

MISSISSIPPI STATE GEOLOGICAL SURVEY

WILLIAM CLIFFORD MORSE, Ph.D.
Director



BULLETIN 82

SEDIMENTS OF MISSISSIPPI SOUND AND INSHORE WATERS

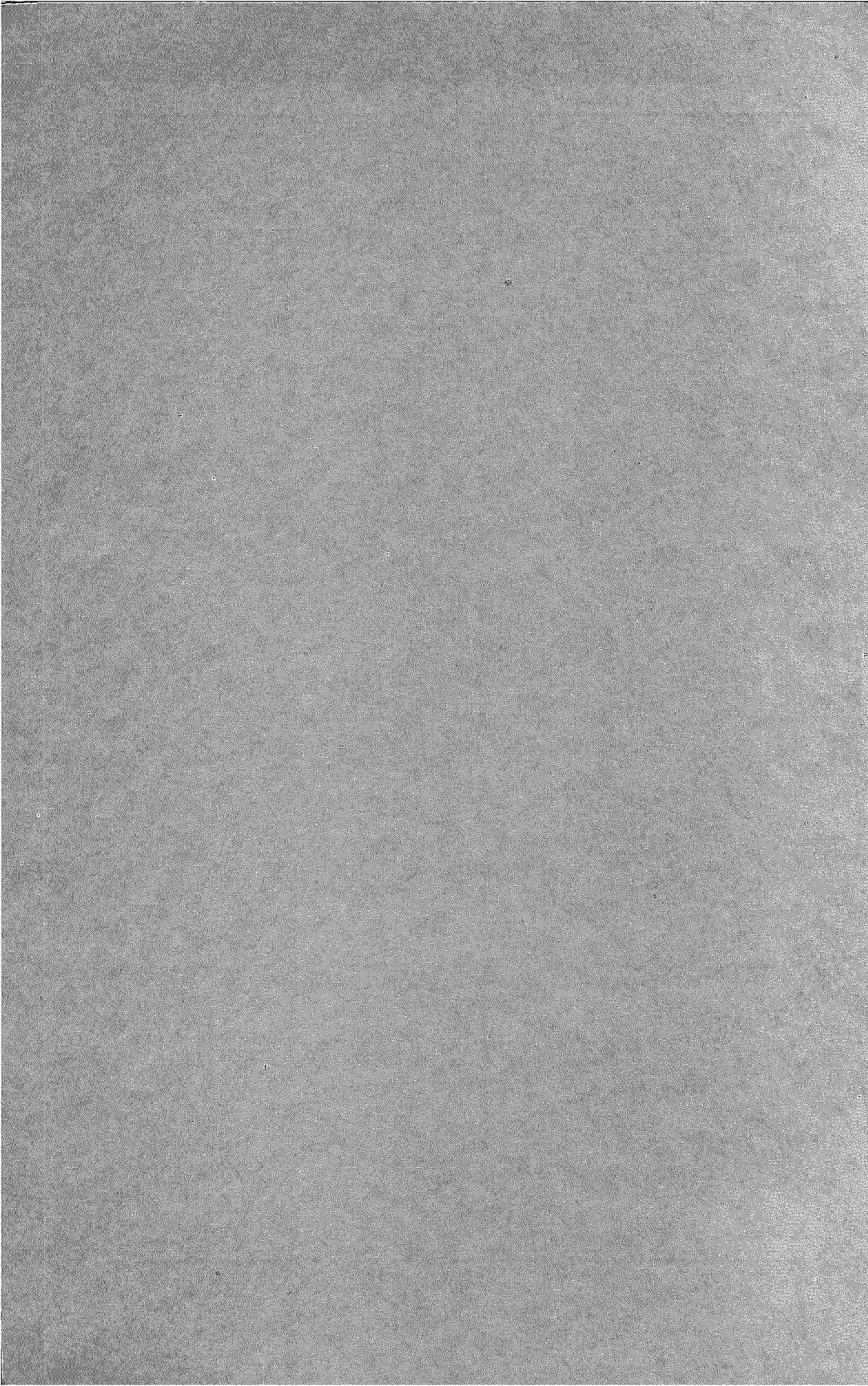
by

RICHARD RANDALL PRIDY, Ph.D., ROBERT MALCOLM CRISLER, JR., M.S.,
CLARENCE PAUL SEBREN, B.S., JAMES DAVID POWELL, M.S.,
HUGH BURFORD, B.S.

A CUMULATIVE REPORT OF SUMMER INVESTIGATIONS,
1952, 1953, 1954

UNIVERSITY, MISSISSIPPI

1955



MISSISSIPPI
STATE GEOLOGICAL SURVEY

WILLIAM CLIFFORD MORSE, Ph.D.
Director



BULLETIN 82

SEDIMENTS OF MISSISSIPPI SOUND AND
INSHORE WATERS

by

RICHARD RANDALL PRIDDY, Ph.D., ROBERT MALCOLM CRISLER, JR., M.S.,
CLARENCE PAUL SEBREN, B.S., JAMES DAVID POWELL, M.S.,
HUGH BURFORD, B.S.

A CUMULATIVE REPORT OF SUMMER INVESTIGATIONS,
1952, 1953, 1954

UNIVERSITY, MISSISSIPPI
1955

MISSISSIPPI GEOLOGICAL SURVEY
COMMISSION

His Excellency Hugh Lawson White.....Governor
Hon. Jackson McWhirter Tubb.....State Superintendent of Education
Hon. John Davis Williams.....Chancellor, University of Mississippi
Hon. Ben F. Hilburn.....President, Mississippi State College
Hon. William David McCain.....Director, Dept. of Archives and History

STAFF

William Clifford Morse, Ph.D.....Director and State Geologist
Franklin Earl Vestal, M.S.....Geologist
Tracy Wallace Lusk, M.S.....Assistant State Geologist
James M. Faulkner, B.A.....Assistant Geologist-Pilot
Richard J. Hughes, Jr., M.S.....Assistant Geologist
Katherine F. Warren, M.A.....Librarian
Louise Womack Hughes, B.S.....Secretary
Margaret M. Jones, M.S.....Secretary

LETTER OF TRANSMITTAL

Office of the Mississippi Geological Survey
University, Mississippi
April 15, 1955

To His Excellency,
Governor Hugh Lawson White, Chairman, and
Members of the Geological Commission

Gentlemen:

Herewith is a report on a rather extensive study of the Sediments of Mississippi Sound and Inshore Waters for the Seafood Commission and the Gulf Coast Research Laboratory, by Dr. Richard Randall Priddy and his Millsaps College coworkers—Robert Malcolm Crisler, Jr., Geologist, B.S. Millsaps College, M.S. Emory University; Clarence Paul Sebren, Geologist, B.S. Millsaps College; James David Powell, Chemist, B.S. Millsaps College, M.S. University of Mississippi; Hugh Burford, Chemist, B.S. Millsaps College, Graduate Student, University of Mississippi. To all these workers the State is under lasting gratitude.

Although it is primarily an economic Biological Study, it is none-the-less almost of equal importance in general geology.

Probably all geologists know of the black amorphous iron sulphide hydrotroilite—perhaps comparatively few have noted it in the field as the chief black pigment—hence referring most such black deposits to carbonaceous material—the thin black shales to carbonaceous shale, rather than to iron (hydrotroilite) shale. “Pyrite or marcasite, the logical iron-sulphur minerals, are not being formed now. Nitrogen is present in the sediments in several forms, and is differentiated here for the first time in unconsolidated sediments. Ammonium and amino nitrogen is present in living and dead organic material and nitrates and nitrites as oxidized products. The mineral glauconite is not being formed in the present day sediments but abundant fecal pellets indicate that they could be precursor of glauconite.”

Very sincerely yours,

William Clifford Morse
Director and State Geologist

CONTENTS

	Page
Introduction	7
Sampling program	10
Nature of the sediments.....	10
Sampling methods	16
Mechanical analyses	19
Microscopic examination	21
General	21
Mineral size determinations	22
Mineral composition	23
Fecal pellets	27
Carbonaceous material	30
Finely flocculant material	31
Volume — density determinations	33
Chemical examinations	36
Aluminum and iron determinations.....	37
Nitrogen determinations	45
Loss-on-ignition determinations	50
Resume of oyster plantings	51
Recommendations	51

ILLUSTRATIONS

PLATES

	Page
1. Mississippi Sound and environs	9
2. Davis Bayou, 1954 samplings	18
3. Graveline Bayou, 1954 samplings	24
4. Back Bay, 1954 samplings	29
5. Bay St. Louis, 1954 samplings	34
6. Middle Mississippi Sound, 1952-1953 samplings.....	38
7. Western Mississippi Sound, 1952-1953-1954 samplings.....	41-42
8. Mixing of Shore, Sound, and Gulf Foraminifera in Mississippi Sound	46
9. Oyster plantings in Western Mississippi Sound.....	49-50

FIGURES

1. Cross-sections of oyster reefs in Mississippi Sound.....	13
2. Device for taking 15-inch cores.....	15
3. Vacuum device for collecting surface sediments.....	16
4. Elutriation cylinders of liter capacity showing fractions of settled sediments	20

TABLES

1. Microscopic analysis of typical oyster bottom sediment (Sample 10-B)	21
2. Grain size comparison of oyster and shrimp bottom sediments.....	23
3. Iron and aluminum content (and loss on ignition) of 3-inch core of bottom sediments.....	42
4. Iron and aluminum content (and loss on ignition) of flocculant surface sediments	44
5. Nitrogen content (and loss on ignition) of 3-inch cores of bottom sediments	48
6. Analyses of 1954 samples.....	50-51
7. Analyses of 1952-1953 samples.....	50-51



SEDIMENTS OF MISSISSIPPI SOUND AND INSHORE WATERS

RICHARD RANDALL PRIDDY, Ph.D., ROBERT MALCOLM CRISLER, JR., M.S.,
CLARENCE PAUL SEBREN, B.S., JAMES DAVID POWELL, M.S.,
HUGH BURFORD, B.S.

INTRODUCTION

Mississippi Sound is a small nearly landlocked body of brackish water between Mississippi's Gulf Coast on the north, the barrier islands on the south, the delta of the Mississippi River on the west, and Mobile Bay on the east. Three large rivers, Pearl on the west and the Pascagoula and Alabama on the east, furnish fresh water to dilute the salty sea water funneling in between the barrier islands from the open Gulf. Thus the Sound is a gigantic mixing bowl for animal and plant life. Samples of the bottoms show that it is also a mixing bowl for land derived and sea derived sediments.

Investigations of inshore bottoms of parts of Mississippi Sound were started in the summer of 1952 and were continued the summers of 1953 and 1954. During the summer of 1954 refinements in collecting and in analysis were applied. The purpose of the study was to determine the physical and chemical nature of the bottom materials with reference to the distribution, mortality, and abundance of oysters, shrimp, fish, and other organisms, in order to find the types of bottom most favorable for the various species. The project was jointly financed by the Mississippi Seafood Commission and the Gulf Coast Research Laboratory.

So far as known, this investigation is the first attempt to study the biologically important uppermost sediments of the Sound floor, from a geological and chemical standpoint. Most other studies have involved the overlying waters, or the relatively barren beach sands, which are so much more accessible. In contrast this is a study of the bottom material, comparable to a study of soil on land.

To date the investigators have made two reports of progress to the Director of the Laboratory, one for 1952 and the other for 1953, both unpublished. As stated, the 1954 report is a part of this cumulative report. However, five papers have been published, or are soon to be published, reviewing different phases of the investigation:

- 1) Priddy, Richard R. and Crisler, Robert M., Preliminary survey of sediments of parts of Mississippi Sound, (abstract), Geological Society of America, Nashville, Tenn., Southeastern Section, p. 8, April 2-4, 1953.
- 2) Priddy, Richard R., Mineral composition of some bottoms of Mississippi Sound, Miss. Acad. Sci. Jour. (in press for 1952-1953)—paper delivered at Miss. State College April 24, 1953.
- 3) Priddy, Richard R. and Crisler, R. M., preliminary surveys of sediments in parts of Mississippi Sound; Southern Fisherman, pp. 44 and 92, June 1953.
- 4) Priddy, Richard R., Crisler, Robert M., and Burford, Hugh, Sediments of parts of Mississippi Sound, (abstract) Southeastern Section, Geological Society of America, Columbia, S. C., pp. 16-17, April 15, 16, 17, 1954.
- 5) Priddy, Richard R., Recent Mississippi Sound sediments compared with some Upper Cretaceous sediments; Trans. Gulf Coast Assoc. Geol. Societies, Vol. IV, Houston, Texas, pp. 159-168, 5 figs., Nov. 3-5, 1954.

The writers are indebted to Dr. A. E. Hopkins, Director of the Laboratory, for his advice and guidance in the project and to the Seafood Commission for the use of its work boat, Uranus, in obtaining deepwater samples. Acknowledgement is also made to the research and teaching staff of the Laboratory for their biological interpretations, and especially to Dr. O. T. Brown who instructed classes in sedimentation in 1953 and 1954. Thanks are also due to Mr. Robert M. Crisler, who devised a core sampler and collected and studied bottom samples in the summers of 1952 and 1953.

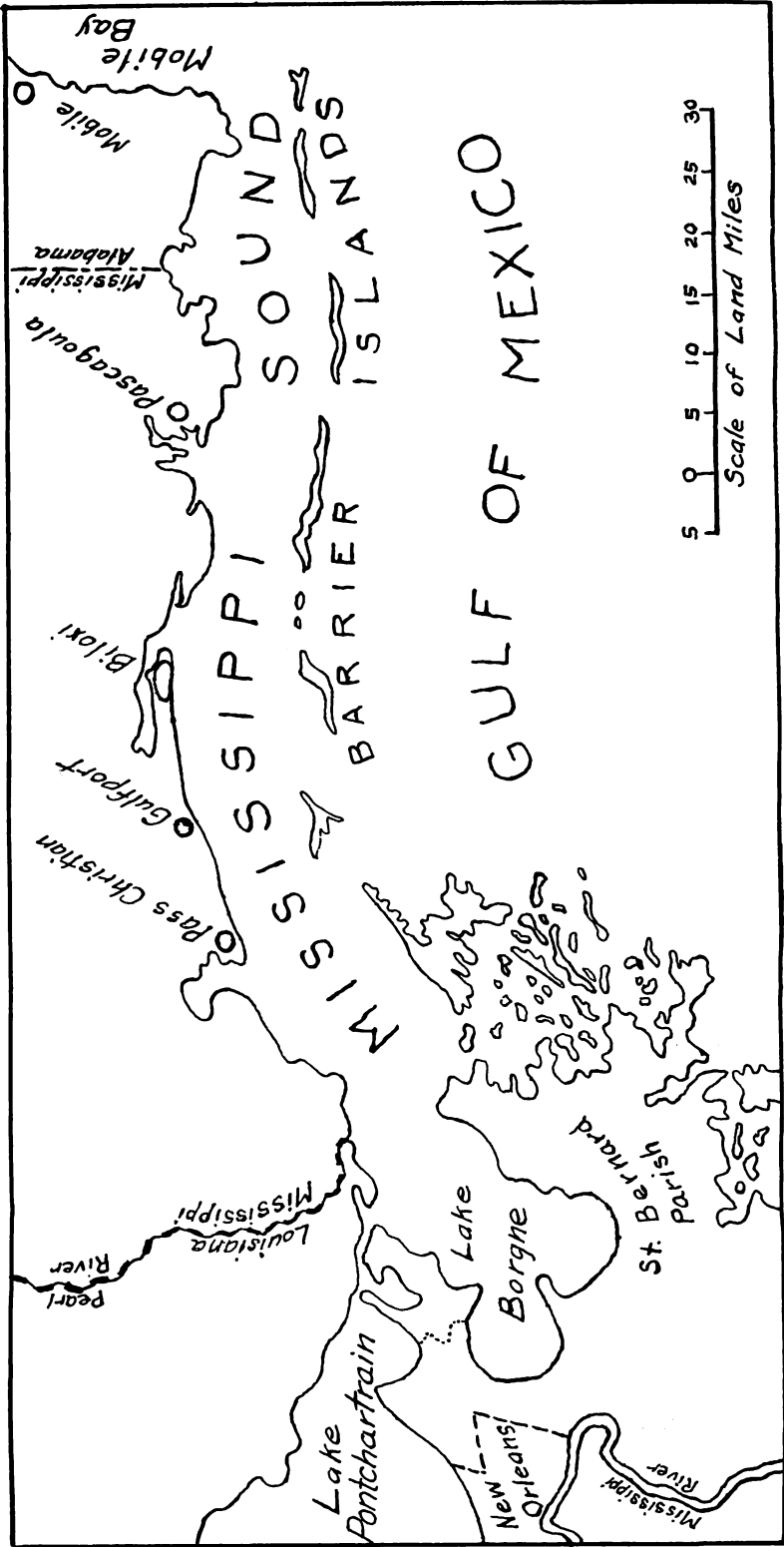


Plate 1.—Mississippi Sound and environs.

SAMPLING PROGRAM

The locations of the bottoms sampled for the first time in 1954, are shown on Plates 2, 3, 4, and 5, and the locations and designations of samples are listed in Table 6.

The locations of the samplings made in 1952 and 1953 are shown by Plates 6 and 7, and they and the sample designations are listed in Table 7. The only overlapping in collecting is indicated by the map (Plate 7).

As is shown by a study of the maps, most of the work in 1954 was along the central and eastern coasts of the Sound, whereas most of the collections in 1953 were in the west. The new work comprised a study of these specific areas: Davis Bayou (Plate 2), Graveline Bayou (Plate 3), Back Bay (the portion of Biloxi Bay north and west of U. S. Highway 90 bridge) (Plate 4), and the Bay of St. Louis in the northwest (Plate 5). This sampling program was in partial fulfillment of recommendations of 1953. Each sample is listed in the tables by number and letter, in the order of date of collecting.

NATURE OF THE SEDIMENTS

Some general observations should be made concerning the bottoms of Mississippi Sound, in order that the nature of the various sedimentational and ecological environments may be understood.

The bottoms are mostly muddy. Beaches composed partly of sand border the mainland and the barrier islands, and there are a few sandy shoals, but the probable sand area of the whole Sound is not more than 5 percent. In contrast, about 80 percent of the Sound has a clay-mud bottom, so soft that a pole can be pushed several feet into the sediments. The remaining 15 percent has a silt or sandy silt bottom which is fairly firm.

Whereas the sand bottoms are sometimes clean, often white, the clay-mud and silty mud bottoms are dark, even black. These dark bottoms support different types of life than the clean sands. The silts or sandy silts are in some places firm enough to hold up growing oysters, and are capable of supporting oysters in the event plantings are made. Although the clay-muds are too infirm to support oysters, they are adequate for shrimp.

Hereinafter, the bottoms composed of silt or sandy silt will be referred to as oyster bottoms. The clay or silty clay, muddier bottoms, will be referred to as shrimp bottoms. The actual differences in size of the mineral grains composing these two types are indicated in Table 2.

It should also be pointed out here that the terms sand, silt, and clay are used in the geological sense, the terms denote grain size only, not composition. The grain relationship is best shown in Table 2, where sizes are indicated in mesh and millimeters.

Microscopic study shows that all three types: sand, oyster bottom, or shrimp bottom, contain grains of the same minerals in about the same proportion. Organic material in the form of both living and dead vegetation is especially abundant in both oyster and shrimp bottom. In addition, fecal pellets, presumably of worms are common in shrimp bottom, in some places up to 30 percent of the visible constituents of the sample. There are a few Foraminifera in the sediments but their identification and ecology must await further study.

However, certain constituents of the oyster and shrimp bottoms were detected by chemical analyses, constituents which were not seen in petrographic work. Thus, aluminum is present in some water-soluble form and iron is present as hydroxides and sulphide. The sulphide, in the form of amorphous black hydrotroilite, acts as the chief pigment. In contrast, the carbonaceous content is surprisingly low and contributes little to the darkness of these fine clastics.

Regardless of whether the bottom as a whole is silty or sandy oyster bottom, or still finer shrimp bottom, the uppermost sediment is a finely flocculant stratum of water-logged organic debris and clay-sized mineral grains. Cores show that on oyster reefs this layer is rarely as much as one inch in thickness, but above shrimp bottom the layer is up to 12 inches in thickness. In this stratum is the greatest concentration of nitrogenous material, aluminum compounds, and iron compounds. In quiet water this superficial water-logged material is partly flocculant. But the layer breaks up and clouds the overlying waters when bottoms are disturbed as by wave action, by flooded streams, or by unusual tides. With the resumption of quiet water the material once more

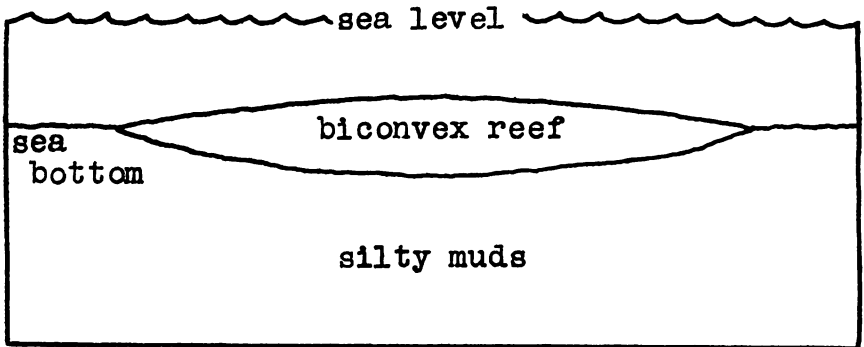
settles to form a stratum composed of clay-sized quartz grains at its base, grading upward into the flocculant, largely organic matter. As explained later, tests show that changes in the settling velocity of these very fine sediments vary with changes in salinity. In consequence of these differences in settling velocity, cores of the upper one foot of sediment frequently show a series of banded alternations, several to the inch.

These banded oyster and shrimp bottom sediments of Mississippi Sound (Plate 1) are accumulating in shallow water at depths of 4 to 20 feet, where the tide has a range up to about two feet. The salinity varies from nearly zero in creek and river mouths to 20 to 25 parts per thousand in the broader areas of the Sound. At times of high rainfall the Sound is nearly fresh, whereas, during low rainfall the salinity increases to almost that of sea water (35 parts per thousand) as the Gulf waters funnel in between the barrier islands.

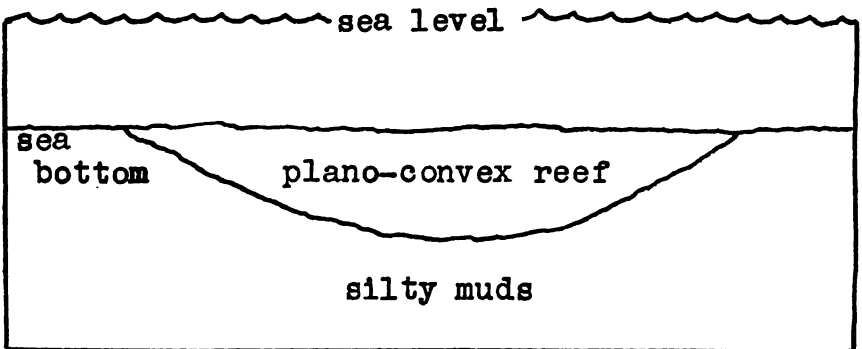
This salinity range within the Sound from fresh to salt water explains the production of a mixed fauna, both microscopic and megascopic. Thus Phleger¹ pictures Mississippi Sound as a gigantic mixing bowl where Foraminifera of marsh, brackish water, and open Gulf facies meet. An adaptation of one of his maps (Plate 8) shows that in some places marine Foraminifera mingle with Sound facies and even estuarine facies, up to the very beaches.

Similarly, the megascopic forms are, in some places, all brackish water species; in others, mixed open Gulf and brackish water species; and in a few places even mixed beach and open Gulf forms. Specifically, healthy oyster reefs are comprised of oysters and their common brackish water associates, only. But dying or decimated reefs show drilled oysters, the gastropods which are doing the drilling, and the boring sponges which weaken the shell. Dead reefs are distinguished not only by dead oysters, but by the shapes of the reefs.

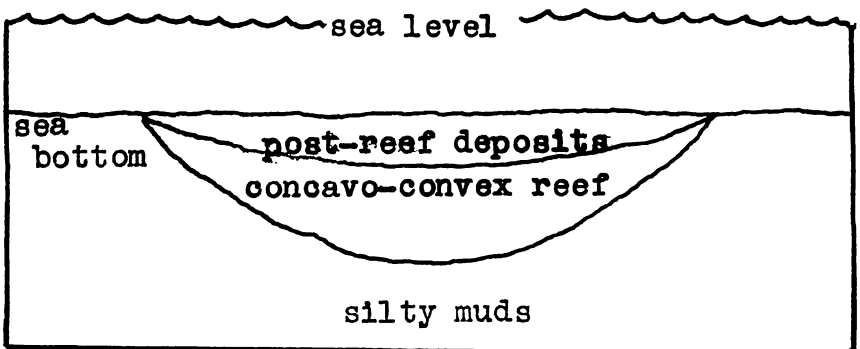
The shape of the modern oyster reef (Figure 1) provides an interesting study because the shape reflects differences in rate of growth due to changing salinities, and the rapidity of burial. Drilling shows that the living, healthy reef in the open Sound (A, Figure 1) is a broad but thin lens, slightly convex upward at



A. living, healthy oyster reef



B. dying or decimated reef



C. reef dead for some time

Figure 1.—Cross-sections of oyster reefs in Mississippi Sound.

the top but more strongly convex downward at the bottom. This peculiar biconvexity is attributed to the year by year growth of individuals and accumulations of new oysters. As the centers grow slightly upward the added weight pushes the older shells downward. Diagram B shows the cross-section of a reef which is dying over a period of increasing salinity. The upper surface flattens since there are few new additions to compensate for the continued sinking of the thickest part of the lens. One such dying reef, nearly a mile in diameter, is located by the diagonally ruled circle (Plate 9). The shell is being dredged to a depth of 35 feet and barged to New Orleans for road metal and concrete aggregate. Diagram C, Figure 1, shows a cross-section of a reef which has been dead for some years. With no new additions the surface becomes concave upward as the weight of the shells continues to increase the convexity of the bottom. Interestingly, this surface concavity is also seen in shell middens left by historic and prehistoric Indians in the Mississippi Delta region.

Whereas the mineral and chemical constitution of the finer sediments varies greatly, the sands of the beaches and shoals show little variation except in shape of grains. These variations in shape seem to indicate changing shore lines and different sources for the sediments. Thus, in the west part of the Sound irregularly shaped, fresh looking quartz and chert grains and flakes of mica suggest recent additions from the Pearl and Mississippi Rivers. However in the east, peculiar rhombic shaped quartz grains are common in both recent and buried sediments. The rhombs are best seen in Davis Bayou, Graveline Bayou, and at Round Island off the mouth of Pascagoula River (Plate 1). They may have been contributed by former streams draining the Piedmont areas where veins of quartz showing rhombic fractures are common.

These peculiar quartz fragments comprise most of the sands of Belle Fontaine Point (Plate 6), a blunt promontory between Davis Bayou and Graveline Bayou. Aerial photographs show that parallel east-west beach ridges have built the point progressively seaward. Longshore currents have produced ever-growing recurved spits sheltering Davis Bayou on the west and Graveline Bayou on the east. These beach ridges are now exposed as cut banks within the bayous suggesting that rejuvenation must

have occurred in the recent past. But inasmuch as these bayous are deeper than their mouths, and inasmuch as tidal action is too weak to cut them so deeply, this part of the Sound may be sinking now. However, marsh-type deposition seems to be more than keeping pace with sinking, for the bayous have narrowed in historical times.

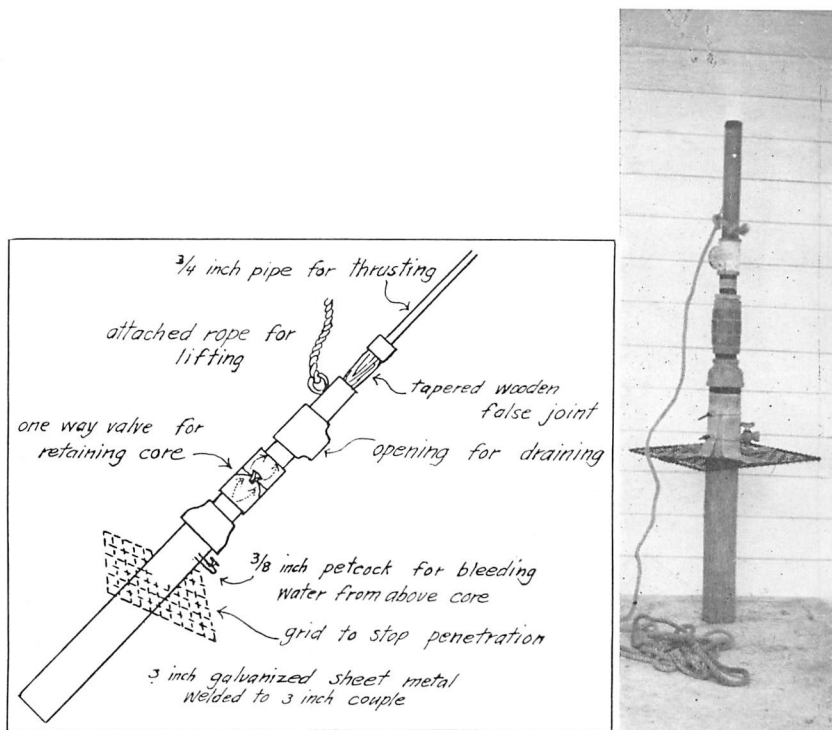


Figure 2.—Device for taking 15-inch cores.

The study of Davis Bayou has proved especially interesting because it and its northern arm, Stark Bayou, comprise much of the area set aside by the state of Mississippi as Magnolia State Park (Plate 4). These winding bayous and their accompanying marsh lands and wooded divides, are described by Morse² as the last remaining Gulf Coast natural bayou. In his report Morse suggested the area as a site for a marine laboratory. Today, the Gulf Coast Research Laboratory is situated on Davis Bayou, adjacent to the park on the southwest, as shown by Plate 4.

SAMPLING METHODS

In previous years only one type of sample, a 15-inch core, of semi-consolidated sediments, was obtained at each station. However, in 1954 an additional sample was collected, a portion of the finely flocculant water-logged material described as thickly covering shrimp bottom. This flocculant portion is sucked up by a vacuum device.

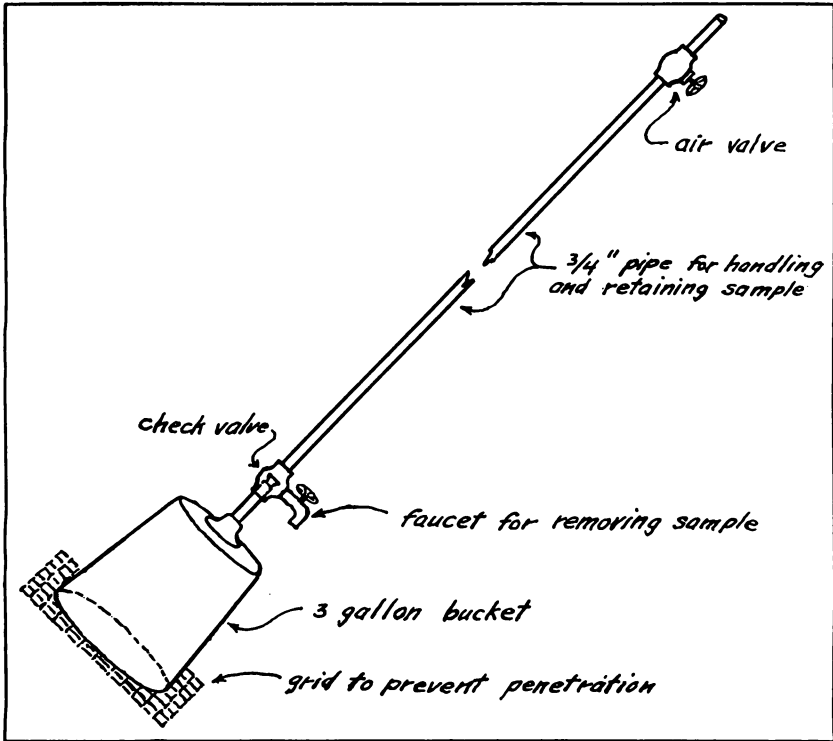


Figure 3.—Vacuum device for collecting surface sediments.

The 15-inch coring apparatus is shown as Figure 2. From this 15-inch core two fractions are reserved for microscopic and chemical study. The larger fraction comprises about one-half of the core, split longitudinally. It is sealed in a one-gallon glass jar with some of the sea water which is trapped in the coring apparatus. The smaller fraction consists of the remainder of the upper 3 inches which is assumed to be the more important biologically. It is collected as dry as possible and sealed in a quart

glass jar to provide a study of the undisturbed, less consolidated bottom.

The innovation, the vacuum device (Figure 3), consists of an inverted three-gallon bucket to which is attached section of pipe equipped with a check valve and faucet near the bucket and an air valve at the top of the pipe. To operate, the bucket is pushed to the bottom with the air valve closed. When the valve is opened the waterlogged sediments are displaced upward into the pipe column. After the valve is closed and the apparatus lifted, the finely flocculant material and the bottom water trapped in the pipe are bled off at the faucet. These vacuum sediments are reserved for chemical, microscopic, and density investigations. Salinity measurements are made on the trapped water.

Certain changes were made in 1954 in the method of obtaining and treating the 3-inch cores preparatory to wet chemical and microscopic examination. In 1953 a portion of each of the 3-inch cores was packed into a stender dish of known volume and weight, at the time of sampling. But the very act of packing was thought to have destroyed the original physical constitution of the sediment as the interstitial water was squeezed out. In 1954, as described above, a portion of the upper 3 inches of the 15-inch core was placed in a quart mason jar and sealed at the time the core was extracted. For a period of 24 hours the jar was placed on its side and tilted so that the excess water could drain off. The sediments were then resealed. The densities of the wet samples so obtained are believed to resemble more closely the true physical constitution of the sediments. This greater accuracy is necessary since many chemical calculations are based on the wet material, that is, on a volume basis, as well as on the customary weight basis.

During the 3-year program bottom samples were collected from 147 stations; 24 in 1952, 38 in 1953, and 85 in 1954. Not all samples proved worthy of analyses, but the analyses record of those which were studied is shown in the tables. Table 6 is the record of study of the samples collected in 1954 for a study of bottom types and for a check against the samplings in the west part of Mississippi Sound which were originally taken in 1952 or 1953. All 1952-53 samples are listed in Table 7 which is the table used in the 1953 report. The same number-letter designation is used

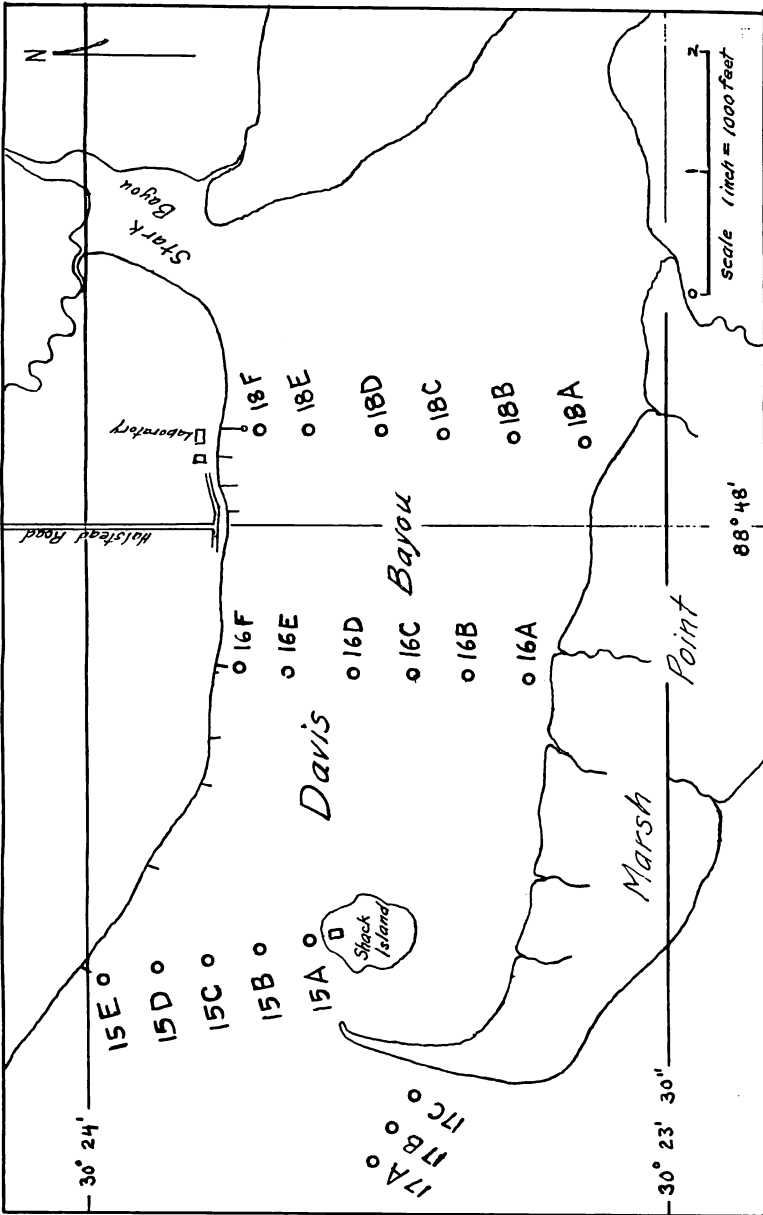


Plate 2.—Davis Bayou, 1954 samplings.

in all tables to show the sequence in collecting. Thus, sample 19-C was taken in a traverse of Graveline Bayou on July 23, 1954, 25-D was sampled at the mouth of Carlose Bayou in Graveline Lake on August 2, 1954, and 6-C is a re-sampling of a bottom near Cat Island Shoal in the west part of the Sound taken on August 3, 1954 (but first sampled August 26, 1953).

All samples have been stored for future reference. They include the 1952-53 samples of the 15-inch core and all 1954 samples, both 15-inch core and 3-inch core. The vacuum samples (taken in 1954 for the first time) have been concentrated by decanting off the water and placing the sediments in 20 ml. vials. Also stored are all residues from loss-on-ignition experiments. Such storage methods will permit re-examination in future years so that bottom changes can be ascertained.

MECHANICAL ANALYSES

The method of mechanical analyses has not been altered from previous years. The method used is elutriation. In this procedure, an homogeneous portion of each 15-inch core is introduced into a column of sea water to permit the layering of sediments as governed by the density of particles, their size, their shapes, and the extent of flocculation. Consequently mechanical and microscopic studies must be made while the samples are wet. But the elutriation method seems to be the only one by which the finer constituents can be separated. Experiments showed that drying cakes the sediment, and that grinding of the cake crushes the more fragile constituents. Moreover, even after crushing, the darkness of the sediment precludes examination, except of those samples which are very sandy.

To insure reasonable homogeneity for elutriation a liter beaker of the sediment (and associated sea water collected with it) is whipped by an electric stirrer. An approximate 200 ml. portion is then poured into a one-liter graduated cylinder and shaken with enough sea water to fill the vessel. On settling, the sediments occupy about one-third of the cylinder. Nearly 90 percent of the particles settle within the first hour, but a 24-hour period is usually necessary for the supernatant liquid to lose its turbidity.

The more sandy the homogenized 15-inch sample the more obvious is the layering. This stratification is indicated by the photograph of the graduated cylinders (Figure 4), identical with Figure 4 of the 1952 and 1953 reports. In an idealized cylinder the lower fractions are sand, whereas the middle portions are silt and the uppermost portions are clay. Inasmuch as the sand-silt line is easily seen in the coarser samples, the relative amounts of sand are easily measured. Such measurements help to provide

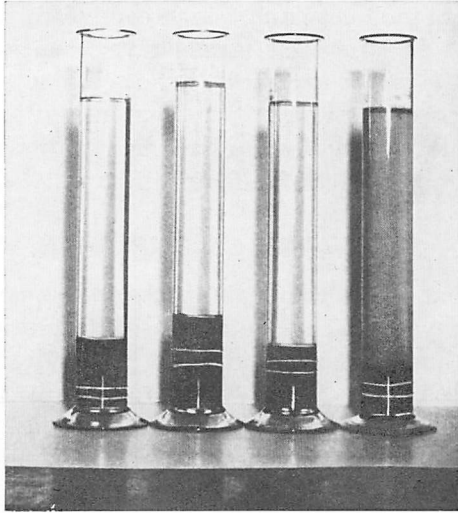


Figure 4.—Elutriation cylinders of liter capacity showing fractions of settled sediments.

the sort of data listed in Table 6 as “kind of sediment.” In most cases larger or rounded sand grains are on the bottom, smaller or irregular and angular grains next above. Successive upper fractions are identified as silt and clay portions. However, a few departures from size uniformity are noticed. Cleavage fragments of muscovite (a mica) settle in an upper fraction whose mineral grains are much smaller than the muscovite. But garnets and other “heavy” minerals settle in the bottom of the cylinders with quartz sand grains much larger than the heavy minerals. Like the muscovite, large fresh fecal pellets, presumably of worms, settle in the finer upper fractions. In contrast, older looking, darker, silt-loaded pellets of all sizes are stratified with the lower coarser fractions. In general, vegetable material, the chief carbonaceous content, shows no order of settling.

MICROSCOPIC EXAMINATION

GENERAL

Layering by elutriation affords an opportunity to study the sediments microscopically. Accordingly, portions are removed by pipetting, the number of portions sampled depending on the relative thicknesses of the sand, silt, and clay layers. Usually extracts from 5 horizons furnish representative fractions: The top one-fifth, a second one-fifth, a middle one-fifth, a fourth one-fifth, and a basal one-fifth. This method fixes a low silt-mud line in the finer sediments comprising shrimp bottom or a high sand-silt line in the coarser sediments comprising oyster bottom. Whatever the number of portions taken, pipetted extracts of each are placed in concave micro-slides for examination by binocular microscope, or sometimes by petrographic microscope. Analyses were thus made on all 15-inch cores, while wet with native sea water.

An example of one such analysis is shown below. The material is typical oyster bottom—10-B from St. Joe Reef in the west part of Mississippi Sound (first sampled July 28, 1953 and re-sampled August 3, 1954). Note the presence of muscovite (mica) flakes, angular chert, and silt-filled, old-looking pellets. Note also the sand-mud line in the fourth fraction.

TABLE 1.

MICROSCOPIC ANALYSIS OF SAMPLE 10-B	
Top 1/5	99 percent finely flocculant 1 percent organic—fine shreds of grass or weeds
Second 1/5	same
Middle 1/5	90 percent finely flocculant 5 percent organic—shredded grass 5 percent fine quartz sand of 600-400 mesh—a few floating muscovite flakes of 400-200 mesh
Fourth 1/5	sand-mud line 80 percent quartz sand and chert—gray angular 30 percent 400-200 mesh—subrounded 60 percent 200-100 mesh—subrounded 10 percent 100 mesh—subangular (about 5 percent angular fresh looking chert)

- 1 percent muscovite flakes 600-60 mesh
- 10 percent finely flocculant
- 9 percent organic—coarse weed fragments—a few old looking silt-filled fecal pellets of 400-100 mesh

Basal 1/5

- 92 percent quartz sand and chert—gray angular
 - 10 percent 400-200 mesh—subrounded
 - 50 percent 200-100 mesh—subrounded
 - 30 percent 100 mesh—subangular to angular
 - 10 percent 100-80 mesh—subangular to angular
- 2 percent muscovite flakes 400-60 mesh
- 1 percent badly weathered biotite (?) 100-50 mesh
- 3 percent organic—coarse grass, weeds—a few old silt-filled fecal pellets
- 2 percent finely flocculant

This natural layering also affords an opportunity to describe samples microscopically. Thus in Table 6, mentioned above, the column entitled "kind of sediment" shows the several categories into which the sediment may fall, based on the quantitative relationship of sand, silt, and clay in the cylinders. For example, sample 27-A has a preponderance of sand, but very little silt, so it is called a silty sand. However, sample 24-B consists of clay-sized grains, so it is called a clay mud. In contrast, sample 22-A is called a silty clay because it is dominantly clay, contains a little silt-sized material, but no sand. Substantiation of this nomenclature is found in the course of the more exact microscopic examination which is described in the following paragraphs.

As pointed out, microscopic examination of the elutriated portions pipetted onto micro-slides is best made while the shallow concavity is water-filled. By a binocular study the size of the grains can be quickly measured, and, in most instances, the mineral composition of the coarser portions ascertained. Fecal pellets and carbonaceous materials are also measured and classified. In addition the finely flocculant materials are described as well as possible.

MINERAL SIZE DETERMINATIONS

Size determinations of the coarser fractions are made by a direct comparison with sand grains (collected on U. S. Standard sieves of sizes 40, 50, 80, and 100 mesh) mounted in Canada balsam.

For convenience, the sieve number, openings in inches, and openings in millimeters, are shown in Table 2, previously referred to. As an example of the relative amounts of each grain size present in a given sediment, the results of analyses of samples 6-E and 2-A (first sampled in 1952) are also recorded in Table 2. Sample 6-E is a silty sand which is typical oyster bottom, whereas sample 2-A is a sandy silt, typical shrimp bottom. In these analyses the grains of silt-clay size (120, 200, 400, and 600 mesh) were determined by measurements with a micro-slide inserted in a binocular microscope.

TABLE 2.

GRAIN SIZE COMPARISON OF OYSTER AND SHRIMP BOTTOM SEDIMENTS

Sieve No.	Openings		Percent retained		
	in inches	in mm.	Oyster bottom (Sample 6E)	Shrimp bottom (Sample 2A)	
10	0.0787	2.000			gravel
30	0.0232	0.590			coarse sand
40	0.0165	0.420	1		
50	0.0117	0.297	2		
60	0.0098	0.250	7	1	
80	0.0070	0.177	15	3	
100	0.0059	0.149	45	6	
120	0.0049	0.125			fine sand
200	0.0029	0.074	25	10	coarse silt
400	0.0015	0.037	4	50	
600	0.0007	0.018	1	30	fine silt clay

MINERAL COMPOSITION

Analysis by direct comparison with the Canada balsam mounts showed that all sand grains fell into mesh sizes 50 through 100, except for a few easily recognized large shell fragments. Regardless of which size fraction is being studied, nearly 95 percent of all grains consist of quartz (crystalline silica); about 4 percent of chert (cryptocrystalline or amorphous silica); and the remainder of igneous or metamorphic minerals, approximately in this order of abundance: Muscovite, garnet, biotite, epidote, feldspar, apatite, magnetite, and zircon. Except for the biotite and muscovite, these minerals are termed "heavy minerals." The

“heavy minerals” seem to be more numerous in the east part of the Sound; in contrast, the micas (biotite and muscovite) and chert grains are most abundant in the west part. The grains of mica and chert may have been brought in by Pearl River or by the Mississippi, a possibility which is supported by the greater amount of angular quartz in the coarser sand fractions to the west.

The above mineral proportions were observed constant in the west part of the Sound through 1952, 1953, and 1954. However, microscopic analyses of samples collected in 1954 from Davis Bayou, Graveline Bayou, Back Bay, Bay of St. Louis, and near Round Island (sampled August 14, 1953) show slightly different amounts of the minor constituents—chert, mica, and “heavy” minerals. But the most striking feature of the samples is the variety of shapes of grains, from very angular to rounded. The following chart with collecting areas named in west-east order, has been devised to show these relative differences in percent. Very small amounts of some constituents are designated as traces, by the symbol T.

Location	Mineral Composition					Shape Quartz Grains				
	quartz sand	chert	muscovite	biotite	“heavies”	rhombic	very angular	subangular	subrounded	rounded
West Sound	95	4	0.5	0.1	T	5	25	50	15	5
Bay of St. Louis	96	3	T	T	T	T	5	40	35	20
Back Bay	99	T	0	0	0	T	4	50	40	5
Davis Bayou	99	0	T	0	0	15	5	48	30	2
Graveline Bayou	99	0	0	0	0	20	5	60	10	5
Round Island	98	1	T	T	T	25	25	20	15	15

The chart indicates the average mineral content and mineral shape for each of the areas. But there are some interesting exceptions. In sample 25-D (where Carlose Bayou empties into Lake Graveline) 95 percent of the grains are subrounded to rounded instead of the subangular to very angular shapes which are typical of the rest of the Graveline area. In this instance the roundness is believed due to recent land-derived additions from upstream. In contrast, samples 15-E and 16-F from Davis Bayou show an

unusually high percentage of angular quartz. The angularity is probably due to concentration through the winnowing action of waves on spoils dumped on the adjacent shore when a channel was dredged several years ago.

This winnowing action is so important that it should be explained here. It is a factor in the building and maintaining of sand beaches and the more sandy oyster bottoms which are scattered through various parts of the Sound. Unusual waves or unusual currents should carry both angular and rounded grains. But less intense agitation removes only the more rounded grains, leaving behind those angular fragments which interlock with each other or lock with irregularities of the bottoms. In this way the dark, malodorous spoils pumped during dredging operations soon become cleaned, and the proportion of angular beach sands becomes relatively greater, as vegetable debris and most of the rounded mineral grains are flushed back to sea by wave action. Thus the oyster bottoms are growing higher and firmer as the slight depressions nearby are becoming muddier and muddier.

One area where this selective deposition by winnowing is at work is St. Joe Reef (Plate 6) in the west part of the Sound. Samples 10-B, 10-C, 10-E, and 10-F were collected here in 1953. The firmness of the silty clay bottom seems due to recent acquisitions of large angular quartz and chert grains, and flakes of mica, as observed in the 1953 report. But on the basis of re-sampling of 10-B in 1954 the winnowing process seems to be continuing, for the proportion of angular grains is greater than in 1953. This increase in the proportion of angular grains could be only relative, because where winnowing action is at work the finer, more rounded materials are being progressively removed, leaving an apparently greater amount of coarse angular grains. It is not improbable that the 1947 hurricane, which is said to have laid bare parts of the bottoms of western Mississippi Sound, introduced a mixture of grains of all sizes and shapes which are being progressively winnowed.

In contrast, there is a preponderance of subangular to sub-rounded grains in Back Bay (the upper part of Biloxi Bay) and in Bay of St. Louis, as shown by the above chart. These shapes are believed to be due either to little winnowing action in these

sheltered waters or to recent additions of land derived grains rounded by stream action.

However, the great variety of grain shapes at Round Island is believed due to deposition of grains of several sizes and various shapes, at several times, and from several sources. Some coarse quartz grains are nearly spherical, some are subangular, and others very angular, and some are cracked. Still others are frosted as if by wind action. Numerous grains, either large frosted or large angular, have limonite-filled cracks in a nearly rhombic pattern.

Some explanation is necessary for the rhombic-shaped quartz grains shown on the chart, for it is more likely that beach sands should be rounded than angular. Likewise, it is difficult to understand the apparent freshness of so many angular grains unless some of the fracturing is now taking place. However, it is not within the scope of this paper to explain the origin and shapes of these grains. These subjects will be treated by Dr. O. T. Brown of Mississippi Southern College, who is teaching the courses in sedimentation at the Gulf Coast Research Laboratory. He will discuss them in an early paper dealing, in part, with the probable sources of the beach sands of Mississippi Sound.

FECAL PELLETS

Each year a surprising amount of fecal material, as pellets, is observed during binocular examination of the elutriated 15-inch cores. In 1954 the pellets were also seen in the finely flocculant material extracted by the vacuum device. The pellets are present in greater abundance in shrimp bottom; rarely in oyster bottom, and never in samples from beaches or sandy shoals. The fecal material is in the form of silt-coated hollow sacs of various sizes, from as small as 400 mesh (37 microns) to as large as 40 mesh (420 microns), most being in the size range 200 mesh (74 microns) to 100 mesh (149 microns). When fresh these sacs, regardless of size, are suspended in the upper, finely flocculant elutriated fractions. However, silt-logged, darker, presumably older pellets, of any size, sink into the lower fractions. In general they are suspended in the midportion of the elutriating column.

Most of the pellets are elongated ovoids but about 5 percent are spheres. An occasional biconcave disc-shaped form is present.

But regardless of shape all seem to be hollow, for they break easily on probing. The constituent silt grains then lose their identity among the other 600-mesh (18 micron) or even smaller quartz fragments which are also suspended in the finely flocculant material. For illustration, an unusual concentration of fecal pellets is described below. The three elutriation portions are from the lower part of Sample 4-C, a mud bottom sample taken in 1952 from near Deer Island in Biloxi Bay.

Sample 4-C (mud bottom near Deer Island)

	Percent
From mud	
Middle one-fifth (100-mesh to 200-mesh quartz sand):	
200 mesh sacs—spheres, discs, ovoids.....	25
300 mesh sacs—spheres, discs, ovoids.....	50
From mud	
Fourth one-fifth (80-mesh to 200-mesh quartz sand):	
80 mesh sacs—elongated ovoids	5
100 mesh sacs—elongated ovoids	30
200 mesh sacs—spheres or discs	20
From sand	
Basal one-fifth (60-mesh, 80-mesh, 100-mesh quartz sand):	
60 mesh sacs—elongated ovoids.....	5
80 mesh sacs—elongated ovoids.....	15
100 mesh sacs—elongated ovoids.....	10

As intimated, the sacs are coated with minute quartz grains of 18 microns or less. However, there is no indication of the nature of the sac itself. Presumably it is a mucous secretion of the animal, most probably organic. Moreover, since the pellets are mostly found in the muds where fine flocculant material abounds, it is not improbable that the thin sac walls are composed of aluminum hydroxide, silicon hydroxide, or ferric hydroxide. As will be pointed out, chemical analyses have shown these hydroxides to be important constituents of the floc.

This investigation has furnished no direct evidence as to what happens to the pellets. Presumably they continue to accumulate. Being fragile, most of them probably break up quickly. Yet some may be preserved sufficiently long to undergo lithification as the sediments compact. Several geochemists³ believe that

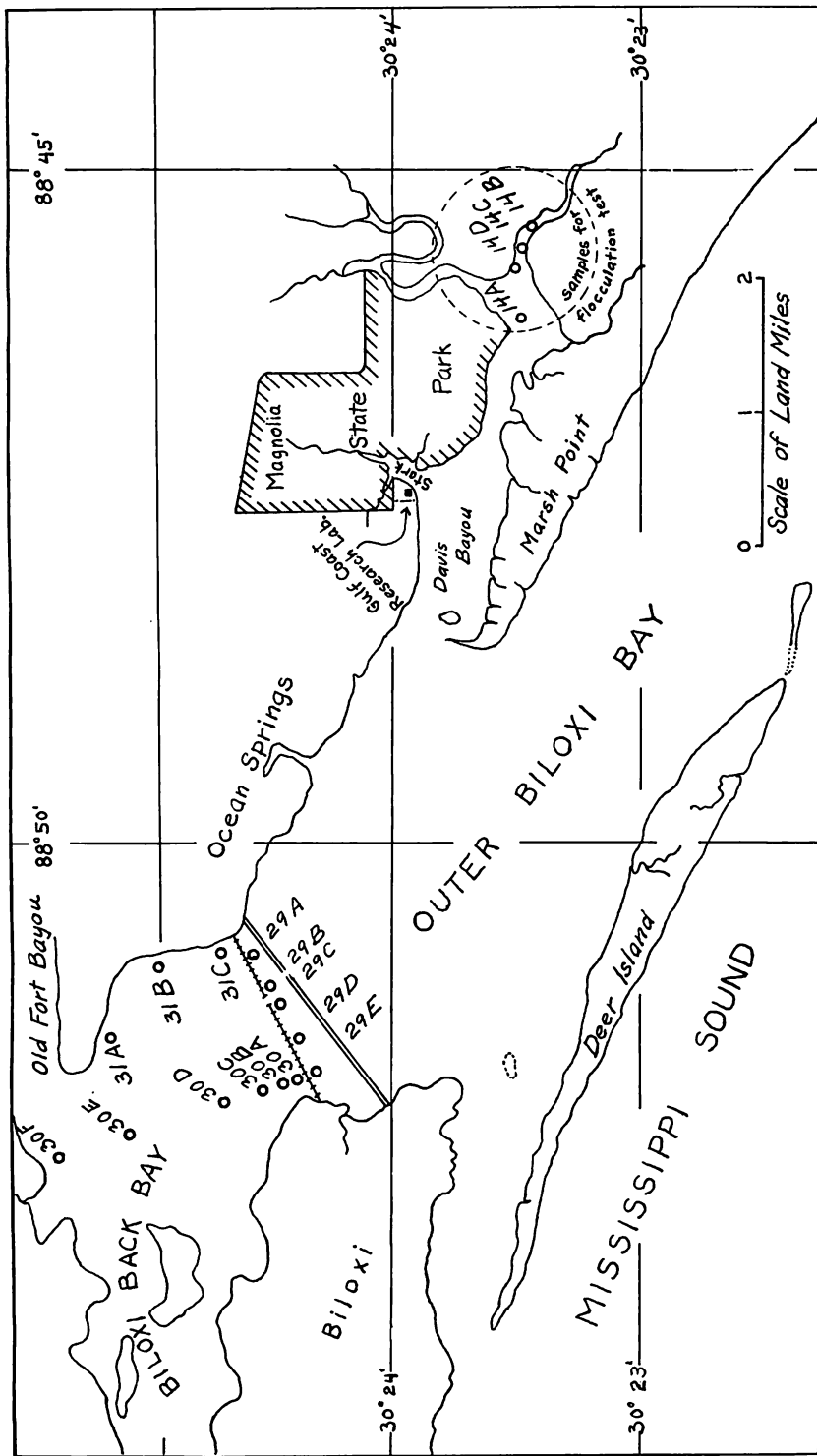


Plate 4.—Back Bay, 1954 samplings.

sometimes the greenish mineral glauconite is formed from fecal pellets through alteration under reducing conditions.

Glauconite is a complex aluminum silicate containing variable amounts of ferrous and ferric iron, potash, soda, lime, phosphate, and titania. As yet, the mineral has not been found in the Mississippi Sound sediments now accumulating. However, Brown and others' report glauconite at shallow depths in several water wells in the region, as shown in the following tabulation:

Well Number	Location	Depth to Zone in feet
185	M. J. Epey home, east edge Pass Christian	45-85
75	Magnolia State Park, near Ocean Springs	20-30
78	E. B. Townsend home, 5 miles west of Pascagoula	92-281

CARBONACEOUS MATERIAL

The carbonaceous content of the elutriation fractions was mentioned on an earlier page. In this category has been placed all visible woody or grassy material which does not show the optical properties of a mineral. The calcium carbonate composing the shells of molluscs and arthropods is not included in this definition. Animal-derived carbonaceous material does exist but examination shows only a few worms, gastropods, or arthropods in the 15-inch and 3-inch cores. Numerous planktonic forms are seen in the finely flocculant material extracted by the vacuum device.

The carbonaceous content for the Sound as a whole is surprisingly small, as shown by loss-on-ignition procedures. Nor is the pigment carbonaceous which makes the oyster and shrimp bottoms dark or even black. Instead, the pigmentation seems due to iron sulphide in the form of the amorphous mineral hydrotroilite, as discussed under chemical analyses.

The fragments of vegetation are of various sizes, and, as intimated on a preceding page, they are distributed through the elutriating columns irrespective of sizes. In the sediments obtained from the outer Sound the vegetable material is finely macerated. But near the shores and especially in the bayous woody and grassy fibers of all sizes commonly constitute 10 to 30 percent of the 15-inch cores. As would be expected, the 3-inch cores from the same samples usually show fresher, coarser mater-

ial and in greater amount, sometimes up to 50 percent. In contrast, the water-logged flocculant sediments extracted by the vacuum device do not show as much carbonaceous material as either of the other cores. In fact, vegetable fibers are so finely divided that they are hard to detect. Loss-on-ignition tests on the residue after iron-aluminum extraction suggest that these floccs usually contain less than 5 percent carbon.

There are, of course, some exceptions. A 15-inch core, Sample 24-E, from the west edge of Lake Graveline, showed an unusual amount of brown peaty material, masses of such thick, little altered vegetation that the cell structure is still intact. Similarly, a resampling of 13-D in Three Oaks Bayou near the west end of the Sound showed vegetation so little altered that grass and weed stems were still erect in the core. In one of the Back Bay samples, 31-B, so much brown peat settled so quickly into the lowest elutriation fraction that sand grains could not drop into their accustomed basal position.

FINELY FLOCCULANT MATERIAL

In the discussion of elutriation, repeated mention was made of the finely flocculant material in which mineral grains, fecal pellets, and carbonaceous matter are suspended. The flocc is more abundant in the water-logged sediments of shrimp bottoms in the open Sound, or in bayous. Lesser amounts are in oyster bottoms. Very little flocc is in beach sand or on the sandy shoals of the Sound. It was for the collection of this fine material that the vacuum sampling device (Figure 3) was constructed.

As intimated, no materials smaller than 600 mesh (18 microns) can be identified with certainty in binocular examination; so chemical analyses are resorted to. They show that the flocc is very high in aluminum and iron. The floccs are presumably hydroxides for they are slowly dissolved in weak hydrochloric and acetic acids and are reassembled on the addition of weak sodium hydroxide or ammonium hydroxide. Since the floccs behave in this manner it is not improbable that they are assembled or dispelled by changes in salinity (if salinity is recognized as a product of varying cations and varying anions). It is here suggested that a seasonal check be made on the relative amounts of flocc at some collecting locality close to the Laboratory and

that a correlation with salinity be established. Samples collected for such purposes could be stored for periodic examination.

The quantity and behavior of the finely flocculant material is believed to be largely governed by salinity. In order to explain this behavior Mr. Sebren and a visiting geologist, Mr. John Small, Jr., conducted a series of experiments on the settling velocities of flocculant matter. Salinity ranges of nearly zero to 30 parts per thousand (approaching that of open Gulf water) were used.

For this experiment three samples of floccs were obtained from eastern Davis Bayou (Plate 4). They were collected with the vacuum device (Figure 3). A 100 ml. portion of each sample was placed in a 500 ml. graduate and shaken with sea water of various predetermined salinities (30, 25, 20, 15, 10, 5, and nearly zero parts per thousand). The heights of the sediments in the columns were recorded for the first 5 hours of settling and compaction. Recordings were made at 30-minute intervals, the first, 15 minutes after the sample was shaken. Graphs of time against height of sediment were then made. They showed that the greater the salinity the slower the settling and compaction. However, there are some minor fluctuations in the curves shown on the graphs. These changes in the curves are explained by an early unhampered settling of the coarser, heavier particles because of little flocculation during the first half hour, and then retarded settling after all the floc had formed.

To see if changes in salinity induced by altering the cation-anion ratio had any effect on the velocities of settling, the water in each column was made more basic by introduction of limewater. In this experiment the settling velocities were decidedly slowed. Then in a later test carbon dioxide was bubbled into the limewater solution, thus making calcium bicarbonate. In this medium the settling velocity was speeded up to nearly that in the original sea water before the limewater was introduced. The calcium bicarbonate experiment also showed that the settling velocity in the interval of one to two hours of elapsed time was greater than that produced by any salinity in the same time interval. This finding helps to explain the clarity of the Florida waters and the rapid deposition of oozes there. Conversely, the

absence of much calcium bicarbonate in Mississippi Sound waters helps to explain the turbidity of the waters of the Sound.

It is hoped to verify in 1955 the observations described above and to introduce other variables in cation-anion ratio. In this way a better understanding may be had of the conditions of deposition in Mississippi Sound. Such an understanding should be helpful, because the Sound is a mixing bowl for land runoff and open Gulf waters.

VOLUME-DENSITY DETERMINATIONS

Volume-density determinations give a picture of the physical consistency of the sediments, just as microscopic and chemical analyses show their mineral and chemical constitution. A portion of each 3-inch core provided volume-density data.

A portion of each core was drained of excess water and its wet density calculated by weighing in a tared stender dish of known volume. Each density is considered a fair expression of the relative compaction of the sediment concerned. All densities are listed in Table 6. Examination of the table shows a surprisingly close correlation of densities with kind of sediment, bottom topography, percent-loss-on-drying, and percent-loss-on-ignition. For example, clays have a low density, a high loss-on-drying, and a high percent-loss-on-ignition. In contrast, the more silty sediments have a higher density, a lower percent-loss-on-drying, and a lower percent-loss-on-ignition. The densities of sand are highest but the percent-loss-on-drying and loss-on-ignition are even lower. These differences in density show that the clayey bottoms are highest in organic content, whereas the more sandy bottoms contain much unalterable quartz and chert, as already indicated by microscopic studies. For simplicity, a chart is appended to show these chief differences as expressed by several samples.

Sample number	Kind of sediment	Bottom topography	Density	Loss-on-drying (percent)	Loss-on-ignition (percent)
15-B	soft clay mud	mud flat	1.31	80.0	8.32
10-B	silty clay	edge of reef	1.77	55.9	3.81
21-A	clayey silt	bank of bayou	1.83	46.9	3.04
27-A	fine sand	sandy shoal	1.91	30.8	0.36

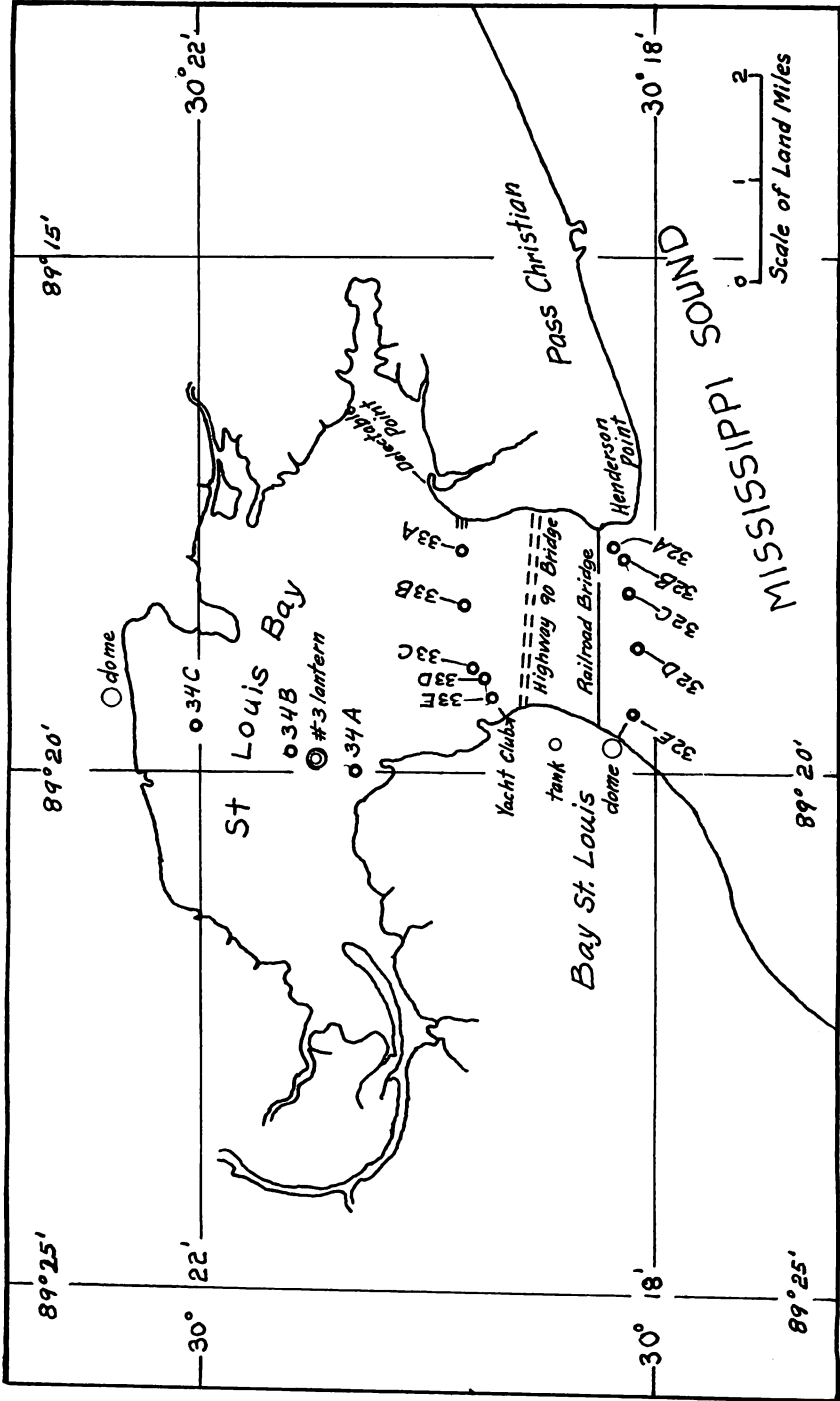


Plate 5.—Bay St. Louis, 1954 samplings.

As pointed out, the above densities were determined on the wet 3-inch cores. However, a glance at the plates shows that two other densities have been recorded on the same samples—dried density and ground density.

The dried density was obtained in the process of finding loss-on-drying values. In each instance the weight of the dried material was divided by the wet volume minus the loss in weight (on the assumption that all the weight lost is water, which, of course, has a weight of 1 gram per milliliter). In most cases this dried density was less than 2.5, the maximum to be expected if all the sediments were consolidated. However, there were several instances in which the dried density exceeded 2.5. Notable examples are recorded in Table 6, the Davis Bayou traverses 15A-E and 16A-F. A comparison of wet and dry densities shows that not all the variations are due to loss of water alone. The higher figures are believed due to some constituent or constituents increasing in weight, such as FeS (hydrotroilite) oxidizing to FeSO₄ (ferrous sulphate) or to Fe₂(SO₄)₃ (ferric sulphate) or even to Fe₂O₃ (ferric oxide) and elemental sulphur. This increase in density is also due to decrease in volume as the hydroxides in the sediments dehydrate, such as Fe(OH)₂ (ferrous hydroxide) or Fe(OH)₃ (ferric hydroxide) or Al(OH)₃ (aluminum hydroxide) theoretically changing to FeO (ferrous oxide), Fe₂O₃ (ferric oxide), and Al₂O₃ (alumina), respectively.

Wherever these dried densities were greater than 2.5 the 15-inch cores showed unusual amounts of clay and finely flocculant material. This observation confirms several statements made earlier that the clays and floccs are high in iron sulphide content. As would be expected, the sandier 3-inch cores showed lower dry densities. Also, as expected, highly carbonaceous sediments showed the lowest dried densities. However, there are some clays and floccs in stagnant waters behind bars or spits which are not very carbonaceous but which showed low dried densities. Inasmuch as these sediments are much higher in aluminum content, it is believed that the low dried density is due to the dehydration of aluminum hydroxide concentrated there.

The third density recorded, the ground density, represents the results of an effort to reconstitute the sediment which had lost so much weight and volume during the loss-on-drying pro-

cedure. The original purpose in grinding the dried, caked sediment was to make binocular examinations. This effort failed because the sediments proved too dark to study and grinding fractured some grains and pulverized the organic material but did not separate the finer sediments from the coarse grains to which they had adhered while drying. However, the ground densities determined did serve a purpose, for it was found that they are always lower than the dried densities and are more consistent with the wet densities. True, they represent nothing in themselves, but they do approximate some of the densities of the darker shales and clays with which geologists are familiar.

CHEMICAL EXAMINATIONS

As mentioned in one of the earlier paragraphs of this report, certain refinements in chemical analyses were instituted in 1954, as recommended in 1953. These investigations were made possible through the diligent efforts of Mr. J. D. Powell and Mr. Hugh Burford, chemists.

One refinement is the quantitative analysis of the 3-inch core samples, on a volume as well as a weight basis. For the second year large quantities of aluminum and iron were identified in the elutriation fractions containing the finely flocculant material in both the 3-inch cores and in the 15-inch cores. Even greater concentrations were found in the flocc taken by the vacuum device. These findings prove that much of the finer sediment is aluminous material which had defied identification in microscopic studies. The iron and aluminum content is indicated on Tables 6, 3 and 4.

A continuation of the 1953 program is the analysis of nitrogen, using adaptations of the old Kjeldahl method, for total nitrogen, nitrate nitrogen, and combined ammoniacal and organic nitrogen (amino nitrogen). However, nitrite nitrogen was measured for the first time in 1954 by means of an adaptation of the nesslerization method used for analyzing sewage. Nitrite determinations were made on wet fresh samples only, for the reason that heating and bacterial action rapidly oxidize the nitrites to nitrates. The results of all nitrogen analyses are listed in the tables.

The next few pages comprise a discussion of the methods used and applications of the findings to the physical environment of

the sediments. Aluminum and iron determinations are treated first, the four nitrogen determinations second, and loss-on-ignition determinations last.

ALUMINUM AND IRON DETERMINATIONS

The identification of large amounts of aluminum and iron proved that much of the finer elutriated fractions contains aluminous and ferruginous materials which had escaped detection during petrographic study. As intimated in the discussion of the nature of the sediments, it was suspected in 1952 that the more clayey sediments must contain aluminous materials, because it is unusual for clay-sized sediments to be constituted of quartz and chert grains, exclusively. To verify previous analyses of aluminum, four 1952 stations and five 1953 stations were re-sampled, as shown in Plate 7. In addition, aluminum and iron determinations were made on 28 of the 1954 samplings to see if differences in content had any relation to differences in environment. Results of these analyses are shown in Tables 6, 3 and 4.

Although aluminum compounds were suspected but never seen, iron compounds are easily recognized in recent nearshore sediments. Bayou margins commonly show beads of red-brown ferruginous gels in matted, partly decayed grasses at the water's edge. Shortly after being piled on the shore by dredging operations, these grassy masses form reddish spongy limonite ($\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$) as the gels are dehydrated and as the vegetable matter dries and decays. In the same way iron oxides are formed within a month on the surfaces of some of the 3-inch cores sealed in glass jars.

But the first hints of a combined iron and aluminum content were noted when sediments were treated with hydrochloric acid and ammonium hydroxide. The addition of the acid produced a greenish-yellow solution and the evolution of large quantities of hydrogen sulphide gas. Addition of the hydroxide then formed a gelatinous yellow-orange precipitate which proved to be combined iron and aluminum hydroxides.

Since iron sulphide produces yellow-green to orange-colored iron chlorides and evolves hydrogen sulphide gas on the addition of hydrochloric acid, it was apparent that the sediments con-

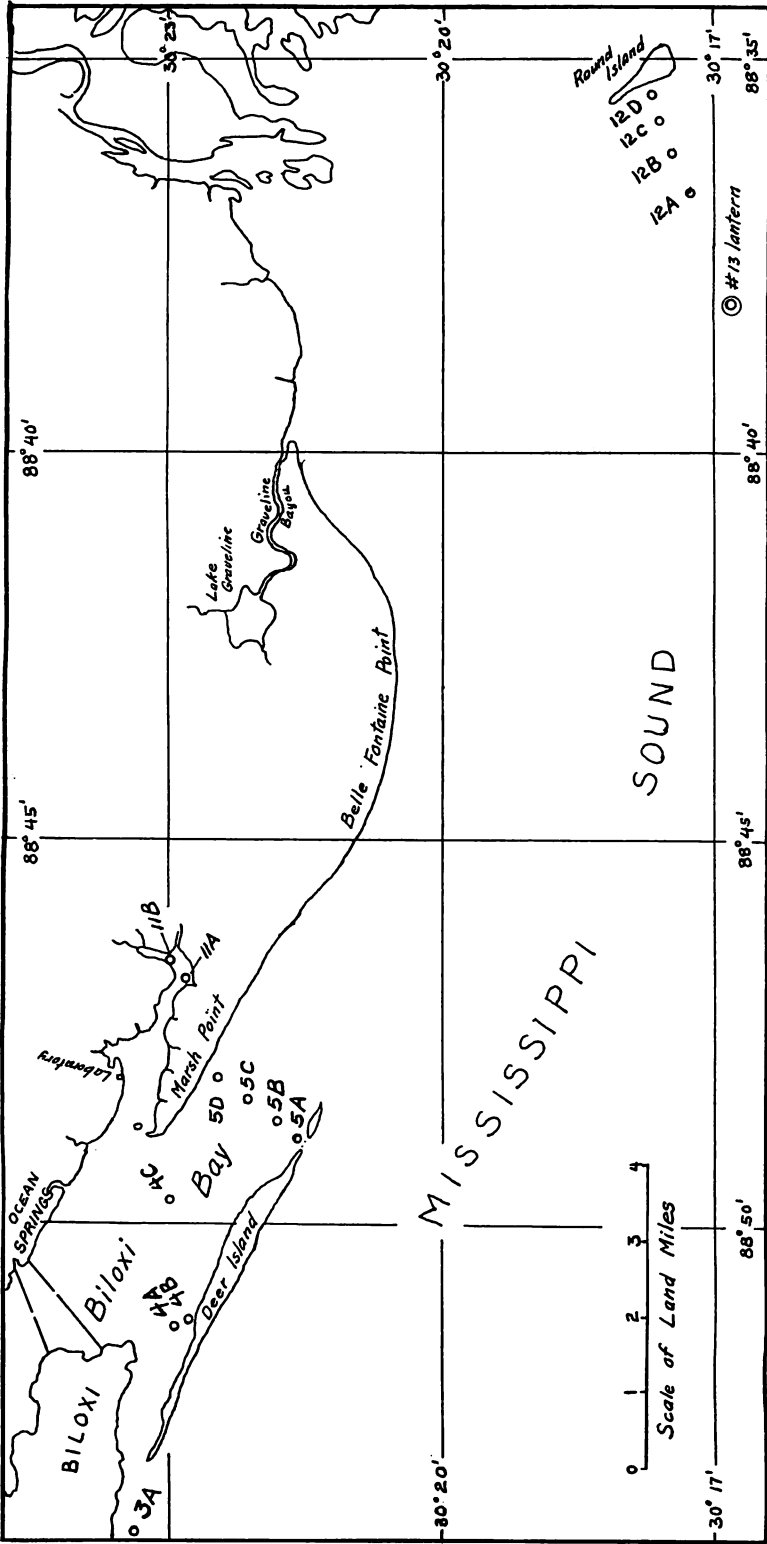


Plate 6.—Middle Mississippi Sound, 1952-1953 samplings.

tained compounded iron and sulphur. Further, it was apparent that the compound must be ferrous sulphide (FeS) because it evolved the gas when treated with the acid, whereas the only other iron-sulphur compound, represented by the minerals marcasite and pyrite (FeS_2), does not evolve H_2S gas when treated with acid. The next step was to determine the exact proportion of iron and sulphur in the sediments. The iron content was calculated in the course of the iron-aluminum procedures next described and the sulphur content was found in approximately the right proportion for compounding with the iron. The sulphur content was ascertained by conducting the hydrogen sulphide gas into solutions of lead acetate arranged in decreasing concentrations until all the sulphur was precipitated as black lead sulphide.

This form of iron sulphide is not unusual in fairly recent unconsolidated sediments and is now being recognized in many ancient dark consolidated fine sediments. It is known as hydrotroilite (FeS), a black amorphous mineral. As already mentioned, it is the chief pigment in most of the dark sediments in Mississippi Sound, especially in shrimp bottoms and in bayous. This finding is surprising since most dark sediments were long considered dark because of carbonaceous content alone. The hydrotroilite pigmentation of ancient Cretaceous sediments on the outcrop in northeast Mississippi has been recently discussed.⁵

Some geologists think that hydrotroilite (FeS) is the precursor of pyrite and marcasite, both FeS_2 minerals found in consolidated sediments. But the change from hydrotroilite to marcasite or to pyrite requires that an additional sulphur atom be made available, and that there be a lapse of time sufficient for the reaction to take place. Microscopic examination of 169 samples to date has failed to show either pyrite or marcasite in any present day Mississippi Sound bottoms, so these minerals must not be forming now. However, abundant pyrite is reported by Brown and others⁶ in wells along the coast and on the barrier islands, in sands so shallow that they are either Pleistocene or Recent (from 1 million to 15 thousand years old). Four pyrite bearing sands are cited.

Well Number	Location	Depth to pyrite in feet
161	U. S. Naval Depot No. 2 in Gulfport	5-25
199	Cat Island (center of south shore)	117-136
75	Magnolia State Park, near Ocean Springs	165-180
112	Horn Island Army Well No. 2 near west end Horn Island	0-46

If the pyrite found in these relatively recent beds was formed from hydrotroilite the additional sulphur atom must have already been in these sediments or it was brought in later by ground-water. If it is assumed that the sulphur was part of the original sediments it is likely that modern bottoms containing FeS also contain elemental sulphur. If such free sulphur is present in the sediments of the Sound today, it may have originated from oxidation of either organic sulphur or hydrogen sulphide gas. The latter seems a logical source, for the reason that this gas is frequently noted bubbling to the surface as the bottoms of some bayous are probed. In theory, the hydrogen sulphide could be oxidized to water and sulphur by air or by oxygen in the sea water when waves agitate the bottom at low tide. The gas could also be oxidized by unusual nitrate concentrations wherever nitrites are converted into nitrates by bacterial action. It is here proposed that in 1955 a search be made for elemental sulphur in Mississippi Sound sediments.

In the quantitative analyses of iron and aluminum it is necessary to remove the iron content first, inasmuch as both hydroxides are precipitated by bases and the brown iron gel masks the colorless to white alumina gel. In 1953 the iron was removed as follows: Ten-gram portions of the wet 3-inch core or 10-gram portions of dried, pulverized, and quartered sediments from 15-inch cores were digested in hydrochloric and nitric acids. The resultant ferric compounds were reduced by stannous chloride and the ferrous iron titrated with standard potassium permanganate in an acid solution. The titration was then calculated as percent iron. Next a 10-gram portion of each of the same sediments was digested in hydrochloric and nitric acids and the

combined alumina and ferric iron precipitated by ammonium hydroxide as aluminum and iron hydroxides. These gels were dried, burned, and weighed as combined alumina (Al_2O_3) and ferric oxide (Fe_2O_3). After the percent iron content found by the potassium permanganate titration was recalculated as ferric oxide it was subtracted from the combined oxides, the difference being the percent alumina. Conceivably there could have been other oxides present in the combined oxides, but they were considered negligible in amount.

The aluminum and iron determinations of the 3-inch cores in 1954 were obtained during the course of nitrite analyses. As will be pointed out, the nesslerization method used in nitrite determination is colorimetric, consequently all colored compounds which might mask the pink of nitrites had to be removed. Since all soluble iron compounds are colored, they were eliminated, by extraction from basic solution, as brown ferric hydroxide gel along with the colorless aluminum hydroxide. Separation and determinations of the iron and aluminum then followed the procedures described above.

Six of the 3-inch cores examined for nitrite, aluminum, and iron content were also examined for percent-loss-on-ignition.

Two bases for calculation of iron and aluminum are shown in Table 3. On the upper line are the actual percentages of alumina, ferric oxide, and the remaining oxides (chiefly silica) in the residue. On the lower line are the same percentages recalculated on the basis of the whole sample after allowance is made for loss-on-ignition (chiefly carbon which has escaped as oxides, and nitrogen as volatile nitrogenous compounds).

TABLE 3

IRON AND ALUMINUM CONTENT (AND LOSS-ON-IGNITION) OF 3-INCH CORES OF
BOTTOM SEDIMENTS

Sample number	Percent loss-on-ignition	Percent solid after ignition	Percent alumina in solid residue	Percent alumina in total sample	Percent ferric oxide in solid residue	Percent ferric oxide in total sample	Percent remaining oxides in solid residue	Percent remaining oxides in total sample
15B	8.32	91.68	44.21	40.53	4.63	4.24	51.16	46.90
9A	4.01	95.99	51.19	49.15	4.00	3.84	44.79	43.00
10B	3.78	96.22	57.49	54.32	3.05	3.27	39.11	37.62
30D	0.98	99.02	17.29	17.22	0.54	0.54	82.17	81.36
29E	0.20	99.80	2.63	2.62	0.16	0.16	97.20	97.01

15B—Davis Bayou, mud flat, clay

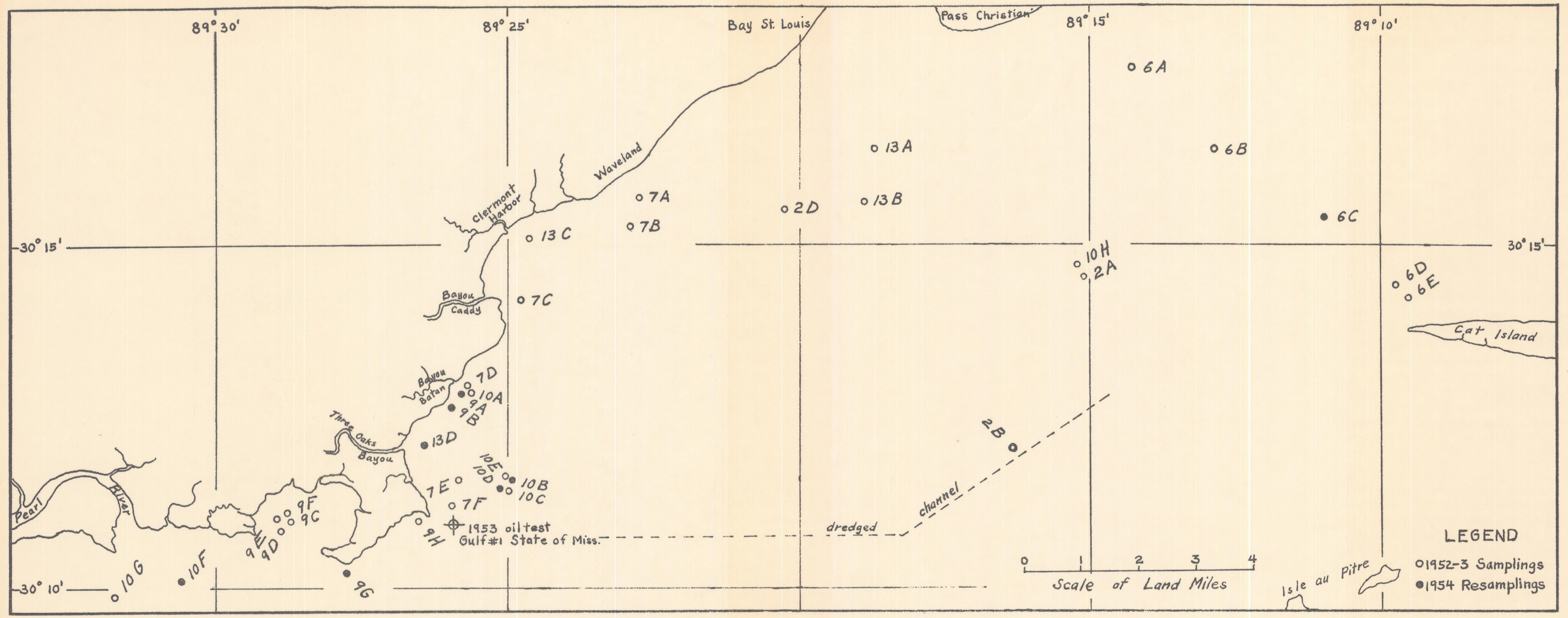
9A—Bayou Batan (Bolan), bayou mouth, silty clay

10B—St. Joe Point, edge oyster reef, silty clay

29E—entrance to Back Bay, low-tide beach, fine sand

30D—Back (Biloxi) Bay, shoal, sandy silt

In addition to indicating that aluminum and iron oxides are present in considerable quantity, the table shows that a definite relationship exists between the amounts of these oxides and the amounts of remaining oxides (chiefly silica as quartz sand grains). After each sample designation the geographical location, bottom topography, and kind of sediment are indicated (See Plates 2, 3, 4, 5, and 6, and all tables). It is easily seen that variations in the iron-aluminum content can be correlated with different bottoms. For example, there is little alumina but much silica in clayey inshore sample 15-B of Davis Bayou where the materials are land derived. Farther offshore at the mouth of Bayou Batan, in Sample 9-A, there is less silica and much more alumina, although the bottom is clay with additions of silt. In the more open Sound silty clay sample 10-B, at the edge of an oyster reef, shows even



more alumina and even less silica. As expected, there is little alumina in sandy shoals (sample 30-D) and almost none in beach sands (sample 29-E). It would therefore appear that alumina, in the 3-inch cores, is more abundant in the more open waters than inshore or than in more closed waters, and is negligible in beach sands.

Analyses show that there is a greater amount of aluminum in the water-logged stratum above shrimp bottom than in the 3-inch or 15-inch cores. As stated, this stratum may have a thickness up to 12 inches over shrimp bottom, rarely exceeds 1 inch over oyster bottom, and is negligible over beach sands. It will be recalled that these finer sediments were extracted by the vacuum device (Figure 3). Early experiments suggested that the aluminum content was high since these water-logged sediments became partly gelatinous on being made alkaline and the gel was dispersed on the addition of acid. Subsequent analyses indicated alumina up to 65 percent. Table 4 shows this alumina content greatest in sheltered waters (sample 15-B) and over shrimp bottom (sample 9-A); considerably less over sandy shoals (sample 30-D); small over oyster reefs (sample 10-B); and negligible over beach sands (sample 29-E). The high content in sheltered waters is believed due to continual additions through land runoff and little dispersion by wave action. But the thick highly aluminous stratum over shrimp bottoms is believed due to concentration of alumina there by wave action as agitated waters progressively remove it from the adjacent slightly higher reefs. The same wave action should also remove most of the aluminous material from sandy shoals, and all of it from sandy beaches.

TABLE 4

IRON AND ALUMINUM CONTENT (AND LOSS-ON-IGNITION) OF FLOCCULANT SURFACE SEDIMENTS

Sample number	Percent loss-on-ignition	Percent solid after ignition	Percent alumina in solid residue	Percent alumina in total sample	Percent ferric oxide in solid residue	Percent ferric oxide in total sample	Percent remaining oxides in solid residue	Percent remaining oxides in total sample
15B	12.41	87.59	65.17	57.08	7.16	6.27	27.67	24.23
9A	14.28	90.72	52.40	47.53	5.48	4.97	42.12	38.21
10B	5.74	94.26	15.22	14.34	3.06	2.88	81.72	77.03
30D	1.61	98.39	20.19	19.86	0.40	0.39	79.41	78.13
29E	0.03	99.97	1.26	1.25	0.09	0.09	98.65	98.62

15B—Davis Bayou, mud flat, clay

9A—Bayou Batan (Bolan), bayou mouth, silty clay

10B—St. Joe Point, edge oyster reef, silty clay

30D—Back (Biloxi) Bay, shoal, sandy silt

29E—Entrance to Back Bay, low-tide beach, fine sand

Tables 3 and 4 also show the distribution of iron, calculated as ferric oxide. Just as comparisons are made on the distribution of alumina, comparisons can be made on the distribution of ferric oxide. Table 3 indicates that the iron content of the 3-inch cores is greater near shore, especially in bayous and on the landward sides of shrimp bottom areas (samples 15-B and 9-A); less in sandy shoals (30-D); small in oyster bottom (10-B); and negligible in beach sands (29-E). The iron in the bayous seems to be in two forms, ferrous sulphide and ferric hydroxide. The ferrous sulphide, the amorphous mineral hydrotroilite (FeS) has been mentioned as the chief pigment in the dark to black sediments. The mineral is so finely divided that it is barely distinguishable, microscopically, but its presence is indicated by great evolution of hydrogen sulphide (H₂S) and the production

of green iron chlorides on the addition of hydrochloric acid. The iron hydroxides are common in the bayous, frequently as bead-like gelatinous masses attached to weeds and grasses at the water's edge. As the vegetation dies during the winter months much of this gel dehydrates to form the limonitic cement for masses of decaying and drying vegetation. In the more open but deeper waters iron sulphide predominates over ferric hydroxide suggesting that the oxidized form is a product of wave action in the shallower bayous or that it is due to the iron-fixing characteristics of some of the plants which line the bayous.

Nearly the same relationships of ferrous sulphide to ferric hydroxide are noted in the vacuum samples of water-logged sediments as in the materials comprising the 3-inch cores. Iron contents of several vacuum samples are recorded in Table 4. The analyses records are similar to those in Table 3 except for a ferric oxide value far greater in the bayous than in the open water. This concentration is probably due to the tendency of the gelatinous ferric hydroxide to float and thereby to accumulate in the flocculant stratum. It may be due, also, to the finely divided ferrous sulphide mineral remaining in suspension longer than the coarser siliceous grains, which settle more rapidly.

NITROGEN DETERMINATIONS

Probably the greatest achievement in 1954 was the recognition of nitrite nitrogen in the vital upper 3 inches of bottom sediments and in the overlying, flocculant, water-logged stratum. Now, four forms of nitrogen are recognized: Combined ammoniacal and organic nitrogen (listed in the plates as amino nitrogen); nitrate nitrogen; nitrite nitrogen; and total nitrogen. As far as is known, this is the first time a differentiation in nitrogen content has been made in a study of unconsolidated marine sediments, although various nitrogen analyses of the overlying waters are common.

As used here, the ammoniacal-organic nitrogen means the ammonium and amino nitrogen present in organic material. Its analysis is made possible by converting ammonium and amino nitrogenous material into ammonium sulphate by means of sulphuric acid digestion in the presence of a catalyst, distilling off the ammonia gas by liberating it with a strong alkali, collect-

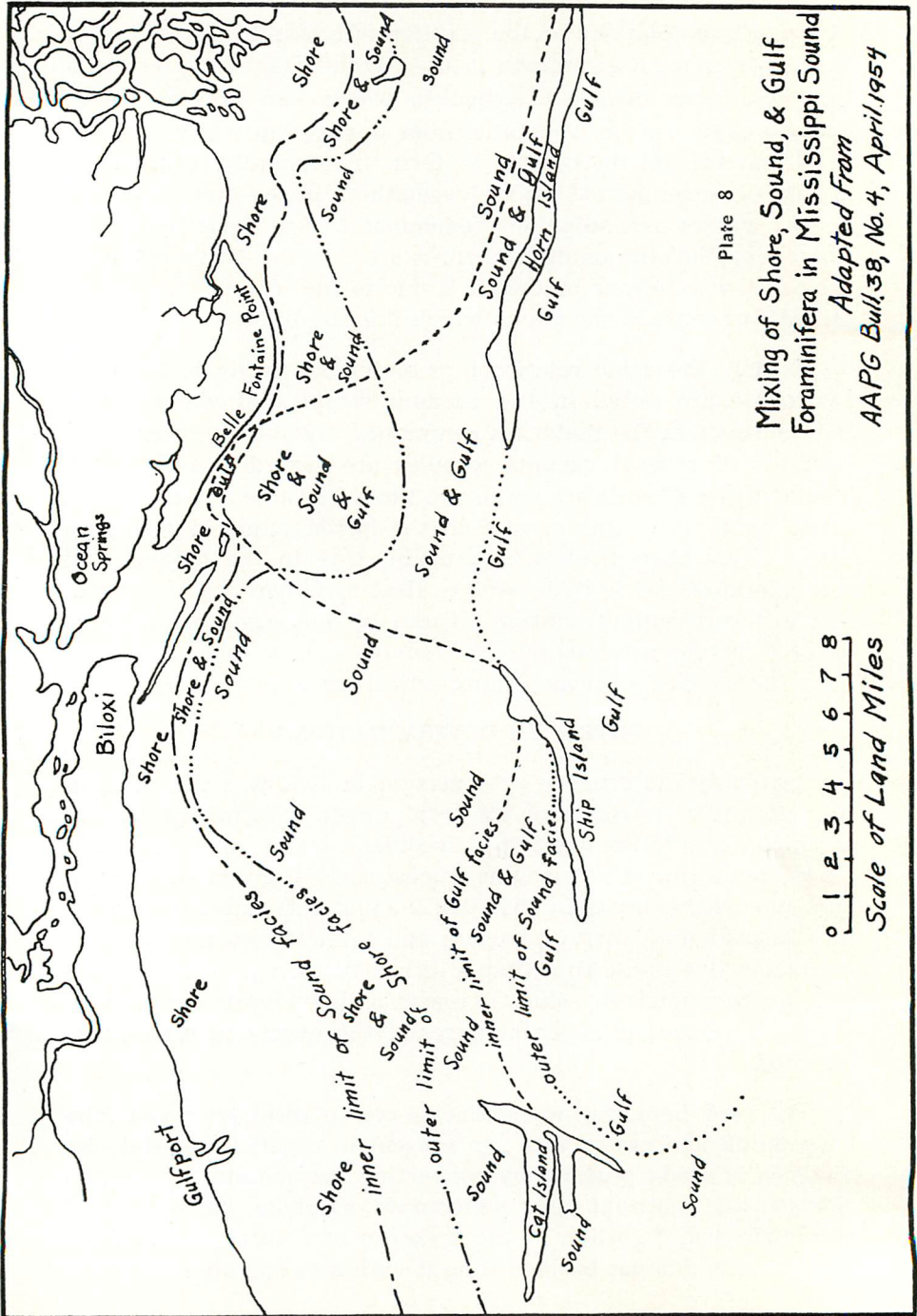
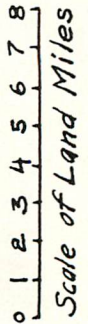


Plate 8

Mixing of Shore, Sound, & Gulf
Foraminifera in Mississippi Sound
Adapted From
AAPG Bull. 38, No. 4, April, 1954



ing the gas in a standard boric acid solution, and, finally, titrating the ammonium borate so obtained with constant boiling hydrochloric acid. A 10-gram sample each of all the wet 3-inch cores and a similar sample of all the dried homogenized 15-inch cores were so analyzed. Determinations of 15 vacuum samples were also made, analyses of which are shown in Table 6.

These tables also show total nitrogen analyses of the same wet and dried 3-inch and 15-inch samples. As stated before, this total nitrogen includes the combined ammoniacal-organic material, nitrate nitrogen, and nitrite nitrogen. The total nitrogen analyses are conducted in the same manner as the analyses of the ammoniacal organic nitrogen, except that the sediments are treated with salicylic acid and sulphuric acid to make nitro-salicylic acid, which is then reduced by sodium thiosulphate before the addition of the alkali.

For the more exacting nitrite determinations a modified nesslerization procedure was used, a variation of the colorimetric method used in nitrite analysis of sewage: A nitrite extract, prepared from the sediment, is compared with standard nitrite solutions in Nessler tubes arranged in order of increasing nitrite content. Twenty-eight analyses of 3-inch cores were thus made while the samples were fresh and wet, and 15 determinations were made on freshly collected vacuum samples. All values are recorded in Tables 6 and 7, and results are summarized in Table 5. The extracts were made by shaking 10-gram portions of the sediment with 10 ml. concentrated hydrochloric acid and a one-ml. portion of stannous chloride in 100 ml. water. The resultant solution is yellow-green due to iron compounds which must be removed by making the solution alkaline with ammonium hydroxide. The precipitated iron and associated aluminum hydroxides are then removed by filtering. The now pink nitrite extract is then compared with the pink solutions of standard nitrites in the tubes. The hydroxides are reserved for the iron-aluminum analyses.

TABLE 5
NITROGEN CONTENT
(AND LOSS ON IGNITION) OF 3-INCH CORES OF BOTTOM SEDIMENTS

Sample number	Percent Amino nitrogen	Percent Nitrate nitrogen	Percent Nitrite nitrogen	Percent Total nitrogen	Percent loss- on-ignition
15B	0.120	0.034	0.020 ** 0.005 *	0.174	8.32
9A	0.138	0.148	0.012 ** 0.004 *	0.298	4.01
10B	0.034	0.015	0.004 ** 0.0012*	0.053	3.81
30D	0.045	0.013	0.001 ** 0.0002*	0.059	0.98
29E	0.005	0.0005	0.0005 too small	0.006	0.20

15B—Davis Bayou, mud flat, clay

9A—Bayou Batan (Bolan), bayou mouth, silty clay

10B—St. Joe Point, edge oyster reef, silty clay

30D—Back (Biloxi) Bay, low-tide beach, fine sand

29E—Entrance to Back Bay, shoal, sandy silt

**recalculated nitrite values

*true nitrite values

However, the method of nitrite analyses described above is not considered entirely satisfactory, because it is suspected that not all of the nitrite is present in the extract. This supposition is based on the discovery that the iron-aluminum content in the extract is only 5 to 15 percent of that obtained by regular iron-aluminum analyses. The deficiency of nitrite in the extract is thought to account for the very low values shown in Table 6—low values which are also recorded in the lower line of Table 5. The larger values on the upper line of Table 5 are recalculated on the basis of the observed iron-aluminum deficiency, as indicated in the footnote. These larger nitrite values are used only until such time as an accurate method of nitrite analysis is found. A better method of nitrite determination is therefore one of the goals of this investigation for 1955.

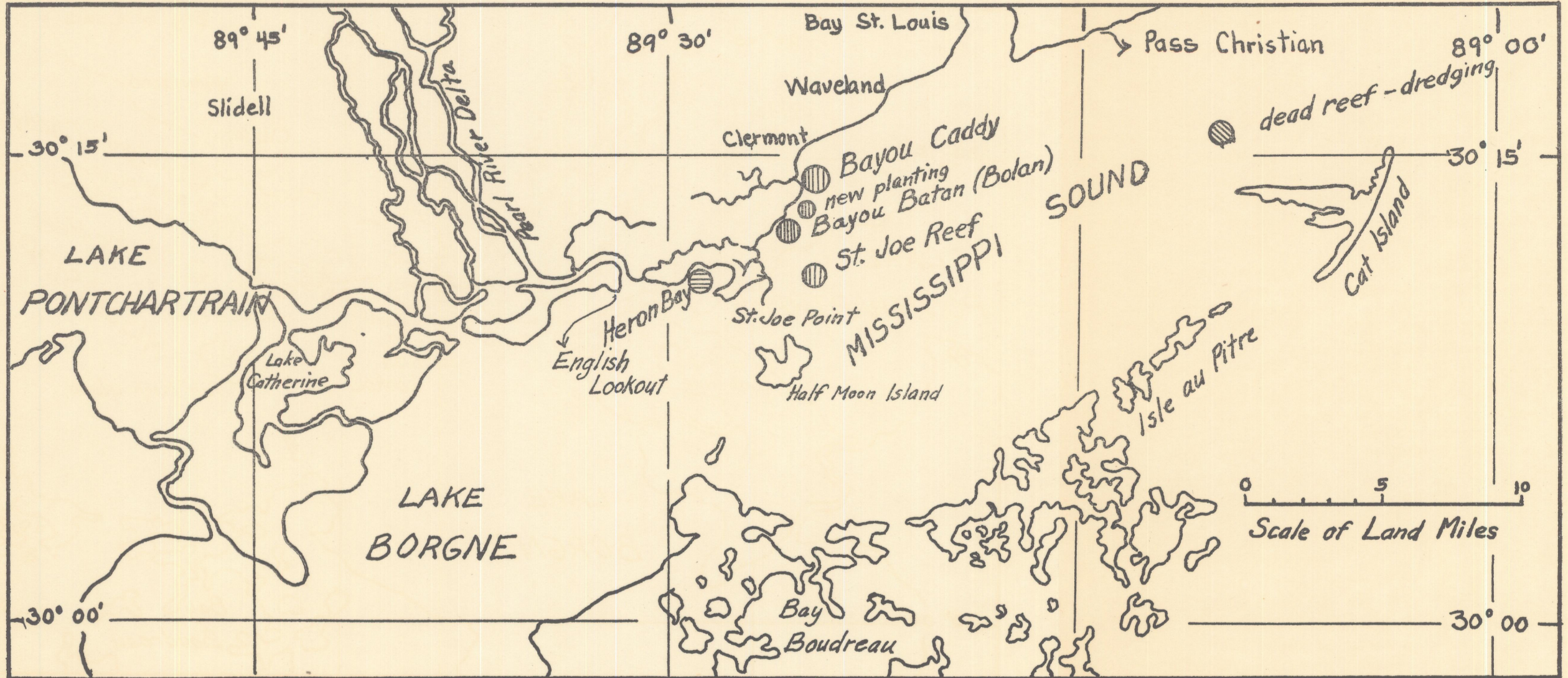


Plate 9.—Oyster plantings in Western Mississippi Sound.

Nitrate nitrogen is calculated as the difference between total nitrogen and the sum of the nitrite and amino nitrogen values. Because of the low nitrite figures explained above, the total nitrogen reported in Table 5 is often at variance with the total of nitrate, nitrite, and amino nitrogen.

Analyses records of five samples are compared in Table 5 in order to show how geographical environment, bottom topography, and kind of sediment are related to differences in the quantity of the four kinds of nitrogen. The fifth column of the table shows percent-loss-on-ignition values which indicate vegetable content and hence are believed to have a direct relation to the amino nitrogen content. The five samples compared are the same as those used in Tables 3 and 4 which were designed to show iron and aluminum content.

In sample 15-B of Table 5 the relatively high total nitrogen content seems to be due to a large amount of amino nitrogen, which in turn suggests a large amount of vegetable material as testified to by a high loss-on-ignition value. Both nitrates and nitrites are high, indicating that oxidation is starting in this shallow area near the mouth of Davis Bayou. The composition of Sample 9-A, from the exposed mouth of Bayou Batan in the west, open part of the Sound, shows that oxidation of nitrites is very effective there, or that land derived nitrates are available, possibly brought in by currents from the not-too-distant mouth of Pearl River (see Sample 10-G of Table 7). In contrast, 10-B, which was sampled nearby and on the same date, shows little nitrate, nitrite, and amino nitrogen, suggesting that the nitrates from the river do not pass over the oyster reef at St. Joe Point. This observed difference in nitrate content of Samples 9-A and 10-B points out the need for a study of currents in the Sound, especially over oyster reefs or bottoms which are believed firm enough to support oyster plantings. Whereas sandy sample 30-D in Tables 3 and 4 showed the expected deficiency of iron and aluminum in sandy shoals, sample 30-D showed an unexpected amount of nitrogen, mostly of the amino type, which may account for the good oyster growth in Biloxi (Back) Bay where the pollution by sewage is high. As expected, nitrogen content is low in sample 29-E from the entrance to Back Bay where winds and tide prevent the accumulation of nitrogen.

LOSS-ON-IGNITION DETERMINATIONS

Loss-on-ignition values are the last chemical determinations to be directly related to the physical environment of the sediments. On page 29 they are discussed as being indicative of carbonaceous content. Some values are shown in Tables 3, 4, and 5 as adjuncts to the iron-aluminum and nitrogen determinations. Table 7, a summary of the 1952-1953 results, shows 49 other determinations, 27 of 3-inch samples, 22 of 15-inch samples. However, because time did not permit the finding of many loss-on-ignition values in 1954, few are shown in Table 6.

These loss-on-ignition determinations indicate the relative amounts of materials capable of being altered by temperatures ranging from 96 degrees Fahrenheit (the maximum temperatures used for obtaining loss-on-drying values) and the highest temperature attained by a Fisher burner (about 1500 degrees Centigrade). The materials believed altered are 1) vegetable debris, both carbonaceous and nitrogenous, 2) calcium carbonate as shell material, and 3) inorganic hydroxides and salts.

Of these, the alteration of vegetable debris is believed to be the most important since samples having the highest loss-on-ignition are in most cases those having the largest visible vegetable content as detected in microscopic examination and in elutriation procedures. The loss in vegetable material is believed due to dehydration, the oxidation of carbon to carbon dioxide or carbon monoxide, and the conversion of nitrogenous materials into oxides of nitrogen. The calcium carbonate material of shells is revealed as loss-on-ignition by calcining as carbon dioxide is driven off, but this alteration is considered negligible except in samples from oyster reefs. Similarly, loss due to alteration of inorganic hydroxides and salts is considered low, inasmuch as dehydration of hydroxides accounts for but little loss in weight.

Brief references to Tables 5 and 7 will show the value of correlating loss-on-ignition determinations of 3-inch samples with environment, especially with vegetation. Sample 15-B in Table 5 was found to contain high amino nitrogen and showed a very high percent-loss-on-ignition, reflecting the high carbonaceous content of a bayou mouth. In contrast, sample 29-E had the very low nitrogen content and very low vegetable content of

depth in feet	Vacuum Sample				top 3 inches of 15-inch core							entire 15-inch core									
	Bottom Topography	salinity	kind of sediments	percent alumina	Percent Fe ₂ O ₃	percent loss on ignition	kind of sediment	Density				Nitrogen Analyses					kind of sediment	Nitrogen Analyses			
								wet	dried	percent loss on drying	ground	percent alumina	Percent Fe ₂ O ₃	percent loss on ignition	total	wet		total	dry	amino	dry

East Stark Bayou 7-13-54																											
14 A	3	mud flat	21.04				Soft clay mud																				
14 B	9	bayou channel	20.72				Soft clay mud																				
14 C	8	bayou channel	20.32				Soft clay mud																				
14 D	7	bayou channel	15.54				Soft clay mud																				
Davis Bayou, Oyster shack traverse 7-15-54																											
15 A	2½	mud flat	25.16				Soft clay mud	1.35	2.35	74.3	1.05			0.052	0.146	0.095							Soft clay mud	0.173	0.165	0.002	0.007
15 B	3	mud flat	25.14	65.17	7.16	12.41	Soft clay mud	1.31	2.49	80.0	1.07	44.21	4.63	8.32	0.060	0.174	0.120	0.034	0.002				Soft clay mud	0.078	0.039	0.011	0.032
15 C	3	mud flat	25.14				Soft clay mud	1.66	2.92	65.8	1.16				0.030	0.155	0.072						4" mud, silty clay	0.029	0.015	0.003	0.010
15 D	3½	edge channel	26.09				Soft silty mud	1.69	2.47	53.6	1.31				0.038	0.134	0.044						alternating clay & silt	0.024	0.020	0.003	0.004
15 E	5	channel	25.66				Sandy silt, hard	1.92	2.60	42.8	1.35				0.026	0.141	0.038						11" silty silt, clay mud	0.055	0.030	0.021	0.006
Davis Bayou, Richards traverse 7-16-54																											
16 A	3	mud flat	24.07				Soft clay mud	1.24	2.06	77.2	0.96				0.134	0.206	0.097						Soft clay mud	0.088	0.055		
16 B	3	mud flat	25.43				Soft clay mud	1.32	2.74	82.5	1.03				0.140	0.265	0.125						Soft clay mud	0.048	0.022	0.004	0.023
16 C	3	mud flat	23.82				Soft clay mud	1.33	2.68	80.1	1.07				0.078	0.176	0.147						Soft clay mud	0.084	0.047		
16 D	3½	edge channel	22.86				Silty clay mud	1.38	2.52	74.8	1.07				0.098	0.165	0.162						alternating silt & clay	0.093	0.070		
16 E	5	in channel	22.85				Sandy silt, oysters	1.49	2.80	73.0	1.13				0.078	0.152	0.125	0.018	0.009				Silt, oyster shell	0.043	0.027	0.011	0.009
16 F	5	edge channel	22.61				Sandy silt, firm	1.64	2.76	64.0	1.21				0.060	0.119	0.099						Sandy silt, shells	0.015	0.011	0.006	0.001
Marsh Point recurved spit 7-19-54																											
17 A			22.88																								
17 B			23.10																								
17 C			23.11																								
Davis Bayou, water intake traverse 7-20-54																											
18 A			23.28																								
18 B			23.55																								
18 C			22.95																								
18 D			22.34																								
18 E			21.76																								
Graveline Bayou, near west end 7-23-54																											
19 A	2	SW bank bayou	17.90				Soft clay mud	1.45	2.16	77.5	0.96				0.108	0.221	0.198						Soft clay mud	0.228	0.162		
19 B	7	center channel	18.69	60.13	5.19	9.00	Sandy silt, oysters	1.45	2.47	75.4	1.02				0.059	0.143	0.129	0.010	0.004				Sandy silt	0.127	0.108	0.020	0.0001
19 C	3	NE bank bayou	18.48				Soft clay mud	1.30	2.28	77.0	1.04				0.062	0.190	0.172						Soft clay mud	0.144	0.119		
Graveline Bayou 7-23-54																											
20 A	2	mouth small bayou	19.11				Soft clay mud	1.55	2.44	72.1	1.13				0.081	0.085	0.064						Soft clay mud	0.113	0.110		
20 B	4	mouth of same	18.08				Sand (sand bar)	1.94	2.89	50.2	1.33				0.061	0.087	0.034	0.052	0.0001				no sample	0.058	0.032		
20 C	5	N bank bayou	18.30				mud, soft	1.29	2.34	78.2	0.93				0.067	0.165	0.138						Soft clay mud	0.106	0.074		
Graveline Bayou 7-23-54																											
21 A	7	W bank bayou	17.90				Silty, oysters	1.83	2.57	46.9	1.19	3.60	3.24	0.035	0.052	0.044							5" silty, clay mud	0.062	0.039		
21 B	9	center channel	18.91				Silty, oysters	1.96	2.56	38.3	1.24	3.72	3.04	0.034	0.050	0.030	0.019	0.0009					Silty clay	0.056	0.032	0.024	0.0001
Graveline Bayou 7-23-54																											
22 A	9	E bank bayou	18.66				Silty, oysters	1.34	2.47	76.9	0.82				0.081	0.139	0.093						6" silty, stiff mud	0.106	0.095		

depth in feet	Vacuum Sample						top 3 inches of 15-inch core								entire 15-inch core												
	Bottom Topography	salinity	kind of sediment	Percent alumina	Percent Fe ₂ O ₃	percent loss on ignition	kind of sediment	Density				Percent alumina	Percent Fe ₂ O ₃	Percent loss on ignition	Nitrogen Analyses					kind of sediment	Nitrogen Analyses						
								wet	dried	percent loss on drying	ground				total wet	total dry	amino dry	nitrate dry	nitrite dry		total	amino	nitrate	nitrite			
<i>Biloxi railroad bridge 8-10-54</i>																											
29A	6 off beach	22.63					silty clay	1.55	2.52	64.2	1.02						0.039	0.105	0.098					alternate clay, silt	0.108	0.091	
29B	10 broad bottom	23.15					silty clay	1.38	2.64	77.5	0.93						0.064	0.172	0.118	0.004					" " "	0.122	0.115
29C	12 broad bottom	22.14					clay mud	1.25	2.34	82.5	0.96						0.055							unstratified			
29D	9 broad bottom	22.09					clay mud	1.32	3.10	83.1	0.96						0.083	0.191	0.131					"	0.161	0.121	
29E	2 sandy shoal	18.69	1.26	0.09	0.03		silty sand	1.88	2.61	45.4	1.31	2.63	0.16	0.20	0.019	0.006	0.005	0.0005	0.0005	0.0005					layers sd, clay		
<i>Back Bay, northwest 8-10-54</i>																											
30A	6 edge channel	19.05					silty clay	1.47	2.60	70.4	0.93						0.074	0.115	0.086					layers sd, silt	0.116	0.085	
30B	5 broad bottom	17.85					clay mud	1.65	2.88	65.2	1.04						0.059	0.166	0.095					layers clay, silt	0.096	0.064	
30C	7 broad bottom	20.21					clay mud	1.31	2.66	81.5	0.90									0.001				" " "			
30D	3 sandy shoal	19.05	20.19	0.40	1.61		silty sand	1.80	2.75	54.0	1.08	17.29	0.54	0.98	0.042	0.059	0.045	0.013	0.001					layers " " "	0.076	0.034	
30E	6 silty shoal	19.83					sandy silt	1.99	2.70	42.4	1.20						0.039	0.050	0.041	0.005				" " "	0.057	0.027	
30F	4 off beach	20.70					silty clay	1.78	2.73	55.2	1.08						0.053	0.062	0.055					layers peat, clay	0.229	0.190	
<i>Back Bay, southeast 8-10-54</i>																											
31A	5 off beach	22.00					silty clay	1.41	2.28	67.9	0.96													alternate clay, sd.			
31B	6 off beach	21.74					silty clay	1.34	2.42	76.1	1.00						0.057	0.112	0.030					" " "	0.139	0.130	
31C	5 off beach	22.01					silty clay	1.36	2.21	80.2	0.84													" " "			
<i>Bay of St. Louis, railroad bridge 8-18-54</i>																											
32A	4 edge beach	21.38					sandy silt	2.00	2.76	43.3	1.30						0.034	0.041	0.012					sand, silty layers	0.060	0.049	
32B	7 edge reef	21.39					silty clay	1.44	2.91	77.2	1.04						0.074	0.114	0.053	0.001				layers clay, silt	0.046	0.041	
32C	8 side channel	21.37					clay mud	1.52	3.04	74.8	1.02													unstratified			
32D	8 side channel	21.38					clay mud	1.31	2.16	73.2	1.01						0.078	0.152	0.096	0.0005				"	0.122	0.088	
32E	7 broad bottom	22.06					silty clay	1.25	2.21	79.3	0.94						0.070	0.155	0.129					layers silt, clay	0.091	0.088	
<i>Bay of St. Louis, Yacht Club 8-18-54</i>																											
33A	4 edge beach	21.38					silty sand	1.89	2.48	40.0	1.24						0.033	0.036	0.027					layers sd, silt	0.015	0.010	
33B	8 edge channel	20.72					clay mud	1.31	2.60	80.8	1.00													unstratified			
33C	8 edge channel	20.74					clay mud	1.28	2.69	82.1	1.04						0.065	0.156	0.161					"	0.110	0.049	
33D	5 edge reef	20.73					clayey silt	1.73	2.68	56.5	1.08						0.098	0.088	0.055	0.001				layers clay, silt	0.111	0.074	
33E	4 edge reef	20.72					clayey silt	1.81	2.67	51.7	1.09						0.066		0.107					" " "			
<i>Bay of St. Louis, Cowland Point 8-18-54</i>																											
34A	5 mud flat	19.38					clay mud	1.59	2.37	70.8	1.06						0.071			0.0009				unstratified			
34B	5 mud flat	19.16					clay mud	1.37									0.064			0.002				"			
34C	5 mud flat	19.20					clay mud	1.48									0.068			0.001				"			

Pass Christian to Telegraph Reef
Sampled July, August 1952
2A
2B
2C
2D
off Biloxi 3A
Deer Island 4A
4B
4C
Marsh Point 5A
5B
5C
5D
Pass Christ. Cat Island 6A
6B
6C
6D
6E
Pass Christian to St. Joe 7A
7B
7C
7D
7E
7F

sampled 1953
Pass Christian to Heron Bay 9A
9B
9C
9D
9E
9F
9G
9H
Pass Christian to Pearl mouth 10A
10B
10C
10D
10E
10F
10G
10H
Davis Bayou 11A
11B
Round Bayou Island 12A
12B
12C
12D
8-14-53

microscopic analysis (kind of sediment)	bottom topography	depth in feet	homogenized 15" sample			stations resampled				stender dish samples — upper 3 inches								
			ammoniacal & organic nitrogen	percent loss on ignition		Aug. 20	Aug. 26	Aug. 31	Sept. 2	volume	weight	density	total nitrogen	ammoniacal & organic nitrogen	nitrate (or nitrite) nitrogen	% loss on drying	% loss on ignition	
sandy silt	edge of reef	11				2A				49.7	103.6	2.08	0.046	0.037	0.009	29.6	6.07	2A
sandy silt	edge of reef	12				2B				51.7	86.8	1.68	0.061	0.044	0.017	38.8	4.10	2B
sandy silt	edge of reef	9																
silty sand	broad water	9																
silty clay	edge channel	10																
silty clay	spoil area	6				4A							0.070	0.059	0.011		5.11	4A
silty clay	backwater	3				4B							0.165	0.143	0.022		7.91	4B
silty clay	broad water	10				4C							0.142	0.123	0.019		7.51	4C
silty sand	edge of reef	4																
silty sand	broad water	9																
silty clay	broad water	11																
silty sand	shallow beach	4																
silty clay	broad water	12				6A				57.3	99.6	1.73	0.083	0.058	0.025	48.8	4.25	6A
silty clay	broad water	15				6B				51.2	68.1	1.33	0.141	0.137	0.004	64.2	10.07	6B
silty clay	edge of reef	16				6C				49.9	78.5	1.57	0.136	0.126	0.010	75.7	9.30	6C
sandy silty	off sandbar	13				6D				54.0	108.2	2.03	0.030	0.023	0.007	22.7	1.97	6D
silty sand	edge sandbar	15				6E				48.7	104.0	2.13	0.032	0.021	0.011	20.1	1.23	6E
sandy silt	*broad bottom	9				7A				49.7	86.6	1.74	0.053	0.051	0.002	17.6	3.00	7A
sandy silt	broad bottom	14				7B				54.2	78.7	1.45	0.086	0.067	0.019	20.3	4.50	7B
silty clay	*bayou mouth	4				7C				50.0	81.1	1.62	0.100	0.097	0.003	23.8	4.65	7C
sandy silt	bayou mouth	12				7D				50.5	65.4	1.29	0.162	0.291		32.0	7.35	7D
sandy silt	off reef	10				7E				55.0	79.4	1.44	0.109	0.076	0.033	23.9	5.10	7E
clay	deep off shoals	12				7F				49.5	64.3	1.30	0.181	0.246		26.1	11.40	7F
silty clay	bayou mouth	9	0.109	9.80		9A				49.7	75.8	1.52	0.133	0.122	0.011	48.9	9.86	9A
clay	*bayou mouth	9	0.103	15.29		9B				50.0	77.7	1.55	0.128	0.125	0.003	46.9	8.21	9B
silt	*shallow bay	5	0.093	6.45		9C				54.0	90.7	1.66	0.072	0.067	0.005	30.9	4.23	9C
silty clay	*shallow bay	6	0.122	5.82		9D				49.5	76.5	1.54	0.123	0.114	0.009	43.8	7.77	9D
silty clay	*shallow bay	6	0.039	8.69		9E				57.3	103.9	1.81	0.160	0.136	0.024	42.9	7.49	9E
silty sand	*shallow bay	6	0.037	2.03		9F				51.7	97.5	1.88	0.042	0.027	0.015	24.0	1.60	9F
silt	deep off point	8	0.091	6.62														
silty clay	shallow point	6	0.156	9.89														
clay	*bayou mouth	10	0.209	15.00		10A				50.5	69.1	1.37	0.172	0.170	0.002	61.5	16.24	10A
silty clay	*edge of reef	9	0.039	3.81		10B				48.7	92.5	1.90	0.052	0.031	0.021	31.6	3.45	10B
silty clay	*edge of reef	9	0.038	3.83		10C				55.0	94.0	1.71	0.058	0.032	0.026	31.7	3.52	10C
clay	*edge of reef	9	0.046	5.35		10D				50.3	83.3	1.65	0.069	0.055	0.014	38.9	3.62	10D
silty clay	*edge of reef	9	0.058	15.92		10E				51.2	82.1	1.60	0.066	0.048	0.018	37.9	4.70	10E
silty clay	off mudbar	6	0.426	5.37														
clay	river mouth	6	0.608	4.99														
silty clay	*edge of reef	10	0.941	14.77														
clay	broad shallow	3	0.111	8.73														
silty clay	broad shallow	1	0.135	7.71														
clay	broad bottom	14	0.129	10.76														
sandy silt	broad bottom	15	0.057	5.27														
silty sand	broad bottom	11	0.056	3.97														
fine sand	edge sandbar	8	0.036	3.90														

* oyster plants dead oyster reef

tide-swept sandy bottoms. Similarly, in Table 7 samples 7-D and 10-A from the west part of the Sound had unusually high amino nitrogen and loss-on-ignition values, due to the proximity of bayou mouths contributing vegetable debris.

RESUME OF OYSTER PLANTINGS IN WEST MISSISSIPPI SOUND

Since continued reference has been made to oyster plantings in Mississippi Sound it is appropriate that they be reviewed here. In the summer of 1952 it was noted that the firmer bottoms in west Mississippi Sound contained more muscovite mica cleavage flakes than those farther east. Inasmuch as the same observation was made in 1953, it was thought that such micaceous sediments might provide a bottom firm enough to support growing oysters, especially since angular quartz grains were predominant. Accordingly, about 75,000 barrels of old oyster shells were planted by the Mississippi Seafood Commission in late 1952 and early 1953 at the localities shown in Plate 9.

Now, in 1954, two years after the first plantings, some oysters four inches long have been harvested in the three larger localities. Oysters three inches long have been sampled at the smaller planting marked "new planting," made in early 1953. Only one planting failed, that is the Heron Bay area farthest to the west where too much fresh water from Pearl River seems to have prevented a good "set" of spat on the old shells.

Early visits having showed the apparent success of these ventures, the areas of plantings were enlarged by the addition of nearly 50,000 barrels of old shell. Another planting has been made recently off Deer Island in outer Biloxi Bay, far to the east, nearer the center of Mississippi Sound. At this point, 4 miles due south of Ocean Springs Harbor, the bottom is relatively firm and already inhabited by a few gigantic hermit oysters.

RECOMMENDATIONS

As a result of three summers' investigation of the bottoms of Mississippi Sound it is recommended that the study be continued with a) the present sampling program, b) continued improvement in collecting techniques, and c) more refined methods of chemical analyses of sediments. However, before these aims are

discussed in detail it is best that certain specific problems be mentioned.

These problems are mentioned in the body of this report as references to the need for specialized study in 1955, to explain discrepancies in earlier findings or to strengthen observations. They are as follows:

A seasonal check on the relative amounts and constitution of the flocculant material which comprises the water-logged stratum so thick over shrimp bottoms and in bayous, at easily accessible locations near the Laboratory. Samples could be stored for periodic examination and a check made against the salinity readings of the water above these sediments. Any changes due to salinity could thus be ascertained.

A search for elemental sulphur in the sediments in order to see if the sulphur necessary for the conversion of hydrotroilite (FeS) to marcasite or pyrite (both FeS_2) is in the sediments when deposited, or whether it is brought in by ground water during later lithification of the clays or silty clays.

A better method of nitrite determination so that nitrite extracts can be made without danger of converting nitrites to nitrates as the colored iron compounds are removed.

A study of the currents of the Sound in order to determine whether highly nitrogenous sediments are due to *in situ* deposition from vegetable materials at hand, or whether, as suspected, they are high in nitrogen because of currents carrying nitrogenous materials from rivers or creeks entering the Sound. A further need in a study of currents is an investigation of the top and bottom movements of waters in Davis Bayou, the two-mile long tidal basin in front of the Laboratory (Plate 2). Dyeing the waters for making current studies is a well established and inexpensive method.

The first general recommendation, a continuation of the present sampling program, should include further sampling of the indentations along the mainland bordering Mississippi Sound. First, outer Biloxi Bay, especially Deer Island Sound, should be examined in great detail for bottoms firm enough to support growing oysters. Second, Pascagoula Bay and its bayous should

be studied in hopes of finding another oyster growing area as prolific as nearby Graveline Bayou where oysters have been propagated. A third area which should be studied is the coastline from Pascagoula east to Mobile Bay where oysters have also been successfully planted. Lastly, it is suggested that a preliminary sampling be made of the outlying areas of the Sound where the charts show harder bottoms or obstructions (which might have collected enough sand or silt to make firm bottoms). Twelve such areas lie between Cat Island and St. Joe Point in West Mississippi Sound, nine lie between Ship Island and the Gulfport-Biloxi mainland, and fourteen are located between Horn-Petit Bois islands and the mainland.

Collecting techniques using the tools pictured in Figures 2 and 3 seem to be satisfactory, but it is still desirable to see the bottoms. For this purpose a caisson could be used, transported by boat to the desired location, pushed into the bottom, and then pumped free of water to expose undisturbed bottom sediments.

Except for nitrite analysis present methods of chemical analyses seem to be sufficient. The chief present limitation is too few personnel in view of the fact that most quantitative analyses take so much time. However, one investigation which would be helpful but which could be conducted independently, is the study as to just what is salinity, whether merely chlorinity or whether, as suspected, it is a product of varying cations and varying anions. Such a study would enable a continuation of the settling velocity studies initiated by Sebren and Small.

REFERENCES

1. Phleger, F. B., Ecology of Foraminifera and Associated Microorganisms from Mississippi Sound and Environs, Amer. Assoc. Pet. Geol. Bull., Vol. 38, No. 4, fig. 5, 1954.
2. Morse, W. C., The geologic history of Magnolia State Park, Miss. State Geol. Surv. Bull. 37, 1938.
3. Sverdrup, H. W., Johnson, M. W., Fleming, R. H., The oceans, their physics, chemistry, and general biology, Prentice-Hall, Inc., p. 997, 1942.
4. Brown, G. F., Foster, V. M., Adams, R. W., Reed, E. W., Padgett, H. D., Geology and ground-water resources of the coastal area of Miss., Miss. State Geol. Surv. Bull. 60, pp. 98-166, 1944.
5. Priddy, Richard R., Recent Mississippi Sound sediments compared with some Upper Cretaceous sediments; Trans. Gulf Coast Assoc. Geol. Societies, Vol. IV, Houston, Texas, pp. 159-168, Nov. 1954.
6. Brown, G. F., Foster, V. M., Adams, R. W., Reed, E. W., and Padgett, H. D., *op. cit.*, pp. 125, 135, 148, and 112.

