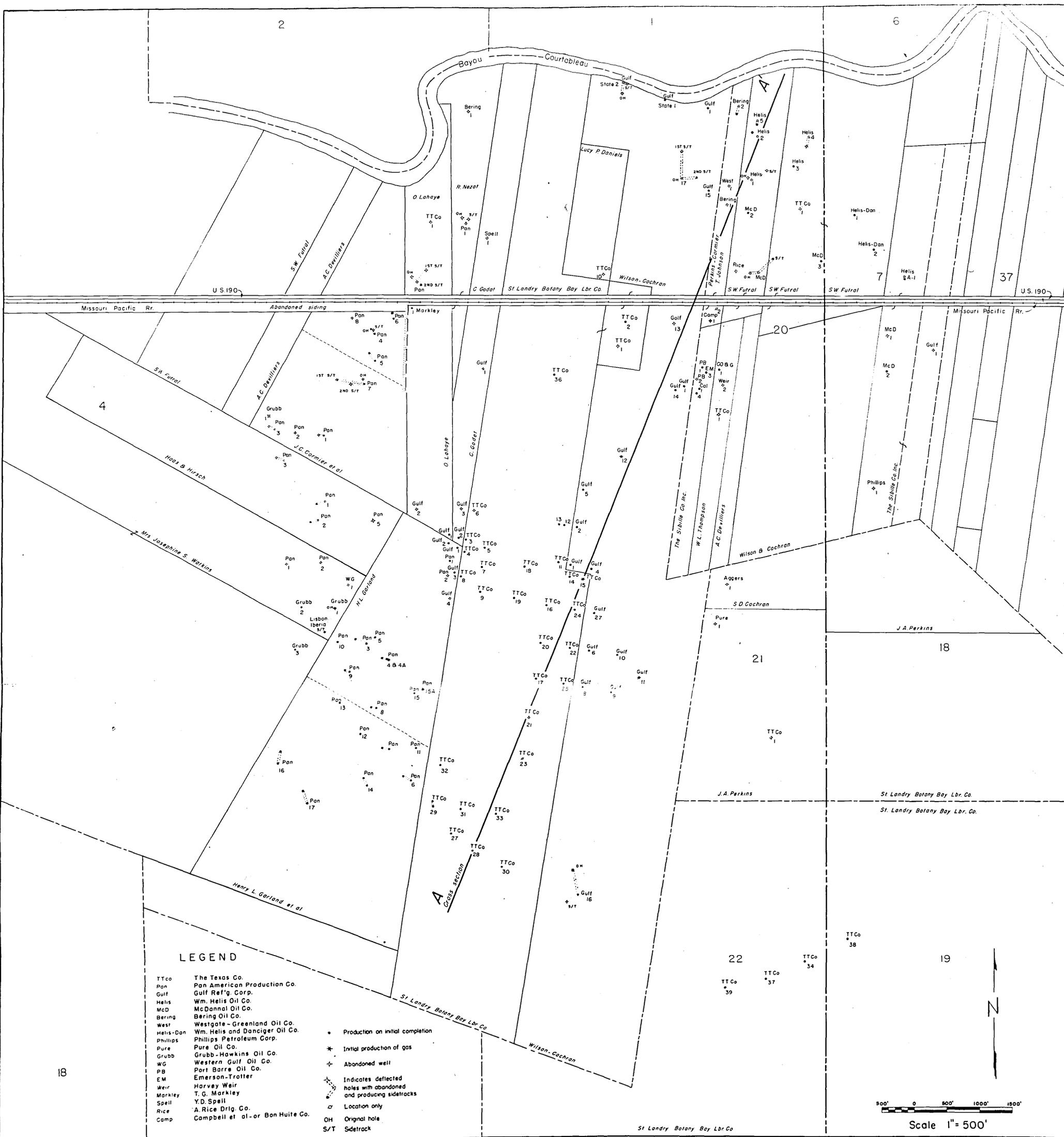
Delineation of Faulted Area Adjacent to Dome: No wells have been drilled to give conclusive proof of the existence of a fault at the southernmost fissure lake. The physiographic features present, comparable to those at the northern fissure lake, indicate that deeper faulting is present. The relationship of this possible faulting to the eastern edge of the structure has been shown in Fig. No. 8. The direction of the fault and amount of displacement is hypothetical. The faulting and interpretations associated with the southern fissure lake have been drawn to conform to the physiographic features present as well as to the general configuration of the dome.

Other Surface Features Indicating Faulting: South of the field the drainage pattern of the northern extremities of Bayou Portage show a relationship to a North-South and East-West system of faulting. Attention was directed to such isolated systems of faulting within the alluvial valley by Fisk. (1944, p. 66.)

Soil differences and irregular drainage patterns on the northern edge of the dome conform to irregularities in the banks of Bayou Courtableau. The alignment of these surface expressions show a close relationship to the subsurface fault pattern on top of the dome. (Fig. No. 8.)

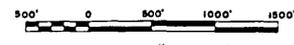
#### HISTORY OF DEVELOPMENT.

The Port Barre dome was discovered by refraction



**LEGEND**

- |           |                                 |     |   |
|-----------|---------------------------------|-----|---|
| TTCo      | The Texas Co.                   | •   | Production on initial completion                                  |
| Pan       | Pan American Production Co.     | *   | Initial production of gas   |
| Gulf      | Gulf Ref'g. Corp.               | +   | Abandoned well  |
| Helis     | Wm. Helis Oil Co.               | +   | Indicates deflected holes with abandoned and producing sidetracks |
| McD       | McDannal Oil Co.                | +   | Location only   |
| Bering    | Bering Oil Co.                  | OH  | Original hole   |
| West      | Westgate-Greenland Oil Co.      | S/T | Sidetrack   |
| Helis-Dan | Wm. Helis and Danciger Oil Co.  |     |   |
| Phillips  | Phillips Petroleum Corp.        |     |   |
| Pure      | Pure Oil Co.                    |     |   |
| Grubb     | Grubb-Hawkins Oil Co.           |     |   |
| WG        | Western Gulf Oil Co.            |     |   |
| PB        | Part Barre Oil Co.              |     |   |
| EM        | Emerson-Trotter                 |     |   |
| Weir      | Harvey Weir                     |     |   |
| Markley   | Markley                         |     |   |
| Spell     | Y.D. Spell                      |     |   |
| Rice      | A. Rice Drig. Co.               |     |   |
| Camp      | Campbell et al-or Bon Huite Co. |     |   |



Scale 1" = 500'

Fig. No.3. Development map and index to cross section.

seismograph in 1926 by the Gulf Refining Corporation.

The Texas Company made a reflection seismograph survey in 1939. (Anonymous, 1942, p. 124.)

First well drilled was the Texas Company Botany Bay Lumber Company Fee No. 1. Drilling commenced on December 20, 1928, and was completed on February 23, 1929. The well was brought in for a total production of 800 barrels at 3763 feet with 23° A.P.I. gravity oil. (Logan, 1929, p. 60.) The well sanded up on the same day. A sidetracked hole hit the top of the salt at 3923 feet and was drilled to a total depth of 4131 feet. The well was finally abandoned as dry on April 11, 1929.

The Texas Company Well No. 2 which was located 150 feet north of the first well had a potential production of 2000 barrels per day and about 5,000,000 cubic feet of gas at 3618 feet. It produced for only one hour. The second completion had an initial production of 1000 barrels per day at 3638 feet.

The Gulf Refining Company No. 1, Gaudet was the first well drilled by that company in the area. It was located 2000 feet west of the Texas Company No. 1 along the western edge of the dome. The drilling commenced April 12, 1929. An oil sand was tested at 3830 feet. Later the well was drilled deeper, penetrating the cap at 4022 feet and entering the salt at 4120 feet.

The Texas Company No. 3, Botany Bay Lumber Company well was completed on January 20, 1930, for an initial

production of 2250 barrels per day. The impressiveness of the initial production in this well stimulated the interest in drilling activities. The field was drilled continuously by various operators until about 1936.

The first flank production was from the Pan American Production Company No. 1, Haas and Hirsch well producing from 4766 to 4883 feet which was completed on December 5, 1935. Pan American's No. 2 well about 300 feet southwest of No. 1 was also productive. Several flank wells drilled north and south of these wells are unproductive.

Field development ceased for a period of about two and one-half years. In November of 1939 Pan American's No. 4, Cormier was completed as a large producer for 450 barrels per day on a one-quarter inch choke. This well renewed interest in flank production.

Flank production on the Garland leases owned by Pan American and The Texas Company's Botany Bay Lumber Company leases extended the field to the southwest. McDannald Oil Company No. 1, Futral was the first flank well to produce on the northeastern edge of the field. Since then, Wm. Helis Oil Company and other independents have drilled about fifteen wells on the northeastern flank.

Several deep producing wells were drilled by Pan American Production Company and The Texas Company on the southwest and southern flanks. The deepest well drilled is The Texas Company's No. 35, Botany Bay Lumber Company well on the southeastern flank of the dome. It was aban-

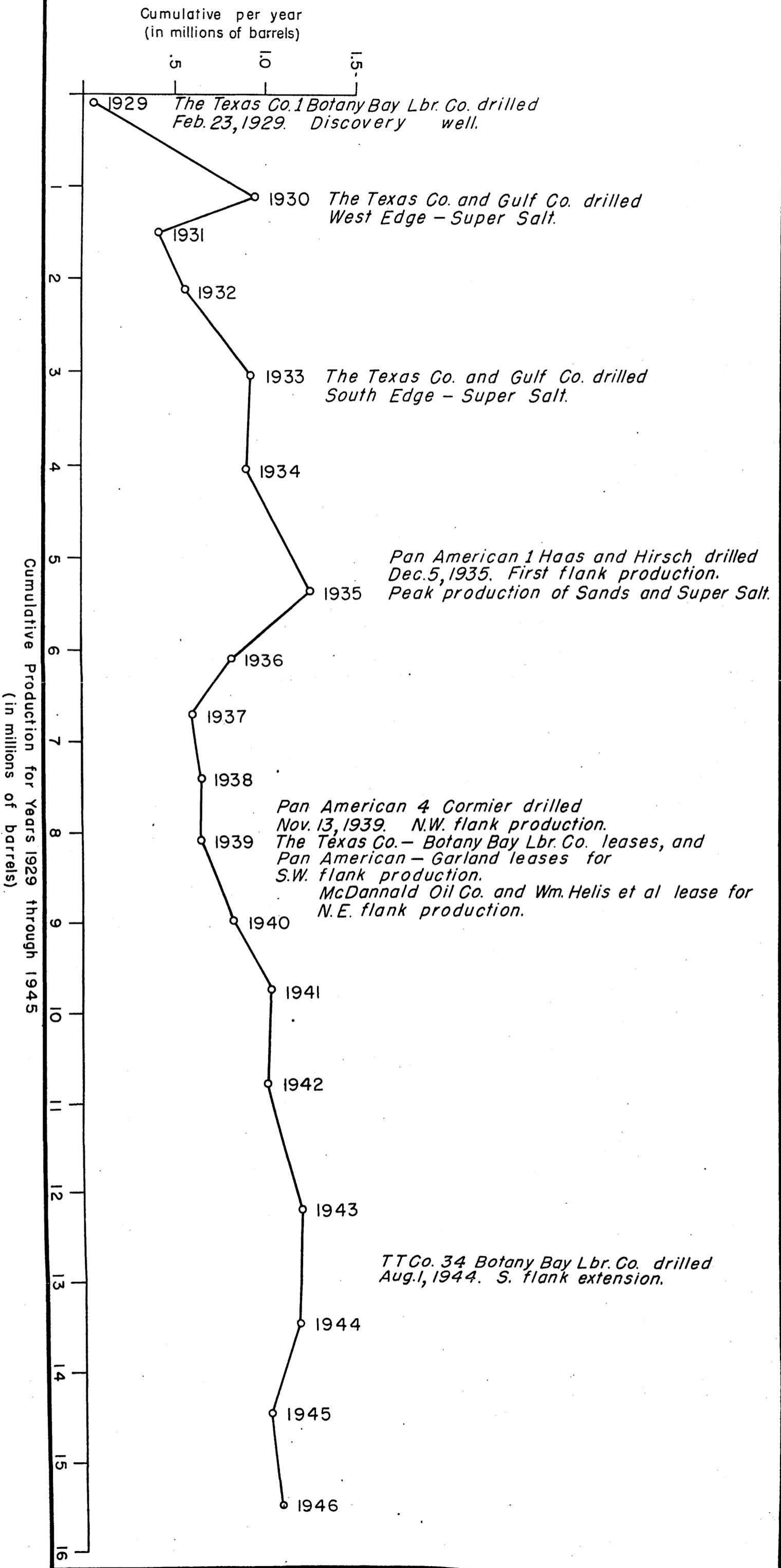


Fig. No. 4

done on November 13, 1944, at 11,705 feet near the top of the Wilcox.

In eighteen years up to January of 1947, 146 tests had been made in the Port Barre field. At the beginning of 1947, a total of 54 wells were producing oil. There were 25 wells flowing and 29 producing by artificial lift. The crude oil production for the year of 1946 was 1,060,449 barrels. The total accumulative for all years at the end of 1946 is 15,486,985. (Anonymous, 1947 A, p. 164.) The present estimated reserve expected is approximately 14,498,000 barrels. (Anonymous, 1947 B, p. 197.)

#### STRATIGRAPHY

A review of a considerable amount of literature is necessary in order to attain correct usage of stratigraphic terminology for the region and for the strata of the area concerned in this report. The information presented by the writer provides a convenient summary of the Louisiana stratigraphy. The review with additional paleontology as it becomes available, may be of valuable aid to others.

Since the publication of H. V. Howe's Review of the Tertiary Stratigraphy of Louisiana, a large amount of stratigraphic data has been made available from surface studies and by the drilling of many deep wells. Since then, several reviews of Louisiana stratigraphy have been published in geological bulletins in an attempt to bring about a more complete knowledge of the application of stratigraphic nomenclature for the strata encountered.

Some writers, however, persist in the improper application of stratigraphic names.

The following review of Louisiana stratigraphy is presented in an attempt to ascertain proper usage and application of stratigraphic nomenclature. It is intended to summarize available knowledge concerning the Quaternary and Tertiary stratigraphy of Louisiana. Often it is difficult to determine whether or not a name has priority, and current or accepted usage. The investigator in dealing with petroleum stratigraphy can be aided with the following summary in determining how to correctly apply the stratigraphic names to strata for which it is intended.

In the following report a brief discussion of the regional sedimentation is given first. Secondly, a summary of the stratigraphy for each unit is given. Each of these discussions is followed by the description of the same units which are encountered in the Port Barre field.

### Sedimentation

Stratigraphy of the Louisiana Gulf Coast is better understood with a knowledge of the sedimentation which has taken place during Tertiary time.

Regionally, marine and deltaic sedimentation alternated in three similar cycles. Each cycle started with wide marine conditions with little evidence of fluvial activity. At the middle of each cycle the deltaic masses were rapidly deposited and fluvial activity reached its maximum. The last part of the cycle is a gradual

decrease in the influx of fluvial sediments. The entire cycle is characterized by an alternation of marine and fluvial deposits. (Fisk, 1944, p. 67.)

The greatest deltaic accumulations occurred during (1) upper Jurassic-late Cretaceous, (2) Wilcox, (3) and Miocene to Recent epochs. Land masses of the continental interior are known to have been rejuvenated by orogenic movements at the same time. (Fisk, 1944, p. 67.)

Regionally, the Claiborne is characterized by alternation of marine and deltaic deposits and the marine advance of the Jackson marks the cessation of fluvial sedimentation. The Oligocene (Vicksburg) is characterized by wide spread marine conditions gradually superseded by delta growth with a gradual retreat of the seas. The thickest Eocene and Oligocene deltaic masses are in southwestern Louisiana and adjacent parts of Texas. (Fisk, 1944, p. 68, Table No. 11.)

#### Stratigraphic Units Encountered

The stratigraphic section encountered in wells on the Port Barre dome ranges from Wilcox (Eocene) to Recent. Most flank wells were completed in the marine and lower Catahoula. A few flank wells were drilled into the Eocene. On top of the dome the Miocene sediments consist of thick incompetent sand bodies and intercalated shale beds. These Miocene sediments are overlain by approximately 2000 feet of lithologically similar beds of

Pliocene to Recent age.

Correlation has been accomplished largely by the comparison of electrical logs. Micropaleontological markers are abundant and diagnostic in the marine Catahoula. Only limited correlations were made below this level because of the limited amount of information at hand and since most of the wells were completed at this depth.

For the Port Barre field the author's studies were limited largely to drillers' logs on top of the dome. Occasional electrical logs and paleontological studies were available. No complete stratigraphic section was available for study by the writer. Scattered parts of sections in various wells over the field were used. In general the study shows as much of the structure and stratigraphy as is possible with the available data. Since the strata are often disturbed and sections are often partially absent in the wells studied, no complete lithologic and paleontologic studies of complete units could be undertaken.

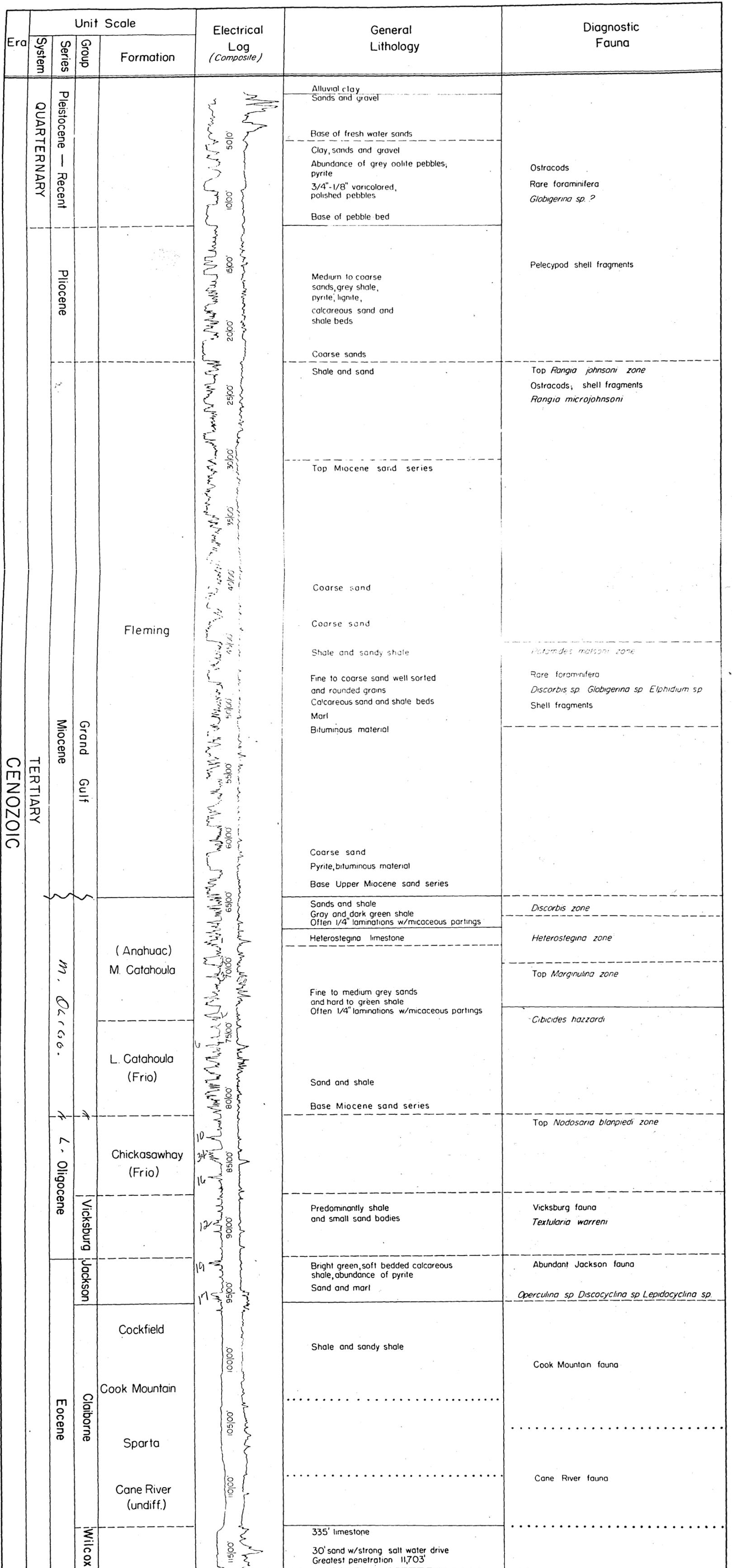


Fig. No. 5 Stratigraphic chart showing in general electrical characteristics in relation to lithology and faunal zones at Port Barre salt dome.

# E O C E N E

## WILCOX GROUP

Former Designations and Usage: The Wilcox was originally named "Lignitic" by Hilgard (1871, p. 391). This is not a geographic name. It has also been termed "La Grange" group by Safford which included portions of the Cretaceous. This name has been discarded. (Crider and Johnson, 1906, p. 9). A decision of the committee on nomenclature of the United States Geological Survey substituted the name Wilcox, which is that of a locality in Alabama where the formation is typically exposed. (Crider, 1906, p. 25).

The term, Wilcox, was formally adopted by the United States Geological Survey on March 23, 1905, as the geographic name to replace the non-geographic term, "Lignitic". (Wilmarth, 1938, p. 2333). The name was selected after correspondence with the State Geologist, E. A. Smith, of Alabama. The type locality was specifically stated in the records to be Wilcox County, Alabama, "which affords good exposures of the entire 'Lignitic' section". (Wilmarth, 1938, p. 2333).

Veatch (1905, p. 84, 85) used the term, "Sabine", to supplant the name, "Lignitic". The name was taken from the typical fossiliferous development of this formation on the Sabine River in Sabine County, Texas, and Sabine Parish, Louisiana. Veatch (1906 B, p. 35) suggested and adopted the name, "Sabine", from the typical development as

given above and from noteworthy exposures of Sabinetown Bluff.

On January 15, 1910, the United States Geological Survey decided to use the Wilcox formation in the report by Deussen (published 1914) and to abandon the admittedly synonymous, "Sabine" formation. (Wilmarth, 1938, p. 1863.) Deussen (1914, p. 37) in his report adopted the use of Wilcox formation as the only name to which there were no objections.

Preferred Usage: The problem as to whether this group should be called "Sabine" or Wilcox was submitted to the committee on stratigraphy of the National Research Council of Washington, D. C. in 1933. Chairman of the subcommittee on the Tertiary, E. C. Weaver, has prepared a complete and critical review of facts in the case and a copy of his findings was sent to each member of the committee for comments and opinions. It is the unanimous opinion of the committee that Wilcox is to be preferred. (Dunbar, 1934, Appendix H. p. 1.)

The Wilcox deposits are now treated as a group for the Eocene deposits overlying the Midway group and underlying the Claiborne in the Gulf Coastal Plain (Wilmarth, 1938, p. 2334.)

Distribution: The thick Wilcox beds form a belt 20 to 50 miles wide, trending northeast from Little Rock, Arkansas, to Wickliffe, Kentucky. The belt is parallel to the trend of the upper Cretaceous and Midway sediments

and to the outcrop of Paleozoic rocks along the Ozark escarpment in Arkansas and Missouri. The Wilcox beds dip toward the axis of the Mississippi embayment where they reach a thickness of 1500 feet. (Fisk, 1944, p. 14.)

The Wilcox deltaic deposits make up one of the thickest accumulations of sediment in the Gulf Coast region. The thickest part is a typical delta deposit. There are two centers of deposition which are connected with a thinner wedge of sediments paralleling the present coastline. One center in Texas reaches a known thickness of more than 5000 feet. The other center lies in Mississippi and exceeds 4000 feet in thickness. (Fisk, 1944, p. 61; fig. 65.)

General Lithology: The deltaic deposits in the outcrop in Louisiana and in the subsurface are dominantly sandy silt, sandy clay, and sand with some sandy glauconitic and calcareous marine beds. Lignite, carbonized plant material, is conspicuous in the deposits either in thin beds or dispersed as small grains in sandy silts and clays. (Fisk, 1944, p. 61.)

Correlation: Thin marine beds included in the Wilcox have been mapped on the surface in Louisiana and correlated with the surface marine Wilcox beds of Alabama and the subsurface beds of Louisiana on the basis of included fossils. Ostrea, Venericardia, and Turritella have long been used for correlation. Species of these genera are among the most diagnostic and characteristic fossils of

the Wilcox in the Sabine uplift area. They are: Ostrea thirsae, O. multilirata, Venericardia densata pendletonensis, V. sabinensis, V. bashiplata, Turritella mortoni post-mortoni, and T. praecincta. (Wasem, 1943, p. 189.)

Work in the Sabine area has shown the important stratigraphic value of three other fossils. They are: Nuculana corpulentoida, Cardium toumeyii var., and Halmesiastraea conferta. For possible use in subsurface correlation three zones have been offered. They are: Cardium toumeyii zone, Nuculan corpulentoida zone, and Venericardia sabinensis zone. (Wasem, 1943, p. 189.) Todd and Roper (1940, p. 702) in their Eocene correlation chart list a Discocyclina cookei for Wilcox correlation.

Typical electrical logs of down dip formations of the Eocene show nearly the same manifestations to extend throughout the Gulf Coast region. (Culbertson, 1940, figs. 1-9 incl.)

Local Application: The preferred usage of the term, Wilcox, is applied to strata which underlies the Claiborne group in the Port Barre field. In this field the top of the Wilcox was determined solely by electrical log characteristics. The Texas Company No. 35 Botany Bay Lumber Company well is the only one in the field which has reached the Wilcox formation at the present time.

The electrical log of the Texas Company's well No. 35 reflects the usual pattern considered to indicate the top of the Wilcox. (Fig. No. 5.) Comparison with other

electrical logs of wells in the region supports the validity of the correlation.

There is a definite break in this well where the overlying Claiborne group, predominately shale, ends and the Wilcox begins. In this well the break appears at 11,350 feet and contains 335 feet of strata reported as limestone. The well was abandoned at a total depth of 11,705 feet. The limestone found here, considered on the basis of electrical log comparisons, probably correlates with the marine wedge in the Herton Oil Company No. 1, Thistlewaite well about nine miles north and west in Sec. 60, T. 4 S., R. 4 E., St. Landry Parish, and near Washington, Louisiana. The exact age of the marine wedge in that well is questionable, according to Fisk (1940, plate 3, p. 128). Todd and Roper (1940, p. 705) identified the section in the Thistlewaite well as the top of the Wilcox.

#### CLAIBORNE GROUP

Former Designation and Usage: T. A. Conrad, in 1847, described many fossil species from the Eocene in the vicinity of Vicksburg, Mississippi. He divided the Eocene into "Upper or Newer Eocene" and "Lower or Older Eocene" and stated that the Vicksburg group belongs to the former and the Claiborne sands to the latter. (Wilmarth, 1938, p. 448.) Neither Vicksburg group nor Claiborne sands were described, but Conrad stated he refers to the sand at Claiborne, Alabama. He stated, also, that the "Lower or Older Eocene" is characterized by Ostrea sellaeformis,

which occurs abundantly beneath the fossiliferous sands at Claiborne. (Wilmarth, 1938, p. 449.)

Present Usage: According to United States Geological Survey, the Claiborne group as now understood is characterized by a distinctive fauna. It is overlain by the Jackson formation and underlain by the Wilcox group. It is chiefly of marine origin. (Wilmarth, 1938, p. 449.)

Distribution and General Lithology: Sediments belonging to the Claiborne group are recognized in the Gulf Coastal Plain from Georgia to southern Texas. The Claiborne group may be said to mantle nearly all that portion of northern Louisiana which lies east of the Sabine uplift, north of the Angelina-Caldwell flexure and west of the Ouachita River, if one disregards the overlying irregular veneer of Pleistocene and Recent deposits. (Howe, 1936, p. 104.)

In exposed deposits marine formations of glauconitic sand and calcareous clay with local limestone concretions are interbedded with thicker brackish-water facies of sands and carbonaceous, chocolate-colored silts and clays. To the north the outcrop area of the Claiborne group has not been identified beyond east-central Arkansas. The brackish-water facies thins and interfingers with marine facies eastward and in Alabama the entire outcropping section is marine. In the Mississippi embayment area, the Claiborne is so similar to the underlying Wilcox that the two have not been separated. It is entirely possible that the upper Wilcox section includes beds laid down

contemporaneously with the Claiborne farther to the South. (Fisk, 1944, pp. 61, 62.)

The Claiborne group thickens toward a subsurface center, the thickest portion of which is in southwestern Louisiana and Texas. The alternation of lithologic groups which characterizes the Claiborne formation of the surface is largely obscured in the subsurface. In the thickest part of the deltaic mass, there is a thick section of carbonaceous shales and sands with a few minor widespread limestones. (Fisk, 1944, pp. 61, 62.)

Correlations: Moody's (1931, p. 535) correlations of the Claiborne group are based on his tracing of the Ostrea sellaeformis fauna across the state of Mississippi. In Louisiana he mapped in detail the strata containing this fauna. In Arkansas and Texas he mapped by reconnaissance.

The Reklaw member of the Mt. Selman formation of Texas is considered as the basal Claiborne formation of Texas. The essential continuity of the lithology of the Tallahatta formation from the Alabama River to San Augustine, Texas, and the remarkably wide distribution of the Ostrea sellaeformis and Ostrea lisbonensis fauna constitute the important evidence on which the correlation of early Claiborne rests. The above diagnostic fauna has been traced from Lisbon Landing on the Alabama River through the Winona sand of Mississippi and the Cane River formation of Louisiana to the Mt. Selman of Texas. (Moody, 1931,

In Louisiana the Claiborne group at the surface has been divided on a basis of lithology into the following formations: Cockfield (continental sediments) 200 feet; Cook Mountain (marine clay and glauconitic sand) 100 feet; Sparta (continental sands and shales) 400 feet; Cane River (marine clays and green sand) 100 feet. These figures refer to the outcrop thickness in the region of Bienville and Winn Parishes, Louisiana. (Howe, 1936, p. 104.) The thickness of the Claiborne increases considerably south of the Angelina-Caldwell flexure and attains a thickness of more than 2500 feet in southwestern Louisiana. (Fisk, 1944, Fig. 66.)

Local Application: The Claiborne section which includes about 1650 feet of shale is present in the deepest flank well at Port Barre. The electrical survey shows a pattern that is typically characteristic and is remarkably uniform; showing no sand breaks.

The group remains undifferentiated at Port Barre since the included formations are not recognizable from the electrical surveys. Except for possible locally developed deposition, no sands can be expected to exist in this group on the flanks of the Port Barre dome.

#### Cane River Formation

Designation: The basal marine formation of the Claiborne group in Louisiana was first recognized to be paleonto-

logically distinct by Vaughan (Howe, 1933, p. 621.) It was then included within the "St. Maurice" which was later divided by Spooner from lithologic and paleontologic studies. Spooner (1926, p. 235) named the basal marine formation the Cane River beds. The name, Cane River was suggested by H. V. Howe, for excellent exposures on the Cane River at Natchitoches, Louisiana. (Spooner, 1926, p. 235.)

Present Usage: The original definition by Spooner of the Cane River formation of western Louisiana, and northeastern and eastern Texas is in current use by the United States Geological Survey. (Wilmarth, 1938, p. 332.)

In the Cane River are 75 to 150 feet of beds above the Wilcox formation and below the massive Sparta sand. These beds outcrop in a narrow belt trending northeast across southern Sabine and Natchitoches Parishes. (Spooner, 1926, p. 235.)

General Lithology: The basal member consists of glauconitic sand and sandy clay, but in some places marine tuff is present at the base. Glauconitic clays predominate in the southern portion of the outcrop. Northward from Bienville Parish they become more sandy. In northern Bossier Parish, they are represented entirely by sands, in part glauconitic, and containing a meagre representation of the prolific fauna found farther south. The fauna of the Cane River beds was described by Vaughan (1900) and Harris (1919). (Spooner, 1926, p. 235.) Shearer (Howe, 1933, p. 622.) later subdivided the Cane River into two members,

the Cane River clay above and Cane River marl below.

The top of the upper member is sandy shale which grades downward into smooth, plastic, slightly calcareous clay-shale. This material is characterized by its dark chocolate-brown color, generally specked and streaked with light green. It is marine and Foraminifera are plentiful. (Howe, 1933, p. 622.)

The lower member consists of fossiliferous sandy and highly glauconitic marl or soft limestone. It is commonly logged as "salt and pepper sand" because of the appearance of the white limestone with grains of dark glauconite. (Howe, 1933, p. 622.)

Faunal Correlation: The Cane River marine clays, the Cane River fossil zone, grade downward through glauconitic clays (characterized on the surface by Discocyclina advena) into the basal Cane River glauconitic marl. (Fisk, 1940, p. 133.)

The Cane River glauconitic marl is characterized by Ostrea sellaeformis var. lisbonensis Harris and Orthopragmina advena Cushman at the type locality north of Natchitoches, Louisiana. (Ellisor, 1929, p. 1343.)

On the surface Cane River marl is approximately 50 feet thick. It contains small molluscs, bryzoans, corals, and other invertebrate organisms characteristic of shallow water littoral deposition. (Fisk, 1940, p. 133.)

Down dip the Cane River marine marls carry the general Cane River assemblage of Foraminifera, but lack the

fossils which characterize the basal part of the surface Cane River. The Foraminifera present are: Ceratobulimina eximia, Eponides guaybalensis, Haplophragmoides sp., Hemicristellaria(?) nudicostata, a smooth Robulus sp., Siphonina claibornensis, Uvigerina spp. and others. (Fisk, 1940, p. 133.)

The basal Cane River marl in Eola field, Avoyelles Parish, carries abundant Globigerina spp. and Globorotalia spp. in addition to the above. Discocyclina advena, however, is found 100 feet below this Cane River to the east of Eola field in Sec. 28, T. 3 S, R. 8 E, in Point Coupee, Parish. This indicates that Cane River marl down dip in southern Rapides Parish is younger and higher in the section than the typical section at the surface and in northern Rapides Parish. Apparently central Louisiana was an area of continuous sedimentation from upper Sabine up into Cane River time and the advance of the Cane River sea did not occur until late in the epoch. (Fisk, 1940, p. 133.)

Local Application: At Port Barre an electrical log (Fig. No. 5) indicates that the Cane River is composed entirely of shale which is underlain by 335 feet of limestone. Data other than the electric logs are not in the possession of the writer, thus, further investigation of lithologic and paleontologic evidences and future deeper drilling may establish the true correlation of the thick limestone unit.

At present the base of the Cane River is placed at

the top of the limestone as shown in (Fig. No. 5.) The boundary is placed thus, because of the foregoing reasons discussed in this paper under Wilcox correlation. This horizon is the most convenient for electrical log correlation and is in accordance with recent regional correlations.

### Sparta Formation

Designation: The name, "Sparta sands", was first proposed by Vaughan (1895, p. 226) because of well developed beds near the town of Sparta in Bienville Parish Louisiana. Vaughan (1895, pp. 225, 226) designated certain sands and gravels in northwestern Louisiana and described their areal distribution. They had been called "drift" by Hopkins and Lerch. Vaughan (1895, p. 225) did not venture an opinion as to their age or attempt a correlation of all the superficial upland sands and gravels.

According to Spooner (1926, p. 236) the "Sparta sands" of Vaughan included portions of the Catahoula sandstone (of Miocene age) and the Citronelle formation (of Pliocene age) as well as the Sparta sand as restricted by Spooner (1926, p. 236.).

Present Usage: The Sparta sand is now treated as a distinct formation. (Wilmarth, 1938, p. 2036.) It is a division of the lower Claiborne which is limited below by the Cane River beds and above by the lowest fossiliferous horizon of the "St. Maurice beds" (Cook Mountain formation.)

(Spooner, 1926, p. 236.)

Distribution: The Sparta sand of Louisiana outcrops in a narrow belt from Sabine River to the northern end of Saline Lake. From this point northward to the vicinity of Minden, it has a width of 10 to 15 miles. (Spooner, 1926, p. 236.)

General Lithology: The lower half of the Sparta sand is chiefly massive sand with interbedded subordinate members of laminated sandy clay. The upper half contains a relatively greater amount of clay than the lower half.

(Spooner, 1926, p. 236.)

In the upper half the massive sands alternate with beds of finely laminated sandy clay, in part lignitic and in many places containing fossil leaves. The upper 50 feet of beds which are particularly well exposed in the vicinity of the town of Bienville contain a considerable amount of lignitic material and some thin lignitic beds. The Sparta sand has a thickness of 400 to 500 feet. Fossils are generally absent from the Sparta sand, but a few species of near-shore forms are found near the middle of the formation. (Spooner, 1926, p. 236.)

Subsurface Distribution and Lithology: In the subsurface and down dip southeastward from the outcrop an overlying seaward-thickening wedge of brackish-water sediments show a transition downward through "blanket" sands into the fluvial Sparta. It in turn has a transition downward through "blanket" sands to lignitic clays. The upper part of these clays carry a small Cyclammina sp. and the

lower part, a larger Cyclammina sp. and Hemicristellaria (?) nudicostrata. The clays merge with the underlying Cane River marine clays, the Cane River fossil zone. (Fisk, 1940, pp. 132, 133.)

The Sparta section in the subsurface of central Louisiana represents deposition in a comparatively local minor delta which was built during the time of faunal change between late Cane River and early Cook Mountain seas. (Fisk, 1940, p. 136.)

The Sparta thins both eastward and westward from central Louisiana and interfingers with the underlying brackish-water clays carrying fossils found associated with the clays overlying the surface marine Cane River and underlying the Cook Mountain. (Fisk, 1940, p. 136.)

Seawardly the Sparta sand is replaced by brackish-water beds. (Fisk, 1940, p. 133.) Down dip in the area represented by the southern end of the cross-sections of Fisk (1940, plate 3) near Washington, Louisiana the fluvial beds are missing.

Local Application: The Sparta formation at Port Barre, about nine miles farther down dip from Washington, Louisiana, contains no sands and grades into the overlying shale beds of the Cook Mountain and the underlying shale beds of the Cane River. Manifestations of an electrical log as shown in (Fig. No. 5) may indicate a division for the Sparta section. Coring and a more intensive study of this section should aid in a better understanding of the down dip

and vertical transitions of the Sparta formation.

### Cook Mountain Formation

Designation and Former Usage: The name, "Cook's Mountain", referring to the marine Claiborne beds exposed at Cook's Mountain in Houston County, Texas was first used by William Kennedy (1892, pp. 54-57.).

In Louisiana Harris (1919, p. 8.) included all of the Claiborne below the Cockfield under the name of "St. Maurice". The "St. Maurice beds" were later restricted by Spooner (1926, p. 237) which now corresponds to the Cook Mountain formation.

The names, "Minden" and "Mount Lebanon", have been used in literature for this formation. The use of these names have been discontinued because of incorrect usage and lack of priority. (Howe, 1933, p. 625.)

The original description by Kennedy (1892, p. 54-57.) included the sediments now known as the Sparta formation. The Sparta sand was for many years treated as a basal member of the Cook Mountain formation. (Wilmarth, 1938, p. 510.)

Present Usage: Moody (1931, p. 535) used the term Cook Mountain for the formation containing Ostrea sellaeformis fauna in Texas, Louisiana and Mississippi. He applied the term to all sediments overlying the Sparta sand and underlying the Cockfield (Yegua of Texas). (Moody, 1931, p. 537.) His correlations are based on his tracing of the

Ostrea sellaeformis fauna across the state of Mississippi, mapping of strata containing the fauna in detail in Louisiana and by reconnaissance in Arkansas and Texas. (Moody, 1931, p. 535.) Howe (1933, p. 624) and others agree to this usage of the term Cook Mountain which is now well established.

Distribution and General Lithology: The Cook Mountain in Louisiana outcrops in a narrow belt across Sabine, Natchitoches, and Winn Parishes. (Spooner, 1926, p. 237.) The formation is predominately marine and reaches a total thickness of about 250 feet. It consists of fossiliferous, sandy clays, silts, sandy silts, and local limestones. (Fisk, 1944, p. 14.)

The upper part of the Cook Mountain in Central Louisiana is predominately brackish-water and the lower part predominately marine. The facies are different down dip in the subsurface. The predominant brackish-water clay section containing Ceratobulimina exima and Eponides guaybalensis characterize the upper part of the Cook Mountain on the surface. (Fisk, 1940, p. 131.)

Subsurface Lithology and Correlation: Fisk (1940, p. 131) describes the transition of these Cook Mountain clays which are much thicker down dip than on the surface and shows north-south cross-sections (1940, pl. 3, 4) containing the formation. At the northern limits of Fisk's cross-sections in Caldwell and Grant Parishes the upper part of the Cook Mountain or the brackish-water clays grade down-

ward through glauconitic marls into a marine section. The marine section is only slightly thicker than the surface section and is marked by Siphonella claibornensis and Planulina sp. (Fisk, 1940, p. 131.)

The above marine section has been described on the surface as the upper part of the Milams marl member (lower Cook Mountain) in Winn Parish by Huner in 1939. (Fisk, 1940, p. 131.) The lower part of the marine section carries Camerina sp., Lepidocyclina gardnerae, Operculinoides sabinensis, and Discocyclina perpusilla, which also occur in surface exposures. (Fisk, 1940, p. 131.)

The thickness of the marl in the subsurface is between 30 to 60 feet and has a characteristic lithologic appearance. It has been referred to as the "Sparta lime". This marl is underlain by less indurated or equally indurated glauconitic limestone containing abundant Operculinoides sabinensis. (Fisk, 1940, p. 131.)

At the southern limits of Fisk's cross-section (1940, p. 3) near Washington, Louisiana, the sands in the Cook Mountain are completely replaced by brackish-water clays of low permeability which can be distinguished by faunal content only. Eponides guaybalensis and Ceratobulimina eximia first appear 200 to 400 feet below Moody's Branch marl (basal Jackson) and identify the section down through the Cook Mountain marine marl. (Fisk, 1940, p. 132.)

Local Application: At Port Barre, down dip, no differentiation could be made since only the electrical survey

was available. A thick shale section with no sands was manifested on the log (Fig. No. 5) which grades up into the overlying Cockfield formation.

### Cockfield Formation

Former Designations, Usages and Correlations: Because of the predominantly lignitic character of the older Eocene formations below the Jackson group much confusion arose in discerning the stratigraphy of these formations. (Huner, 1939, p. 119.)

Hilgard (1869 A, pp. 8, 9) noting the Jackson group no farther west than the Ouachita River of Louisiana considered that all lignitic strata (including the present Cockfield) corresponded to strata overlying the Jackson group and underlying the Vicksburg group. (Huner, 1939, p. 119.) Hilgard (1869 A, pp. 8, 9) named these beds the "Mansfield group" from an exposure near Mansfield, Louisiana.

F. V. Hopkins (1870, pp. 83-91) challenged Hilgard's age assignment pointing out that these strata lie below the Jackson. Hopkins included the beds now called Cockfield in this "Mansfield group" and described a section exposed as a bluff fifteen miles upstream from Columbia, Louisiana. (Huner, 1939, p. 120.)

Hopkins (1870, p. 90) said that his selected sections from all parts of the "Mansfield group" have great similarity which proves that this group is but one formation from Texas to the Ouachita River and from Grand Ecure (Natchitoches Parish) and Columbia to the Arkansas River.

(Huner, 1939, p. 120.)

Hopkins in 1871 (pp. 7, 8) made an error in his paleontologic determinations and correlated the entire "Mansfield group" with the Jackson group. Apparently, Hilgard was not fully convinced that Hopkins was correct. Hilgard in 1871 used "Northern Lignitic" which included the lignitic material below the Jackson and correlated this with Tuomey's "Buhrstone" of Alabama and Hilgard's "Siliceous Claiborne" of Mississippi. This correlation was probably based only on superposition of beds and negative paleontologic evidence, yet in a restricted sense, Hilgard was close. (Huner, 1939, p. 120.)

L. C. Johnson in 1888 offered the first clues for correlation of the lignitic strata of northern Louisiana, but did not state any final conclusion as to the probable age of the horizon. In reference to the "Mansfield group", Johnson (1888, p. 16) placed the lignitic strata below the marine Claiborne formation because of its contact with that "terrane" throughout its entire occurrence. This was the first time that the occurrence of the marine Claiborne in Louisiana was recognized. (Huner, 1939, p. 120, 121.)

Designations: Johnson had recognized a lignitic group below marine Claiborne and Otto Lerch (1892, p. 14) recognized a lignitic group above the marine Claiborne. (Huner, 1939, p. 121.) Lerch gave numerous sections which were favorable for a type section but a descriptive rather than a geographical name was given. Thus, Vaughan (1895,

p. 209, 220) renamed this formation and proposed the local name "Cocksfield Ferry beds" for those beds which lie conformable above the fossiliferous "Lower Claiborne" at St. Maurice, Louisiana, (Vaughan, 1895, p. 220) and below the Jackson Group. (Huner, 1939, p. 121.)

Harris in 1902 (p. 21) using the term, "Cocksfield beds", correlated the Cocksfield beds with upper Claiborne of eastern Mississippi and Alabama. This was the first time that the Cocksfield was given an upper Claiborne age. (Huner, 1939, p. 123.)

Veatch (1906 A, p. 32) explained why he previously (1905, p. 89) had used the term, "Cocksfield", stating that maps of the Red River Survey show two adjacent plantations belonging to A. P. and W. J. Cocksfield, and that the formation term (for the ferry landing) should be spelled the same as the owners of the ferry.

Usage: Since 1905 the name, Cocksfield, has been in common use in Louisiana despite several attempts to alter it. Later, the Cocksfield was elevated to a formation and the Claiborne to a group.

In 1912 the equivalency of the Cocksfield formation of Louisiana with the Yegua formation of Texas was established and the term, Cocksfield, was dropped for the name, Yegua, which was proposed earlier. (Wilmarth, 1933, p. 479.)

The name, Cocksfield, was later revived when a more recent intensive work of Julia Gardner showed that the

deposit of the Yegua type locality is a thin marine bed belonging to the underlying Cook Mountain formation. It was then considered that a single name should be applied to the deposits of both states and the term, Yegua, for a time was discarded in favor of the Cockfield. (Wilmarth, 1938, p. 2384.)

In 1933 Texas geologists and the United States Geological Survey decided to revive the term, Yegua, for the dominantly nonmarine unit forming the top formation of the Claiborne group and to abandon the term, Cockfield. (Wilmarth, 1938, p. 2384.)

Stenzel in 1938 (Huner, 1939, p. 124) advocated that the name, Cockfield, currently used in Louisiana and the name, Yegua, currently used in Texas be changed to "Lufkin". The term, "Lufkin", has priority (Kennedy, May, 1892). Its usage is practically nil, perhaps, because Kennedy did not define it precisely. His description included beds now referred to as the Sparta. (Huner, 1939, p. 124.)

Present Usage: Although the term, Cockfield, may not have priority in the Gulf Coast region, it does in Louisiana. The type section lies approximately in the middle of the Cockfield. The description is clear and concise. The type locality is typical of the unit it represents and the name is well established. The term is consistently used in many publications in Louisiana and by the Louisiana Geological Survey. (Huner, 1939, p. 124.)

Usage of the term, Cockfield, in this paper is the same as that of the Louisiana Geological Survey.

Recognition at Surface: The Cockfield at the surface is one of the more easily recognized formations in Louisiana because of its nonmarine strata and its stratigraphic position above the marine Cook Mountain formation and below the Jackson group. The outcrops of this formation along the Ouachita River are perhaps among the best stratigraphic exposures in Louisiana. (Huner, 1939, p. 125.)

As was shown by various sections in Winn Parish, (Huner, 1939, pp. 103-114) the contact of the Cockfield formation with the Cook Mountain is definitely gradational. The presence of fossils is the only criterion that separates the lower from the upper formation. (Huner, 1939, p. 134.)

In Catahoula Parish the top of the Cockfield, or the contact with the Jackson, is generally well marked by a change from greenish shale to gray or lignitic sand and shale. The lower contact of the Cockfield is a gradation downward into the Cook Mountain formation. (Shearer, 1930, p. 438.)

General Lithology and Distribution: Exposures of the formation average 500 feet thick in central Louisiana and consists of a series of lignitic silty clays, silts and sands. Beds are particularly rich in plant remains and contain local seams of lignite. Thinly laminated, black lignitic clays and sands mark the transition into the

overlying Jackson marine beds. (Huner, 1939, p. 82.) Lignitic sands are neither extensive nor as well developed as the silts and shales. Some of these shales in the Cockfield are strikingly similar to shales occurring in the marine Jackson and the Cook Mountain and can be differentiated only by the presence or absence of fossils. The more massive sands in the Cockfield appear to have been deposited in local bodies of water whose depth would govern their thickness and lateral extent. (Huner, 1939, p. 125.)

Apparently there is a definite increase in thickness of the Cockfield south of Caldwell and Winn Parishes which indicates that the main area of Cockfield deposition is south of the main area of Sparta deposition. (Huner, 1939, p. 157.) The bulk of the Cockfield sediment was deposited to the west in Texas. The Cockfield decreases in thickness eastward across Texas. In Louisiana a section 500 feet thick, slightly thickened down dip, is present. (Fisk, 1938, p. 89.) Its eastern limit in Clarke and Wayne Counties, Mississippi, is reported to consist of only 80 feet of continental materials. (Bland-pied, et al., 1934, p. 4.)

#### Subsurface, Lithology, Distribution and Correlation:

The subsurface Cockfield and Cook Mountain if shown accurately can be considered as a gradational unit. The average thickness is 750 feet. The unit gains in thickness southward to 840 feet in southern La Salle Parish

and is largely Cockfield. (Fisk, 1938, p. 38.)

The subsurface lithology differs little from the lithological character of this formation along the outcrop. Lignites and the general lignitic aspect of the sands and clays are somewhat more emphasized in the subsurface, chiefly, because weathering has not been able to attack these sediments. (Huner, 1939, p. 137.)

In the southern part of Winn and Caldwell Parishes, wells which are in the belt of the Jackson outcrop have penetrated 550 feet and 600 feet of Cockfield sediments. (Huner, 1939, p. 137.) The Moody's Branch marl (basal Jackson) is underlain by clays which contain in the upper 50 feet Nonionella cockfieldensis. At a lower interval Discorbis yeguaensis and Eponides yeguaensis occur. (Fisk, 1940, p. 131.)

The lower part of the clays includes thin "blanket sands" and grades into widely spaced fluvial sand units. These sands also grade downward through "blanket" sands and brackish-water shales into the predominantly brackish-water clay section containing Ceratobulimina eximia and Eponides guaybalensis which characterize the upper part of the Cook Mountain on the surface. (Fisk, 1940, p. 131.)

Down dip near Washington in St. Landry Parish, Louisiana, in the Herton-Thistlewaite well, the fluvial sands and "blanket" sands have been completely replaced by the brackish-water clays of low permeability which can

be differentiated on faunal content only. (Fisk, 1940, p. 132.)

The sequence of brackish-water fossils found here is the same as the one up dip. Nonionella cockfieldensis occurs within 50 feet below the Moody's Branch marl. Discorbis yeguaensis generally makes its first appearance 10 feet below Nonionella cockfieldensis and is either accompanied by Eponides yeguaensis or followed by it, generally within 10 feet. The thickness of the Cockfield-Cook Mountain unit varies 700 feet to nearly 1000 feet, down dip, with the thickest part of the section at the point where the channel sands have been replaced by brackish-water beds. (Fisk, 1940, p. 132.)

Local Application: Down dip at Port Barre, electrical log manifestations show nearly the same sedimentary sequence to exist as are evident at Washington, Louisiana. This indicates there is little change in facies within the Cockfield formation between these two localities. Since no cores or samples were available to the writer for this section, it is important that further study be made in order to determine the relationship between the Cockfield and the overlying Jackson group. The division as shown in Fig. No. 5 is based on comparison with electrical logs of this section within a distance of about 10 miles.

## JACKSON GROUP

Conrad in 1834 (p. 120) recognized the existence of Eocene material west of the Mississippi River for the first time. The locality referred to in his report was in a bank of the Ouachita River near the town of Monroe, Louisiana. He stated that, apparently, the most abundant fossil found here is Corbula oniscus nobis, a shell very common in the arenaceous stratum at Claiborne. (Huner, 1939, p. 144, 145.)

The Eocene was divided by Conrad in 1848 (pp. 111, 112) into the "Upper or Newer Eocene" and the "Lower or Older Eocene". The division was based on observations and new fossils from the vicinity of Vicksburg, Mississippi. He placed the above "Washita River" locality in the "Lower or Older Eocene". (Huner, 1939, p. 145.)

Designation: Conrad in 1855 (p. 257) described the Jackson group from the type locality at Jackson, Mississippi, and placed it stratigraphically above the Claiborne group and below the Vicksburg group. The exposures are along Pearl River and Moody's Branch.

Conrad (1855) stated that Cardium nicolletti Conrad (1841, p. 33) which was found in the bank of the "Washita" River of "Monroe County", Louisiana, will probably prove to belong to the same division of the Eocene as that of Jackson, Mississippi. This is the first reference to the existence of the Jackson group in Louisiana. (Huner, 1939, p. 145.)

Hilgard in (1869 A, p. 9) applied the term to rocks in the general area of central Louisiana. Moody (1931) published a generalized map showing the area of the Jackson outcrop in Louisiana and adjacent states. The map represents a compilation from various sources. (Fisk, 1938, p. 89, 91.)

Present Usage and Distribution: The Jackson is now recognized by the United States Geological Survey in the Gulf Coastal Plain from southern Texas to Tombigbee River in southwestern Alabama. East of Tombigbee River in Alabama and in western Georgia the deposits of Jackson age are represented by Ocala limestone. Farther east in Georgia and in South Carolina they are represented by the Barnwell formation. In eastern South Carolina they are represented by Cooper marl (above) and Santee limestone (below). The Fayette sandstone of eastern Texas is also of Jackson age. (Wilmarth, 1938, p. 1035.)

In central Louisiana the outcrop of the Jackson extends southwestward as a narrow belt from the Ouachita River, in southern Caldwell Parish to the Red River south of Montgomery. (Fisk, 1938, p. 91.) In this area the group has been assigned a thickness that ranges from 400 feet to 600 feet in numerous reports. (Howe, 1936, p. 106.)

The Jackson deposits reach a maximum thickness of 600 feet in southwestern Louisiana and are generally thinner to the east in Mississippi. The marine facies thin seaward from the zone of thick deposition. (Fisk, 1944, p. 62.)

Basal Contact: The Eocene closed with the deposition of marine beds of uniform thickness over much of the central Gulf Coastal Plain. Included fossils show that a widespread marine transgression took place. The basal facies of the marine Jackson are highly glauconitic beach sediments deposited as the Jackson sea transgressed the Claiborne deltaic plain. (Fisk, 1944, p. 62.)

The basal facies are overlain by massive marine clays containing a comparatively deep-water, continental-shelf fauna. In Mississippi and central Louisiana these clays reach a thickness of 250 feet and grade upward into overlying carbonaceous, brackish-water clays of the upper Jackson. (Fisk, 1944, p. 62.)

The contact between the Jackson and overlying Vicksburg deposits cannot be easily established inasmuch as it is transitional both on the surface and in the subsurface. (Fisk, 1944, p. 62.) Down dip the upper marine clays merge with the overlying Vicksburg and with lower Jackson marine clays which overlies the Moody's Branch marl. The transition between the Jackson and Vicksburg is referred to the Red Bluff formation of Mississippi by some paleontologists. (Fisk, 1940, p. 131.) The two groups combined include most of the marine beds in the central part of the Cenozoic stratigraphic section and provide a convenient unit for generalized mapping. (Fisk, 1944, p. 62.)

General Lithology and Correlation: The Jackson group is divided into three formations in the south-central Gulf

Coastal Plain area of Louisiana and Mississippi; the Moody's Branch marl, the Yazoo Clay, and the Danville Landing beds. (Fisk, 1944, p. 14.)

The Moody's Branch consists of a fossiliferous, glauconitic, sandy marl with limestone concretions. It is readily distinguishable from the underlying Cockfield formation which is largely nonmarine and practically devoid of fossils. (Fisk, 1944, p. 14.) Both on the surface and in the subsurface, this glauconitic marl is the most widespread bed in the Gulf Coast. It is from 10 to 40 feet thick wherever encountered. (Fisk, 1940, p. 130.) It is characterized in the basal part of the marl by the large Foraminifera, Camerina moodybranchensis, Discocyclina flintensis, Lepidocyclina mortoni and Operculina vaughani. (Fisk, 1940, p. 130.)

The Moody's Branch marl is overlain by the Yazoo Clay formation which consists of basal fossiliferous, calcareous clays and middle and upper deposits of silty, lignitic sandy shales. (Fisk, 1944, p. 15.) The Textularia hockleyensis zone, on the surface (central Louisiana) at least, extends from the base of the upper Danville Landing beds downward to the top of the transition phase where Textularia dibollensis is first encountered. Although Textularia hockleyensis continues to the base of the Jackson, the zone is properly limited by the appearance of the T. dibollensis. The Textularia dibollensis extends from the top of the above transition phase to

the base of the Jackson; however, it is limited by the first appearance of Operculina vaughani and Camerina moodybranchensis. (Huner, 1939, p. 167.) Besides Textularia dibollensis, these beds carry Bitubulogenerina montgomeryensis, Sigmomorphina jacksonensis, and many others. (Fisk, 1940, p. 130.)

The Danville Landing beds, the uppermost Jackson formation, is largely marine in origin and is characterized by fossiliferous and calcareous clays and silty shales. (Fisk, 1944, p. 15.) It is a thin group of beds which carry Massilina pratti and Valvulineria texana. These fossils are not universally present down dip and in their absence the appearance of Bulimina jacksonensis, Marginulina fragaria, Planulina cocoaensis, Uvigerina cocoaensis, and many other common species indicate Jackson age. (Fisk, 1940, p. 130.)

Faunal Zones and Down dip Correlation: The Jackson group has been divided into four recognizable zones upon the basis of micro-faunal content which are applicable to the Jackson in Louisiana. (Fisk, 1938, p. 93, 94.) Contributions on establishing the sequence of these zones in the Gulf Coastal area were by Cushman and Applin (1926), Ellisor (1933), Gravell and Hanna (1935), Monsour (1937), and others. The sequence of the zones is as follows:

Massilina pratti (upper) zone

Textularia hockleyensis zone

Textularia dibollensis zone

Camerina (Operculina) zone

Fisk has shown in cross-sections (Fisk, 1940, p. 3, 4) that down dip from Grant and Avoyelles Parishes and in a well near Washington, Louisiana, the upper Jackson marine clays merge with the overlying Vicksburg above and with marine clays below which overlie the Moody's Branch marl. He shows that the thick section which is characterized by Textularia hockleyensis zone is completely absent. In this well Fisk (1940, p. 3) has restricted, vertically, the Jackson to only the fossiliferous section which is approximately 100 feet thick.

Local Application: Data indicates a thickness of approximately 80 feet farther down dip and in wells on top of the dome at Port Barre. The basal beds of about 31 feet in thickness are identified by the included fossils to be the Moody's Branch marl.

The Jackson which was penetrated on top of the dome by the Texas Company's No. 10 Botany Bay Lumber Company well shows fossiliferous Jackson shales from 3902 to 3951 feet.

The microfauna between 3902 and 3916 feet is prolific. Included are Uvigerina cf. jacksonensis, Uvigerina cf. pigmaea d'Orb, Siphonina cf. coenica, Nodosaria cf. jacksonensis, Textularia cf. mississippiensis, and Spiroloculina sp. (Norton, 1951.)

From 3951 to 3982 feet the material is mainly crystalline limestone with small amounts of sandstone. Fossils

found in the last foot are Operculina (large form), Amphistegina sp?, Discoicyclina sp?, and Lepidocyclus sp?. Much greenish-gray, calcareous shale, and glauconitic marl is present with pyrite crystals. (Norton, 1931.)

From 3959 to 3969 feet a ten-foot bed of white soft, fine grained, non-calcareous sandstone containing some large quartz grains was present. A few Foraminifera (probably Amphistegina) were found and a small show of oil was noted. (Norton, 1931.)

Evidence observed in cores from 3982 to 4160 feet show a 240-foot section which is mainly crystalline and cryptocrystalline limestone with a little sand. Some of the cores taken within this interval suggests a brecciated condition or the cap. (Norton, 1931.)

Recently several flank wells have penetrated the Jackson group. The greatest depth at which this group has been encountered is in the Texas Company No. 35, Botany Bay Lumber Company well. The base occurs near the 9600-foot level. The base of the Jackson as shown in Fig. No. 5 can be determined by comparing electrical logs within the region. Since the Jackson is transitional with the overlying Vicksburg, the top of the Jackson cannot definitely be determined.

## O L I G O C E N E

### VICKSBURG GROUP

Designation: The name, Vicksburg, for exposures at Vicks-

burg, Mississippi came into use as the result of Conrad's (1846 A, 1846 B, 1847) studies in which he described and illustrated a large number of Vicksburg mollusca from fossiliferous beds.

At this time Conrad decided that Vicksburg beds occupied an intermediate position between the Eocene and the Miocene. (Mornhinveg, 1935, pp. 1648, 1649.) Conrad (1847, pp. 280-289) had divided the Eocene into the "Upper or Newer Eocene" and the "Lower or Older Eocene" and stated that the Vicksburg group belongs to the former and the Claiborne sands to the latter. Neither the Vicksburg group nor the Claiborne sands were described.

Usage: For many years the Vicksburg was referred to the Eocene until after the Oligocene (a term introduced by Beyrich in 1853) was recognized as a subdivision of the Tertiary in Europe. Conrad in 1866 (p. 26-27) referred the Vicksburg beds to this new epoch. This age assignment has not been severely questioned by subsequent workers. (Chawner, 1936, p. 94)

Hilgard (1869B, p. 339) first called attention to the presence of Vicksburg strata in Louisiana. He thought that the beds extended across the state in a band about 30 miles wide and in 1870 Hopkins published a geologic map of Louisiana showing a band extending across the state. However, this band included Jackson and Claiborne as well as Wilcox sediments. (Welch, 1942, p. 34.)

Harris (1902) definitely limited the Vicksburg to the

region about Rosefield, Catahoula Parish. This locality had been described by Lerch (1893, pp. 92-98) and the fauna was listed by Vaughan (1894, p. 225.) Veatch (1906B, p. 41) also called attention to the fact that Hilgard's Louisiana Vicksburg localities, except those of Catahoula Parish, proved to be Jackson in age. Field examination of Hilgard's localities in Grant and La Salle Parishes by Fisk upheld Veatch's contention. However, Vicksburg sediments do outcrop at least as far west as the Red River. (Fisk, 1938, p. 125.)

Two localities west of the Red River in southeastern Natchitoches Parish, Louisiana, were discovered by Rukas and Gooch in 1939 (pp. 246-250). They reported fossiliferous Vicksburg beds near the towns of Montrose and Derry. Welch (1942, p. 35, 36) describes outcrops in northwestern Vernon Parish (western Louisiana) in an area of about one square mile.

Present Usage: The present usage of the Vicksburg group on the surface conforms to these early definitions in that the group is characterized by a distinctive fauna, is overlain by the Catahoula sandstone, and is underlain by the Jackson. (Wilmarth, 1938, p. 2246.)

The Vicksburg in Mississippi is divided into the following descending order: Byram marl, Glendon formation, Marianna limestone and the Forest Hill sand. (Wilmarth, 1938, p. 2246.) The present generally approved definition of the Vicksburg group includes at the base the contempor-

aneous or approximately contemporaneous formations of the Red Bluff clay to the east and the Forest Hill sand to the west. (Wilmarth, 1938, p. 1782.)

Vicksburg beds outcrop in the lower Mississippi Alluvial Valley as a narrow southwestern to northeastern belt of irregular width which trends eastward from near Sicily Island, Louisiana, to Vicksburg, Mississippi. (Fisk, 1944, p. 15.)

General Lithology: The Vicksburg group which is best known from its exposures at Vicksburg, Mississippi, consists of fossiliferous, glauconitic sands, clays, and massive soft thin-bedded argillaceous limestones. The group maintains similar lithologic characteristics on the outcrop as far west as central Louisiana. From there the deposits thicken westward and the marine elements are gradually replaced by carbonaceous shales and sandy deposits which are transitional with the overlying Miocene beds. Southeast of Vicksburg the group becomes thinner and predominantly marine both on the outcrop and in the subsurface. (Fisk, 1944, p. 62.)

Vicksburg sediments on the surface in central Louisiana are nonresistant to erosion and in general occupy the lowland. The exposures are limited to comparatively few localities in the stream valleys where erosion has destroyed the Pleistocene terrace materials. (Fisk, 1938, p. 125.) In this area sedimentary conditions suggest a conformable and transitional relationship between the

Vicksburg and the Catahoula. In the field no definite contact can be drawn and none can be drawn separating the Vicksburg from the underlying Jackson marine beds. (Fisk, 1938, p. 129.)

In the subsurface the combined groups of Vicksburg and Jackson age reach their greatest thickness in southwestern Louisiana and adjacent parts of Texas where they form a typical deltaic mass. (Fisk, 1944, p. 62, Fig. 67.)

Correlation: Formational distinctions which are apparent in the Vicksburg of Mississippi cannot be isolated in the surface Vicksburg of Central Louisiana. (Fisk, 1938, p. 129.) Certain sedimentary characteristics permit the beds to be divided into two interrelated members of sedimentation; a lower, gypsiferous member and an upper, sandy clay member. (Fisk, 1938, p. 129.)

The lower member of the sequence varies from 30 to 60 feet in thickness and grades into the upper member. The lower member consists of a series of massive clays and a few thin beds of sand which are characterized by a considerable quantity of gypsum. Haplophragmoides sp. and Amnobaeculites are commonly found in the lower part of this phase and are associated with the gypsiferous beds. (Fisk, 1938, p. 129.)

The upper member consists of a series of nonmarine, micaceous, sandy clays and lenticular bodies. The lenticular bodies include definite marine material and micro-

fauna characteristic of both the Byram marl and the Mint Spring marl (member of Marianna ls. fm.). (Fisk, 1938, p. 131.) In the lower part of this sequence and directly above the top of the beds of the lower gypsiferous member a typical Mint Spring marl fauna occurs. This fossiliferous phase is overlain by clays carrying Textularia tumidulum. (Fisk, 1938, p. 132.)

Down dip and in the subsurface where more abundant faunas are encountered, the following key fossils are used by commercial geologists to indicate the first appearance of the Vicksburg: Anomalina bilateralis, Bolivina caelata, Camerina sp., and a coarse grained Liebusella sp. (Fisk, 1940, p. 129.)

Farther down dip in the Herton-Thistlewaite well near Washington, Louisiana, as shown in Fisk's cross-section (1940, p. 3), the combined Jackson-Vicksburg faunal units has a thickness of approximately 600 feet. The top of the Vicksburg faunal unit is shown near the 8250-foot sub-sea level.

Local Application: At Port Barre the regional thickness of the combined Jackson and the Vicksburg sediments is approximately 1000 feet. The regional sub-sea level elevation for the top of the Vicksburg is 9500 feet, plus or minus. (Fisk, 1944, fig. 67.)

Several flank wells have penetrated the Vicksburg sediments in the Port Barre field. The unit in this field consists predominantly of a shale section containing

minor sand lentils and sandy phases. Electrical logs manifest no pronounced textural changes in the formation at either the Jackson-Vicksburg contact or at the upper limits, the Vicksburg-Chickasawhay contact.

For purposes of study the top of the Vicksburg has been placed where the first Vicksburg fauna is first encountered. The top of this zone on the flanks of the dome has been encountered as high as the 8250 contour level. (Fig. No. 6.)

At present no differentiation can be made between the Vicksburg and the Jackson on top of the dome. However, sediments which appear to carry both Vicksburg and Jackson fauna are encountered at the 3200 and 3500 contour levels. (Fig. No. 6.)

The combined Jackson and Vicksburg units which have been penetrated in a few of the flanking wells are represented by approximately 900 feet of sediments as shown by the electrical log in Fig. No. 5.

#### Chickasawhay Formation

Designation: B. W. Blanpied, et al., in 1934 (charts, pp. 3, 4, 12, 16-19, etc.) proposed the name Chickasawhay for a series of marine beds overlying the Bucatunna clay. Blanpied applied the Chickasawhay to the Miocene as a result of a detailed study of these beds and their fauna.

Usage: In 1918 Cooke (p. 193) included these beds of limestone, marls and sands in the upper Oligocene Byram marl of Alabama and Mississippi. Cooke in 1926 (pp. 287-

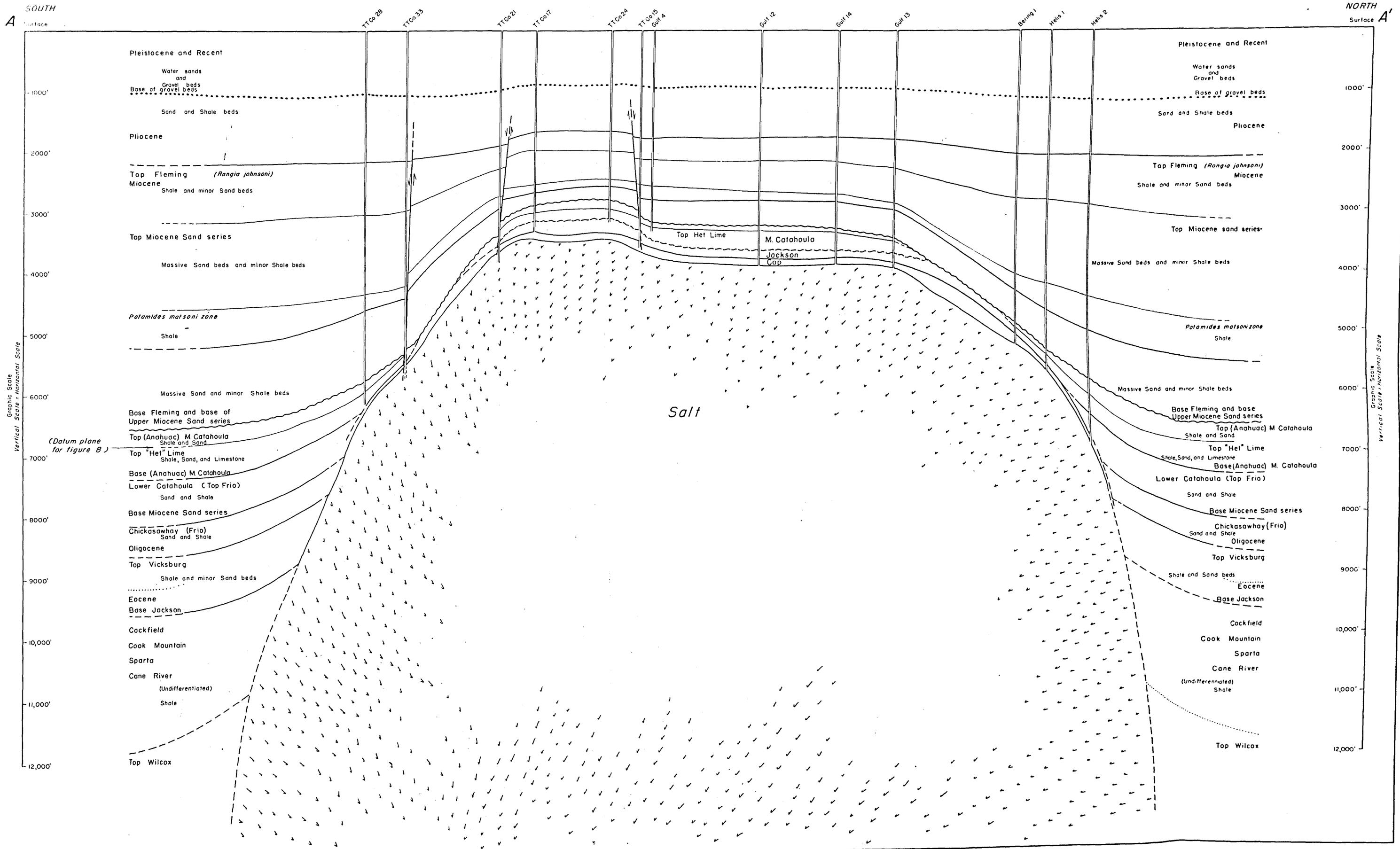


Fig. No. 6. Cross-section of Port Barre, Louisiana Salt dome, showing, in general, stratigraphy in position to the salt mass.

293) included in the Byram of Alabama many localities and sections herein referred to the Chickasawhay limestone. Cooke in 1935 (pp. 1162-1172) accepted the Chickasawhay marl and the Bucatunna clays as members of the Bryam marl, thus designating them to be of Oligocene Vicksburg group.

The Chickasawhay of the 1934 Guidebook (Blanpied, et al.,) was divided into two parts; the "Upper Chickasawhay member" and the "Lower Chickasawhay member". The underlying Bucatunna clay and the two Chickasawhay members were included with the Catahoula s.s. in a "Catahoula group" and referred to the Miocene.

M. A. Hanna and D. W. Gravell, two of the contributors to this Guidebook, however, dissented and grouped the Bucatunna and the "Lower Chickasawhay member" together in a "Limestone Creek group". They regarded this group as distinct from the Vicksburg group, but still of Oligocene age. (MacNeil, 1944, p. 1344.)

Hanna and Gravell in the Guidebook included the "Upper Chickasawhay member" within the overlying Catahoula to make a "Catahoula group" of Miocene age. Apparently, the grouping was without paleontological evidence, as no species of the upper member was cited. (MacNeil, 1944, p. 1345.)

Division of the Chickasawhay into the two members as used in the Guidebook is a system of nomenclature not acceptable by the United States Geological Survey. The

entire interval was named "Chickasawhay marl" of Miocene age and has been the accepted usage by the United States Geological Survey. (MacNeil, 1944, p. 1346.)

In 1938 Hazzard and Blanpied (1938, p. II) accepted the "Limestone Creek group" (Bucatumna clay and "L. Chickasawhay") of Hanna and Gravelle as distinct from the overlying Catahoula. Although they maintained a Miocene age, Hazzard and Blanpied stressed a correlation upon which everyone agrees that the "Lower Chickasawhay" beds are equivalent of the Flint River formation of Alabama, Georgia, and Florida, and of the Suwannee limestone of Florida (Oligocene age). (MacNeil, 1944, p. 1345.)

Restricted Usage: MacNeil in 1944 (p. 1346) restricted the "Lower Chickasawhay member" to the name of Chickasawhay limestone and named the "Upper Chickasawhay member" as the Paynes Hammock sand. He placed the Chickasawhay limestone, as restricted above, in the Oligocene as a formation but excluded it from the underlying Vicksburg group. He placed the Bucatumna clay as a member of the Byram formation in the Vicksburg group, and indicated a disconformity between the Byram and the overlying Chickasawhay. (MacNeil, 1944, p. 1316.)

This restriction and the renaming of the two members of the "Chickasawhay marl" was the result of detailed studies in the relationship of faunas in the "Lower" and "Upper Chickasawhay" and the actual tracing of recognizable lithological units eastward from Mississippi to Florida

and westward to Louisiana. A reconnaissance was made across Louisiana. (MacNeil, pp. 1316, 1347, 1348, 1352.)

The Chickasawhay, as restricted by MacNeil, is used in this report to designate the Oligocene strata overlying the Vicksburg group and underlying the Catahoula formation of Miocene age. This formation so designated includes characteristic surface fauna which are considered to be traceable into the subsurface.

Distribution: The Chickasawhay limestone is not exposed over a widespread area, being restricted to a band of strike outcrops in southeastern Mississippi and southwestern and southcentral Alabama. Westward the Chickasawhay and Vicksburg are progressively overlapped by the Catahoula. The Chickasawhay limestone is not definitely known west of Eucutta in northwestern Wayne County, Mississippi. (MacNeil, 1944, p. 1317.)

Lithology: Type section of the "Lower Chickasawhay member" along highway No. 45, three miles north of Waynesboro, Wayne County, Mississippi, consists of 30 feet of fossiliferous gray chalky marls, limestone, and clays. (Blanpied et al., 1934,) MacNeil (1944, p. 1346) says the best exposures of the Chickasawhay limestone are to be seen along the Chickasawhay River. They begin about 500 yards below the bridge on the old Waynesboro-Laurel road at Woodward and continuing intermittently for more than a mile south, where its contact with the Paynes Hammock ("Upper Chickasawhay") can be seen.

Near Waynesboro the Chickasawhay is predominately limestone with soft marl, hard calcareous sandstone and dark, probably, bentonitic clay near the top. (MacNeil, 1944, pp. 1346, 1348, 1349.) The texture of the limestone ranges from soft chalky limestone through crumbly, fossiliferous limestone to hard, dense limestone. (MacNeil, 1944, p. 1346-47.)

The basal Chickasawhay limestone is a smooth, cream-colored limestone and is seen in exposures from south-central Alabama to the westernmost exposures known which are in northwestern Wayne and southeastern Jasper Counties, Mississippi. (MacNeil, 1944, p. 1352.)

Westward Correlation: At Keys Mill, Smith County, Mississippi no Chickasawhay limestone or Bucatunna clay is present. MacNeil (1944, p. 1352) has interpreted that here, these strata have been cutout or overlapped. Brief reconnaissance of known Vicksburg deposits of Louisiana seems to give clear evidence that the Catahoula overlaps the Vicksburg at the surface in Louisiana between the Mississippi and Sabine Rivers. (MacNeil, 1944, p. 1353.)

Ellis (1939, p. 423) describes species of smaller Foraminifera of the Chickasawhay formation ("Lower Chickasawhay"). Their stratigraphic significance was indicated by examination of material from localities at the outcrop and by subsurface observations in the Gulf Coast.

All type specimens of two new species described are from the Chickasawhay ("Lower Chickasawhay") which are

Nodosaria blandpiedi Ellis, and Nonion struma Ellis.

(Ellis, 1939, p. 423-424.)

Subsurface Correlation: Down dip, subsurface marine strata which overlie the Vicksburg contain a fauna designated as the Hackberry assemblage. The assemblage was originally described by Garrett (1938) for a fauna especially well developed in the Hackberry field, Cameron Parish, Louisiana. Garrett (1938, p. 313) considers the Hackberry assemblage to be equivalent in part to the "Chickasawhay beds" of Hazzard. (Blandpied, et al., 1934.)

The assemblage carries species common to the Marginulina mexicana var. vaginata zone and to the Vicksburg, however, most species occurring in the assemblage are not present in the Vicksburg. (Garrett, 1938, pp. 310-311.)

The subsurface Vicksburg fauna has a large number of species which are found in the type locality of Vicksburg outcrops, thus indicating that beds containing the Hackberry assemblage are of younger age than the underlying Vicksburg. (Garrett, 1938, pp. 311, 313.)

Fisk (1940) shows in cross-sections of central Louisiana a wedge-like clay unit that he considers to be Chickasawhay (unrestricted) which overlies the uppermost appearance of Vicksburg (Oligocene) fossils. To the west in southern Allen Parish and Jefferson Davis Parish, the Chickasawhay fauna has been accurately differentiated from the underlying marine Vicksburg and is separated from the Vicksburg by a thin shale break. (Fisk, 1940,

pp. 128, 146, pl. 6.)

Local Subsurface Correlation: East and in the Herton-Thistlewaite well at Washington, Louisiana of St. Landry Parish a shale sequence above the Vicksburg contains marine lentils having a Foraminiferal assemblage considered to be of Chickasawhay age.

At Anse la Butte, south of the Port Barre field the Hackberry faunal assemblage is present close to the top of the Chickasawhay in moderate numbers and has been employed as the criterion for determining the upper limit of the formation. (Bates, 1943, p. 1139.) This fauna becomes increasingly abundant in both species and individuals with depth. Nonion lunatum, Gyroidina scalata, Pseudoglandulina comatala, Uvigerina stephensoni, and Bolivina mexicana with rare Nodosaria blanpiedi are used as index fossils. (Bates, 1943, p. 1139.)

Local Application: At Port Barre no attempt is made to establish definite limits for the Chickasawhay formation (restricted by MacNeil). Electrical log surveys show 600 to 800 feet of shale and sand bodies. The largest sand body has a thickness of approximately 225 feet and separates two other sand sections of lesser proportions. Electrical log comparisons with the one given (Bates, 1943, fig. 4) of a well at Anse la Butte show like manifestations.

The top of the Chickasawhay formation at the lowest level found at Port Barre is at 8200 feet and lies just beneath the prominent sand series of the overlying

Catahoula. (Fig. No. 5.) The formation lies against the side of the dome at approximately the 7600 contour level.

Observations of well samples from the top of the dome show Cibicides cf. americana and other forams immediately above beds containing a Jackson fauna. Sample study indicates that only traces of the Chickasawhay formation are represented on top of the dome.

## O L I G O C E N E - M I O C E N E B O U N D A R Y

The Oligocene-Miocene boundary in the United States depends upon placement of the boundary in Germany and Belgium where the Oligocene is typically developed. It depends upon the accurate correlation of the upper Oligocene and lower Miocene beds of Europe with those in North America. (Cooke, 1939, p. 1560.)

Original Designation: Beyrich's original definition in 1854 of the Oligocene included beds in Germany and Belgium that are now called Sannoisian, Rupelian and Chattian. The next younger stage is Aquitanian followed by Burdigalian and the Helvetian. Beyrich placed the Oligocene-Miocene boundary between the Chattian and the Aquitanian. (Cooke, 1939, p. 1560.)

Usage: Dall (1898 A, table facing p. 334) regarded the Aquitanian and the Burdigalian as Oligocene and drew the boundary line at the base of the Helvetian. Thus, the Aquitanian and Tampa were Oligocene. (Cooke, 1939, p. 1560)

Present usage: Woodring (1928, table facing p. 41) regards the Aquitanian and Burdigalian as lower Miocene and therefore, presumably would draw the boundary at the base of the Tampa limestone. Schenck (1935, pp. 521-536) studied the Oligocene problem in Europe and arrived at the conclusion that the Aquitanian Stage of Europe should be Oligocene. This is the current practice of the United States Geological Survey. (Cooke, 1939, p. 1561.)

Correlation: The Antigua limestone of the West Indies is classified as Oligocene because it contains a large coral fauna that Vaughan regards as of Rupelian age (European middle Oligocene division). If the correlation is correct at least part of the Antigua is middle Oligocene. (Cooke, 1939, p. 1561.)

The equivalents in the United States appear to be the Suwannee limestone (Mansfield, 1937, pp. 46-62) of Florida, the Flint River formation of Georgia and eastern Alabama, and the "Chickasawhay marl" of western Alabama and eastern Mississippi. (Cooke, 1935, pp. 1162-1172.)

The Flint River formation of Georgia and eastern Alabama, and the "Chickasawhay marl" of western Alabama and eastern Mississippi contain species of Lepidocyclina and several molluscs in common with the Antigua. The Flint River and the Chickasawhay are, therefore, classified as Oligocene by the United States Geological Survey. This reference to the Oligocene is confirmed by their stratigraphic relations because the Chickasawhay appears to be

the equivalent to the Flint River which is known to be older than the Tampa limestone. (Cooke, 1939, p. 1561.)

Westward Correlation: A contribution to the Oligocene correlation of the Chickasawhay limestone is the description of a molluscan fauna by the late W. C. Mansfield (1940, pp. 171-225.) MacNeil (1944, p. 1347) states that Mansfield's stratigraphy notes were never compiled but comments in the discussion of species show he was of the opinion that fauna from "Lower Chickasawhay" localities is similar to that of the Flint River formation and the Suwannee limestone, and that the "Lower Chickasawhay" is upper Oligocene in age.

A table of selected species from the "Lower Chickasawhay" by Mansfield (1940) shows a preponderance of species comparable with Byram (upper Vicksburg) species over those comparable with Tampa species. Two Byram species and twelve Flint River species are specifically identical to the "Lower Chickasawhay" forms. None were cited as being specifically identical to the Tampa species. (MacNeil, 1944, p. 1347.)

Some species described by Mansfield (1940) of the "Upper Chickasawhay" give strong evidence of the Tampa age. A large gastropod Ampullina (Ampullinopsis) amphora (Heilprin), apparently restricted to the "Upper Chickasawhay", has not been found to occur below the Tampa limestone in Florida. (MacNeil, 1944, p. 1347.)

MacNeil (1944, p. 1348) made collections of fossils

from the highest beds of the "Chickasawhay" in Alabama. These beds contain species which seem to correlate with the Tampa of Florida. A species different than any known from the Suwannee and the Chickasawhay limestone (as restricted) is a large Crassatella which is closely related to one of the Tampa. In addition a large Cyrena, probably Cyrena floridana Dall of the Tampa limestone is found in the highest beds heretofore referred to the Chickasawhay of Alabama. (MacNeil, 1944, p. 1348.)

Placement of Boundary: From the aspect of the Suwannee to the Tampa, apparently there is a change of fauna within the beds formerly included in the "Chickasawhay marl" (former U.S.G.S. designation of "U. & L. Chickasawhay"). Since the Tampa is considered to be basal Miocene, then the Oligocene-Miocene boundary should lie between the "Upper" and the "Lower Chickasawhay". (MacNeil, 1944, p. 1348.)

Local Application: The Oligocene-Miocene boundary is based herein according to the current practice of the United States Geological Survey in classification of the Tampa limestone as basal Miocene. Westward the boundary is placed at the top of the Chickasawhay limestone (as restricted by MacNeil, 1944, p. 1346.).

At Port Barre the Oligocene-Miocene boundary is placed at the top of the Chickasawhay formation which is in accordance with the restricted Chickasawhay of MacNeil discussed on pages 57 to 64 of this report.

## M I O C E N E

### GRAND GULF GROUP

Original Designation: Wailes, the first State Geologist of Mississippi, was the first to use the term, Grand Gulf, in the Gulf Coast. (Wailes, 1854, pp. 214-219.) He applied the name to the basal Miocene sandstone and clay exposed in a bluff on the Mississippi River at Grand Gulf, Claiborne County, Mississippi. Wailes referred to them as the "Grand Gulf sandstone". (Welch, 1942, p. 40.)

Usage: Six years later Hilgard (1860, pp. 147-154) used Grand Gulf as a group term in Mississippi and included in it almost the entire Miocene section, although he did not divide it into formations. Following Hilgard, Hopkins in 1871 used Grand Gulf group on his map of Louisiana. (Welch, 1942, p. 40.)

In 1899 Harris and Veatch also mapped the Miocene deposits as Grand Gulf. The original "Grand Gulf sandstone" was then called "typical Grand Gulf" by Dall (1898 A, opp. p. 334) and later referred to the "Grand Gulf Proper" by Harris in 1902. (Fisk, 1940, p. 141.)

Miocene terminology in Texas is more involved than either Louisiana or Mississippi. Hilgard (1871, p. 391) mapped the Grand Gulf group in Texas, but in Texas literature the term has not been retained, probably because Hilgard included older beds and later writers misused and confused the term. (Plummer, 1932, pp. 710-711.)

Mississippi Usage: The Grand Gulf was divided into four "phases" in Mississippi in 1893 by Johnson (p. 90). In ascending order they are: (1) Bayou Pierre phase (sandstone and clay), (2) Ft. Adams or Ellisville phase (sandstone and clay), (3) Hattiesburg phase (lignitic clay), (4) and Pascagoula phase (calcareous marine clay). (Welch, 1942, p. 40.)

The Mississippi Geological Survey still recognizes the Grand Gulf group. Lowe (1925, p. 73) divides it into the following formations: (1) Pascagoula clay (2) Hattiesburg clay (3) Catahoula sandstone.

Louisiana Usage: The long list of names used for the various Miocene beds of central Louisiana reflects the difficulties in attempting lithologic correlation in an area where facies change both vertically and horizontally. It also presents a complex problem as to what constitutes correct present-day usage. Names which were established early have been discarded in favor of newer names. Formational terms as discussed above have been brought in from neighboring states and used for generalized correlations across the country. (Fisk, 1940, p. 140.)

The Grand Gulf in Louisiana is divided into two formations, the Catahoula and the Fleming. The subdivision was made by Veatch in 1905. The Catahoula was described by Veatch in 1905 and used as a synonym for the "typical Grand Gulf" or the Grand Gulf Proper" for the coarser basal

deposits of typical exposures in Catahoula Parish, Louisiana. The Fleming was originally described for Texas deposits by Kennedy in 1892 (pp. 62-63), and is applied to all Miocene sediments in Louisiana above the Catahoula.

Apparently, if common Gulf Coast usage is to be accepted, the three terms deserving priority are Grand Gulf Group, Catahoula Formation, and the Fleming Formation.

The Grand Gulf Group is considered to include all sediments exposed in central Louisiana from the Vicksburg (Oligocene) to the southernmost exposures of Tertiary sediment in Rapides Parish. (Fisk, 1940, p. 143.) Since Pliocene sediments do not crop out then Grand Gulf and the Miocene series present a synonymy in both surface and subsurface usages.

Distribution: The Miocene epoch is marked by the thickest known deltaic sequence in the central Gulf Coastal Plain. (Fisk, 1944, p. 62.) It is present in the entrenched valley area of the lower Mississippi River as a wide east-west belt south of the Vicksburg group. These deposits are located on the north flank of the Gulf Coast geosyncline and dip seaward into the geosynclinal region where they reach a thickness of more than 8000 feet near the Louisiana coast. (Fisk, 1944, p. 15.) The manner in which the deltaic mass thickens indicates that at least 12,000 feet of Miocene sediments are deposited near the present gulf shore line. (Fisk, 1944, p. 62.)

Central Louisiana: Central Louisiana is on the north-

western flank of the great Miocene deltaic mass, but a thick mantling of cyclic Quaternary deposits has buried most of the older sediment. However, landward uplift accompanying seaward tilting toward Quaternary deltas has entrenched the main streams in central Louisiana. Thus, narrow belts of Miocene sediments are exposed beneath Quaternary fluviatile sequences in the valley walls. Farther south Miocene sediments are carried beneath the thickening Quaternary deposits and do not again appear. Beds exposed at the surface can rarely be followed more than a few feet. (Fisk, 1940, p. 138, 140.)

Lithology: The Grand Gulf outcrop is characterized by complexly interfingered fluviatile and brackish-water facies. This alternation makes it possible to set up local divisions, but the complexity of the interfingering relationships hinders the establishment of regional correlations. (Fisk, 1944, p. 62.)

The brackish-water sediments are thick calcareous clays and silts and are locally fossiliferous. The fluviatile deposits consist of thick lenticular sands incorporated in a thick sequence of massive silts and sandy silts which contain local tuffaceous beds (volcanic origin). (Fisk, 1944, p. 62.)

Most of the sediments are poorly indurated, but resistant beds formed by silty clays and sands, shape the topography in the Miocene terrain. (Fisk, 1940, p. 139.)

Subsurface: The Miocene series in the subsurface is a

typical deltaic mass of sands, silty sands, silts and clays. It includes wedges of marine calcareous sandstone and limestone which thin landward. (Fisk, 1944, p. 62.)

Borings in central Louisiana show lenticular sands are distributed throughout the mass of sediments and along any line down dip the sands interfinger with silty clays. In southern Rapides Parish the first marine equivalent of the nonmarine sediments are found at a depth of 3000 feet, but marine beds are not everywhere present at that depth. (Fisk, 1940, p. 139.)

Correlation: Marine beds of lower Miocene age which outcrop in eastern Mississippi and Alabama and several marine zones in the subsurface Miocene section permit regional correlation. (Fisk, 1944, p. 62.) Further discussion of correlation of the group is given later under the various formational correlative zones.

Local Application: In accordance with priority and Louisiana usage the writer is forced to assign herein all Miocene sediments to the Grand Gulf group. The group contains the Catahoula and Fleming formations and is applied to sediments at the Port Barre field overlying the Oligocene strata of the Chickasawhay formation (as restricted) and underlies sediments of probable Pliocene age.

Miocene sediments at the lowest sub-sealevel found at Port Barre has its base at 8250 feet. The top ranges from about 2250 feet to about the 1650 contour level on top of the dome. The group is approximately 6000 feet thick

at the flanks. The group has been reduced to a thickness of about 2300 feet as a result of the lower Miocene sediments having thinned over the dome. In part the lower Miocene sediments have been completely cut-out by the salt plug during its development.

### Catahoula Formation

Original designation: Probably the first note in literature concerning what is now designated as Catahoula formation in Louisiana, was made by William Dunbar (1817) in his report of 1806 to President Jefferson. In this paper he described Catahoula Shoals and the adjacent bluff on the Ouachita River. (Chawner, 1936, p. 110.)

A few years later William Darby (1816, pp. 45-46) gave a description and a discussion of the correlation of the same outcrops at Catahoula shoals. These rocks were named "Grand Gulf sandstone" by Wailes in 1854 (pp. 214-219). Between 1893 and 1902 there was considerable discussion in literature concerning the age, position and subdivision of the Grand Gulf group. (Chawner, 1936, p. 110, 111, 115.)

Restricted Designation: The term, Grand Gulf, was used with various meanings by different authors. Veatch in 1905 (p. 90) proposed the name, Catahoula formation, as a synonym for beds frequently called "typical Grand Gulf" of the "Grand Gulf proper", in order to furnish a name not likely to be misunderstood.

The name is from Catahoula Parish, Louisiana, and for the many outcrops which are lithologically and stratigraphically counterparts of beds directly across the Mississippi Valley from Grand Gulf, Mississippi where the type locality of the "Grand Gulf sandstone" is located. (Veatch, 1906A, pp. 42-43.)

Veatch (1906A, p. 42, 43) applied the Catahoula formation to a series of nonmarine greenish clays and sandstones, locally quartzitic, which were equivalent in age to the lower part of the Grand Gulf of Wailes (1854, pp. 216, 217.)

Usage: The name, Catahoula, became widely used and has appeared in the literature of the adjacent coastwise states. The lower limit of the formation has never been definitely established. The upper limit was not and cannot be established from the type locality where the beds pass beneath the Mississippi River flood plain. Lithologic correlation has not been definitely established, yet usage of the Catahoula formation has been extended into the subsurface on lithology. (Fisk, 1940, p. 141.)

In the subsurface the position of the base of the Catahoula has been shifted vertically by various authors. This is a condition that has existed because of the (1) early Miocene designation of the Catahoula and (2) the uncertainty of regional correlations concerning the age of sediments which lie above the Vicksburg fauna.

Present Usage: The Grand Gulf group is separated into the

Catahoula and Fleming formations in Louisiana. The surface Catahoula formation is representative of the oldest fluvial facies of Miocene deltaic deposition. (Fisk, 1940, p. 173.) According to Fisk (1940, p. 143) the Catahoula formation, in its present-day usage, is applied to the sandstone beds in the basal part of the deltaic mass.

Howe (1936, p. 108) considers the Catahoula formation of Louisiana and western Mississippi to be a great deltaic deposit built out into the lower Miocene "Chattahoochee" or Tampa sea. He also considers the Discorbis, Heterostegina and the Marginulina zones as coastward, down dip, marine equivalents of the Catahoula delta and that these marine beds interfinger with continental sediments irregularly within the region between the Catahoula outcrop and the coastal salt domes. (Howe, 1936, p. 108.)

Many authors have used the Catahoula to represent deltaic sedimentary facies which include in the subsurface marine tongues of the Chickasawhay (unrestricted) as well as the Discorbis, Heterostegina, and Marginulina zones. This has been the recent practice of the Louisiana Geological Survey. (Fisk, 1940, 145, 174; Howe, 1934, pp. 16-21, 1936, p. 106, 108.)

Thusly, the Catahoula has been used as a term to include only beds which are equivalent both in lithology and age to the Catahoula of the type locality. The recent work of MacNeil (1944, pp. 1352, 1353) has shown that the

"Lower Chickasawhay" is Oligocene in age and the "Upper Chickasawhay", which merges both laterally and vertically with lower beds of the Catahoula sandstone, is Miocene in age.

Hence, since the Catahoula is representative to the oldest fluvial facies of the Miocene deltaic deposition (Fisk, 1940, p. 143, 173) then, the lower limit of the Catahoula necessarily falls between the divisions of the "Upper and Lower" Chickasawhay. In accordance to foregoing discussions this line, also, marks the Oligocene-Miocene boundary, previously discussed in this report.

Surface Distribution: The Catahoula is recognized in the Gulf Coastal Plain in Texas, Louisiana, Mississippi and southern Alabama. Veatch (1906A, p. 42-43) traced beds of the Catahoula formation eastward through Mississippi into Alabama where they apparently grade into a series of fossiliferous sands and calcareous clays known as the "Chattahoochee group".

Stratigraphic workers to the east of Louisiana have concluded that the Catahoula sandstone is a continental deposit more or less contemporaneous with the "Chattahoochee", now called Tampa limestone. (Cooke and Mossom, 1928, p. 78-93.)

Outcrop: The outcrop of the Catahoula formation forms the line of hills across Louisiana, termed the Kisatchie Wold by Veatch (1906A, p. 42, 43; 1906B, p. 391.) Westward the Catahoula extends from southeast Texas across

the state into southwest Texas. (Sellards, et al., 1932, pp. 713, 714.)

In the area of northwestern Catahoula Parish the Catahoula formation is a definite stratigraphic unit and is equivalent to the basal part of the Grand Gulf group of Mississippi. The formation is divided into two local members; the Cassel Hill member at the base and the Chalk Hills member for upper Catahoula. Here the formation reaches a maximum of 350 feet. (Chawner, 1936, p. 120, 121.)

The Catahoula extends southwestward as a distinct unit, the Kisatchie Wold, from Rosefield, northwestern Catahoula, Parish to central La Salle Parish where it is exposed along a steep escarpment partly hidden by alluvial fans. (Fisk, 1938, p. 143.) The formation thins westward from 500 feet in Rapides Parish to 50 feet in Vernon Parish, Louisiana. (Welch, 1942, p. 37.)

Subsurface Accumulation: The subsurface Catahoula in Louisiana represents deltaic sedimentary facies which include tongues of marine sediments. The position of accumulation can be accurately shown from lithology indicated on electrical logs. The areas of thickest accumulation spread seaward to the southwest through Grant and La Salle Parish diagonally across Avoyelles and southeast Rapides Parish.

The fact that Catahoula sediments were laid down close to the sea is indicated by the occurrence of marine beds

of the Heterostegina zone in the upper part of the sequence. True continental sediments of massive sands which were deposited in late Catahoula time extend as far southwestward as Evangeline and St. Landry Parishes. (Fisk, 1940, p. 149, 150.)

Southwest of the outcrop in western Rapides Parish the upper Catahoula section consists of brackish-water clays of low porosity with comparatively few "blanket" sands. Only the finer sediments were deposited. This indicates that major deltaic centers lay to the southeast. (Fisk, 1940, p. 150.)

Lithology: The Catahoula formation consists of basal tuffaceous siltstones and coarse, graveliferous sands, interbedded silty clays and silts which grade upward into the overlying Fleming formations. (Fisk, 1944, p. 15.) Two mappable units are exposed in central Louisiana; a lower tuffaceous siltstone member and an upper thicker member, composed of lenticular sands, clays and silts. (Fisk, 1938, p. 145.)

In Grant, La Salle and Catahoula Parishes the massive lower member everywhere present grades downward into loose sands and lignitic clays containing large stumps and palm fronds near its base. (Fisk, 1938, p. 146.) This clay phase is 15 to 25 feet thick and contains petrified wood in Catahoula Parish and has been termed Cassel Hill member by Chawner, (1936, p. 121.).

The lower member contains a massive, blocky, tuffaceous

silt-stone. In fresh exposures it has a characteristic fine-grained, purplish, tuffaceous phase easily distinguishable from other phases of the formation. (Fisk, 1938, p. 145.)

In Grant and La Salle Parish this phase is locally interbedded with thin bedded pure tuff deposits varying from one to five feet undoubtedly similar to the famous Chalk Hills of Catahoula Parish. (Fisk, 1938, p. 145)

In Catahoula Parish it is prominently exposed in the Chalk Hills as a white or cream colored volcanic ash or tuff about eight feet thick. It is the "Chalk rock" of Hilgard and the bed which gives the Chalk Hills their name and has been termed the Chalk Hills member by Chawner. (1936, pp. 122, 123.)

Fisk's (1938, pp. 146, 147) upper member of the Catahoula formation in central Louisiana (Grant and La Salle Parishes) presents an entirely different lithologic appearance. It consists of a heterogeneous mixture of lenticular bodies of loosely compacted coarse sands, finely bedded silty clays and leaf-bearing silts. The coarse sands, more common near the base, are locally quartzitic. Detailed mapping is exceedingly difficult, since every bed, or series of beds are of local extent, and no ideal section could be constructed that would substantiate local exposures. (Fisk, 1938, p. 147.)

Subsurface Lithology: A gradation from a coarse sandy Catahoula on the surface to finer silty clays in the subsurface

presents a sequence of sands and clays that increased rapidly down dip. The scattered thick, massive sand bodies are replaced by a regular alternation of "blanket" sands, clays and shales. The high proportion of "blanket" sand beds down dip denotes deposition of a rapidly growing and active subsiding deltaic plain. (Fisk, 1940, p. 148, 149.)

Farther down dip in the Tepehate field, Acadia Parish, marine tongues incorporated in the sequence include a regular alternation of brackish-water shales and "blanket" sands, the Discorbis, Heterostegina and Marginulina zones. The Marginulina zone overlies a thick shale sequence with fewer sand bodies referred to as the Frio. West of Tepehate subsurface beds containing Chickasawhay fauna occur about 600 feet above the marine Vicksburg. (Fisk, 1940, p. 149.)

Surface Correlation: The surface Catahoula formation contains no marine fossils. Land plants are abundant and fresh water molluscs are found in several places. (Berry, 1917, p. 28; Chawner, 1936, p. 130.)

The Tampa limestone is generally regarded as the time equivalent of the Catahoula sandstone. According to Cooke and Mossom (1928, p. 78-93) this correlation has been based principally upon relative stratigraphic positions of the two formations without reliable paleontological evidence. Thus, the correlation should be regarded as only provisional.

The weakness in the correlation is chiefly due to the nature of sedimentation and stratigraphic positions of these formations. Early recognition of an unconformity, between the Vicksburg and Catahoula, has increased the difficulty in establishing correlation by means of stratigraphic positions which would not be questioned.

Unconformable Relationship: Surface studies early led Hilgard (1881), Harris and Veatch (1899) and others to the conclusion that the Catahoula lies unconformably on older sediments. Howe (1933, p. 636, 637) and other investigators consider the Catahoula lies unconformably on the Vicksburg in Louisiana and in places completely overlaps it. They consider the Vicksburg and the Catahoula different lithologically and that the units are not interbedded. The field studies of Chawner in 1936 (p. 119) bear out this opinion. Meyer (1939) on the basis of subsurface evidence expressed the same viewpoint.

The unconformable relationship between the Catahoula and the Vicksburg is considered to be regional. (1) Southwest of Derry in Natchitoches Parish, Louisiana, the Catahoula appears to rest on the Mint Spring marl member of the Marianna limestone (middle Vicksburg). (2) In Vernon Parish the Catahoula rests on Forest Hill sand (basal Vicksburg) between Hornbeck and Anacoco along Highway 171. (3) In eastern Louisiana near Rosefield, Catahoula Parish, the Catahoula formation rests on marl of the Byram. (4) In western Mississippi the Catahoula

rests variously on the Bucatunna clay and the marl members of the Byram. (MacNeil, 1944, p. 1353).

MacNeil's studies in 1944 have supported the correlation of the Catahoula to the Tampa limestone of Florida. He interprets a lateral and vertical merging of the lower beds in the Catahoula to the Paynes Hammock sand ("Upper Chickasawhay"). Here the Ostrea blanpiedi is used for correlation. The fossil is found only in the beds referred to the Paynes Hammock sand ("Upper Chickasawhay"). (MacNeil, 1944, pp. 1352, 1353.)

The Paynes Hammock overlaps the Chickasawhay limestone (restricted to "Lower Chickasawhay") in central Mississippi. Eastward the Paynes Hammock becomes equivalent to the fossiliferous Tampa limestone of Florida. (MacNeil, 1944, p. 1353.)

Subsurface correlation: Present-day usage of the term Catahoula, as presented in the foregoing discussion, is applied to all sediments overlying the Oligocene and underlying the Fleming which includes divisions known as the "Lower Catahoula" and "Marine Catahoula". These divisions are used in this report for the discussion of subsurface correlation.

The lower Catahoula (Frio): The lower Catahoula represents the interval of sediments underlying the Discorbis, Heterostegina and Marginulina zones, and overlying the Oligocene. At present, correlations indicate that the Oligocene-Miocene boundary, as used herein, lies between "Upper and Lower Chickasawhay". Thus, the lower Catahoula

is the equivalent of the "Upper Chickasawhay" or MacNeil's Paynes Hammock sand. (MacNeil, 1944, p. 1346.)

The term, Frio, was proposed by Dumble in 1894 (pp. 554-555) for the clay and sand above the Fayette sands or Jackson formation (Plummer, 1932, p. 703) and beneath the Oakville beds near the mouth of the Frio River, Live Oak County, Texas. After its introduction the term was used in many conflicting ways.

Meyer in 1939 (pp. 177, 178) conferred that definite upper or lower limits of the subsurface Frio could not be established from known data. He included sediments above the Textularia warreni beds of the Vicksburg and, in part, sediments of the Marginulina zone which had not been definitely limited.

The Frio is used in the subsurface of southern Louisiana and Texas by commercial geologists for the sparingly fossiliferous sands and shales that lie above the Vicksburg and below the fossiliferous marine shales of the Discorbis, Heterostegina and Marginulina zones. (Welch, 1942, p. 42; Beckelhymer, 1946, pp. 57, 58.)

The lower Catahoula as used in this report, apparently, is equivalent, in part, to the Frio. Also, the lower Catahoula is equivalent, in part, to the same interval referred to as beds containing species of the "Hackberry Assemblage" that is described by Garrett (1938, p. 309) as underlying the Marginulina zone and overlying the Vicksburg.

Correlation of lower Catahoula: Ellis in 1939 (p. 423) describes two species of smaller Foraminifera from the "Upper Chickasawhay" south of Waynesboro, Mississippi, from material above the bed containing Ostrea blanfordi. This fossil is used to designate Miocene beds. (MacNeil, 1944, p. 1352-1353.) The two Foraminifera are: Elphidium Rota Ellis, and Cibicides hazzardi Ellis, and are listed as diagnostic of the "Upper Chickasawhay". The types are similar to Cibicides concentricus Cushman, from the Miocene of Florida and to a form of Cibicides in the type Vicksburg. (Ellis, 1939, p. 424.)

Kornfeld (1939, p. 1836) states that Cibicides hazzardi Ellis, is a new name for "Cibicides americanus" var., and that J. B. Garrett and A. D. Ellis, Jr. are in agreement that Cibicides hazzardi is one of the most consistent horizon markers which can be used elsewhere.

In the subsurface Cibicides hazzardi is ordinarily found in the shale interval above the fourth Marginulina sand in typical Louisiana Gulf Coastal fields. (Bates, 1943, p. 1138.)

The marine Catahoula (Anahuac); Discorbis, Heterostegina, Marginulina zones: Marine sediments in the subsurface known as the Discorbis, Heterostegina and Marginulina zones were described in 1925 by Applin, Ellisor and Kniker (1925, pp. 79-122.).

Ellisor in 1944 (pp. 1367-1375) published faunal lists and plates of the more or less diagnostic species

of these zones which have been published by various authors. In the same paper she has proposed the name, Anahuac, for these zones.

Discorbis zone: The Discorbis zone is named for Discorbis vilardeboana d'Orbigny, the only Discorbis given in the original faunal list. (Howe, 1933, p. 64.) Cushman in 1927 placed this Foraminifera under the genus Valvulineria. Cushman and Ponton in 1932 (p. 88) decided that the Discorbis vilardeboana was Discorbis candeina d'Orbigny. This particular species occurs abundantly in the Tampa limestone at Falmouth Springs, Florida. (Howe, 1933, p. 641.)

Other characteristic species of the Discorbis zone are Discorbis gravelli, Discorbis subauracana, D. subauracana var. dissona, Discorbis nomada and other associates. (Ellisor, 1944, p. 1367.)

Heterostegina zone: The key fossil of this section was Heterostegina sp. identified by Cushman as Heterostegina antillea. (Ellisor, 1944, p. 1356.) In 1937 Gravell and Hanna (pp. 517-529) described a number of larger Foraminifera from this zone. Two species are Heterostegina texana and Heterostegina israelskyi. They also described Lepidocyclina colei and Lepidocyclina texana. Other characteristic fossils are listed by Ellisor (1944, p. 1367, 1368.).

Marginulina zone: Marginulina vaginata Garrett and Ellis, is the diagnostic species. Both Marginulina idio-

morpha Garrett, and Marginulina howei Garrett and Ellis, occur in this zone. There is a characteristic Uvigerina and Siphonina (not described) which occur abundantly and are used for identifying the Marginulina zone. Some species of the Heterostegina zone are present. The Marginulina texana is a Frio ("Lower Catahoula") species and is not used to identify the Marginulina zone. (Ellisor, 1944, p. 1368.)

Local Occurrence; lower Catahoula: The lower Catahoula at Port Barre corresponds to the upper part of the Frio-Marginulina sands of company reports of this field and other areas. Electrical logs depict a shale section intercalated with sand bodies. These beds of sand become more numerous and thicker with depth and are sparingly fossiliferous. The inference is that of a transgressive sea or a shifting of deltaic deposits to another area.

Electrical logs depict the lower Catahoula as having a thickness of about 725 feet between the 7500 and 8225 contour levels. The interval thins or "pinches-out" against the flank. The upper part of this section is known to occur as high as the 6150 contour level. The sediments apparently have been flexed and partly dragged upward some 1350 feet. Also the cross-sections, showing wells drilled close to the salt mass, depict the erratic appearances of sands outwardly from the flank. This implies local depositional changes or displacement contemporaneous with the uplift or development of the structure.

Cibicides hazzardi is found in the shale interval above the lower Marginulina sand at Port Barre field. The fossil is diagnostic and is used in company reports to designate the Frio in this field. It is used in this report to determine the top of the lower Catahoula which is in part the Louisiana equivalent of the Frio of Texas. Local Occurrence; The marine Catahoula (Anahuac); Discorbis, Heterostegina, Marginulina zones: Marine Catahoula at Port Barre field includes sediments which are recognized and delimited by Foraminifera contained, by the sequence in its stratification and by the characteristics of its facies. These characteristics and the structural position of the marine Catahoula to the dome provides the most prolific oil horizons in the field.

The total interval penetrated includes about 850 feet of sediments. At its lowest level the marine Catahoula occurs between the 6500 and 7350 contour levels, and flexes upward thinning to less than 250 feet in thickness near the 5200 contour level. The marine Catahoula, apparently has been flexed and partly dragged upward some 1300 feet.

Above the 5200 contour level occurs a periphereal non-productive zone where the whole section apparently is missing throughout the circumference of the dome. At the upper limit of the periphereal zone the more resistant sediments of the Heterostegina zone reappear. At higher levels sediments of all three zones of the marine Cata-

houla are included with an average thickness of about 400 feet where the formation is flexed across the top of the dome.

Local Lithology: Lithologically the top of the marine Catahoula is easily recognized by the sudden change of facies from the overlying coarse sand bodies. The sands are calcareous, micaceous, and often intercalated with shale. Electrical logs depict the whole formation as having characteristic features, making it easily recognizable and suitable for correlative purposes.

Discorbis zone: The sand phase of the Discorbis zone consists of about 40 feet of thin oil sands with thin streaks of shale. This group of sediments is generally dually completed or by-passed for the more prolific oil sands lying a few feet below in the Heterostegina zone.

Cores from wells penetrating the Discorbis zone section generally show shales with fine micaceous sandy partings that give the core bodies an appearance of stacked "poker chips". The angle of dip can be easily calculated from these cores when inclination of the borehole is known. The steepness of dip, often nearly  $60^{\circ}$  indicates the nearness of the formation to the salt mass and the existence of deformational stresses or a probable fault plane parallel to the slope of the salt.

Variations in the thickness, disappearance of sand bodies up-structure and the deformational stresses associated with this section which have been encountered

in the majority of wells renders the top of the marine Catahoula most unfavorable for contouring.

The zone is relatively unfossiliferous in this locality. Some of the Foraminifera associated with this zone at Port Barre contain Siphonina sp. (common), Nonion sp. (very rare). Globigerina sp. (rare), and Bolivina sp. (very rare). (Norton, 1951.)

Heterostegina zone: The top of the Heterostegina zone is placed at the first appearance of the Heterostegina fauna. The fauna occurs in a hard sandy shale section of about 4 feet in thickness immediately below the sandy phase of the Discorbis zone.

In the Texas Company well No. 27, a flank well, the top occurs at 6004 feet. From 6008 to 6054 feet are 46 feet of thin, sandy gray limestone and shale beds overlying 42 feet of prolific oil sand.

The Heterostegina zone as delineated in the Port Barre field (Fig. No. 5) and at its greatest depth encountered attains a thickness of approximately 350 feet between the 6600 and 6950 contour levels. The zone is flexed upward against the side of the salt mass where it has thinned to a thickness of about 182 feet between the 6004 and 6186 contour levels. The strata thins upward and is partly dragged to higher elevations. The highest occurrence of the zone generally varies from the 5200 to the 5300 contour levels.

Heterostegina limestone: The Heterostegina limestone

occurs from 100 to 350 feet below the top of the marine Catahoula in the Port Barre field. The persistency of the Heterostegina limestone and its position in relation to the top of the marine Catahoula and the productive zones offer the best datum plane for contouring in the Port Barre field. Recognition by examination of cores is unquestionable and correlations are expedited by the use of the electrical log.

The Heterostegina limestone as a unit attains a thickness of about 150 feet at the greatest depth penetrated in the field. The unit has thinned to a thickness of 78 feet in the Texas Company well No. 27. The 78 feet of limestone cored in this well ranges from 6108 to 6186 feet and is intercalated with shales and sandy shale. The limestone is hard, predominantly gray in color, contains streaks of calcite and shale, is crystalline and abundantly fossiliferous.

The Heterostegina zone contains a distinctive faunal assemblage. At the top of the Heterostegina limestone, shale streaks contain Heterostegina cf. antillea, Lepidocyclina sp. Faunal associates are Discorbis vilardebona, Bolivina cf. marginata, Nonionella sp., Quinqueloculina sp., and Textularia sp.

An abundance of Heterostegina antillea were obtained from a two foot core of sandy limestone seven feet above the base of the Heterostegina limestone unit in the Texas Company well No. 27. Associated with this diagnostic

Foraminifera were Cytherides thousaui, Discorbis vilardeboana, Amphistegina sp., Siphonina sp., and Virgulina cf. ponteri. (Calahan, 1940.)

Marginulina zone: The Marginulina zone in the Port Barre field is generally recognized by its stratigraphic position as depicted by electrical logs. At the greatest depth encountered, as delineated for the Port Barre field, the zone attains a thickness of approximately 350 feet between the 7050 and 7400 contour levels. This zone also is flexed upward and thins or "pinches-out" where it lies against the dome.

Cores containing fauna of this zone have been taken in a few wells in the field. However, studies are yet incomplete, merely for the reason that the overlying Heterostegina zone holds more interest.

The top of the zone lies immediately below about 14 feet of hard gray and white crystalline limestone beds. Sediments first encountered consist of gray sandy shale with thin sandy streaks. Associated genera present in cores are Lepidocyclina sp., Amphistegina sp., Cytherides sp. and Ostrea sp. (Calahan, 1940.)

#### Fleming Formation

Original Designation: Clays, sands and sandy clays included above the "Corrigan sandstone" (now Catahoula) and below sand deposits then referred to the "Lafayette" (Pleistocene) of eastern Texas and Louisiana were named

the, "Fleming beds," by Kennedy (1892, pp. 62-63.) Type exposures are near Fleming a station on the Missouri, Kansas and Texas railroad east of Corrigan, Polk County, Texas.

Usage: Terminology for beds overlying the Catahoula formation has been established from generalized work, and correct usage is complicated because of a duplication of terms accompanying different reports. The oldest and probably the most widely used term for these beds is "Fleming Clays". (Fisk, 1940, p. 141.)

The name, Fleming, came into general use to designate the strata in east Texas between the Catahoula and the Lissie (Pleistocene beds). The same sequence of strata in southern Texas was divided by Dumble (1894, pp. 556-559) into three formations, the Oakville, Lapara, and Lagarto. The United States Geological Survey mapped the sandy strata as the Oakville and the Lagarto. (Plummer, 1932, p. 728.)

Present Texas Usage: In Texas the name, Fleming, as a group term is preferred because of the difficulty of separating the Oakville and Lagarto beds in Texas east of the Brazos River where they grade laterally and vertically into clays. The group includes all strata above the Catahoula formation and below the sands of the Citronelle group. The names, Oakville and Lagarto, are applied preferably to formational divisions of the Fleming group. (Plummer, 1932, p. 728.)

The Oakville overlies the Catahoula unconformably and the Lagarto is overlapped unconformably by Pliocene and Pleistocene sand and gravel deposits. (Plummer, 1932, pp. 732, 742.)

The basal contact of the Oakville in places is marked by a conglomerate of rolled water-worn Cretaceous fossils and pebbles. In other places the contact is between coarse-grained sand above and greenish or yellowish white tuffaceous clay below. The top of the Lagarto is drawn at the contact of silty calcareous clays with overlying "orange" sands or with beds of gravel more or less cemented by calcareous matter. (Plummer, 1932, pp. 732, 742.)

Louisiana Usage: The term, Fleming, has remained in use for the Louisiana sediments equivalent to the Fleming group of Texas. The limits can nowhere be definitely established from the existing data, however, the term is used in Louisiana for beds overlying the Catahoula and underlying Pleistocene gravels at the surface outcrop. (Fisk, 1940, pp. 141, 143.)

The Catahoula-Fleming contact was never clearly defined by Kennedy in the original designation of the Fleming and criteria as used by later workers for locating the contact are misleading. Early workers appear to have thought of the Fleming as it was described by Veatch (1905, pp. 84-85) who divided the Grand Gulf in Vernon Parish, Louisiana. Veatch divided the Grand Gulf into the

Catahoula and Fleming clay. Since then, the location of the contact separating the two formations has been in controversy. (Welch, 1942, pp. 43, 46.)

Catahoula-Fleming contacts drawn on earlier geologic maps cross the strike in central Louisiana. The contact cannot be established at the Catahoula type locality in eastern Louisiana. There, the beds pass beneath the Mississippi River flood plain. The line of separation between the two formations is tentatively placed on beds marking the lower limit of abundant Rotalia becarii var.; lithologically, at the base of the first calcareous clay-bearing sequence. (Fisk, 1940, pp. 146-147, 173-174.)

Subsurface Usage: It has been customary in petroleum reports concerning southern Louisiana to refer to the section lying below the "Citronelle" gravels and above the Discorbis zone as Fleming or simply as Miocene. (Howe, 1936, p. 108.) The Fleming as logged in wells in southern Louisiana and Texas may also include strata of Pliocene age, however, no definite Pliocene faunal correlations have been reported. (Welch, 1942, p. 37.)

Present Louisiana Usage: In general the concept of present day usage of the term, Fleming, in Louisiana is that the name applies to all Miocene sediments above the Catahoula. The term is used in this report following Louisiana Geological Survey usage for subsurface sediments that represent the Miocene lying above the Discorbis zone and underlying the Pliocene.

Surface Distribution: The Fleming parallels the outcrop of the Catahoula. The Fleming clays form the local black belt areas in Texas and southwestern Louisiana, but the outcrop area is largely masked by Quaternary graveliferous beds. (Fisk, 1944, p. 62.) The Pascagoula and Hattiesburg of Mississippi are considered to be equivalent of the Fleming of eastern Louisiana. (Vestal, 1942, p. 17.)

The surface Fleming exposes an alternation of younger fluviatile and brackish-water facies of Miocene deltaic deposition. (Fisk, 1940, p. 173.) Although exposures are badly weathered, eroded and difficult to differentiate lithologically, Fisk (1940, pp. 140, 141, 171) subdivided the Fleming into six members as follows: (1) Blounts creek, fluviatile; (2) Castor Creek, brackish-water; (3) Williamson Creek, fluviatile; (4) Dough Hills, brackish-water; (5) Carnahan Bayou, fluviatile; (6) Lena, brackish-water.

Fisk (1940) named, mapped and described the members of the Fleming formation in Rapides Parish, central Louisiana. Welch (1942) mapped these same units in Vernon Parish of southwestern Louisiana.

Subsurface Distribution: The subsurface Fleming thickens down dip and occurs throughout the lower Gulf Coastal region. The interval represents from 5000 to 8000 feet of sediments in the region of the lower Mississippi River. The subsurface Fleming sediments are generally grouped

together and are undifferentiated. However, certain faunal horizons are used for correlative purposes. (Howe, 1936, p. 108.)

Surface Correlation: The Fleming in its present usage contains fauna which is used for the correlation of both the surface and the subsurface strata. The Fleming is considered to include all Miocene sediments containing abundant Rotalia becarii var. at its base, Potamides matsoni zone in the middle part of the section, and Rangia johnsoni marking the top of the Miocene series.

Fisk (1940, p. 174) correlates the four basal members of the Fleming of Louisiana (Lena, Carnahan Bayou, Dough Hills, and Williamson creek) as the fluviatile and brackish-water equivalents of the Oak Grove and Shoal River formations of Florida. Fisk (1940, p. 146, 147) tentatively placed the surface Fleming-Catahoula contact at the lower limit of the Rotalia becarii var. parkinsoniana which occurs in abundance in the calcareous clays of the Lena member (basal Fleming).

Potamides matsoni zone: The snail, Potamides matsoni Dall and a number of other brackish-water shells from a hand dug well southwest of Alexandria, Louisiana, were described by Dall in 1913 (pp. 225-237). He considered the zone to be merely a slightly different phase of the Miocene Pascagoula of Mississippi. Stephenson in 1935 (p. 187) pointed out that the Potamides matsoni zone lies below the Rangia johnsoni (Miocene guide fossil) and that the

Potamides matsoni, therefore, must be Miocene in age.

Dall (Deussen, 1914, pp. 72-73) obtained Potamides matsoni from an excavation in the Lagarto formation (upper Fleming of Texas) in Newton County, Texas. (Plummer, 1932, p. 748.) Fisk (1940, p. 164) called attention to the Castor Creek member (upper Fleming of central Louisiana) which is particularly interesting because the member carries the Potamides matsoni and the associated fauna of Dall's type locality.

Rangia johnsoni zone: The Pascagoula formation of Mississippi (Johnson, 1893) carries the fossil Rangia johnsoni Dall (Dall, 1898B). The fossil has been used for many years as a guide for upper Miocene deposits. The top of the Miocene series is indefinite but it is considered by Fisk (1944, p. 62) to be marked by the uppermost occurrence of Rangia johnsoni. The fossil is a brackish-water clam which occurs in the exposures of beds in southeastern Mississippi but is found only in the subsurface to the west in Louisiana.

Subsurface Correlation: Some detailed subsurface correlation has been made for the lower part of the Gulf Coastal region by Howe, McGuirt, Ellisor and others, but much remains to be done. Down dip correlation of the Fleming from the outcrop is difficult because of the type of deposits encountered and much of the section back from the coast is unfossiliferous.

Catahoula-Fleming contact: Rotalia becarii var. which

occurs in abundance in the basal beds of the Fleming outcrop in central Louisiana can be traced into the subsurface down dip where the fauna lies directly above the marine Discorbis zone. (Fisk, 1940, p. 146.) Although R. becarii is common in Recent brackish-water deposits, Fisk (1940, p. 147) considers that, there is stratigraphic significance in their abundance above the Discorbis zone and that few are found in brackish-water beds older than the Discorbis zone.

The lower limit of the Rotalia becarii was checked by H. V. Howe and several commercial paleontologists. Most of these men agreed that Rotalia becarii var. was sparingly represented in the marine Miocene sediments and occurred in greatest abundance above the Discorbis zone. From this paleontological evidence in addition to lithologic characteristics the approximate position of the Catahoula-Fleming contact has been established tentatively in the subsurface. (Fisk, 1940, p. 147.)

Down dip Subsurface Fleming Correlation: The middle Miocene of Florida is divided into the Oak Grove sand, Shoal River formation, and the Choctawhatchee formation (divided into Area zone and Yoldia zone). Cushman's and Ponton's paper (1932) contains a summary of the zonation of the Florida Miocene.

Middle Miocene sediments of Louisiana are probably not much over 2000 feet thick in the northern part of the area of southern Louisiana. They thicken rapidly and

evidence suggests that they are over 4000 feet thick in the lower part of the Mississippi delta. (Howe, 1936, p. 110; Ellisor, 1940.)

Howe's studies (1936, p. 108) show that some microfossils ranging in the Florida Miocene are most useful for recognition of the middle Miocene sediments in the region of coastal Louisiana. The Bigenerina floridana Cushman and Ponton is contained in the upper Shoal River (upper middle Miocene). Yet, the separation of the Oak Grove from the Shoal River by means of Foraminifera is difficult, even with the large faunas available at the surface. (Howe, 1936, p. 108, 110.)

Howe (1936, p. 108) states that sediments below the Bigenerina floridana zone and above the Discorbis zone of the Louisiana subsurface may correspond to the Oak Grove of Florida. Fisk (1940, p. 174) considers the basal four members of the surface Fleming (Lena, Carnahan, Dough Hills, and Williamson Creek) as the fluviatile and brackish-water equivalents of the Oak Grove and Shoal River formations of Florida; the Amhistegina and Bigenerina floridana zones of the Louisiana subsurface. (Howe and McGuirt, 1938.)

Subsurface Potamides matsoni zone: The Potamides matsoni zone is brackish-water in origin. Surface exposures of the Castor Creek member (upper Fleming) in Louisiana carry Potamides matsoni and in the subsurface occurs in beds correlated by Howe and McGuirt (1938)

with upper Shoal River beds above the Eigenerina floridana beds. (Fisk, 1940, p. 174.)

The Potamides matsoni zone can be recognized in cores, even if the snail is not present, by means of the microfauna which accompanies it. (Howe, 1936, p. 110.) Some of the most common associates of this zone are described for the southwest Louisiana subsurface by Stephenson (1935) which are: Elphidium incertum, Rotalia becarii (Linné) var. cf. tepida Cushman, Eponidella Cushman, Cytheridea locketti, Microcythere (?) moresiana, Cytheridea (?) matsoni, the latter is most common in the zone.

Electrical logs are helpful in outlining this lithologic zone as the diagnostic fossil does not occur abundantly. Potamides matsoni Dall is found only in the northern part of the Atchafalaya basin and west of the Atchafalaya River. Eastward and down dip east of the Atchafalaya River, this brackish-water zone grades into the upper part of the marine Uvigerina lirettensis zone. The Potamides matsoni zone is 500 to 600 feet in thickness. (Ellisor, 1940, p. 438.)

Stephenson in 1935 (p. 187) pointed out that the Potamides is normally encountered in wells several hundred feet below the occurrence of the Rangia johnsoni and that the Potamides matsoni zone must, therefore, be Miocene in age.

Howe (1936, p. 110) assigns the Potamides matsoni

zone to the upper Miocene. The zone in southwestern Louisiana is considered the brackish-water equivalent of the Cancellaria zone of Florida. The Cancellaria zone (divided into upper and lower members) is assigned to the lower beds of the upper Miocene portion of the Choctawhatchee formation of Florida. The Choctawhatchee formation is considered by the Florida Geological Survey to represent all of the upper Miocene and a portion of the middle Miocene. (Cushman and Ponton, 1932.)

The following Foraminifera are found associated with the Potamides matsoni zone as listed and figured by Ellisor (1940, p. 438, 464-475). Some of these Foraminifera range outside of the zone, but indicate correlation of the Potamides matsoni zone, in part, to the Shoal River of Florida. The Foraminifera listed are: Amphistegina lessoni, Bigenerina floridana, Bigenerina humblei, Cibicides concentricus, Discorbis subauracana var. dissona, Elphidium rolshauseni, Eponidella cushmani, Globigerina bulloides, Nonion pizarrense, Quinqueloculina sp., Robulus americanus, Robulus vaughani, Rotalia beccarii (Linné), Siphonina jacksonensis var. limbosa, and the Virgulina pontoni.

Subsurface Rangia johnsoni zone: It was mentioned, previously, in this report that Rangia johnsoni is a brackish-water clam which occurs in the exposures of Miocene beds in southeastern Mississippi, but is found only in the subsurface to the west in Louisiana.

Rangia microjohnsoni is the subsurface key fossil for

this zone and is considered the uppermost Miocene horizon. The fossil has not been found in outcrop samples. Rangia microjohnsoni is the form commonly called Rangia johnsoni in the subsurface of Louisiana and is named from Miorangia johnsoni, the type of the subgenus which is founded upon R. johnsoni Dall. The R. microjohnsoni differs, only, in that it is much smaller in size. The adult johnsoni usually exceeds 10 mm. and the height of the microjohnsoni rarely reaches 5 mm. The fossil is described and figured from specimens from a well in St. Mary Parish, Louisiana by Gardner (1940, p. 477).

The key fossil is found as far down in the section as the top of the Potamides matsoni and the Uvigerina lirettensis zones. The sandy shales and sands including the Rangia microjohnsoni varies in thickness up to 3000 feet in eastern province of the lower Gulf coastal region. (Ellisor, 1940, p. 438.)

Local Application: The term Fleming as used for the Port Barre field follows the present-day usage as given in the foregoing discussion. The name is applied to all sediments overlying the marine Catahoula and below the top of the Rangia johnsoni zone. The section also includes sediments containing the Potamides matsoni zone near its middle.

With care individual sands can be correlated reasonably accurately with electrical logs throughout the entire area. Various cross-sections constructed indicate that much of the Fleming below the Potamides matsoni zone has been "pinched-

out" during the development of the dome.

The top of the Fleming ranges from the 2250 contour, its lowest level on the flanks of the dome, to the 1645 contour, its highest level on top of the dome. The relief given is approximately 600 feet. Thickness of the Fleming ranges from 4350 to 4450 feet on the flanks and 1150 to 1500 feet on top of the dome. (Fig. No. 6.)

(Bigenerina floridana zone?) Sediments below the Potamides matsoni zone are stratigraphically equivalent to the Bigenerina floridana zone of the region southeast of Port Barre. The section in the Port Barre field varies in thickness from 1100 to 1300 feet at the flanks and 200 to 400 feet on top of the dome. The average loss in thickness is approximately 900 feet. (Fig. No. 6.)

In the Pan American Production No. 15, Garland well the section below the Potamides zone contains 200 and 300 feet of sand bodies separated by shale beds, approximately 30 feet in thickness. These shale beds thicken rapidly down the flanks to about 200 feet and more in thickness.

Sediments encountered consists of thick, soft, medium to coarse, porous sand bodies with shale breaks. Cuttings logged, maintain throughout the field, the abrupt appearance of coarse sand immediately below the Potamides matsoni zone. Much fragmental bituminous material and an abundance of shell fragments with Ostracodes is found within the sand bodies.

Potamides matsoni zone: Even though fragments of the

diagnostic fossil, Potamides matsoni, of this zone were observed in the Port Barre field; actual presence of the fossil was not necessary to delineate the Potamides matsoni zone. Identification of the various associates and use of the electrical logs are most helpful in correlation of this zone throughout the field.

The zone in the Port Barre field is a persistent shale section lying below the middle of the Fleming formation. The thickness varies from 650 feet on the flanks of the dome to 135 feet on top of the dome. The top ranges from the 4800 to 4600 contour levels on the flanks to the 2700 and 2500 contour levels on top of the dome.

Sediments encountered consist of a series of 10 to 20 feet of alternating sand and shale beds. The shale beds consist of loosely cemented silty clay containing shell fragments and numerous Ostracodes.

Rangia johnsoni zone: The Rangia johnsoni zone includes all Miocene sediments above the Potamides matsoni zone. The top of the zone ranges from the 2250 contour, its lowest level, to the 1645 contour, its highest level, on top of the dome. The thickness varies from 2700 feet on the flanks to 850 feet on top of the dome.

The sediments encountered contain alternating sandy shale and sand bodies above the "Miocene sand series". Thicker sand bodies and shale breaks persist in the lower part. The upper strata are medium to fine-grained, porous sand beds with intercalated sandy clay and silt, loose-

ly cemented with calcareous material. The larger sand bodies in the lower portion consist of medium to coarse sand grains that are separated by sandy to silty clay beds, loosely cemented with calcareous material and containing pyrite.

An abundance of Rangia microjohnsoni, shell fragments, Ostracodes and some fish vertebrae are found in the upper part. They range downward in the section.

"Miocene Sand Series": Electrical logs in the Port Barre field manifest a definite series of massive sand bodies separated by less massive sandy shale beds. The base lies at the top of the Chickasawhay. (Fig. No. 5.) The top lies above the Potamides matsoni zone and below the top of the Rangia johnsoni zone.

The "Upper Miocene Sand Series" has been referred to in company reports for the Port Barre field as the "Miocene Sand Series" or simply just "Miocene". This interval includes sediments that lie above the Discorbis zone to a point above the Potamides matsoni zone. The top is characteristically depicted on electrical logs in the Port Barre vicinity and is shown as a distinct transition from a sand to a shale sequence.

The entire "Miocene Sand Series" encountered at its greatest thickness penetrated is approximately 5200 feet thick. (Fig. No. 5.) The top ranges from about the 3150 contour level on the flanks to the 1900 contour level on top of the dome. (Fig. No. 6.) The relief given is

approximately 1250 feet.

### P L I O C E N E (?)

Former Surface Designations: Formations cropping out in central Louisiana and overlying the Miocene series were regarded by Veatch (1905, pp. 44-60; 1906B pp. 291-312) as Pliocene, Pleistocene and Recent in age. The deposits which Veatch regarded as Pliocene were originally termed the "Lafayette" formation by Hilgard (1891, p. 130).

Howe in 1933 (pp. 648-655), however, questioned the Pliocene age of this formation, and Chawner in 1936 (pp. 136-137) regarded it as Pleistocene. Still later, Fisk in 1938 (pp. 149-172) included the formation in a series of terraces classed as Pleistocene in age.

A report on geological investigations in the central Gulf Coastal Plain was presented by Fisk in 1944. The report represents a vast amount of work involving many drill holes. As a result of these investigations, Fisk (1944, p. 63) determined that Pliocene subsurface sediments (as delineated in his report) do not crop out.

Former Subsurface Usage: For many years the gravel-bearing beds encountered in wells, with few exceptions, were referred to the Pliocene. The formations below the gravels were included within the Fleming. (Howe, 1936, p. 111.)

Howe in 1933 (p. 647) considered a large amount of sediments underlying the gravel beds to be Pliocene in

age. He observed the Rangia cuneata in cores as much as 1000 feet below the gravels. This brackish-water clam is generally considered to indicate Pliocene or younger beds. (Howe, 1933, p. 647.)

Present Subsurface Usage: The lack of detailed paleontological information prevents any accurate separation between the Miocene and Pliocene beds. Whether the Louisiana gravel horizons are, wholly or in part, Pleistocene in age; or all Pliocene in age has not been determined paleontologically. (Howe 1933, p. 647; 1936, p. 111.)

Present-day usage of the term Pliocene, however, tentatively includes all sediments overlying the top beds containing Rangia johnsoni and underlying the chert-bearing graveliferous deposits. (Fisk, 1944, p. 63.)

Distribution: Fisk's report of 1944 (fig. 69) contains a map showing the sub-sea level contours on top of the Pliocene (?) sediments and the thickness of the Pliocene-Miocene (?) sediments in the central Gulf Coastal Plain. The subsurface section mapped include deltaic sediments over 4000 feet thick.

Lithology and Correlation: Beds included within this section are lithologically similar to the alternation of the underlying Miocene series. The Pliocene (?) deposits contain marine fossil beds in the lower Gulf Coast, but detailed paleontologic studies are absent and definite correlation has not been established. (Fisk, 1944, p. 63.)

Local Application: Usage of the term Pliocene in this

report follows that of Fisk (1944) which is given above. The Pliocene at Port Barre varies in thickness from about 1100 feet on the flanks to 750 feet on top of the dome. The top ranges from about the 1150 contour, its lowest level, to the 850 contour on top of the dome. (Fig. No. 6.) The sediments included contain medium to coarse sands, gray sandy clay, pyrite and shell fragments.

### P L E I S T O C E N E

Former Designations: At least 50 names in more than 100 articles have been applied to the Pleistocene deposits of the Gulf and Atlantic Coastal Plains. Most of the terms used by early workers for the Pleistocene deposits in Louisiana were first used in other states.

Thomas Nuttall (1821, pp. 44, 46) first described the Pleistocene deposits in Louisiana as a "ferruginous conglomerate" which he said extended for a distance of 1000 miles above Alexandria. Various other names were given to the gravel-bearing deposits such as "Ferruginous Sand" (Morton, 1833), "Orange Sand" (Safford, 1856), the "Drift" and "Prairie diluvium" (Hopkins, 1870, 1872).

Former "Theories" on Accumulation: Provisional conjectures as to the reasons or relationships of the Pleistocene deposits are almost as numerous as the names applied to them. The most interesting of these hypotheses are: "fluvio-glacial" (Tuomey, 1848, pp. 51-52), "eolian" (Wailles, 1854, p. 213), "Noachian deluge"

(Wailles, 1854, p. 245), "melt water" (Hilgard, 1860, p. 28), "glacier and iceberg" (Hilgard, 1866, pp. 343-357), and "arctic current" (Hopkins, 1870, pp. 858-890 b.p.).

Present Theory: The present interglacial-fluviatile-uplift theory was first presented by Fisk in 1938. This theory advanced for the explanation of the Pleistocene deposits in the Gulf Coast has been preceded by contributions from various authors which are, more or less, similar. Hypotheses have been advanced by Shattuck (1906, pp. 79-110), Matson (1916), Weeks (1933), and Doering (1935). Barton (1930, pp. 381-382) made an important contribution when he demonstrated by means of soil maps that the broad coastwise surfaces were deltaic plains built of coalescing river deltas. The significance or the detail involved in the terrace deposits, however, was not shown by these men.

As a result of much detail study in central Louisiana, Grant and La Salle Parishes, Fisk advanced the interglacial-fluvistile-uplift theory in 1938. The theory is regarded as being the most consistent with known facts. (Fisk, 1938, 1939, 1940, 1944; Huner, 1939; Frink, 1941; Welch, 1942.)

Present Louisiana Usage: The term Pleistocene as now used in Louisiana Geological Survey Literature includes the graveliferous deposits or terraces which lie unconformably upon older Tertiary deposits at the surface and

underlie the Recent alluvium. (Fisk, 1938; Huner, 1939; Welch, 1942; etc.) These gravel-bearing beds are considered to have been deposited during interglacial periods and are divided into four formations; the Williana, Bentley, Montgomery and Prairie. (Fisk, 1938; 1940, p. 175.)

Subsurface: Pleistocene subsurface sediments were separated by Frink in 1941. The correlations are difficult, however, and the series, generally, is not differentiated.

The base of the Pleistocene is placed at the lowest occurrence of gravel-bearing beds. (Frink, 1941, Fisk, 1944.) The top of the series is mapped by oxidized deposits at the upper surface of the Prairie formation, the youngest Pleistocene unit. The Prairie is downwarped beneath the Recent alluvium of the deltaic plain and can be traced seaward from the uplands by means of borings. (Fisk, 1944, p. 15.)

Distribution: The distribution of Pleistocene deposition is mapped in Louisiana. Maps may be found in Fisk's reports. (Fisk, 1939, figs. 3-7; 1944, fig. 5.) A generalized surface and subsurface distribution of the Quaternary deposits in the central Gulf Coastal Plain is shown in Fisk's report of (1944, fig. 70.)

Terraces were traced inland to the head of the Mississippi Embayment by H. N. Fisk and R. J. Russell. They established a direct correlation with the Louisiana deposits over a long distance. (Fisk, 1944, p. 63.)

The older fluvial formations have been uplifted

to form terraces in the uplands. Each fluviatile sequence thickens seaward in the coastwise plains and is down-warped into the subsurface. Each sequence merges with a thick subsurface deltaic complex which attains a thickness of more than 4000 feet in the lower delta region. (Fisk, 1944, p. 15.)

Only the Prairie formation, the youngest sequence, is present on the entrenched valley floor. The Prairie formation is distributed as a low coastwise terrace throughout southern Louisiana. This formation geographically is the most southern unit in the regressive overlap sequence. Its hinge point of downwarping, beneath the Recent alluvium, occurs farther basinward than any of the hinge points of the older formations. (Fisk, 1938, fig. 4, p. 68; 1939, fig. 4, p. 192; 1944, p. 15.)

General Lithology: The Pleistocene terraces were named the Williana, Bentley, Montgomery, and Prairie (from oldest to youngest). They were later raised to the rank of formations. Their type sections are located in Grant and La Salle Parishes (central Louisiana). A description of each formation is given in Fisk's reports. (Fisk, 1938, 155-166; 1940, 175.)

In general each formation exhibits 3 phases; (1) the coarse phase, a basal gravel and coarse sand facies; (2) the sandy phase, a predominantly sand facies; (3) the silty clay phase, containing silts and clay facies. Each fluviatile terrace deposit dips southward and merges

with thick subsurface deltaic prisms. The sequence of sediments in the deltaic deposits is similar to that of their thinner fluvial extensions. (Fisk, 1944, pp. 15, 63.)

Age: The Pleistocene age assigned to these terraces is based fundamentally, upon the special conditions of sedimentation. Eustatic changes in ocean levels during the Pleistocene glacial period seems to be the most likely explanation for the terraces. The depositional stages of the terrace sequence appear to be correlated with interglacial stages, the valley cutting stages with glacial advance. (Fisk, 1938, pp. 69, 170, 171.)

Five cycles (each an alternation of erosion and deposition) after each glacial period may be accounted for by the eustatic changes in ocean level. The eustatic changes in ocean level, possibly are attributed to volumes of water taken from the oceans to make up the glaciers and the subsequent return of water to the oceans when glaciers melted. This accounts satisfactorily for the repetition of cycles. (Fisk, 1938, pp. 67, 69, 75, 170, 171.)

Oscillations of this type have not characterized the Tertiary Gulf Coast history as it is now interpreted and seemingly require such special conditions as are evidenced by Pleistocene glacial history. (Fisk, 1938, p. 75.)

Correlation: Correlation of the Pleistocene sediments in the Gulf Coastal region is paleontologically insecure at the present time. Projection of terrace profiles first

applied to the Pleistocene sediments of Louisiana by Fisk in 1938, appears to be one of the most important principles as a tool for correlation of the terraces. Subsequent work by himself and others has demonstrated its practical application in all cases.

Fauna: Marine fauna have been recorded to the south near the surface on the eastern side of the Mississippi and to the west. (Bridges, 1939; Richards, 1938, 1939.) Borings at New Orleans show that marine sands contain an abundance of fossils. (Hilgard, 1856.) Marine fauna at the surface in central Louisiana have not been reported.

Precepts: Formerly, most writers have attempted wide spread generalizations, emphasizing correlation on the basis of materials underlying the terraces, rather than on the definite topographic or physiographic position of terrace slopes. (Fisk, 1938, p. 72.) The precept of three-dimensional-information was applied successfully to the studies of Pleistocene terraces in central Louisiana by Fisk. (1938, p. 183.).

Principle of Correlation: From his terrace studies Fisk then applied the most important principle that has been used in the correlation of the Gulf Coastal Pleistocene deposits. The principle is, essentially, as follows: that projection of the profiles of each terrace surface may prove a satisfactory means of correlating the different surfaces. (Fisk, 1938, p. 73; fig. 4, p. 68.)

Evidences and Results in Favor of the Principle: As a

result of detailed studies of the terraces in Grant and La Salle Parishes (central Louisiana) Fisk found that deposition predominated over erosion during interglacial periods. He determined that the depositional sequence of each inter-glacial period remained as terraces because of an uplift and erosion subsequent to each depositional period. Thus, each of the older terraces would remain as depositional remnants. The gradients of the older terrace surfaces which are successively steeper landward (youngest to the oldest) is the evidence offered to indicate that there had been uplift. In addition evidence of intervening scarps of Tertiary material between terrace deposits suggest that each terrace was uplifted separately. (Fisk, 1938, p. 75; fig. 4, p. 68.)

By the use of the principle of projection and computation Fisk (1938, 1939, 1940, 1944) and others (Welch, 1942; Huner, 1939) have demonstrated that the Pleistocene terraces slope coastward and that tilting has given to each terrace a different angle of slope. Gulfward each terrace eventually becomes buried beneath the dip of the next succeeding terrace. In the subsurface they merge with thick deltaic prisms underlying the coastwise plain. (Fisk, 1944, p. 15, 63.)

Local Application: The Pleistocene in this report follows the Louisiana Geological Survey usage as given in the foregoing discussion.

The Pleistocene in Port Barre field contains about

1000 feet of graveliferous, sand and clay deposits which underlie about 150 feet of Recent Alluvium. No differentiation of the Pleistocene has been attempted.

Characteristics of the graveliferous beds are recognizable on electrical logs, but few surveys have included these sediments. A study of closely spaced samples of cuttings reveals that gravel beds contain pebbles with an average size of about 3/4 inch in length. These are well polished and some are quartz, quartzites, novaculites and oölitic pebbles. Their color varies and the pebbles may be brown, tan, gray or white. Often one color or kind of pebble predominates within different horizons. In the lower part of the section, well polished gray oölitic pebbles are found in abundance. Ostracodes and shell fragments are found in the silty clay phases in nearly every case.

#### RECENT

Usage: The Recent depositional stage still in progress represents the youngest cycle of the five interglacial periods. A slight readvance of the ice, as a fifth glacial stage, is indicated in the entrenchment of the streams to comparatively shallow depths in central Louisiana.

(Fisk, 1938, pp. 67, 69, 172.)

Distribution: Recent alluvium, except for deposits which occur along most smaller streams, cover nearly all of the Mississippi alluvial valley. (Fisk, 1944, fig. 1.) The Recent deposits attain a thickness of over 350 feet in the latitude of Houma, Louisiana. They thicken at an un-

known rate southward. (Fisk, 1944, p. 63.)

General Lithology: The alluvium is lithologically similar to the Pleistocene terrace formations and is considered to have been deposited under the changing conditions of the latest epoch of the glacial age. The various phases of deposition may be observed. Gravels are found at the mouths of the tributary streams. Lenticular silty clays of the natural levees merge with the fine clay deposits in the backwater areas. (Fisk, 1938, p. 172; 1944, p. 63.)

Local Occurrence: Recent alluvium in the Port Barre field is mostly natural levee deposits of Bayou Courtableau characteristic of Mississippi River alluvial sediments. The alluvium is approximately 140 feet thick and consists of light, gray sandy to silty micaceous clay with traces of lignitic material.

#### CAP ROCK AND SALT AT PORT BARRE

Anhydrite cap rock is formed by the accumulation of water-insoluble residues of the salt. Formation in this manner accounts for the great irregularity in the development of cap rock. (Taylor, 1938, p. 93.) Subsequent remineralization in varying degrees resulting from various conditions is more or less common to all cap rocks. Succession of the characteristic assemblages of minerals, most often encountered in cap rock, from the salt contact upward, is anhydrite, gypsum and calcite. They occur in zones of varying thicknesses and degrees of consolidation and transition. (Taylor, 1938, p. 60.)

A complete study for zonation of the cap rock at Port Barre is not possible at present with the information available. However, numerous logs of wells drilled on top of the dome record "cap rock" varying from 30 to 200 feet in thickness. "Top of the cap rock" is often estimated because of the "false cap rock" which grades into it, and because of the "broken" or brecciated condition of the cap rock itself. From available data, it appears that the cap rock attains a much greater thickness at the edges of the dome than toward the center. In some cases the "cap rock", as logged, corresponds to the "false cap rock" or calcite zone of other domes (described by Taylor in 1938, pp. 24, 51, 78, 80) in which calcification extends upward into sediments immediately overlying the cap rock or salt wherever cap rock is absent.

Cap rock as manifested in electrical logs shows a medium amount of self-potential and high resistivity which resembles characteristics normally shown by oil-bearing stratum. However, core studies are essential to ascertain the existence and true nature of the cap rock. Some electric logs available show the probable anhydrite cap rock with a thickness of 30 feet at Port Barre.

Norton (1931) reported "limestone" cap rock in the Texas Company No. 10 Botany Bay Lumber Company well at 4090 feet or 70 feet above the salt. No anhydrite was noted. Gulf Refining Company reported one foot of anhy-

drinite at 5123 feet in contact with the salt in their No. 17, Wilson-Cochran well.

In the The Texas Company No. 10 well, eight feet of core at 3982 feet shows cryptocrystalline limestone containing large white irregularly shaped nodules. Powdered or brecciated limestone with some green calcareous clayey shale was present immediately below this limestone. Twenty-three feet of dark gray, hard crystalline limestone having a granular appearance was cored at 4004 feet.

From 4090 to 4121 feet white hard finely crystalline limestone contained a considerable amount of black hard cryptocrystalline limestone. Thin veins of calcite crystals were present.

The core from 4121 to 4123 feet showed dark gray to black soft brecciated material. It consisted of irregular limestone fragments with coarse and fine quartz grains cemented with black and calcareous material.

Ten feet of core from 4152 to 4162 feet has white crystalline limestone containing thin seams of pyrite and some light brown fairly large calcite crystals. It also includes dark gray to black hard brecciated material consisting of limestone fragments and sand grains. Secondary calcite was present in thin layers. (Norton, 1931.)

These studies and other data from well logs show that a great deal more mineralization has taken place on the edge of the dome than towards the center. Although anhydrite was absent in the Texas Company No. 10 well, it

does not follow that anhydrite is completely absent on top of the dome. In some cases where it is not reported, exploration or examination of cores probably has not been complete.

Probability of the absence of the cap rock in part at Port Barre may be due to one or more reasons comparable to reasons given by Taylor (1938, p. 94) for the absence of cap rock on shallow domes. He proposed that (1) solution of the salt mass took place at or near the surface, with the immediate removal of water-insoluble residual material, (2) or erosion of the cap rock occurred subsequent to its formation, (3) or the cap rock which was formed prior to upthrust of the salt plug was left behind.

#### PRODUCING SANDS

Production at Port Barre has been obtained from sand bodies ranging in age from Fleming to Cockfield, inclusive. The width of the surface area directly over each producing sand on the flanks is narrow. The area is limited by the high angle of dip and peripheral faulting. Most of the production on top of the dome is from sands within the Catahoula and from sands underlying shales containing a Jackson fauna. Production limits are associated to structural conditions and are reflected in the Heterostegina limestone. (Fig. No. 8)

Oil from the sands on top of the dome occur at depths varying from 3100 feet to 3800 feet and has a gravity of 21° to 23° A.P.I. A few shallow wells on the flanks were

first completed for natural gas production near the top of the Fleming. They later produced oil with a low A.P.I. gravity.

The Discorbis zone on the flanks consists of shale with thin sand bodies and is often saturated with oil. The erratic conditions of the oil-bearing sands and shale has not been too favorable as a producing horizon. The zone is often disregarded or dually completed with the prolific sands of the underlying Heterostegina zone.

First appearance of the Heterostegina sands on the flanks vary from about 4600 feet downward. The producing sand is soft and medium grained with a porosity of about 30 percent and 18 percent saturation. The oil obtained from this horizon has a gravity of about 36° A.P.I. The "Marginulina-Frio" sands are first encountered at about 5400 feet and constitute one of the most prolific producing horizons in the field. The oil has a gravity of about 37° A.P.I.

Near the end of 1944 new producing sands were encountered in deep wells on the northeastern and southwestern flanks. Further development extended the field to the southeast in the early part of 1946. The upper producing horizon encountered is apparently of Chickasawhay age. The deeper horizon is apparently the Cockfield. Until 1947 no production has been encountered below the Cockfield.

## STRUCTURE

To give a clearer picture of the structural conditions encountered at Port Barre two maps have been prepared. One of these has contour intervals of 100 and 500 feet showing the configuration of the salt mass. (Fig. No. 7.) The other map (Fig. No. 8) has similar contour intervals and shows the structure of the Heterostegina limestone.

Shape of Salt Mass: As shown in Fig. No. 7 the salt mass is hexagonal to elliptical in outline with the elongated axis trending northwest and southeast. Oligocene and upper Eocene limestone beds appear to have controlled the shape of the mass well down its flanks.

The top of the dome is relatively flat and has rounded steeply sloping sides at the periphery. Two prominences are on the southwestern edge which apparently resulted from the weakness of the overlying thin cap and accompanying faults in the strata above. Contours on top are irregular giving a general average slope of 10 feet per hundred feet in directions radial from the center. The highest part of the salt mass rises within 3642 feet of the surface.

Maps and numerous cross-sections made by the writer show that the sides of the salt mass become increasingly steeper with depth. The vertical intervals before each increase in slope are about 1300 feet. The levels at which these changes occur are in apposition to the more resistant beds penetrated by the salt. Apparently, the configura-

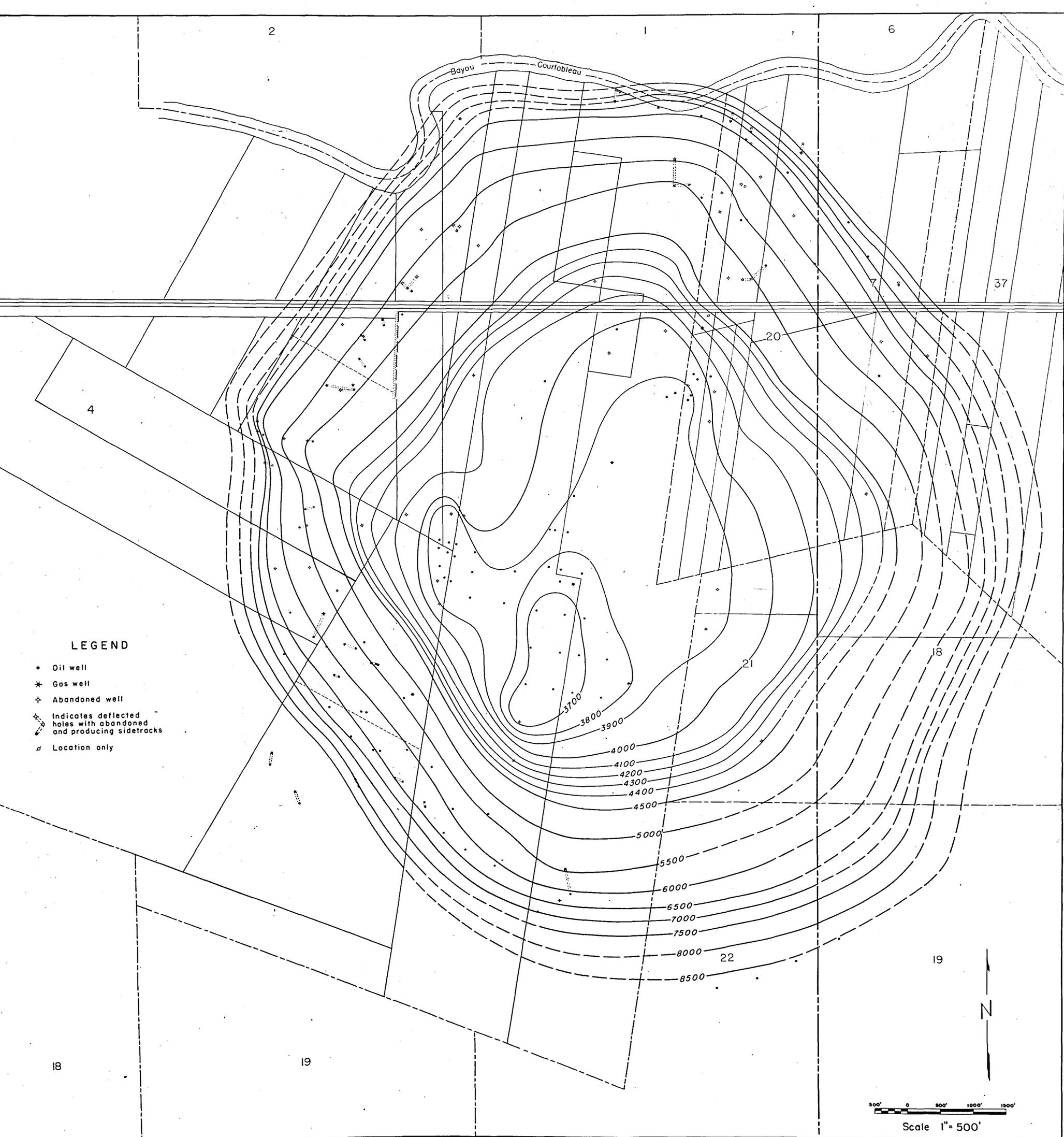


Fig. No. 7 - Contours on top of salt (100' & 500' intervals)

tion that the salt mass attained during its upward movement is influenced by the resistance of the strata encountered.

The salt surface slopes abruptly from the 4100 contour to its 5300 contour level at 85 feet per hundred feet, approximating a dip of  $40^{\circ}$ . Below the 5300 contour level to the 6500 contour level, the dip increases from  $48^{\circ}$  to  $56^{\circ}$  or 110 to 150 feet per hundred feet. The salt mass retains a flat hexagonal shape down to the 6500 contour level. Below this level a more elliptical shape is attained. From the 6500 contour level to the 8000 contour level, the slope increases uniformly around the dome to 168 feet per hundred feet or a  $60^{\circ}$  dip. A few wells were drilled into the salt below 8000 feet.

Structure of Overlying Sediments: Contours on top of the Heterostegina limestone (Fig. No. 8) show close relationship to the configuration of the salt mass. Attention is drawn to the flanks which are remarkably flat with a regular dip showing that the face closely approximates a plane. The plane surfaces are reflected well up into the overlying beds. Two, and in some cases, three, plane surfaces are apparent along the flanks.

Dips of strata from cross-sections at various places around the dome were studied. In the deep wells dips of the overlying strata as given by dip-meter surveys are harmonious to the attitude of the slope on the salt mass.

The peripheral levels at which the salt slope changes



occur affect the limits of production and show that disturbances in the overlying beds are adjusted to the shape of the salt mass. Nearly all flank production is trapped in sands that conform to these plane surfaces.

Deviations of Bore-holes: Many wells in the Port Barre field have been side-tracked. Contouring and determinations of faulting must be adjusted to the deviations of bore-holes in order to maintain reasonable accuracy.

The writer had many directional surveys of recent flank wells and study of them reveals a great deal of variation in the inclination of the well-bore from the vertical. It was observed that deviation followed the usually expected trend, that is, up dip when strata has a dip of less than  $45^{\circ}$ , down dip when greater than  $45^{\circ}$ , and transversally when dips approached  $45^{\circ}$ .

Known deviations are plotted on the maps and datum points were adjusted to others. In dealing with dips as steep as those found at Port Barre deviations from the vertical were generally down dip. Deviation, in most cases, began when the bit encountered the more resistant and steeper dipping beds of the marine Catahoula.

Faulting: There is much faulting on the flanks of the dome. Electrical logs have revealed the presence of major faults and innumerable minor faults. Faults are difficult to identify and to map. Only approximate values can be given for displacements because of the inconstancy of stratigraphic intervals and the lateral variation in sand con-

ditions within short distances. Faults were necessarily traced in most cases by three-point problems.

The Heterostegina limestone is used as a datum plane for contouring in the Fort Barre field. It is easily correlated and a larger number of wells in the field reaching the Heterostegina limestone allows better control in contouring than any other horizon.

Major Faults: Major faults are shown on the contour map of the "Het" limestone (Fig. No. 8). The means employed for representation of some faults is by the use of two parallel lines within which the Heterostegina limestone is generally missing. The scaled distance between two limiting lines is approximately equal to the displacement. With increase in the angle of dip, the width of the fault zone decreases. The faults are normal and vary between  $50^{\circ}$  to nearly vertical in dip.

A great amount of disturbance occurs at the periphery where the beds have been truncated delimiting producing sands. Several flank wells with one or more side-tracks were drilled at this delimiting level. A study of these bore-holes clearly show the complete disappearance or appearance of major sand bodies within a few feet. In figure No. 8, a "pinch-out" line has been drawn, showing the approximate position of the Heterostegina limestone around the flanks.

Minor Faults: Small faults have divided larger flanking areas into small units, particularly, near wells of Gulf

Refining Company No. 16, Wilson-Cochran; Pan American Production Company No. 7, Cormier and Pan American Production Company No. 1 and 2, Watkins. Most of the minor faults are radial and have throws of 50 to 60 feet, 80 to 90 feet, and 120 to 135 feet. They are apparently adjustments in the strata caused by the failure of larger faults to absorb all the deformational stresses resulting from the intrusion of the salt mass. The accumulation of oil seems to be controlled to a considerable extent by this radial faulting, in that, certain blocks are highly productive and others are barren.

A net-work of many minor faults exist in strata near the salt mass, particularly in the Marine Catahoula. Such conditions exist on the flanks around wells of Pan American Production Company No. 1 and 2, Watkins and wells on top of the dome. In most cases they had to be ignored because of the extreme difficulty of tracing them with any assurance of accuracy or separate identification.

#### STRUCTURAL HISTORY

Structural and sedimentary history of the salt dome was gained by a careful study of numerous cross-sections prepared by the writer. In preparation of the sections, it was found that with care, correlations of individual sand bodies of the "Miocene Sand Series" in the flank wells, could be made in radial directions. Electrical log correlations in directions laterally to the dome on the flanks were more easily done. However, sedimentary

changes manifested by changes in the electrical log self-potential occurred abruptly upon rounding the dome. The electrical logs, also, have strikingly different appearances for each flank in their manifestations of the sediment encountered.

Erosion and deformation characterize the large mass of older beds carried upward on top of the Port Barre salt plug. These older beds (M. Catahoula-Jackson) are in juxtaposition to upper Miocene sand and shale deposits. The maximum thickness attained is approximately 650 feet. The Jackson is the oldest known formation top of the dome.

Erosion, possibly, superceded Jackson deposition and was contemporaneous to deposition of overlying sediments and the upward growth of the salt mass. Outwardly, from the periphery of the dome the appearance of additional sand bodies at the top and bottom of the "upper Miocene Sand Series" suggest that sedimentation occurred contemporaneously with the upward movement of the salt mass. The older beds (marine Catahoula-Jackson) probably were carried upward on top of the dome contemporaneously to deltaic deposition and until the retreat of the late Miocene seas.

The marine Catahoula on top of the dome was carried upward from its regional level about 2600 feet, about 1300 feet above its highest position around the flank. The weight of rapidly deposited deltaic sediments of the upper Miocene, apparently, in part, halted its upward movement.

Evidence from dip-meter surveys indicate that the upper

Miocene sand and shale beds at the flanks have relatively slight dips that increase only in the proximity of the dome. Cross-sections of flank wells show that sand and shale bodies above the marine Catahoula "pinch-out" against the marine Catahoula in a transgressive overlapping manner.

The thinning of the highest sediments over the top of the dome and their relatively small amount of dip is shown in dip-meter surveys and cross-sections. Appearance and disappearance of sand and shale bodies in the Miocene sand series was noted in cross-sections radial to the structure. These evidences indicate truncation or secondary deposition contemporaneously to regional sedimentation with the upward movement of the salt mass.

In the Texas Company No. 10, Botany Bay Lumber Company well Jackson fauna were identified in 80 feet of shale and limestone beds. (Norton, 1931.) The top at 3902 feet is 260 feet above the top of the salt. Core examination and microfaunal evidence indicate that 250 feet of shale and limestone, apparently all marine Catahoula, is superimposed unconformably on the Jackson sediments. The deepest flank well penetrated nearly 2850 feet of sediments from the top of the marine Catahoula to the top of the Jackson. (Fig. No. 6.)

Mathematically a loss of about 2600 feet of sediments between the top of the marine Catahoula and the base of the Jackson can be established by comparing the thickness encountered on top of the dome and at the flanks.

The loss may be due to the less competent sediments being "pinched-out" and compacted or the sediments were never laid down or they were eroded.

In accordance with the above it appears that growth of the salt plug was temporarily arrested at intervals of approximately 1300 feet when the salt mass encountered more competent beds. Thus, the salt was more or less confined by the resistance and weight of blocks of more competent beds lying against the dome.

The writer concludes that the growth of the salt plug, seemingly, was accelerated whenever it broke through the more competent beds. The apparent periodicity of the accelerated growth of the salt plug appears to be contemporaneous to the influx of rapidly deposited deltaic masses or less competent beds.

#### CONCLUSIONS

The subsurface structure of the Port Barre field is that of a relatively shallow piercement-type salt dome. It appears that the location of the salt dome was determined, primarily, by the zone of weakness produced by two intersecting faults which are related to the regional subsurface faulting of the Red River fault zone.

The configuration of the salt plug has been influenced by the marine Catahoula and Jackson beds at the time when these beds were upwarped and punctured by the salt mass. A mass of marine Catahoula-Jackson beds have been carried upward on top of the dome.

The growth of the salt mass upwarped the resistant beds. Functuring occurred and the salt mass moved upward more rapidly through the less competent beds and was confined to less space. A measurable difference in slope on the salt surface became apparent at the flanks. In each case the slope change was in apposition to the more resistant beds. The latest upward movement is apparent on top of the dome where the salt mass has forced the overlying displaced marine Catahoula-Jackson beds upward into two prominences.

The more resistant beds are flexed upward and lie against the salt dome. They produce plane surfaces upon the face of the salt mass which are reflected into overlying sediments producing plane surfaces that are harmonious to the attitude of the salt slope surfaces. Major faulting radial to the dome delineate the blocks of strata lying against the dome and produce a hexagonal to elliptical shape to the dome. Productive zones are generally associated only with larger blocks which give the effect of steeply tilted grabens. These blocks are associated with faults lateral to the dome which occur in juxtaposition to the salt slope changes and delimit productive zones.

A banded non-productive area on the surface circumscribes the dome and delineates a zone in the subsurface where productive sands have been "pinched-out" and are absent. Strata older than lower Catahoula which have been upwarped against the dome contain production zones on

the southeastern, southwestern and the northeastern sides of the dome. The remaining flank areas should also be productive at these depths.

Areas adjacent to the larger radial faults are dissected with lesser faults which have produced smaller blocks of strata. Some of these smaller blocks contain productive sands. Relatively minor faults on top of the dome are parallel to each other and appear to be associated with a regional system of parallel north-south faulting.

Careful study of aerial photographs show various physiographic features which furnish surface indications of deeper faulting and adjustments to the subsurface structure. Use of surface leads which can be traced more accurately by careful sampling and study of shallow bore-holes would permit more accurate delineation of faulted areas.

Faulting in the subsurface has affected the course of Bayou Courtableau on the northern side of the dome. Small lakes at the edge of the dome, termed fissure lakes, are present on the eastern side of the dome. One of these lakes is associated with deeper radial faulting as observed by subsurface data. The surface lead extends outwardly from the dome and indicates that deeper faulting has influenced the course of Bayou Courtableau. The other fissure lake and additional surface indications of fault-line drainage permits the writer to outline a possible fault block area favorable for future production drill-tests. (Fig. No. 8.)

Erosion appears to be contemporaneous to the upward development of the salt dome. Differences of the thickness from the top of the marine Catahoula to the base of the Jackson as observed on top of the dome and at the flanks indicate erosion contemporaneous to uplift. The above conditions for local or secondary sedimentation are conducive to sedimentary traps adjacent to the dome which may be productive.

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