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IN SOUTH AMERICA DURING THE QUATERNARY:
PAST - PRESENT - FUTURE

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VARIATIONS OF THE CABO FRIO (STATE OF RIO DE JANEIRO, BRAZIL) UPWELLING INTENSITY, DURING THE HOLOCENE, RECORDED IN CARBONATE SEDIMENTS OF A HYPERSALINE LAGOON

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The coastal area between Niterói and Cabo Frio (State of Rio de Janeiro) is characterized by the existence of two lagoon systems. One located more to the interior (Maricá, Guarapina, Saquarema, Araruama) is separated from the ocean by a chain of sand ridges. Between them, there is a pratically continuous low zone, parallel to the actual coast line. This depression was occupied by another lagoon system at a time when the sea level was higher. Presently some parts are dry, but between Saquarema and Cabo Frio the depression is still occupied by a series of small lagoons. The Lagoa Vermelha which is the objetct of this study, is the largest of them. The lagoon does not receive any fresh water from subaerial drainage, but possibly it may receive salt water from the neighbouring lagoon of Araruama, via percolation. The large lagoons show a gradient of salinity, increasing from West to East (Maricá 15‰, Guarapina 20‰, Araruama 58‰). Lagoa Vermelha is also hypersaline, but its salinity changes depending on the precipitation.

These hypersalinities are the consequence of a dry microclimate in that region. The precipitation reaches 1400 mm/yr at Maricá, but falls to 750 mm/yr at Cabo Frio. This effect is due to the intermittent occurrence of cold waters in the region of Cabo Frio, as a phenomenon of upwelling controlled by three factors: the local topography of the coastline, the position of the Brazilian Stream axis, and the wind pattern.

ALLARD (1) was the first to point out a relationship between the direction of the wind and temperature variations of the surface water, around the Cabo Frio Island. The occurrence of low temperatures is associated with the predominance of NE winds, and the temperature will go up when the wind turns to SW. In spring time and summer, the wind pattern is disturbed, in the middle and upper trophosphere, by the passage of successive northward waves and, in surface, by the corresponding frontal systems which are associated to SW, South and SE winds. MOREIRA DA SILVA (2) observed that the upwelling happens in two steps: the removal to East of the Brazilian Stream axis causes an up-movement of the Central South Atlantic Waters which remain upon the continental shelf. The NE winds then are responsible for the raising of these waters up to the surface. On the other hand, south winds accompanying the cold fronts provoke an elevation of the coastal waters and thus suppress the cold waters into the depth.

Annual variations in the intensity of the upwelling at Cabo Frio and the possibility of long-term variations.

It is known that the El Ninõ Phenomenon can modify the wind pattern in the South-West Atlantic (3). There is also evident that there were, during the Holocene epoch, several inversions in the direction of coastal sand transport along the Rio Doce coastal plain, and this evidently as a consequence of changes in the direction of the dominant waves which, in turn, must have resulted from modifications in the atmospheric circulation (4). This fact suggests that in the past there were periods of El Niño-like conditions of much longer duration than now. This hypothesis is supported by the existence of an alternation of wet and dry periods, at a secular time scale, in the southern part of Cape Santa Helena at the coast of Ecuador (5). If situations of El Niño-like conditions of long duration occurred during the Holocene epoch, then necessarily also occurred modifications in the intensity of the upwelling at Cabo Frio with all consequences upon the microclimate of that region.

Characteristics of the sedimentation in Lagoa Vermelha

A core of 1 m long was taken at the center of lagoa Vermelha and analysed chemically and mineralogically by SANTELLI (6) - Fig. 1. The core is essentially of organic and carbonate material. The carbonates make up 46-96% of the total. A gamma-ray diffraction analysis showed that there are magnesium calcite, aragonite and dolomite. An electron microscope study revealed the existence of numerous aragonite crystals between 13 and 45 cm depth what indicates that the aragonite must have been precipitated and is not the product of calcareous organisms. Total phosphor is practically constant between 5 and 32 cm, increases then between 32 and 56 cm, and turns back to be constant until the end of the core. This allows to define two distinct phases or periods: an upper one between 5 and 46 cm, and another one below 46 cm. Also the curve of $\delta^{13}C(PDB)$, in the carbonates, leads to the same division of the core. Between 5 and 46 cm, the mean value of $\delta^{13}C(PDB)$ is - 4‰ while below 46 cm it is -10,5‰. In addition, also the $\delta^{18}O(PDB)$ values, measured in the carbonates, lead to the same sub-division of the core. Between 5 and 46 cm, $\delta^{18}O(PDB)$ is more or less constant around +2 ‰, although there are four peaks of significantly less positive values at 18 cm, 28 cm, 36 cm and 46 cm. Below 48 cm the $\delta^{18}O(PDB)$ values are clearly more positive, and even two zones may be distinguished: between 48 cm and 78 cm (average $\delta^{18}O(PDB) \tilde{=} + 3‰$), and between 81 and 93 cm (average $\delta^{18}O(PDB) \tilde{=} + 3‰$).

Conclusions

The surface layer at the bottom of the lagoon is very liquid, and it was therefore not analysed (0 to ca. 5cm). It is, however, a remarkable fact that nowadays there are no molluscs living in the lagoon, while there are many shell in the core between 5 and 46 cm. Moreover, at 5 cm depth, the carbonates are partly dolomite which immediately after disappears and only shows up again in the lower part/period.

From these facts, it looks likely that the existing carbonates precipitated under different conditions than they are now, and that, during the precipitation of the lower part of the core, the environment was clearly more saline. The primary productivity, measured by the P_2O_5 content, was more intensive during that period. The $\delta^{13}C(PDB)$ values show that the lagoon was rich in microalgae, cyanobacteria and photosynthetic bacteria, and that there were only few calcareous organisms existing.

On the other hand, during the deposition of the upper part of the core, the lagoon had evidently a lower salinity and was rich in calcareous organisms. The degradation of algal organic matter, as source of Mg, (lower phase) together with a strong evaporation are responsible for the formation of dolomite during that phase. In the upper part, the change from an environment rich in algae to one rich in calcareous organisms, together with a lower salinity favoured the precipitation of aragonite. The presence of dolomite close to the actual lagoon's bottom and the great abundance of algae together with the absence of molluscs leads to the conclusion that the present conditions in the lagoon are similar to those during the deposition of the lower part of the core.

Considering the Lagoa Vermelha as a closed system (as it is now) over all the time recorded by the core, leads to the conclusion that the registered variations in salinity can only have been caused by variations of the precipitation/ evaporation ratio. For the presence bhis has been proved by parallel analyses of ^{2}H and ^{18}O in water samples from the surface of the lagoon, the ocean, and from a nearby well. They all show a linear relationship between the enrichment in ^{2}H and ^{18}O, a fact from which follows that evaporation is the dominant process in the water balance. Our conclusion is that the water balance of precipitation/evaporation is a function of the microclimate which, in turn, is governed in this region by the intensity of the upwelling.

Unfortunately, we do not yet have samples of the core dated so that the registered climatic changes could not yet be chronologically identified. But this is now under preparation.

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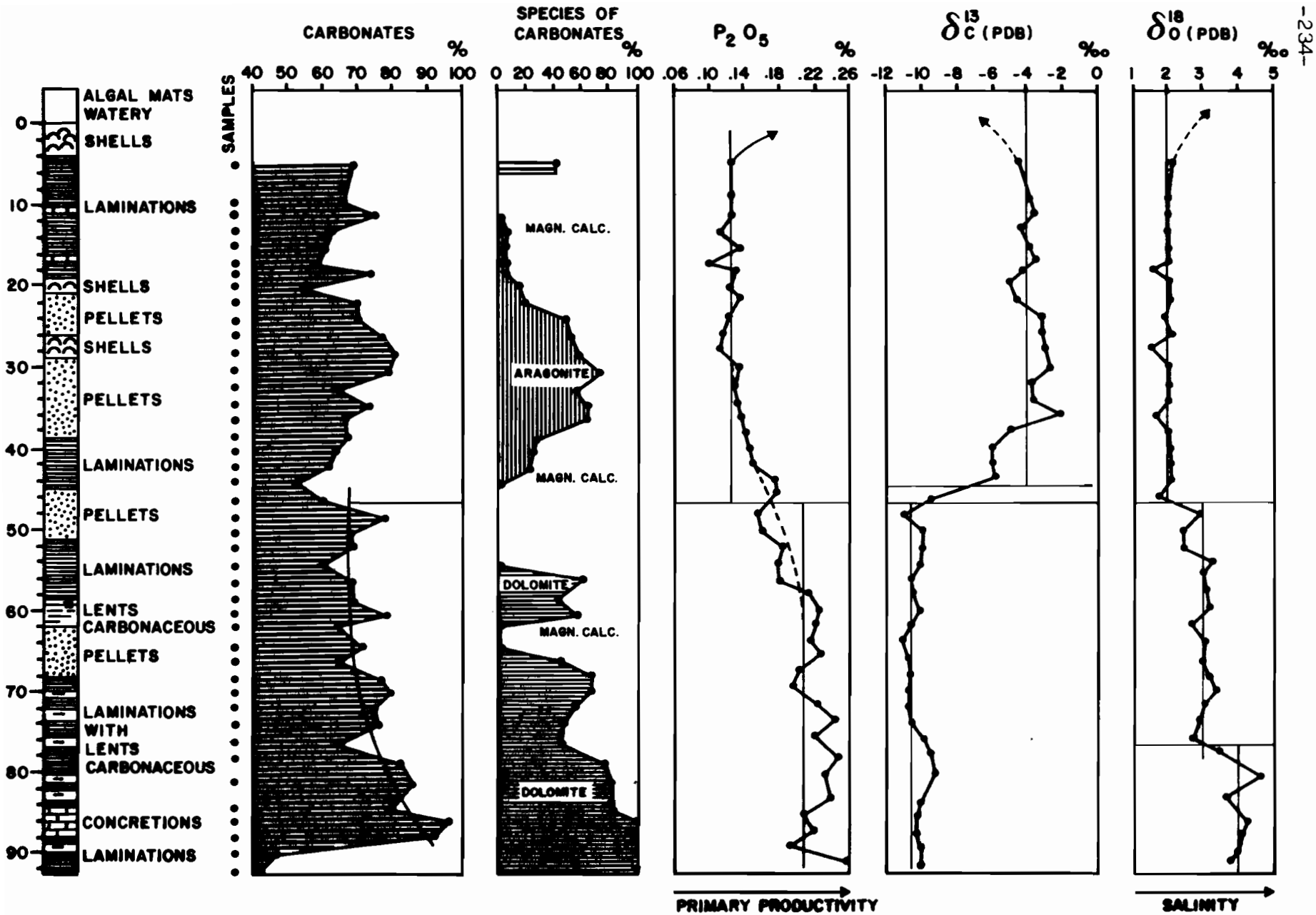
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