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U.S. Army Corps
of Engineers
New Orleans District

REMOTE SENSING SURVEY OF MISSISSIPPI RIVER-GULF OUTLET, BRETON SOUND DISPOSAL AREA, PLAQUEMINES PARISH, LOUISIANA

February 1993

FINAL REPORT

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A magnetic and acoustic remote sensing survey for submerged cultural resources was conducted over a 1,600-acre project area off shore of Breton Island, Plaquemines Parish, Louisiana. The project area, which measures a mile wide and 2.5 miles long, encompasses the proposed site of the Mississippi River-Gulf Outlet Breton Sound Disposal Area. The survey was conducted for the U.S. Army Corps of Engineers, New Orleans District, pursuant to Delivery Order 0010, of Contract DACW29-90-D-0018. The proposed disposal of dredge spoil may impact several of the anomalies recorded during the survey.

A controlled hydrographic survey was performed over the project area utilizing a proton precession magnetometer to collect magnet data, a side scan sonar to record acoustic anomalies, and a precision echosounder to acquire bathymetry. Real time positioning was maintained by a Differential Global Positioning System (DGPS) linked to a computer navigation program.

Seventy-eight magnetic anomalies and one acoustic anomaly were recorded during the survey. The acoustic anomaly, which is associated with a cluster of magnetic targets, appears to be related to modern steel wreckage. In addition to this target, six other clusters of anomalies were distinguished. Of the seven anomaly clusters, additional archeological investigations are recommended for five. Further consideration of other isolated anomalies is not recommended based on the assumption that a ship wrecking in the Breton Sound environs would disperse over a field of at least 50,000 m^2, creating multiple anomalies within a confined area.

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REPLY TO
ATTENTION OF

Planning Division
Environmental Analysis Branch

To The Reader:

This cultural resources effort was designed, funded, and guided by the U.S. Army Corps of Engineers, New Orleans District as part of our cultural resources management program. The work documented in this report was performed to provide information needed to assess cultural resource impacts which could result from the placement of disposal material in the Breton Sound Disposal Area.

This report has been reviewed and accepted by the New Orleans District. We commend the contractor's efforts and careful scholarship.

Howard R. Bush
Authorized Representative
of the Contracting Officer

R. H. Schroeder, Jr.
Chief, Planning Division

REMOTE SENSING SURVEY OF MISSISSIPPI RIVER-GULF OUTLET, BRETON SOUND DISPOSAL AREA, PLAQUEMINES PARISH, LOUISIANA

FINAL REPORT

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For

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CHAPTER I

INTRODUCTION

Introduction

This report documents the results of a submerged cultural resource survey of a 1,600-ac area in the Gulf of Mexico east of Breton Island, Plaquemines Parish, Louisiana (Figure 1). This study is intended to provide the New Orleans District with a basis for managing potential cultural resources in the Mississippi River-Gulf Outlet Breton Sound Disposal Area. The project area, which is 1 mile wide and 2.5 miles long, consists of a proposed disposal area to support maintenance dredging of the Mississippi River-Gulf Outlet Channel, which lies immediately to the north. By depositing material in the area seaward of Breton Island, the U.S. Army Corps of Engineers, New Orleans District hopes to slow the island's shoreward advance and associated erosion. By doing so, an important vanishing ecosystem may be preserved. However, the rapid deposition of dredge material on fragile cultural resources such as shipwrecks could constitute an adverse effect resulting from increased weight, changes in environmental chemistry, the masking of magnetic signatures (thereby making relocation more difficult), and the hinderance of future recovery efforts. In keeping with the New Orleans District's mission to preserve, document and protect significant cultural resources within its project areas, a magnetic and acoustic remote sensing survey was funded to locate potential archeological remains. All archeological investigations were accomplished in full compliance with the National Historic Preservation Act (NHPA) of 1966, as amended, 36 CFR 800, ACHP, Protection of Historic Properties, the Abandoned Shipwreck Act of 1987 (43 U.S.C. 2101-2106); Abandoned Shipwreck Guidelines, National Park Service; National Register Bulletin Nos. 14, 16, and 20; and, 36 CFR 66.

In the course of human history, tiny Breton Island served as a distant proscenium to greater events at nearby New Orleans and Biloxi, and even at her sister islands in the Chandeleur chain to the east. She never served as a locus of military or commercial activity aside from a brief period as a rendezvous for rum runners during Prohibition. Rarely a destination, passage of the island was certainly a commonplace event for many coastal sailers and steamers on their way to and from New Orleans and other ports in the Gulf. Small vessels in particular may have utilized the natural tidal channel that passed by the northern end of Breton Island. The island, and its surrounding shoal waters, was a natural hazard to navigation in the centuries before modern electronic aids. Barely rising above the surface of the surrounding Gulf, it would have been all but invisible to ships seeking sheltered waters in a gale.

Which, if any, ancient mariners came to grief on Breton's shores is lost to history. Perhaps its isolation and lack of conditions to support human life precluded any survivors from bringing back the tale. Perhaps, like their modern counterparts, it was the boats of forgotten fishermen and not well documented merchantmen that were buried beneath the sand. Judging from the wreckage of modern shrimp trawlers that dot the surrounding waters, it certainly is possible that ships have grounded and sunk here for over two centuries.

Organization of the Report

This report is organized according to the format used in previous U.S. Army Corps of Engineers, New Orleans District, submerged cultural resource reports. The project area is placed in its natural and historical setting in Chapter II. This review includes discussion of the natural and cultural history of the surrounding area, and previously recorded archeological sites. The focus of this work was to develop data to support predictions concerning the presence and nature of shipwrecks in the project area, and to forecast the potential preservation of historic remains.

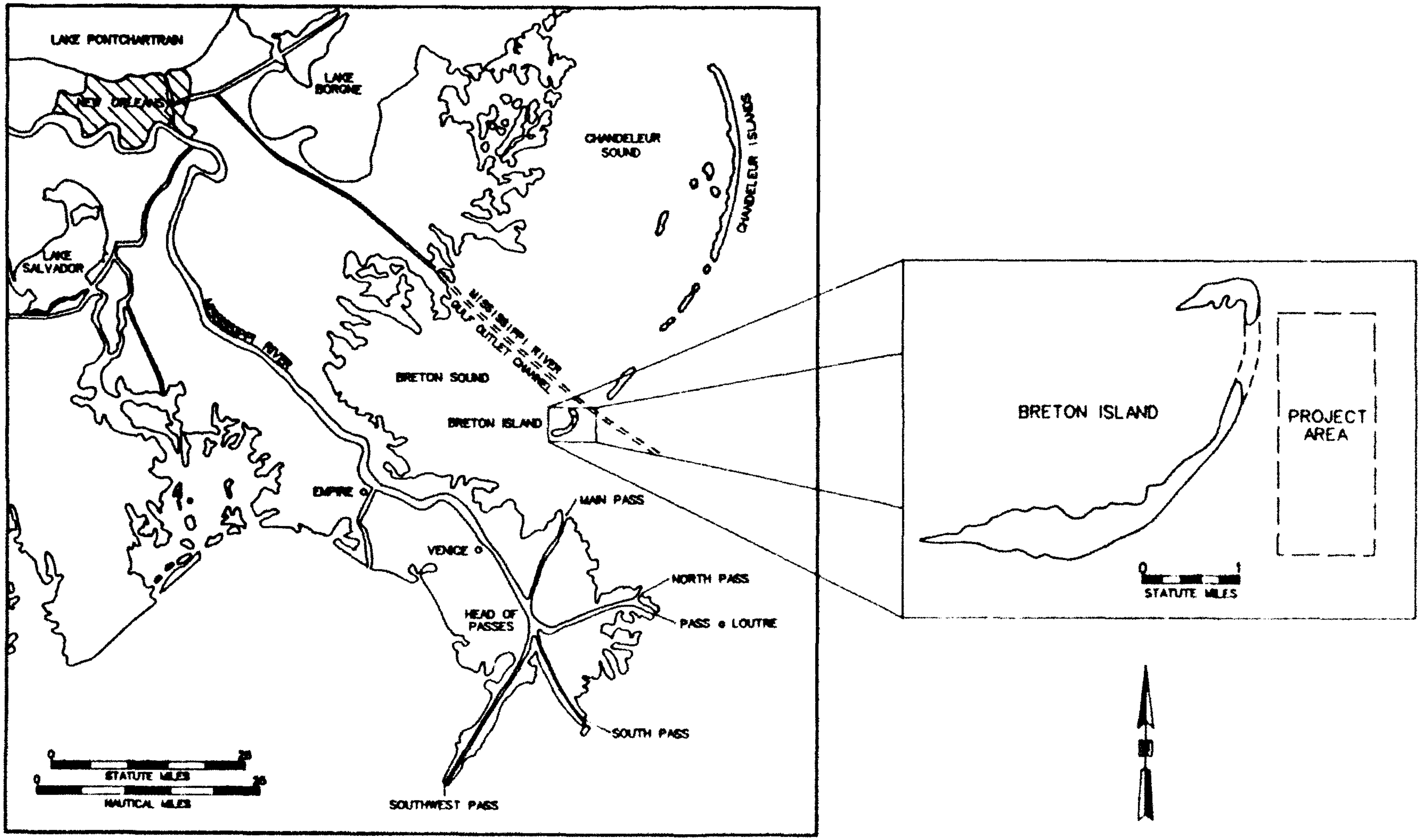


Figure 1. Project area location map.

Chapter III examines the methods and theories of remote sensing as applied to the Breton Sound project. A brief summary of previous investigations and the theories employed in formulating the survey methodology are contained in Chapter III. Details concerning the instrumentation and the survey's utilization of a revolutionary new positioning system are fully described. The results of the survey are reported at the end of that chapter. The principal tools employed to test these predictions within the project area were the proton precession magnetometer and side-scan sonar. The effectiveness of this equipment in locating historic shipwrecks in the New World has been demonstrated repeatedly over the last two decades.

Finally, Chapter IV contains conclusions and recommendations based upon a thorough analysis of the data within the theoretical framework developed for the project area. Significant areas are identified for further testing, and a proposed testing methodology is presented.

CHAPTER II

NATURAL AND HISTORICAL SETTING

Natural History

This section reviews the natural setting of the project area. The three principal goals of this section are to provide: (1) a description of the natural setting of the project area, (2) a preliminary determination of the natural and cultural processes that have shaped the project area, and (3) a discussion on how these processes have influenced the occurrence and preservation of archeological deposits.

Shelf Bottom

Shepard (1956) has mapped the character of the surficial sediments of the gulf and sound bottoms of the East Mississippi Delta region, which includes Breton Island. On the basis of surficial sediments, he mapped two major sedimentary environments within the project area: the "open lagoonal inlet" and the "reworked Mississippi Delta." The majority of the project area lies within the open lagoonal inlet sedimentary environment. The southernmost portion of the project area lies within the "reworked Mississippi Delta sedimentary environment (Figure 2).

The open lagoonal inlet sedimentary environment occupies two open tidal inlets cut into the reworked surface of the St. Bernard Delta. One lies between Breton Island and the modern Mississippi Delta to the southwest, and the other lies between Breton Island and Gosier Island to the northeast. The northern tidal inlet starts at the strait between Breton Island and Gosier Island and turns abruptly southward, crosses in front of Breton Island, and merges with the southern tidal inlet. The tidal inlet is characterized by strong tidal currents and by a firm bottom of either sand, silty clay, or an erosional shell lag. Between the islands, the depth of the tidal inlet, 7 to 11 m below mean sea level, is significantly greater than that of the adjacent shelf and sound. As it spreads seaward, the tidal inlet shallows to depths of 3 to 4 m (Figure 2) (Shepard 1956:Figure 5).

Surficial sediments of the open lagoonal inlet sedimentary environment found within the northern channel consist primarily of clayey silt (Shepard 1954). Its medium-grain size varies between 0.004 to 0.0625 mm (8 to 4 phi) in diameter. The percentage of sand present varies from 1 to 20 per cent within the center of the inlet, to about 80 per cent at the edge of the inlet. Similarly, the amount of clay varies from 30 to 50 per cent within the center of the inlet, to less than 10 per cent at its edge. The sediment consists primarily of detrital clastic grains with 1 to 10 per cent shredded wood and a highly variable percentage of whole and fragmentary shells. Other grains often found in marine environments, such as foraminifera tests, carbonate grains, glauconite, and fragments of echinoids either are absent or occur in trace amounts (Shepard 1956).

The remainder of the project area, which lies outside of the open tidal inlet channels, consists of the reworked Mississippi Delta sedimentary environment (Figure 2). This former surface of the St. Bernard Delta Complex has been eroded deeply and reworked by shelf currents and waves. The surficial sediments consist of sand (Shepard 1954). The medium-grain size of these sediments ranges from 0.0625 to slightly over 0.125 mm (4 to less than 3 phi) in diameter. Typically, these sediments consist of greater than 80 per cent sand and lack clay altogether. These sands contain an average of only 0.3 per cent shredded wood and 1.0 per cent fragmentary shell material; thus, they consist almost entirely of detrital clastic grains (Shepard 1956).

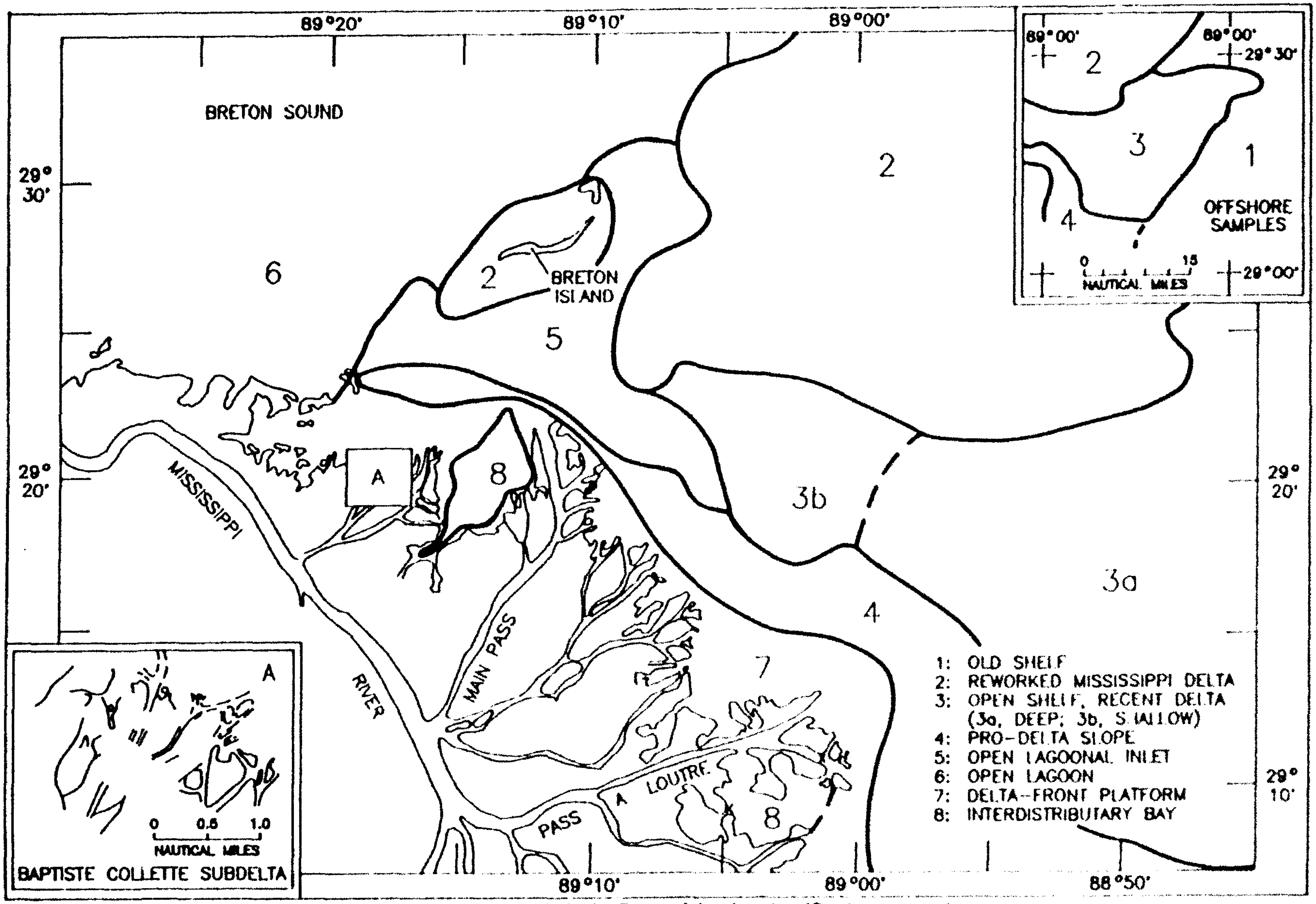


Figure 2. Areal distribution of sedimentary environments within the Breton Island region (Curtis 1960:476).

Stratigraphy

The sediments underlying the shallow shelf bottom of the project area consist of a complex assemblage of Pleistocene and Holocene deltaic, nearshore marine, and coastal sedimentary deposits. Unconformities and other discontinuities divide the Holocene deposits into three major, informal sedimentary sequences: the St. Bernard, Chandeleur Island, and unnamed marine complexes. The oldest of the Holocene sedimentary sequences lies upon a significant package of older, Late Pleistocene fluvial and deltaic sediments called the Prairie Complex.

Because of the complex heterogeneous nature of the sediments underlying the project area, these sediments are defined on a basis of regionally mappable unconformities. Because they are defined and mapped on the basis of bounding unconformities instead of lithology, each sedimentary sequence is an alloformation. An alloformation is a mappable body of sedimentary rock or unconsolidated sediment that is defined and identified on the basis of bounding discontinuities. A bounding discontinuity can be either an erosional unconformity or a construction surface (North American Commission on Stratigraphic Nomenclature 1983:865-868).

Allostratigraphic units have not been defined adequately nor have they been formally named within the Louisiana continental shelf and adjacent Mississippi River Delta. Since these are informal stratigraphic units, an informal allostratigraphic term, the "complex" is used. A complex is simply an alloformation that has not been defined formally. It consists of a single depositional sequence composed of sediments deposited within different depositional environments and lying between distinct, regionally mappable bounding discontinuities. After a complex is named and described as a formal allostratigraphic unit, the use of a complex should be abandoned (Whitney J. Autin, personal communications 1992; Autin et al. 1990; 1991).

Prairie Complex

As defined by Autin et al. (1991:556), the Prairie Complex consists of two, and possibly three, depositional sequences and possible alloformations that underlie the Holocene deltaic deposits of the St. Bernard Delta Complex (Figure 3). Each depositional sequence consists of an indistinguishable and heterogeneous assemblage of deltaic, shallow marine, and strandplain deposits that vary from Sangamonian to Middle Wisconsinan in age. Because of their age, these deposits predate the human occupation of the project area and, therefore, lack any archeological deposits.

The upper contact of the Prairie Complex lays beneath younger Holocene deltaic and nearshore deposits at a depth of 50 to 60 m below sea level (Figure 3). It consists of a formerly exposed portion of what was once the Louisiana coastal plain within the project area. In the subsurface, the top of the Prairie Complex is marked by the occurrence of a typically truncated weathering zone that developed within its uppermost sediments when the coastal plain was subaerially exposed during Wisconsinan glaciations. This weathering zone is distinguished from the overlying Holocene deposits by a mottled orange, tan, or greenish gray color, an abrupt increase in stiffness and shear strength, and by the presence of pedogenic calcareous nodules (Autin et al. 1991:556; Fisk and McClelland 1959; Frazier et al. 1978).

Available radiocarbon dates indicate that the former coastal plain, which formed the surface of the Prairie Complex, was flooded sometime after 10,000 to 9,000 radiocarbon years Before Present (B.P.). As a result, it was available for occupation during the initial stages of human occupation of this area. However, shoreface erosion during the Holocene submergence of the survey area by the Gulf of Mexico apparently has eroded deeply the surface of the coastal plain, and probably has destroyed the majority of archeological deposits that would have been present on its surface (Fisk and McClelland 1959; Frazier et al. 1978; Nummedal and Swift 1987).

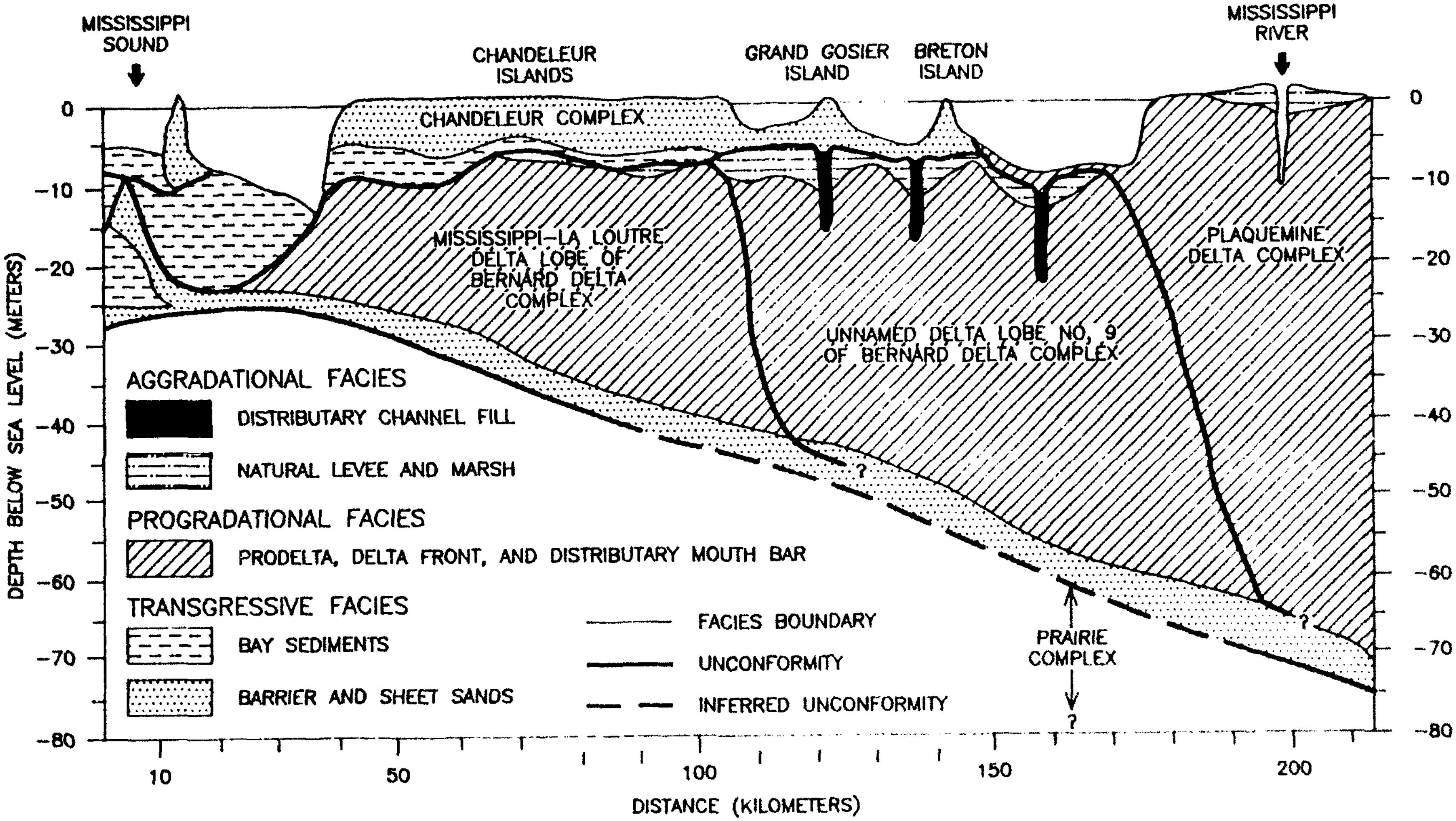


Figure 3. Geologic cross-section of Chandeleur Barrier Island Chain. Modified from Penland et al. (1985).

St. Bernard Delta Complex

The St. Bernard Delta Complex is an allostratigraphic unit bounded by a lower marine erosional surface, called a "ravinement surface," cut across the Prairie Terrace and erosional surfaces that were cut to varying depths across its delta plain. Between these bounding unconformities, this complex consists of a basal layer of transgressive sediments, a middle unit of fine-grained progradational deltaic sediments, and an upper unit of aggradational, deltaic natural levee and marsh sediments. Internally, a minor unconformity formed by a minor period of nondeposition, called a "diastem," separates the deposits of individual delta lobes within this complex. The sediments of either the Chandeleur or unnamed marine complexes unconformably overlie the St. Bernard Delta Complex (Figure 3).

Deltaic sediments lying between the erosional boundaries of the St. Bernard Delta Complex are approximately 45 to 50 m thick (Figure 3). This depositional sequence consists of a basal layer of transgressive deposits not exceeding a thickness of 5 m; it is overlain by 35 to 45 m of progradational deposits. About 2 to 5 m of aggradational swamp and marsh deposits overlie the progradational deposits, and form the surface of the St. Bernard Delta Complex (Frazier et al. 1987).

The landward movement of the shoreline over previously subaerial coastal plains formed the basal erosional unconformity of the St. Bernard Delta Complex. As the shoreline migrated landward, the beach shoreface typically cut deeply into the underlying Pleistocene sediments of the Prairie Complex. As a result, the upper meters of this coastal plain were eroded almost uniformly and reduced to a transgressive sand lag. During the period that elapsed between the submergence of an area beneath the Gulf of Mexico and the influx of deltaic sediments, sediments eroded from this coastal plain were reworked into a thick transgressive sheet sand. As the water depth increased, clayey silts and silty clays accumulated upon the basal sand lag (Frazier et al. 1978).

As the St. Bernard delta prograded into the Gulf, a thick sequence of progradational deposits accumulated. Initially, clay was deposited from suspension to form a thick blanket of unfossiliferous, parallel-laminated, and fine-grained sediments called the "prodelta facies." As this delta prograded seaward, the accumulating prodelta facies became siltier and developed parallel and lenticular laminae of silt. As progradation continued, laminated silts and clays with thin sand layers, called the "delta front facies," accumulated as part of the St. Bernard Delta Complex. Locally, distributaries deposited interbedded silts and silty sands that displayed a wide variety of sedimentary structures associated with currents and waves at their mouth. These sediments are called "distributary mouth bar facies" (Coleman 1982; Frazier et al. 1978).

Once this delta had built up to sea level, natural levee and marsh sediments accumulated upon the subaqueous progradational deposits to create a subaerial delta plain of the delta complex. The deposition of sediment by floodwaters formed low ridges, called "natural levees," which bordered the distributary channel. Through breaks in the natural levees, floodwaters built crevasse splays on the adjacent delta plain and subdeltas that filled in the adjacent interdistributary bays (Coleman 1982:52).

The natural levee and crevasse splay deposits consist of silts, sandy silts, silty sands, and very fine sands that are characteristically small-scale, cross-laminated and rippled with intensively bioturbated zones. These sediments commonly are oxidized and contain abundant digenetic materials such as iron sesquoxide and carbonate nodules and cements. Organic marsh deposits accumulated within the periodically flooded land away from the main distributaries (Coleman 1982:52).

Eventually, long-term delta lobe progradation lead to the overextension of the distributary network, and to a decrease in hydraulic efficiency. With time, the decrease in hydraulic efficiency caused an upstream diversion of the trunk channel. As a result, the channel switched to a shorter, more efficient course with a steeper gradient; it generated a new delta complex; and, it caused the abandonment of St. Bernard Delta (Fisk 1960).

With the sediment needed to maintain the abandoned delta complex diverted to building a new delta, tectonic and compactional subsidence and eustatic sea level rise caused the delta plain of the St. Bernard Delta to begin sinking into the Gulf of Mexico. As the delta sank, waves and currents eroded the deltaic plain at the inner shore of the lagoon and at the shoreface of the barrier or transgressive shoreline forming erosional surfaces. The composite erosional surface formed by each of these erosional surfaces forms the top of the St. Bernard Delta Complex within the project area (Shea Penland, personal communication 1991; Penland et al. 1985; 1987).

Chandeleur Island Complex

The Chandeleur Island Complex consists of a complex unconformity-bounded package of lagoonal, barrier island, and tidal channel deposits (Figures 3 and 4). The basal unconformity of this complex consists of a low-relief erosional unconformity that separates its basal lagoonal deposits from the deltaic deposits of the underlying St. Bernard Delta Complex. As previously noted, the transgression of the inner shoreline of Breton and Chandeleur Sound over the delta plain of the St. Bernard Delta has created and still is forming this basal unconformity. In addition, tidal inlets between the barrier islands often cut channels that are 10 to 15 m below the bottoms of the adjacent sound and shelf. As a result, where tidal inlets have formed and their channels have been filled, the Chandeleur Island Complex can be over 10 m thicker, and the depth to its basal unconformity is correspondingly deeper. Seaward of Breton Island, the upper contact of the Chandeleur Island Complex is a marine erosion surface termed a "ravinement surface." The continuing westward migration of the shoreface of the Chandeleur Barrier Island Chain is actively eroding the deposits of both Chandeleur Island and the St. Bernard Delta Complex to form this ravinement surface (Penland et al. 1985; 1987).

Typically, the basal portion of the Chandeleur Island Complex consists of 1 to 2 m of lagoonal sediments unconformably overlying the deltaic sediments of the St. Bernard Delta Complex (Figure 4). The basal lagoonal sediments consist of bioturbated silty clays with shell fragments and sand lenses. The silty clays accumulated within the lagoon formed behind the Chandeleur Islands as a result of the continued subsidence of the former delta plain. Because of slow sedimentation and high biological activity, these deposits are highly bioturbated. The sand lenses are remnants of lag deposits formed during infrequent storms (Heerden et al. 1985:193-194).

Beneath and adjacent to the landward edge of the barrier islands, a meter or more of thinly interbedded silty clays and silty sands overlies the lagoonal silty clays. Within this unit, the coarser layers generally increase in thickness upward, with a corresponding decrease in the thickness of the finer layers. These sediments commonly are either parallel or cross-laminated and have been bioturbated to a minor degree. These sediments represent the distal edge of washover deposits that form the leading edge of the landward moving barrier island system (Heerden et al. 1985:194).

The barrier islands within the Chandeleur Barrier Island Chain consist primarily of approximately 3 m of silty sands (Figure 4). These sands are highly bioturbated and display very few primary sedimentary structures. Often, they contain organic-rich root horizons and thin clay layers. These silty sands represent washover deposits that form the core of the barrier island. These sediments often are overlain by an additional 1 to 1.5 m of clean parallel-laminated and bioturbated sands. The clean sands represent both dune and washover sediments. Periodically, hurricanes erode and wash these sands from the seaward portion and shoreface of the barrier island and transport them either over the barrier island into the lagoon or onto the island. The result of this process is that Breton Island and other islands of the Chandeleur Barrier Island Chain are migrating landward. The landward migration of the island and its associated

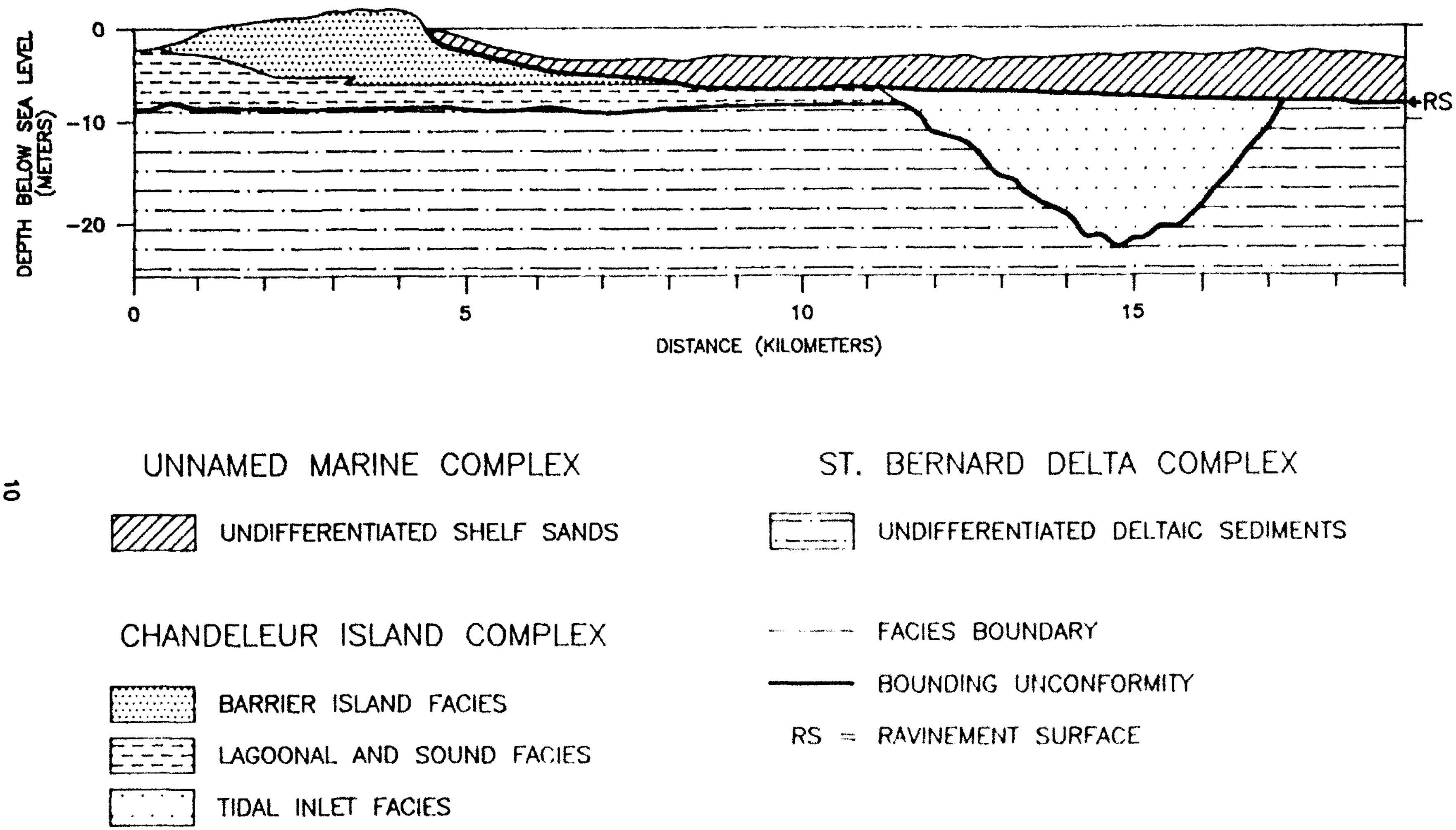


Figure 4. Diagrametric cross-section of Holocene deposits underlying shelf east of the Chandeleur Islands. Constructed from data and figures of Penland et al. (1985).

shoreface eventually results in the erosion of the entire barrier island - lagoonal depositional sequence. As a result, any historical or prehistoric archeological deposits associated with the subaerial barrier island sediments of the Chandeleur Island Chain have a negligible chance of being preserved (Heerden et al. 1985:194; Penland et al. 1985).

Locally, the barrier island deposits overlie the sandy channel fill of the tidal inlets. These sediments consist of upward fining, horizontally bedded to bioturbated sands containing numerous shells. These sediments are the coarse-grained fill of abandoned tidal channels. Because they are often 10 to 15 m thick, the basal parts of the deposits lie below the level of the ravinement surface and commonly are the only part of Chandeleur Island Complex to survive shoreface erosion. Because of their deposition in a subaqueous environment within an active tidal channel, it is unlikely that they will contain prehistoric archeological deposits (Penland et al. 1985, 1987).

Unnamed Marine Complex

Overlying the ravinement surface are the sands of the unnamed marine complex (Figure 4). These sediments consist of sands eroded from the shoreface and adjacent bottom and transported and redeposited seaward of the contemporaneous shoreline. These deposits frequently are reworked and redistributed by storm waves and geostrophic currents to form a blanket and scattered subaqueous bars of relatively clean sand across the ravinement surface. The ravinement surface is a regionally mappable erosional unconformity that forms the base of this unit (Nummedal and Swift 1987; Penland et al. 1985).

Geological History

During the Late Pleistocene Stage, 132,000 to 10,000 years B.P., the accumulation and dissolution of continental ice sheets caused eustatic sea level to fluctuate generally between 20 to 70 m below present sea level in 20,000 year cycles. Maximum high stands of sea level occurred at approximately 120,000 year intervals during interglacial periods such as the Holocene Epoch and early Sangamonian Stage. As a result, the paleogeography of southeastern Louisiana changed as the shoreline migrated north and south across the southeast Louisiana continental shelf and coastal plain. The Sangamonian high stand of sea level reached an elevation of 6 to 7 m above present sea level around 120,000 years B.P., during Oxygen Isotope Stage 5E. It was at this time that the northern portion of the coast-parallel Prairie Terrace was an active series of coalesced alluvial plains (Autin et al. 1991:556-558; Moore 1982; Suter et al. 1987).

Wisconsinan Stage

During the Late Wisconsinan Stage, the 20,000 year cycle of eustatic sea level fluctuation created a series of depositional sequences. A fall in sea level resulted in the expansion of the coastal plain onto the modern continental shelf, in the accumulation of thin, laterally extensive deposits of shelf-phase deltas, and, eventually, in thick fluvial deposits on the continental shelf. At maximum low stand, the dropping of sea level below the shelf edge caused the entrenchment of the shelf by fluvial systems; subaerial exposure of the shelf; and, the deposition of thick shelf-margin deltas at the shelf edge. When sea level rose, the ensuing transgression submerged, eroded, reworked, and redistributed fluvial and deltaic deposits as broad sand sheets and shoals. As the rise in sea level ceased or slowed to a low rate, fluvial systems, delivering an abundant supply of sediment to the coast, then built deltaic complexes that prograded seaward onto the shelf (Suter et al. 1987).

Around 21,000 years B.P., at the start of the Late Wisconsinan Substage, relative sea level dropped from the highest Middle Wisconsinan high stand of 20 m below present sea level to its maximum Late

Pleistocene low stand at about 120 m below present sea level. In response, the shoreline moved to the modern shelf edge, subaerially exposing large areas of the continental shelf. At this time, subaerial weathering formed a well-defined weathering horizon within the upper sediments of the Prairie Complex (Fisk and McClelland 1959).

During the latter part of the Late Wisconsinan Substage, relative sea level rose episodically from approximately 120 m below sea level to 30 m below sea level by 10,000 radiocarbon years B.P. A wide, deeply cut, erosional terrace along the edge of the outer continental shelf records a still stand of sea level about 90 to 80 m below modern sea level that occurred during the Late Wisconsinan Substage. In addition, during a stillstand between 9200 and 8200 radiocarbon years B.P., the Outer Shoal Delta Complex, whose delta plain lies currently at depths of 25 to 15 m, might have formed (Frazier 1967, 1974; Goodwin et al. 1991:36).

Holocene Epoch

As the Late Wisconsinan-Holocene sea level rise submerged the modern Louisiana Continental Shelf, the transgressing shoreline substantially modified its surface. The degree of transgressive erosion varied from the minor removal of overbank deposits from natural levees to the complete erosion of the alluvial plains within coast-parallel terraces. During still stands of sea level, local accumulations of lagoonal, chenier, or other aggradational coastal plain deposits may have buried the coastal plain deeply enough to have protected it from transgressive erosion (Suter et al. 1987).

In addition, shelf and transgressive shoreface processes substantially modified both strandlines and deltas. Shoreface erosion deeply eroded the surfaces of Late Wisconsinan and Early to Middle Holocene deltas forming extensive ravinement surfaces. Shelf and sound processes eroded and redistributed the upper parts of many barrier islands, cheniers, and deltas into marine sheet sands and east-west oriented sand shoals. Even though three or four these offshore sand ridge trends are the remains of drowned strandlines, the original barrier islands and beach deposits have been reworked almost totally into marine sand shoals. During this time, the entrenched valleys of the Mississippi River and local streams were filled with fluvial, estuarine, and sometimes lagoonal sediments (Frazier 1967, 1974:19-24; Penland et al. 1985, 1987; Suter et al. 1987:210-214).

From about 7500 to 5500 radiocarbon years B.P., a stillstand occurred during an otherwise rapid rise in sea level, at a depth of 5 to 6 m below present sea level. During this stillstand, the Mississippi River apparently built the Maringouin Delta Complex around 7300 to 6200 radiocarbon years B.P. (Frazier 1967, 1974). Frazier (1967:269) noted the presence of two stacked, depositional sequences within this delta complex.

The Gulf of Mexico flooded the Late Wisconsinan eastern Louisiana coastal plain when sea level rose. By 5000 radiocarbon years B.P., the shoreline had reached the edge of the modern Prairie Terraces forming the Pontchartrain Embayment. Longshore currents created and maintained a chain of barrier islands and shoals that extended southwest across the embayment from the mouth of the Pearl River between 5100 and 4000 radiocarbon years B.P. This chain of shoal and scattered islands, called the "New Orleans Trend" (Otvos 1978), created the gulfward boundary of an ancient Pontchartrain Bay (Figure 5). By about 5000 radiocarbon years B.P., rising sea level also flooded the Mississippi Alluvial Valley and created a brackish water embayment that extended to the latitude of Baton Rouge (Otvos 1978; Saucier 1963:44-46).

To the west, the renewed rise in sea level submerged most of the surface of the Maringouin Delta Complex. After rising sea level had submerged most of the Maringouin Delta Complex, the Teche Delta Complex formed around 5800 radiocarbon years B.P. (Figure 5) (Frazier 1967; Weinstein and Gagliano 1985:120-123).

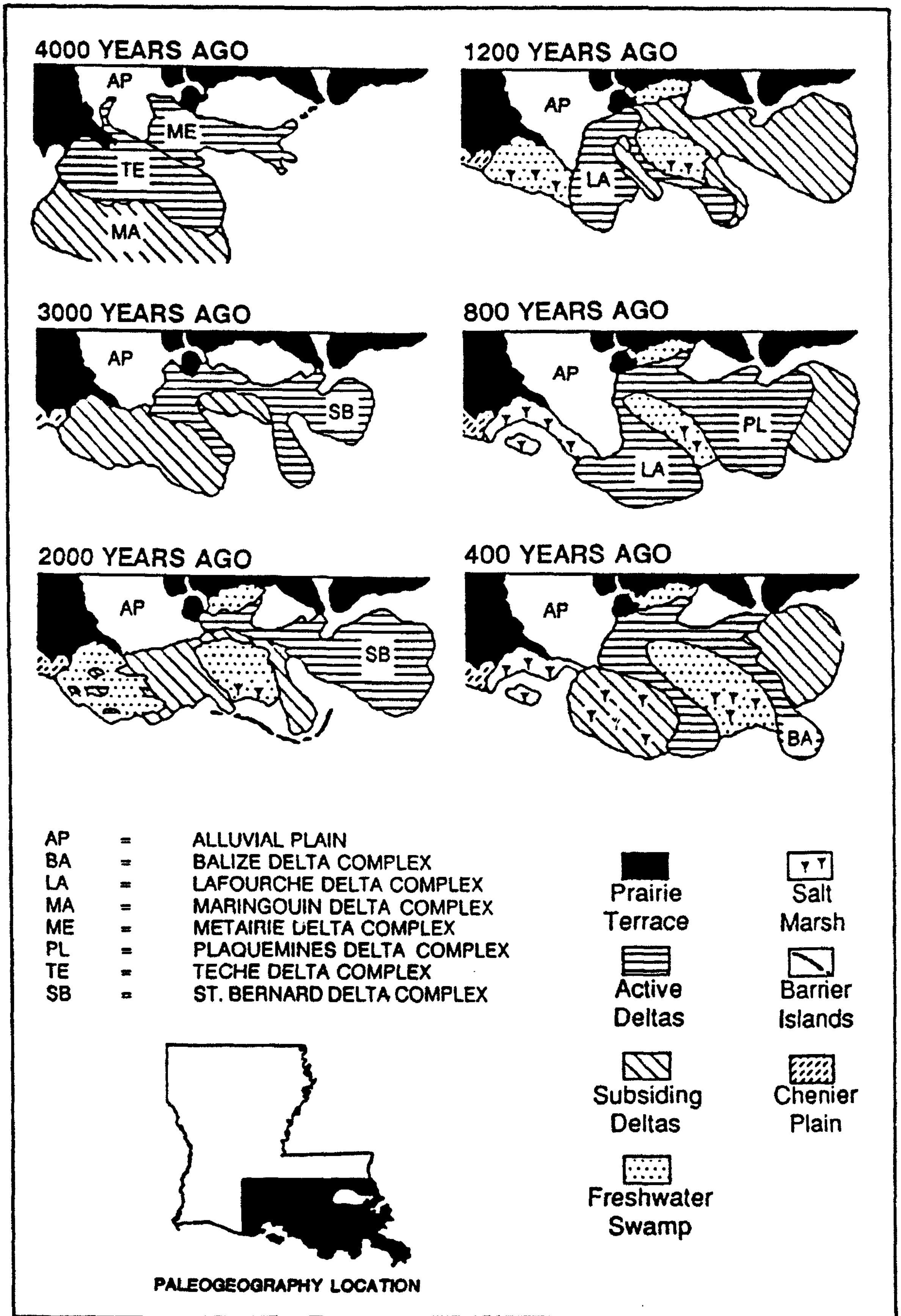


Figure 5. Paleogeography of Mississippi River Delta. Modified from Kosters (1987).

About 4800 radiocarbon years B.P., the Mississippi River began to shift its course from Meander Belt No. 3 to Meander Belt No. 2 at Marksville, Louisiana, which diverted much of its flow down the eastern and central part of the Mississippi Alluvial Valley (Autin et al. 1991). As a result, a new delta complex, called the "early St. Bernard Delta Complex" by Frazier (1967), prograded into and through the New Orleans area (Figure 5). The main delta of this complex prograded about 70 km southeast of New Orleans into the Gulf of Mexico. By 4000 radiocarbon years B.P., another small delta of this complex had prograded northeast and buried a chain of southwest trending barrier islands, the New Orleans Barrier Island Trend. The New Orleans Trend shifted slightly eastward to form the Bayou Sauvage Trend of shoals and barrier islands. The burial of the New Orleans Trend by deltaic deposits remade Pontchartrain Bay into a brackish water bay ancestral to Lake Pontchartrain (Otvos 1978:Figure 16; Saucier 1963:56-59).

From about 3400 to 1600 radiocarbon years B.P., the St. Bernard Delta Complex, according to Frazier (1967), formed two major delta lobes that prograded westward from the New Orleans area (Figure 5). The larger delta lobe, the La Loutre Delta Lobe, prograded eastward into the survey area. Starting about 3000 years B.P., this delta lobe buried the New Orleans Trend creating Lake Pontchartrain and forming most of St. Bernard Parish. From 2500 to 1600 radiocarbon years B.P., unnamed Delta Lobe No. 9 of the St. Bernard Delta Complex prograded into and built a delta plain within the project area. A smaller delta, the Des Familles Delta in the Bayou des Familles area, prograded southward from the New Orleans region. From 1800 to 600 years B.P., only the Bayou Sauvage delta of the St. Bernard Delta Complex remained active (Weinstein and Gagliano 1985:123).

Between 4800 and 2000 years B.P., Bayou Lafourche slowly prograded southward from the New Orleans region (Figure 5) building the Terrebonne and Lafourche delta lobes. It reached Thibodaux by the end of this period. The distributaries of the Terrebonne Delta Complex probably reoccupied relict distributaries of the former Teche Delta Complex. By 2000 years B.P., the Lafourche Delta Complex reached its peak discharge (Weinstein and Gagliano 1985:123).

By about 1000 years B.P., the discharge through the Lafourche Delta Complex began to wane as the discharge of the Mississippi River reoccupied the St. Bernard/La Loutre Delta Complex. Flow through the Terrebonne Delta stopped, and active progradation of that delta ceased. Since then, the Terrebonne Parish region has been subsiding and deteriorating. Bayou Lafourche remained an active distributary of the Mississippi River until closed in 1904 (Weinstein and Gagliano 1985:144).

About 1000 radiocarbon years B.P., the relict feeder channel of the St. Bernard Delta Complex was reoccupied partially, and a delta of the Plaquemines Delta Complex prograded through the interlobe basin between the Des Familles and La Loutre Deltas of the St. Bernard Delta Complex. Initially, the discharge flowed through a series of channels in this basin, such as the River aux Chenes, Belair, and Bayou Grande Cheniere. By approximately 600 years B.P., the Bayou Grande Cheniere became the modern course of the Lower Mississippi River. As the shoal-water Plaquemines Delta Complex prograded off the shelf edge, the shelf-margin Balize Delta formed (Weinstein and Gagliano 1985:125, 143).

Fauna

Parker (1956) recognized the presence of two different benthic faunal assemblages, the inlet and shallow shelf assemblages within the project area. Extending northeast from the tidal inlet between Breton and Gosier Islands, the inlet assemblage covers a large part of the northern and western portions of the project area. The shallow shelf assemblage covers the eastern part of the project area (Parker 1956:312).

The inlet faunal assemblage is associated with the tidal inlet between Breton and Gosier Islands. This assemblage consists of 100 species of macro-invertebrates, of which 12 species are restricted to the inlets. The other species consist of a mixture of invertebrates that either occur within the adjacent sound or shallow shelf. Some of the characteristic species are pelecypods such as *Anadara brasiliana, Chione cancellata, Trachycardium muricatum, Lucina amiantus, Cyrtopleura costata, Pandora trilineata*, and *Petricola pholadiformis*; gastropods such as *Diodora cayenensis, Natica pusilla, Anachis obesa, Anchis avara semiplicata, Mitrella lunata, Busycon contrarium, Busycon spiratum plagosum*, and *Olivella Mutica*; a chiton, *Chaetopleura apiculata*; echinoderms (brittle stars) such as *Hemipholis elongata* and *Ophiolepis elegans*; Crustaceans such as *Heterocyrpta granulata* and *Porcellana sayana*; a polychaete worm, *Owenia fusiformis*; a coelenterate, *Calliactis tricolor*; and, bryozoa such as *Discoporella umbellata, Cupuladria canariensis*, and *Membranipora* sp. Of these, *Anadara brasiliana, Chione cancellata, Pandora trilineata, Trachycardium muricatum, Diodora cayenensis, Natica pusilla, Anchis avara semiplicata, Hemipholis elongata* and *Ophiolepis elegans* are among the species restricted to the inlet faunal assemblage (Parker 1956:229-337).

Microfauna found within the tidal inlet that crosses the project area are sparse. They consist primarily of a small number of species and individuals of ostracods and foraminifera. Generae of ostracods typically present within the open tidal inlets are *Loxoconcha, Cytherura, Cushmanidea, Perissocytheridea*, and *Haplocytheridea*. The open tidal inlets on either side of Breton Island are characterized by a foraminiferal fauna consisting of a mixture of species found within Breton Sound and the inner continental shelf. Species of foraminifera typically found within the open tidal inlet environment include *Ammobaculites salsus, Ammoscalaria psuedospiralis, Elphidium incertum mexicanum, Gaudryina exilis, Quinqueloculina cultrata*, and *Triloculina sidebottomi* (Curtis 1960:489; Phleger 1955:727).

The shallow shelf assemblage consists of approximately 81 species of invertebrates occurring on the shallow bottom of the inner shelf of the Gulf of Mexico adjacent to the Chandeleur Island Barrier Chain. This faunal assemblage ranges in water depth from 0 to 24 m in depth and is characterized by invertebrates that are confined to high-salinity, shallow-shelf environments. This faunal assemblage occupies Gulf waters with salinities generally above 14 parts per thousand and usually above 17 parts per thousand. Some of the characteristic species that form the shallow shelf faunal assemblage are pelecypods such as *Nuclana acuta, Anadara campechiensis, Anadara chemnilzi, Noetia ponderosa, Atrina serrata, Dinocardium robostum, Dosinia discus, Labiosa plicatella, Labiosa lineata, Donax tumida, Tellina vesicolor, Strigilla mirabilis*, and *Ensis minor*; gastropods such as *Strombus alatus, Cantharus cancellarius, Busycon spiraltum plagosum, Oliva sayana, Phalium granulatum, Murex fulvescens, Murex pomum*, and *Terebra cinera*; coelenterates such as *Renilla mulleri* and *Leptogorgia setacea*, echinoderms such as *Luidia clathrata, Luidia alternata, Mellita quinquiesperforata*, and *Moira atropos*; a polychaete worm, *Aglaophamus dicirris*; a bryozoa, *Zoobytron* sp.; and, crustaceans such as *Ovalipes ocellatus* and *Sicyonia dorsalis* (Parker 1956:337-343).

The microfauna associated with the inner shelf, open-gulf environments of the reworked Mississippi Delta are sparse. They include a small number of species and individuals of ostracods and foraminifera that vary inversely with the sedimentation rate. The typical genera of ostracods present are *Loxoconcha, Pellucistoma, Cytheretta, Luvula, Cytherura, Cushmanidea*, and *Puriana*. In addition to these ostracods, the microfauna of the inner shelf contains a number of foraminifera. The species that are restricted to these open-gulf environments include *Bigenerina irregularis, Bolivina lowmani, Buccella hannai, Buliminella cf. bassendorfensis, Cibicidina strattoni, Espistominella vitrea, Nonionella atlantica, Nonionella opima, Nouria polymorphinoides, Quinqueloculina cf. compta, Rotalia rolshauseni*, and *Virgulina pontoni* (Curtis 1960:489; Phleger 1955:725).

Historical Overview of Breton Island

Beginning with Lemoyne d'Iberville's first voyage to French Louisiana in 1699, many ships subsequently steered near Breton Island on their way to the mouth of the Mississippi River. Located at the southern end of the bow-shaped Chandeleur Island chain, this small sandy island occasionally has been at the center of important maritime activity. French vessels coming from such Gulf ports as Mobile and Biloxi sailed close to it as they plied toward the mouth of the Mississippi heading for New Orleans. The French also anchored warships there in the late 18th century to protect French shipping. Likewise, the British stationed their armada off the island in December 1814 as they prepared to assault the city of New Orleans. During the early 1920s, rum runners anchored near the island, since it lay near the 3 mile limit and thus out of the jurisdiction of American Coast Guard cutters. Therefore, this small southern tip of the Chandeleur chain played a minor, yet not insignificant role in the maritime history of the northwestern section of the Gulf of Mexico.

The French explorer, Iberville, was one of the first Europeans to visit Breton Island. Leaving the port of Brest in 1698, he eventually reached Mobile Bay and then relocated his three ship fleet to Ship Island. Iberville then explored the coastline along the Chandeleur Islands including Breton. Leaving his fleet, the Frenchman then set out in small boats across "a headland of black rocks," entered the mouth of the Mississippi, and proceeded up the mighty river (Crouse 1954:171; McWilliams 1981:5).

In May 1699, Iberville initiated the second of his three voyages to French Louisiana. He again took small boats up the mouth of the Mississippi. During his absence, Spanish ships encountered two French frigates anchored at Ship Island. The Spanish vessels opted not to challenge their French counterparts and sailed away. However, the main Spanish ship was wrecked on Chandeleur Island, losing all its cargo (McWilliams 1981:9)

One of the earliest descriptions of Chandeleur Island was made by Antonine Simon Le Page Du Pratz. During a voyage to Louisiana in 1718, Du Pratz investigated the island which he dubbed "candlemas island." According to Du Pratz, the island was so flat that he could barely distinguish it when his ship was as close as one league away. He also noted that the water was four fathoms deep (Du Pratz 1774:13).

One of the few descriptions of Breton Island was made by Colonel Samuel Henry Lockett, a professor of engineering at the old Louisiana State Seminary at Pineville, Louisiana. In 1869, Lockett initiated a topographical survey of the state. The Chandeleurs, he recorded, were sandy and marshy with an occasional group of pine and oak trees. Breton Island, he wrote, was crooked and low with a general direction of northeast and southwest and about 11 miles long. According to Lockett, there was a "good channel" between Breton and Grand Gosier Island, which lay 5 miles west (Lockett 1969:127).

Though Breton, in Lockett's estimation, had a good channel, many Gulf islands did not offer safe locations for anchorage. The frequent and violent hurricanes, which arrived near the end of summer, altered the shapes of these barrier islands as well as the shoreline. One such wrathful storm partially destroyed Ship Island in 1701, and another obstructed the channel of Massacre Island in 1717. A French missionary summed-up the problem in a 1711 letter to his uncle, lamenting that "our coast changes shape at every moment; what was a muddy ridge becomes an island, and what was an island becomes a muddy ridge" (Giraud 1974:65-66). Consequently, a good, usable safe channel could quickly become a shallow and dangerous one.

The vast deposits of sediments at the mouth of the Mississippi formed a virtual mud blockade which prevented all but the smallest of vessels from ascending up the river. The late winter and spring floodwaters would inundate the waterway with even more sediment, thereby reducing the depth of water and grounding vessels for months at a time. Some French ship captains ignored orders--even when accompanied by threats of violence--to proceed up the treacherous river channel. Captain Le Gac of the *Dromedaire*, for example, secured a signed certificate from another captain stating that it would be easier for an elephant to go through the eye of a needle than for the *Dromedaire* to move up the river. The first sea-going ship to attempt to enter the river was an English vessel which the French turned away in the famous English-Turn incident in 1700. Not until 1718, when the *Neptune* entered the Mississippi, did another ship dare to sail up the river (Lowrey 1964:233-234).

The establishment of New Orleans in 1718 soon led to an increase in water traffic between the new city and the French ports of Biloxi and Mobile. This development meant that more vessels would pass near Breton Island as they sailed between Gulf ports and the mouth of the Mississippi. These ships carried such products as silk. tobacco, rice, indigo, sassafras, quinine, and lumber (Surrey 1916).

Though vessels plied between Gulf ports and the mouth of the Mississippi, many instead took the shorter, safer route across the Rigolets, through Lake Pontchartrain, and down Bayou St. John to New Orleans. This way was of course preferable because the sand and mud bars at the entrance of the river made navigation slow as well as treacherous. Swift river currents made beating upstream difficult. It sometimes took as long as a month for a ship to travel from the mouth of the Mississippi to New Orleans. On the other hand, Lake Pontchartrain created a clear water route to the Gulf when it overflowed. In fact, this route was accessible to a substantial number of vessels, and it became the path of "ordinary communications" between Gulf ports and New Orleans in the early eighteenth century (Giraud 1974:347; Pearson 1989:88-89; Surrey 1916:33).

Despite the difficulties involved with navigating the Mississippi, many French as well as Spanish vessels landed at the mouth of the river. For example, a Spanish ship arrived from Havana in 1725 and another appeared two years afterward (Giraud 1974:347).

During the early 1720s, the French did a considerable amount of work at the mouth of the river in order to make it a more usable route to New Orleans. Their efforts centered on the harbor at Balise where vessels entered the river. There they constructed various buildings to house products from Gulf ports, such as pitch and tar from Mobile. When ships arrived at Balise, pirogues helped to lead them into the channels and pilots took them over the bar (Giraud 1974:155-156, 347).

Both Spain and Britain stationed warships off the Chandeleur Islands, including Breton at various times. In a 1794 military report to the Spanish government on Louisiana and western Florida, Governor Carondelet wrote that war vessels were anchored "with all safety, on Ship [Navios] Island, the Chandeleurs [Candalaria], and Breton Island" (Robertson 1911:I:320). Two decades later, during the War of 1812, the British anchored their huge armada off the Chandeleur Islands as they prepared to invade New Orleans. Shortly after arriving, the fleet came under attack from six American gunboats. The British returned the fire and reported to have sunk one of the vessels (Grummond 1962:330-332).

Throughout most of the 19th century, many ships continued to ply up the Mississippi, though the navigation was difficult and dangerous. The New Orleans and Ship Island Canal Company, which lobbied for a canal through the Rigolets, complained of the delays and damages to vessels entering the river. The company noted that in March 1859 there were 35 vessels waiting to egress, 3 grounded on the bar, and 17 outside the entrance (*The New Orleans and Ship Island Canal* 1869:1-7).

Toward the close of the 19th century, the state of Louisiana and the federal government finally took steps to alleviate the navigational difficulties at the mouth of the river. The city of New Orleans wanted to construct a canal from Fort St. Philip into Breton Island Sound. Benjamin Buisson, the state engineer for Louisiana, had first formulated this plan back in 1832 (Lowrey 1964:246). However, in 1875 Congress instead authorized the construction of the Eads jetties at South Pass--one of the four main entrances to the river. The project was completed in 1879, giving the Mississippi a 35 foot deep channel (Roberts 1946:274-275). Of course, the deepening of the river channel led to more traffic up the waterway, and therefore to more vessels passing by Breton Island.

The initiation of Prohibition in 1920 led to the emergence of a "Rum Row" off of Breton and the Chandeleur Islands as vessels loaded with alcohol assembled there just beyond the United States 3 mile limit. Most of these rum ships, many of which were British, were under foreign registry, though a great number were locally owned. Coming from Cuba and British Honduras, they rendezvoused at Breton and the Chandeleur Islands with contact or "mosquito" boats which took the alcohol through Lake Borgne, Lake Pontchartrain, or passes at the mouth of the Mississippi. Coast Guard cutters and Customs boats were, initially, too slow to catch these vessels as they skirted for the American coast (Jackson 1978:277-278).

Until about 1925, there was considerable activity near Breton Island as rum runners played cat and mouse games with Coast Guard and Customs vessels. In September 1925, the New Orleans *Times-Picayune* reported that patrol cutters were picketing a British schooner loaded with 9,000 cases of whiskey off Chandeleur Island. The ship, according to the paper, was 18 miles east-southeast from the lower end of the Chandeleurs and near the 3 mile limit. Later in the month, a Coast Guard vessel fired upon and sank the power vessel, *Emilia G*, in Breton Sound off Errol Island. However, activity in this area soon wound down as rum runners relocated to a point off Timbalier Light that provided access through Barataria Bay and Bayou Lafourche (Jackson 1978:277-278; New Orleans *Times-Picayune* 1925).

Despite being a small and relatively useless island [from a commercial standpoint], Breton was often in the vortex of maritime activity in the Gulf because of its location. Many vessels steered near the tiny, sandy island since it lay along the heavily-traversed route from the mouth of the Mississippi to such important Gulf ports as Biloxi, Mobile, and Pensacola. Therefore, it was the location of the island, rather than its intrinsic value, which made it a significant point on the Louisiana coast.

Historical Shipwreck Site Potential

Traffic routes define the nodes around which the highest concentrations of shipwrecks will be located. Total shipping traffic represents the population from which shipwrecks are a sample. Other factors, including the location of natural or manmade hazards (barrier islands, shoals, bars and reefs, pilings, or previous wrecks), wind, wave, and current conditions, storm tracks and storm frequency, and incidence of collision, fire, and explosion, significantly modify this predicted distribution. It is these factors that lead to wreck incidents: location of trade routes only indicate why the vessels were there in the first place (Garrison et al. 1989a). The relationship between the location of the most travelled routes during different periods and these modifying factors indicate where the highest densities of shipwrecks are likely to have occurred.

The nature of the initial wrecking incident, and the natural conditions into which the wreck settles are important factors in determining the quality of post-depositional preservation of wreckage. The nature of the sedimentation process is of particular importance. The combination of the frequency of wreck incidents with the probable quality of preservation determines the potential for significant sites in a particular study area. A fourth overlying factor in this equation is the efficacy of the search methods used (Garrison et al. [1989a]). These factors are discussed below, with regard to the possible preservation of wreck sites in the vicinity of the Breton Island Project area.

Traffic Routes. Breton Island is located adjacent to historically recorded shipping routes described by Garrison et al. (1989a) and Pearson et al. (1989), although it does not lie directly in their path. Shoal waters with depths less than 10 feet extend for more than a mile seaward from the Breton Island shore, with waters only gradually deepening beyond that. This situation effectively precludes safe passage of ocean going vessels in the vicinity. However, vessels travelling between Main Pass, Northeast pass, Southeast Pass, or South Pass out of the Mississippi River and Mobile or Biloxi, would travel only a few miles to the windward of the Chandeleur Islands and Breton Island (Garrison et al. 1989a:II,25). This would be particularly true of vessels travelling between Biloxi and Main Pass (Pearson et al. 1989:88). Ocean going vessels would not be able to take advantage of the more sheltered water in Breton and Chandeleur Sounds, due to the shoal waters that lay between the barrier islands and the mainland. This situation, which entailed the exclusion of large craft under normal circumstances, did not change until the twentieth century, when the U.S. Army Corps of Engineers began maintaining the Mississippi River Gulf Outlet Channel, which only recently brought large vessel traffic within a mile of North Point.

Small local craft, on the other hand, have probably frequented the waters surrounding Breton Island since the earliest French colonization of the region, either for fishing or in transit along the coast. This situation continues today, as the area is popular among sports fisherman and shrimpers alike. Small craft would not be excluded from the shoals surrounding the barrier islands, or from the shallow waters in Breton Sound and Chandeleur Sound. In fact, the relatively sheltered waters found in the sounds would have greatly increased the safety of small craft transiting the area, permitting such vessels to remain in sheltered water for almost the entire distance between Biloxi or Mobile and the entrances to the Mississippi River. For these vessels, the natural deep tidal channel that separates Breton Island from Grand Gosier Island to the north would have been one of the easiest places to cross from the Gulf into the sounds, just as it is today.

Currents and Winds. The overlying system of currents in the Gulf of Mexico is largely controlled by the location of the clockwise circulating Loop Current, and its associated counterclockwise flowing eddy currents (Garrison et al. 1989a). One such eddy flows westward along the eastern Louisiana coast, curving to the southwest towards the Mississippi River Delta, and then swinging around to the east again. The southwest flowing portion of this current runs just offshore of the Chandeleur Islands. The exact nature of these flows are strongly affected by seasonal shifts in the Gulf Loop (Garrison et al. 1989a). The mean seasonal flows are well understood in the Texas-Louisiana Shelf region, but are less well understood in the eastern gulf, including the Breton Sound project area. Local currents in the project area take the form of the tidal flows discussed in the natural history section of this report.

Garrison et al. (1989a) describe the typical wind patterns in the northwest Gulf of Mexico, following Blumberg and Mellor (1981). Typical summer winds are dominated by the easterly trades. These blow from the southwest in the summer, shifting to the northeast through the winter months. The winter pattern frequently is interrupted by rapidly moving cold fronts known as northers. This shift between the summer and winter patterns occurs between September and October.

Typical wave conditions in the Gulf of Mexico consist of 1-1.5 meter waves, with the mean significant wave height near the Breton Island Project area being about 1.1 m. The highest significant wave height near the project area is nearly 4.0 m (Garrison et al. 1989a:II, F11).

The importance of these currents and the prevailing winds is their influence on the routes normally chosen by the master of a vessel, and in the timing of a voyage. It is only under the exceptional conditions of a storm that waves and wind normally would be hazardous.

The incidence of severe storms in various areas of the Gulf is one factor in the probable distribution of shipwrecks, but is not in itself an overriding factor (Garrison et al. 1989a). It is only where storm paths, heavily trafficked routes, and port locations converge that the significance of storms becomes clear in interpreting the shipwreck data for the northern Gulf (Garrison et al. 1989a:II,51).

Normal causes of shipwrecks are numerous. Causes typically reported include: collision, explosion, fire, open water foundering, grounding, striking an obstruction, scuttling, or war action. Because of the nature of these various events, it is possible to identify the setting under which some of them are most likely to occur. Collisions are most likely to occur in the most heavily travelled channels and shipping lanes. Victims of such an accident, if the accident is severe enough to cause sinking, will probably be located in or near the channel where the accident occurred. Foundering is likely to occur in exposed seaways, particularly under storm conditions, and perhaps where shoaling causes waves to pile up and break. If such an accident occurs in the vicinity of a lee shore, the vessel may subsequently ground. Grounding, by the very nature of the accident, can only occur in shallows, or on a shoreline. Groundings can occur either in severe weather conditions, through errors in navigation, or as a secondary result of other crises. For instance, a motor or steam vessel could drift ashore after engine failure, even under fair weather conditions. However, a vessel in this situation may be able to free itself eventually, avoiding a wreck, while a vessel forced aground in a storm is likely to be lost. Likewise, submerged obstructions are only likely to cause sinkings in shallows, where such an object is within reach of vessels on the surface. Fire, and perhaps explosions, may occur just about anywhere along a vessel's voyage with equal probability. The probable location of scuttled wrecks and war victims will be related to very particular historical events.

One caveat to these generalizations was noted in studying wreck incidents on the Chesapeake Bay, Maryland and Virginia. On the Chesapeake Bay, when a stricken vessel remained under partial control, there was a documented tendency for the captain to attempt a run for shallow water. Apparently, this was done in an effort to improve the chances for rescue of passengers and crew, and to improve the chances of successful subsequent salvage (Polglase et al. 1992:95). Thus, burned vessels or vessels which have suffered collision may tend to accumulate in shallows adjacent to the traffic lanes, rather than in deep water.

Natural Hazards. Breton Island represents the southwestern-most island in the chain of barrier islands that consist of the Chandeleur Islands and Breton Island. This Chain runs in a northeast-southwest trending arc between Mississippi Sound near Biloxi and the birds-foot delta of the Mississippi River. Depths are very shallow along this island chain, both on the inside and outside of the islands. Deep drawing ocean-going vessels venturing close to these islands would begin to encounter shoal waters while still well off the exposed spits of sand that form the islands. Given the prevailing direction of the easterly trades in the northern Gulf of Mexico, any vessel travelling between the eastern Gulf ports and the western Gulf ports or the Mississippi River Mouth would have this island chain on its lee at some point. In storm conditions, vessels without sufficient searoom would find no shelter in this exposed shoreline. Vessels could be driven ashore, or if drawing enough, could be driven aground while still well off of the islands themselves. This situation should lead to a relatively high shipwreck density along the entire Chandeleur Island chain, including Breton Island.

Smaller vessels would not have been immune, and in fact would have been subject to the same hazard under correspondingly milder weather conditions, such as those found under the squall conditions associated with fast moving winter cold fronts known as "northers." This appears to be borne out by the high number of modern sport fishing vessels and small shrimp boat wrecks that litter the Breton Island area today.

Preservation Conditions. The historic archeological deposits, e.g., shipwrecks, within the project area will have been impacted by hydrological and biological processes. The bottom of the project area lies well above wave base. Therefore, exposed maritime archeological deposits will have been subjected to significant disturbance by storm waves, in addition to previously described tidal currents. Also, tropical storms frequently have crossed the project area and adjacent Chandeleur Island Barrier Chain. These storms very likely have created occasionally strong bottom currents, called "geostrophic currents," which would have scoured significantly the sandy bottom of the survey area. However, these currents primarily would deflate the sandy bottom sediments and laterally disperse only the smaller artifacts (Walker 1984:142-145). As a result, the lateral relationships of historical artifacts within maritime archeological deposits likely will remain partially intact, although condensed vertically into a single lag layer at the depth determined by maximum amount of deflation caused by either storm or wave currents. The preservation of some lateral relationships between artifacts within a site despite extensive wave and current induced deflation has been observed by Murphy (1990) at the Douglass Beach Site (8SL17) within the high-energy shoreface environment of the eastern Florida Coast. This also was noted with respect to the artifact distribution associated with the ballast pile site in the northern Chandeleur Islands (Garrison et al. 1989b). Another notable site, situated in an analogous high energy setting, is the 1554 Spanish wrecks on Padre Island, a barrier island located off of the Texas coast. Spectacular preservation conditions on that site permitted the recovery of metal, ceramic, and numerous organic artifacts (Olds 1976). This included important portions of the hull (Bass 1988:89). Wave energies near Padre Island may be comparable to those affecting the Chandeleur Islands (Garrison et al. 1989a:II,48; III,F11).

Environmental conditions of shallow inner shelf waters also impact the preservation of artifactual materials. Potential for the preservation of organic material is low because the bottom sediments experience medium temperatures, are oxygen-rich, lie well within the photic zone, and are frequently disturbed by waves. In addition, shipworms (*Teredinidae*) thrive in these waters. As a result, it is likely that unburied, sunken wood, e.g., the exposed hull of a ship, would be damaged quickly, and eventually destroyed by them (Pearson et al. 1989:36-37).

Discussion

Based on previous investigations (Garrison et al. 1989a; Pearson et al. 1989), the Breton Island area has a moderate probability of having been the site of historical wrecks. However, based on the concurrence of a lee shore immediately adjacent to historical shipping lanes in a storm prone region, it is suggested that a fairly large number of wreck sites probably would have accumulated along the Chandeleur Islands and on their seaward shoals. This prediction, which applies to the Breton Island shore and the shallow water to the southeast, indicates that a large number of magnetic and acoustic anomalies, and perhaps a relatively high number of potentially significant anomaly clusters, should be expected in the Breton Island project area.

The National Register of Historic Places recognizes cultural and historical significance for a property based on four criteria: (1) association with events that have made a significant contribution to the broad patterns of our history; or (2) association with the lives of persons significant in our past; or (3) embodiment of the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or (d) that have yielded, or may be likely to yield, information important in prehistory or history (36 CFR 60.4 [a-d]). It is this last quality, which can be rephrased simply as "research potential," which is most likely to be manifest in any sites located along the Chandeleur Islands, including Breton Island. To be eligible for the National Register, a property must also posses integrity, with regard to the applicable quality of significance.

Pearson et al. (1989) list 63 specific and general classes of vessels which have been identified as having wrecked at one time or another in the area now administered by the New Orleans District. Many of the classes listed, including keel boats, flat boats (broadhorns), canal boats, pirogues, pontoon boats, and some types of steamboats, would be relegated to river, bayou and canal transportation (if these classes did frequent the coastal waters, they can be expected to be over-represented in the wreck assemblage).

Garrison et al. (1989a:III,E3) list vessels considered to be common in northern gulf waters during the historical period, including 26 classes common during the sixteenth and seventeenth centuries, 15 classes common during the eighteenth century, and 27 classes common during the nineteenth century and into the twentieth century. Almost all of the classes appearing in this list, including the smaller classes such as bateaus and shallops, would have been suitable for ocean or coastwise voyages. Remains of wrecked examples of many of these vessel types could be located on the shores of the Chandeleur Islands, or in the surrounding waters.

Although European vessels occasionally visited the northern Gulf region between Mobile Bay and the Mississippi River Delta, regular commerce in the region did not begin until the French established their colony at Biloxi in 1699 (Pearson et al. 1989). Shipping lanes used during this time passed near Breton Island and the other islands in the Chandeleur chain, which suggests that some vessels from that period would have wrecked along the Chandeleur shoreline. As the population in the region grew, commerce also would have increased, leading to a correspondingly greater incidence of wrecks. Because of this, later vessels types are more likely to be represented. This assessment is based on the presumed increase in traffic over time, and due to the fact that later vessels are more likely to remain preserved, exposed to discovery, or a combination of both.

The existing data base is very limited with regard to the early vessels and their cargo, particularly during the first two centuries after contact. However, this generalization also holds true in most cases for craft built and used during the eighteenth century. Few examples of craft dating to the sixteenth, seventeenth, or eighteenth centuries, actually survive afloat for direct study.

Nineteenth century descriptions are available for certain vessel classes, but the details remain sketchy in many cases. Some exemplars of late nineteenth century vessels have survived for direct study, and data approaching extensive documentation are available in limited instances. Even for that period, there are important data gaps, that archeological examples could fill. Indeed, in some cases, particularly with respect to rare classes, early twentieth century vessels would be valuable, too. Locally built traditional craft in particular have gone largely unrecorded. This is true through the entire historical period, including much of the twentieth century. Information concerning these vessels can only be derived archeologically. Such craft have received little study, although this lack of attention has been cited frequently (Pearson et al. 1989; Terrell 1991).

The degree of integrity in any sites located in the project area is going to be controlled by many complicated factors. The first factor controlling integrity is the extent to which a vessel is broken up in the initial wrecking process (Muckelroy 1978). In a severe case, a vessel breaking up before sinking will leave a scatter of heavy artifacts, with lighter artifacts floating away. At Breton Island, one of the most likely scenarios is for a vessel to be driven aground intact in heavy wave conditions. A grounded and exposed vessel is subsequently subject to two initial forces: continued wave action and salvage. Wave action serves to further break up a wreck (probably breaking a wooden or composite vessel faster than an iron or steel vessel). Salvaging can vary from removal of personal items, souvenirs, or fittings, to wholesale removal of major components, to the removal of the vessel itself. In remote places such as Breton Island, such salvage is likely to be incidental, rather than intensive. However, the degree to which beachcombing and salvaging has affected wrecks on the Chandeleurs and on Breton Island has not been studied.

Once a vessel was grounded, one of the most important factors influencing future preservation is how fast the wreckage becomes buried, or indeed, whether or not the wreckage becomes buried at all. The correlation between sedimentation and the level of wreck preservation noted by Muckelroy (1978) could be related to several specific effects: (1) soft bottoms can allow settling, increasing the rate of burial; (2) burial effectively removes the buried portions of a wreck from exposure to the detrimental effects of current erosion and wave action. I.e., even in high energy zones, the buried portions of a wreck effectively experience zero wave energy; (3) burial in chemically reduced sediments can prevent rapid decay of organic material; and, (4) burial may remove organic material from detrimental exposure to such boring organisms as the well known teredo worm (*teredo navalis*). In the Breton Island area, the first, second, and fourth factors are probably most important in this regard. Vessels lost in the shoals offshore of Breton Island may become buried, or partially buried relatively quickly under normal conditions. Such burial can occur even in a "high energy zone" such as exists on a beach front, or in the fore-shore shallow waters.

Burial could be reversed episodically, during periods of extremely high energy water movement. In particular, storm wave and storm surges could quickly uncover a submerged object that had taken years to be buried initially, temporarily re-exposing it to the mechanical and organic attack until it was reburied. However, for the periods during which a site is buried, it should remain largely protected from rapid deterioration. Therefore, historical wrecks in the Breton Island project area are likely to retain some degree of integrity, although only recent metal hulled vessels are likely to remain in perfect or near perfect preservation. Earlier wooden hulled vessels will probably be moderately to severely disarticulated, although artifacts may retain meaningful spatial distributions.

Prehistoric Site Potential

Shoreface erosion associated with the transgression of the Gulf of Mexico has cut deeply into the sediments that comprise the St. Bernard Delta Complex; as a result, erosion probably has destroyed associated archeological deposits. As described in detail by Penland et al. (1985) and briefly in Chapter II, the Chandeleur Barrier Island Chain, currently is moving landward over the St. Bernard Delta Complex. As these islands migrate landward, their shoreface erodes not only the lagoonal deposits that have accumulated within Breton and Chandeleur Sounds, but also erodes the natural levee and marsh sediments that form the upper part of the deltaic deposits, which contain most, if not all of the in situ prehistoric archeological deposits. As a result, the prehistoric archeological deposits associated with the St. Bernard Delta Complex within the project area likely have been destroyed. Evidence for the destruction of archeological deposits by shoreface erosion consists of concentrations of reworked and redeposited artifacts, e.g., Sites 16SB23 and 16SB25, which have been observed on the beaches of the Chandeleur Islands.

Penland et al. (1985) clearly demonstrates that the channels of the tidal inlet frequently cut over 8 m down into underlying deltaic deposits (Figure 3). Where they have developed, the upper part of the St. Bernard Deltaic Complex has been removed by erosion down to its delta front deposits, resulting in the complete destruction of any archeological deposits. Sedimentological models by Reinson (1984:125-129) and Levin (1990) indicate that archeological deposits may have been reduced to erosional lags at the base of the channel deposits filling the tidal inlets. If extensive lateral migration of these channels occurred, then archeological deposits contained by the underlying sediments within large areas of the St. Bernard Delta will have been obliterated.

Finally, significant erosion of deltaic deposits, particularly natural levee sediments, occurs at the landward-moving inner shoreline of the subaerial delta plain and Breton and Chandeleur Sounds. As the subaerial delta plain subsides beneath these sounds, their shorelines erode the upper 1 to 2 m of the delta plain and any archeological deposits that they contain. Wiseman et al. (1979) have documented the destruction of archeological deposits by the landward migration of these shorelines. In addition, Treadwell (1955) has described shell beaches formed by the erosion and redeposition of shell middens.

Previously Recorded Sites

No archeological sites in the vicinity of the Breton Island project area are recorded with the Louisiana Division of Archeology. Secondary sources (notably Garrison et al. [1989a] and Pearson et al. [1989]) do not discuss specific wreck locations. General distribution maps included in the study by Garrison et al. (1989a) show that wrecks have occurred in the general Breton Island/Breton Sound area, but details of specific incidents and their exact locations are not included.

The proprietary list of shipwrecks that resulted from that study, and which was made available for this study by the Mineral Management Service (MMS), gives latitude and longitude data for several thousand wrecks in the northern Gulf of Mexico. However, those positions, which are carried out to six decimal degrees, were generally based on much less precise fixes; the source is often an inexact statement with reference to a general region (Garrison et al. 1989a:II 10-11). Assigning such precise latitude and longitude coordinates based on imprecise documentary information was necessary in order to carry out the statistical manipulations used in the MMS study. However, the process removed any sense of the uncertainty actually present in the original citations. This assignment of precise locations makes the MMS data largely unusable for purposes other than the statistical manipulations for which they were intended.

Pearson et al. (1989) give no specific site locations, other than to report that there were four recorded shipwrecks in the overall Breton Sound and Breton Island area. No information was given about when or where these wrecks actually occurred.

The New Orleans District provided initial information regarding three shipwrecks in Breton Sound: the vessel *Fidget* and two unidentified vessels. The *Fidget* was a gas-screw vessel which foundered in Breton Sound on 7 October, 1923, with the loss of four lives. Until 1922, the annual *List of Merchant Vessels of the United States* reported the vessel as a tow boat. In 1923, the vessel was listed as a yacht, indicating a change in its use. The loss of the vessel is recorded in the 1924 listing (U.S. Department of Commerce 1922-1924). The wreck of the *Fidget* is reported to have been west of the project area (Stout personal communication 1992). Nothing is known concerning the other two reported incidents.

The current navigation chart for Chandeleur and Breton Sounds (National Ocean Service 1991) shows two exposed wrecks on the shore at Breton Island, and a submerged wreck lying in the shallows approximately 700 yards southeast of the island. Wreckage also is shown within the actual project area. This apparently recent wreckage was charted based on a report appearing in a 1971 "Notice to Mariners." Other wrecks charted in the general vicinity include an exposed wreck off of the southwest end of Grand Gosier Island, 1.7 nm northeast of the project area, and four submerged wrecks lying in Breton sound within 4 nm of Breton Island. The very number of wrecks recorded on the current-issue charts, is interesting, but available information does not shed light on the possible significance of any of the charted wrecks. An inquiry directed to the National Ocean Service's Automated Wreck and Obstruction Information System (AWOIS) ascertained that the agency had no information on obstructions in the project area.

CHAPTER III

REMOTE SENSING SURVEY

Previous Investigations

Four previous cultural resources studies are particularly pertinent to the current investigations with regard to submerged historical resources. These are three overview-studies conducted for the National Park Service, the Minerals Management Service, and the U.S. Army Corps of Engineers, New Orleans District, and an investigation of a reported eighteenth century artifact and ballast deposit located on the shore of the northern Chandeleur Islands, Louisiana. A fifth study (Pearson et al. 1986), is important as a discussion of the potential for prehistoric sites in offshore waters of the northern Gulf of Mexico. No previous investigations have been conducted specifically within the current project area.

In 1977, the Minerals Management Service commissioned Coastal Environments, Inc. (CEI) to investigate the probable distribution of cultural resources in the northern Gulf of Mexico (CEI 1977). As a result of this study, recommendations were made as to the creation of Cultural Resources Management Zone 1 (CRMZ1). This management zone was intended to encompass those areas identified as having high submerged cultural resource sensitivity.

In 1989, the Mineral Management Service commissioned a new study, which was intended in part to reevaluate the boundaries of CRMZ1 (Garrison et al. 1989a). The three stated purposes of this study, which was similar in scope to the CEI study, were: (1) to evaluate the boundaries of Cultural Resource Management Zone 1 for the Outer Continental Shelf, and make recommendations for changes, if indicated; (2) to determine the relationship between survey-line spacing and survey effectiveness; and, (3) to determine if current methods of remote sensing could produce results capable of reliably distinguishing between modern debris and potentially historically significant shipwreck sites. For current investigations, the report is most important for its modeling of possible wreck distribution in the northern Gulf of Mexico, and for its analysis of forces and circumstances expected to affect the distribution of historical shipwrecks in that area.

The model constructed by Garrison et al. (1989a) looked at several factors and assessed their probable impact on the distribution of shipwrecks, and on the prospects of such wrecks retaining integrity with regards to the National Register of Historic Places criteria of significance. In particular, the placement of historic shipping routes; historic ports, harbors, and waterways; and, natural hazards such as barrier islands, shoals, bars and reefs were examined. The study also reviewed the normal and extreme effects of currents, winds, and waves, and the historical paths of hurricanes and tropical storms. Finally, the authors examined sedimentation rates, and re-analyzed current and wave patterns, with an eye towards post-wreck site formation processes.

Several important inferences can be drawn from this study that may have direct bearing on the present project area. First, the wreck distribution patterns (Garrison et al. 1989a:II,85-98) show a high concentration of wrecks east and west of the Mississippi River Mouth, particularly during the period of French dominance during the first half of the eighteenth century. This suggests that such sites could be located at Breton Island, and in its environs. The same general area also shows a high incidence of wrecks in modern times. Second, once a wreck occurred, it would likely be subject to moderate to heavy wave forces (Garrison et al. 1989a:II,73-74). This would adversely affect those portions of a wreck site that were not buried.

A History of Waterborne Commerce and Transportation within the U.S. Army Corps of Engineers New Orleans District and an Inventory of Known Underwater Cultural Resources (Pearson et al. 1989) had much the same purpose as the MMS study, but that study was oriented specifically around the needs of the U.S. Army Corps of Engineers, New Orleans District, which commissioned the study. The report's historical background section outlined the history of waterborne traffic within the area now administered by the U.S. Army Corps of Engineers, New Orleans District. That discussion included a detailed account of the variety of watercraft known to have been used in the region during late prehistoric times and throughout the historical period. Discussion was framed with focus on property types that could be represented in the archeological record. A brief analysis of the current state of the data base, against which the potential significance of submerged cultural resources would have to be weighed, also was included.

This report discussed site potential in two different ways. First, CEI presented general distribution maps, which showed the possibility of sites occurring in different waterways within the district as a simple yes or no proposition for each of six broad temporal and cultural divisions: aboriginal craft, European craft to 1718, 1718-1812, 1812-1861, 1861-1865, and 1865-1936 (Pearson et al. 1989:280-285). The only significant conclusion that can be drawn from these maps with regard to the current project area is that sites from any period could be located there, although it is unlikely that any significant wrecks occurred during the Civil War.

Elsewhere in the report, a rating of low, moderate, or high probability for shipwrecks was assigned to various waterways discussed in the report for each of six general periods: to 1718, 1718-1812, 1812-1861, 1861-1865, 1865-1936, and post-1936. The generalized "offshore" area, which would include the current project area, is given a rating of moderate for each of these general periods (in this case, including the Civil War Period [Pearson et al. 1989:291]).

Instead of thinking in terms of "probability," perhaps a more useful way to interpret these data is as an assessment of the likely *density* of wreck sites in any given body of water. The meaning of "probability" in this context is rather vague. Thus, the "moderate," rating for offshore waters becomes one of moderate site density, or in other words, a "moderate probability" that a wreck from a given period might be encountered in a survey area of some (undefined) size.

The report also reviewed the natural and man-made post-depositional forces that could affect the integrity of submerged cultural resources. The natural forces listed were: erosion, sedimentation, subsidence, and channel migration (Pearson et al. 1989:263). The manmade forces listed emphasize potential effects of Army Corps of Engineers navigation projects, with particular emphasis on their effect on cultural resources located on inland waterways. These man-made forces are channel snagging, channel dredging, revetment construction, canal construction, and levee construction. Shell dredging and the potentially detrimental effects of undisciplined avocational wreck diving, were two other factors listed in this study (Pearson et al. 1989:263-171.

The authors note that erosion is probably most significant in the coastal zone. It is certainly important to some degree in the Breton Island project area. In its brief discussion of sedimentation, the report only notes that it may be important in hiding sites from discovery. This misses some important effects of sedimentation on the preservation of submerged cultural resources. For instance, Muckelroy (1978) shows that for 20 shipwreck sites investigated around the British Isles, the quantity of recent sediment, and the nature of the sedimentation, were the most important factors influencing the degree of preservation once the wreck reached the ocean floor.

Based on the report's assessment of possible past and future threats to submerged cultural resources, each waterway under the U.S. Army Corps of Engineers, New Orleans District, jurisdiction was rated for "sensitivity." Sensitivity was defined as a composite measure of current site integrity (based on natural conditions and the degree of past man-made disturbance within a waterway), and the potential for future man-made disturbances. The "offshore" region was rated as low or moderate sensitivity for sites dating from each of the six periods (Pearson et al. 1989:291). This rating was apparently based on the low degree of past U.S. Army Corps of Engineers disturbances offshore, and the low probability that sites will be disturbed by future Corps projects. However, for the purposes of the present study, any sites that lie within the Breton Island project area must be considered "highly sensitive" to future Corps activity, given the proposed shore nourishment project.

In 1988, partly as an outcome of the research conducted for the MMS study on magnetic anomalies and shipwreck distribution in the Northern Gulf of Mexico (Garrison et al. 1989a), a historical ballast pile was identified near the shore of one of the northern-most islands in the Chandeleur Island chain. The results of subsequent investigations of this site were detailed in a report titled *An Eighteenth-Century Ballast Pile Site, Chandeleur Islands, Louisiana* (Garrison et al. 1989b). This study was significant as a partial test of the distribution model developed for the MMS Study, and because the wreck lies in an environment analogous to that of the Breton Island project area. The site consisted of a concentration of ballast stone, several ceramic sherds, a lead patch, a cast lead tube (possibly from a pump), and six cannons. No evidence was found of actual hull material. Based on this, it was suggested that the site represents the location of the grounding of a French vessel during the last quarter of the eighteenth century. This pile, consisting of ballast, cannon, and other heavy objects, represents evidence of the crew's efforts to lighten the vessel enough to free her.

This site is important in that it is initial confirmation of the hypothesis that the area east and west of the Mississippi River would have seen many shipwrecks corresponding to the increased settlement of the region beginning at the turn of the seventeenth and eighteenth century. The site also is important because it demonstrates that a deposit can retain spatial integrity, even though it lies in an area exposed to waves and long shore currents, and because it demonstrates the potential for preservation of non-organic material (including several types of metal) in this environment. This same conclusion may also hold true for any wrecks that lie along the Breton Island shoreline, or in the surrounding shoal waters.

Another study conducted on behalf of the Mineral Management Service was reported by Pearson et al. (1986). It was intended to investigate the validity and usefulness of predictions presented in the CEI study in 1977 concerning the location of prehistoric archeological sites in association with certain inundated late pleistocene and holocene landforms. For this study, project personnel placed an extensive series of corings in the vicinity of the submerged Sabine River channel, on the Outer Continental Shelf, between Texas and Louisiana. One intriguing result of this study was the discovery of two apparent archeological sites adjacent to two pre-transgressional stream tributaries of the Sabine River, about 10 miles offshore of the present shoreline. These discoveries demonstrated the potential for apparently intact prehistoric cultural resources surviving subsequent marine transgression, in certain settings. This finding should be considered during the planning of any offshore cultural resource investigations in the northern Gulf of Mexico.

A final report to be mentioned, is the *Louisiana Submerged Cultural Resource Management Plan* prepared by Bruce Terrell (1991). This study was designed to formalize the Louisiana Division of Archeology's philosophy towards the preservation of submerged cultural resources, and to prioritize the preservation and study of such resources within state jurisdiction. The plan includes a brief historical overview of waterborne commerce in the state, and an overview of previous cultural resources studies in the state. This document, taken together with the MMS Study (Garrison et al. 1989a), and with the New Orleans District study (Pearson et al. 1989), represents an excellent general framework for use in planning further submerged cultural resource investigations, as well as for use in interpreting the results of such studies.

Remote Sensing and Data Interpretation

Numerous attempts have been made at characterizing the types of magnetic signatures made by shipwrecks. Clausen (1966) and Clausen and Arnold (1975:169) suggested through an examination of early sailing vessels in Florida and Texas that their signature consisted of "a central area of magnetic distortion characterized by a number of intense and generally localized anomalies surrounded and, depending upon the depth and dispersion of the wreck, in some instances, interspersed by scattered, smaller magnetic disturbances." Later work by Watts (1980) demonstrated that shipwreck sites can generate minimal signatures, producing broad-based, 20 gamma anomalies. A magnetic survey of known eighteenth century ferries in the Cape Fear River near Wilmington, North Carolina, produced no reliably detectable signature (Watts 1983).

Studies conducted on vessels dating after 1850 suggest that large ships of this period generate magnetic perturbations in excess of several hundred gammas. Work on iron or steel hulled ships of the Civil War period by Watts (1975), Cussler (1981) and Irion (1986) indicates that such vessels produce a signature which is bi-polar or multi-component in excess of a thousand gammas. Subsequent efforts directed at groundtruthing similar anomalies in Mobile Bay revealed that modern debris can generate virtually identical signatures (Irion and Bond 1984; Irion 1986). Archeological groundtruthing on the Tombigbee River (Saltus 1976; Murphy and Saltus 1981), the Elizabeth River, Virginia (Watts 1982), in Mobile Bay (Irion and Bond 1984; Irion 1986), and Matagorda Bay, Texas (Arnold 1982b), established that while there are characteristics that can be associated with various types of shipwreck sites, it is impossible to identify them on the basis of magnetic data alone. Watts (1986:14) observed that "the remains of vessels can be demonstrated to generate every type of signature and virtually any combination of duration and intensity."

A major study conducted by Garrison et al. (1989a:165) for the Mineral Management Service sought to model single and multiple component anomalies to allow for the development of an interpretive framework to help discriminate between the signature characteristics of modern debris and the remains of historic shipwrecks. Two offshore lease blocks which had been surveyed previously at a line spacing of 150 m were re-surveyed with a line spacing of 50 m. A three-dimensional contour map of the resulting anomalies was prepared, and the sources of the anomalous readings were sought by diver inspection. The objective of the procedure was to compile a sample inventory that would reflect a real population of shipwrecks or modern debris in the study area. The researchers concluded that the relationship of magnetic signatures and spatial distribution is at the core of determining patterns for shipwrecks and then discriminating these patterns from those of ferromagnetic debris (Garrison et al. 1989a:II-214). In essence, their conclusions agree with Arnold (1982b), who stated, "The patterning of anomalies on adjoining survey tracks (spaced 50 m apart) is the key to identifying significant anomalies and distinguishing them from those far more numerous anomalies caused by isolated iron debris, which often show up only on one track." Unfortunately, not all anomalies exhibiting the patterning of readings described by Arnold (1982b) necessarily relate to historic shipwrecks. Long strands of wire cable, for example, frequently have been observed to produce similar results.

Other researchers have attempted to construct models of anomaly patterning based on frequency. Mistovich and Knight (1983:154) defined a pattern for magnetic readings indicative of a shipwreck that had broken apart and scattered its cargo over a wide area as three or more anomalies within an area of 50,000 m^2. However, Mistovich based his model on data from the high energy Texas coast, and applied it to the more placid waters of Mobile Bay (Irion 1986). This distributional model is not ill suited for use in the Breton Sound area, which is subject to many of the same kinds of environmental forces (i.e. hurricanes) as the Texas coast. Clausen (1966) also reports that it is not unusual to encounter shipwrecks that cover as much as 100,000 m^2, although 50,000 m^2 is more common. Garrison's (1986) survey of the 19th century wreck *Will O' The Wisp* supports this model with an archeomagnetic record extending over approximately 55,000 m^2.

Although magnetic data are not always reliable in identifying historic shipwrecks, this is not the case with acoustic imaging. The processed sonogram record produced by state-of-the-art equipment such as the EG&G 260 can yield an image of almost photographic quality. The War of 1812 schooners, *Hamilton* and *Scourge*, lost in Lake Ontario, and the H.M.S. *Breadalbane*, lost in Resolute Bay in 1853, are classic examples of high structural integrity and photographic quality sonar images. Sonograms of the *Herbert Maxwell* and "Vessel No. 2" located in a survey off Kent Island, Maryland (Irion 1989) are of such quality as to lead to no doubt as to the identification of these targets as historic sailing ships. However, in cases where structural integrity is no longer preserved, or where sites are partially or totally buried in bottom sediments, identification can be extremely difficult, if not impossible.

Over the past 25 years, the combined use of magnetic and acoustic remote sensing equipment has proven to be the most efficacious means of identifying and assessing the potential for submerged cultural resources in American waters. Generally, however, the remote sensing survey only produces targets that still must be groundtruthed by an underwater archeologist to determine their significance.

Survey Methodology

The remote sensing survey of the Breton Sound Disposal area was designed to identify specific targets or clusters of targets that could represent shipwreck sites. As discussed in Chapter II, these sites are likely to have been broken up and dispersed by a variety of natural forces, resulting in a scattering of ferrous objects such as fasteners, anchors, cargo items, tools, etc., each of which would contribute some degree of magnetic perturbation to the surrounding field. Since the patterning and duration of these anomaly locations is important in the interpretation of the potential significance of targets, accurate positioning was critical to establishing the relationship of individual targets to one another. The discussion that follows details the justification for the selection of the particular equipment that was employed during the survey and critiques its performance.

<u>Positioning</u>

Positioning is a critical issue in cultural resource remote sensing surveys that has been applied with widely varying degrees of accuracy and success. Unlike terrestrial archeological surveyors, who can rely on topographic or physical features that can guide others to their discovery, the marine archeologist must produce a coordinate as the sole address of a relatively minuscule patch of featureless ocean. He must be able to return to that same small point, and, by inspecting the bottom with the aid of diving equipment, ascertain the cause of the magnetic disturbance. As a result, the system employed in guiding the survey must supply a coordinate that is not only accurate within the system employed for the survey, but that also must have a repeatable accuracy that will enable researchers to revisit that location years later.

Although electronic microwave surveying equipment has been available for many years, its great expense and complexity have tended to keep this equipment out of the hands of most archeologists, restricting its use to professional hydrographic surveyors. In the late 1970s, some marine archeologists sought alternatives to paying the high cost of a professional surveyor. Clausen and Arnold (1975) described a method applied to the magnetic survey of a shipwreck off the Texas coast using a combination of visual range markers to provide steering guidance and sighting with optical transits from two shore stations to provide a triangulated position. The application of this method is both labor intensive and limited in use to near-shore areas. Later surveys such as Watt's reconnaissance of Charleston Harbor (1986) have attempted to use Loran "C", a relatively low-cost receiving unit that processes synchronized land based radio transmissions to provide reasonably accurate position fixing.

Loran "C" depends upon a group of transmitters linked together in "chains" with each chain being identified by its Group Repetition Interval (GRI). The GRI identifies not only its particular chain but also indicates how often that particular chain repeats its signals. For example, a chain identified as 7980 will repeat its series of transmissions every 79,800 microseconds. Each chain is made up of a master transmitter and at least two secondary transmitters. The series of transmitted signals starts from the master station followed by signals from the secondary stations. The Loran receiver detects the signals from the master station and each of the secondary stations. To determine the position of the observer, the Loran "C" receiver measures the difference in arrival time between the master station signal and the two secondary stations. The difference in arrival time is measured in microseconds with reference to the master station signal. The receiver reads out two sets of six digits called Time Delays (TDs). Each TD represents the difference in arrival time between the master signal and one secondary signal. Two TDs are required to establish a position. In addition, most commercially-available lorans will process internally Latitude and Longitude solutions for each pair of LOPs. However, each pair of LOPs has two Latitude and Longitude mathematical solutions that can be anywhere from 6 to 60 nautical miles apart. When TDs are plotted on a chart, they form hyperbolic curved lines known as Lines of Position (LOPs). The angle at which the LOPs cross is a determining factor in the accuracy of Loran "C".

In discussing the accuracy of Loran "C" positioning, there are two types of accuracy to consider: absolute and repeatable. The design accuracy for this type of positioning is 0.1 to 0.25 nautical miles (608 ft to 1,520 ft). Thus any coordinate supplied by this equipment has an error of several hundred feet in reference to the "true" position. Another condition that may affect the absolute accuracy of Loran "C" is landpath delay, caused by a slowing of loran signals as they pass over land. In some areas, TDs can be thrown off by as much as 12,000 ft.

The repeatable accuracy of Loran "C", i.e. the ability to return to a specific location using Tds obtained there once before, generally is the most accurate mode of operation for any loran. Using the same loran unit, one can often return to within 50 ft of the Tds derived previously. Unfortunately, there is often considerable difference in the position solution from one loran receiver to another. In 1989, an attempt was made to relocate a number of targets derived from a magnetic survey of Charleston Harbor directed by Gordon Watts (1986) that utilized loran "C" positioning. Watts reported target coordinates in Latitude/Longitude, and the subsequent researchers employed a Loran "C" receiver in an attempt to duplicate his positioning solutions. In all cases, no magnetic anomaly was located within 500 ft of the reported position. The researchers concluded that it was impossible to re-acquire the specific targets recommended for testing with any degree of confidence (Beard 1989:4).

The present survey sought to utilize a positioning device that incorporates state-of-the-art technology with ease of use at a reasonable cost. A number of factors contributed to the selection of the positioning system, including the distance and geometry from survey bench marks, true accuracy, reliability, and ease of use. It became apparent that satellite positioning represented the system of choice. The use of this revolutionary system, known as the Global Positioning System (GPS), for survey control only has become feasible within the last year. GPS is based on satellite ranging from a baseline constellation of 24 satellites operating in 12-hour orbits at an altitude of 20,183 km (10,898 mi) (Denaro 1984). This satellite system, known by the acronym NAVSTAR, is maintained by the US Department of Defense.

Four satellites normally are required for navigation purposes, and the four offering the best geometry can be selected manually or automatically by receivers using ephemeral information transmitted by the satellites. The GPS system works by timing how long a radio signal takes to reach the receiver and then calculating the distance from that time, based on the fact that radio waves travel at the speed of light, 186,000 miles per second (Hurn 1986). The satellites' altitude eliminates the signal errors inherent in ground-based loran radio transmissions. In addition, since it was designed as a defense system, it is intended to be impervious to jamming and interference.

Using GPS alone, true position accuracies on the order of ten meters or less may be anticipated. However, the Dept. of Defense purposefully degrades the accuracy of GPS using an operational mode called "Selective Availability" or S/A. S/A is designed to deny hostile forces the tactical advantage of GPS positioning. When it is implemented, positioning accuracy drops to within 350 ft. S/A may be overcome through the use of a differential GPS system, which can achieve accuracies of better than one meter.

Differential GPS (DGPS) is based on placing a GPS receiver on the ground at a known location as a static reference point. A computerized processing system analyzes the incoming data to determine what errors the satellites' data contain, and broadcasts a correcting message to mobile field receivers. The Breton Sound Disposal Area survey successfully utilized DGPS to provide real-time positioning. In this case, the differential correction signals were received from a transmitting station on Grand Island, Louisiana, operated by Offshore Navigation, Inc. (ONI). The transmitted corrections were received and processed using ONI's Micronet terrestrial MF data link on board the survey vessel. Correction signals then were supplied to a professional model Magnavox MX-200 GPS receiver which displayed the differentially corrected position in Latitude and Longitude referencing the WGS-84 datum.

In addition to displaying the position, the Magnavox MX-200 transmitted the position information in NMEA 0183 code to a computer navigation system. The Breton Sound survey utilized a Macintosh Classic II with 4 MB RAM and a 40 MB hard-drive. The NMEA 0183 code was received from the GPS device through the modem port and processed using *Navigate!* software. The *Navigate!* program translates the NMEA message to display the vessel position on the screen relative to pre-plotted track lines, and it logs incoming positions in either binary or Text Only format. During post-mission analysis, the positioning text files were imported into a mapping program called *Azimuth* to produce post-plots of the survey lines. The resulting *Azimuth* files then were exported in a DXF format and transferred via *Apple File Exchange* to a DOS-formatted disk. The resulting files then were incorporated into the Microstation CAD files used to produce the illustrations in this report.

Coordinate Reporting. The coordinates of individual anomalies that have been supplied to the New Orleans District were derived originally from the GPS positioning system in Latitude and Longitude coordinates referencing the WGS-84 datum. Because of engineering requirements, however, the District requested that coordinates be supplied in Louisiana South State Plane coordinates referencing the North American Datum of 1929 (NAD29) and the Clarke 1866 local projection. This necessitated not only a datum shift from WGS-84 to NAD-27, but also a conversion from an ellipsoidal to a planar coordinate system. It is important to understand these distinctions since they can have an important effect on any subsequent work performed in the area involving the re-acquisition of specific targets.

The State Plane Coordinates System of 1927 (so called because it was based on the North American Datum of 1927), was devised by the US Coast and Geodetic Survey (C&GS) in the 1930s. Its purpose was to allow surveyors and engineers to compute accurate coordinates using plane trigonometry. Corrections to observed angles and distances are made to account for discrepancies between planar and ellipsoidal computations. Originally, tables of constants were computed by C&GS using common logarithms. Later, Claire (1973) provided algorithms and constants for machine computations of positions. These algorithms were designed to duplicate results obtained using the tables, and they were designed purposefully to be inaccurate to a slight degree to simulate the results that had been obtainable to hand calculation (Floyd 1985:5).

The State Plane Coordinate System of 1983 was necessitated by the 1983 adjustment of the North American Datum, a direct result of the accuracies that are afforded now by satellite positioning. For all practical purposes, NAD-83 and the global standard WGS-84 are identical and represent a vast improvement in accuracy over the old 1927 survey. In Breton Sound, a difference of approximately 0.8 minute Latitude and 0.16 minute Longitude was observed between the two spheroids.

The transformation from the 1927 coordinate system to that utilizing the 1983 datum is far from complete. Since most existing mapping utilizes the 1927 datum, coordinates continue to be supplied in that form. Two separate DOS-based computer programs were used in the present study to convert the recorded coordinates: *NADCOM*, supplied by C&GS, converts Latitude/Longitude coordinates from NAD83 to NAD27; *Plane*, acquired from the US Park Service, converts Latitude/Longitude to State Plane. Selected coordinates were converted by ONI using a proprietary VAX program to verify the accuracy of our conversions, which were found to produce an identical coordinate.

On Re-acquiring Magnetic Targets Derived from the Survey. In the Scope of Services supplied by the New Orleans District to R. Christopher Goodwin & Associates, Inc., control points were required every 100 ft along track lines spaced 150 ft apart. In order to comply with this directive, positioning data were acquired and logged every 10 to 15 seconds. The positions supplied to the district represent the point along any given track line at which an anomalous reading was recorded. These positions do not necessarily represent the focus of that disturbance that could be some distance to either side of the track line. In some instances where anomalous readings were detected nearby on an adjacent track line, the focus of the disturbance may be assumed to lie somewhere in between. Four such anomalies were subjected to close interval re-survey to determine if they could be distinguished as separate entities or two different expressions of the same general field. The results of this experiment are summarized at the end of this chapter.

Magnetometer

A Geometrics G866 proton precession marine magnetometer was selected for use during the Breton Sound survey. The G866 offers high precision measurement of the magnetic field within 0.1 gamma resolution. This unit has a built-in dual trace recorder which produces a permanent record annotated with exact readings in gammas, time scale, and date factors. The magnetometer is synchronized to the positioning system by means of its internal clock. The G866 is widely used in offshore hazards surveys and has been the instrument of choice for most professionally performed cultural resource surveys for nearly ten years.

Magnetic data was acquired at one-second intervals along track lines spaced 150 ft apart. Over 40,000 readings were recorded along 37 track lines oriented north to south. Each track line was 2.5 statute miles (13,200 ft) long (Figure 6).

Contouring of Magnetic Data

By contouring magnetic data (wherein the magnetic reading supplies the Z value), a complicated statistical table describing the distribution, shape and extent of localized magnetic perturbations may be reduced to a more readily grasped graphic form. The area of distributional studies holds great promise:

> Our visual pattern recognition capability can be exploited to help deal with spatial temporal relationships. Graphics can be used to describe dynamic problems that are difficult to describe by conventional methods. We have an innate visual ability to scan and organize information as clusters and patterns, which can overcome some of the problems associated with the description of complex systems (Csuri 1977:53).

Computer graphics have been applied to underwater archeology for nearly as long as geophysical survey techniques have been used to search for historic shipwreck sites. Arnold (1975, 1976) reported on a large magnetic survey with automated data acquisition and processing that relied heavily on computer drawn contour and three-dimensional plots to display the data. Contoured magnetic data can provide clues to the location of subsurface features in the manner that subtle changes in land topography have spoken to terrestrial archeologists of the secrets hidden below (Arnold 1982a). Golden Software's *Surfer* program was utilized to contour both magnetic and bathymetric data.

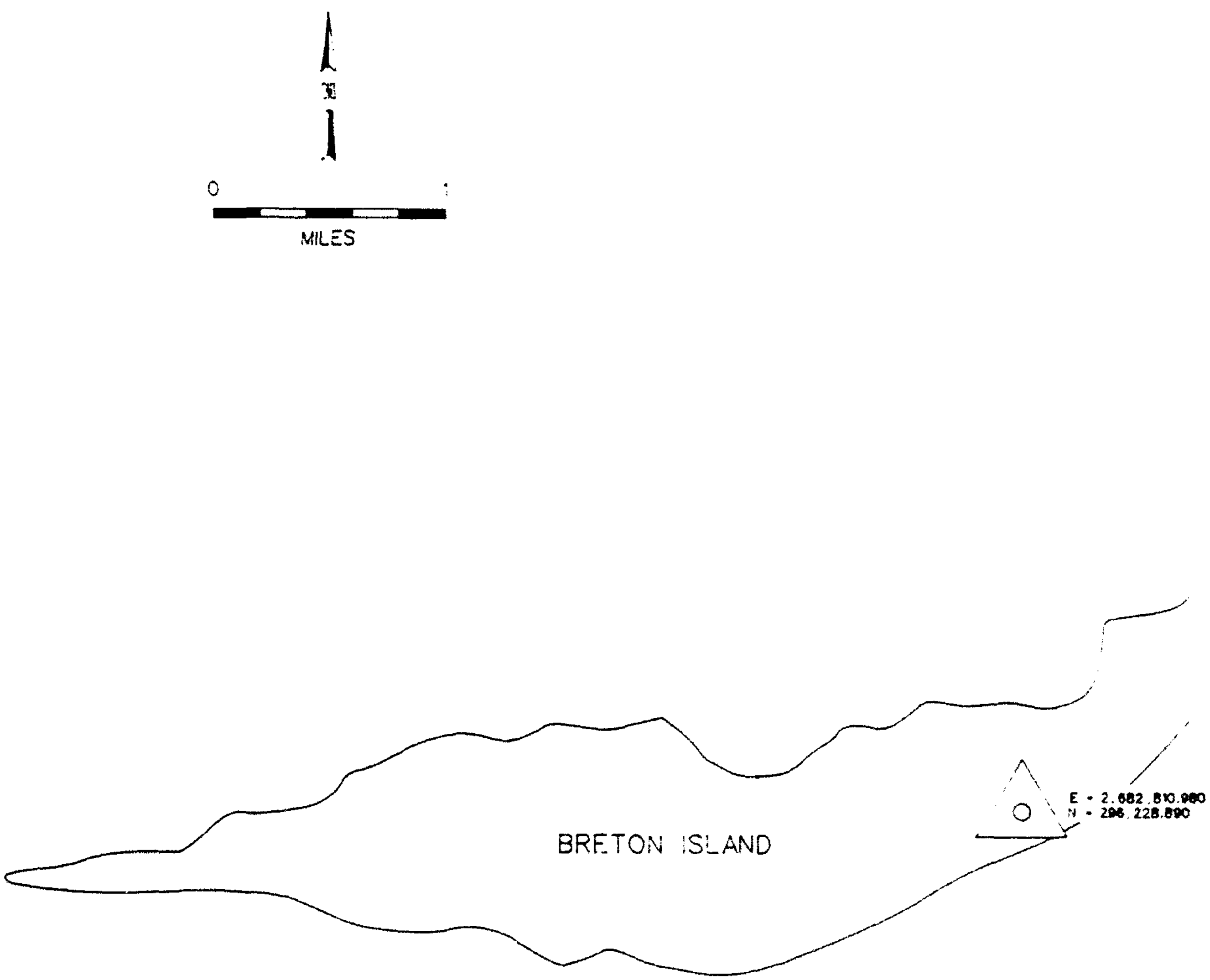
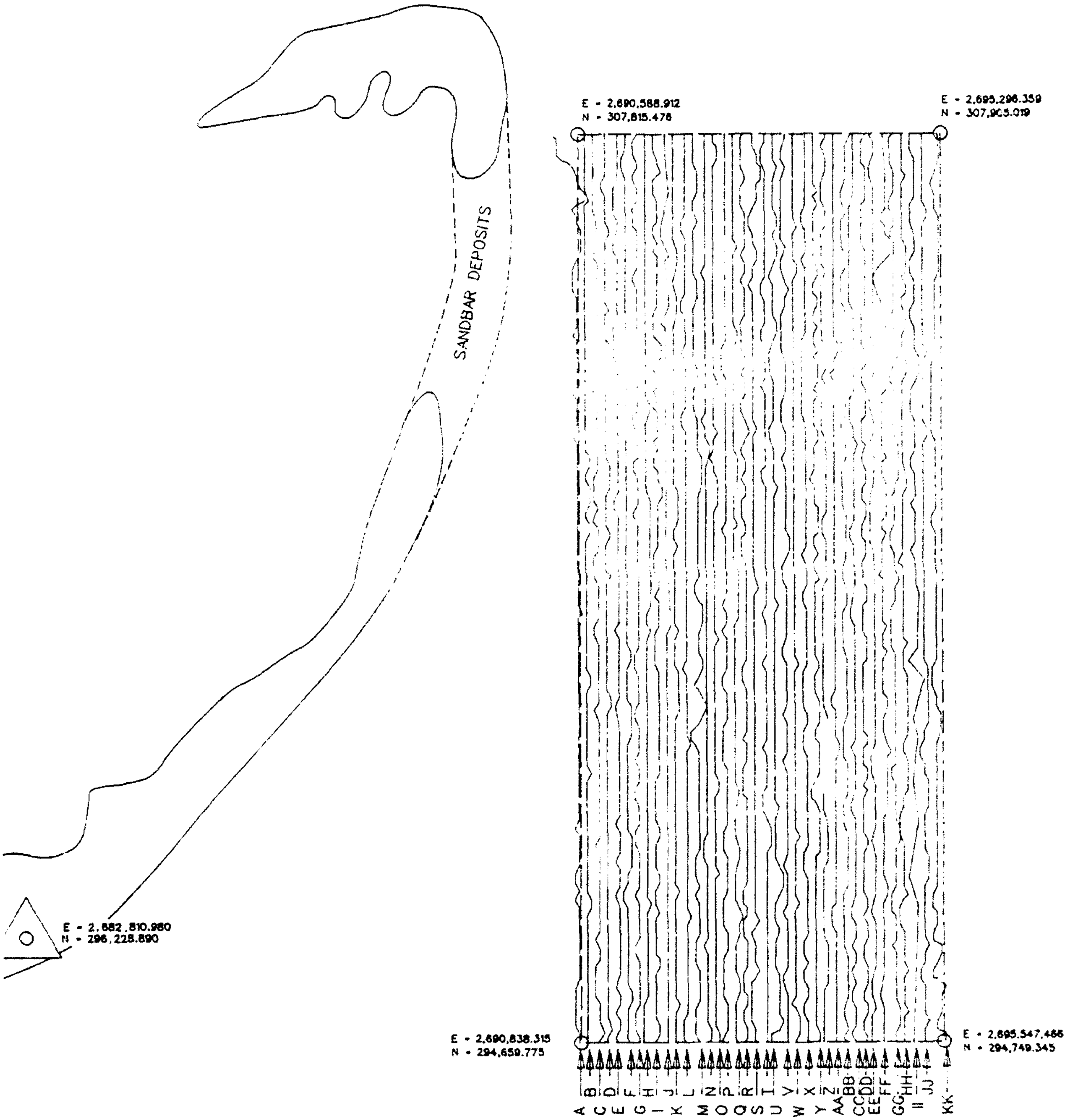


Figure 6. Map of project area showing survey tracks.

(2)


SANDBAR DEPOSITS
E - 2,690,588.912
N - 307,815.478
E - 2,695,296.359
N - 307,905.019
E - 2,682,810.980
N - 296,228.890
E - 2,690,838.315
N - 294,659.775
E - 2,695,547.466
N - 294,749.345

Side-Scan Sonar

An EG&G Model 260 seafloor mapping system was utilized during this project. The EG&G 260 is a versatile side-scan sonar that has the ability to be tuned to a variety of conditions and survey requirements. It may be operated at either 100 or 500 Khz. During the present survey, it was found that the 500Khz setting produced the best resolution. The Scope of Services required that acoustic data be acquired at 600-ft intervals, as opposed to the 150-ft intervals required for the magnetic survey. This demanded that the sonar be operated on its maximum range setting of 100 meters. However, for the sonar to function optimally at this range, the sensor should be towed no less than 60 ft above the bottom (distance to bottom should equal 20 per cent of the range setting). Since water depths in the project area ranged from 8 to 32 ft, a range setting of 25 meters would have been preferable for obtaining records of the highest possible resolution. However, this would have added considerably to the cost of the survey, and the nearly total absence of any distinguishable bottom features would not have justified the additional expense. Only one sonar target was distinguished during the survey.

Bathymetry

An Odom DF3200 Echotrac Echosounder with 200/24 Khz transducer was used for acquiring fathometer data. The Echotrac is a precision survey echo sounder with an accuracy of 0.1% of total depth. The instrument produces a permanent chart of recorded depths on thermal paper. Bathymetry was collected simultaneously with acoustic and magnetic data along track lines spaced 150 ft apart. Depths in the project area ranged from 8 to 32 ft, with the shallowest depths having been recorded in the western side of the project area near Breton Island and the deepest in the north east corner of the project area near the Mississippi River-Gulf Outlet (MRGO) channel (Figure 7). No bathymetric anomalies were recorded in association with any of the magnetic targets.

Survey Vessel

The 42-ft Hatteras yacht *Fiesta*, with Mr. Mike McRaney as captain, was chartered for the project to act as both survey vessel and crew quarters. The fiberglass-hulled *Fiesta*, built in 1967, was found to have ample room for deploying the remote sensing equipment; it provided a seaworthy platform from which to conduct the survey. The presence of a main deck steering station (most modern fishing yachts are steered from a flying bridge) greatly facilitated the communication of navigation guidance information.

Critique of Methods Employed in the Survey

The methods employed in the survey produced favorable results. The positioning system from ONI, which previously had not been utilized for this type of close interval survey within the New Orleans District, exceeded the researchers expectations for accuracy and reliability. Prior to the initiation of fieldwork, it was expected that two hours daily would be lost due to a lack of continuous satellite coverage. Fortunately, the Department of Defense enabled two additional satellites a few days before the project began. The addition of these two satellites filled the dead time, and enabled the project to continue uninterrupted during the daylight hours.

Over 40,000 magnetic readings were acquired as a result of this survey. Both magnetic and depth data were recorded solely on paper charts. It is recommended in the future that both data sets also be recorded on magnetic media to facilitate post-mission processing. This could be done easily by transferring the data via a standard RS-232 port to a portable PC using communication software. By editing the initialization string preceding the data string using a word processor and then reading the resulting text file

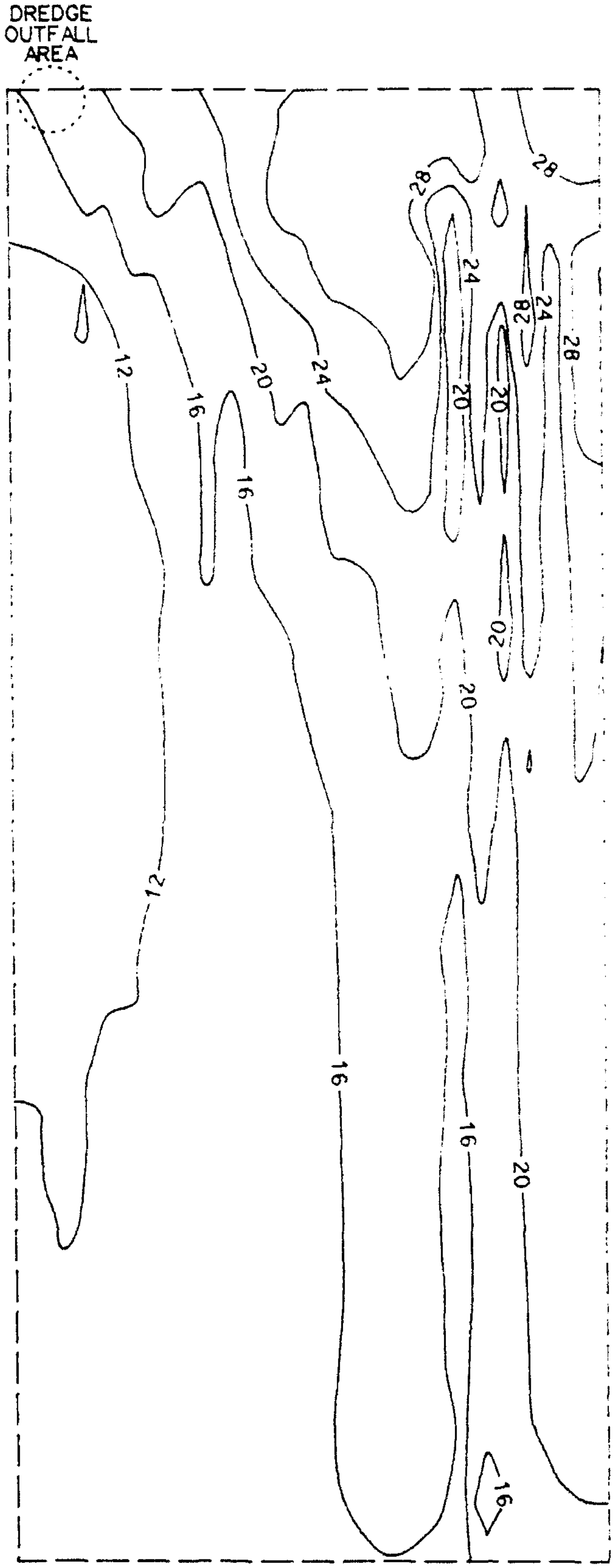


Figure 7. Bathymetric contour map of the Breton Sound Disposal Area.

into a spreadsheet, the data would be in a format that could be combined with the positioning data, and machine-contoured with a mapping program such as *Surfer*. In this way, large data sets could be processed much more efficiently, and subtle anomaly patterns could be distinguished that might otherwise be lost.

Caution should be exercised in contouring large data sets of magnetic readings collected over the period of several days to avoid the appearance of falsely anomalous areas resulting from diurnal changes in the magnetic field, solar activity, or other natural phenomena. This can be avoided in one of two ways. First, a base station magnetometer such as a Geometrics G856 can be established at a stationary point on land to collect continuous readings that can be used as a filter for the data collected on the mobile unit. In the past, this has proven to be simpler in theory than in practice. The base station is susceptible to a number of problems ranging from theft, to dead batteries, to effects from passing cars or ships that render its data less than 100 per cent reliable. An alternate method that has been employed successfully on large hydrographic surveys involves averaging the data collected on the mobile mag. By changing every point to an average of the ten readings preceding and the ten readings following it, it is possible to smooth the data and minimize the effects of solar flares and diurnal shifts. This method tends to mask anomalies of short duration (point sources), but these generally are not regarded to be indicative of potential shipwrecks; therefore, the importance of such location is questionable.

In addition to collecting magnetic and bathymetric data on magnetic disk, it also is recommended that the interval for collection of acoustic data be reduced in shallow water. Ideally, acoustic data should have been collected at the same interval as the magnetic and bathymetric data with a range setting of 25 to 50 m to produce optimal resolution. As a rule of thumb the sonar sensor must be towed above the bottom at a distance of no more than 20 per cent of the range setting. For example, with a range setting of 25 m (82 ft), the sensor should be towed 5 m (16 ft) from the bottom.

Survey Results

A total of 78 magnetic anomalies were located as a result of the survey of the Breton Sound Disposal Area. The results of this survey are presented in Table 1 and graphically in Figure 8. Interestingly, 58 per cent of the recorded anomalies clustered in the northwestern quadrant of the project area, with the largest grouping falling in the shallows near the island at the extreme northwestern corner. Other major clusterings of anomalies recorded during the survey trended along the western edge. In general, the frequency of targets dropped dramatically as one moved farther away from the island and into deeper water. The hydrology for this area suggests that prevailing currents would tend to deposit material on the north end of Breton Island; the results of the present survey seem to confirm this hypothesis. This leads one to suspect that the high density of anomalies concentrated near the island results from drift deposition and that the trend would continue to be repeated outside the project area approaching the island's shore. These results also suggest that winds and currents could carry a derelict or capsized vessel from some distance offshore into the project area until it grounded in shallow water. Significantly, the majority of anomalies are located in less than 12 ft of water. Analysis of the acoustic record indicates that only one anomaly cluster, T-111/U-16 produced a sonagram signature. This target appears to be vessel-shaped, measuring approximately 50 ft long (Figure 9). The strong magnetic perturbation (1,476 gammas) certainly suggests a vessel with an iron or steel hull, or at least with a large ferrous mass such as an engine. Neither of these possibilities, of course, necessarily precludes the possibility that the target is a vessel of historic origin.

Cluster Analysis

As discussed above, most researchers (Clausen 1966, Arnold 1982b, Mistovich and Knight 1983, Garrison 1986) have concluded that the most useful means of distinguishing the magnetic signatures of

Table 1. Magnetic and Acoustic Anomalies, Breton Sound Disposal Area.

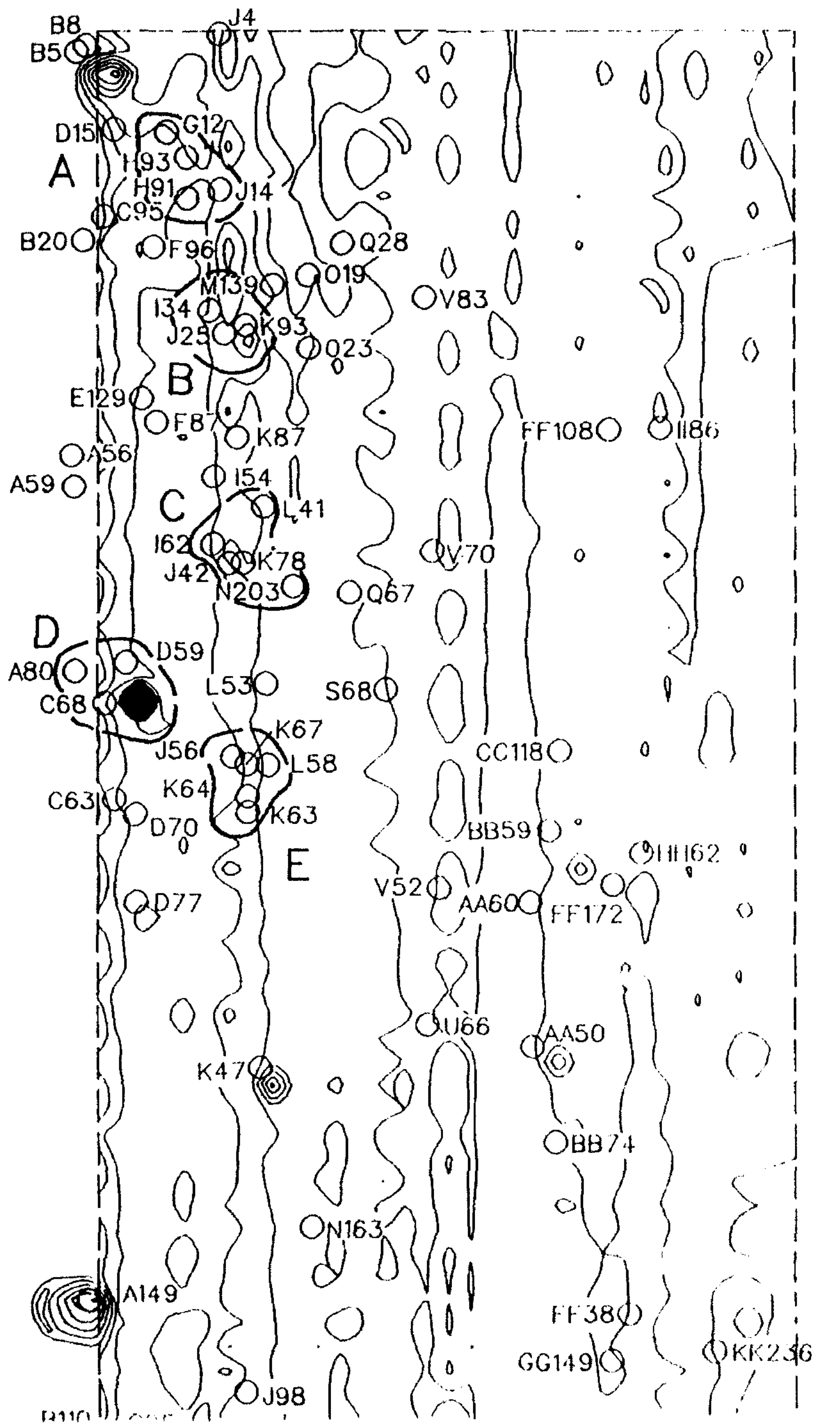
TRACK/SHOT POINT	GAMMAS	DURATION (SECS.)	TYPE
A-56	30	9	bi-polar
A-59	24	15	negative
A-80	18	9	positive
A-149	163	30	bi-polar
A-183	11	20	multicomponent
B-5	267	20	bi-polar
B-8	110	25	bi-polar
B-20	23	7	negative
B-110	91	20	negative
B-124	10	6	positive
C-25	591	15	bi-polar
C-63	34	7	bi-polar
C-68	568	30	bi-polar
C-95	44	13	negative
D-15	660	20	bi-polar
D-59	20	5	positive
D-70	12	10	multicomponent
D-77	20	15	multicomponent
E-1	76	20	positive
E-17	15	35	multicomponent
E-129	71	11	bi-polar
F 37	10	7	bi-polar
F-96	31	16	positive
G-12	61	30	bi-polar
G-123	15	6	bi-polar
H-13	10	6	negative
H-91	20	9	negative
H-93	27	13	negative

Table 1, continued

TRACK/SHOT POINT	GAMMAS	DURATION (SECS.)	TYPE
I-34	13	11	positive
I-54	14	7	positive
I-62	34	20	positive
J-4	16	6	positive
J-14	7	30	multicomponent
J-25	9	11	negative
J-42	14	10	positive
J-56	16	6	bi-polar
J-96	23	6	bi-polar
J-121	11	15	multicomponent
J-117	13	1	positive
K-47	90	8	positive
K-63	13	3	bi-polar
K-64	17	3	bi-polar
K-67	12	7	multicomponent
K-78	13	7	bi-polar
K-87	18	20	multicomponent
K-93	9	15	multicomponent
L-41	16	7	multicomponent
L-53	11	10	multicomponent
L-58	15	3	bi-polar
M-139	11	7	bi-polar
N-163	14	30	multicomponent
N-203	13	5	bi-polar
O-19	15	3	positive
O-23	41	9	negative
Q-28	57	8	positive

Table 1, continued

TRACK/SHOT POINT	GAMMAS	DURATION (SECS.)	TYPE
Q-67	43	9	bi-polar
S-11	20	11	bi-polar
S-68	41	15	positive
T-111	1,476	100	multicomponent
U-16	436	33	bi-polar
U-66	17	5	negative
V-52	16	5	bi-polar
V-70	16	5	bi-polar
V-83	10	30	multicomponent
AA-50	83	10	bi-polar
AA-60	12	6	bi-polar
BB-59	56	9	positive
BB-74	8	3	negative
CC-118	85	27	multicomponent
FF-38	18	4	bi-polar
FF-72	133	25	negative
FF-108	22	20	multicomponent
GG-149	10	6	positive
HH-22	9	4	negative
HH-62	25	6	bi-polar
HH-102	16	6	negative
II-86	20	12	negative


A
B
C
D
E
B8
B5
J4
D15
G12
H93
H91
J14
C95
B20
F96
Q28
O19
M139
I34
K93
J25
V83
O23
E129
F87
K87
FF108
II86
A56
A59
I54
L41
I62
K78
J42
V70
N203
Q67
D59
A80
L53
S68
C68
K67
J56
L58
CC118
K64
C63
K63
D70
BB59
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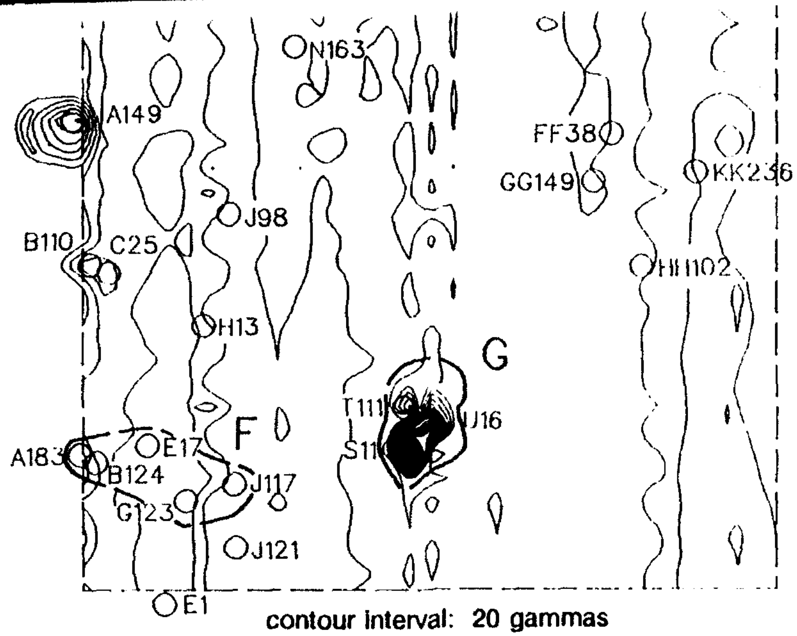
FF38
GG149
KK236
J98



contour interval: 20 gammas

A: HIGH POTENTIAL. PHASE II TESTING RECOMMENDED.

B: NO FURTHER WORK RECOMMENDED.

C: MODERATE POTENTIAL. PHASE II TESTING RECOMMENDED.

D: MODERATE POTENTIAL. NEAR REPORTED WRECK OF *FIDGET*. PHASE II TESTING RECOMMENDED.

E: NO FURTHER WORK RECOMMENDED.

F: HIGH POTENTIAL. PHASE II TESTING RECOMMENDED.

G: HIGH POTENTIAL. PROBABLY MODERN (FIRST REPORTED IN 1971). GROUNDTRUTHING RECOMMENDED

Figure 8. Magnetic contour map of the Breton Sound Disposal Area.

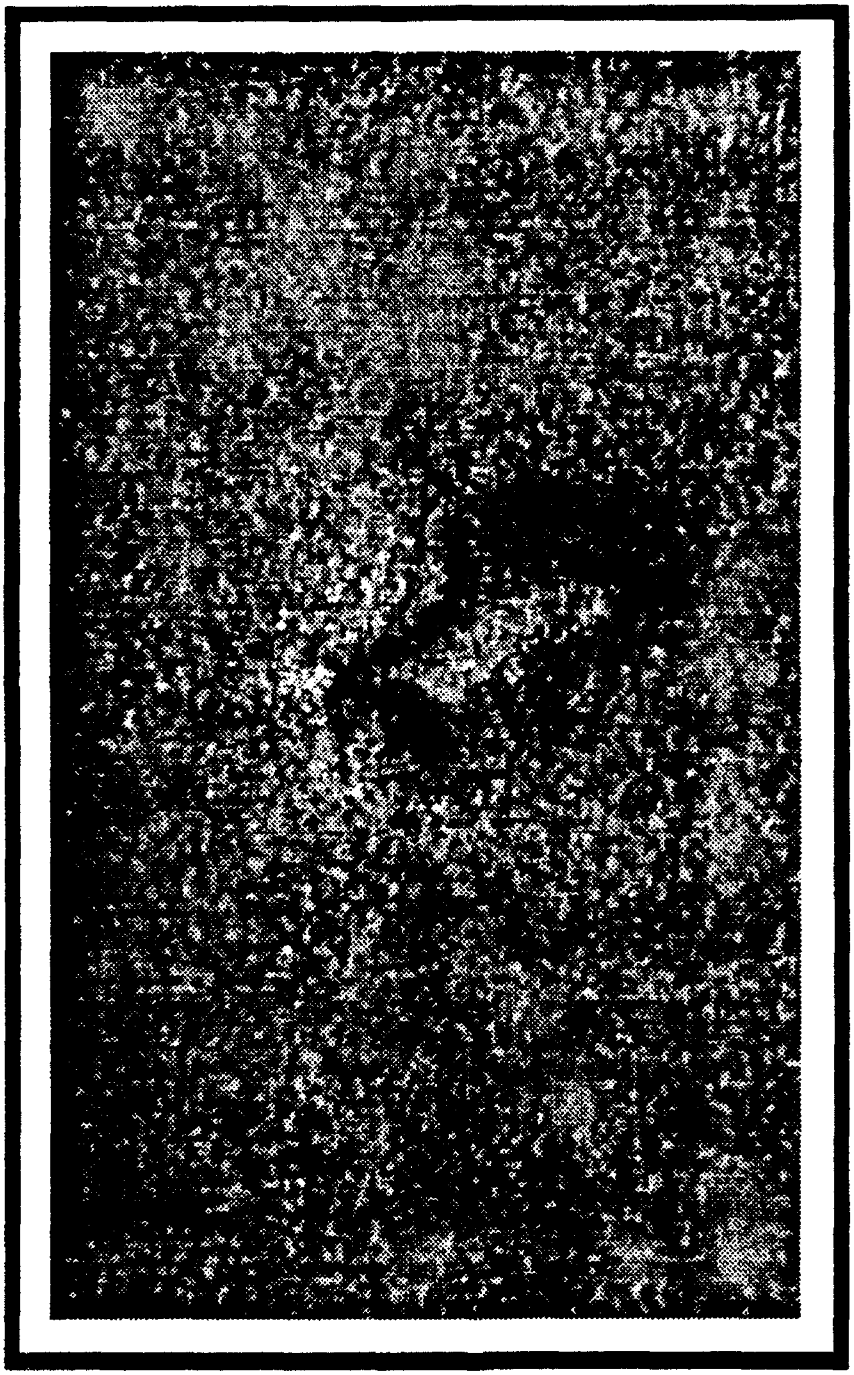


Figure 9. Sonagram of anomaly cluster T-111/U-16.

potentially significant historic sites from modern debris is based on a combination of the duration of signatures and the clustering of three or more anomalies in a 50,000 m^2 area that has been surveyed at 50 m intervals. This model was developed for the Texas and Florida Gulf coast and can be applied to waters off Breton Island, where many of the same environmental conditions exist.

By applying this model to the Breton Sound project area, seven clusters of anomalies may be distinguished. The following discussion identifies the observed clusters and analyzes their potential significance.

Cluster A. Cluster A contains four anomalies, G-12, H-91, H-93, and J-14. Anomaly G-12 is a moderately strong perturbation of 61 gammas with a long duration of 30 seconds, while anomaly J-14 is a low amplitude multi-component anomaly of equally long duration. Both anomaly H-91 and H-93 are moderate magnetic moments of low amplitude. The long duration of two of the anomalies in this cluster, and the fact that one exhibits a multi-component signature that is generally indicative of a clustering of 9 smaller objects, strongly suggests the possibility of an historic shipwreck. Similar moderate to low amplitude anomalies (10 to 100 gammas) have been recorded over very early historic shipwreck sites such as the 1554 wreck of the *San Esteban* in Texas (Figure 10). The cluster lies in about 10 ft of water.

Cluster B. Cluster B is composed of three anomalies: I-34, J-25, and K-93. All of the contributing anomalies are of low amplitude with brief magnetic moments. This type of signature is compatible with that observed for lengths of steel cable. The cluster lies in about 10 ft of water.

Cluster C. Five anomalies comprise Cluster C: I-62, J-42, K-78, L-41, and N-203. Anomaly I-62 exhibited a moderately long duration of 20 seconds (about 130 ft). Other associated anomalies display a low magnetic perturbation and brief signature duration. It is conceivable that this type of signature could be produced by a small wooden-hulled sailing vessel such as a fishing smack. The historical framework developed for this area suggests that such small, undocumented vessels are more likely to have wrecked in these waters than are larger coasters. The cluster lies in about 10 ft of water.

Cluster D. Three anomalies form Cluster D: A-80, C-68, and D-59. Anomaly C-68 produced one of the largest anomalous readings of the survey (568 gammas). Its associated anomalies were comparatively weak, showing 18 and 20 gammas respectively for durations of less than 10 seconds. The position of this cluster is extremely close to that reported for the loss of the *Fidget*, which grounded on Breton Island in 1923. The cluster lies in about 10 ft of water.

Cluster E. Cluster E is comprised of five small anomalies: J-56, K-63, K-64, K-67, and L-58. None of these anomalies are significant perturbations of the surrounding field, exhibiting low amplitude and brief durations. It is surmised that this cluster is composed of a scattering of small isolated objects. The cluster lies in about 10 ft of water.

Cluster F. Cluster F is composed of five magnetic anomalies: A-183, B-124, E-17, G-123, and J-117. Both E-17 and A-183 exhibit multi-component signatures of moderately long duration (between 130 and 230 ft) with low magnetic amplitudes between 11 and 15 gammas. It is conceivable that this signature could be produced by a wooden-hulled vessel lacking massive ferrous components. The target lies in about 15 ft of water.

Cluster G. Three magnetic anomalies (S-11, T-111, and U-16) and an acoustic target characterize Cluster G. Anomaly T-111 exhibited an extremely long duration of 100 seconds in a complex multi-component signature with a peak-to-peak amplitude of 1,476 gammas. The sonogram of this area exhibited a complex object or objects protruding several feet above the bottom. The amplitude of the anomaly makes it unlikely that it was produced by an historic wooden vessel, unless it was carrying iron ballast as did British ships during the last three quarters of the eighteenth century (Peterson 1973:128). It is equally unlikely that

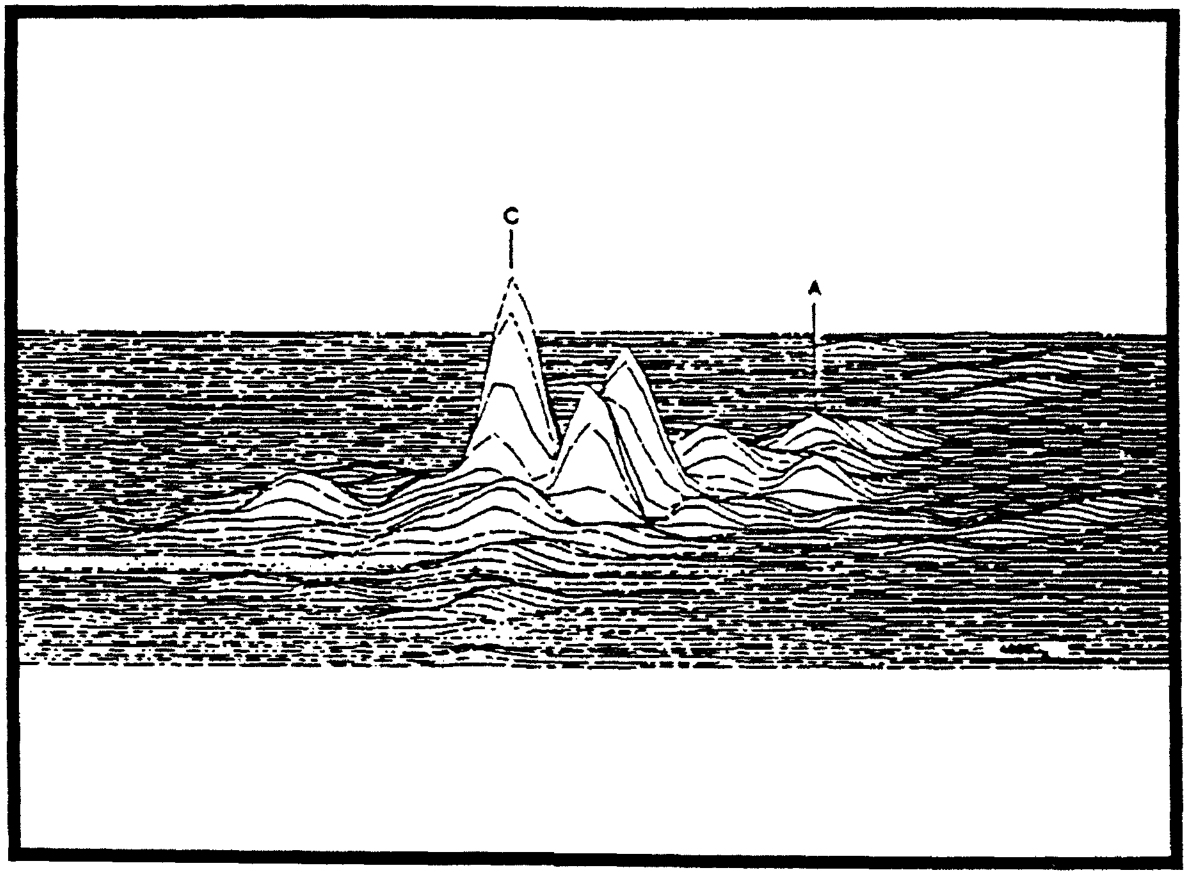


Figure 10. Three-dimensional contour plot of the 1554 wreck of the *San Esteban* (after Clausen and Arnold 1975).

a wooden structure would survive for long under the conditions present in Breton Sound. It is possible that the target is a steel or iron hulled vessel, giving it a possible date range from about 1840 to the present (Paasch 1890:1). The sonogram, however, indicates a relatively small structure with an overall measurement of about 50 ft. A number of possible interpretations exist, the most likely being that the target is a small fishing trawler. A number of such wrecks were observed with their superstructures protruding above the surface of the water in the surrounding area. The target lies in about 18 ft of water.

Re-contouring of Selected Anomalies

Six anomalies were selected for close interval survey for purposes of obtaining a higher resolution contour plot than would be possible using 150-ft lane spacing. Four of these anomalies initially appeared to be components of two clusters; two were isolated targets without corresponding signatures on adjacent lanes. The clustered anomalies were selected in order to determine if they could be distinguished as separate entities or if they were merely different expressions of the same field. The anomalies were selected on the basis of an initial analysis of the data in the field for duration, strength, and signal characteristics. The selected anomalies were B-5, B-8, C-95, D-15, T111, and U-16. It should be noted that the selection of anomalies for re-survey was performed in the field without benefit of many of the tools necessary for analysis of a complex data set.

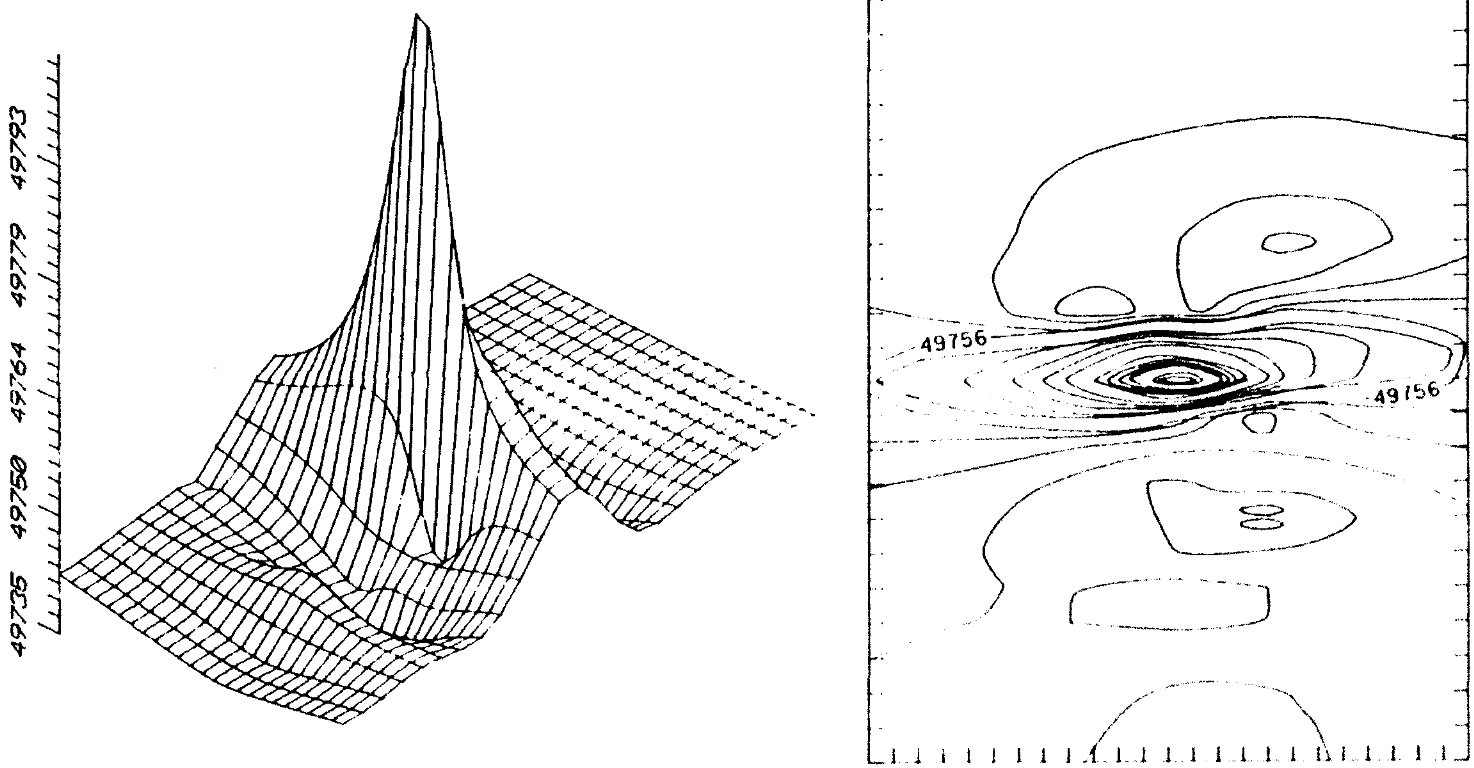
B-5 and B-8. (Figure 11) Both the isometric and contour plots of anomaly pair B-5 and B-8 seem to indicate the presence of a single large object with a nearly vertical orientation and a mass of approximately 500 pounds. A clustering of debris surrounds it. This type of signature has been observed in the past associated with core borings performed for the oil and gas industry (Irion 1989).

C-95. (Figure 12) The re-contouring of anomaly C-95 revealed the structure of a classic dipole anomaly whose moment is not parallel to the inducing field (Breiner 1973:40). The initial survey of the track produced a negative anomaly of 44 gammas. Detailed contouring suggests a localized source near the surface with a mass of approximately 500 pounds.

D-15. (Figure 13) Both the isometric and contour plots of anomaly D-15 show an elongated negative anomaly produced by a single source, probably a length of cable.

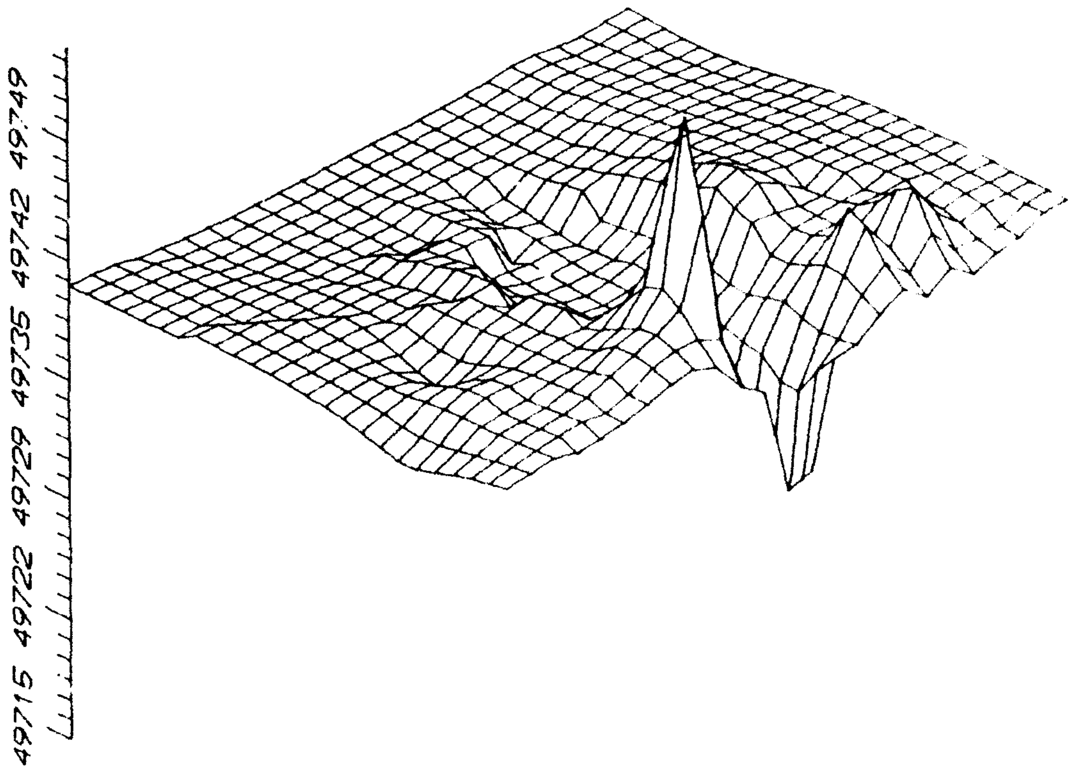
T-111 and U-16. This cluster of anomalies was the only one that produced a side-scan image and created, by far, the largest magnetic perturbation of any of the anomalies recorded during the survey. During the initial survey, a multi-component anomaly with a maximum perturbation of 367 gammas and a duration of 85 seconds was recorded on track T, centered at shot point 111. An even stronger disturbance, expressed as a bi-polar anomaly registering 430 gammas with a duration of 56 seconds, was recorded on the adjacent track U at shot point 16. A re-survey of the area at a tighter lane spacing produced a magnetic reading of 1,476 gammas. The contour plot of this anomaly (Figure 14), shows one principal magnetic peak. The close-interval survey demonstrates that anomalies T-111 and U-16 were produced by the same massive ferrous structure. Interestingly, the contour plot mirrors the general configuration of the sonogram image, with a main core, a hard line protruding to the north and a secondary structure to the east.

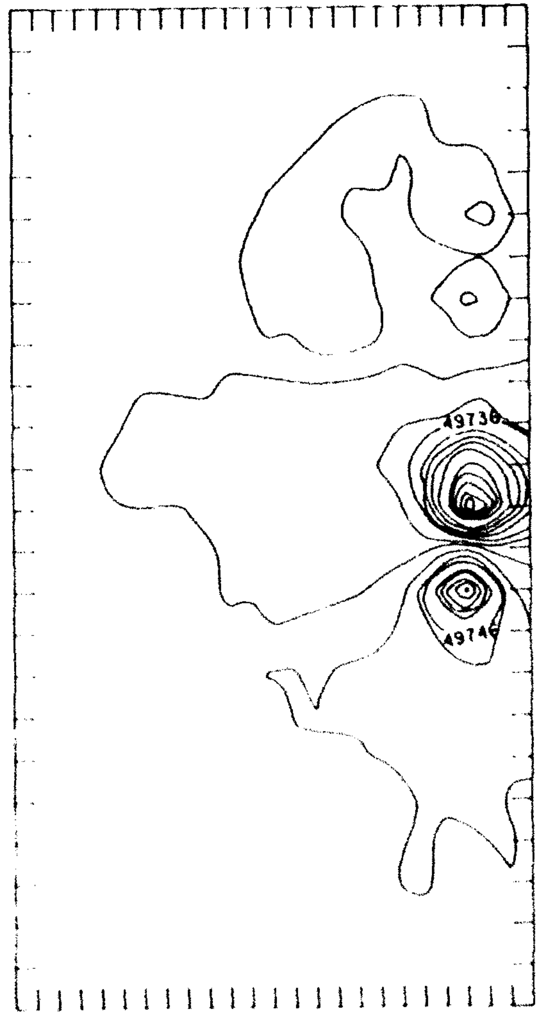
Based on an analysis of the contour plots resulting from the close interval survey, it was possible to eliminate four of the six anomalies surveyed from further consideration as potentially significant sites. Therefore, the efficacy of this procedure is beyond question. However, two of the anomalies would have been eliminated from consideration during the course of post-mission analysis as isolated targets. In fact, only Anomalies T-111 and U-16 (Cluster G) of the five clusters subsequently identified as potentially significant were able to be distinguished as such in the field without the benefit of comparative analysis. It has been stated before that duration and spatial extent are the principal factors to be considered in discriminating between a possibly significant shipwreck site and modern debris. Without benefit of extensive



contour interval: 20 gammas

Figure 11. Isometric and contour plots of Anomalies B-5 and B-8.





contour interval: 2 gammas

Figure 12. Isometric and contour plots of Anomaly C-95.

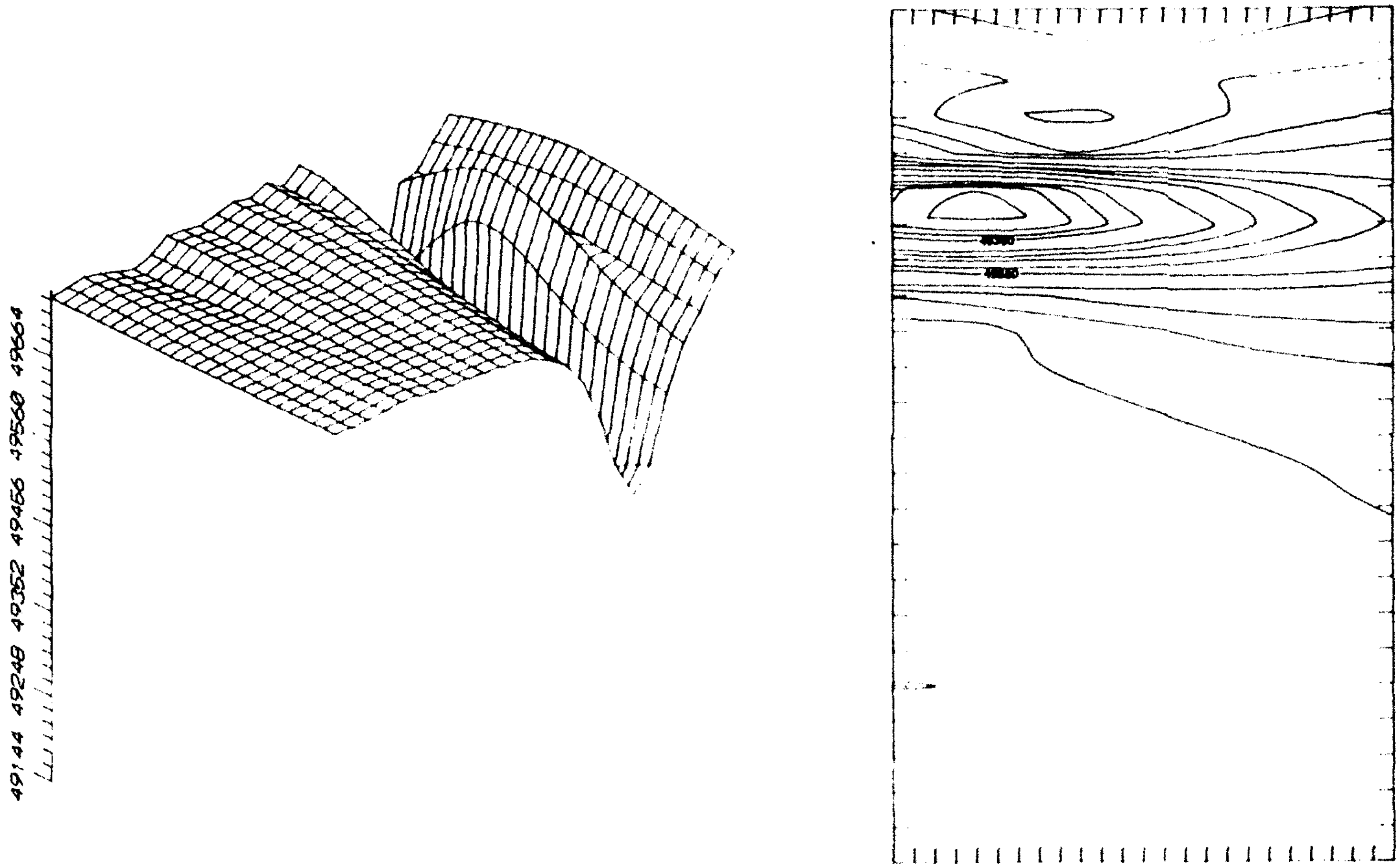


Figure 13. *Isometric and contour plots of Anomaly D-15.*

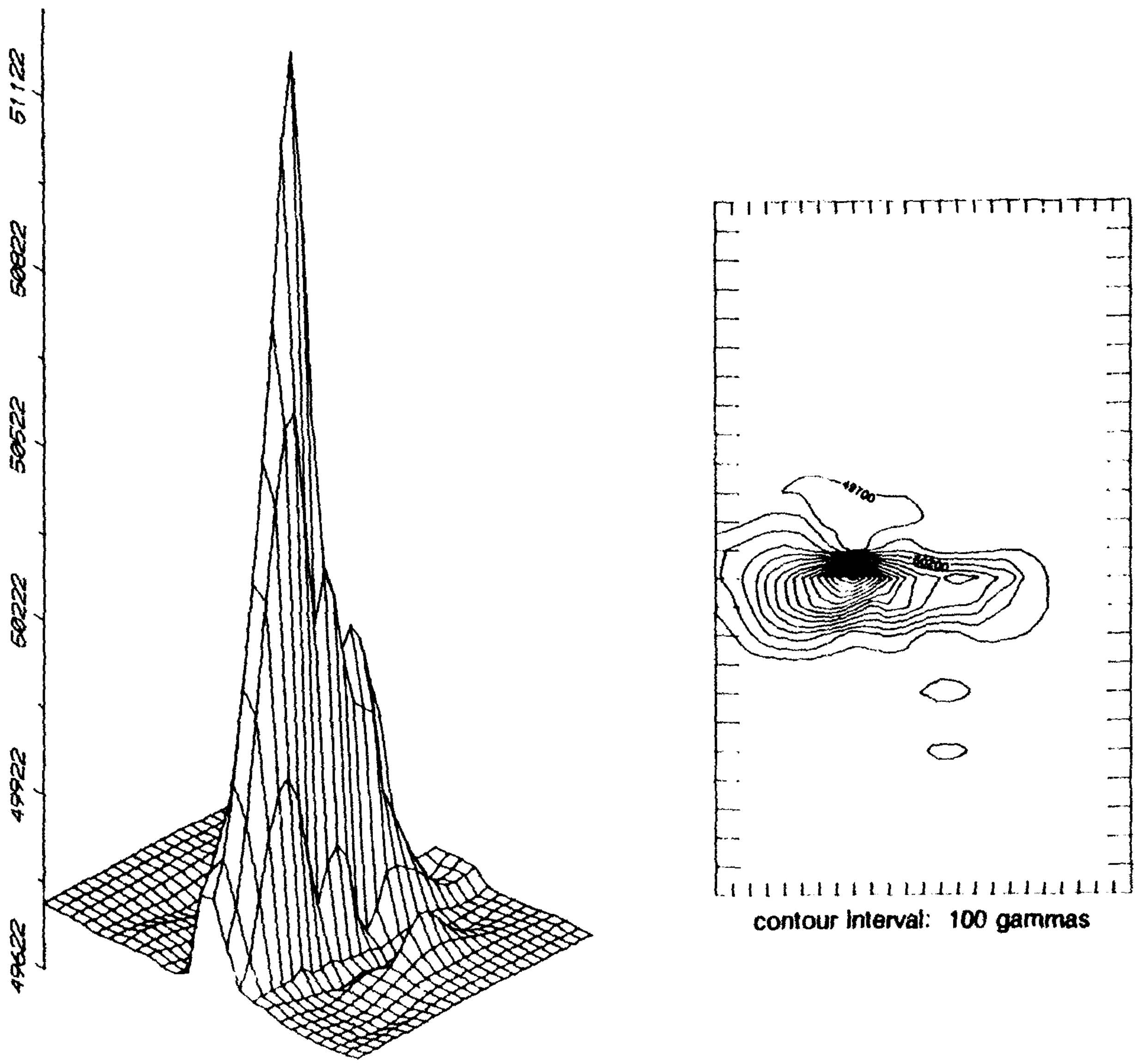


Figure 14. Isometric and contour plots of Anomalies T-111 and U-16.

post-mission analyses, these subtle patterns are not always apparent. While the utility of close internal survey is not questioned, it is this researcher's contention that it could be applied more effectively after the analysis phase has been completed.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

Recommended Areas for Testing

As discussed in Chapter III, 58 per cent of the 78 anomalies discovered during the Breton Sound survey may be dismissed from further consideration based on an analysis of their magnetic signature and their lack of association with other anomalies. By subjecting the area to survey at a close interval of 150 ft, it may be assumed with confidence that a target the size of a shipwreck would create a localized magnetic disturbance that would be detected on at least two survey lines.

The remaining 42 per cent of the total universe of anomalies may be grouped into seven clusters on the assumption that shipwreck remains would produce groupings of three or more anomalies within a 50,000 m^2 area in a high energy environment (Table 2) (Figure 15). Two of these seven clusters, Clusters B, and E, are formed entirely of weak anomalies with a duration of less than 15 seconds. Based upon the comparison of results from a number of other surveys as discussed in Chapter 3, the signatures produced by the anomalies forming these clusters are judged to be too brief to have a shipwreck, or a portion thereof, as their source.

The areas of the remaining five clusters, A, C, D, F, and G, are adjudged to have some potential for containing historic shipwreck remains. Cluster A, which is comprised of four anomalies on three tracks, has the greatest shipwreck potential. Two of the anomalies forming this cluster are of long duration; one is a multicomponent signature suggesting the presence of multiple objects. In addition, the location of the cluster, falling as it does near the northern end of Breton Island in shoal water, represents a high probability locus for a wreck event. Additional testing is recommended for this cluster to determine the presence of potentially significant cultural resources.

Cluster C, comprised of five anomalies, has moderate potential as a shipwreck site. One of its contributing anomalies is of long duration. The very fact that so many anomalies are located in such close proximity suggests that something out of the ordinary transpired in this location. Cluster C is recommended for additional testing.

Cluster D is adjudged to have moderate potential as a shipwreck location. This cluster is composed of three anomalies, one of which produced an extremely high disturbance of over 500 gammas for a duration of 30 seconds. The other anomalies in the cluster are relatively weak and confined. This cluster falls near Breton Island, close to the reported coordinates of the 1923 wreck of the *Fidget*. Cluster D is recommended for further testing.

Cluster F, located near the southwest corner of the project area, is comprised of five anomalies on five track lines. Two of the anomalies in the cluster exhibit long duration, multi-component signatures of the type generally considered to be the most characteristic signature of a shipwreck site. The cluster also is considerably isolated from the other targets in the project area. Sixty-seven per cent of the anomalies were recorded in the northern one-half of the project area, with the majority of those falling in the northwest quadrant nearest Breton Island. Prevailing current patterns are likely to deposit a variety of marine debris in the northern part of the project area, whereas clusters in the southern portion are more likely to be related to a single event. Cluster F is adjudged to have a high potential for historic shipwreck remains; therefore, it is recommended for further testing.

Three anomalies form Cluster G, which produced by far the greatest magnetic disturbance of any cluster in the survey. The side scan exhibited an acoustic image of what appears to be a small

Table 2. Clustered Anomalies.

CLUSTER	TRACK / SHOT	RECOMMENDATION
A	G-12 H-93 H-91 J-14	High Potential Phase II Testing Recommended
B	I-34 J-25 K-93	No further work recommended
C	I-62 J-42 K-78 L-41 N-203	Moderate Potential Phase II Testing Recommended
D	A-80 C-68 D-59	Moderate Potential, Near reported wreck of *Fidget* Phase II Testing Recommended
E	J-56 K-63 K-64 K-67 L-58	No further work recommended
F	A-183 B-124 E-17 G-123 J-117	High Potential Phase II Testing Recommended
G	T-111 U-16 S-11	High Potential, Probably Modern (first reported 1971) Groundtruthing Recommended

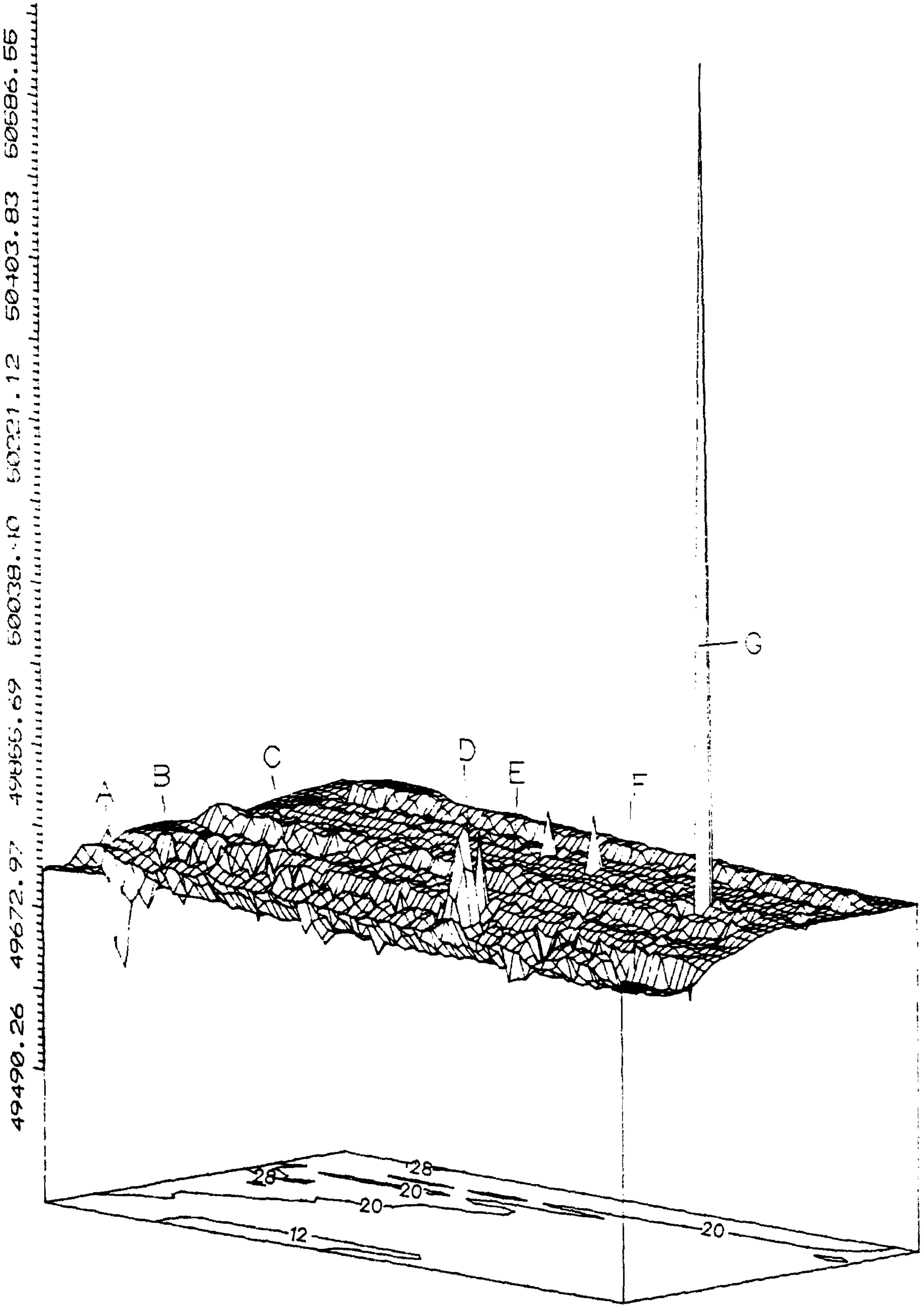


Figure 15. Isometric plot of the magnetic field of the project area overlaid on the bathymetric contour plot, showing the location of anomaly clusters.

vessel, possibly a shrimp trawler. The modern NOAA chart of this area (Chandeleur and Breton Sounds, No. 11363) indicates wreckage (position approximate) in the general area. The AWOIS list (Automated Wreck and Obstruction Information System), prepared by the National Ocean Service, contained no references to wrecks anywhere in the area between 29° 30' 00" N and 29° 27' 00"N, and 89° 08' 00" W and 89° 10' 00" W, an area subsuming a good deal more that the project area. According to the National Ocean Service, the symbol was posted on the cha' as a result of Local Notice to Mariners Number 96, dated November 25, 1971 (Verry, personal communication 1992). The Notice to Mariners described "a large piece of unidentified wreckage" trailing a length of wire rope. The wreckage was described as old, weather-beaten, and having no identifying marks. It may be presumed that this reported wreckage constitutes Cluster G. Verification of this target should be made by a diving investigation.

Paired anomalies B-110 and C-25, while failing the definition of three anomalies within a 50,000 m^2 area, are of sufficient size and duration to warrant some attention. However, the duration of the signature decreases with an increase in magnetic perturbation, and the signal exhibits a classic bi-polar curve. The contour plot generated by a close internal survey (cf. Chapter III) suggests a single object of dense mass, possibly an anchor. Based on this signature, it is predicted that there is a single large object with a mass of approximately 100 pounds producing this anomaly and that it is probably unrelated to a shipwreck site. No further work is recommended for this anomaly pair.

Recommended Testing Procedures

Any significance evaluation begins with the placement of a site within its geographic and temporal or developmental framework. The site then must be related to a relevant theme that provides the context for evaluation of the site. Those contexts and the relevant historical themes are outlined in Chapter II. Further investigations should examine the sites in the context of those themes, as well as within the appropriate spatial and chronological framework.

At a minimum, Phase II testing should seek to expose, delineate, and record the most areally significant magnetic target associated with each anomaly cluster. Each contributing anomaly in the cluster need not be tested on the theory that any significant shipwreck would produce a single wreck focus with a scattering of associated debris. Testing of the focus should be sufficient to determine significance.

<u>Significance of Submerged Sites</u>

Underwater anomalies recommended for testing should be subjected to diver groundtruthing, laboratory analysis, and archival research in order to evaluate their potential historical significance. Significance will be assessed using the following criteria:

- Association with events which have made a significant contribution to the broad patterns of our history;
- Association with the lives of persons significant in our past;
- Distinctive characterization of a type, period, or method of construction, or representative of the work of a master, possession of high artistic values, or representation of a significant and distinguishable entity whose components may lack individual distinction;
- Ability to yield information important to history (36 CFR 60.4 [a-d]).

A combination of documentary research and field work should be undertaken in order to evaluate submerged sites for significance. Assuming that submerged sites result from the remains of sunken ships, wrecks from the colonial or exploration eras would be of special public interest. Other grounds for assessing a wreck's significance could include uniqueness in the themes of architecture, commerce, invention, and transportation (Delgado 1985).

The identity, state of preservation, and potential cultural significance of each recommended cluster of anomalies should be ascertained. A flexible approach is recommended in undertaking the investigation to achieve the best results under variable conditions of water depth, sediment depth, current, and visibility.

Recommended Procedures for Clusters A, C, D, and F

Prior to initiating subsurface investigations, it is suggested that each recommended cluster of anomalies be subjected to a close-interval magnetic survey. The search grid should include the 50,000 m^2 used to define the cluster (224 m to a side). Survey tracks should be spaced 15 m apart. Survey instrumentation should include a proton precession marine magnetometer capable of logging data to magnetic disk for rapid processing. Real time positioning data should be logged on magnetic media at 5 second intervals. Either DGPS or UHF radio-positioning is recommended. The survey instrumentation should be capable of processing the data to produce a magnetic contour plot of the survey area while in the field. The results of the contour plot then should be utilized to guide subsurface testing at the area of broadest magnetic disturbance, based on the hypothesis that this area should represent the greatest concentration of submerged wreckage.

In cases where the targets have been identified by magnetic signature alone, without accompanying side-scan return, accurate location of the point of maximum magnetic deviation will become crucial to the rapid recovery of the magnetic source by divers. This can be accomplished most effectively through the use of a gradiometer, such as a Schonstedt GAU-20 Marine Gradiometer. This instrument consists of a diver-held sensor connected by a cable to an analog meter. The diver carries the sensor over a pre-established search pattern while the meter is monitored from the surface. When the greatest magnetic deviation is detected, the location should be buoyed to become the focus of further search procedures.

An initial visual survey should be made of the bottom surrounding the anomaly by conducting a circle search using a 45-ft guide rope knotted at five-ft intervals. Any cultural material located during the search will be buoyed for future investigation.

Following the detection of possible features by means of visual and electronic search techniques, work will begin to delineate, expose, record, and identify the material associated with each anomaly. The technique employed will depend upon the depth of the sediment covering each anomaly.

In the event that the target is exposed above the bottom, limited excavation will be conducted to expose enough of the feature to identify it and to enable limited artifact collection to assist in assessing cultural significance. If the target is buried, a series of probes should be employed to determine the depth of the overburden. Either an eight-ft solid steel probe or a '5-ft hollow-core hydraulic probe will be utilized to determine if the anomaly may be uncovered by standard excavation techniques.

If material is encountered under three feet or less of overburden, a small test trench should be excavated using either a hydraulic dredge or an airlift. Since the airlift requires that air introduced in the mouth of the tube rise at least one atmosphere in pressure (33 ft), the hydraulic venturi dredge operates more efficiently in shallow water.

In the event that material is located beneath the overburden at a depth at which it may be impractical to utilize hand excavation techniques, then more radical mechanical means may need to be considered. Such devices as prop washes, for example, have been used effectively on archeological sites in Texas (Arnold 1982b).

Recommended Procedures for Examining Cluster G

Cluster G is probably modern wreckage as described in Notice to Mariners No. 96 of 1971. Since the side-scan revealed substantial wreckage proud of the sea bottom, no subsurface excavation would be required for the investigation of this site. Diver groundtruthing is recommended to verify that the wreckage is modern in date.

Mapping and Recording - All Recommended Clusters

The process involved in mapping and recording sites within a project area is a direct function of the visibility that is encountered. At a minimum, a measured map incorporating horizontal and vertical controls should be made of each potentially significant site. This should be accompanied by measured drawings of significant features that may contribute to a determination of significance. If visibility permits, all anomalies should be photographed in situ using Nikonos 35-mm cameras. VHS format video documentation of each site also should be made if possible. Photo and video documentation of top-side support activities should be made for the District's use. A daily archeological log should be maintained detailing conditions and observations throughout the project.

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APPENDIX I

SCOPE OF SERVICES

CELMN-PD-RN 23 March 1992

SCOPE OF SERVICES
Remote Sensing Survey of
Mississippi River-Gulf Outlet,
Breton Sound Disposal Area,
Plaquemines Parish, Louisiana

1. Introduction. The Breton Sound Dredged Material Disposal Area is located at Mile 0.0 to -2.5 just south of the Mississippi River Gulf Outlet (MRGO). The barrier islands along the coast are experiencing severe erosion. The purpose of this proposed berm construction is to provide for the beneficial use of material dredged during routine maintenenace of the Mississippi River Gulf Outlet. The plan for marsh creation provides for the construction of a pilot berm consisting of dredged material on the right descending side of the channel southeast of Breton Island. The River and Harbor Act of March 29, 1956 House Document 245, 82nd Congress, 1st Session, authorized the construction of the Mississippi River - Gulf Outlet, as well as protective jetties at the channel's entrance. Periodically, the MRGO has to be dredged to maintain its 36 foot depth and 500 foot wide channel. In the past, dredged material was deposited along the right descending bank (west) of the MRGO. Recently, the Corps of Engineers has focused its efforts on depositing dredged material in areas which would benefit the marsh by replenishing the soils in highly erosive areas.

2. Study Area. The study area consists of the berm construction site where dredged material will be deposited south of the Mississippi River - Gulf Outlet (see attached map).

3. Background Information. The study area has not been surveyed for cultural resources. A general history of Louisiana's maritime heritage and an inventory of reported shipwrecks in the study area is provided in the cultural resources report entitled A History of Waterborne Commerce And Transportation Within the U.S. Army Corps of Engineers, New Orleans District and an Inventory of Known Underwater Cultural Resources prepared by Coastal Environments, Inc. This study documents two shipwrecks in the vicinity of the project area. The National Oceanic and Atmospheric Administration, Chandeleur and Breton Sounds, chart number 11363 indicates another shipwreck within the boundaries of the project area. These reported wrecks are listed below:

Recno	Boat Name	Date Lost	Waterbody	Source
20	Unknown	Unknown	Breton Sound	CEI Report
1177	Fidget	10/7/23	Breton Sound	CEI Report
NA	Unknown	Unknown	Breton Sound	NOAA Chart

Breton Sound has been an important navigation route since early colonial times. During the French colonial period, ships would travel from New Orleans to the settlements located along the Gulf of Mexico at Biloxi and Mobile. Later, during the Spanish period, ships from Pensacola would also travel to trade in New Orleans. Numerous types of ships such as bateaux, broadhorns, longboats, shallops, feluccas, ketches, and traversiers traveled the Breton Sound. Later during the American period, waterborne commerce in the area was related to shrimping, and fishing. Today, there are a number of recreational boats enjoying the area. Based on the historical records available, the planned berm construction has the potential for impacting historic shipwreck remains, due to its proximity to historically important shipping lanes . The barrier islands along the Louisiana coast are high frequency environments for shipwreck locations. Loss and abandonment of vessels in this area is expected to have occurred.

4. General Nature of the Work. The study consists of a systematic magnetometer and side scan sonar survey of the study area using precise navigation control and a fathometer to record bathymetric data. All potentially significant anomalies located by the survey will be briefly investigated via intensive survey and probing of the water bottom. No diving will be performed under this delivery order. The purpose of the study is to locate any historic shipwrecks which may exist in the areas. All magnetic, bathymetric, and sonar anomalies will be interpreted based on expectations of the character of shipwreck signatures.

5. Study Requirements. The study will be conducted utilizing current professional standards and guidelines including, but not limited to:

* the National Register Bulletin 15 entitled, "How to Apply the National Register Criteria for Evaluation";

* the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation as published in the Federal Register on September 29, 1983;

* the Louisiana Division of Archeology's Comprehensive Archeological Plan dated October 1, 1983 and the Cultural Resources Code of Louisiana, dated June 1980;

* the Advisory Council on Historic Preservation's regulation 36 CFR Part 800 entitled, "Protection of Historic Properties."

The study will be conducted in three phases: Review of Background Sources, Remote Sensing Survey, and Data Analyses and Report Preparation.

A. Phase 1. Background Research. This phase will begin with research of available literature and records necessary to establish the historic setting, predict the nature of the resource base in the project area, and refine the survey methodology. This background research will include a literature review of the geomorphology and research of historic maps and records.

B. Phase 2 . Remote Sensing Survey. Upon completion of Phase 1, the contractor shall proceed with execution of the fieldwork. The equipment array required for this survey effort is:

(1) a marine magnetometer
(2) a positioning system
(3) a recording fathometer
(4) a side-scan sonar

The contractor will begin by establishing the shore reference stations for the positioning system, if necessary. The following requirements apply to the survey:

(1) transect lane spacing will be no more than 150 feet for the magnetometer survey and 600 feet for the sonar survey,
(2) two separate runs will be made along the transects, one with the side scan sonar and another with the magnetometer,
(3) positioning control points will be obtained at least every 100 feet along transects,
(4) background noise will not exceed +/- 3 gammas,
(5) magnetic data will be recorded on 100 gamma scale,
(6) the magnetometer sensor will be placed to avoid noise from the survey boat (eg. towed a minimum of 2 1/2 times the length of the boat or projected in front of the survey vessel,
(7) the survey will utilize the Louisiana Coordinate System,
(8) additional transects will be run over all potentially significant anomalies, and
(9) probing of the water bottom will be performed at all potentially significant anomalies.

Two copies of a brief management summary which presents the results of the fieldwork will be submitted to the COR within 6 weeks after delivery order award. The report will include a brief description of each anomaly located during the survey and recommendations for further identification and evaluation procedures when appropriate. A preliminary map will be included showing the locations of each anomaly.

C. Phase 3: Data Analyses and Report Preparation. All data will be analyzed using currently acceptable scientific methodology. The post-survey data analyses and report presentation will include as a minimum:

(1) post-plots of survey transects, data points and bathymetry;
(2) same as above with magnetic data included;
(3) plan views of all potentially significant anomalies showing transects, data points, and contours;
(4) correlation of magnetic, sonar, and fathometer data, where appropriate.

The interpretation of identified magnetic anomalies will rely on expectations of the character (i.e. signature) of shipwreck magnetics derived from the available literature. Interpretation of anomalies will also consider probable post-depositional impacts, and the potential for natural and modern, i.e. insignificant, sources of anomalies.
The report shall contain an inventory of all magnetic anomalies recorded during the underwater survey, with recommendations for further identification and evaluation procedures when appropriate. These discussions must include justifications for the selection of specific targets for further evaluation. Equipment and methodology to be employed in evaluation studies must be discussed in detail. The potential for each target or submerged historic property to contribute to archeological or historical knowledge will be assessed. Thus, the Contractor will classify each anomaly as either potentially eligible for inclusion in the National Register, or not eligible. The Contractor shall fully support his recommendations regarding site significance. The report will include a summary table listing all anomalies, the assessment of potential significance, and recommendations for further work.

One set of project area maps with the locations of all anomalies accurately plotted thereon will be submitted with the draft reports. The base project maps will be provided by the COR. In addition to the locations of all anomalies, the maps will also show other pertinent features such as: channel beacons and buoys, channel alignments, bridges, cables and pipeline crossings. The maps will be accompanied by tables listing all magnetic anomalies recorded during the survey. At a minimum, the tables will include the following information: Project Name; Survey Segment/Area; Magnetic Target Number; Gammas Intensity; Target Coordinates (Louisiana State Plane).

If determined necessary by the COR, the final report will not include detailed site location descriptions, state plane or UTM coordinates. The decision on whether to remove such data from the final report will be based upon the results of the survey. If removed from the final report, such data will be provided in a separate appendix. The analyses will be fully documented. Methodologies and assumptions employed will be explained and justified. Inferential statements and conclusions will be supported by statistics where possible. Additional requirements for the draft report are contained in Section 6 of this Scope of Services.

6. Reports:

Management Summary Two copies of a brief management summary will be submitted to the COR within 6 weeks after delivery order award.

Draft and Final Reports (Phase 1-3). Eight copies of the draft report integrating all phases of this investigation will be submitted to the COR for review and comment within 8 weeks after work item award. As an appendix to the draft report, the Contractor shall submit the state site forms. The written report shall follow the format set forth in MIL-STD-847A with the following exceptions:

(1) separate, soft, durable, wrap-around covers will be used instead of self covers;
(2) page size shall be 8-1/2 x 11 inches with 1-inch margins;
(3) the reference format of American Antiquity will be used. Spelling shall be in accordance with the U.S. Government Printing Office Style Manual dated January 1973.

The COR will provide all review comments to the Contractor within 6 weeks after receipt of the draft reports (14 weeks after work item award). Upon receipt of the review comments on the draft report, the Contractor shall incorporate or resolve all comments and submit one preliminary copy of the final report to the COR within 3 weeks (17 weeks after work item award). Upon approval of the preliminary final report by the COR, the Contractor will submit 30 copies and one reproducible master copy of the final report to the COR within 22 weeks after work item award.

7. Weather Contingencies. The potential for weather-related delays during the survey necessitates provision of weather contingency days in the delivery order. As agreed during negotiations, two weather contingency days have been added to the fieldwork. The Contractor assumes the risk for any additional costs associated with weather delays in excess of two days. If the Contractor experiences unusual weather conditions, he will be allowed additional time on the delivery schedule but no cost adjustment.