# RESPONSE IN THE SEDIMENTATION OF THE CHANGES IN THE UPWELLING PROCESS IN CABO FRIO, SOUTHEASTERN BRAZIL.

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**RESUMO**
Análise de testemunhos rasos na região de ressurgência de Cabo Frio revela mudanças na paleotemperatura superficial e nas características dos sedimentos, principalmente nos indicadores de matéria orgânica, aproximadamente nos últimos 700 anos, que podem estar relacionados a variações na extensão e deslocamento da região de ressurgência. Apesar da aparente ausência de ciclicidade, os dados demonstram a ocorrência de alternâncias na intensidade dos ventos SE, o que poderia ocasionar variações nos processos de ressurgência.

**ABSTRACT**
Analysis of sedimentary columns in the Cabo Frio upwelling zone reveals changes in the surface paleotemperature as well as in the sediment characteristics, mainly bulk organic matter indicators during the last ca. 700 years, which can be associated with changes in the spreading as well as in the displacement of the upwelling area. Despite the apparent absence of cyclicality, the data reveal the occurrence of phases of the alternating weakness and strength of the SE winds, which diminished the intensity of the upwelling process.

Palavras-Chave: sedimentation, bulk organic matter, upwelling, Holocene, Brazil, South Atlantic.

## 1.INTRODUCTION

Upwelling zones are considered key areas for the comprehension of the Quaternary climatic changes. Due to this fact the western South Atlantic tropical and subtropical margin, which is characterized by the displacement of the warm and oligotrophic waters of the Brazil Current (BC), is much less studied, when compared to the eastern South Atlantic (Cohen and Tyson, 1995; Ternois et al., 2000; Sicre et al., 2001).

The Cabo Frio upwelling zone seems to be one of the exceptions to this oligotrophic pattern due to the occurrence of a very well studied present upwelling phenomenon. Systematic measurements of the upwelling process have been made since the 1920’s (Böhnecke, 1936; Emilsson, 1959, 1961; Silva and Rodrigues, 1966; Ikeda et al., 1974; Miranda and Castro, 1979). More recent works deal not only with the role played by the wind regime but also with the relationship between the coastal upwelling and the meandering of the Brazil Current (Castro and Lee, 1995; Lorenzetti and Gaeta, 1996; Castro and Miranda, 1998; Campos et al., 2000), as well as with the primary productivity (Valentin, 1984a, 1984b).

## 2. STUDY AREA

The Cabo Frio region represents a conspicuous coastline change in the South American shoreline and marks the limit between two distinct oceanographic, physiographic and sedimentary provinces of the Southwestern Atlantic Margin.

The occurrence of upwelling in the Cabo Frio region is caused by an almost 90$^o$ change in the orientation of the coastline, from N-S to the north, to E-W to the south. The origin of this change is related to the Tertiary reactivation of the Brazilian Shield, which led to the uplifting of the Serra do Mar range as well as to the outcropping of several alkaline intrusions such as the present Cabo Frio Island.

The present upwelling is thus the response of the interaction of a tectonic-controlled coastline change to the wind regime and the BC displacement. During the summer, with the prevalence of NE trade winds, the Coastal Water (CW) is displaced oceanwards, favoring the upwelling of the cold waters of the South Atlantic Central Water (SACW). The more constant and effective the trade wind the greater is the area of the ocean surface covered by the cold upwelled waters. Analogously, winds coming from the south, related to the displacement of the Polar Anticyclone, reduce the occurrence of upwelling in the area. In a quasi-daily experiment, in 2001, Silveira et al. (2002) identified the upwelling of 14$^o$C waters at a vertical speed ranging from 2.8 to 3.2x10$^{-4}$ m.s$^{-1}$. Subsidence of the SACW was observed in July 2001, when the passage of a cold front over the region with SE winds allowed the displacement of the Tropical Water (TW) domes towards the coast with temperature higher than 20$^o$C and salinities exceeding 37.

## 3. MATERIALS AND METHODS

Eight box cores were collected during the cruise of the R.V.Prof. W. Besnard (Figure 1). The cores were subsampled continuously at intervals of 2 cm and the subsamples were immediately frozen and later freeze-dried. Due to the lack of sufficient well preserved carbonate material it was decided to use the organic fraction of the sediment for AMS $^{14}$C dating. Calibrated ages were obtained with the Calib Software (Stuiver et al., 1998). For the organic fraction datings we used a $\delta^{13}$C end-member model for terrestrial (-26.0‰) and marine (-19.0‰) organic matter based on the results obtained by Mahiques et al. (1999).

For evaluation of surface paleotemperatures we determined the alkenone unsaturation values ($U^{K'}_{37}$), by means of a 6890 Agilent Gas Chromatographer equiped with FID, using the methodology described in Gogou et al. (1998), Villanueva and Grimalt (1999), and Benthien and Müller (2000).

Grain size was determined with a Malvern 2000 Laser Analyser. Calcium carbonate was determined by weight difference prior to and after the acidification of each sample with 1N HCl.

Organic carbon, total nitrogen, and total sulfur were determined with a LECO CNS200 Analyser after the total elimination of the calcium carbonate of the samples with 1N HCl.

δ13C (reported in ̣o PDB) and $\delta^{15}N$ (reported in ̣o Air) analyses were performed with a VG-SIRA 10 Mass Spectrometer at the Coastal Science Laboratories (Austin, USA).

## 4. RESULTS

The variations of paleotemperatures and sedimentological parameters along the core 6949 are shown in Figure 2.

There is a general trend of cooler temperatures towards the present. Temperatures decrease approximately 3°C from ca. 650 years B.P. to 350 years B.P. (Figure 2).

Figure 2 reveals a change in sedimentological parameters approximately in ca. 550 years B.P.. In the base of the core (between ca. 700 and 550 years B.P.), we can observe a coarser sedimentation, and the values of $CaCO_3$ are lower (7-9%). From ca. 550 years B.P. up to approximately 300 years B.P., a fining-upward is observed. The finer sedimentation is accompanied by an increase of $CaCO_3$ content (up to 14%). Higher values of total nitrogen (0.20) and a decrease in C/N ratio, $\delta^{13}C$ and $\delta^{15}N$ are observed in this interval.

Upwards from ca. 300 years B.P, the sedimentation becomes coarser.

## 5. DISCUSSION

The results show that during the last ca. 700 years the Cabo Frio upwelling zone was submitted to oceanographic changes that were reflected in variations in paleotemperatures as well as in the sedimentation in the area. Together with grain size and calcium carbonate, the bulk organic matter parameters indicate that the amount as well the nature of the organic sources changed in such a way as to allow them to be interpreted as due to oscillations in the intensity of the upwelling process.

The period before ca. 550 years B.P. seems to represent a phase of lower levels in the primary productivity in the Cabo Frio region in comparison with the present day conditions. Assuming that a decrease of the upwelling is related to the more intense action of the stronger southerly winds which reduces the upwelling, this period can be associated with a cooling of SE Brazil. This period has been identified in other tropical and subtropical areas as the onset of the Little Ice Age (Cohen and Tyson, 1995; Nyberg et al., 2001).

For the period between 550 years B.P. and 300 years B.P., the sedimentological parameters and paleotemperatures indicate conditions of stronger upwelling in the area.

## 6. CONCLUSIONS

The sedimentological and bulk organic parameter variations in box-cores were used better to understand modern upwelling oscillations in the Cabo Frio (Southeastern Brasil) region.

Before ca. 550 years B.P., a more effective action of the southerly winds seemed to reduce the occurrence of upwelling in the area, as observed in the cores. Between ca. 550 and 300 years B.P., data indicate a period of stronger upwelling in the area.

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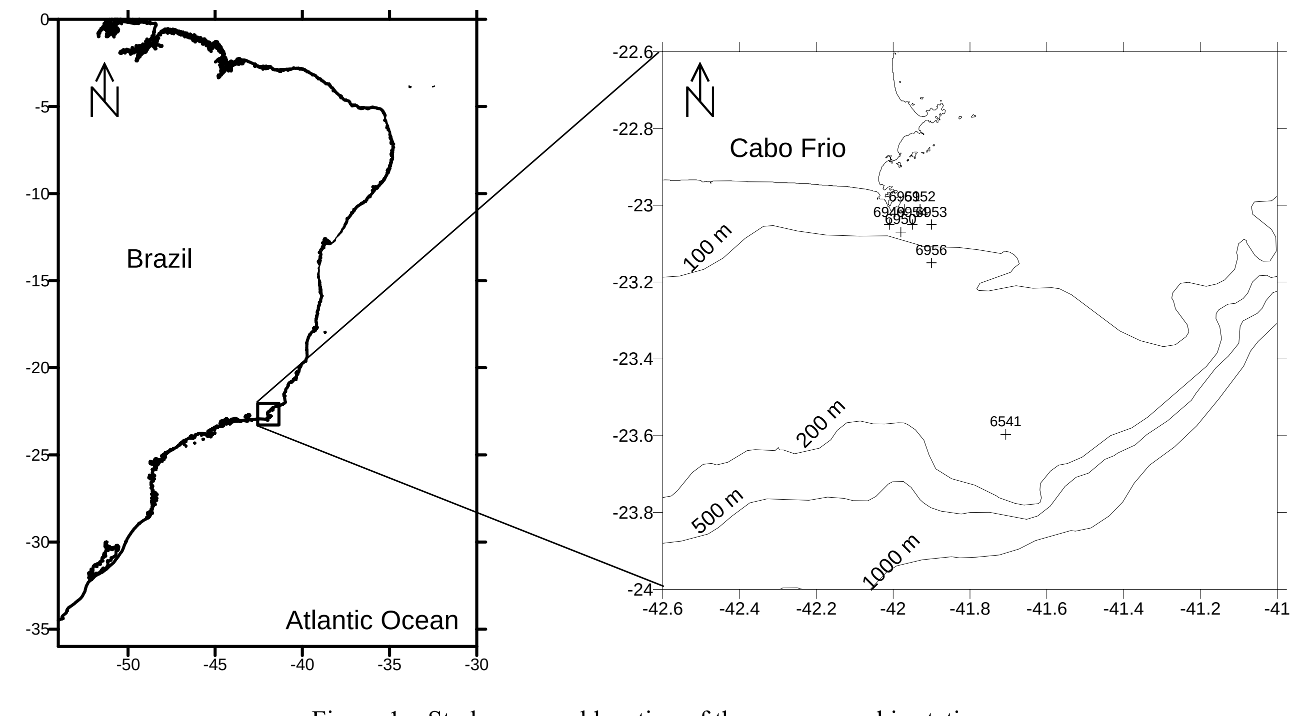


Figure 1 – Study area and location of the oceanographic stations.

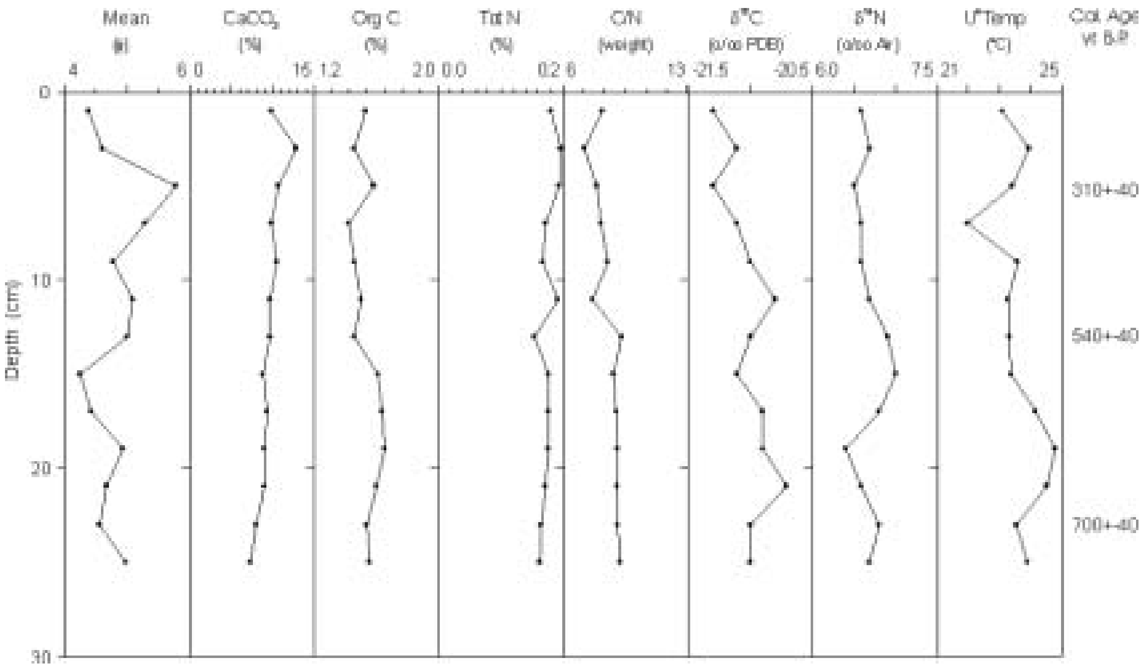


Figure 2 – Sedimentological parameters and paleotemperatures along the 6949 core.