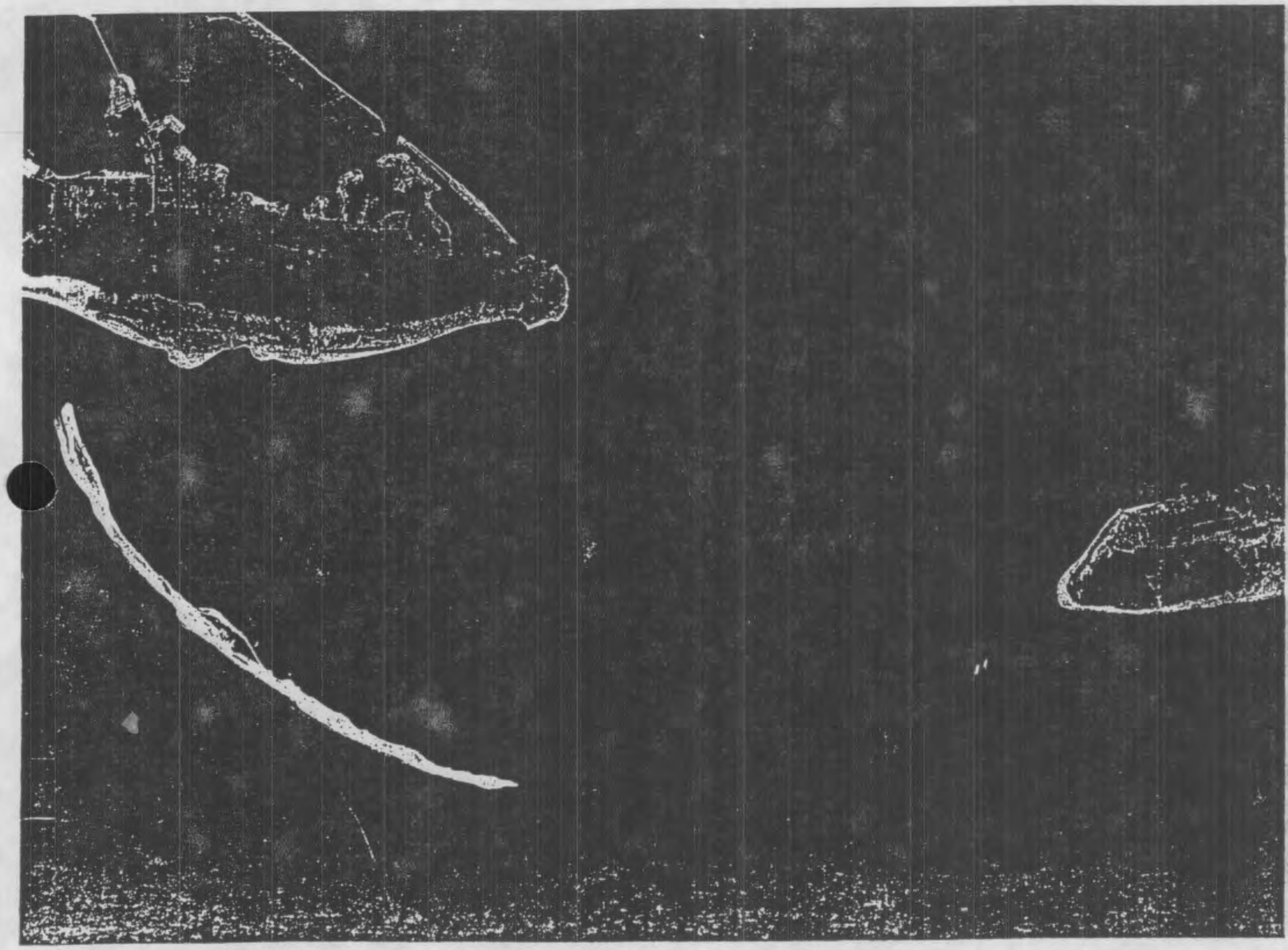
MAIN PASS AND THE EBB-TIDAL DELTA OF MOBILE BAY, ALABAMA

GEOLOGICAL SURVEY OF ALABAMA CIRCULAR 146



GEOLOGICAL SURVEY OF ALABAMA

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CIRCULAR 146

MAIN PASS AND THE EBB-TIDAL DELTA OF MOBILE BAY, ALABAMA

By

Richard L. Hummell

Tuscaloosa, Alabama
1990

GEOLOGICAL SURVEY OF ALABAMA

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May 10, 1990

Honorable Guy Hunt
Governor of Alabama
Montgomery, Alabama

Dear Governor Hunt:

I have the honor to transmit herewith a report entitled "Main Pass and the Ebb-Tidal Delta of Mobile Bay, Alabama," by Richard L. Hummell, which has been prepared and published by the Geological Survey of Alabama as Circular 146.

Main Pass and the ebb-tidal delta of Mobile Bay are at the geographic center of man's activities in coastal Alabama. This site contains the Mobile Ship Channel and Intracoastal Waterway, both vital to commercial boat traffic. Natural gas exploration and production occur within the study area and adjacent state and federal waters.

There have been numerous requests from government and industry officials and the public for information about this area. Information is needed in order to prepare and evaluate environmental impact statements and to assist in assessment of natural resources of the area. This report was prepared and published for the purpose of summarizing and synthesizing what is known about the physical environment of this important area.

Respectfully,

Ernest A. Mancini

Ernest A. Mancini
State Geologist

Geological Research Key to Alabama's Future

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Richard L. Hummell

ABSTRACT

Main Pass and the ebb-tidal delta of Mobile Bay comprise a physically complex, dynamic system that acts as a transition zone between Mobile Bay and the Gulf of Mexico. Through man's activities and natural processes, the system has shown significant change over the past 210 years and has evolved from a natural system to one dominated by man.

Seaward of Main Pass, a tide-dominated, tidal inlet, is a well-developed ebb-tidal delta. The delta is thought to be between 4,000 and 5,000 years old and is primarily constructed of sediments transported out of Mobile Bay and supplemented with nearshore shelf and barrier island sediments. Once established, the delta acquired its present appearance by vertical accretion and progradation. Circulation through the inlet involves a cyclical exchange of water masses between Mobile Bay and the Gulf of Mexico. Pelican Bay is an ebb ramp through which most of the ebb- and flood-tidal water masses flow. Most of the sand-sized sediments transported out of Mobile Bay are deposited in Pelican Bay, whereas much of the clay- and silt-sized sediment is deposited on the shelf, seaward of Pelican and Sand Islands. Estuarine clays and silts cover southern Mobile Bay and line the deepest parts of the ebb-flood tidal channel. This textural pattern is typical of ebb-tidal deltas along the southeastern coast of the United States. In the study area, this pattern was stable from circa 1968 to circa 1983, except for increased quantities of sand in Pelican Bay and the southeastern quarter of the study area. From 1973 to 1987, the average sedimentation rate for the ebb-tidal delta was calculated to be 0.025 foot (0.76 centimeter) per year.

The gradual aggradation of southern Mobile Bay and Pelican Bay and dredging activities in the Mobile Ship Channel account for the bathymetric changes that have occurred within the study area over the past 210 years. These changes in bathymetry affect water circulation, which in turn profoundly affects salinity and water temperature distributions in Mobile Bay and eastern Mississippi Sound.

In the shallow subsurface of the study area, five lithofacies are defined. Lithofacies 1 is shelly sand that represents many barrier strandline depositional environments and subenvironments including barrier island, ebb-tidal delta, tidal inlet, and ebb-flood tidal channel. Lithofacies 2 is composed of shelly sand containing sand lenses corresponding to ebb-tidal delta clays, silts, and sands deposited seaward of the ebb shield. Lithofacies 3 is shelly, clayey sand that represents shelf environments. Lithofacies 4 consists of shelly clays with silty sand lenses, shelly sands without lenses, and sandy clays interpreted to be estuarine clays, silts, and sands. Lithofacies 5 comprises shelly, clayey sand containing clay lenses and is interpreted to be Mobile Bay marginal sands.

INTRODUCTION

Coastal Alabama is a completely integrated dynamic system that interacts peripherally with coastal waters of Mississippi and Florida and with the Gulf of Mexico. Rate of change of the physical environment in coastal Alabama has been accelerating since the start of this century due to natural physical processes and man's activities. Historically, this region has been a multiuse area, important to waterborne commercial transportation, travel, tourism, recreation, residential and commercial development, and commercial fisheries. The region also contains important prehistoric and historic archaeological sites.

One of the geographic focal points for activity is the mouth of the Mobile Bay estuarine system (figs. 1 and 2). This site is influenced by the north-south oriented Mobile Ship Channel, a vital access route connecting Mobile Harbor to the Gulf of Mexico and to the east-west trending Intracoastal Waterway, important to commercial boat traffic. Because of its mild climate, Gulf of Mexico frontage, and close proximity to several interstate and state highways and numerous rail

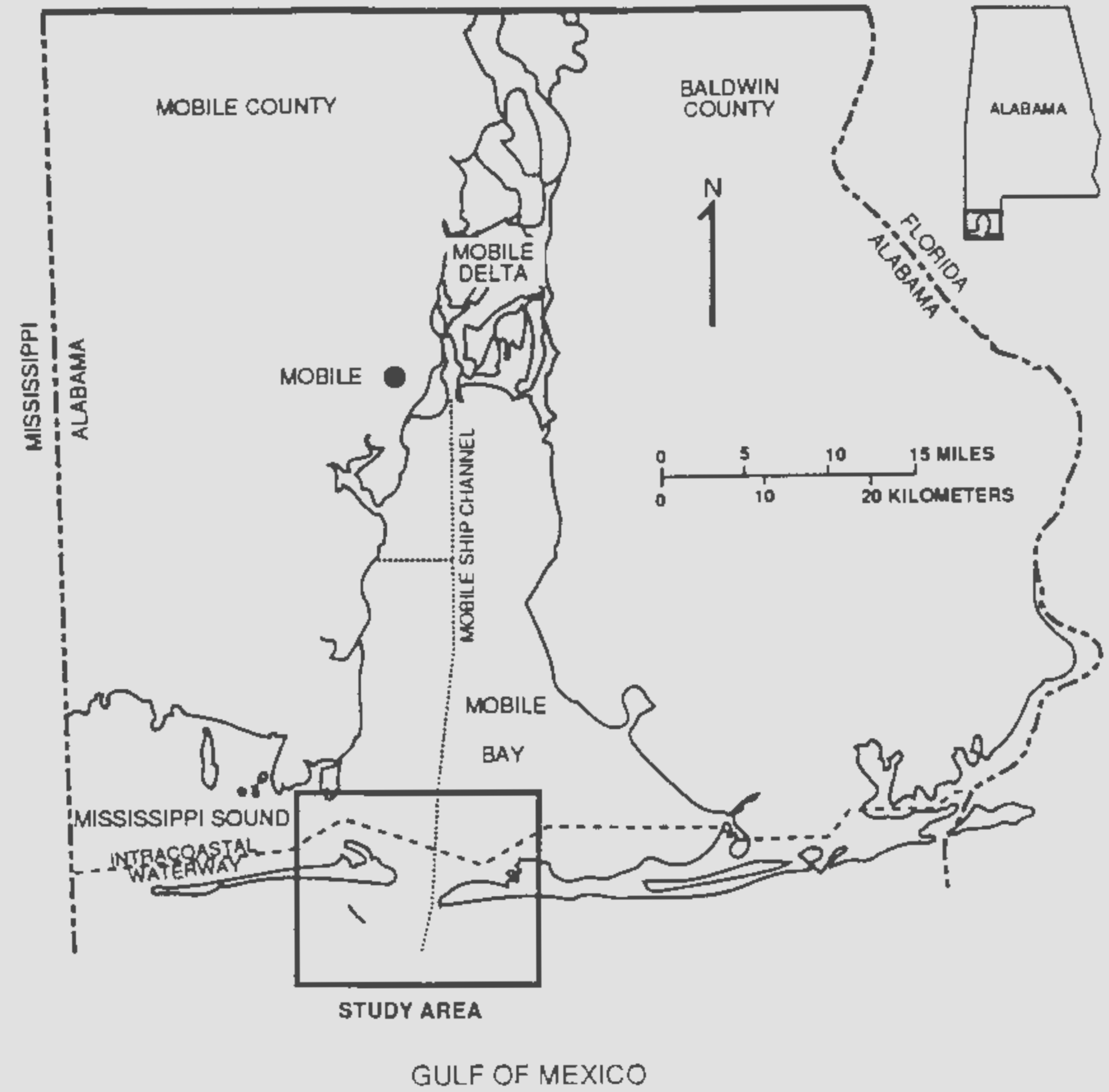


Figure 1.--Mobile Bay and vicinity.

lines and airports, coastal Alabama is attractive for travel, tourism, recreation, and residential and commercial development. Development in the coastal area leads to increasing demands on water supplies and beach front properties. With this development, issues such as beach and dune erosion, wetland loss, changes in sea level, and saltwater intrusion become important. As coastal population density increases, the type, quantity, distribution and residence times of particulates in the water are becoming topics of concern in regard to sport and commercial fishing and recreational activities. In addition, increasing exploration and development activity for natural gas in Alabama coastal waters and adjacent federal waters leads to the emplacement of production platforms, pipelines, and shore-based hydrocarbon processing facilities, with concomitant environmental stresses.

A tidal inlet is "any inlet through which water flows alternately landward with the rising tide and seaward with the falling tide; specifically a natural inlet maintained by tidal currents" (Bates and Jackson, 1987). A tidal delta can be defined as "a delta formed at the mouth of a tidal inlet on both the seaward and landward sides of a barrier island, spit or baymouth bar by changing tidal and wave currents that move sediments in and out of the

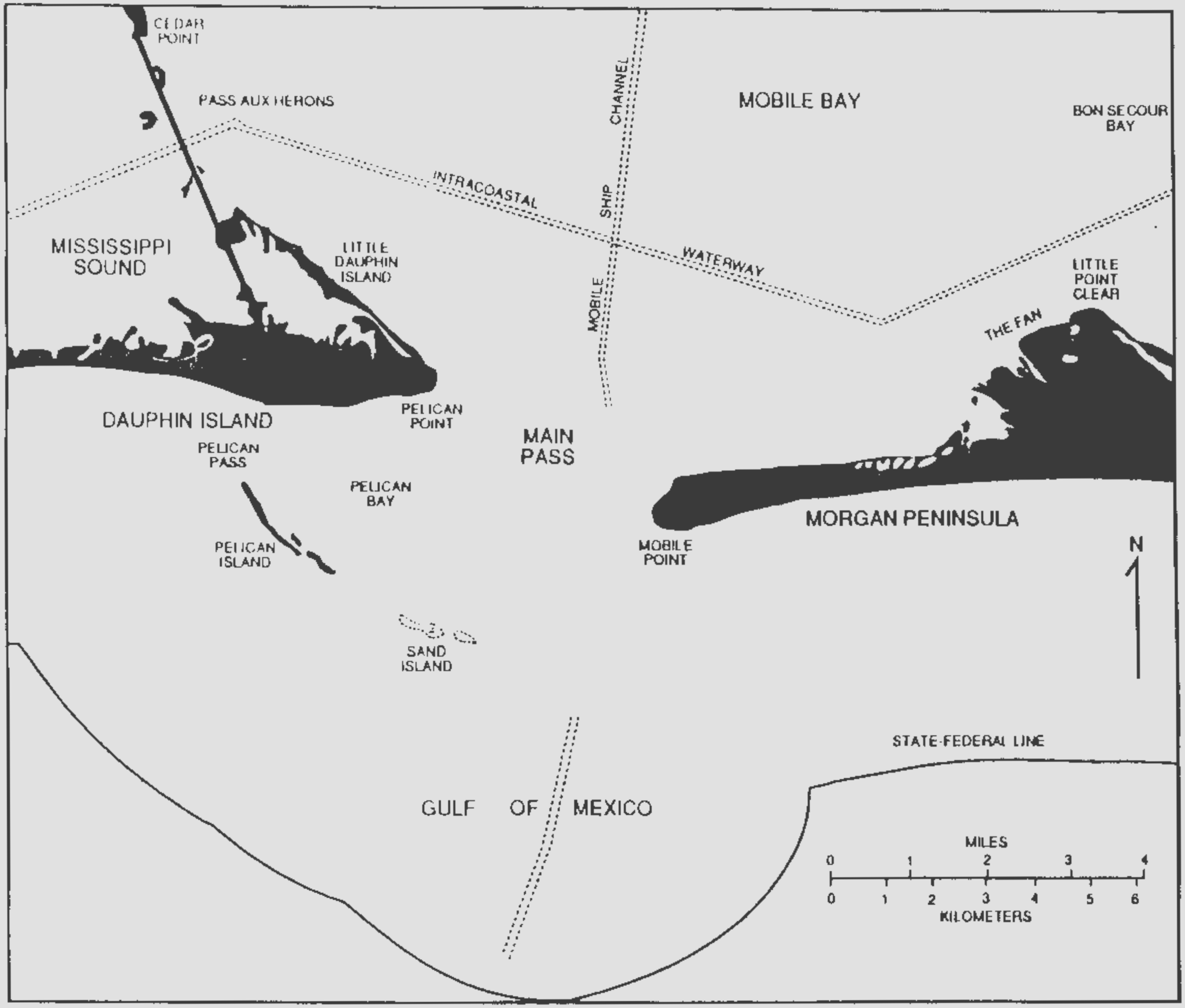


Figure 2.--Map of study area (modified from Hardin and others, 1976).

inlet" (Bates and Jackson, 1987). An ebb-tidal delta is "a tidal delta formed by ebbing tidal currents and modified in shape by waves" (Bates and Jackson, 1987).

The ebb-tidal delta of Mobile Bay (fig. 3) is related to the Mobile Bay estuary, a submerged portion of the Mobile-Tensaw river valley. This bell-shaped estuary measures about 31 miles (49 kilometers) in length from Main Pass to the Mobile delta at the northern end, and 23 miles (37 kilometers) at its widest point between Mississippi Sound and Bon Secour Bay. It has a surface area of more than 390 square miles (1,000 square kilometers), an average depth of 10 feet (3 meters) (excluding the Mobile Ship Channel), and a volume of 122 billion cubic feet (3.48 billion cubic meters) (Jarrell, 1981). Main Pass measures about 3 miles (4.8 kilometers) in width between Mobile Point and the eastern tip of Dauphin Island.

Mobile Bay is the terminus of the Mobile-Tensaw River system, the nation's sixth largest river system in terms of total drainage area and fourth largest in terms of discharge (Isphording and Flowers, 1987) (fig. 4). The Mobile-Tensaw River is formed by the confluence of six major rivers, which together form a watershed area of nearly 43,200 square miles (112,000 square kilometers) with an average discharge of 61,945 cubic feet per second (1,755 cubic meters per second) (Isphording and others, 1985). Each year, this volume of water brings into Mobile Bay an average of nearly 4.7 million tons (4.3 billion kilograms) of suspended material and an unknown quantity of bed load (Ryan, 1969). Approximately 85 percent of the total river system discharge exits Mobile Bay via Main Pass, with the remaining 15 percent emptying into Mississippi Sound through Pass aux Herons (Ryan, 1969).

These rivers drain the Alabama, Georgia, and Mississippi Appalachian Valley and Ridge, Plateau, Piedmont, and Coastal Plain areas, so that the deposits of these streams consist of sediments derived from erosion of these areas (fig. 4). In general, the Valley and Ridge and Plateau areas are underlain by a sequence of Paleozoic sandstones, shales, and limestones, which are, in part, chert-bearing. Major lithologic contributions from these areas to fluvial deposits include sand, clay, and chert gravel. The Piedmont area consists of metamorphic and igneous rocks that contain many accessory minerals, such as zircon, rutile, ilmenite, monazite, and others, which are constituents of the sands. Additional sediments from this area include quartz sand, clay, and quartzite gravel. The Coastal Plain area consists of poorly consolidated sedimentary rocks which are derived, in part, from the Valley and Ridge and Piedmont terranes. Erosion of this area contributes sand, clay, gravel, and detrital heavy minerals to the fluvial deposits.

The ebb-tidal delta at the mouth of Mobile Bay is a submerged, arcuate delta seaward of Main Pass, which measures approximately 10 miles (16.1 kilometers) wide, extends approximately 6 miles (9.7 kilometers) out into the Gulf of Mexico, and has an average depth of about 10 feet (3 meters) over its top (fig. 3). Its emerged portion consists of numerous shoals and ephemeral islands which enclose Pelican Bay (fig. 2).

The most noteworthy island associated with the ebb-tidal delta is Sand Island, the northwest-southeast-trending intermittent bar adjacent to the Mobile Ship Channel (fig. 2). This bar continually changes shape, size and location as a result of storm events, fair weather waves and sediment movement within Pelican Bay. In the past, this bar has existed essentially either as two separate islands or as one continuous island and, as a result, has been labeled on various maps as Pelican and/or Sand Islands. On the latest nautical chart (National Oceanic and Atmospheric Administration (NOAA), 1987), the emergent, northern part of the bar is labeled "Sand Island." However, by convention the northern island(s) will be referred to as "Pelican Island," and the southern island(s) (at present shoals) will be called "Sand Island" (fig. 2).

The Port of Mobile, located at the head of Mobile Bay, is one of the major international ports in the United States, ranking second in coal transport and twelfth in total traffic (U.S. Department of the Navy, 1986). Mobile Harbor is connected to the Gulf of Mexico by the Mobile Ship Channel, the main north-south oriented ship channel which runs down the middle of Mobile Bay (fig. 1). This and other channels in the area are maintained by the U.S. Army Corps of Engineers by dredging, with the excavated material added to one of the several designated disposal sites located around the bay area. The Mobile Ship Channel is divided into three parts, the lower, middle, and upper bay segments. The lower part is maintained at a depth of 42 feet (12.8 meters) and a width of 600 feet (183

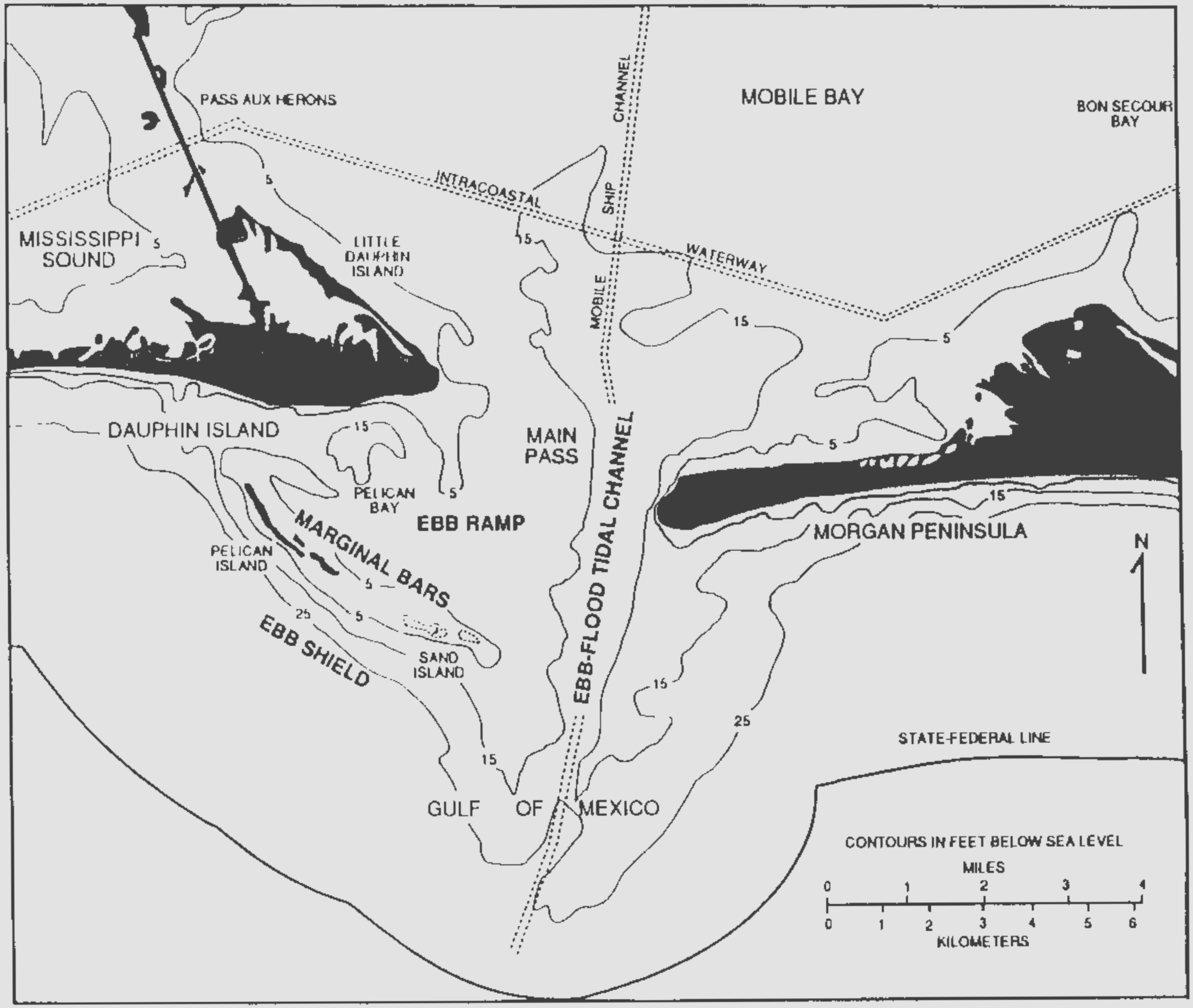


Figure 3 --Geomorphology of ebb-tidal delta of Mobile Bay.

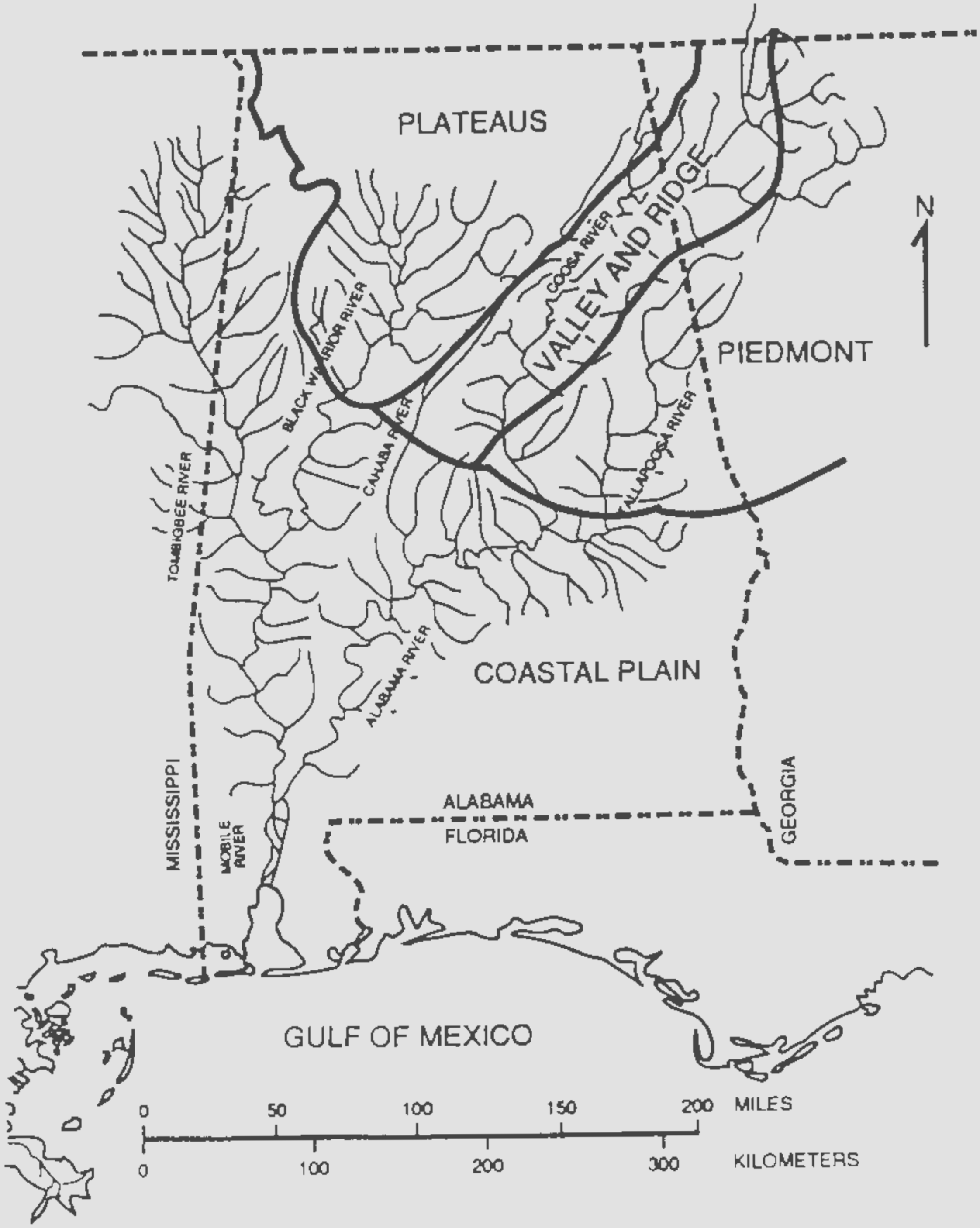


Figure 4.--Mobile River drainage basin (modified from Hardin and others, 1976)

meters), whereas the middle and upper parts are kept at a depth of 40 feet (12.2 meters) and a width of 400 feet (122 meters) (U.S. Department of the Navy, 1986). The maximum channel depth is 60 feet (18.3 meters) due west of Mobile Point (U.S. Department of the Navy, 1986).

PURPOSE AND SCOPE

It is the purpose of this report to summarize the current state of knowledge about Main Pass (the tidal inlet separating Dauphin Island from Morgan Peninsula) and the ebb-tidal delta system (located within and seaward of Main

Pass) of Mobile Bay (figs. 2 and 3). The study area extends from 30°19' north latitude to 30°8.5' north latitude and from 88°10' west longitude to 87°55' west longitude and contains approximately 110 square nautical miles (80 square statute miles or 210 square kilometers) of water.

ACKNOWLEDGMENTS

The author acknowledges Scott Brande, Department of Geology, University of Alabama at Birmingham, Birmingham, Alabama, for providing a copy of an unpublished Minisparker seismic line.

TIDAL INLETS AND TIDAL DELTAS

Three basic types of tidal inlets are recognized: ebb (prominent ebb-tidal delta seaward of the inlet), flood (prominent flood-tidal delta landward of the inlet), and transitional (presence of shoals within the tidal inlet and little tidal delta development) (Hubbard and others, 1979). Criteria for classification of tidal inlets are gross morphology, distribution of sand bodies within the system, and internal structure of the deltas, which results from the interaction between tidal currents and waves. The deltas themselves indicate the dominance or equality of tidal and wave processes in the inlet system. As is true of other depositional environments, tidal deltas vary greatly in their characteristics, even within each type. This variability is due chiefly to the magnitude of the tidal range (Israel and others, 1987) and the types of depositional environments bordering the inlet (for example, lagoon or estuary).

According to the classification scheme of Hubbard and others (1979), the tidal inlet of this study would be classified as tide-dominated owing to its well-developed ebb-tidal delta, poorly developed flood-tidal delta, and deep central channel through which tidal currents flow flanked by channel margin bars (Pelican and Sand Islands and associated submerged shoals) (fig. 3).

Although ebb-tidal deltas are common along barrier island coasts of the Gulf of Mexico and western Atlantic, their sedimentary processes, stratigraphy, and facies are not well understood. Sediment is transported seaward through the tidal inlet by ebb-tidal currents. In some cases, transport is assisted by freshwater discharge from rivers. This sediment laden water slows down where it encounters coastal waves or flood-tidal currents, initiating deposition. The coarsest particles in transport are deposited first with progressively smaller clasts deposited as the current gradually slows down. This results in the formation of a fan-shaped apron of sediment or ebb-tidal delta in which the coarsest clasts are found in the landward part and the finest in the seaward part.

Pelican Bay overlies an ebb ramp over which much of the ebb-tidal water and freshwater masses flow from Mobile Bay into the Gulf of Mexico. In this region, velocity of these water masses diminish as they encounter increasing wave energy of the open Gulf. This results in deposition of much of the sand-sized sediments being transported seaward through the inlet by ebb-tidal and freshwater masses. An equilibrium point is reached (zone of equilibrium) between current velocity of these water masses and wave energy which is demarked by a crudely semicircular escarpment seaward of Main Pass and Dauphin Island called the ebb shield. Here, sand depositional rates are high, resulting in the formation of channel margin bars (Pelican Island, Sand Island, and associated shoals) that are enlarged and modified by dredge disposal activities. Deposition also is enhanced by the time-velocity asymmetry inasmuch as maximum flood tide and, therefore, least restriction to circulation occurs when bars are the most submerged, whereas maximum ebb tide occurs after the bars are exposed (Hubbard and others, 1979).

The ebb-tidal delta of Mobile Bay is reworked by fair-weather and storm waves. Some of the delta sediments are transported along the coast by longshore currents and nourish beaches downcurrent. Some of the delta sediment is transported landward during flood tide.

The surfaces of the ebb ramp are ordinarily covered by shoals, sand waves, dunes, and megaripples. Usually, only ripples are found on the ebb shield and in the finer grained facies seaward of the ebb shield. The bottoms of ebb-flood tidal channels are generally covered with either a coarse lag deposit or megaripples.

Ebb-tidal delta water circulation is complex and depends on the bedforms present and the geographic and oceanographic setting.

The internal structure of ebb-tidal deltas is difficult to characterize and depends on the sediment sizes available, the constructing or destructing nature of the delta, oceanographic and geographic setting, position on the delta, and depth below the sediment-water interface. Ebb-tidal deltas of the northern Gulf of Mexico and southwestern Atlantic comprise a fining-upward sequence that includes in ascending order: (1) shoreface facies clays and sands; (2) ebb-flood tidal channel facies consisting of lag deposits containing the coarsest clast size available, interbedded with cross-stratified sand, and overlain in turn by rippled and planar bedded sand; and (3) ebb shield and ebb ramp facies planar bedded and cross-stratified sands (Israel and others, 1987; Imperato and others, 1988).

PHYSICAL ENVIRONMENT

TIDES

The astronomical tide along coastal Alabama is diurnal, i.e., with one high and one low tide per day (U.S. Department of the Navy, 1986). During the biweekly neap tide, however, two highs and two lows occur within one day (U.S. Department of the Navy, 1986). The mean tidal range is 1.2 feet (0.37 meter) at Mobile Point (Hardin and others, 1976), which is classified as microtidal (Hubbard and others, 1979). Mean low water during the winter months ranges from 0.5 to 1.0 foot (0.15 to 0.31 meter) below that during the summer months (U.S. Army Corps of Engineers, 1979b).

WAVES

Wave intensity along coastal Alabama is low to moderate, with periods ranging from 3 to 8 seconds and wave height rarely over 3 feet (0.9 meter) (Upshaw and others, 1966). This is consistent with the limited flood-tidal delta development landward of the tidal inlet (fig. 3). These fair-weather waves are important for longshore transport of sediments in the nearshore zone (Upshaw and others, 1966). Wave approach is predominantly from the southeast. Intense wave activity associated with hurricanes and other storm events help rework shelf sediments (Upshaw and others, 1966, Chermock and others, 1974).

Wave heights in the nearshore area generally are proportional to wind speeds, with wave heights at a minimum during the summer and a maximum during the winter (Chermock and others, 1974). Chermock and others (1974) state that wave heights of 12 feet (3.7 meters) occur throughout the year, but heights of 20 feet (6 meters) or greater have been reported in February and October only. Some statistical estimates are given by these workers for wave height frequency, but these are probably more representative of the offshore region of Alabama (table 1). For example, unusually strong winds associated with the passage of cold fronts versus hurricanes and tropical depressions.

Table 1.--Mean occurrence interval for maximum significant wave heights (from Chermock and others, 1974)

Mean occurrence interval (years)	Maximum significant wave height	
	Feet	Meters
5	31	9.4
10	34	10.4
25	39	11.9
30	43	13.1

CURRENTS AND CIRCULATION

Tidal movement and freshwater discharge are the two most important factors that affect currents in Mobile Bay (Moser and Chermock, 1978). The ebb- and flood-tides that flow into and out of Mobile Bay are of approximately equal duration, about 6 hours each (Chermock and others, 1974; Moser and others, 1978). The change from flood to ebb to flood produces periods of slack water with zero current velocity (Chermock and others, 1974). When the rate of freshwater discharge from the Mobile-Tensaw River system is high, flood tide velocity slows and ebb tide velocity increases. The reverse is true when freshwater discharge is low. Freshwater has a lower specific gravity than saltwater, so it tends to float on the surface. This can result in freshwater flowing southward over northward-moving saline water from the Gulf of Mexico. This salt wedge complicates the current pattern in Mobile Bay.

Circulation patterns in Mobile Bay and nearshore Alabama are controlled by the tides, river discharge, configuration of the coast and bay, wave approach and wave energy, bathymetry and the Coriolis Force.

During early flood tide, Gulf of Mexico water enters Mobile Bay through Main Pass and is deflected toward the right (Austin, 1954). Figure 5 is a compilation of the most recent surface current data available for the study area. Bottom current data are too few to be dependable, but bottom currents within the study area appear to mimic surface currents. Note the greater density of flood current arrows east of the Mobile Ship Channel and the compass rose diagrams for Main Pass. These indicate that most of the surficial flood water flows along the eastern half of the pass. Some water flows eastward into Bon Secour Bay, where it encounters freshwater discharge from the Fish and Bon Secour Rivers. This produces an eddy in Bon Secour Bay between Mullet Point and Great Point Clear (Chermock and others, 1974; U.S. Department of the Navy, 1986). The eddy is then deflected westward to rejoin the generally northward flow in the central part of the bay (U.S. Department of the Navy, 1986).

A portion of the water that flows in on the west enters Mississippi Sound through Pass aux Herons (U.S. Department of the Navy, 1986). Within approximately 4 hours, the flow through Pass aux Herons reverses and water enters Mobile Bay from the sound and moves toward the northeast (Chermock and others, 1974; U.S. Department of the Navy, 1986). This complicates the main inflow, producing turbulence and mixing of waters.

In the north end of the bay, flood-tidal waters are forced eastward by incoming freshwater from the Mobile-Tensaw River system (U.S. Department of the Navy, 1986). The surficial freshwater continues southward along the western side of the bay (U.S. Department of the Navy, 1986). Mississippi Sound becomes brackish as quantities of this freshwater enter the sound. McPhearson (1970) reports that the salinity in Mississippi Sound has been increasing in recent years, probably due to increased sedimentation associated with the Dauphin Island Bridge, which restricts freshwater flow from Mobile Bay into the sound, and with widening of Petit Bois Pass, which promotes exchange of saltwater between the sound and the Gulf of Mexico.

During ebb tide within Mobile Bay, there is a fairly uniform movement of water to the south, with some slight eddies resulting from irregularities in the shoreline (Chermock and others, 1974). About 72 percent of the water leaves the bay through Main Pass, the remainder flowing into Mississippi Sound (Chermock and others, 1974). A salt wedge moves inland during ebb tide, following the ship channel and clinging to the bottom and then surfaces in Mobile Bay during ebb tide (Chermock and others, 1974). Freshwater discharge and wind have an effect on tidal range by piling up water in the northern part of the bay during high freshwater discharge or strong southerly winds, and removing bay water during low freshwater discharges or strong northerly winds (U.S. Department of the Navy, 1986).

In the study area, longshore currents flow from east to west at rates of 1 to 3 miles per hour (1.6 to 4.8 kilometers per hour) (Chermock and others, 1974). These rates increase to 3 to 6 miles per hour (4.8 to 9.7 kilometers per hour) during incoming tides (fig. 5) (Chermock and others, 1974).

The ebb- and flood-tidal current patterns in the ebb-tidal delta region have not been studied. However, ebb/flood-tidal current data collected southwest of the study area (U.S. Army Corps of Engineers, 1985b) and south of the study area (Kjerfve and Sneed, 1984), plume studies (Abston and others, 1987), and the shape of the ebb-tidal delta itself suggest that most flood waters flow into Mobile Bay through Main Pass from the south to east following the Mobile Ship Channel. Ebb-tidal waters appear to flow out of Mobile Bay, again following the ship channel, but southeasterly winds seem to force the surface water to flow down the west side of Main Pass and a significant portion empties into Pelican Bay and exits through Pelican Pass into the Gulf (Abston and others, 1987). Longshore currents usually direct the exiting water masses toward the west unless offset by a strong westerly wind, in which case the water masses move southward or even eastward (Abston and others, 1987).

SALINITY

Main Pass is the primary avenue through which Gulf of Mexico waters meet freshwater from the Mobile-Tensaw River system. Salinity distribution in Mobile Bay and the study area is a result of the interaction of freshwater discharge, tides, currents, winds, circulation, evaporation,

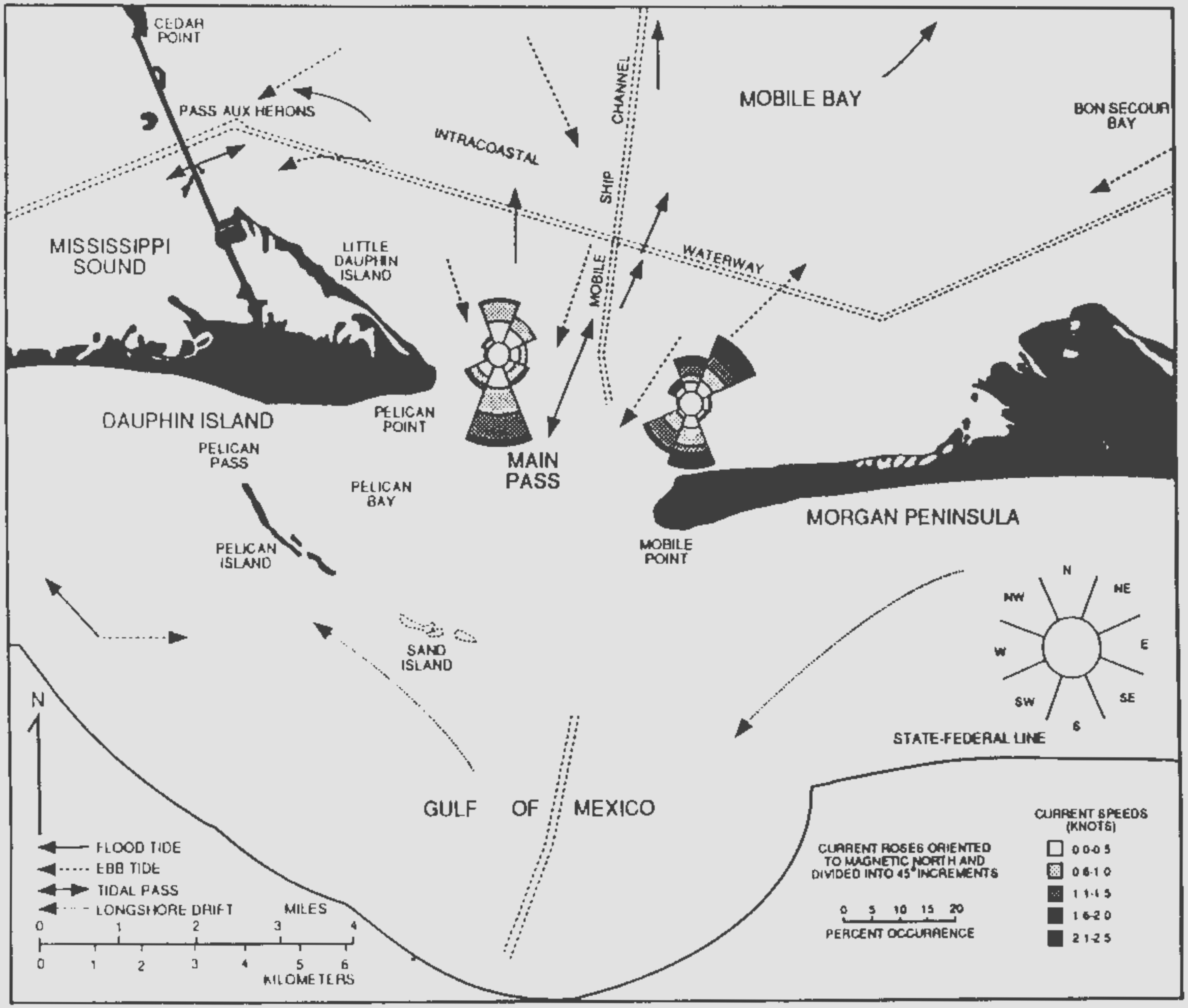


Figure 5 --Average annual surface current distribution flood and ebb tides in the study area (data from Schroeder, 1976, and Smith, 1981).

and bathymetry. Most of these parameters vary constantly and, as a result, the geographic distribution and range of salinity values change continuously.

Throughout most of the year, salinities in Mobile Bay are higher east of the Mobile Ship Channel than to the west, and there is a gradual increase in salinity from the head of the bay to its mouth (fig. 6) (Vittor and Associates, Inc., 1985). In the Mobile Bay estuary system, the most important factor affecting salinity is freshwater discharge from the Mobile-Tensaw River system (Chermock and others, 1974). In the lower part of the bay, salinity values can range from 0 to 36 parts per thousand (ppt) (Schroeder and Lysinger, 1979). Lowest salinities are present normally sometime between January and May, when high river discharge and flooding ordinarily occur, and average 15 ppt in the southern part of Mobile Bay (Boone, 1973; Schroeder and Lysinger, 1979). The highest salinities are present normally sometime between June and November, when low river discharges normally occur, and average 30 ppt in the southern part of Mobile Bay (Boone, 1973; Schroeder and Lysinger, 1979). In general, average annual bottom salinities are higher than those at the surface (Chermock and others, 1974). The greatest contrast appears to be at the entrance to Mobile Bay (table 2). During droughts, saline water tends to dominate the surface waters in the lower part of Mobile Bay and Main Pass and can intrude as much as 21 miles (33.8 kilometers) upstream in the Mobile-Tensaw River (U.S. Department of the Navy, 1986). During moderate river discharges, riverine and transitional waters dominate the entire surface field in the lower part of the bay (U.S. Department of the Navy, 1986). During floods, surface salinities can be reduced from 20 ppt to nearly 0 ppt in the southernmost part of the bay, while the bottom waters are largely unaffected (U.S. Army Corps of Engineers, 1979b; Department of the Navy, 1986). These high discharges produce a high hydrostatic head, which results in higher tides and currents at the mouth of the bay (U.S. Department of the Navy, 1986). During floods, a southward surface flow continues out into the Gulf of Mexico even during flood tides (U.S. Army Corps of Engineers, 1979b).

Bathymetric control on salinity distribution is exemplified by the Mobile Ship Channel, which is flanked by an almost unbroken line of spoil

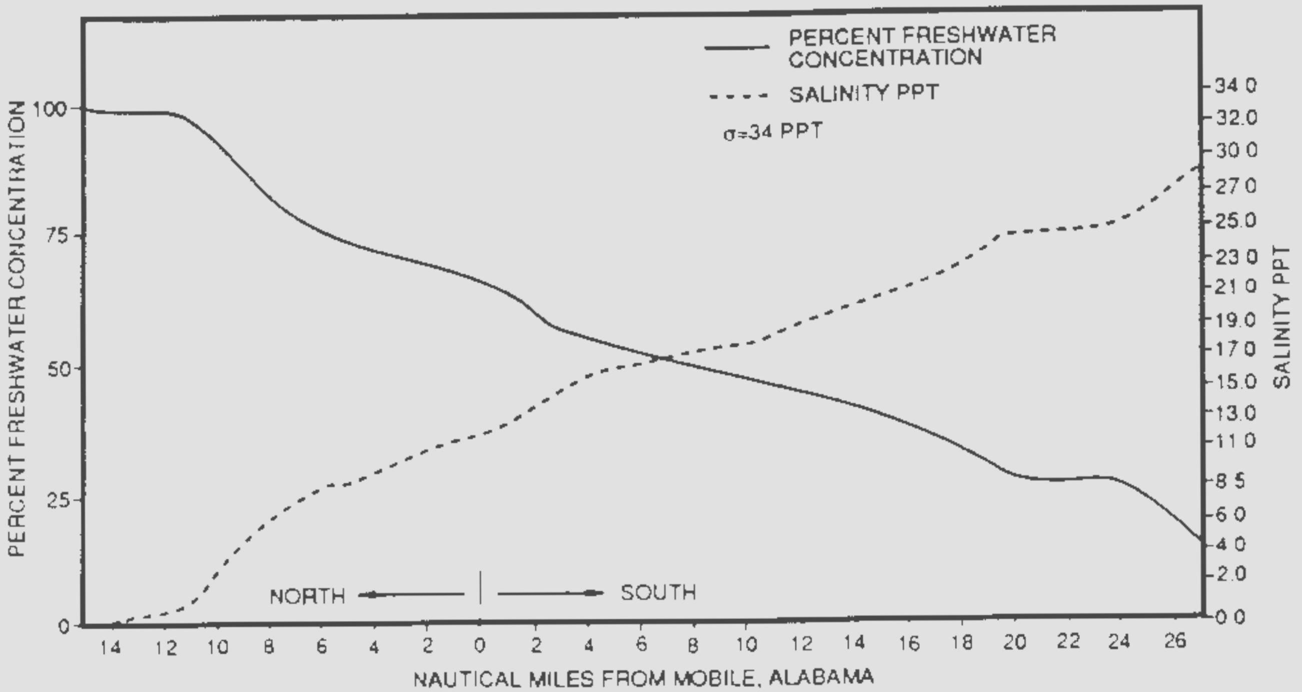


Figure 6.--Relationship between freshwater and salinity for Mobile River and Bay, Alabama (modified from Chermock and others, 1974)

Table 2.--Average annual surface and bottom salinities (ppt) (from Chermock and others, 1974)

	1963-64		1965-66	
	S	B	S	B
Mobile Bay				
all stations	9.9	12.1	10.4	12.5
greater than 5 feet	9.6	13.3	10.3	14.1
west of channel	10.8	11.6	12.6	14.0
east of channel	9.1	11.6	9.3	14.0
Mississippi Sound				
all stations	21.0	22.5	22.0	23.5
greater than 5 feet	22.2	23.8	22.6	24.8
Bon Secour Bay	16.3	16.4	16.1	17.6
Entrance to bay	18.7	29.4	22.3	30.3

S = Surface B = Bottom

material on both sides for its entire length. This topographic barrier between the deep channel and shallow bay bottom produces a salt water wedge in the Mobile Ship Channel and Mobile-Tensaw River most of the year (fig. 7) (Boone, 1973).

Wind is an important agent for the distribution of surface and bottom waters in Mobile Bay due to its large surface area and shallow depth (Schroeder and Lysinger, 1979). Northerly winds complement river flow and move the influence of the river farther south; the opposite occurs with a southerly wind (Schroeder and Lysinger, 1979). West winds push surface water toward the eastern part of the bay; this is often accompanied by a shift in bottom waters toward the west. The opposite is true for an easterly wind (Schroeder and Lysinger, 1979).

Tidal action normally results in a daily north-south shifting of salinity fields, which can range from little or no movement up to 3.7 to 6.2 miles (6 to 10 kilometers) (Schroeder and Lysinger, 1979).

During low river discharges, the highly saline lower part and mouth of Mobile Bay approaches vertical homogeneity, whereas during high discharges these areas become stratified (Vittor and Associates, Inc., 1985). Vertical salinity stratification is variable seasonally, becoming more pronounced in late summer and fall (Vittor and Associates, Inc., 1985). Figure 8 shows the salinity regime across Main Pass during times of oceanic and riverine dominance.

WATER TEMPERATURE

Surface and bottom water temperatures in estuaries vary directly with air temperature (Chermock and others, 1974) (fig. 9). Within the study area, the average annual temperature is fairly constant, with bottom water usually slightly cooler than water at the surface (table 3). The Main Pass area is warmer in the winter and cooler in the summer than upper Mobile Bay (compare upper bay to bottom waters at Main Pass, table 4). Seasonal periods are well defined, except for the bottom waters at Main Pass, which has a warmer season lasting four months, a summer delayed one month behind the rest of the bay, and a fall cooling season only two months long. Table 5 lists average monthly surface and bottom water temperatures for Main Pass versus air temperature and upper Mobile Bay water temperatures. The same measures for Main Pass are displayed graphically in figure 10. From October through February, bottom waters are warmer than surface waters; surface waters are warmer than bottom waters from April through August. The water column is nearly homogeneous during the months of March and September. Bottom waters are linked to the Gulf of Mexico, which, due to its greater volume, does not cool down or warm up as fast as Main Pass, nor does it become as cold or warm as its own surface waters. Hence, during the spring warming season, surface waters warm up faster than bottom waters and remain hotter through early fall and during the late fall cooling season. Throughout the winter, they become cooler than bottom waters and remain cooler.

BATHYMETRY

One of the earliest maps showing detailed soundings of the study area is a chart of the northern Gulf of Mexico produced by Romans between 1772/73 and 1775 (hereafter referred to as circa 1774) for the Marine Society of the City of New York. His data were used to draft the contoured bathymetric map shown in figure 11.

Ryan (1969) analyzed a series of U.S. Coast and Geodetic Survey Charts published between 1847 and 1851 (hereafter referred to as circa 1849), in order to produce a bathymetric map

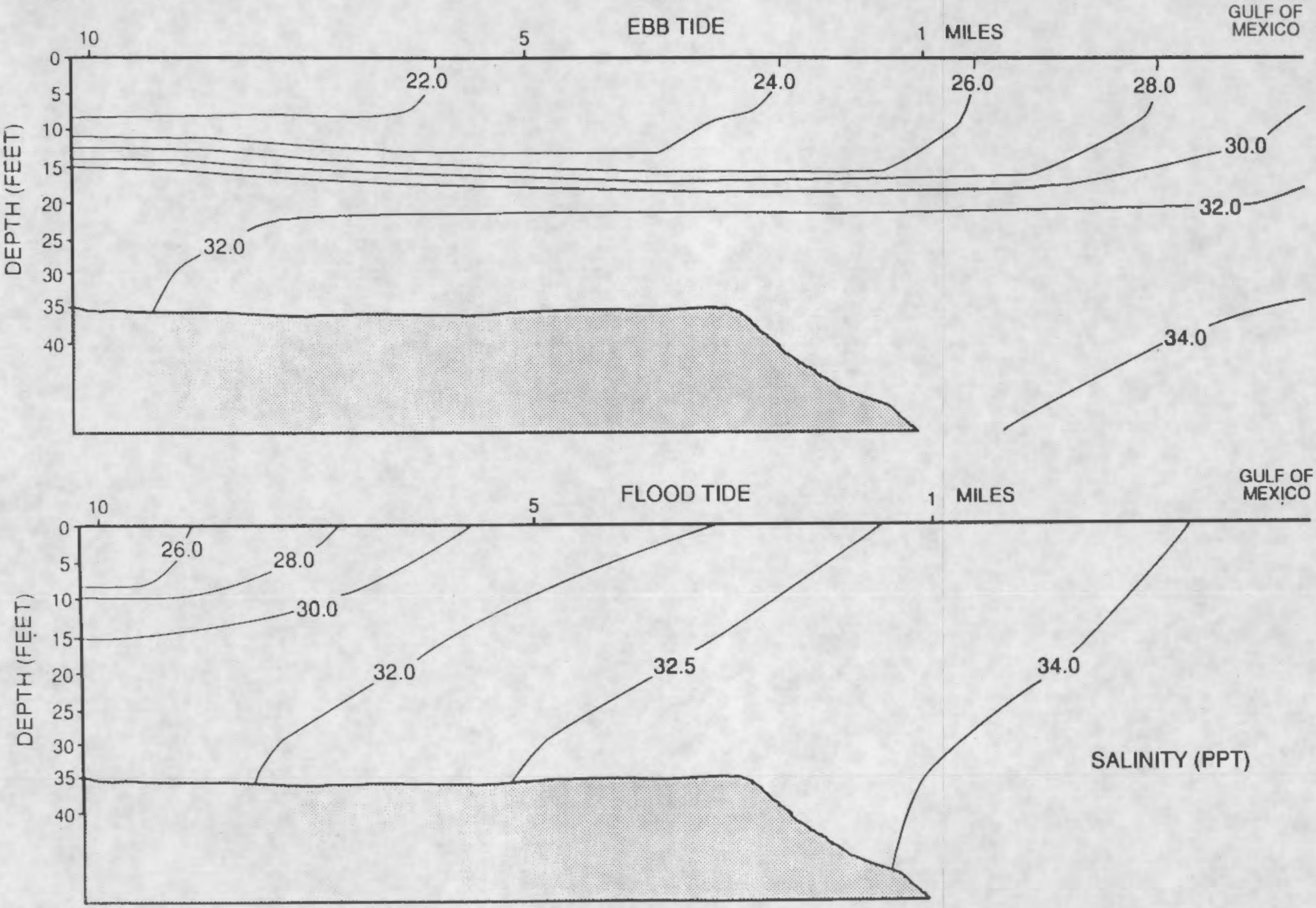


Figure 7.--Salinity-depth section, lower Mobile Ship Channel (modified from Chermock and others, 1974).

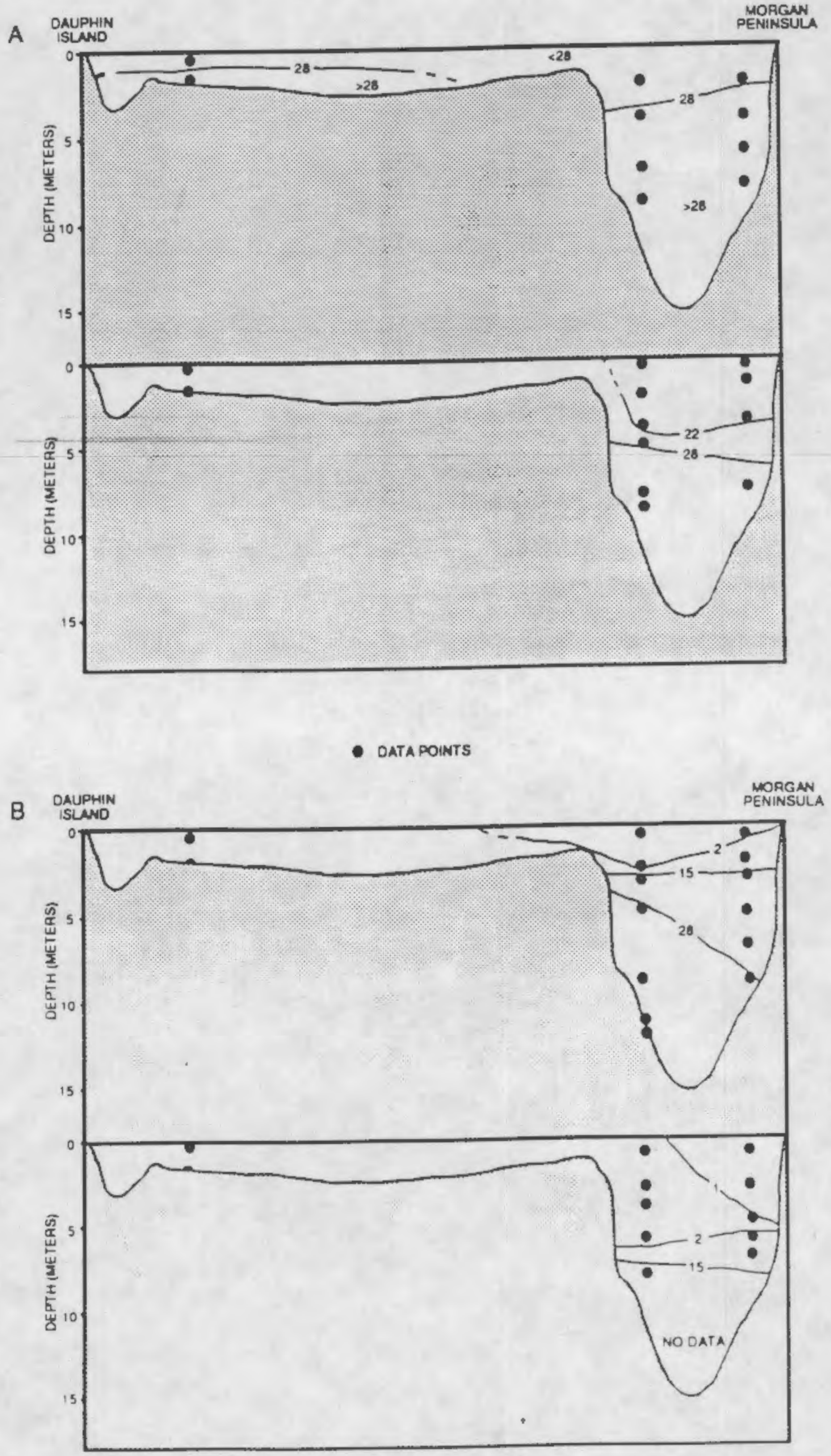


Figure 8.--Vertical cross-section of salinity (ppt) through Main Pass, Mobile Bay during (a) low river discharge on October 11, 1976, and (b) flooding river discharge on April 8, 1977 (modified from Schroeder and Lysinger, 1979)

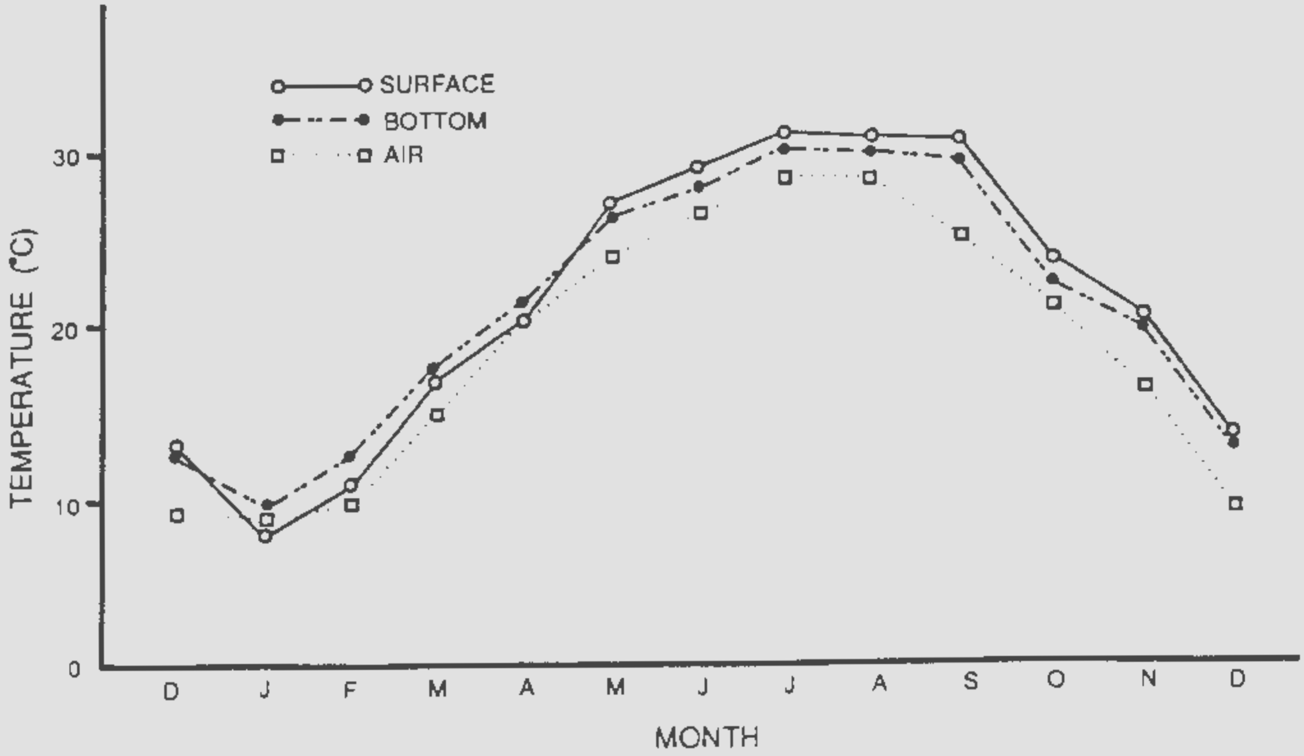


Figure 9.--Monthly average temperatures for Alabama estuaries (modified from Chermock and others, 1974).

Table 3.--Average annual surface and bottom temperatures in Alabama estuaries (from Chermock and others, 1974)

Location	Surface	Bottom
Upper Mobile Bay	22.4	21.9
Middle Mobile Bay	22.9	22.4
Lower Mobile Bay	23.5	23.3
Bon Secour Bay	23.4	21.5
Entrance to Mobile Bay	23.5	23.1
Northern Mississippi Sound	23.7	23.3
Southern Mississippi Sound	23.0	22.5
Little Lagoon	22.7	
Perdido Pass	20.8	20.1
Wolf Bay	20.9	20.9
Perdido Bay	20.4	20.9
Oyster Bay	20.7	20.3
Pass aux Herons	20.2	19.6

for Mobile Bay. The part which covers the study area is reproduced as figure 12.

Hardin and others (1976) drafted four similar bathymetric maps for 1929, 1941, 1962 and 1973. These cover the entire study area except for the southernmost part of the ebb-tidal delta. These are reproduced as figures 13 through 16, respectively.

A map of present-day bathymetry was drawn for the study area using the latest chart available (NOAA, 1987) and is given as figure 17.

In order to describe as completely as possible the bathymetric changes that have occurred in recent times, the 1973 map was extended to include the southern part of the ebb-tidal delta

Romans' circa 1774 map shows several noteworthy features. First, there appears to be a series of islands in Pass aux Herons and a pass between Little Dauphin Island and eastern Dauphin Island. Pelican Island is present and the shoal to its southeast may represent Sand Island. A prominent basin north of Main Pass was probably scoured by ebb- and flood-tidal currents. The deepest point within Main Pass is

Table 4.--Seasonal temperature (°C) data for Mobile Bay (from Schroeder and Lysinger, 1979)

Season	Months	Water temperature range			Air temperature range Mobile (Bates Field NWS)
		Upper Bay	Main Pass[a] Surface	Main Pass[a] Bottom	
Winter	D, J, F	<13.0	<14.0	<16.0	<13.0
Spring	M, A, M	13.0 - 27.0	14.0 - 26.0	16.0 - 24.0[b]	13.0 - 26.0
Summer	J, J, A	>27.0	>26.0	>24.0[c]	>26.0
Fall	S, O, N	27.0 - 13.0	26.0 - 14.0	24.0 - 16.0[d]	26.0 - 13.0

[a] Because of the bathymetric differences between East and West Main Pass, the surface observations at East Main Pass are combined with the water column observations at West Main Pass and are treated as the surface zone of Main Pass. The bottom zone of Main Pass is characterized by bottom East Main Pass data exclusively.

[b] Months of March, April, May and June.

[c] Months of July, August, and September.

[d] Months of October and November.

Table 5.--Temperature (°C) data for Mobile Bay (from Schroeder and Lysinger, 1979)[1]

Month	Upper Bay		East Main Pass		West Main Pass	Air temperature
	Surface 0.5 m	Bottom 2.0 m	Surface 0.5-1.0 m	Bottom 8.0-9.0 m	Water column 0-3.0 m	Mobile (Bates Field NWS)
J	10.6	10.3	12.0	14.2	12.4	10.7
F	10.7	11.5	13.5	15.1	13.9	12.2
M	14.9	15.9	16.4	16.9	17.0	15.2
A	19.1	20.6	20.6	20.3	21.2	19.9
M	23.9	24.7	23.4	21.1	23.9	23.7
J	26.5	27.4	26.6	23.3	26.6	26.8
J	28.9	28.9	27.4	24.4	27.4	27.6
A	29.2	28.8	27.7	26.8	28.1	27.5
S	26.9	26.1	25.6	26.2	26.1	25.2
O	22.7	21.9	22.7	23.5	22.5	20.5
N	17.6	16.6	18.0	19.5	17.5	14.7
D	13.0	12.3	14.1	16.1	13.8	11.6

[1] Water temperatures are 3-month running averages and air temperatures are monthly averages

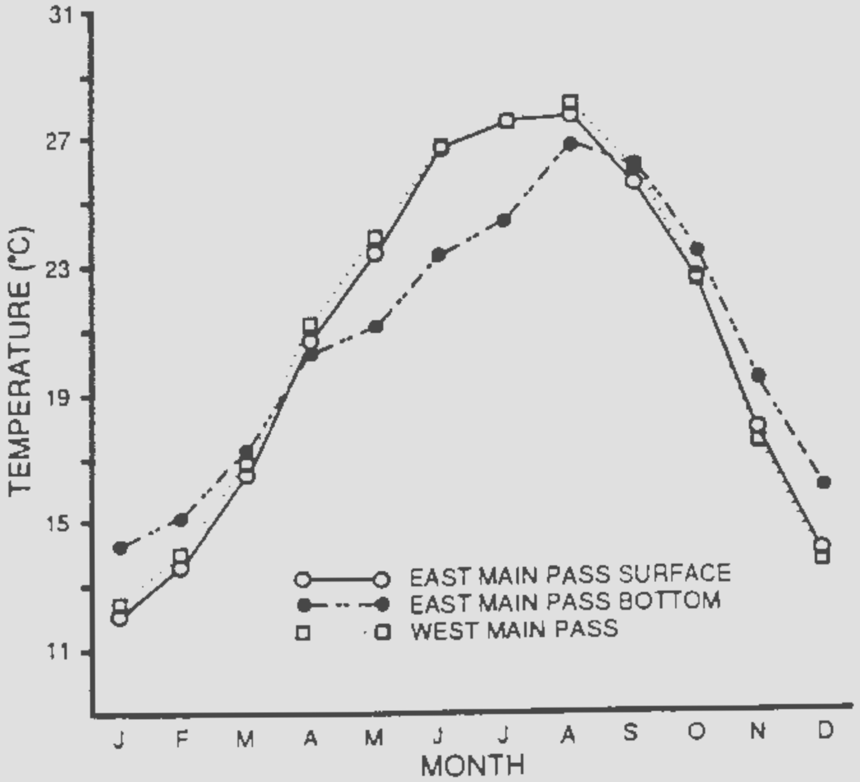


Figure 10.--Thermal regime of Main Pass, Mobile Bay (modified from Schroeder and Lysinger, 1979). Values are 3-month running averages.

55 feet (16.8 meters) and is located north-northwest of Mobile Point in the central channel. The shoal or bar shown south-southeast of the Morgan Peninsula may be fictitious, as a single sounding of 18 feet (5.5 meters) is responsible for contouring this feature. Also, this apparently prominent bar does not appear on any of the more recent maps utilized in this report.

The deepest parts of ebb-flood tidal channels are floored either by a coarse lag deposit or by sand waves (Hubbard and others, 1979). The nature of the bottom evidently depends on the position of the deepest part of the channel with respect to the strandline. Tidal inlets that have the trough in line with or seaward of the strandline, are floored with sand waves. If the trough is landward of the strandline, the bottom of the channel is covered by a lag deposit. In circa 1774, the trough in Main Pass was landward of the strandline and, therefore, probably was floored by a lag deposit produced by ebb-tidal currents. Sand waves and megaripples are usually found in the shallower and seaward parts of ebb-flood tidal channels (Hubbard and others, 1979).

The bathymetry of circa 1849 shows the natural configuration of the study area before the advent of dredged ship channels and associated spoil banks (fig. 12; Ryan, 1969). The eastern side of Main Pass was naturally scoured to depths of 59 to 62 feet (18 to 19 meters) off Mobile Point; shallowing occurred both toward Mobile Bay and the Gulf of Mexico. Within the estuary, Main Pass bifurcated to form a narrow, steeply sloping eastern limb and a wider, gently sloping western limb. The eastern limb was probably maintained by flood tides, and the western limb by both ebb- and flood-tidal currents, which have worked to scour the southern part of Mobile Bay adjacent to Main Pass into a broad, spoon-shaped depression (Ryan, 1969) Seaward of Main Pass, a large ebb-tidal delta existed at depths of less than 20 feet (6 meters) with three islands superimposed on it.

Comparison of figures 11 and 12 shows that the study area had changed significantly in 75 years Some remnants of the islands in Pass aux

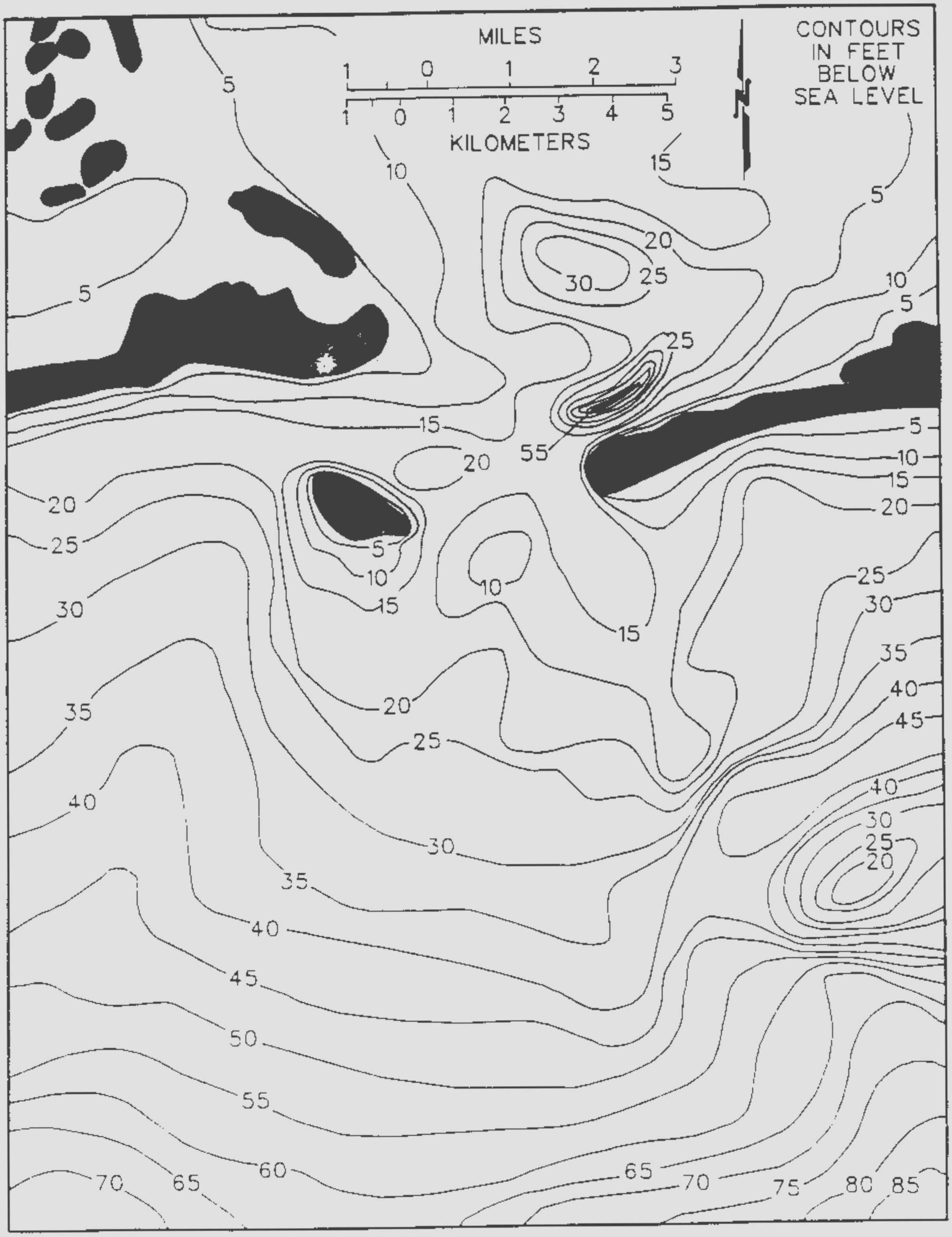


Figure 11 --Bathymetric map of the study area, circa 1774 (soundings from B Romans, 1772/73-1775)

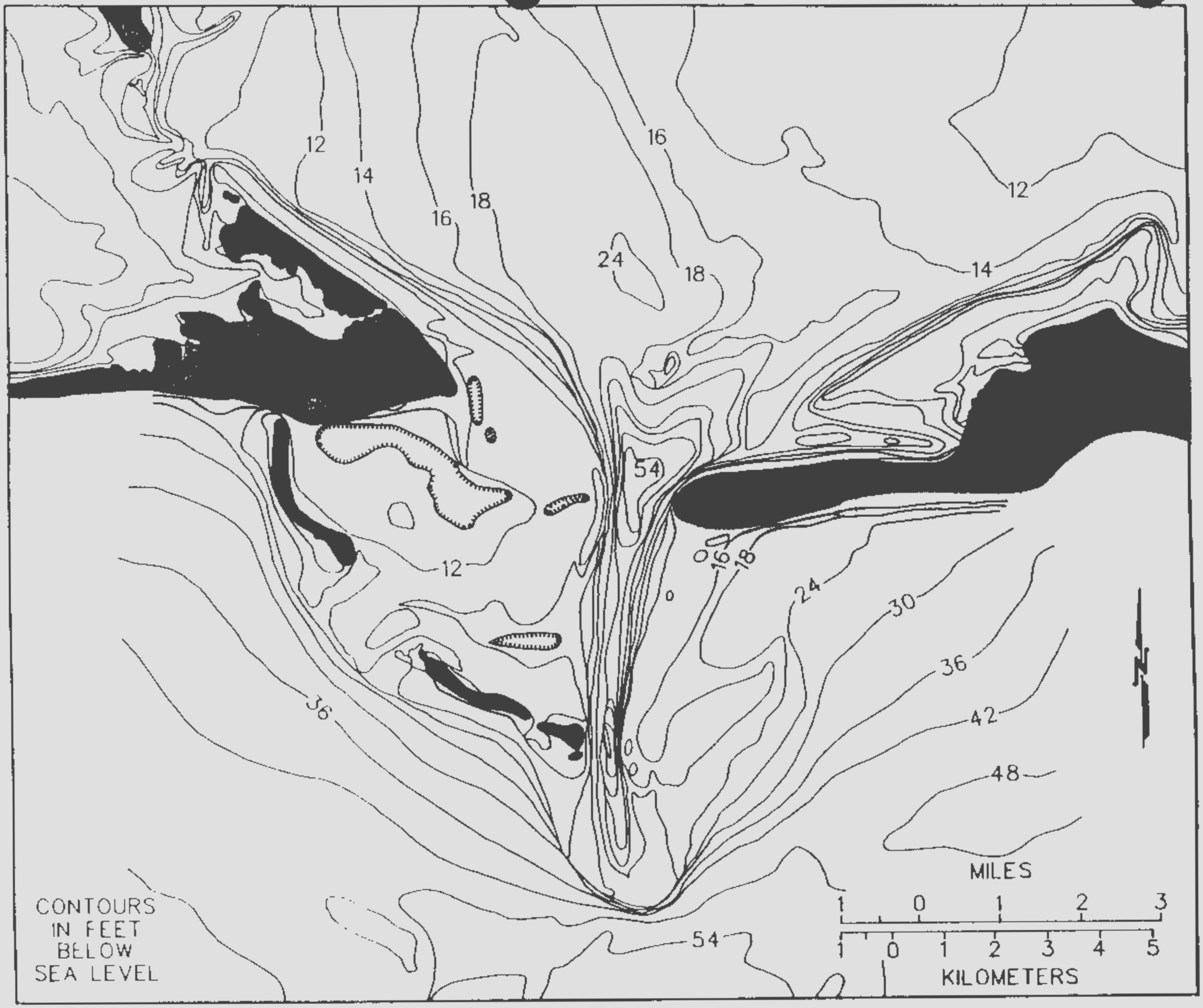


Figure 12.--Bathymetry circa 1849 (1847-51) for the study area. Contours in feet below sea level (modified from Ryan, 1969).

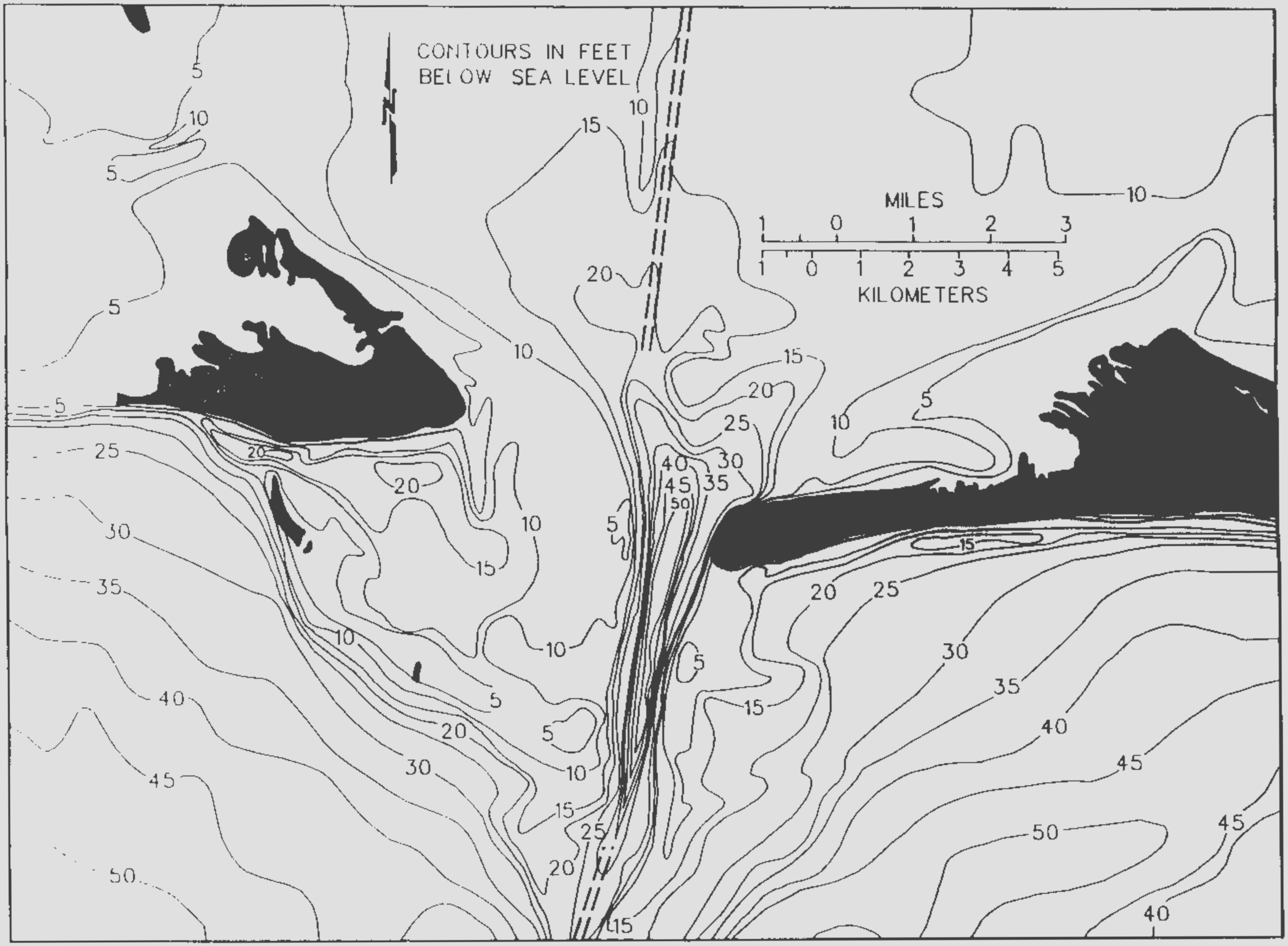


Figure 13 Bathymetric contours, Mobile Bay entrance and associated passes, 1929 (modified from Hardin and others, 1976)

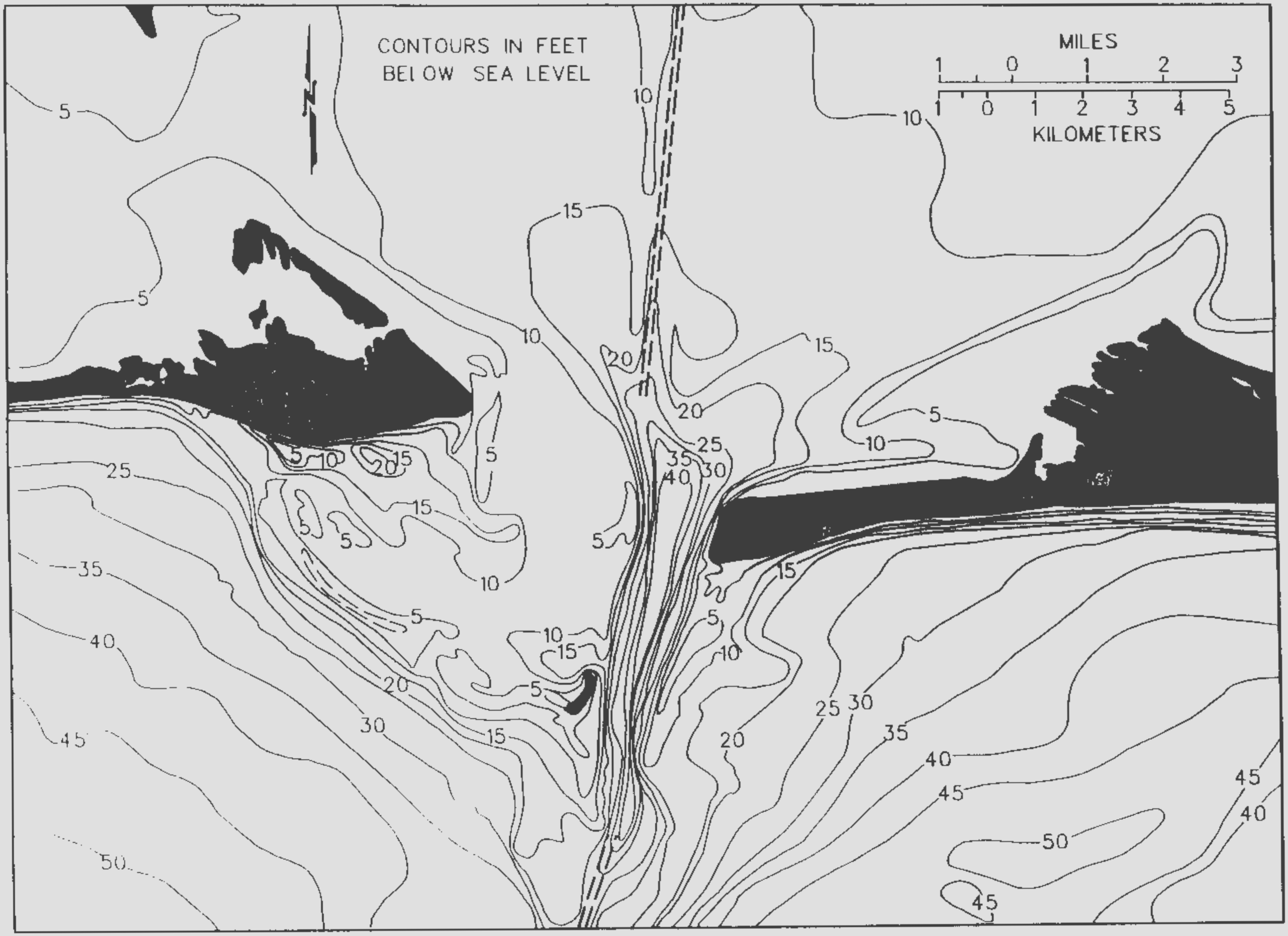


Figure 14 Bathymetric contours, Mobile Bay entrance and associated passes, 1941 (modified from Hardin and others, 1976).

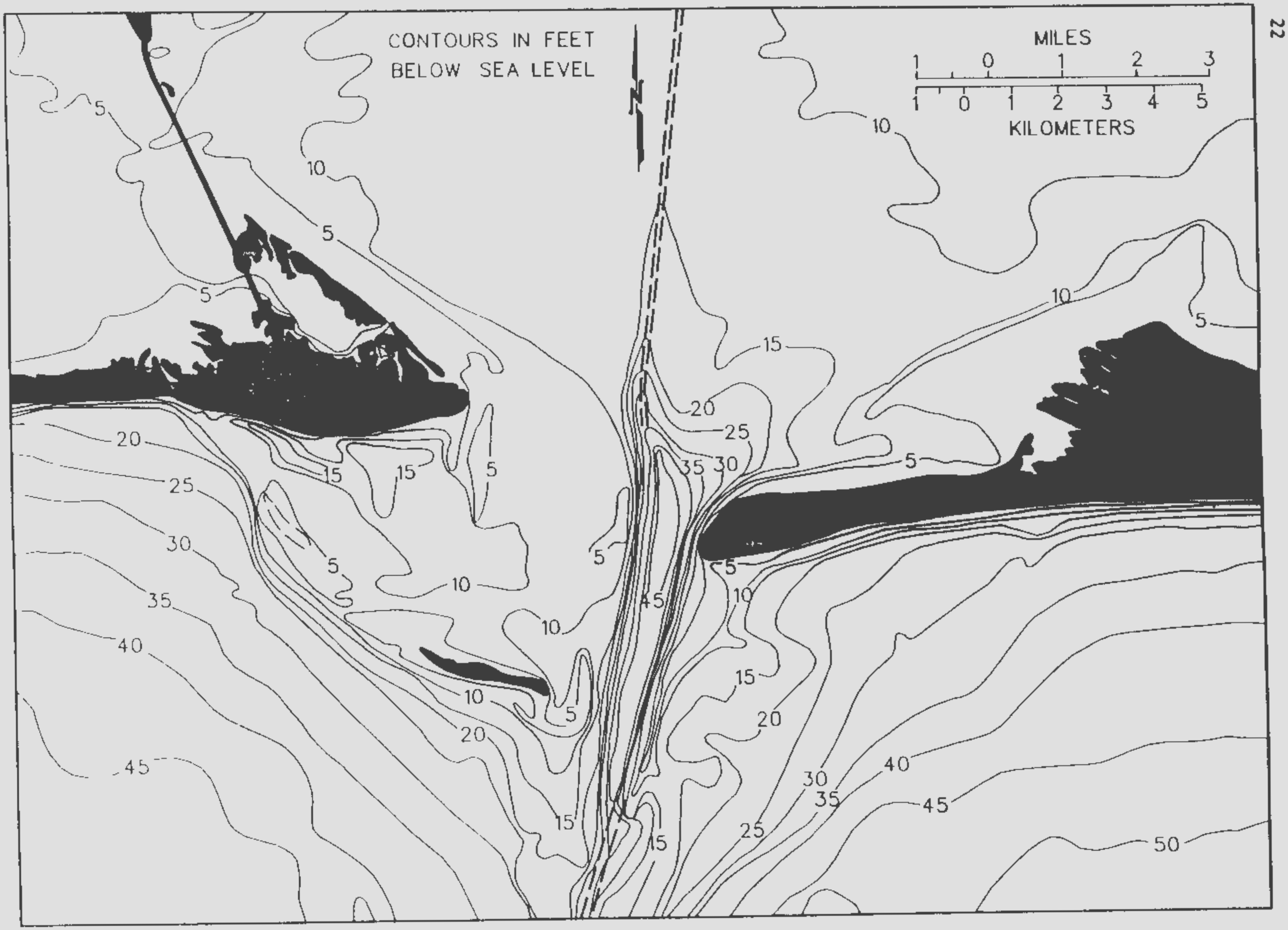


Figure 15 --Bathymetric contours, Mobile Bay entrance and associated passes, 1961 (modified from Hardin and others, 1976).

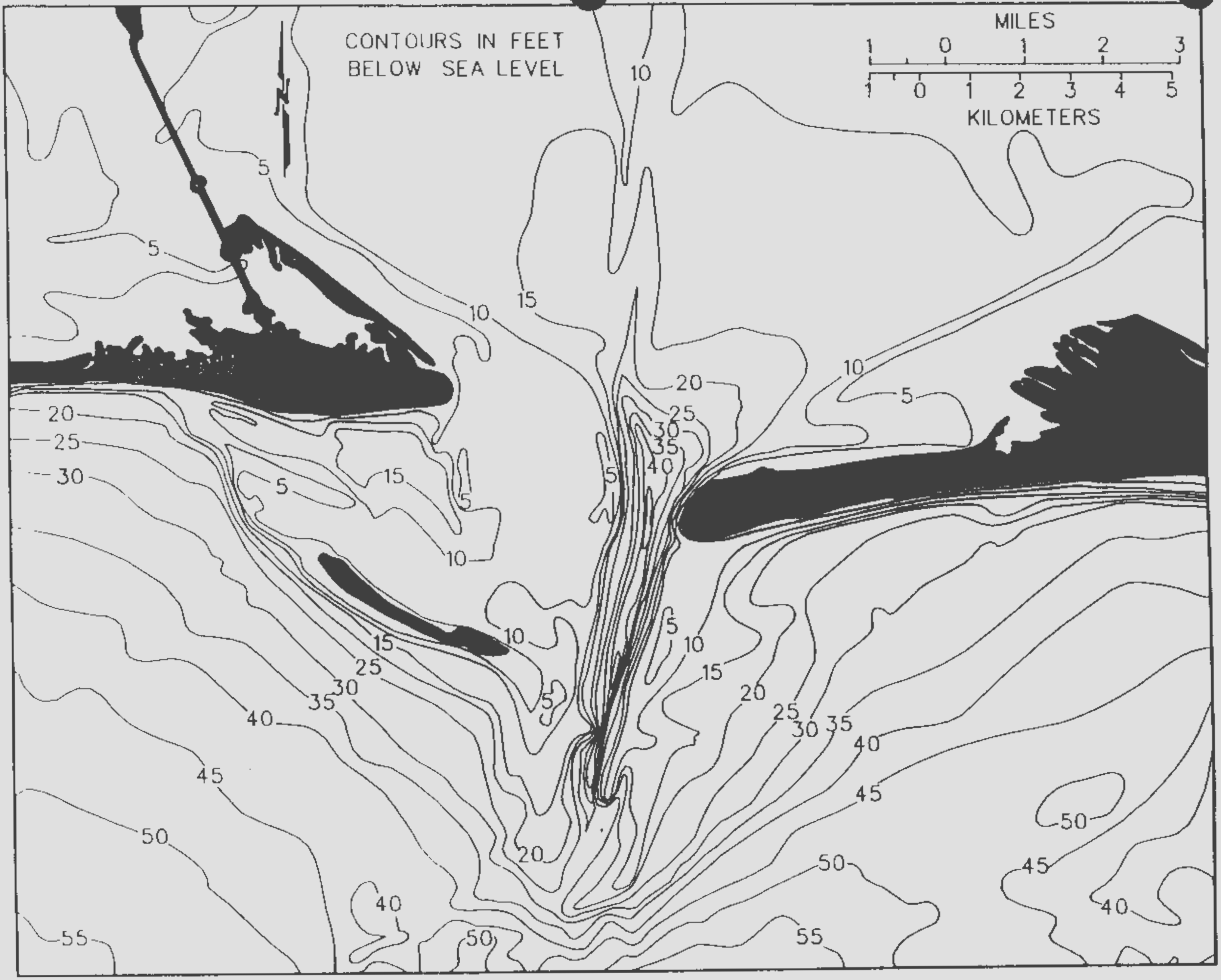


Figure 16 --Bathymetric contours, study area, 1973 (modified from Hardin and others, 1976).

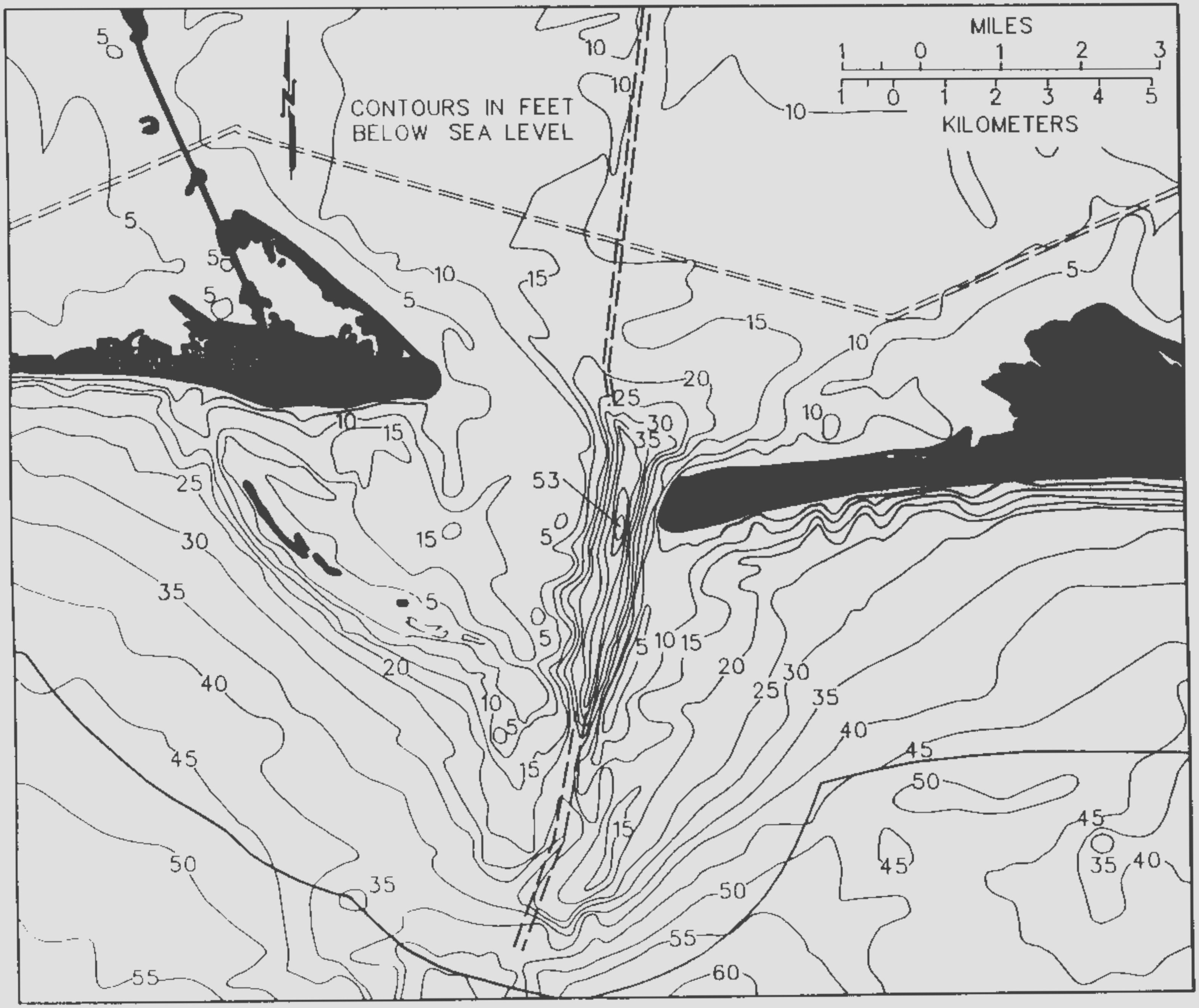


Figure 17 --Bathymetric contours, study area, 1987 (data from NOAA, 1987).

Herons and the pass between Little Dauphin Island and eastern Dauphin Island (probably Pass Drury), seen circa 1774, were still present circa 1849. Pelican Island had changed shape and location. Sand Island emerged as a series of three islands. Mobile and Pelican Bays shallowed slightly. The deepest point within Main Pass shifted south, so that circa 1849 it lay west of Mobile Point. In addition, the deep area north of Main Pass had also shifted west, broadened and shallowed. This seaward shift of the trough probably allowed the development of sand waves within it. The increased deposition in southern Mobile Bay indicates that flood-tidal currents became stronger relative to ebb-tidal currents, enabling the transport of shelf sands into the bay. Also, the change in size and position of the Sand Island shoal and the shallowing of Pelican Bay indicates a shift in the zone of equilibrium landward, which is consistent with a strengthening of flood-tidal currents.

Dramatic changes occurred in Mobile Bay in the period circa 1849 to 1973. Ryan and Goodell (1972) documented a general shoaling of the bay to depths ranging from 10 to 13 feet (3 to 4 meters). The bathymetry was greatly modified by the dredging of a ship channel from Mobile to the tidal inlet, the cutting of a channel through the outer bar of the ebb-tidal delta, and the disposal of dredge material within Mobile Bay and on the shelf south of the tidal inlet.

During the period from circa 1849 to 1973 (figs. 12 through 16), few changes in bathymetry occurred in the study area. The once broad depression in southern Mobile Bay north of Main Pass progressively shallowed and shrank to perhaps half of its circa 1849 areal extent owing to siltation of the bay. Although not reflected by the maps, the ship channel has been dredged over the years becoming progressively wider and deeper. Pelican Bay has gradually shallowed, owing primarily to the vertical growth of the ebb-tidal delta. The seaward end of the ebb-flood tidal channel has become realigned to a more northerly orientation, perhaps because of dredging operations across the bar seaward of Main Pass (Ryan and Goodell, 1972).

Southwest of the Main Pass, Sand/Pelican Island, an emergent bar on the ebb-tidal delta, has repeatedly joined, split, and changed size, shape and location (figs. 12 through 16). This feature is especially sensitive to storms from the Gulf of Mexico (Smith, 1981). Hardin and others (1976) state that the bathymetry at the mouth of Mobile Bay and around Little Dauphin Island is heavily affected by dredging activities in the inlets and that these areas are gradually silting up (figs. 12 through 16). Unless they are dredged regularly, the numerous small passes around Little Dauphin Island will close (Hardin and others, 1976).

The bathymetry from the period 1973 to 1987 shows the continuing shallowing of southern Mobile Bay (figs. 16 and 17). The ebb-flood tidal channel is noticeably broader; its western slope has become gentler and contains what appears to be three or four canyons. The depth of the ebb-flood tidal channel has remained essentially constant during this time. Sand Island has separated from Pelican Island and now exists as two submerged shoals. Pelican Island has migrated northwestward and has split into three separate islands.

One of the major changes, which occurred between 1973 and 1987, was the continued shoaling and redistribution of sediments in Pelican Bay. Figure 18 is a bathymetry differencing map for the time period from 1973 to 1987 and was produced by comparing charts from the U.S. Coast and Geodetic Survey (USC&GS) (1974) and NOAA (1987). It shows a mosaic of centers of net erosion or deposition which, based on aerial infrared photographs, probably represents movement of shoals as sediment is continuously redistributed within Pelican Bay and the addition of dredge spoil material.

It is uncertain what the effect dredging has had on the ebb-tidal delta system over the last 135 years. During this period, the delta has clearly evolved from a natural system to one dominated by man. The gradual silting up of Pelican Bay and southern Mobile Bay seems to have been a continuous process over at least the last 210 years. The cause or causes are unknown, but probably involve several factors, such as freshwater discharge, sedimentation rate, wave energy, relative sea level change, tectonic framework, and the history of deforestation and dredging.

BEDFORMS

Based on inspection of side-scan sonar, black-and-white aerial photographs, and high-altitude infrared photographs, it was

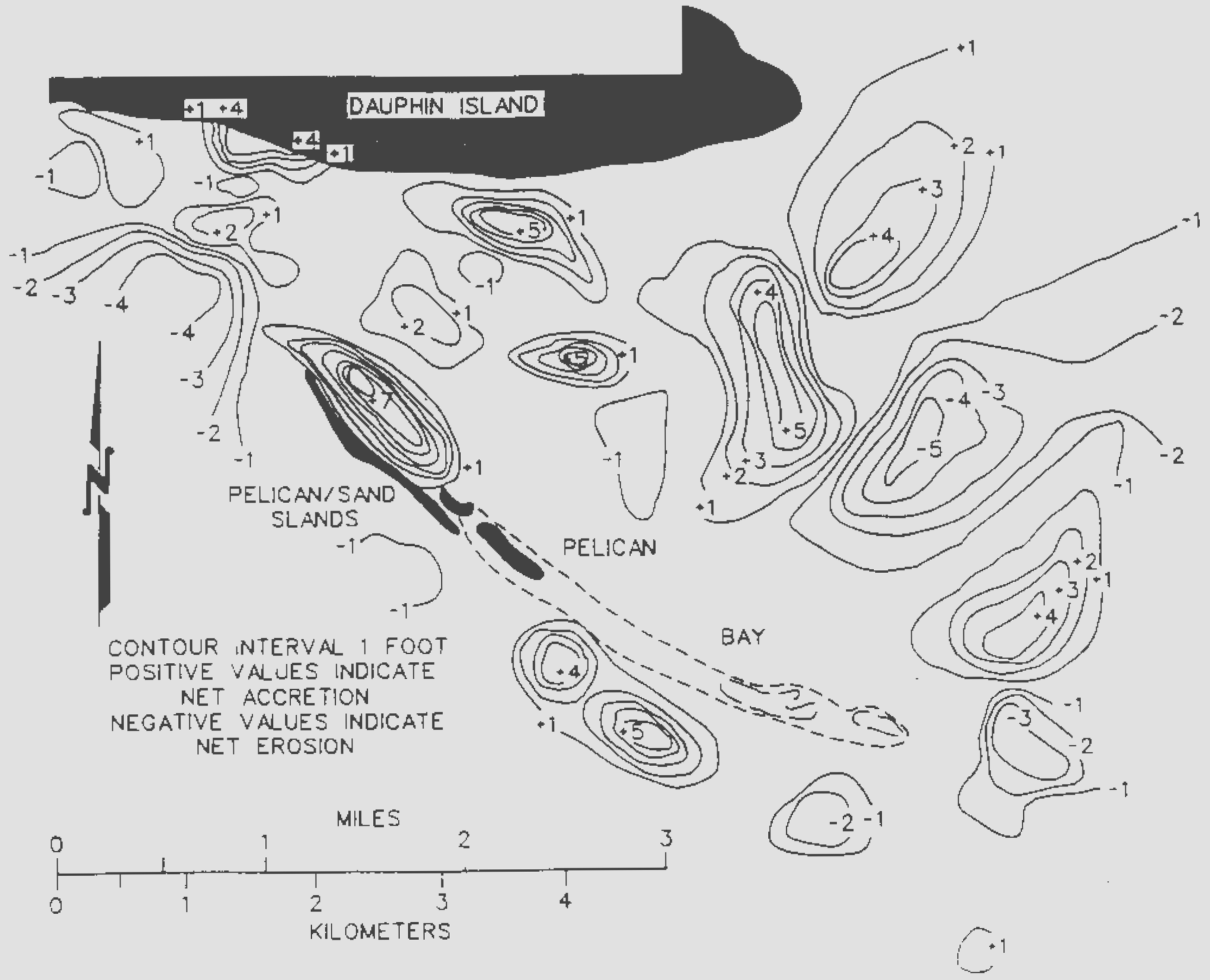


Figure 18.--Bathymetric differencing map for Pelican Bay and Sand/Pelican Island, 1973 to 1987.

determined that much of the ebb ramp is probably covered with shoals and sand waves. Within the shoreface zone of the study area, shoals, transverse bars and longshore bars are formed that appear, disappear, and shift about in response to changing hydrodynamic conditions. Bathymetry of the shelf area seaward of the ebb shield indicates that the shelf is featureless and flat. Imperato and others (1988) state that most ebb delta shields are covered with ripples. The resolution of the existing data does not allow this to be evaluated. The ebb-flood tidal channel is probably floored by predominantly ebb-oriented sand waves (Hubbard and others, 1979; Imperato and others, 1988).

Bedform type and distribution on this ebb-tidal delta are consistent with those of other reported ebb-tidal deltas (Hubbard and others, 1979; Imperato and others, 1988).

SURFACE SEDIMENTS

TEXTURAL

A current surface sediment map is not available for the ebb-tidal delta and Main Pass.

Published granulometric (grain size) data from bottom sediment samples collected within the study area are widely scattered in the literature; differ widely in collection dates; are site specific; differ widely in the nature of the project, methods used and the form of presentation of the data in a report; and are largely qualitative. The collection of data falls into two separate time intervals: from 1966 to 1971 (hereafter referred to as circa 1968) and from 1979 to 1987 (hereafter referred to as circa 1983). The temporal separation of data is conducive to a comparative study between these two time periods.

Upshaw and others (1966) and Ryan (1969) have published the most comprehensive investigations of bottom sediments in coastal Alabama, including the study area. In recent years, other reports, such as Isphording and Lamb (1980), U.S. Army Corps of Engineers (1985a), Exxon Company, U.S.A. (1986), and Browning, Inc. (1987), have made available much granulometric and stratigraphic information from bottom grab samples, borings and vibracores.

Owing to the low density of data in the study area, the granulometric data from Upshaw and others (1966), Ryan (1969) and one datum point from Schneeflock and Dills (1971) were combined to form the data base for circa 1968. Based on the original published form of the data and the need to compare it to the qualitative data base from circa 1983, the data were plotted as percentage clay and silt on a USC&GS (1970) base map. These data were then contoured at a 20 percent interval (fig. 19). Several of the data from each study coincide at the map scale used, which provides a crude means of comparing the separate data sets. Without exception, the discrepancy between overlapping points was between two and four percentage points, which is an acceptable margin of error. From this, it is concluded that (1) the granulometric laboratory techniques employed by Upshaw and others (1966) and Ryan (1969) produced comparable results on samples collected from essentially the same location, and (2) little change in sediment texture occurred between the sampling dates of Upshaw and others (1966) and Ryan (1969).

Figure 19 shows an approximately east-west belt of sand encompassing Dauphin and Little Dauphin Islands, Main Pass and Morgan Peninsula. This occurs between the bay-bottom clays and silts and the ebb-tidal delta clays and silts. Clay and silt extend down from Mobile Bay and line the ebb-flood tidal channel bottom off Mobile Point. A hook-shaped finger of sand essentially follows the ebb-flood tidal channel and Mobile Ship Channel from Mobile Point to the southern apex of the ebb-tidal delta.

Geographic variation in bottom sediment type is subject to prevailing hydrologic and oceanographic conditions (many of which show distinct seasonal variation), which in the study area constantly rework and redistribute the surficial sediments. In the southern part of the bay, sediments are estuarine silts and clays with mixed clay-silt-sand and sand around the periphery of the bay (Isphording and Lamb, 1979; U.S. Army Corps of Engineers, 1979b). Tidal inflow and outflow through Main Pass redistributes the estuarine sediments in the southern half of Mobile Bay and transports fines out of the bay, where most of it is deposited to the south and southwest of the Main Pass, in response to the predominant westward directed littoral drift forming an ebb-tidal delta (U.S. Army Corps of Engineers, 1979b). During the summer months, some of the fines move eastward in response to an eastward component of the longshore drift (U.S. Army Corps of Engineers, 1979b).

Average bottom sediment grain size gradually decreases both landward and seaward of the strandline. Deposition of sand from ebb-tidal sediment plumes occurs seaward of the tidal inlet on the ebb ramp, with clays and silts being deposited on the shelf seaward of the ebb shield. Flood-tidal currents carry shelf sands landward of the strandline, which mix with clays and silts encountered in southern Mobile Bay. This bottom sediment distribution is similar to that of the ebb-tidal delta of North Edisto Inlet, South Carolina, which was described by Imperato and others (1988).

The data base for circa 1983 is, in general, very qualitative and comprised of bottom sample data from Isphording and Lamb (1980), Marine Environmental Sciences Consortium (1981), U.S. Army Corps of Engineers (1985b), and Browning, Inc. (1987), and descriptions contained in U.S. Army Corps of Engineers (1979a, 1985a) about sediment-water interface samples from borings and Exxon Company, U.S.A. (1986). These data have been pooled, the major constituent (clay/silt or sand) for each sample plotted on a current base map (NOAA, 1987) and a boundary drawn (50 percent

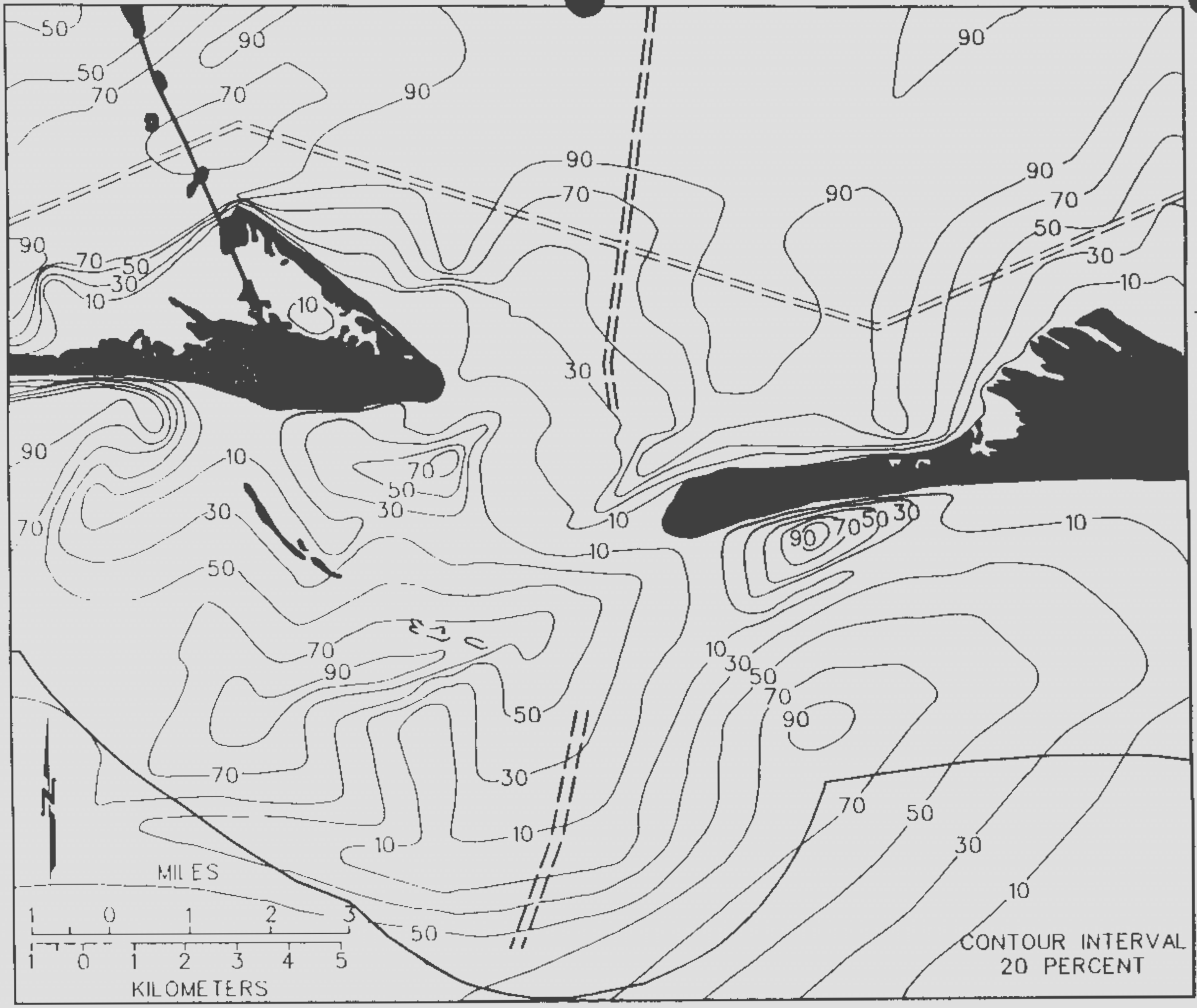


Figure 19.--Percent clay/silt of bottom sediments within study area, circa 1968 (1966-71) (data from Upshaw and others, 1966; Ryan, 1969; and Schneeflock and Dills, 1971).

contour) between the two constituents. The resulting map appears as figure 20. Comparison of figures 19 and 20 shows that the same general pattern shown in circa 1968 was still present in circa 1983, namely, an east-west ribbon of sand separating two regions of clay/silt. The major changes occurred seaward of Main Pass and Morgan Peninsula. Here, even though the plot is highly qualitative, the band of sand has widened considerably in the Pelican Bay area and the southeastern quarter of the study area. The cause for this expansion is not known, but conceivably is in response to an interaction between the ebb-tidal delta and longshore drift. Pelican Bay is filling up and the Mobile Ship Channel in this area is continually dredged, with the excavated material piled up, in many cases, next to the channel. The ebb-tidal delta is therefore slowly aggrading and may increasingly act as a barrier to the westward directed littoral drift transport of sand and an area of absorption of Gulf of Mexico wave energy. This may result in continued sand deposition in the southeast corner of the study area.

Another possibility is that Hurricane Frederic (1979) moved sand into southern Mobile Bay by overwash and removed sand offshore by erosion of Dauphin Island and Morgan Peninsula. If this has occurred, the bottom sediments in these areas are in equilibrium with storm rather than fair-weather wave regime. It would require many years for fair-weather waves to reestablish equilibrium, if the changes are indeed reversible.

CARBONATES

Ryan and Goodell (1972) found that total detrital carbonate in Mobile Bay ranges from 0 to 100 percent. They found that high carbonate percentages were due to the presence of whole and disarticulated bivalve shells and that most of the gravel-sized clasts were composed of shell debris. Carbonate content increases southwest of Main Pass (Ryan and Goodell, 1972). Isphording and Flowers (1987) found that carbonate in Mobile Bay ranged from 0 percent in sand-rich areas to almost 8 percent in the vicinity of modern and ancient oyster reefs. May (1971) surveyed the bay's natural oyster beds in 1968 (fig. 21). Ryan (1969) mapped the location of buried oyster reefs in Mobile Bay, but the study area of this report was not surveyed. Clay-rich areas within the bay contain carbonate percentages greater than 2 to 3 percent and commonly as high as 6 percent, whereas coarser grained sediments are generally low in organic carbon (Isphording and Flowers, 1987). The higher permeability of the coarser grained sediments allows greater water circulation, which promotes bacterial action and oxidation of the organic matter present (Isphording and Flowers, 1987).

CLAY MINERALS

The clay fractions of Mobile Bay sediments average 60 percent smectite, 27 percent kaolinite, and 13 percent illite (Isphording and Lamb, 1979). Highest percentages of smectite occur at the head of the bay (up to 80 percent) and lowest values near its mouth (fig. 22). This reflects the fact that the older rocks of the Coastal Plain and Piedmont have served as the principal sources of the mineral (Isphording and others, 1985; Isphording and Flowers, 1987). Kaolinite increases from the head to the mouth of the bay (fig. 23). Erosion of sediments exposed adjacent to the bay, older Coastal Plain rocks, and rocks of the Appalachian Piedmont supply some of the kaolinite (Isphording and Lamb, 1979). However, the higher concentrations seen near the mouth of the bay suggest that some of it is derived from westward longshore-transported fines that are carried into the bay by tidal currents (Isphording and others, 1985, Isphording and Flowers, 1987). Illite shows a random distribution within Mobile Bay and is largely obtained from the weathering of Coastal Plain and Piedmont rocks (fig. 24). On the shelf, smectite and kaolinite are the predominant clay minerals, with illite present in smaller quantities (fig. 25) (Doyle and Sparks, 1980). Smectite increases, while kaolinite decreases offshore, over most of the shelf south of the area (Doyle and Sparks, 1980).

HEAVY MINERALS

The study area is part of the open shelf clastic facies, called the Mississippi-Alabama-Florida (MAFLA) Sand Sheet by Doyle and Sparks (1980). Its heavy mineral suite reflects a southern Appalachian signature (Fairbank, 1962). Diagnostic minerals are kyanite and staurolite, with accessory minerals ilmenite, zircon, and tourmaline (Doyle and Sparks, 1980). The

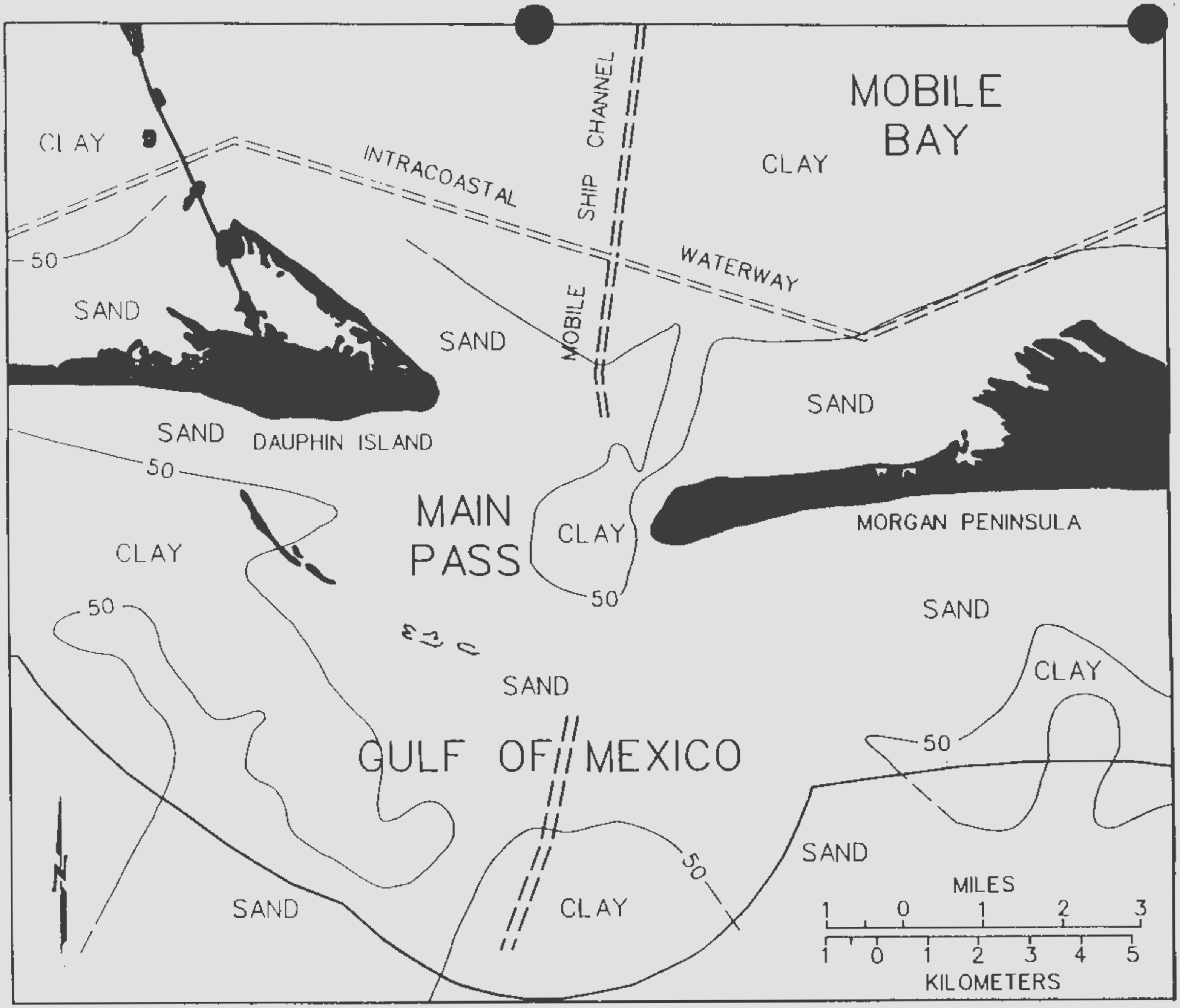


Figure 20 --Clay/silt versus sand for bottom sediments within study area, circa 1983 (1979-87) (data from U.S. Army Corps of Engineers, 1979a, 1985a, 1985b; Isphording and Lamb, 1980, Marine Environmental Sciences Consortium, 1981; Exxon Company, U.S.A., 1986; and Browning, Inc., 1987)

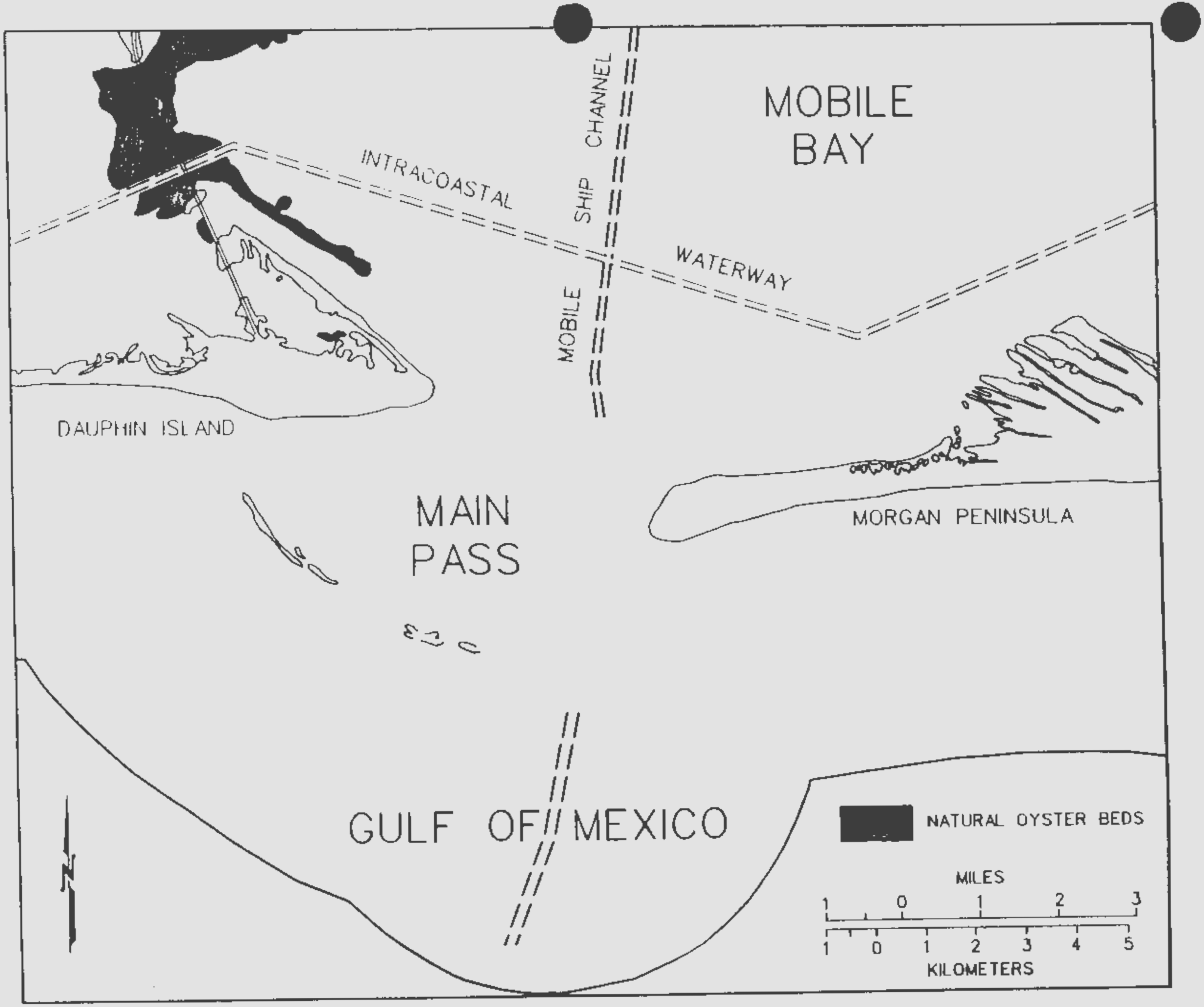


Figure 21.--Location of natural oyster beds in the study area. Survey conducted from February 19 to April 5, 1968 (modified from May, 1971).

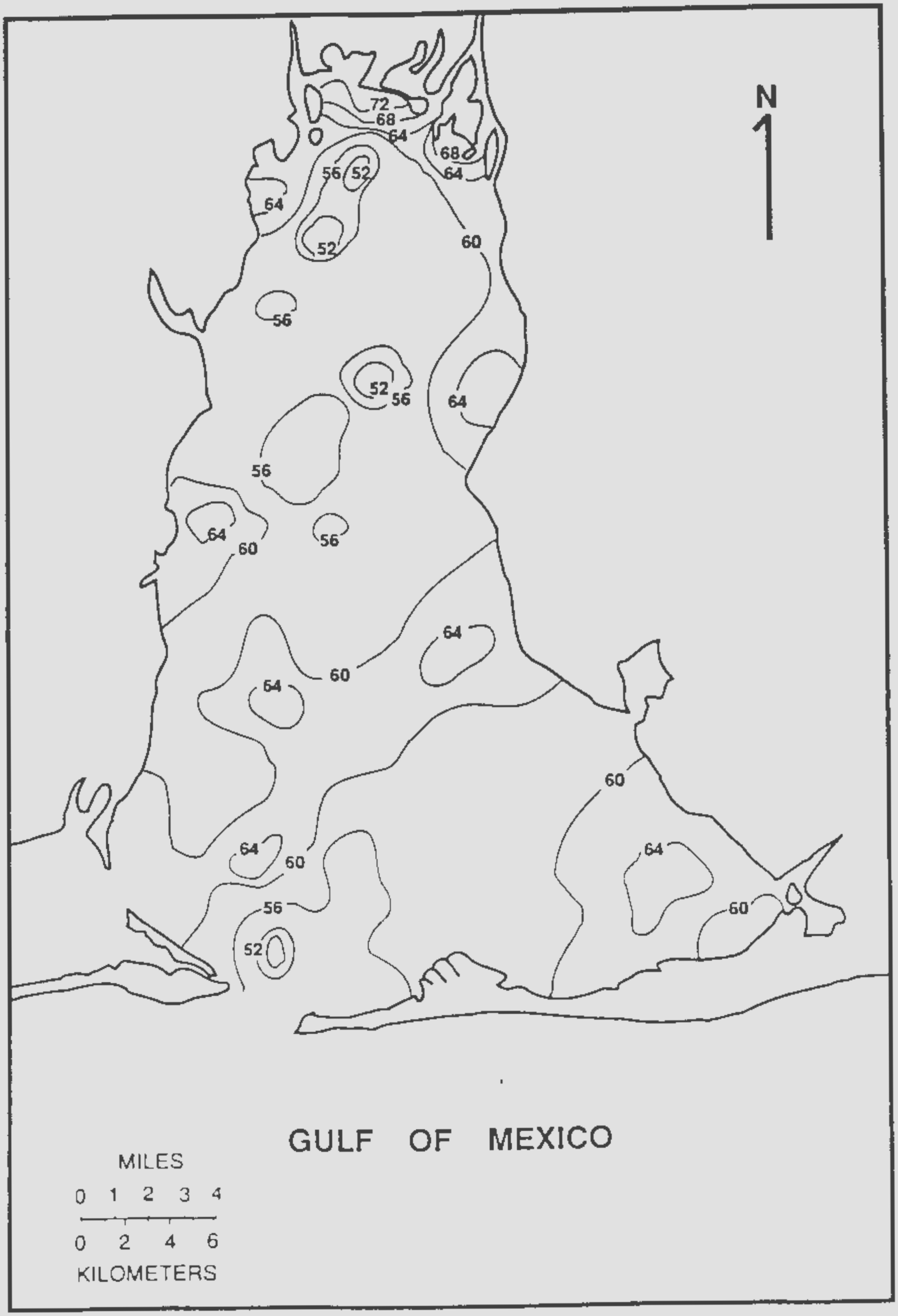


Figure 22 --Contour map of smectite percentages in Mobile Bay bottom sediments (modified from Isphording and Lamb, 1979)

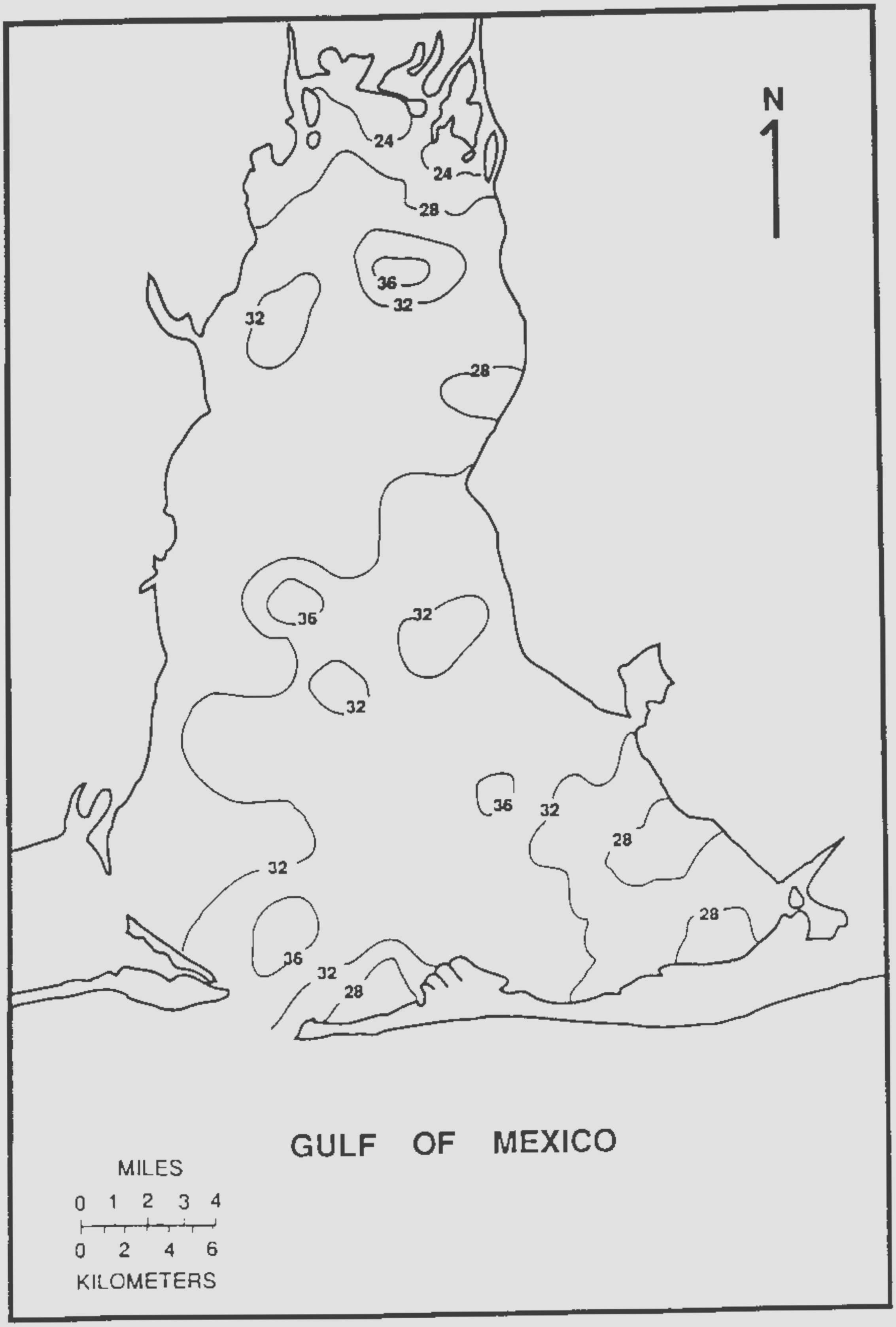


Figure 23.--Contour map of kaolinite percentages in Mobile Bay bottom sediments (modified from Isphording and Lamb, 1979).

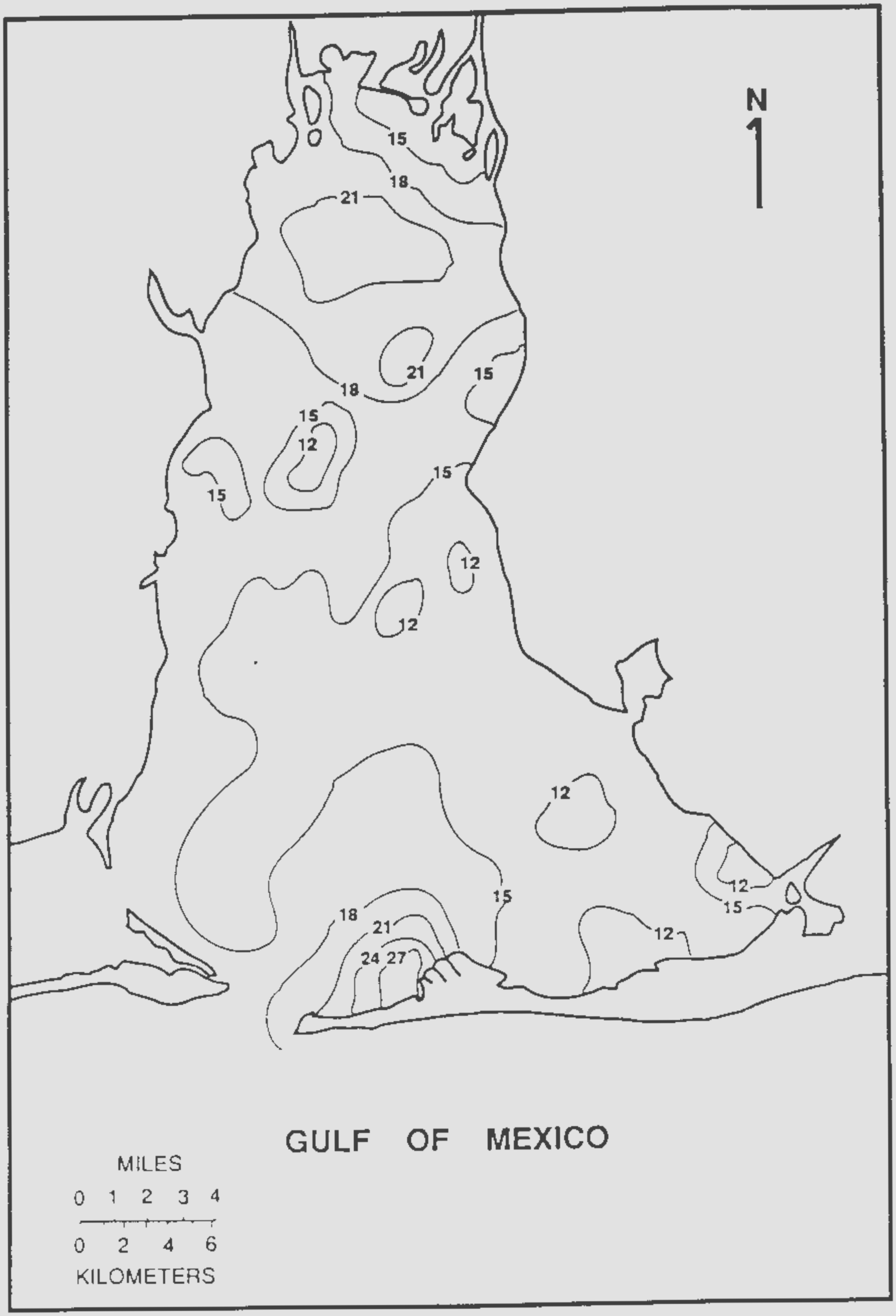
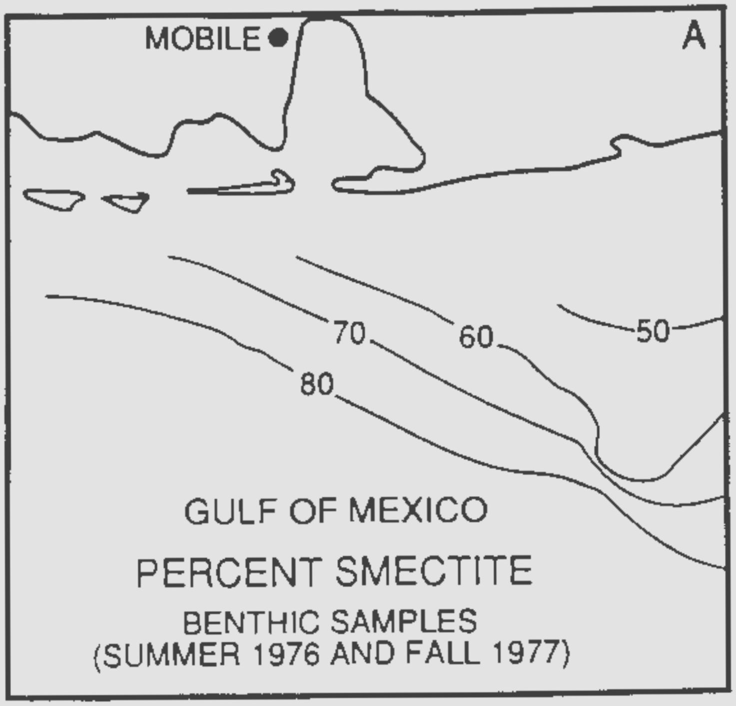


Figure 24.--Contour map of illite percentages in Mobile Bay bottom sediments (modified from Isphording and Lamb, 1979)



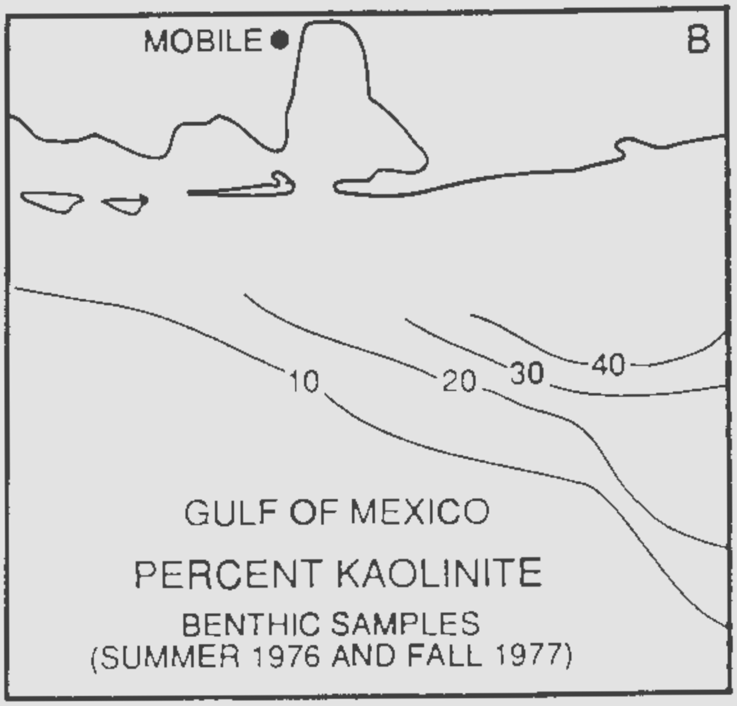


Figure 25.--Smectite and kaolinite contents averaged for summer 1976 and fall 1977 sampling periods. Contour interval—10 percent. Percentages are the total clay mineral fraction (modified from Doyle and Sparks, 1980).

Mississippi River suite is characterized by hematite, pyroxenes and amphiboles, and their presence in the MAFLA Sand Sheet suggests some contribution of sediments by the Mississippi River (Doyle and Sparks, 1980). Stow and others (1975) report heavy mineral concentrations of up to 2.4 percent in an area encompassing Pelican Bay.

RATES OF SEDIMENTATION

An annual load of 2.1 to 8.1 million tons (1.9 to 7.3 million metric tons) per year (U.S. Army Corps of Engineers, 1979a) of suspended sediment enters Mobile Bay, with an average annual load of 4.7 million tons per year (U.S. Army Corps of Engineers, 1984a). The quantity of bed load entering the bay is unknown (U.S. Army Corps of Engineers, 1979a). However, Ryan (1969) thought that it could be up to 0.5 million tons (0.45 million metric tons) annually. Ryan (1969) calculated the average rate of sediment accumulation for the entire bay to be 1.7 feet (0.52 meter) per century, which is in approximate agreement with the 1.6 feet (0.49 meter) per century figure determined by the U.S. Army Corps of Engineers (1984b). Nevertheless, these figures include areas receiving dredge spoil (4 to 8 feet or 1.2 to 2.4 meters per century) and areas far removed from spoil disposal zones (0 to 4 feet or 0 to 1.2 meters per century) (Brande and McAnnally, 1983). Between 1852 and 1920, the sedimentation rate in the lower part of Mobile Bay is estimated to have been about 1.3 feet (0.40 meter) per century (U.S. Department of the Navy, 1986) This rate increased to 2.3 feet (0.70 meter) per century between 1920 and 1973 (U.S. Department of the Navy, 1986). Ryan (1969) determined the carbon-14 dates of buried oyster shells from Mobile Bay, which indicate rates of sedimentation of 1.3 to 6.5 inches (3.3 to 16.4 centimeters) per century over the past 5,000 to 6,000 years, falling within the range of May's (1976) figures of 1 2 to 8.3 inches (3 to 21 centimeters) per century. Brande and McAnnally (1983) obtained an average sedimentation rate of 0.46 foot (14 centimeters) per century utilizing two carbon-14 dates, which is much greater than Ryan's (1969) average rate of 0 29 foot (9 centimeters) per century.

An ebb-tidal delta-wide average sedimentation rate of 0.025 foot (0 76 centimeter) per year, or 2 5 feet (0.76 meter) per century, was calculated from figure 18 for the period 1973 to 1987. This figure is comparable to the current sedimentation rate in Mobile Bay as calculated by Ryan (1969) and U.S. Army Corps of Engineers (1984b).

STRATIGRAPHY

The author is unaware of any publicly available information on the internal structure of the ebb-tidal delta of Mobile Bay. Gas well platform and pipeline foundation borings were taken by various oil companies, but the findings are proprietary. The U.S. Army Corps of Engineers has taken many borings in the study area in order to supply subsurface information for dredging projects. All of these borings are taken within the Mobile Ship Channel and largely represent disturbed bedding, spoil material or deposits resulting from siltation in the bottom of the channel.

Exxon Company, U.S.A. (1986), provides engineering descriptions (physical-mechanical sediment properties) of 63 foundation borings taken in coastal Alabama in support of a pipeline route survey. Two stratigraphic cross-sections were constructed along lines A-A' and B-B' utilizing some of these borings (fig. 26). The highly generalized nature of these lithologic descriptions and lack of information about sedimentary structures make stratigraphic correlations and facies interpretations difficult. Based on gross morphology and lithology, elevation of lithologic units, and comparisons with other stratigraphic cross-sections constructed from similar ebb-tidal deltas (Hubbard and others, 1979; Imperato and others, 1988), five lithofacies are defined herein (fig. 27).

Lithofacies 1 consists of a lenticular body of quartz sand, measuring up to 30 feet (9.1 meters) thick. It is thickest along the east-west axis of Dauphin Island and Morgan Peninsula, where it consists of a clean, shelly sand. Landward, it is less shelly and grades to silty sand with numerous clay lenses. Seaward, it grades into shelly, clayey sand with clay lenses. This lithofacies interfingers with marine shelf and estuarine lithofacies. These sands probably represent a mixture of many barrier strandline depositional environments and subenvironments. These include barrier island, ebb-tidal delta (ebb ramp and ebb shield), and tidal inlet environments and are analogous to the sands currently exposed at the sediment-water

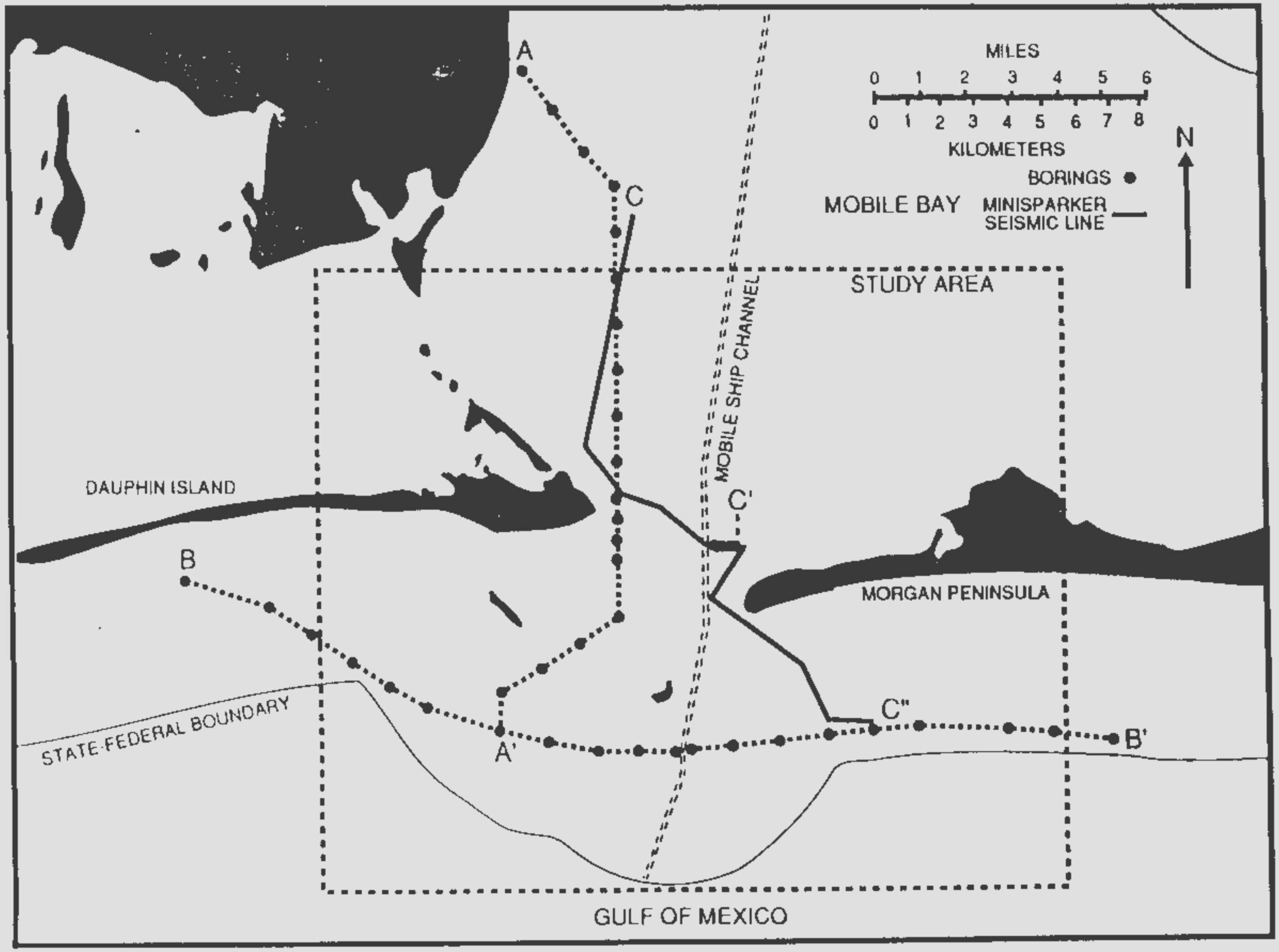


Figure 26.--Locations of lithostratigraphic cross-sections of study area. (Cross-sections A-A' and B-B' constructed from boring descriptions from Exxon Company, U.S.A., 1986. Cross section C-C" drawn from an unpublished Minisparker record from S. Brande, Department of Geology, University of Alabama at Birmingham, Alabama and boring descriptions from U.S. Army Corps of Engineers, 1985a, and Exxon Company, U.S.A., 1986.)

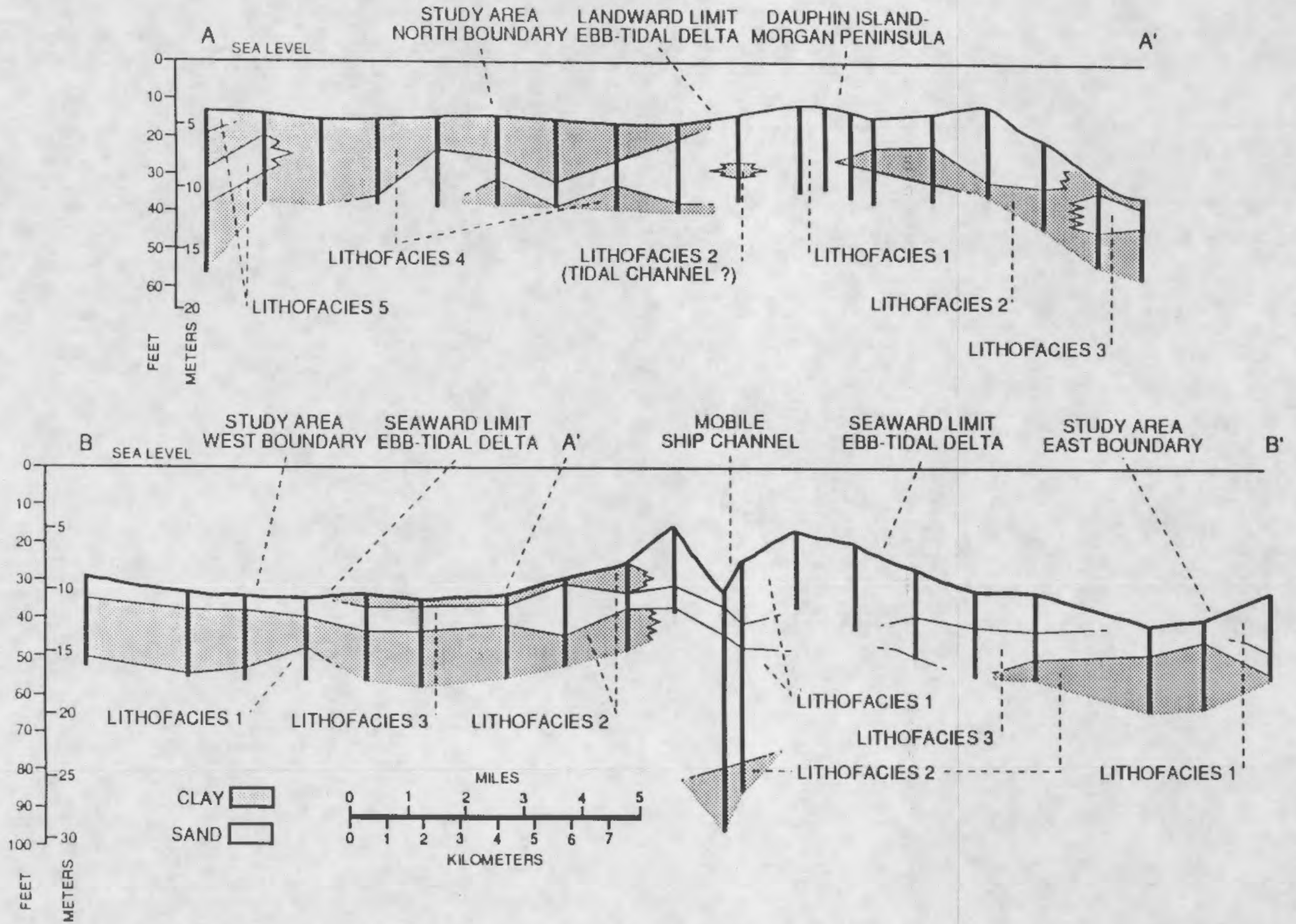


Figure 27 --Lithostratigraphic cross-sections A-A' and B-B' (constructed from boring descriptions from Exxon Company, U.S.A., 1986).

interface in approximately the middle third of figure 20. The upper portions of this lithofacies are no doubt composed in part of spoil. The same lithofacies probably occurs at the base of some of the borings. In the lower portion of two borings taken in the ebb-flood channel, Lithofacies 1 reaches about 45 feet (13.7 meters) in thickness.

Lithofacies 2 is composed of wedge-shaped bodies of shelly clay containing sand lenses. These pinch out into Lithofacies 1 and 3. This facies measures up to 20 feet (6.1 meters) in thickness. The lithofacies is interpreted to consist of ebb-tidal delta clays and shoreface and ebb-tidal delta sands deposited seaward of the ebb shield. It is observed at the sediment-water interface as patches of clay as shown in the lower third of figure 20.

Lithofacies 3 is tabular, pinches out into Lithofacies 1 and 2, and from the east-west cross-section, appears to be laterally continuous throughout the study area seaward of the barrier axis. Typically, it measures 5 to 10 feet (1.5 to 3.0 meters) thick, but can be up to 15 feet (4.6 meters) thick. This lithofacies is composed of shelly, clayey sand with locally abundant clay lenses. It grades to shelly clay with sand lenses in the vicinity of the flood-ebb channel (B-B', fig. 27). This facies is interpreted to represent shelf facies that are evidently exposed at the modern sediment-water interface seaward of the study area. Lithofacies 3 may have been penetrated at the base of the two borings drilled in the flood-ebb tidal channel shown on the cross-section B-B'.

Lithofacies 4 consists of wedge-shaped bodies containing a mixture of shelly clays with silty sand lenses, shelly clays without lenses, and sandy clays. This facies can be up to 30 feet (9.1 meters) thick, but is usually less than half that thickness. It interfingers with Lithofacies 1 and 5 and is interpreted as estuarine clays and sands that are exposed at the sediment-water interface in southern Mobile Bay (fig. 20).

Lithofacies 5 is present at the extreme north end of the north-south stratigraphic cross-section (fig. 27, A-A'). It is made up of shelly, clayey sand containing clay lenses. This facies is approximately 10 feet (3 meters) in thickness, is wedge-shaped, and interfingers with Lithofacies 4. Lithofacies 5 probably represents Mobile Bay marginal sands.

Figure 28 is a line drawing of a seismic stratigraphic profile along the line C-C" (fig. 26) made from an unpublished Minisparker seismic line obtained from S. Brande (University of Alabama at Birmingham) and borings from U.S. Army Corps of Engineers (1985a) and Exxon Company, U.S.A. (1986). The poor quality of the printed seismic record, lack of groundtruthing borings along the seismic line, and unavailability of seismic parameters permit only generalizations to be made about the nature of the subsurface sediments and identification of facies.

Along the seismic line, Lithofacies 1 is exposed at the surface or underlies the entire region. Around the northern study area boundary, Lithofacies 4 and 5 are exposed at the surface and underlie Lithofacies 1. At the western end of the line, Lithofacies 3 appears to be present in the subsurface. The bottom of the Mobile Ship Channel is lined by a blanket of estuarine mud (Lithofacies 4) several feet (few meters) thick, which has been transported out of Mobile Bay by ebb-tidal currents. Southeast of the ship channel, Lithofacies 1 contains sets of climbing, accretionary, avalanche face cross-strata about 20 feet (6.1 meters) thick. The cross-strata appear to be angular to incipiently tangential, uniform and relatively sharp on the seismic record. Brande (1983) encountered these features on Minisparker seismic records taken in the vicinity of barrier islands on both the Mobile Bay-Mississippi Sound and Gulf of Mexico sides. He determined that the cross-strata dip seaward on the Gulf side and toward the mainland on the Mobile Bay-Mississippi Sound side. They probably represent ebb-flood tidal channel facies (Hubbard and others, 1979; Imperato and others, 1988).

GEOLOGIC HISTORY

At this time there is insufficient information for constructing a detailed geologic history of the present ebb-tidal delta of Mobile Bay. Vittor and Associates, Inc. (1985) mentions the existence of drowned coastal geomorphology on the Alabama-Mississippi continental shelf built during late Pleistocene (Wisconsinan) regression and transgression. Tidal deltas probably are represented, but at present no one has mapped, described or located these features.

Tidal deltas have no doubt been associated with the Mobile-Tensaw River system since at least the late Pleistocene. This valley contains the

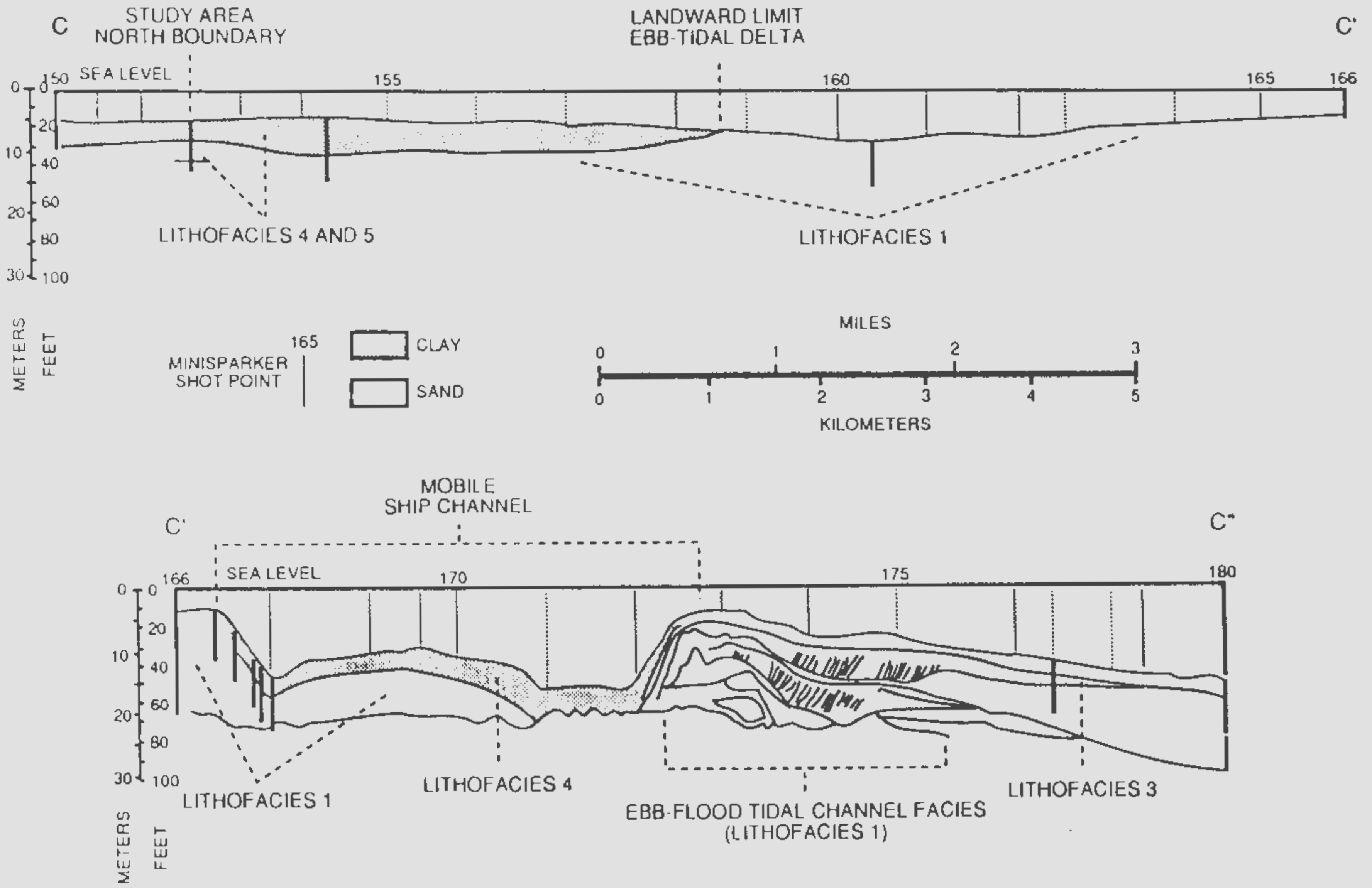


Figure 28 --Lithostratigraphic cross-section C-C" (borings from U.S. Army Corps of Engineers, 1985a; Exxon Company, U.S.A., 1986; and unpublished Minisparker record from S Brande, Department of Geology, University of Alabama at Birmingham).

Mobile-Tensaw River system, Mobile delta, Mobile Bay, and the ebb-tidal delta of Mobile Bay. The valley is thought to have developed its present configuration as a result of downcutting, headward erosion, slope retreat, and extension of the fluvial channel downslope during regression and the subsequent lowstand of the middle to late Pleistocene (Smith, 1988).

Modern Alabama and Mississippi barrier islands are thought to be Holocene in age. They formed around Pleistocene deposits by shoal aggradation using shelf sands supplemented with fluvial and nearshore sediments transported from the east by longshore drift (Otvos, 1982, 1984; Vittor and Associates, Inc., 1985). This age and mechanism of formation is consistent with modern Florida panhandle barrier islands. Radiometric dating indicates that these islands are from 3,000 to 6,000 years old. The ebb-tidal delta of North Edisto Inlet, South Carolina, is similar to the ebb-tidal delta of Mobile Bay in shape and coastal geographic setting. This delta is thought to be 4,500 years old (Imperato and others, 1988). The modern ebb-tidal delta of Mobile Bay is probably no older.

Otvos (1973) suggests that ebb-tidal delta sands were obtained from the western end of Morgan Peninsula by wave erosion and supplemented with sediments emerging from Mobile Bay. Evidence of the amount of erosion required to supply the necessary material to build the ebb-tidal delta is not readily apparent on Morgan Peninsula (Vittor and Associates, Inc., 1985). The results of this study and those from the study of other similar ebb-tidal deltas indicate that the ebb-tidal delta of Mobile Bay is primarily constructed of sediments transported out of Mobile Bay. These sediments are undoubtedly supplemented by nearshore shelf and barrier island sediments. Once established, the ebb-tidal delta acquired its present appearance through vertical accretion and progradation

SUMMARY

The ebb-tidal delta system of Mobile Bay is a dynamic, physically complex system which acts as a transition zone between the Mobile Bay estuary and Gulf of Mexico. As such, it is sensitive to physical changes occurring in coastal Alabama. Historically, the study area has been a multiuse area and will continue to be a center for man's activities. The area has shown significant change over the past 210 years and has evolved from a natural system to one dominated by man.

Main Pass, the tidal inlet located at the mouth of Mobile Bay, is tide-dominated as evidenced by its well-developed ebb-tidal delta, poorly developed flood-tidal delta, and deep ebb-flood tidal channel flanked by channel margin bars (Pelican and Sand Islands and associated shoals). Pelican Bay is an ebb ramp over which most of the tidal water mass flows. The escarpment at the seaward edge of the ebb ramp (the ebb shield) is where most of the sand transported during ebb tide is deposited. This sand is subsequently reworked by wave activity into channel margin bars. Some sand is exported by longshore currents and nourishes beaches downcurrent. Clay and silt is deposited on the shelf seaward of the ebb shield.

Tidal currents and water mass circulation within the study area are part of the overall estuarine regime. This involves a cyclical exchange of water mass between these two water bodies. Further work is needed in order to describe the details of this process and dynamics of bottom water circulation on the ebb-tidal delta. In addition, it is uncertain what effect the continued sediment accumulation in Pelican Bay and Mobile Ship Channel dredging will have on the circulation pattern within the study area.

Since Main Pass is the primary avenue through which Gulf of Mexico waters meet freshwater from the Mobile-Tensaw River system, changes in bathymetry modify the circulation pattern, and, in turn, salinity and water temperature distributions within Mobile Bay and eastern Mississippi Sound.

In general, the gradual aggradation of southern Mobile Bay and Pelican Bay and the dredging of the Mobile Ship Channel account for the bathymetric changes that have occurred within the study area over the last 210 years. The cause of this filling is unknown, but it probably involves several factors, such as freshwater discharge, sedimentation rates, wave energy, relative sea level change, tectonic framework, and history of deforestation and dredging.

Within the study area, limited information suggests that much of the ebb ramp is covered with sand waves and shoals, whereas the ebb delta shield is covered by ripples. The shoreface zone of the study area contains shoals, transverse bars and longshore bars. It is likely that ebb oriented sand waves and lag deposits floor the sandier parts of the ebb-flood tidal channel.

Available bottom sediment data indicate the presence of an east-west band of sand encompassing Dauphin and Little Dauphin Islands, Main Pass and Morgan Peninsula. The band is flanked to the north by clays and silts in southern Mobile Bay and by ebb-tidal delta clays and silts to the south. Generally, clays and silts line the deepest parts of the ebb-flood tidal channel. This textural pattern is typical of ebb-tidal deltas along the southeastern coast of the United States and in the study area has not changed significantly over the 15-year period between circa 1968 and circa 1983. Increased quantities of sand in Pelican Bay and the Gulf of Mexico shelf south of Dauphin Island are exceptions. The ebb ramp may be acting as an impediment to longshore transport of sand, bringing about coarse clastic deposition. Alternatively, strandline sands may have been moved offshore by Hurricane Frederic in 1979.

Carbonate content in bottom sediments is low except where shell lags or beds or modern and ancient oyster reefs occur. In the study area, natural oyster beds are located in Pass aux Herons and accumulations of shell material are found on the Gulf of Mexico shelf south of Morgan Peninsula.

Smectite is abundant with some kaolinite and small quantities of illite. Heavy mineral concentrations up to 2.4 percent occur in the surficial sediments of Pelican Bay.

The average sedimentation rate of the ebb-tidal delta from 1973 to 1987 was 0.025 foot (0.76 centimeter) per year or 2.5 feet (0.76 meter) per century.

Two lithostratigraphic cross-sections were constructed for the study area utilizing engineering descriptions of pipeline route survey foundation borings taken in coastal Alabama. An additional lithostratigraphic cross-section was drawn from a Minisparker seismic record and engineering descriptions of several borings. Based on gross morphology and lithology, elevation of lithologic units, and comparisons with other stratigraphic cross-sections and facies descriptions from similar ebb tidal deltas, five lithofacies are defined.

Lithofacies 1 is a lens-shaped body of clean, shelly sand up to 30 feet (9.1 meters) thick, grading into silty sand with numerous clay lenses landward and shelly, clayey sand with clay lenses seaward of Dauphin Island-Morgan Peninsula. These sands interfinger with marine shelf and estuarine lithofacies and probably represent many facies associated with barrier strandline depositional environments and subenvironments. These include barrier island, ebb-tidal delta, tidal inlet, and ebb-flood tidal channel environments.

Lithofacies 2 consists of wedge-shaped bodies measuring up to 20 feet (6.1 meters) thick and is comprised of shelly clay containing sand lenses. These bodies pinch out into Lithofacies 1 and 3 and are interpreted to represent ebb-tidal delta clays and sands deposited seaward of the ebb shield.

Lithofacies 3 is shelly, clayey sand with locally abundant clay lenses that becomes shelly clay with sand lenses in the vicinity of the ebb-flood tidal channel. This lithofacies is laterally continuous, tabular, measures 5 to 10 feet (1.5 to 3.0 meters) thick, and represents shelf facies.

Lithofacies 4 consists of wedge-shaped bodies containing a mixture of shelly clays with silty sand lenses, shelly clays without lenses, and sandy clays. This facies can be up to 30 feet (9.1 meters) thick, interfingers with Lithofacies 1 and 5, and is interpreted to represent estuarine clays and sands.

Lithofacies 5 is a wedge-shaped unit measuring around 10 feet (3 meters) thick that interfingers with Lithofacies 4 and is comprised of shelly, clayey sand containing clay lenses.

Tidal deltas are thought to have been associated with the Mobile-Tensaw River valley since at least the late Pleistocene. The ebb-tidal delta of Mobile Bay is thought to be about 4,000 to 5,000 years old and is primarily constructed of sediments transported out of Mobile Bay, supplemented by nearshore shelf and barrier island sediments. Once established, the ebb-tidal delta acquired its present appearance through vertical accretion and progradation.

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