Origin of Mud Deposits in a Wave Dominated Shallow Inner Continental Shelf of
the State of Paraná Coast, Southern Brazil


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ABSTRACT


This study attempt to figure out the origin of mud sediments founded in the wave dominated inner shelf of the State of Paraná, southern Brazil. Cores were performed by scuba diving in depths of 8 meters and 14 to 16 meters. In the nearshore, between depths of 6 to 10 m, there is a 2 km wide zone of mud and very fine sand sediments. The cores show silt and very fine sand laminate sequences suggesting changes in environmental energy. It could be possible that the sets were deposited on the shallow inner shelf during fair wave conditions and after populated by benthic organisms, resists the action of coastal currents. Micropaleontological analysis and AMS radiocarbon dating performed on organic mud sample that gives 1,517-1,189 calibrated C years BP supports this hypothesis. The mud found in the cores at 14 to 16 meters water depths gives 40,000 and 46,000 C years BP. Blysmaphaera brasiliensis, an organic test foraminifer occurs in the Pleistocene mud samples in levels with high rates of vegetal debris that could be preserved in acidic pH closed environments.

ADITIONAL INDEX WORDS: Late Pleistocene, relic sediments, energy fence.

INTRODUCTION

The study area of the shallow inner continental shelf of the State of Paraná is located near 7160000 S and 760000 W UTM coordinates 22J zone WGS 84 datum in south Brazil (figure 1). There are two estuarine complexes near the area: Paranaguá Bay in the north with approximately 612 km² of total liquid surface area (KNOPPERS et al., 1987) and Guaratuba Bay in the south with 48 km² (1990).

There are two wave preferential systems in the region, from E/NE and SSE/SE (PORTOBRAIS, 1983). Waves from SSE/SE occur associated with frontal systems with high wave energy episodes and appear to rule local dynamics as well as the estuaries. The wave period varies between 4 and 12 seconds and the significant wave height is between 0.4 and 1.3 meters (MARTINS, 2002). The tidal range is 1.5 meter (MARONE and CAMARGO, 1994) and it is a wave dominated coast according to ANGULO and ARAÚJO (1996).

Sampling sediments in the study area there were found (a) superficial mud sand sediments between 6-10 m depth, until 40% of silt and clay (VEIGA et al., 2001) and (b) mud with wood fragments in depths of 14 - 16 m under 20 - 80 cm of coarse sand (VEIGA et al., 2002).

Attempt to figure out the origin of these mud sediments in a wave dominated inner shelf, grain size analysis, foraminifer identification and radiocarbon dating were performed.

METHODS

The cores were taken by scuba diving using 1 m long and 75 mm of diameter aluminum pipes and 1.5 meter long and 50 mm of diameter PVC pipes. Scuba divers made 2 cores in the near to coast fine sediment belt at 8 meters water depth, 20 cores near Currais Island in 14 to 16 water depths and 18 in front of Matinhos beach in 14 to 16 meter water depths (figure 2).

The method consists of introducing the pipe with a 5 Kg hammer, then close the upper mouth and take it off. Next, close the bottom mouth and transport it with the topside up to the surface to preserve the structures. At the boat take off the upper cap, carefully throw out the excess water and always leave to dry with the topside up. Finally dry it was open with a circular saw.

Grain size analyses were performed according the method described by SUGUIO (1973) for the sand fraction and to CARVER (1971) for silt and clay fractions. Intervals of 0.5 phi was used to sand sediments and 1.0 phi to clay and silt sediments. The results were processed in SysGran program to obtain the statistic parameters. Depths were obtained from the Nautical Chart 1824 (DHN, 1961) and adjusted by local field observations using echo bathymetry, all data reduced to mean sea level.

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Figure 1. Bathymetric contours of the study area. The shallow area on north corresponds to the Paranaguá bay ebb tidal delta.
One wood fragment sample and one mud sample were dating by $^14$C conventional method on Laboratório de $^14$C of CENA/USP. One core of 50 cm thick of mud was used to perform the AMS (accelerator mass spectrometry) $^14$C dating on the Radiocarbon Dating Laboratory. This $^14$C age was calibrated with the program CALIB 4.4 (STUIVER & REIMER 1993) and a $\Delta R$ of 63 ± 29 years (ANGULO et al., submitted).

RESULTS

In the nearshore, between depths of 6 to 10 m, a wide concentration zone of very fine sand and coarse silt with silt and clay rates between 20% and 40% was found (figure 2).

The cores performed at 8 m depth in this zone, two sequences of coarse silt to very fine sand laminae set and bioturbated silt layers with erosional contact were observed (figure 3A). Silt layers contain high organic matter rates (5 to 12%). Dating performed on an organic mud sample gave 1,517-1,189 calibrated $^14$C years before present (B.P.). The 14 to 16 meters water depths PVC cores shows a very compact mud sediments sequence apparently without sedimentary structures (figure 3B). In Matinhos, this mud occurs on 39% of the cores and in Currais in 50% of the cores performed. Two samples that occur at 70 cm below bottom surface gives Pleistocene ages 40,600 +2,250/-1,750 (CENA-433) (Currais site) and 46,700 +5,800/-3,350 (CENA-434) (Matinhos site) $^14$C years B.P. (figure 2).

Foraminiferal analysis of the Holocene sediments samples indicates a shallow inner continental shelf typical fauna, the same that occurs in the surface bottom sediments at present days (DISAR et al., 2001).

In the Pleistocene mud with wood fragments samples were found an unusual foraminiferal assemblage. The *Blysmashaera brasiliensis* BORNIMANN, 1988 occurs alone in some levels with high rates of vegetal debris.

DISCUSSION AND CONCLUSIONS

The fine sediment belt that occurs at 6 to 10 meters water depth (figure 4) doesn’t seem to agree with the local environmental energy because wave action should not allow this grain size sediment deposition. The laminae set suggests changes in environmental energy and the erosional contact between the sets suggests high-energy episodically erosional events One hypothesis for the occurrence of that mud zone is that the sediments could be relic. The wave erosion could expose Holocene back barrier lagoons or the Pleistocene substratum. Holocene back barrier lagoons were described by LESSA et al. (2000) in the near coastal plain, below sand barrier sediments, between 6 ± 2 and 14 ± 2 meters below mean sea level and could be the same mud layer that outcrop in the inner continental shelf.

The second hypothesis is that the mud sediments can be deposited in the present environmental conditions.

The fine sediments found at 14 to 16 meter water depths appear to be different from the mud found at 8 m depth. The wood fragments were bigger and well preserved. Besides, occurs below fine, medium and coarse sand sediments layers (20 to 80 cm thick) and not in the surface bottom sediments.

Field and satellite image observations show a high concentration of suspended sediments coming out of these estuarine complexes as described by NOERNBERG (2001) (figure 5). The supply of fine sediments to the inner platform could be large in rainy periods. This fine sediment could be trapped close to the surf zone by the "littoral energy fence" proposed by ALLEN (1970) that describes "shoaling and breaking waves create a landward directed bottom stress that move sediments towards the shore". However, SWIFT and THORNE (1991) affirm "the coastal fine-sediment budget is more complex; several hydraulic mechanisms work together to move suspended fine sediments landward, against the concentration gradient". It could be possible that fine sediments were deposited on the shallow inner shelf during fair wave conditions. After deposited and populated by benthic organisms, the mud sediment can resist the action of coastal currents.
The dating of 1,517-1,189 calibrated \(^{14}C\) years before present could be interpreted as a mean age of the entire 50 cm sample core dated. Therefore, the superficial mud could be deposited at present time. More detailed dating are necessary to confirm this hypothesis.

The foraminiferal assemblages of the core samples are typical of shallow inner shelf waters and are similar to that found in the present surface bottom sediments.

Holocene back barrier lagoon does not seem to occur in the area. The sediment pack described by LESSA et al. (2000) apparently was deposited in the shallow inner shelf environment. SOUZA et al. (2003), analyzing cores and profiles adjacent to the study area, discard the occurrence of a Holocene back barrier lagoon when interpret fine sediments sequences presence between Holocene transgressive sand bodies.

The mud layer found at 14 to 16 meters water depths that gives Pleistocene ages is different because there are no sediment structures or bioturbation preserved. This sediment could be deposited during an ancient shallow marine inner continental shelf environment or in a lagoon or estuary.

The occurrence of well-preserved wood fragments is not a good indicator of a close deposition environment because SOUZA et al. (2003) describes wood fragments levels in Holocene shallow continental shelf sediments at the adjacent coastal plain and interpret as a transported material from the near estuarine complexes.

The foraminifer *Blysmasphaera brasiliensis* occurs in mangrove ecosystems inside the Paranaguá estuarine complex at the present days. According to BRÖNNIMANN (1988) *B. brasiliensis* is common in some of the samples of brackish water sediment in the mangrove areas of Guaratiba, Rio de Janeiro, and of Acupe, Bahia, Brazil, but rare to very rare in the marine shallow water sediments of Campos Shelf and the Baia de Sepetiba, both localities near Rio de Janeiro. After him, in the samples from the marine sediments, *B. brasiliensis* occurs probably alochtonous, carried from the mangrove areas into the bay to the shelf. However, *B. brasiliensis* occurrence in the Pleistocene mud samples has a singularity. In some levels it occurs alone with high rates of vegetal debris. This species has an organic test that could be preserved in acidic pH closed environments were calcareous tests are not usually well preserved.

Although those evidences indicate that the mud was deposited close to the continent, the tests of *B. brasiliensis* could be transported easily and is not possible to confirm the depositional environment based on these data.