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## Morphology and sedimentology of the Itaipú Embayment – Niterói/RJ

MARCUS VINICIUS S. SALVADOR<sup>1</sup> and MARIA AUGUSTA M. DA SILVA<sup>2</sup>

<sup>1</sup>CONSUB – 24050-090 Ilha da Conceição, Niterói, RJ

<sup>2</sup>Departamento de Geologia, UFF, Campus da Praia Vermelha, Boa Viagem – 24210-340 Niterói, RJ

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### ABSTRACT

Bathymetric and sedimentological data from water depths between 3 and 28 meters are the basis of a detailed bathymetric map of the Itaipú Embayment and an understanding of its sedimentary dynamics. Shallower than 16 meters the contours are parallel to the shoreline whereas the morphology of the deeper bottom is influenced by the Menina, Mãe, and Pai islands. Medium sand is prevalent, with local variations in more protected or less protected areas. Minor amount of black mud possibly derives from the Itaipú Lagoon. Siliciclastic granules and pebbles may be relict. The Itaipú Embayment's bottom morphology is controlled by stormy waves and the calmer easternmost part of the embayment presents a tendency to accumulate finer sediments.

**Key words:** coastal dynamics, coastal sedimentation, geomorphology, quaternary.

### INTRODUCTION

The main objective of this work is to characterize the morphology and sedimentology of the Itaipú Embayment (Niterói, Rio de Janeiro State). Despite the enormous growth of population along the shoreline in Niterói, no systematic work has ever been carried out in this embayment and, consequently, this original research aims to contribute to projects of coastal planning and management.

The study area extends from the Imbuí Point on the west to the Itaipú Point on the east, containing the Piratininga, Cambainhas and Itaipú beaches, and its seaward limit corresponds to the aligned islands of Pai, Mãe, and Menina (Fig. 1). The water depth varies from a minimum of about 3-4 m (just seaward of the average breaking wave zone) to a

maximum of 28 m, all of these depths pertaining to the shoreface environment. The Itaipú Embayment, a clastic wave-dominated environment, experiences a micro-tidal semi-diurnal variation with maximum spring tidal fluctuation of 1,4 m (DHN 1974). Coastal current velocities rarely exceed 10 cm/s (ECP 1979, in: Lavenère-Wanderley 1999).

There is a regional NE/SW structural alignment of Precambrian rocks that comprise the floor of the Itaipú Embayment resulting from Mesozoic-Cenozoic tectonic reactivation that was characterized by the parallel emplacement of Cretaceous dike dikes (Asmus and Ferrari 1978, Ferrari 1990). Quaternary sandy sediments make up the barrier beaches (DRM/RJ 1981). Of the two lagoons, Piratininga and Itaipú (Fig. 1), only the Itaipú has an open tidal inlet through the Itaipú Canal which was artificially opened at the end of the 70s. Local

Correspondence to: M. Augusta M. da Silva  
E-mail: augusta@igeo.uff.br

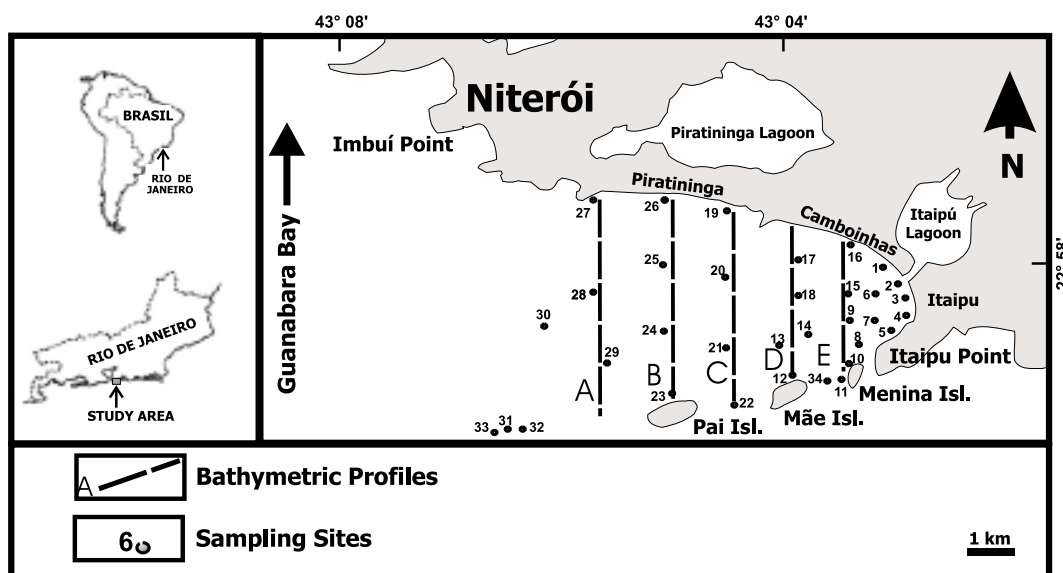


Fig. 1 – Location of the Itaipú Embayment (Niterói/Rio de Janeiro) and sampling sites and bathymetric profiles.

drainages to the lagoons do not deliver great amounts of sediment. Waves coming from S and SE reach the Itaipú Embayment after suffering diffraction by the Itaipú Point and the islands; the important SW storm waves are less frequent, occurring mainly in autumn and winter, but play an important role in the dynamics of this embayment and on the beaches (Lavenère-Wanderley 1999). The work of Muehe and Sucharov (1981), about sediment transport in the continental shelf near the Maricá Islands (Rio de Janeiro), states that, although not frequent, southwest winds associated with cold fronts present the maximum velocities and cause the highest storm waves observed in this region. Similar south winds, also from cold fronts, play an important role in shaping the bottom morphology between the Pai, Mãe and Menina Islands (Muehe and Sucharov 1981).

The Itaipú Embayment's bottom morphology as mapped in 1987 by the Diretoria de Hidrografia e Navegação (DHN) was used as reference in this work. Muehe et al. (1977), Muehe and Sucharov (1981), and Muehe (1984, 1989) present information about the topography of beaches and the inner shelf based on profiles located at the center of the

shorelines between Niterói and Cabo Frio and sediment distribution along these profiles. Our work is a more detailed description of the submarine morphology and the sedimentary cover of the Itaipú Embayment.

This coastline, and other shorelines of Rio de Janeiro, are undergoing enormous growth of population, coupled with intense deforestation of hill slopes and basic sewage treatment that is not appropriate. Itaipú is a traditional fishing village, and both the beaches and the calm waters of the embayment are an important leisure area for the communities of Niterói, other nearby towns, and the city of Rio de Janeiro.

#### MATERIALS AND METHODS

The submarine morphology of the Embayment was initially characterized through two 1987 DHN Charts (FB-1511-002/87, FB-1511-003/87), with bathymetric lines contoured at every 50 m. On the basis of these data, a map was produced (1:10.000), using the software Autocad 14 (datum Córrego Alegre) with isobaths spaced at intervals of one meter. New bathymetric data were collected from specific

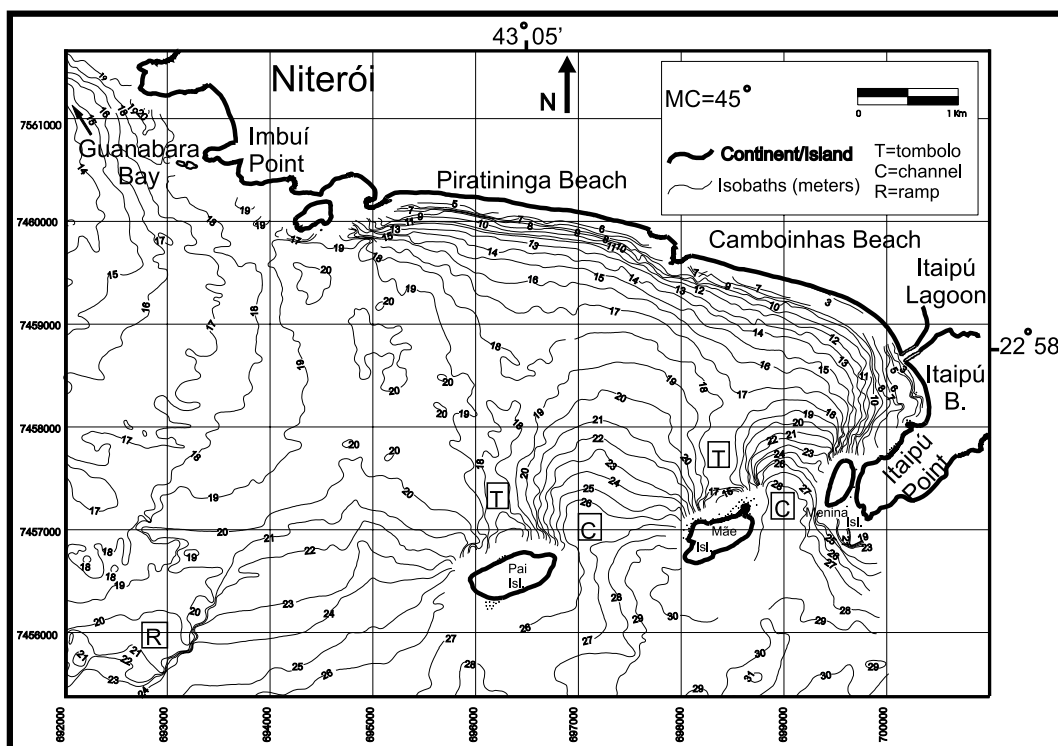


Fig. 2 – Bathymetric map of the Itaipú Embayment based on data collected during this work combined with data from DHN (1987).

sites not covered by previous DHN works, mainly in the vicinity of the Itaipú Canal in water depths between 3 and 6 m. The results of the field work associated with the 1987 DHN charts gave rise to the bathymetric map presented in Fig. 2. For the field work, the following equipment was utilized: DGPS Fulgro Seastar with satellite ‘Link’, computer with Hydro 6.0 for navigation, Raytheon 719-C.

Based on the topography shown in this map, five bathymetric profiles were selected along which we accomplished sampling (Fig. 1). A total of 34 samples were collected using a Dietz-Lafond sampler and positioned with a GPS. The samples were sieved for grain size analysis and interpreted with the program Grânulo (Lagemar – UFF), according to Folk and Ward (1957). Samples of fine sediments were sent to the Geosciences School, Queen’s University of Belfast (Northern Ireland), for geochemical analyses as described by Bernas (1968).

## RESULTS AND DISCUSSION

### SUBMARINE MORPHOLOGY OF THE ITAIPU EMBAYMENT

Between 3 and 16 m water depth, the trend of the submarine morphology is parallel to the coast (Fig. 2), but deeper than the 16 m isobath the bottom morphology is distinctly different. North-trending channels are present between the islands at depths of about 26 to 28 m, becoming shallower shoreward. A less well defined channel also occurs west of Pai Island, and at about 2500 m to the southwest there is a ramp with a slope gradient of 1:10, changing from a depth of 21.5 m to 24.5 m within a distance of 30 meters. The position of this feature coincides with the northeast/southwest regional structural alignment of the three islands, suggesting that such feature is also part of the basement.

Between the islands of Pai and Mãe and the

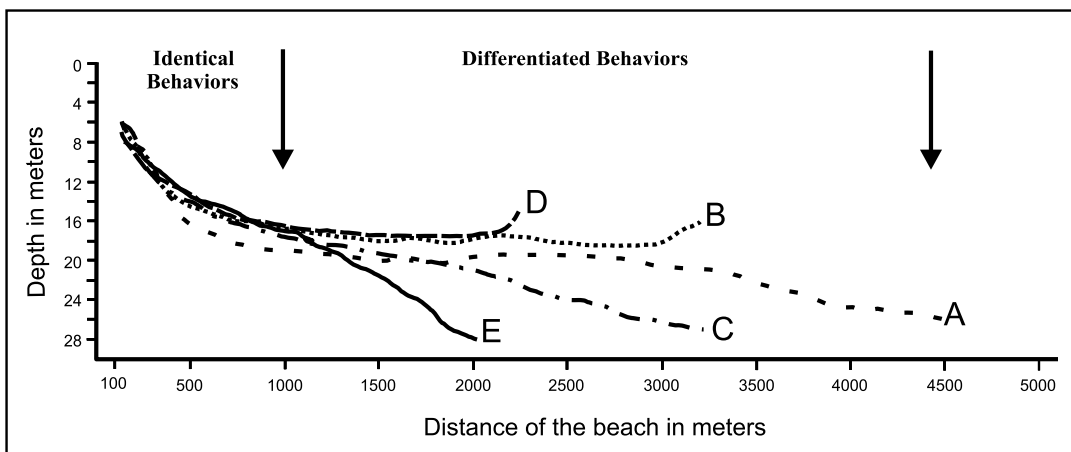


Fig. 3 – North-south oriented profiles characterizing the bottom of the Itaipú Embayment (location in figure 1).

shore, at water depths of about 18 m, bathymetric highs trend perpendicular to the shoreline for a distance of about 1500 m from the islands (Fig. 2). The bottom morphology of these highs is reminiscent of a tombolo, a shadow zone for wave propagation and a calm location for accumulation of sediments.

Five mutually parallel north/south profiles are shown in Fig. 3. Profile A is very steep and deep within the first 1 km from the beach probably governed by southwest high-energy waves associated with cold fronts as observed on the nearby Piratininga beach profiles (Bastos and Silva 1995). Farther seaward than 1 km, profiles A, C and E (Fig. 3) present a uniform seawards inclination and they pass between the islands with channel-like shapes, whereas profiles B and D (Fig. 3) located between the islands and the shore show a concave shape due to the sediment accumulation near the islands as in a tombolo. The existence of these channels is due basically to wave diffraction as described by Duxbury and Duxbury (1993). Although diffraction occurs with all the waves, only storm waves can reach the local sea bottom to mobilize sediments. The channel between Pai Island and the ramp (Fig. 2) may also have originated by wave diffraction, though during a lower sea level stand. These five profiles resemble what Barrel (1912, *apud* Niedoroda et al. 1985)

define as shoreface, in which a concave surface just beyond the surf zone slopes offshore with a gradient of 1:200.

#### SEDIMENT DISTRIBUTION

The Itaipú Embayment bottom is mainly covered by quartz-rich sand; granules and pebbles of biological detritus are minor (except in samples 31 and 32), and silt and clay fractions occur only locally (samples 11 and 34).

Although grain size analysis shows that the quartzose sandy sediments are anything from very fine to coarse, most of the embayment floor, at water depths less than 30 m, is covered by medium size sand consisting of well reworked and shiny quartz (Fig. 4). Fine sand occurs as a long strip beginning at the nearshore of the center of the Camboinhas beach and extending towards the Itaipú beach, plus other minor isolated bodies (Fig. 4).

The occurrence of fine sand is most probably related to reworking of tidal inlet sand by storms; storms working in conjunction with ebb tidal currents move the sand out which then forms bars at the inlet mouth. Lagoonal-derived finer sediment is seen as plumes coming out of the Itaipú inlet after heavy rainstorms, (especially in summer time) and moving to deeper waters of the embayment (Silva et al. 1997).

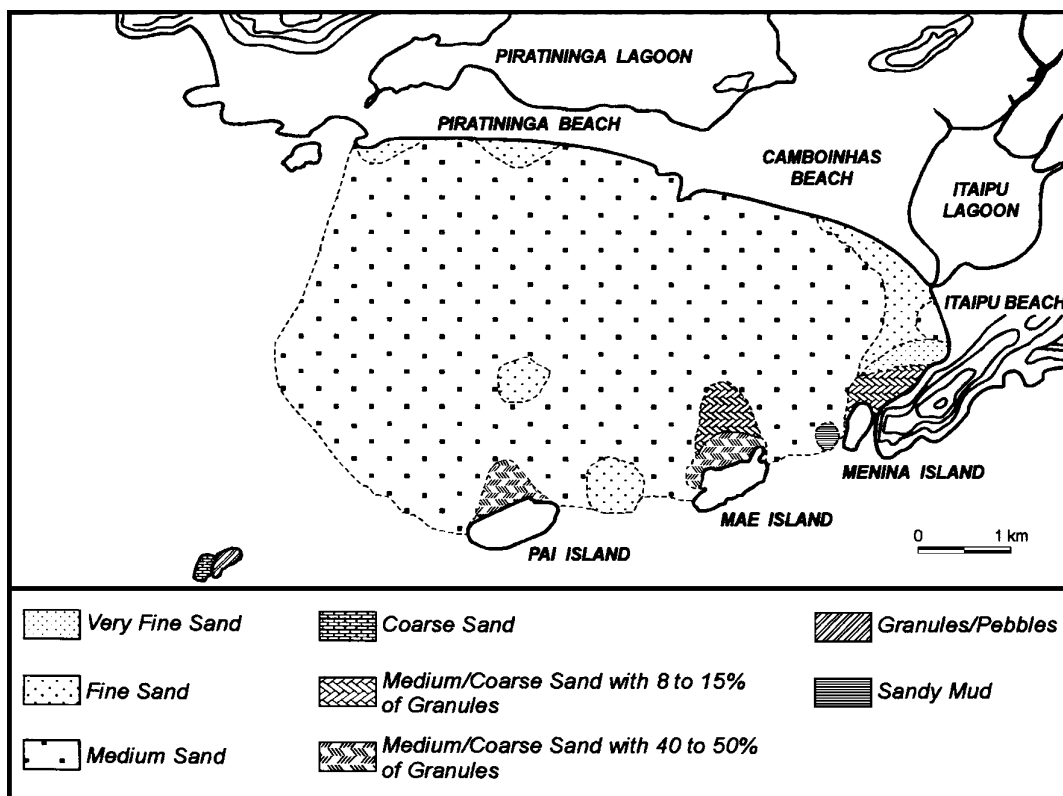


Fig. 4 – Distribution of bottom sediments in the Itaipú Embayment.

Submarine regions off the eastern part of Piratininga Beach (water depths less than 3 m) and off the western part of Camboinhas do not contain fine sand, possibly as a result of diffraction of south-advancing storm waves passing through the Pai and Mãe Islands, causing dissipation of wave energy where fine sands persists, and concentration of wave energy in regions of coarser sand.

Near the Itaipú Point and on the landward side of the islands, medium to coarse sand and granules predominate, with abundant biological detritus (Fig. 4), eroded from nearby islands and cliffs.

About 2500 meters west of Pai Island, where water is deeper than 20 m, the bottom sediment consists of quartz-rich coarse sand and granules (Fig. 4); a diabase pebble was collected 150 m northeastwards of this site. The coarser sediments

are probably relict deposits left as the shoreline retrograded during the last stages of the Post-Glacial Transgression, as proposed by Muehe (1989) for similar nearby deposits.

Muddy sediment was found only in two samples (11 and 34) collected between Mãe and Menina Islands (Fig. 4). Black color, characteristic of an anoxic environment, probably indicates a contribution of fine lagoonal sediment through the Itaipú Inlet after heavy storm rains, especially at times of ebb tides (Silva et al. 1997). The plume of fine sediment survives at water depths around 28 m, below normal wave base. The concentrations of Ca, Mg, Na, K, Fe, Mn, Zn, Cu, Cr, Ni and Pb were investigated for the recognition of potential sources (Table I). The concentrations of Cu, Cr and Ni proved to be useful for correlation to nearby source environments

TABLE I

Results of geochemical analyses carried on samples from the Itaipú Embayment compared to nearby coastal areas.

Samples	Ca	Mg	Na	K	Fe	Mn	Zn	Cu	Cr	Ni	Pb
11-Itaipú Embayment*	43250	10500	1950	4950	37250	575	137.5	37.5	120	32.5	60
34-Itaipú Embayment*	33500	11750	17250	6000	36000	550	135	75	112.5	47.5	57.5
Jurujuba Embayment (maximum)*	82500	20000	60000	15000	21250	412	338	212	230	79	122
Jurujuba Embayment (minimum)*	2000	6250	6250	6875	11250	125	162	40	79	44	45
Itaipú Lagoon (maximum)**					35250	155	85	35	227.5	35	30
Itaipú Lagoon (minimum)**					11000	102.5	32.5	12.5	117.5	15	5
Rio de Janeiro Port***						138.4	418.6	104.7	48.9	13.3	93.4
Close to centro of the Bridge Rio/Niterói***						166.1	199.5	43.3	25.1	8.4	41.7
Guanabara entrance***						74.6	172.5	27.2	20.4	5.6	24.7
Close to bridge and port of Rio/Niterói****								76.2	39.6		96.8

Obs.: values in ppm. – \*Baptista Neto (1996); \*\*Lavenère-Wanderley (1999); \*\*\*Perin, Fabris, Manente, Wagener, Hamacher and Scotto (1997) and \*\*\*\*Haekel, Schroeder, Felsen, Rebello, Moreira and Santelli (1985).

(Baptista Neto 1996, Haekell et al. 1985, Lavenère-Wanderley 1999, Perin et al. 1997). Cu values are similar to those in the Itaipú Lagoon and in parts of the Guanabara Bay; Cr and Ni resemble those in the lagoon and average values found in the Jurujuba Sound, Guanabara Bay. These preliminary geochemical results corroborate the observations that sediment plumes exiting through the Itaipú inlet are the main sources, although sediment in Guanabara Bay may contribute with small amounts of these elements.

#### CONCLUSIONS

The bottom morphology of the Itaipú Embayment is clearly controlled by the influence of Itaipú Point and by the Pai, Mãe, and Menina islands which are obstacles to wave propagation. Wave diffraction in-

fluences the formation of channels between the islands, and sediment accumulations on the protected side of the islands, producing tombolo-like features. At depths below the 16 m isobath the average bottom gradient is 1:200, corresponding to the lower shoreface. Between 3 and 16 m the isobaths are parallel to the shoreline with a 1:90 gradient, which is quite steep for the upper shoreface (Barrel 1912, apud Nedoroda et al. 1985). To the Southwest, the ramping bottom morphology follows the trend of the Pai, Mãe, and Menina islands, suggesting control by the northeasterly grain of the basement.

The Itaipú Embayment sedimentary cover, mostly medium sand, is typical for the ocean side coast of Niterói. Other sediment includes coarser biotrital deposits on the landward-facing side of the islands and at the base of the Itaipú Point, and minor isolated deposits of fine sand. Coarse terrige-

nous sediment at 21 to 24 m is a relict from bottom reworking during the last sea transgression and retained behind a topographic barrier. Muddy sediment (over 60% of fine particles) in two samples has a source in the Itaipú Lagoon. Concentrations of Cu, Cr and Ni in the mud suggest a source in seasonal plumes of sediments exiting through the Itaipú inlet.

Storm waves are the dominant control of the Itaipú Embayment bottom sedimentation and morphology, also influenced by the configuration of Precambrian basement. Quiet waters in the eastern part of the embayment provide a suitable environment for accumulation of fine sediment.

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#### RESUMO

Dados batimétricos e sedimentológicos coletados na enseada de Itaipú, em lâminas d'água variando de 3 a 28 metros, produziram um mapa batimétrico detalhado bem como permitiram a compreensão da dinâmica sedimentar dessa parte do litoral de Niterói. Os contornos batimétricos entre as isóbatas de 3 e 16 m exibem um comportamento paralelo a linha de costa, enquanto que a morfologia de fundo em profundidades superiores a 16 m é influenciada pelas ilhas da Menina, Mãe e do Pai. Areias médias predominam no fundo da enseada de Itaipú, com variações locais em áreas mais ou menos protegidas. Uma pequena ocorrência de lama preta possivelmente deriva da laguna de Itaipú. Grânulos e seixos siliciclásticos podem ser relíquias. A morfologia de fundo da enseada de Itaipú é controlada pelas ondas de tempestades e o seu lado mais calmo a leste apresenta tendência de acumular sedimentos mais finos.

**Palavras-chave:** dinâmica costeira, sedimentação costeira, geomorfologia, quaternário.

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