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Sedimentary Environments Within Little Sarasota Bay, Florida

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ABSTRACT

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Tidal circulation within Little Sarasota Bay is a major factor controlling the sediment distribution within the bay. The dominant sediment is fine grained, quartz sand with minor amounts of shell gravel, phosphorite pebbles and granules, quartz granules, and mud. The three major sedimentary environments characterized by these sediments are; low energy bay, protected bay and open bay. The low energy bay and protected bay environments are restricted to the shallow bay margins and central area of the bay where circulation is very sluggish, while open bay environments are in the north and south areas of the bay where higher energy conditions exist. With the closure of Midnight Pass, the direct link to the Gulf of Mexico, the central area of the bay has experienced an even greater reduction in energy levels. With the continued closure of this pass, the organic matter content within the sediments in this area will rise drastically, thus, possibly, causing a decrease in the quality of bay water.

ADDITIONAL INDEX WORDS: *Coastal bays, sedimentary environments, circulation patterns, organic matter.*

INTRODUCTION

"Coastal bay" is a loosely used term designating any coastal body of water partly open or partly isolated from the open ocean (CURRAY, 1969a). PRITCHARD (1967) discusses two types of bays; estuaries and lagoons. He defines an estuary as a semi-enclosed coastal body of water which has a free connection with the open ocean and within which sea-water is measurably diluted with fresh water. A lagoon is defined as an isolated body of water with little to no fresh water dilution. PRITCHARD (1967) divides estuaries into four distinct types; (1) drowned river valleys, (2) fjord type, (3) bar-built, and (4) tectonic. Of these four types of estuaries, the bar-built estuary is at the borderline of the estuarine definition, having characteristics of both estuaries and lagoons.

A bar-built estuary is formed when offshore bars build above sea-level or spits enclose bays; in both cases barrier islands are formed. Bar-built estuaries are commonly elongated parallel with the shore and have varying circulation with the open ocean, depending on the number and prisms of inlets in the related barrier island chain. Usually, one or more streams provide fresh water and sediment input to the bay or estuary. Little Sarasota Bay (Figure 1) is such an estuary.

Numerous studies have been conducted on the nature and sources of sediments in bays (*e.g.* IPPEN, 1966; GORSLINE, 1967; GUILCHER, 1967; RUSNAK, 1967; RUSSELL, 1967; CURRAY, 1969b; DRAKE, 1976; WANLESS, 1976; NICOLS and BIGGS, 1985). All agree that the factors controlling sedimentation in bays include; (1) climate, (2) hydrodynamic setting, (3) sea-level history, and (4) pre-existing topography.

The bays of the Texas Gulf Coast have been extensivly studied by many authors (*e.g.* SHEPARD, 1953; SHEPARD and MOORE, 1960; RUSNAK, 1960), however, the bays of the Florida Gulf and East Coasts have been sparsely studied. GOODELL and GORSLINE (1961) described the major sediment-types within Tampa Bay as a mixture of terrigenous quartz sand derived from the erosion of Pleistocene terrace deposits and biogenic carbonate in the

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form of mollusc shells produced within the bay. These sediments are deposited and transported throughout the bay by tidal currents, which are the principal circulation agents acting in the bay.

KOFOED and GORSLINE (1963) indicate that sediment distribution patterns within Apalachicola Bay are greatly influenced by the submarine topography. The coarse fraction of the sediments consists of relic quartz sand and indigenous calcareous material and was found to be associated with topographic elevations and channel floors. They attribute all the fine-grained material to the Apalachicola River.

The sediments in Charlotte Harbor consist primarily of terrigenous quartz sand and biogenic carbonates with only minor amounts of finer materials (HUANG and GOODELL, 1967). Sediment distribution within the bay is controlled by the major tidal circulations of the harbor. They found that the coarse fractions accumulated within the high energy areas at the harbor mouth and in the channels, while the finer fractions are concentrated at the harbor head and lagoons.

KNOWLES (1983) constructed a Holocene geologic history for Sarasota Bay using vibracores and surficial sedimentary analysis. He found that the dominant sediment types within the bay are quartz sand and biogenic carbonate material with minor amounts of finer material. The sand is derived from the Gulf of Mexico and the barrier islands and from the nearby Pleistocene terrace deposits and exposures of Miocene quartzitic limestone. The carbonate material is produced within the bay and is also transported into the bay from the Gulf and barriers during severe storms.

This paper will discuss the process-response mechanisms in the sedimentary environments within Little Sarasota Bay (Figure 1) including the nature, distribution, and probable sources of the sediments.

STUDY AREA

Little Sarasota Bay is located on the west-central coast of Florida in Sarasota County (Figure 1). It is bounded by 2715' - 2711' north latitude and 8232' - 8229' west longitude. The bay is a long and narrow, shallow-water embayment oriented parallel to the coast. Siesta and Casey Keys separate the bay from the Gulf of Mexico (Figure 1). Until late 1983 these two barrier islands were separated near the central portion of the bay by Midnight Pass (Figure 1).

With the closure of Midnight Pass, Little Sarasota Bay now has restricted connection with the Gulf of Mexico. To the north the bay is connected to the Gulf by Big Sarasota Pass through Sarasota Bay and Roberts Bay. To the south the bay is connected to the Gulf by Venice Inlet through Dryman Bay and Blackburn Bay. The Intracoastal Waterway traverses the length of the bay and connects the pass through Stickney Point to the north and Blackburn Point to the south (Figure 1).

Little Sarasota Bay is approximately 9.5 kilometers long by 1.5 kilometers at its widest point. The bay has a total area of approximately 9.5 km^2. The average depth of the bay is 0.9 meters. The bay is subdivided into several smaller embayments by natural barriers such as oyster bars, sand bars, and small peninsulas which extend into the bay producing constrictions to flow to the central portion of the bay. Some of these peninsulas have been modified by man while some of the sand bars are the result of dredging operations within the bay and have been colonized by mangroves. In the central part of the bay a flood tidal delta, Bird Keys (Figure 1), has been deposited by tidal currents and storm surge through Midnight Pass. Bird Keys has received a large amount of the dredged material from dredging the Intracoastal Waterway and is highly vegetated.

Tidal currents are the primary circulating agents acting in the bay. The tides in Little Sarasota Bay show a mixture of diurnal and semi-idiurnal modes which alternate twice each lunar cycle with the diurnal tides tending to be larger than those of the semi-diurnal tides. The tides are nearly pure semi-diurnal when the moon is near the equinoxes. The bay has a spring tidal range of 0.82 meters, which would place it in the microtidal coast category of DAVIES (1964).

Waves play a minor role in the circulation of the bay and are only a factor during the passage of severe storms when wind setdown allows waves to disturb the bottom sediments. Little Sarasota Bay is located along the moderate energy coast of west Florida with mean breaker heights along Gulf Coast beaches of about 25 cm (TANNER, 1960).

Little Sarasota Bay is fed by several small

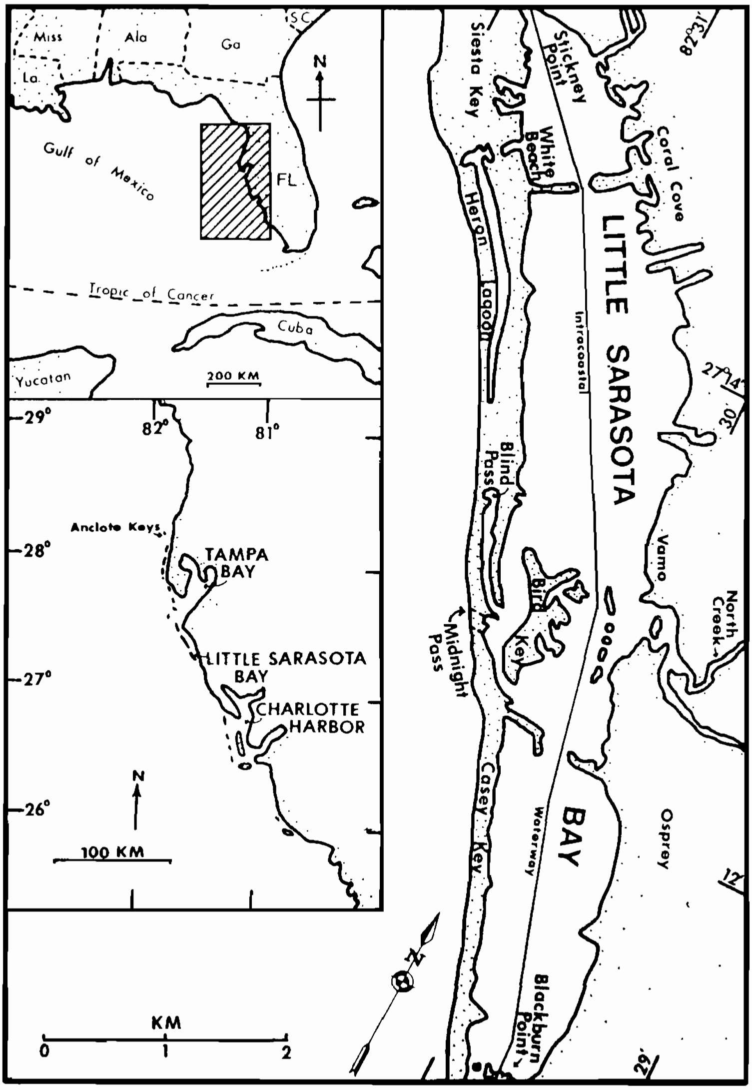

Figure 1. Location map for Little Sarasota Bay and localities discussed in the text.

streams that provide a small amount of fresh water and sediment to the bay. As a result, the bay does not receive much dilution and maintains a nearly normal marine salinity throughout the year. During periods of high rainfall salinity may drop significantly below normal marine concentrations.

The dredging of the Intracoastal Waterway has had a drastic impact on circulation within Little Sarasota Bay. Prior to the waterway dredging the tides were forced largely through Midnight Pass as well as through Stickney Point and Blackburn Point (Figure 1). After dredging the waterway there was a considerable increase in tidal forcing through the pass at Stickney Point from Big Sarasota Pass to the north and through the pass at Blackburn Point from Venice Inlet to the south. The pass at Stickney Point now shows current velocities of around 30 cm/sec (DENBROU *et al.*, 1983). Subsequent closing of Midnight Pass probably further increased this tidal circulation although measurements have not been made.

General Geology

Little Sarasota Bay is located in the Floridian section of the coastal plain province and lies in the Gulf Coastal Lowlands. Several Pleistocene terraces are exposed east of the bay. They are correlated with the Wicomico shoreline at 30.5 meters, the Penholoway shoreline at 21.3 meters, the Talbot shoreline at 12.8 meters, the Pamlico shoreline at 7.6 meters, and the Silver Bluff shoreline at 1.5 meters (COOKE, 1945).

COOKE (1945) describes three formations that are exposed at the surface in the Little Sarasota Bay area; the Hawthorn, Bone Valley, and Caloosahatchee. Exposures of the Hawthorn Formation, a phosphatic, sandy limestone of Miocene Age, are present at Stickney Point Bridge, at White Beach on the eastern side of Siesta Key in the northern part of the bay, and on the shore at Osprey (Figure 1). Exposures of the Miocene Bone Valley Formation and the Pliocene Caloosahatchee Formation are present a short distance east of the bay on the mainland. A molluscan beachrock considered to be the equivalent of the Pleistocene Anastasia Formation (RUSSELL, 1978) is also exposed at Point of Rocks on the north end of Siesta Key (Figure 1).

SURFACE SEDIMENTS

Seventy-three surface sediment samples were collected from various locations throughout Little Sarasota Bay (Figure 2). Each sample was analyzed texturally and for organic content.

Mud

As a result of the dredging of the Intracoastal Waterway, the circulation pattern of the bay has changed drastically. Tidal forcing now occurs through the pass at Stickney Point from Big Sarasota Pass in the north and through the pass at Blackburn Point from Venice Inlet in the south (DENBROU *et al.*, 1983). The swiftest tidal currents, averaging 26 cm/sec, are concentrated along the Intracoastal Waterway while slower current velocities, averaging 6 cm/sec, are present to either side of it (DENBROU *et al.*, 1983). Tidal currents decrease in velocity from 43 cm/sec at Stickney Point and 49 cm/sec at Blackburn Point down to 12 cm/sec (DENBROU *et al.*, 1983) toward the central portion of the bay where a null area is present as shown in Figure 3. The mud content in surface samples of Little Sarasota Bay (Figure 4) ranges from 1% to 36% by weight with the highest percentages found in areas of low energies near the central portion of the bay.

Since the closure of Midnight Pass in late 1983, circulation in the central portion of the bay is minimal, with waves and wind-stress being the primary circulating mechanisms. SAUERS and SERVISS (1985), in a recent study of the ecological status of the bay, found that this central area had a widely ranging dissolved oxygen content and high nutrient values. As a result, they found that this part of the bay is ecologicly distinct from the bay as a whole, containing a phytoplankton community that is distinct from other areas of the bay and with high growth rates for macroalgae. Grass beds, sand bars, and oyster bars are found in this area of the bay and help to characterize the low energy environment which permits the accumulation of fine grained material.

High mud content is also present in areas where natural and man-produced barriers occur. These include sand bars, oyster bars, and man-modified examples of both. They form small peninsulas extending out into the bay which produce constrictions to flow. The mud accumulates on the lee side of these barriers, away from the main current velocities. These pensinsulas were small prior to the development of the bay area but have now been enlarged and highly developed, producing even greater hinderence to the flow into the central portions of the bay.

The primary sources of the fine grained material found in Little Sarasota Bay are; (1) the erosion of the bay margins during high rainfall events when surface runoff and wave energy are high, (2) the adjacent bays where the fine material is brought in by tidal currents and distributed throughout the bay, and (3) organic detritus produced within the bay itself.

Sand

The predominant sediment within Little Sarasota Bay is fine quartz sand. This sand has two

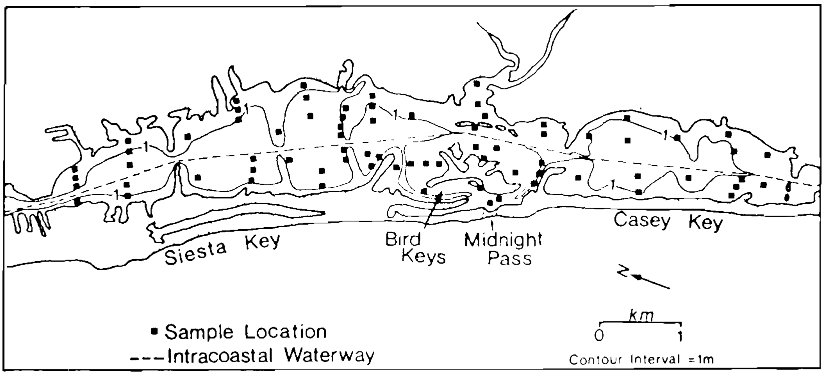

Figure 2. Bathymetric map of Little Sarasota Bay with surface sediment sample locations.

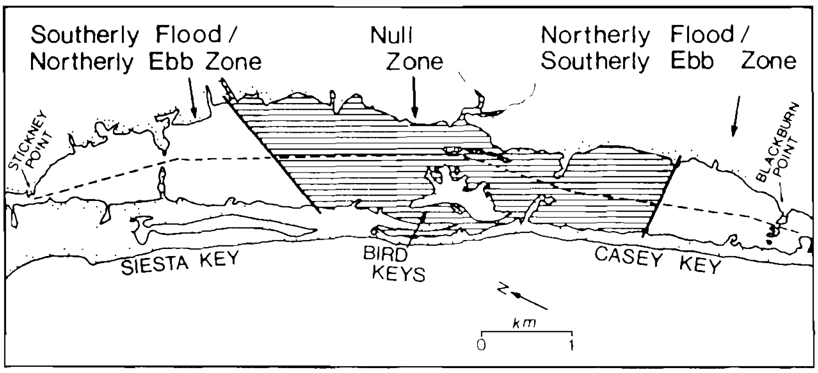

Figure 3. General map of Little Sarasota Bay showing major zones of water motion (modified from Sauers and Serviss, 1985).

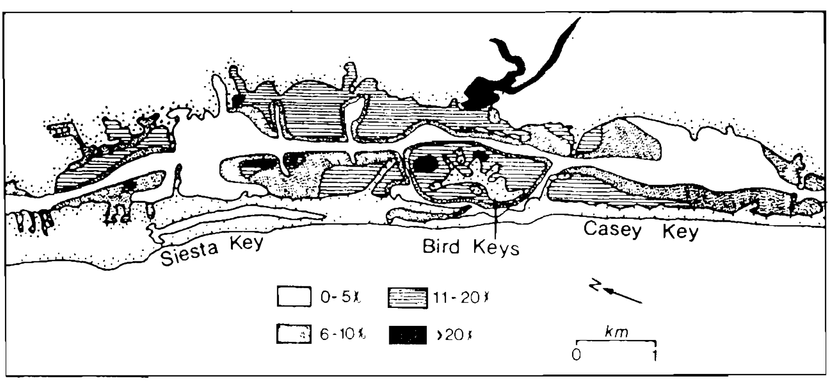

Figure 4. Distribution of mud by weight percent in surface sediments of Little Sarasota Bay.

primary sources: (1) the Gulf of Mexico and the barrier islands seaward of the bay, and (2) Pleistocene terraces on the eastern margin of the bay and exposures of sandy limestone which are scattered along both margins of the bay. Some biogenic sand is also produced by the degradation of skeletal material produced within the bay.

Along the eastern margin of the bay this sand has a bimodal size distribution, containing a large, fine quartz sand mode derived from the barrier islands and distributed by tidal currents, and a smaller, coarse to very coarse sand mode derived from the erosion of the Pleistocene terrace deposits and exposures of sandy limestone. This sand is highly phosphatic and contains a very small carbonate fraction.

The sand along the western margin is predominantly fine quartz sand derived from the Gulf and barrier islands. A minor, coarse grained fraction is present where exposures of sandy limestone are present along the bay margins. The sand, like the barrier-island sand, contains a small amount of phosphorite and has a high carbonate fraction.

Gravel

The gravel content of the sediment in Little Sarasota Bay (Figure 5) is highest along the bay margins and on sand bars and oyster bars scattered throughout the bay. The gravel consists of two constituents; (1) a carbonate-shell fraction, and (2) a terrigenous phosphorite, limestone, and quartz fraction.

On the eastern margin of the bay, the dominant gravel fraction is phosphorite granules and pebbles with various amounts of limestone lithoclasts and quartz granules. Shell material consists of a diverse population of bay molluscs with a moderate amount of bored oyster, *Chione*, and *Cardita* shells. Gravel is eroded from the Pleistocene terrace deposits and exposures of Miocene sandy limestone which contain abundant phosphorite, fossil shell material, and quartz granules. Fossil shell material has been partially phosphatized in some of the sample locations.

The dominant gravel fraction is shells and shell hash on the western margin of the bay. Some of this material is brought into the bay from the barrier islands during washover events. The majority of the shells are from bay molluscs such as *Tellina*, *Lucina*, *Cerithium*, and *Tagelus*. A minor amount of the shell material consists of rounded and abraded *Chione* and *Donax* shells which are abundant along the barrier island beaches. Phosphorite and limestone lithoclast content is low and only found near exposures of sandy limestone.

High gravel content characterizes the scattered sand bars and oyster bars, such as the one trending east-west in the north-central part of the bay. Along with oyster shells, the sediment on these bars contains abundant barnacles and a variety of shells from bay molluscs. Sea-grass beds scattered throughout the bay and mangrove areas are also sites of gravel accumulations of a variety of bay molluscs which flourish in these muddy, low energy environments.

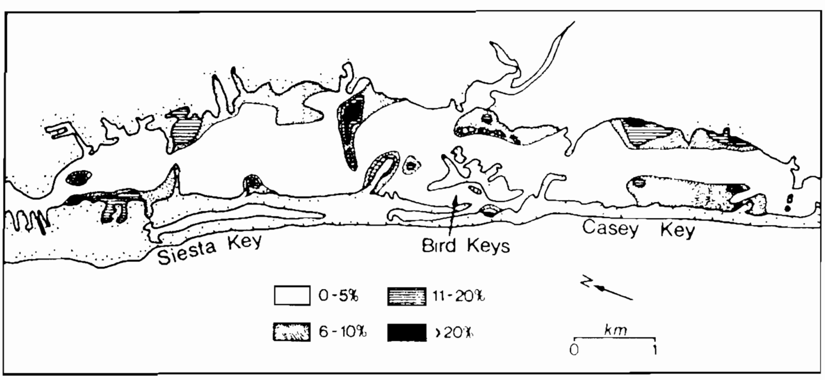

Figure 5. Distribution of gravel by weight percent in surface sediments of Little Sarasota Bay.

Organic Matter

The average organic matter content in the surface samples within Little Sarasota Bay is less than 0.5 weight percent with a maximum of 4.7 weight percent on the eastern margin of the bay and near the mouth of North Creek (Figure 6). High concentrations of organic matter are also present in grassy areas fringing sand bars.

The high organic matter content found along the eastern margin of the bay is the result of the extensive urban development that is present in this area. Nutrients from these developments enter the bay and stimulate organic production. Because of the poor circulation in this area the organics are not oxidized and are incorporated into the sediments.

The western margin of the bay shows a lower organic matter content than the eastern margin because the barrier islands have less influx of nutrients than has the eastern margin. Seagrass and mangroves fringing the undeveloped back-barrier areas and Bird Keys contribute to the organic matter content in these areas. FRY *et al.* (1977), in a study of stable carbon isotope values in sediments in Laguna Madre and Corpus Christi Bay, Texas, found that the highest values were in sea grass beds and in areas with high macroalgae and phytoplankton populations, similiar to the central portion of Little Sarasota Bay. They conclude that organic matter in sediments is ultimately derived from photosynthetic organisms, with sea grasses contributing 35-70% of the organic carbon present in the average lagoonal sediment and phytoplankton contributing 0-30%.

SURFACE SEDIMENTARY ENVIRONMENTS

Three distinct sedimentologic regions are present in Little Sarasota Bay, based on the circulation pattern of the bay, (Figure 3). The north and south regions are areas that experience significant tidal currents and have small amounts of fine material, gravel, and organic matter. The central region is an area that receives little to no tidal currents and therefore has large amounts of fine material and organic matter and small to moderate amounts of gravel. As a result of these differences, three major sedimentary environments can be delineated in the surficial sediments of the bay. The major characteristics of these and other, minor environments found in Little Sarasota Bay are summerized in Table 1.

Open Bay

The sediment in the north and south regions of the bay consists of a light-medium grey, fine grained, quartz sand containing less than 5% by weight of both gravel and mud. The gravel is predominately fine shell fragments with a few small, whole *Dosinia* shells. The sand in these areas is slightly bioturbated by bay molluscs and worms. The sediment is concentrated in the deeper portions of this environment where tidal flow tends to be concentrated.

Because tidal forcing occurs through the

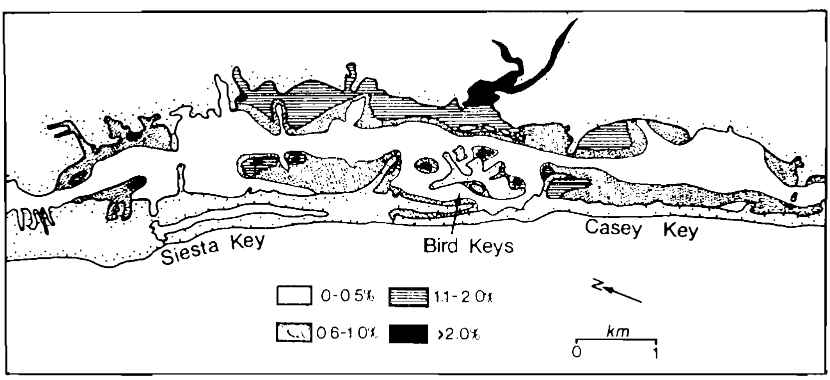

Figure 6. Distribution of organic matter by weight percent in surface sediments of Little Sarasota Bay.

TABLE 1. *Characteristics of surface sedimentary environments.*

Sedimentary environment	% mud	% gravel	% organic matter	bioturmation	fauna	description
Low energy bay	5-15	5-10	0-1.0	moderate-high	*Lucina* *Dosinia* *Tellina* *Chione*	fine quartz sand, mottled medium-dark gray, moderate amount shell material, some plant material
Protected bay	> 10	> 10	0.5-4.7	high	*Crepidula* *Crassostrea* *Cerithidea* *Tellina* *Balanus*	fine quartz sand with minor coarse quartz mode, mottled medium-very dark gray, high shell, phosphate, limestone, and plant content
Open bay	< 5	< 5	0-0.5	low-moderate	*Dosinia*	well sorted, medium-fine quartz sand, medium gray with some mottling, small amount shell material, no plant material

passes at Blackburn Point and Stickney Point, these regions experience the highest current velocities (DENBROU *et al.*, 1983) which transport the fine material to the lower energy portions of the bay.

Low Energy Bay

The central region of the bay is an area which is subjected to sluggish tidal currents and is an area of extremely low energy conditions. These low energy conditions are interupted only during the passage of severe storms when waves, because of shallow depths, disturb the bottom sediments and rework them, concentrating coarse material in thin (1-5 cm) layers. The sediment consists of a medium-dark grey, fine grained, quartz sand with 5-15 weight percent mud and 5-10 weight percent gravel. The gravel consists of whole shells and shell fragments of a large number of bay molluscs, such as *Tellina*, *Lucina*, *Chione*, *Cerithium*, *Crepidula*, and *Dosinia*, and worm tubes. These organisms extensively bioturbate the sediment and give it a homogeneous character with few sedimentary structures preserved. The central region contains abundant seagrass beds and a number of oyster bars and sand bars which help maintain the low energy conditions and support a large diversity of fauna.

Protected Bay

This environment is found along the shallow bay margins in all three regions. The sediment is a medium-dark grey, fine quartz sand containing greater than 10% by weight of both mud and gravel and has a high organic matter content in some areas. The sediment is highly bioturbated by a large diversity of bay organisms which gives the sediment a homogeneous character and detroys physical sedimentary structures. The sediment on the eastern margin of the bay contains a abundant (20-30%) phosphorite granules and pebbles, limestone lithoclasts, and quartz granules derived from the Pleistocene terrace deposits and outcrops of sandy Miocene limestone present along this margin of the bay. Sea-grass and mangroves fringe the undeveloped bay margins and support a large diversity of bay organisms.

CONCLUSIONS

The sediment distribution within Little Sarasota Bay is controlled by the circulation pattern of the bay. Fine grained material is concentrated in the lower energy portions of the bay away from the main current velocities, which are concentrated along the Intracoastal Waterway and in the extreme northern and southern sections of the bay. Coarse material is concentrated along the bay margins and in scattered areas within the bay on oyster bars and sand bars. This coarse material when deposited is immediately incorporated into the sediment and is not transported due to the sluggish tidal crrents present in these areas. With the closure of Midnight Pass, circulation in the central portion of the bay has become greatly restricted. Nutrients entering the bay are not transported far into the bay, but instead settle out and become incorporated in the sediments along the bay margins and in the null area of the bay. The amount of organic matter in these areas is still rather low but with the continued closure of Midnight Pass and further reduction of energy levels within the bay, the organic content of the sediments could increase significantly thereby possibly causing a decrease in the quality of the bay water.

The dominant sediment in Little Sarasota Bay is fine quartz sand. Some biogenic sand is produced within the bay by the degradation of shell material, and a minor coarse quartz sand mode is derived from Pleistocene terrace deposits and exposures of Miocene quartzitic limestone. Gravel, in the form of shell material with varying amounts of phosphorite pebbles and granules, limestone lithoclasts, and quartz granules, along with mud, are minor constituents in the sediment in Little Sarasota Bay.

The effects of man over the past 40 years have had a drastic impact on Little Sarasota Bay. Development along the bay margins and within the bay itself has lead to severe changes in the ecology of the bay (SAUERS and SERVISS, 1983). Peninsulas built out into the bay have caused severe hinderences to flow within the bay. The dredging of the Intracoastal Waterway has had the most significant impact on the bay by actually reversing the circulation pattern of the bay and indirectly leading to the closure of Midnight Pass. As a result of these changes the central portion of the bay has become an area of very sluggish circulation and has become ecologically distinct from the bay as a whole (SAUERS and SERVISS, 1983).

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□ RESUMEN □

El factor que predominantemente controla la distribución sedimentos en Little Sarasota Bay es la circulación mareal. El sedimento dominate es arena fina de cuarzo con pequeuas cantidades de gravas conchiferas, guijarros y gránulos de fosforita, gránulos de cuarzo y lodos. Las tres principales, caracterizadas por estos sedimentos, son: bahia de baja energia, bahia protegida y bahia abierta. Las zonas de baja energia y protegida están restringidas a las márgenes de arguas someras y a la zona central de la bahia donde la circulación es muy lenta, mientras que las de bahia abierta corresponden a las áreas norte y sur, donde existen condiciones de alta energia. Con el cierre del Mignight Pass, punto de unión directa con el Golfo de México, el área central de la bahia ha experimentado una gran reducción de los niveles de energia. Junto con el cierre contenuado de este paso, el contenido en materia orgánica de los sedimentos en este área crecerá drásticamente, causando, posiblemente, un descenso en la calidad del agua de la bahia.—Department of Water Sciences, University of Santander, Santander, Spain.

□ RÉSUMÉ □

La circulation des eaux sous l'influence des marées dans le baie de Little Sarasota est un des principaux facteurs régissant la répartition des sédiments dans la baie. Le sédiment dominant est un sable fin à éléments quartzeux avec des quantités moindre de gravier coquiller, de gallets et de granules de phosphorite, de granules de quartz et de vase. Les trois environments sédimentaires majeurs qui caractérisent ces sédiments sont une baie à basse énergie, une baie protégée et une baie ouverte. Le deux premiers types d'environments sont restraints aux marges de la baie peu profonde et à la région centrale où la circulation est très lente, alors que les environments à baie ouverte se trouvent au nord et au sud de la baie où existent de plus forts courants. Avec la fermeture de la Passe de Midnight qui était la communication directe avec le Golfe du Mexique, la partie centrale de la baie est devenue une zone à plus basse énérgie. Si la passe continue à être fermée, la quantité de matière organique du sédiment à ce site augmentera sensiblement, ce qui pourrait causer une diminution de qualité de l'eau de la baie.—*B. Salvat and M. Amat, Ecole Pratique des Hautes Etudes (EPHE), Paris, France.*

□ ZUSAMMENFASSUNG □

Dis Sedimentverfrachtung in der Little Sarasota Bay wird im wesentlichen durch Tideströmungen gesteuert. Die feinkörnigen Sedimente bestehen hauptsächlich aus Quarzsand mit Muschelschill, phosphoritischen Körnern und Schlick. Die drei grösseren Sedimentmilieus werden durch diese Sedimente charakterisiert: Die niedrig energetische Teil der Bucht, die geschützte Bucht und die offene Bucht. Die beiden erstgenannten Buchtabschnitte sind begrenzt auf die seichten Buchtränder und das Zentrum der Bucht, wo die Strömungsgeschwindigkeit gering ist. Im offenen Teil der Bucht im Norden und Süden herrschen stärkere Strömungen. Durch den dauerhaften Abschluss des Midnight Pass, der direkten Verbindung zum Golf von Mexico, wird der Zentralteil der Bucht eine Sedimentation mit einem erhöhten organischen Anteil erfahren, der möglicherweise die Wasserqualität der Bucht verschlechtern wird.—*Ulrich Radtke, Geographisches Institut, Universität Düsseldorf, F.R.G.*