# SURFACE AND SHALLOW SUBSURFACE SEDIMENTS OF THE NEAR-SHORE CONTINENTAL SHELF OF SOUTH CENTRAL LOUISIANA

*by P. Oetking, R. Back, R. Watson, and C. Merks*

## ABSTRACT

High resolution acoustic profiling and sediment sampling were conducted in the study area over an 18-month period in 1972-1974, to map the bottom and sub-bottom and to examine the sediments near an offshore petroleum platform. Profiling records, verified by bottom samples, delineated a variety of sediment types and topographic bottom and sub-bottom features. More than 1000 kilometers of survey traverses were used in the preparation of a revised bathymetric map and the construction of a sediment distribution map. An analysis of information developed from the detailed profiling and sediment sampling conducted in the vicinity of an offshore petroleum platform showed no recognizable changes in the sediments attributable to drilling or production activities.

## INTRODUCTION

The study area lies immediately offshore from the Holocene Lafourche lobe of the Mississippi Delta Complex. The outer limits are landward of the head of the Mississippi submarine trough and cross the axis of the buried Mississippi Trench, which was incised by the Mississippi River during Pleistocene low stands of sea level. With rising

At the time of this investigation, P. Oetking was Director and R. Back and C. Merks were Research Scientists at Southwest Research Institutes Ocean Science and Engineering Laboratory, Corpus Christi, TX. R. Watson was at the Marine Science Institute, The University of Texas, Port Aransas, TX.

sea level after Wisconsin glaciation, the site of active deposition retreated from the area of the present Continental Slope landward to the Continental Shelf. As a result, the study area is underlain by a thick sequence of delta plain facies including distributary channel sands, natural levee silts and sands, interdistributary marsh deposits, and near-shore marine sediments. In some places these relict sediments are covered by a thin veneer of modern prodelta clays (figure 1).

The modern Continental Shelf sediments are primarily the result of marine processes acting on the relict Late Pleistocene and Early Holocene delta sediments on the shelf. Near the shore, in water depths of less than about 30 feet (9 m), waves and currents actively modify the bottom by winnowing out the muds, leaving a sandy bottom with the mud content increasing with depth of water. Farther offshore, where turbulence on the bottom is significantly reduced, the sand-size sediments usually are not transported except during storms.

Water depth and bottom sediment data within the study area were obtained from about 600 miles (1100 km) of high resolution acoustic profiling traverses. In addition to the regional traverses, profile records and bottom samples were acquired near an offshore production platform in order to discern any evidence of sediment changes.

Mapping of subsurface and surface sediments, grain size analylses, and quantitative evaluation of wave, tide, and wind-induced currents provided criteria to place limits on the location of the maximum seaward advance of the Lafourche delta lobe. Analysis of the sediment transport capability of bottom current demonstrated that the medium and fine sands of the middle shelf are relict from lower stands of sea level.

## METHODS AND MATERIALS

Bottom and sub-bottom acoustic records were made with three different frequencies: 34, 12, and 3.5 kHz. Each of the frequencies furnished records for different purposes. The two higher frequency systems are hull-mounted Edo Western, Model 353, transducers with Gifft, Model 4000T, recorders and are capable of high resolution profiles at vessel speeds of 18 knots. The highest frequency was used to define the water/sediment interface and to examine the upper few feet of the bottom sediments. The 12 kHz system normally showed detailed density variations in the upper 20 feet (6 m) of the sedimentary sections and occasionally penetrated to 40 feet (12 m) in the soft muds. When penetration requirements were greater than those attainable with these units, the towed 3.5 kHz profiling system (Hydro Products, Model 4600, transducer) was used in addition. Boat speed was considerably reduced

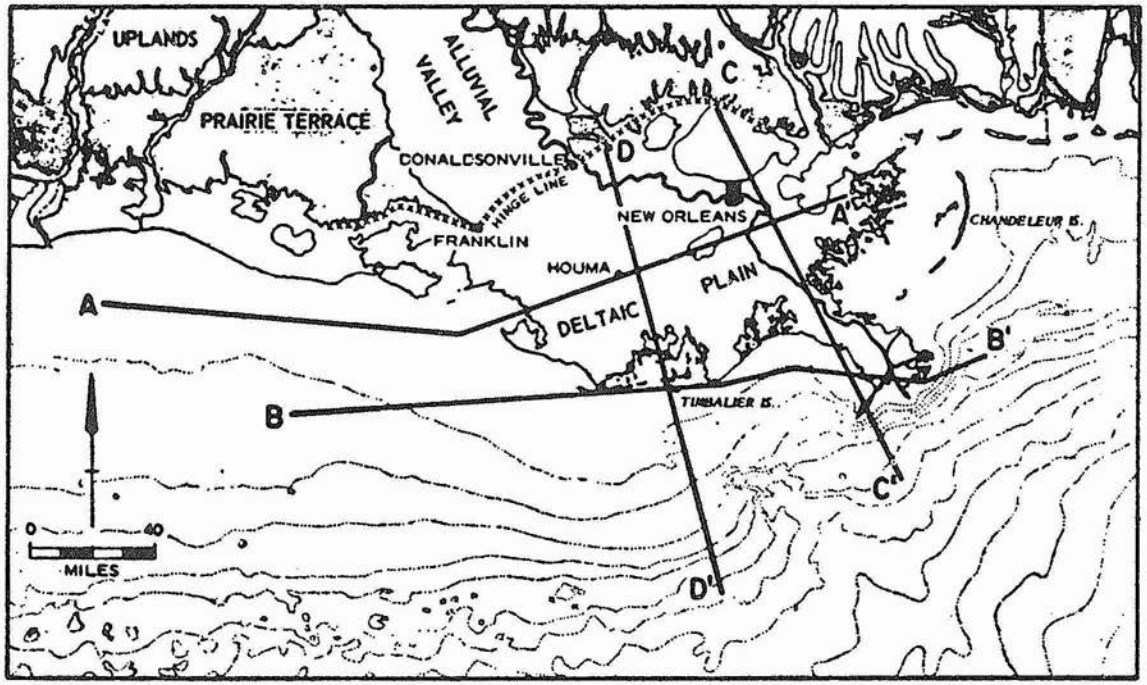
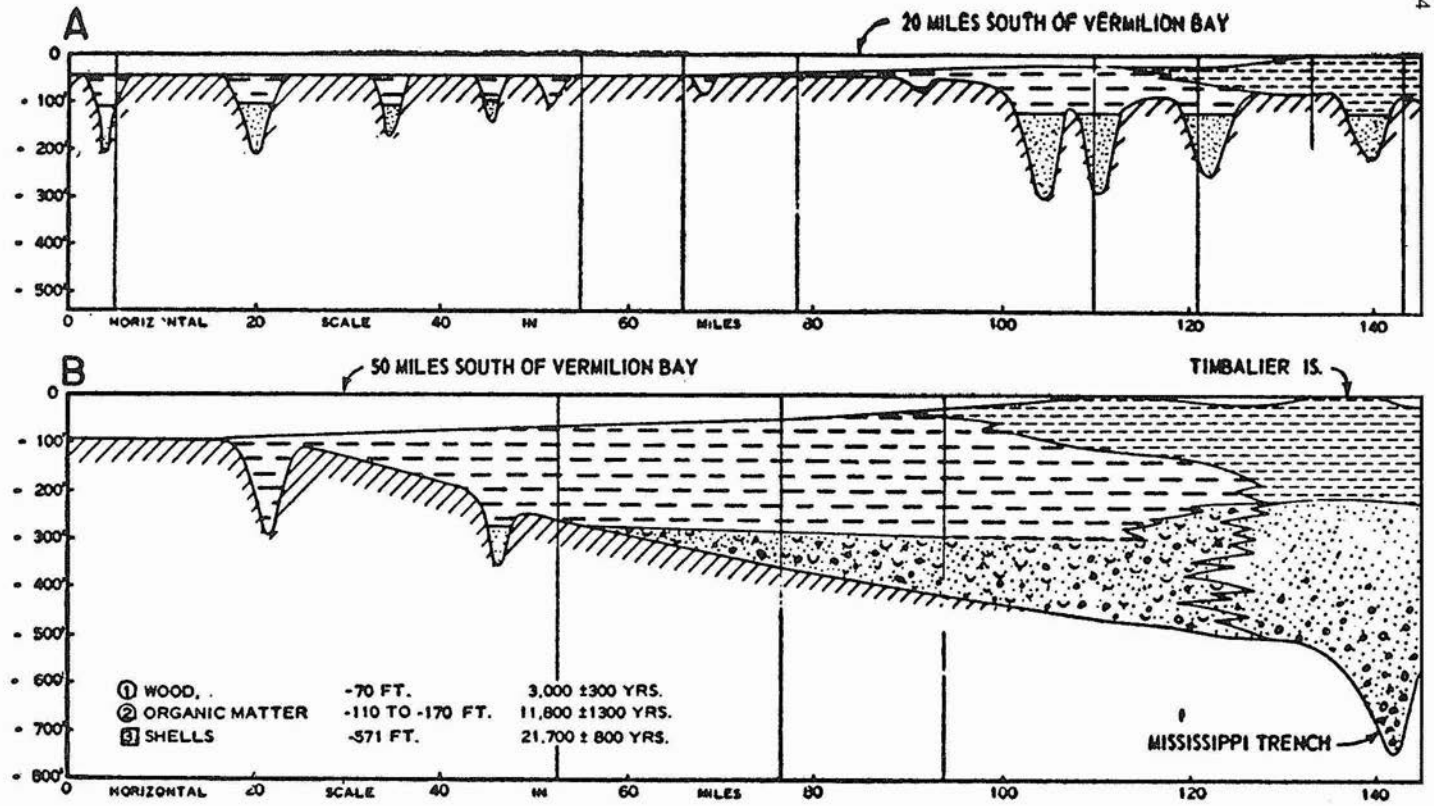



FIG. 1. CROSS-SECTIONAL RELATIONSHIPS AND FACIES OF THE LATE QUATERNARY DELTAIC MASS (continued overleaf). Reprinted by permission of the Geological Society of America from Fisk and McFarlan (1955).


A
20 MILES SOUTH OF VERMILION BAY
0
100'
200'
300'
400'
500'
0 HORIZONTAL 20 SCALE 40 IN 60 MILES 80 100 120 140
B
50 MILES SOUTH OF VERMILION BAY
TIMBALIER IS.
0
100'
200'
300'
400'
500'
600'
700'
800'
① WOOD, . -70 FT. 3,000 ±300 YRS.
② ORGANIC MATTER -110 TO -170 FT. 11,800 ±1300 YRS.
③ SHELLS -571 FT. 21,700 ± 800 YRS.
MISSISSIPPI TRENCH
0 HORIZONTAL 20 SCALE 40 IN 60 MILES 80 100 120 140

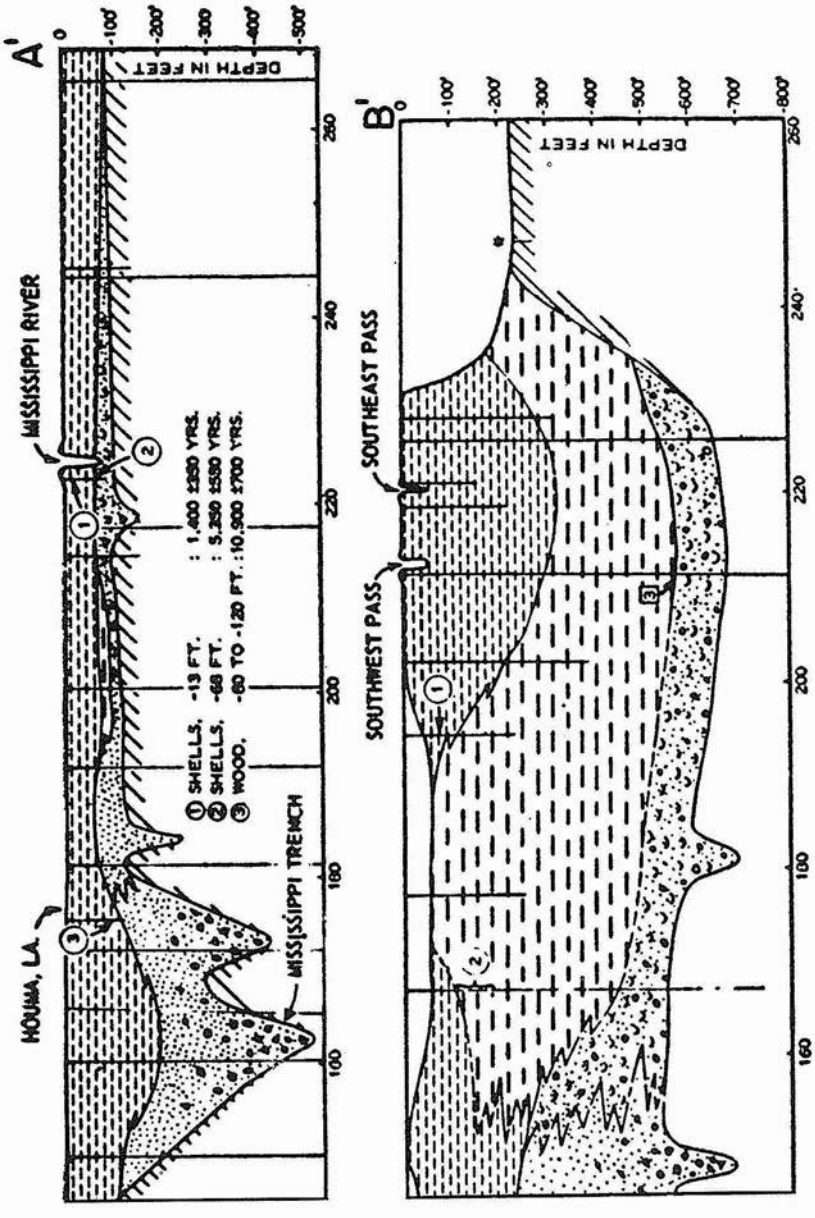



FIG. 1 continued.

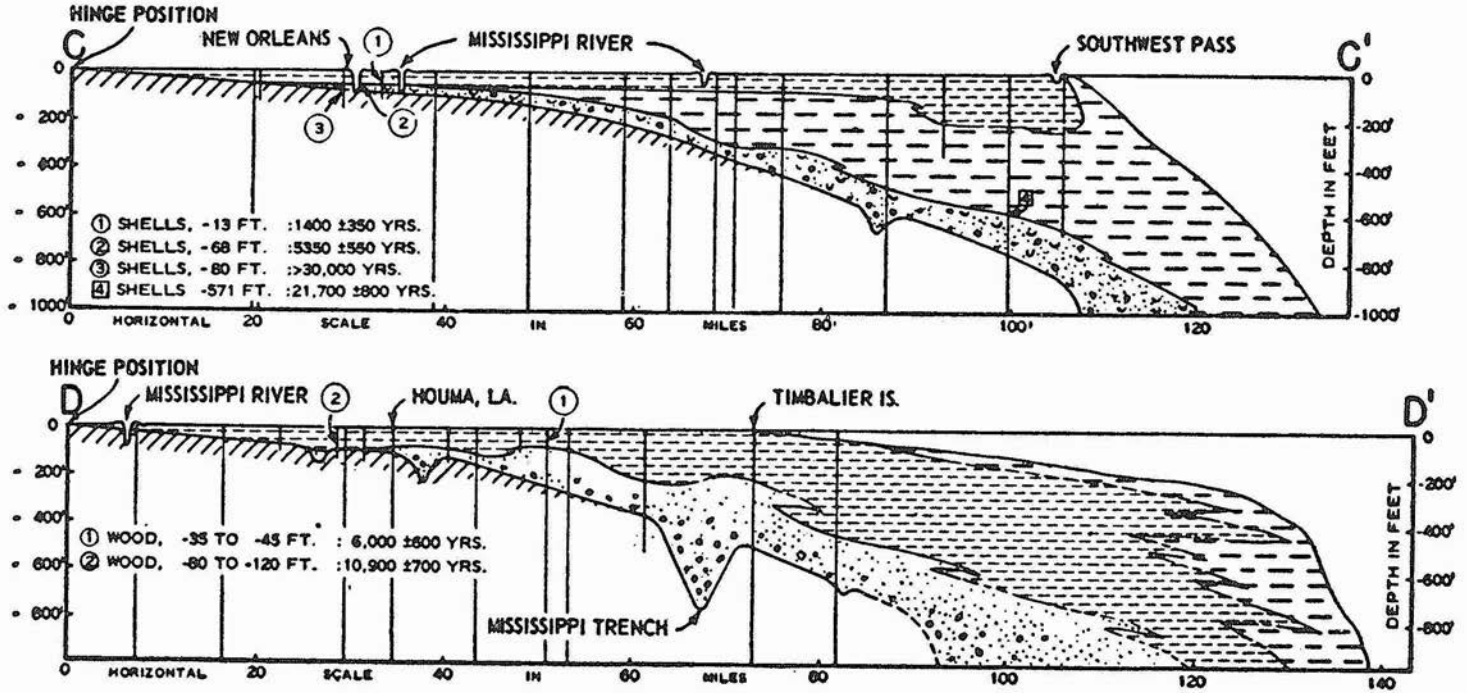



FIG. 1 continued.

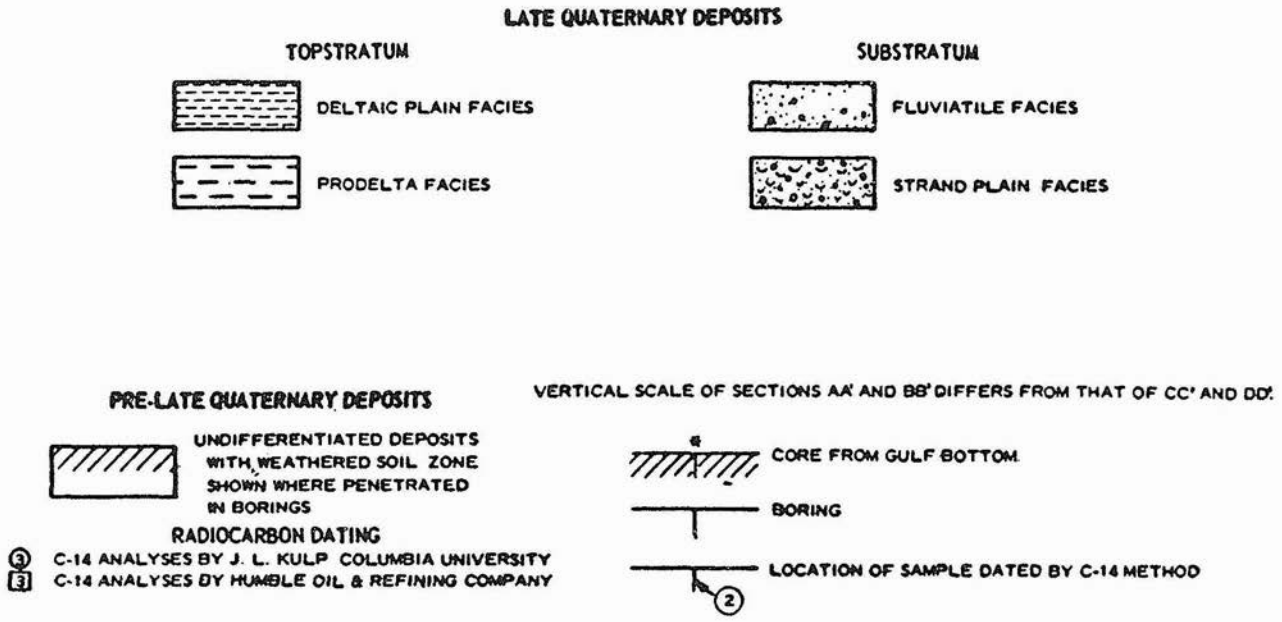

LATE QUATERNARY DEPOSITS
TOPSTRATUM
SUBSTRATUM
DELTAIC PLAIN FACIES
FLUVIATILE FACIES
PRODELTA FACIES
STRAND PLAIN FACIES
PRE-LATE QUATERNARY DEPOSITS
VERTICAL SCALE OF SECTIONS AA' AND BB' DIFFERS FROM THAT OF CC' AND DD'
UNDIFFERENTIATED DEPOSITS WITH WEATHERED SOIL ZONE SHOWN WHERE PENETRATED IN BORINGS
CORE FROM GULF BOTTOM
BORING
LOCATION OF SAMPLE DATED BY C-14 METHOD
RADIOCARBON DATING
C-14 ANALYSES BY J. L. KULP COLUMBIA UNIVERSITY
C-14 ANALYSES BY HUMBLE OIL & REFINING COMPANY

FIG. 1 legend.

with the operation of this instrument, but underway "scoopfish" sediment samples were obtainable during these traverses. The principal sediment samples were acquired with a Shipek sampler, Model 860 (1/25 square meter) and a Phleger gravity coring device.

The R/V/*Southwest Researcher I* was the principal vessel used in this study. The sampling plan for this project was designed to make acoustic profiles of the bottom and sub-bottom along the traverses depicted in figure 2. Most of the profiles were made while the vessel was en route to OEI sampling stations during six cruises from 1972 through 1974. A majority of the sediment grab and core samples were collected in July 1973. To determine if there was discernible evidence of sediment changes resulting from drilling or other platform activities, over 50 miles (90 km) of profiles were made and 54 grab and core samples were taken on concentric square traverses around platform HOR-ST-54A.

## RESULTS

### Bathymetry

Navigational chart data and 34 kHz profile records acquired during the study traverses show that the near-shore region, within a few miles of the present shoreline of the Lafourche subdelta, slopes seaward at 15 feet/mile (2.5 m/km). Most of the remainder of the study area slopes seaward at 4 to 6 feet/mile (0.7 to 1.0 m/km).

Platforms HOR-ST-66D and HOR-ST-54A are located on a flat region of the shelf that probably resulted from wave action on a submerged delta lobe during a lower stand of sea level. The sediments underlying this area will be discussed in conjunction with the examination of sub-bottom profiles.

### Sub-bottom sediments

The recorded response characteristics of the various sediments to the profiling frequency provide the means of identifying different types of sediment. The five sub-bottom sediment types distinguished were:

Hard material (sand, stiff clay, or shell)
Sandy silts
Soft silt and clay
Multilayered soft silt and clay
Deformed multilayered soft silt and clay.

The limits of distribution of sediment types are delineated on the sub-bottom map shown in figure 3.

The near-shore area is underlain dominantly by sand and muddy sand, which probably represent the Lafourche delta front sheet sands

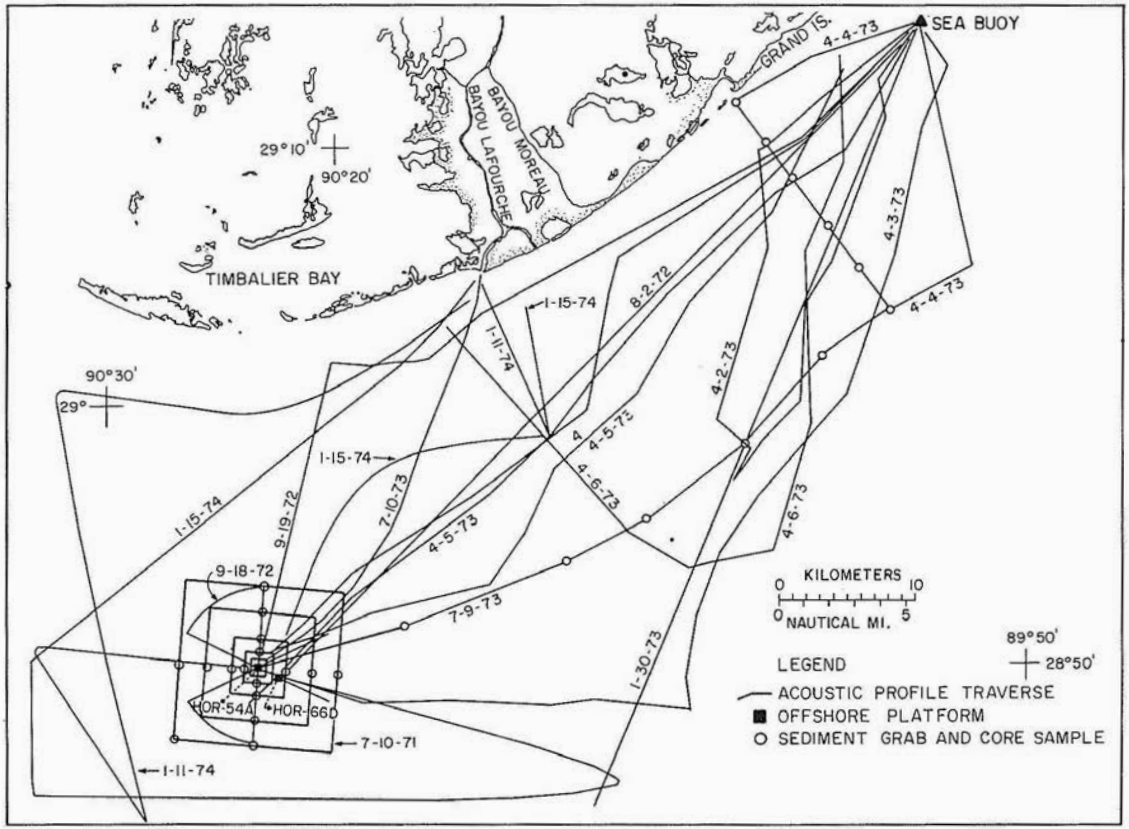



FIG. 2. INDEX MAP OF ACOUSTIC PROFILE TRAVERSES AND SEDIMENT SAMPLING SITES on the near-shore continental shelf of South Central Louisiana.

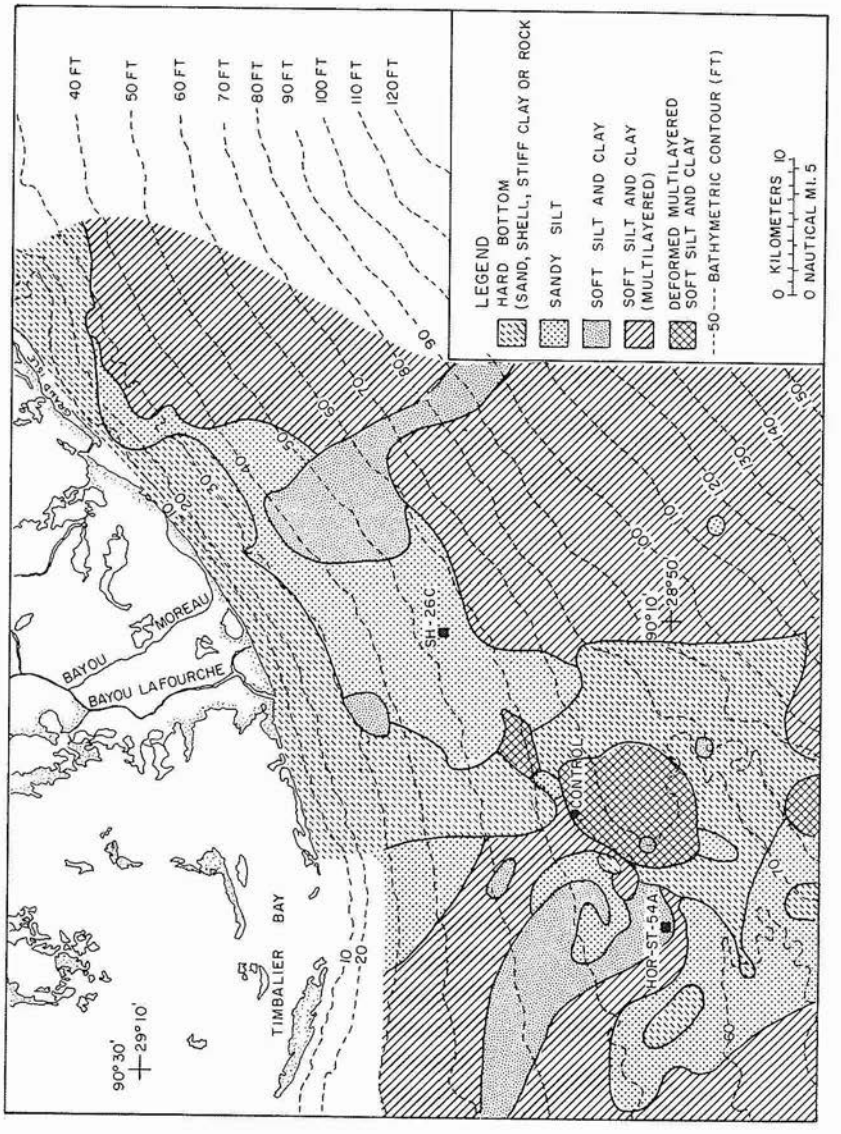



FIG. 3. SUB-BOTTOM SEDIMENT MAP.

deposited where the distributaries discharged into deeper water. Since the abandonment of the delta lobe, these sands have been further distributed into a narrow zone alongshore by waves and currents. In water depths greater than 30 feet (9 m), the sand content of the sediment progressively lessens and the silt and clay content increases. Farther offshore, the clay content increases and the sub-bottom shows pronounced layering. The multilayered silts and clays may have been deposited as part of the delta plain facies during lower stands of sea level. In the greater depths of the study area, there may be some deposition resulting from clays transported in suspension by high density underflows moving along the bottom. It should be noted that currents and low transmissivity measurements at numerous hydrographic stations provide evidence of near-bottom suspended particle movement.

Although the general trend in the offshore direction is decreasing grain size and firmness of the sub-bottom sediment, it is obvious from the distribution map that other influences disturb this pattern. Offshore from Bayou Lafourche, a zone of soft nonlayered clays and silts exists that appears to be composed of numerous small filled channels that tend to be perpendicular to the shoreline and directly downslope. The proximity of the near-shore end of this zone to the mouth of Bayou Lafourche and Bayou Moreau and the fact that the zone trends nearly downslope suggest that it may represent the site of shallow submarine channels.

The channels off Bayou Lafourche and Bayou Moreau vary from narrow steepsided channels to broad channels with gently sloping sides. Often a layer of soft multilayered silt and clay overlies the nonlayered channel sediments. Morgan (personal communication 1974) views the channels as "slump channels" and suggests the lack of layering is attributed to repetitious slumping coupled with sediment deposition. The profile records of this study do not show recognizable evidence of slumping associated with the channels. Platform HOR-ST-54A, a key station in this study, is located in one of the mapped channels filled with soft silt and clay (see figure 3). The lithology interpretation from the profile record is supported by a cored section in South Timbalier block 54 area where Fisk (1956) describes a 25 foot high water content/low bearing strength gray clay overlying a 50 foot sand body.

Gently deformed beds of soft material occur several miles (4-9 km) to the east and northeast of platform HOR-ST-54A and suggest slumping possibly related to sediment adjustments along the Mississippi Submarine Canyon (see figure 3). Surrounding the deeply penetrated deformed beds are firm sediments that exhibit only a few feet (1 m) of penetration with the high frequency signal.

**Surface sediment distribution near Platform HOR-ST-54A**

Twenty-four surface grab samples and numerous short cores were taken on a north-south and an east-west traverse 3 miles (5.5 km) to each side of platform HOR-ST-54A. These were acquired to determine the surface sediment distribution as well as to detect any characteristics in surface sediments that could be attributed to platform operations. Sand to silt-clay ratios were determined for each of the grab samples. The degree of penetration of the surface sediments by the profiler was used to indicate the density or, in this case, sand content, of the surficial sediments.

Sand percentages of the surface sediments are shown in figure 4. The general trend is increasing grain size in the offshore direction. The sediments range from 10% to 98% fine to medium sand. Most of the area south of the platform contains more than 67% sand, while the area to the north has less than 33% sand, with a transitional zone trending east-west in the vicinity of the platform. This sand body with modal sizes in the 0 phi to 2.9 phi range (1 to 0.12 mm) was mapped by Curray (1960).

## DISCUSSION

Shown in figure 4 is a lobe of sandy silt and clay, which extends southward into the area immediately north and east of the platform, and which may have originated from fine sediments released during the oil well drilling. The dominant bottom currents in this area are to the north and northwest, and thus tend to be in the same direction as the finer sediments. Most of the sands in the vicinity of the platform are coarser than the very fine sands supplied by the modern Mississippi River, and are probably coarser than any supplied since the post-Pleistocene still-stand in sea level. Therefore, one could assume that the source of the fine and medium sand fractions could be attributed to drilling operations in the area.

On the other hand, consider the conditions that must prevail if the medium to fine sands found south of the platform are to be attributed only to drilling operations. In figure 4, the mapped area with more than 67% sand is approximately 20 square nautical miles (70 sq km) or $753 \times 10^6$ square feet ($70 \times 10^6$ sq m). Short cores indicate surface sand deposits from 1 to 7 inches (2.5 to 18 cm) thick. Assuming an average sand thickness of only 0.1 foot (3 cm), the sand volume is $75.3 \times 10^6$ cubic feet ($21.2 \times 10^5$ cu m). Using the mean sand content in the area as 83% and a medium to fine fraction of 87%, the total volume of medium and fine sand in the area would have to be at least $54 \times 10^6$ cubic feet ($15 \times 10^5$ cu m). In contrast, the total volume of sediments produced by

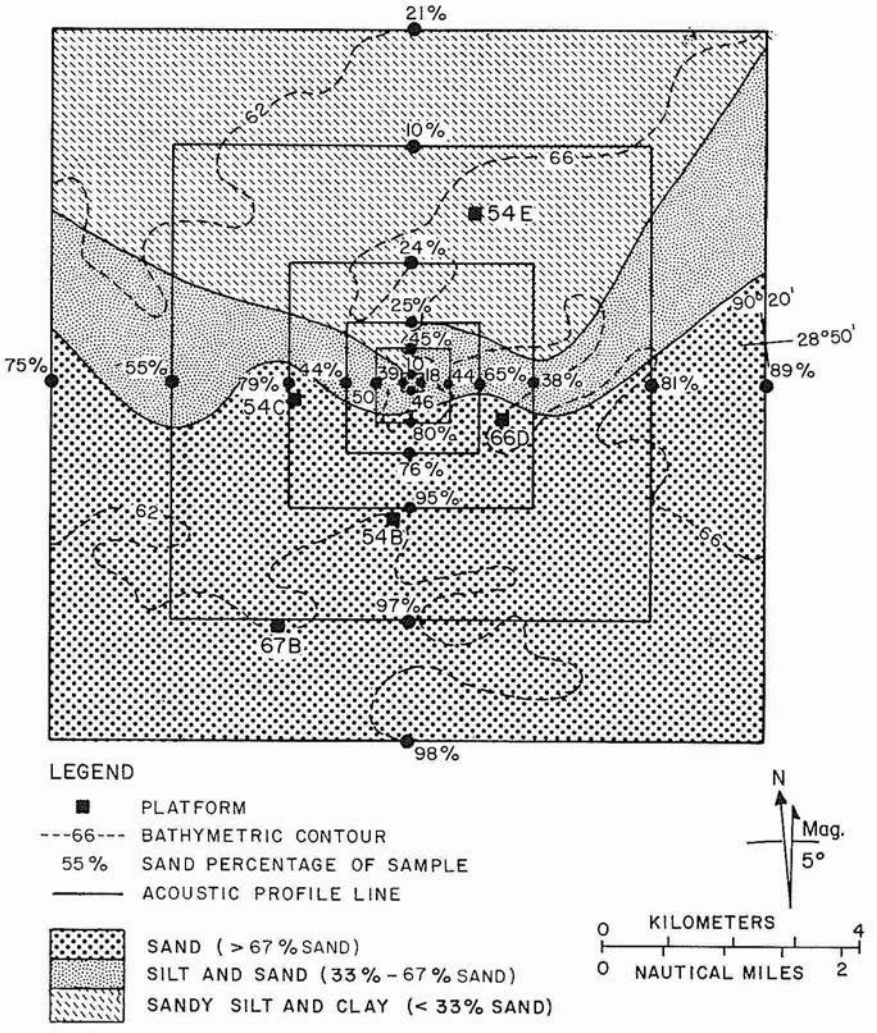



FIG. 4. SAND PERCENTAGE MAP OF THE SURFACE SEDIMENTS around Platform HOR-ST-54A on the near-shore continental shelf of South Central Louisiana.

a 10,000 foot (3050 m), 10-inch (25.4 cm) diameter boring is only 5440 cubic feet (154 cu m). If it were assumed that all of the sediment removed by boring was medium to fine sand, nearly 10,000 separate drillings would be required to yield this amount of medium to fine sand in an area of 20 square nautical miles (70 sq km).

It is also necessary to examine the dispersal mechanisms available to transport sediment away from the platforms. A current speed of about 1

ft/sec (30 cm/sec) is required to erode sand (Hjulstrom 1935). An examination of the continuous current records for the period from August 1972 through July 1973 shows that bottom currents greater than 1 ft/sec (30 cm/sec) at platform HOR-ST-66D existed for only 14 hours out of 66 days of measurements, amounting to only 1% of the time. Furthermore, these currents were in an offshore direction for only 5 out of 14 hours. The possibility also exists that the sand can be suspended by wave action and then transported by currents less than 1 ft/sec (30 cm/sec). The maximum horizontal orbital velocity at the bottom (Umax) produced by a sinusoidal wave is given by the following relationship:

$$\text{Umax} = H/\ (T\sin h\ (kh)\ )$$

where $H$ is the significant wave height, $T$ is the wave period, $k$ is the wave number ($2\pi/L$), $L$ is the wave length and equal to $5.12\ T^2$, and $h$ is the water depth. For any given depth of water, the maximum horizontal bottom velocity can be determined as a function of a given wave height and period. If this computation is made based on the 60-foot (18 m) water depth at platform HOR-ST-54A (figure 5), the results indicate that either very high waves, waves with very long periods, or a moderate combination of both are required to disturb sand at that depth.

Wind velocity, duration, fetch, and decay distances were determined from 12-hourly synoptic weather charts for the Gulf of Mexico for the years 1950, 1952, and 1954, to calculate wave statistics for the region off of Burrwood, Louisiana (Bretschneider and Gaul 1956). These hindcast wave statistics, together with figure 5, were used to compute the following monthly and annual durations of wave-induced bottom currents greater than 1 ft/sec (30 cm/sec) at a depth of 60 feet (18 m):

| MONTH | HOURS |
|---|---|
| Jan. | 16 |
| Feb. | 40 |
| Mar. | 40 |
| Apr. | none |
| May | 4 |
| June | none |
| July | 8 |
| Aug. | 10 |
| Sept. | 28 |
| Oct. | 20 |
| Nov. | 56 |
| Dec. | 60 |
| YEARLY TOTAL | 282 hours or 3.4% of the time |

The figures given above are for waves moving in all directions. Waves moving offshore and thus capable of transport of sediment offshore occurred less than 54 hours per year (0.6% of the time). It seems unlikely that sand at a point source could have been transported very far under these conditions. The effect of severe tropical storms is unknown; Curray (1960), however, suggests that hurricane waves rework relict shelf sands with little or no net transport.

Size analyses of the sand fraction were performed on several sediment samples collected near platform HOR-ST-54A in an attempt to determine sand origins (figure 6). These analyses were conducted on a Woods Hole-

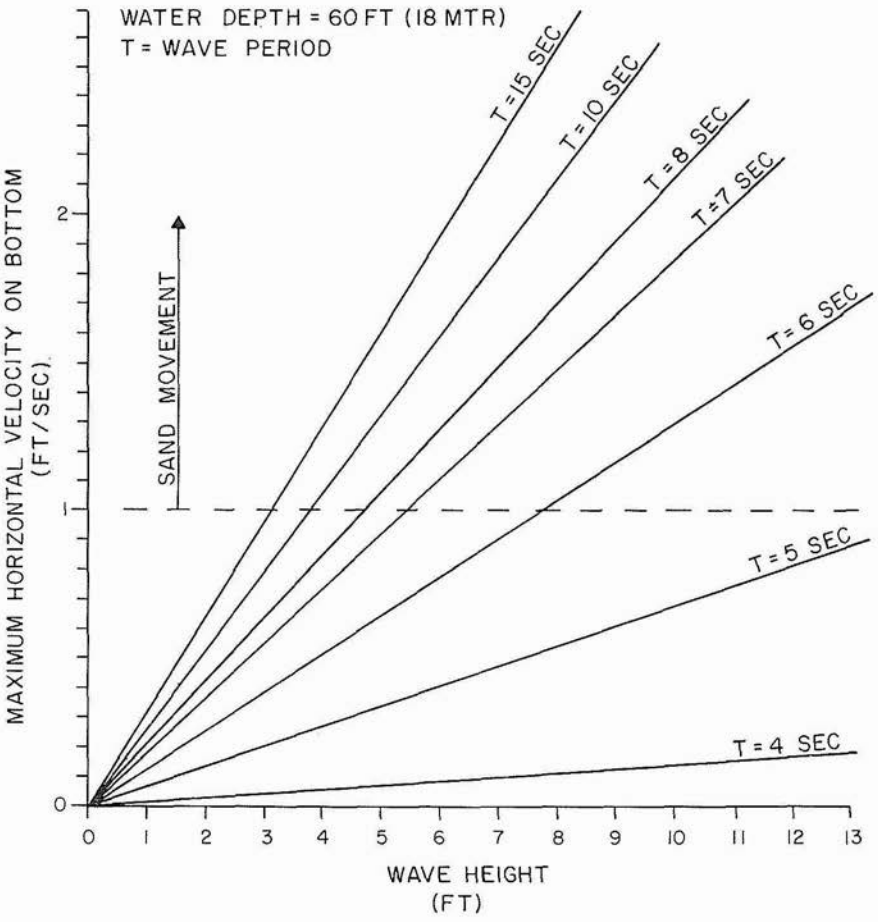



FIG. 5. MAXIMUM HORIZONTAL ORBITAL VELOCITY AT BOTTOM.

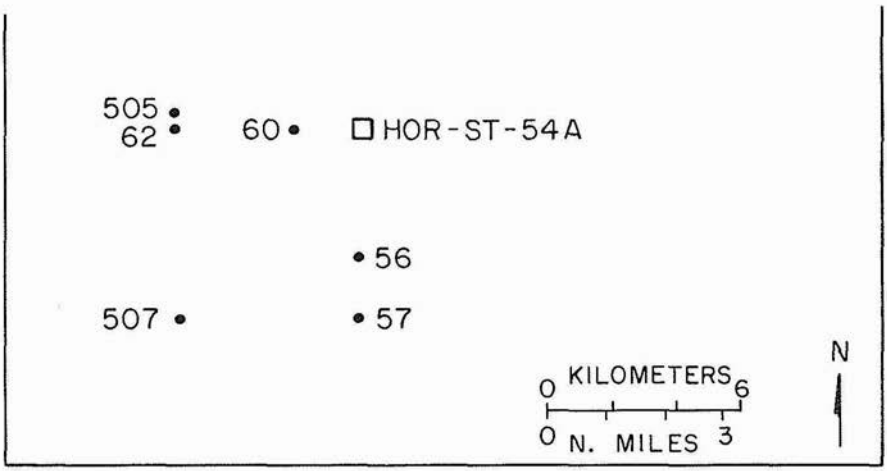



FIG. 6. SAND FRACTION SAMPLING STATIONS near Platform HOR-ST-54A, near-shore continental shelf of South Central Louisiana.

type rapid sediment analyzer (Schlee 1966). The grain-size distribution was determined by relating sediment settling velocity to grain-size (phi units) on the basis of a modified Rubey Equation for the settling velocity of spheres in a viscous fluid (Watson 1970). The mean size and standard deviation, computed by the graphic methods of Folk (1965), are presented in table 1.

The mean sizes of the sand fraction were in the fine sand range (2.0 to 3.0 phi). The samples contained an average of 25% medium sand (1.0 to 2.0 phi). No coarse sand (0.0 to 1.0 phi) was detected by the rapid sediment analyzer, although a very small amount was observed in some of the samples by microscopic examination. The phi standard deviations (ranging from 0.49 to 0.71 phi) indicate that most of the sands were moderately sorted. If medium sands brought to the surface by drilling operations had been mixed with very fine sands on the shelf, the standard deviations would have been higher because of poor sorting. The moderate sorting and the infrequent occurrence of bottom currents capable of transporting sand indicate that the sands are relict from a lower stand of sea level.

The Mississippi River deltaic plain, fashioned during the past approximately 5000 years since sea level reached its present stand, contains sands of only the very fine to fine size, such as those of the present river mouth bar and the destructional islands. Coarser sands would get into the delta only when the river gradients were steeper, i.e., during a lower stand of sea level. It can be concluded that the medium sands found on the continental shelf in 60 feet of water around platform HOR-ST-54A are most likely relict sands left from a period when sea level was

TABLE 1
SAND FRACTION CHARACTERIZATION

| Sample Number | Grain Size Parameters | | % sand in each size class | | | |
|---|---|---|---|---|---|---|
| | Size Mean ($\phi$) | Standard Deviation | Coarse 0-1 $\phi$ | Medium 1-2 $\phi$ | Fine 2-3 $\phi$ | Very Fine 3-4 $\phi$ |
| **Platform HOR-ST-54A Louisiana** | | | | | | |
| 56 | 2.47 | 0.71 | | 25 | 62 | 13 |
| 57 | 2.28 | 0.52 | | 34 | 57 | 9 |
| 60 | 2.40 | 0.52 | | 34 | 63 | 13 |
| 62 | 2.48 | 0.62 | | 17 | 64 | 19 |
| 505 | 2.02 | 0.54 | | 43 | 53 | 4 |
| 507 | 2.78 | 0.49 | | | 71 | 29 |
| **Platform GU-MU-889-1 Mustang Island, Texas** | | | | | | |
| 516 | 3.51 | 0.40 | | | 10 | 90 |
| 517 | 3.46 | 0.36 | | | 12 | 88 |
| 518 | 3.33 | 0.36 | | | 21 | 79 |
| 519 | 3.39 | 0.32 | | | 15 | 85 |
| 520 | 3.14 | 0.52 | | | 36 | 64 |
| 521 | 3.28 | 0.59 | | 5 | 24 | 71 |
| 522 | 2.02 | 1.39 | 43 | 19 | 11 | 27 |
| 523 | 3.43 | 0.47 | | | 19 | 81 |
| 524 | 3.42 | 0.37 | | | 15 | 85 |
| 525 | 3.51 | 0.40 | | | 11 | 89 |
| 526 | 3.50 | 0.33 | | | 13 | 87 |
| 527 | 3.44 | 0.40 | | | 17 | 83 |
| 528 | 3.49 | 0.34 | | | 11 | 89 |
| 529 | 3.37 | 0.33 | | | 15 | 85 |
| 530 | 3.36 | 0.39 | | | 19 | 81 |

significantly lower. Furthermore, it can be concluded that the Holocene Lafourche delta did not prograde into the area of HOR-ST-54A. Occurrence of the relict medium-grained sand fraction near the platform probably delimits the maximum seaward extent of the Holocene Mississippi delta (Lafourche). The "hard bottom" sand distribution of figure 3 suggests that the Holocene delta extended only a few miles offshore from the present destruction phase barrier islands.

In order to evaluate further the effects that an offshore petroleum platform has on the sediments surrounding it, a suite of samples was acquired at a platform off the Texas coast (Platform GU-MU-889-1, located offshore Mustang Island near Port Aransas, in 48 feet of water [15 m] ).

The mean sizes of most of the sand fractions of the Texas samples were in the range of very fine sand (3.0 to 4.0 phi). For the most part, the sand fractions were well-sorted, as indicated by the low standard deviations in table 1. Several exceptions were found. Sample 522, nearest the platform on the northeast side, has a mean size of 2.02 phi, poor sorting, and a bi-modal sand fraction composed of coarse and medium as well as very fine sand. On the near southwest side of the platform, sample 521 has a mean size of 3.28 phi, a standard deviation of 0.59 phi, and about 5% medium sand. The rapid sediment analyses of the samples did not provide evidence of coarse sands at stations beyond the 40 foot (12 m) distance from the platform.

However, microscopic examinations of the sand fractions did reveal a trace amount of medium and coarse sand to 40 feet (12 m) southeast and northwest, 760 feet (230 m) northeast, and 1500 feet (460 m) southwest from the platform. Sample 522, with the greatest amount of coarse sands, has a high percentage of very angular grains of quartz and feldspar and some irregular shiny black grains with conchoidal fractures. The black fragments and most of the coarse and medium sand surrounding the platform may be blasting material used in the maintenance of the structure.

There is almost no detectable evidence of the drilling operations other than very near the Mustang Island platform, even though it is located in shallower water and in a more severe wave climate than the Louisiana platform HOR-ST-54A. Medium and fine sand, so abundant and extensive south of platform HOR-ST-54A, are minor constituents off the Texas platform and probably not a product of drilling operations.

## SUMMARY AND CONCLUSIONS

1. The study area is underlain by Early Holocene deltaic deposits, by prodelta sediments of the Late Holocene Lafourche lobe, and by modern prodelta clays.

2. Sub-bottom sediments grade from sands near shore to multilayered silty clays offshore. This general pattern is altered by buried channels, areas of deformed sediments, and areas of thinly-covered firm sediments.

3. Sandy muds on the north side of platform HOR-ST-54A change to muddy medium sands on the seaward side. The amount of medium sands around the platform is too large to be accounted for by well cuttings.

4. Bottom current measurements and wave calculations indicate that

the transport of many sand particles seaward of the platform would be unlikely.

5. Sands in the vicinity of the platform are coarser than the fine and very fine sands supplied by the modern Mississippi River. Grain-size analysis of the sand fractions of the sediment samples near the platform showed an average of 25% medium sand. We conclude that the medium sands were deposited during a lower stand of sea level, about 5000 years ago, when the Mississippi River had a steeper gradient.

6. Sediments surrounding an offshore Texas platform that were similarly examined for effects of drilling and operational activities showed a dominance of very fine sand and only samples near the platform had particles larger than fine sand. The medium and coarse sands are thought to be blast sands.

7. The Holocene Lafourche delta lobe must have been located landward of the zone of medium sands near platform HOR-ST-54A. Its boundary may be represented by the seaward limit of the near-shore fine sands reworked from Lafourche delta front and distributary channel sands.

8. Drill cuttings and operational activities of an offshore platform are not significant factors in altering the bottom sediments except near the structure.

## ACKNOWLEDGMENTS

This Project was funded under Gulf Universities Research Consortium Contract GU853-8; Southwest Research Institute, Corpus Christi, Texas.

We are indebted to D. E. Feray and the late E. Heuer for their generous assistance, to L. Rastrelli, R. Case, and J. P. Morgan for criticism of the manuscript, to R. Weed, E. Baker, and D. Krueger for their dedicated data acquisition, and to L. Lakatos and M. Lynch for their aid in the preparation of the illustrations.

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