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**Coquinas from the Paleolagoon of the Tauá-  
Pântano da Malhada Reserve, State of Rio de  
Janeiro**

*A record of holocenic climatic optimum*

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# Coquinas from the Paleolagoon of the Tauá-Pântano da Malhada Reserve, State of Rio de Janeiro

## *A record of holocenic climatic optimum*

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The Reserva Tauá is a private natural reserve that has approximately 1,0 km<sup>2</sup> and is located on the west limit of the Malhada marsh at the Lagos Fluminenses Region - Rio de Janeiro State, between Cabo Frio and Búzios municipalities. In this humid area has been an important outcrop of coquina in excellent taxonomical and environmental preservation. The Late Holocene geological evolution of this area occurred after 5,100 years BP., was initially determined by a phase of a sea-level rising around 4,8 +/- m above the present one, responsible for drowning of the coastal plain of the São João river and Retiro stream, and an extensive lagoon development. After that a fast regression registered around 4,900 years BP., lead to a gradual sea level falling and to the uncovering of the borders of the lagoon and , consequently a generalized death of several mollusk species, which many of their shells kept in the life position. The main geological record of shells concentration happens along the border of the marsh, but decreases towards the center of the paleolagoon body. The biogenic outcrop, displayed by a recent hollowing, is found at 0,40 m deep. It is characterized by a coquina 0,60 m thickness layer composed by shell fragments of high density and low diversity. Its spatial distribution constitutes one of the most important records of higher sea level during the Holocene in the State of Rio de Janeiro. Thus the coquina of the Reserva Tauá fits in the concept of a geological heritage site, mainly in respect to paleoenvironmental and sedimentological aspects. In the same way the outcrop presents important cultural, scientific and didactic values for the geosciences and environmental sciences.

**Keywords:** coquina, paleolagoon, marine transgression-regression, sea level rise, Reserva Tauá, Cabo Frio, Rio de Janeiro.

## INTRODUCTION

Over the last few years, the importance of geological heritage has received increased attention from the scientific and governmental institutions of the State of Rio de Janeiro within the larger field of natural resource preservation policy. The main institutions involved in this re-evaluation of the importance of geological heritage have been the Coastal Geology and Sedimentology Laboratory of the Museu Nacional/Federal University of Rio de Janeiro (UFRJ), the Geology Department of the State University of Rio de Janeiro (UERJ) the Taphonomic Studies Nucleus of the University of Rio de Janeiro (UNIRIO) and the Department of Mineral Resources of the State of Rio de Janeiro (DRM/RJ).

The outcropping of coquina in the Reserva Tauá (Malhada Marsh in the Fluminense Lakes) has become of central importance within this context, due to its geological uniqueness and for the environmentally preserved state of a deposit of mollusk shells which were created by a marine flooding and regression during the Holocene. The Tauá paleolagoon which contains the coquina deposit was formed before sea-levels rise approximately 5,100 BP. During this period,

sea levels in the region of the Malhada Marsh were about 5.0 m higher than the current level of the center of the paleolagoon and 0.5 m higher than its margins. According to Castro *et al* (2004) and Santana (2005), C<sup>14</sup> dating of the shells situate the formation of the deposit at around 5,034 to 5,730 years BP. The calibrated results of the *Calib Radiocarbon Calibration Program* corroborate Suguio & Martin's (1989) dating of the last flooding event to occur in the region.

Though no solid data exists with regards to the cause of the generalized die-off of the shellfish species in the lagoon, this is attributed to a rapid sea-level regression around 4,900 BP which may have resulted in hyper-salinity within the lagoon environment. The coquina deposit, which is situated some 4.0 m above today's sea-levels, is unquestionable proof of higher earlier sea-levels. Because of this, the Reserva Tauá deposit is mainly covered by those portions of geologic patrimony concept which refer to paleo-environmental sites (such as the environment created by the encroaching seas +/-5,100 years ago) and sedimentological site (such as the paleolagoon complex). The paleolagoon is also a valuable resource for the teaching of geology, oceanography, biology and the study of the environment in general. Finally,

the great beauty of the scenery surrounding the outcroppings site adds to their worth as natural phenomena which should be preserved. Unless the paleolagoon receives official recognition as geologic patrimony, however, it may soon be threatened by environmental degradation caused by urban expansion in the Fluminense Lakes region.

## LOCALIZATION

The mollusk shell deposits in the Tauá lagoon (22°45' S – 42°00' W) is located in the eastern sector of the Malhada Marsh, in the northeastern region of the State of Rio de Janeiro between the municipalities of Cabo Frio and Armação de Búzios, next to the Praia Rasa beach (Fig. 1). One arrives at outcropping (coming from the city of Rio de Janeiro) by following the Amaral Peixoto Highway (RJ-106) to the Tamoios

off-ramp (RJ-102), which leads into the city of Búzios. A dirt road runs some 10 km from Rasa beach into the Reserva Tauá. The Malhada Marsh is contained by low hills (overlying a crystalline base formed by the dissected plates of the Barreiras Formation) and holocenic coastal structures. The area's morphology can be characterized as a plain set at about 4.0 meters above the current sea-level which is overlaid by material mainly made up of dark-colored clayey sands with high organic content. The area's drainage system is made up of the Retiro creek, the Ubá River and several artificial canals. The maritime origins of the biogenic deposit have been confirmed through sedimentological and malacological analysis and the evidence thus far encountered suggests that the connection to the sea which existed in the area some 5.100 years BP ran through Però Beach.

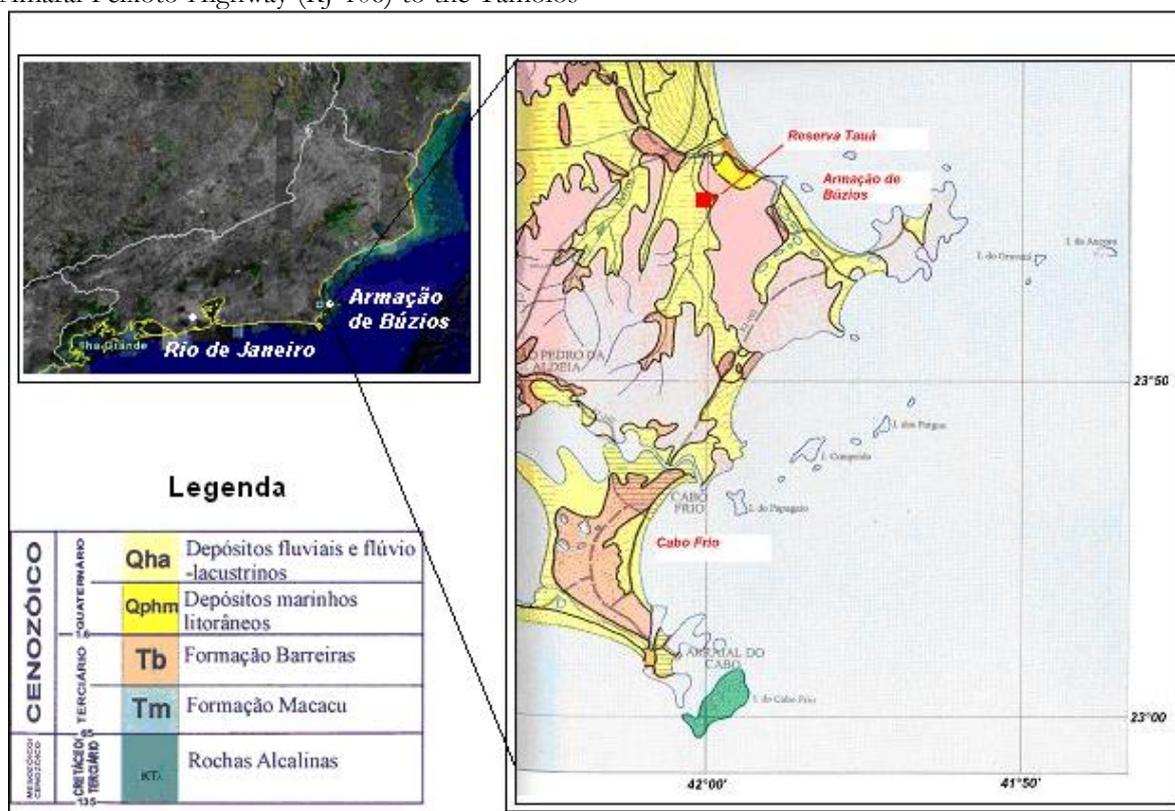


Figure 1: Geological and location map of Reserva Tauá - Malhada marsh / RJ. Source: Martin et al (1997)

## HISTORIC OF STUDIES IN THE AREA

Lamego's work (1945, 1946) was the first to provide a general overview of the Fluminense coastal plain and the coastal environments known in Portuguese as "brejos". Lamego dealt with aspects of the morphological development of the coastal plains, swamps and seaboard, as well as the formation of sandbars and lagoon complexes. He also described the evolutionary process of lagoons and the factors which create them, such as the lateral growth of sandbars and the formation of swamps (coastal marshes).

In 1974, sea level fluctuations along the Brazilian coast during the Quaternary (principally over the last

7,000 years BP) began to be studied by several researchers in the field of coastal geology. This work concentrated on the seaboard of São Paulo, Rio de Janeiro, Bahia and Rio Grande do Sul states. Roncarati and Neves (1976) developed a study of the evolution of the Jacarepaguá coastal plain, identifying the area's different deposits and surface sediments. The data obtained in this study also allows us to interpret and understand depositing processes and sediment transport and depositing mechanisms for the coastal plains and marshes of Rio de Janeiro State.

Dias Jr. et al (1979) conducted the first archeological excavations at Malhada, where they found many artifacts made of chipped quartz and also

several burial sites. The humic layer which they encountered was dated at 700 years BP and is made up of dark grey material with reddish chunks, rich in stone artifacts and burial remains. Bones and shells found at the site were dated at  $4,020 \pm 80$  years BP, demarcating the beginning of human occupation of the Malhada Marsh.

Martin *et al* (1984) conducted the first  $C^{14}$  radiocarbon dating along the Jacarepaguá coastal plain, linking its evolution to sea level variations during the Holocene. Martin *et al* (1996) studied these variations along the central part of the Brazilian coast from a dynamic, historical point of view, emphasizing their consequences for the construction of coastal plains. In *Geologia do Quaternário Costeiro do Litoral Norte do Estado do Rio de Janeiro e do Espírito Santo, scale 1:200.000*, Martin *et al* (1997) furnished further information regarding relative sea level variations and the distribution of quaternary marine and lagoon deposits along the coastline of the above-mentioned region, which includes the marshes of northeastern Rio de Janeiro. In this last work, Martin *et al*. Claims that the region containing the Malhada Marsh was invaded by the sea some 5,100 years BP, forming a lagoon system which was established behind a series of barrier islands. After the seas receded 4,900 years ago, some lagoons began to dry up and began to be replaced by marshes.

Through the process of paleoenvironmental reconstruction, Scheel-Ybert (1999) demonstrated that the vegetation in the region of the Malhada Marsh was made up of several sandbar, marsh and bayou species. This make up did not change during the middle Holocene, from 5,500 to 1,400 years ago. The native inhabitants of this region were perfectly adapted to the surrounding environment, which they dominated, collecting and managing the region's plant life. Though sea-levels during that period were much higher than they are today, the typical vegetation of the region has remained practically unchanged.

Morais (2001) developed a physiological of the deposits of the Barreiras Formation in the region of Rasa Beach. He defined this regional unit as an intertwined, distal, sandy fluvial deposit, varying with a high-energy model with associated gravitational flows. The greater part of the material deposited in the marsh originated in this unit.

Senra *et al.* (2003) developed the first paleoenvironmental of shellfish in the region surrounding the Reserva Tauá and Malhada Marsh, undertaking comparative analyses of the diverse biotic elements found in the coquina deposits. Interpretation of the taxonomic properties of the bioclasts permitted the authors to conclude that these were deposited in varying energy states.

Castro *et al* (2004) undertook the first  $C^{14}$  studies of mollusk shells in the Reserva Tauá area, dating the coquina deposit at around 5,034 to 5,730 years BP.

This study also discovered that the sea level for this period was at approximately 4.5 meters in the center of the paleolagoon and at 0.5 m in the region corresponding to the paleolagoon's paleobeach and transitional zone. The bioclastic material depositing process was possibly influenced by storm waves driving in from the southwestern quadrant at the time when the Arraial do Cabo promontory was not yet connected to the continent. During the marine invasion approximately 5,100 years ago, the paleochannel linking the paleolagoon to the open sea ran through the northeastern extremity of what is today Peró beach in the municipality of Cabo Frio.

Summing up, the works cited above (among others) allow us to comprehend the processes involved in the construction and evolution of the region under study. Variations in sea level during the Holocene greatly influenced the construction of the coastal plains of the State of Rio de Janeiro. The low-lying region of the Malhada Marsh fits within this historical framework principally with regards to the morphological development of the region's marsh environments and their relationship to sea-level variations during the Holocene.

## SITE DESCRIPTION

### Site Geology

The Reserva Tauá outcropping along the northeastern limits of the Malhada Marsh occupies an area some 100 meters long and 40 wide with a total of 4,000 m<sup>2</sup>. Geological investigations using probes reveal that the basal sediments of the paleolagoon are made up of light grey sandy silt material which can be characterized as tidal plain deposits. Above this base, one finds a layer of bioclastic material some 0.60 m thick. This is composed of a high density, low diversity deposit of mollusk shells in an excellent state of taxonomic and environmental preservation (**Fig. 2 and 3**). Many of these maintain their original shape and color and some are preserved in the positions they maintained during life. The next layer, overlaying the shells, is 0.40 m thick and is made up of interwoven levels of silt, clay and fine sand deposited by the current environmental conditions of the swamp.

Samples of mollusk shells in the deposit reveal three families of bivalves and two of gastropods. The species in these families can tolerate varying levels of salinity and are found in shallow-water, sandy-bottomed environments (Castro *et al.*, 2004).

The formation of the paleolagoon in the Reserva Tauá occurred following the flooding of the region's drainage system following the marine invasion 5,100 years AP. During this period, the region's sandbars moved towards the continent, forming canals linking the area's several lagoons. Carbon dating of the shells

collected in the outcropping under study show that they were deposited around 5,034 to 5,730 years ago

during the period in which the Reserva Tauá paleolagoon was formed (Castro *et al.*, 2004).



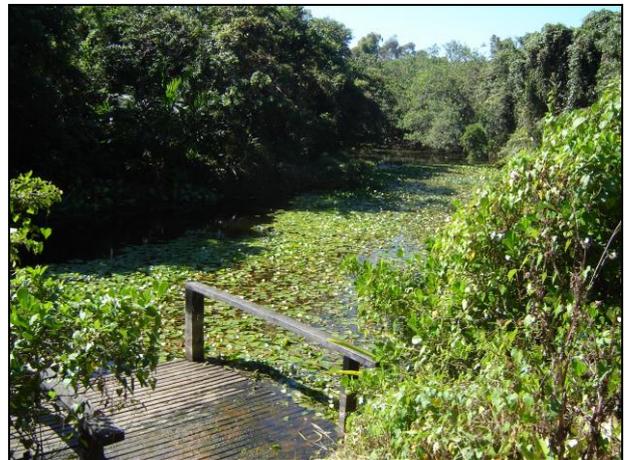
**Figure 2** - General and detail aspect of the molusk shells outcrop “coquina” in the Reserva Tauá area - Malhada marsh / Rio de Janeiro State.



**Figure 3** - Stratigraphic positioning of the molusk shells outcrop “coquina” Reserva Tauá - Malhada marsh / Rio de Janeiro State.

The current marsh environment developed due to a rapid decline in the region’s sea-levels, occurring around 4,900 years ago, which led to dunes forming along Però and the closing of the canal linking the paleolagoon to the open sea. Current environmental conditions in the region of the Tauá geological site are of a tropical climate with semi-arid characteristics, pluviometric readings of approximately 850 mm/year, northeastern prevailing winds and southeastern secondary winds. Along the northeastern border to the outcropping, one encounters an area of vegetation made up of sandbar environment bush and tree species. This is the private property of the environmentalist Tereza Kolontai Soldon (Fig. 4).

The rest of the area surrounding the outcropping is made up of fields of grass species, subsistence agriculture and (in the lowlands) urban areas.



**Figure 4** - Physiognomy of the restinga vegetation, Reserva Tauá - Malhada marsh.

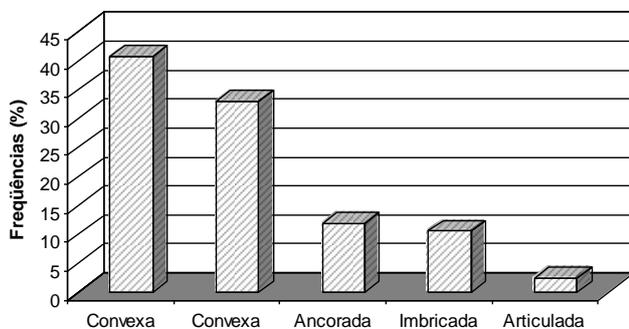
### Site Paleocology

The initial studies of the coquina deposits on the Reserva Tauá show levels of bioclats with a vertical extension of 0.60 m. The shells are distributed in a chaotic manner with suspensivorous bivalves dominating (Senra *et al.*, 2003). The deposit is densely compacted and follows the line of the paleobeach. The spatial distribution of the biomineral components can be characterized as concave, convex, anchored,

imbricated and articulated, demonstrating a notable nesting pattern (Fig. 5 and 6).



**Figure 5** - Spatial distribution of the mollusk shells with notable organization pattern



**Figure 6** - Spatial distribution of bioclasts in section.

In the area of the out-cropping, trophic groups of macrofauna were identified as well as associations of foraminiferous such as *Ammonia tepida-Elphidium excavatum-Pseudonion* sp., ostracodes of the genus *Cyprideis*, monaxonic and triaxonic espicules and disarticulated cirripedium plates which reflect hypoaline and hiposaline environmental conditions (Barreiro *et al*, 2003). Taphonomic analysis of the malacofauna show that 10 % of the shells were found still connected state, 45% were found unconnected and the rest were found as fragments. An expressive fraction of the fragments can be characterized as having been subject to bioclastic transportation processes (Barreiro and Senra, 2005).

The baxtonic macro-gaegs found in the deposit are made up of fragmented filaments lacking pressing mechanisms, giving evidence to the effects of mechanical action. The population of *Anomalocardia brasiliana* contains both adult and young members, suggesting a non-selective or catastrophic death process overtaking an entire community, possibly during the sea's withdrawal from the area (Serra and Silva, 2002). Shells of this species also show perforations made by the *Oichnos*, *Caulostrepsis* and *Entobia* fish species, interpreted as a bio-erosive

activity. This was produced by poliquettes, sponges and carnivorous gastropods in 18.8%, 4.4% and 0.34% of the cases studied. Analysis of the frequency of bioerosion caused by poliquettes shows that this occurred most often along the posterial-ventral margin of the medium-sized shells and that this encouraged mechanical fragmentation processes. Within this context, the shell deposits of the Malhada Marsh shows such paleo-ecological properties as the predominance infaunal mollusks (with a relative abundance of *A. brasiliana*) and fragmentation and bio-erosion biostratinomics which enable us to infer a lagoon environment.

Bernardes and Senra (2005) demonstrate that the biodiversity of the Reserva Tauá is slightly lower than that seen at the Sitio da Paz and the Fazenda Junqueira, two sites also located in the Malhada Marsh. In the paleo-environment around the Malhada Marsh, the polynic types associated with the sedimentary deposits indicate bush, tree and *restinga* vegetation.

## PROTECTION MEASURES

Though the mollusk shell deposits in the Fluminense Lake Region have been found by dredging projects in the Araruama lagoon for several decades now, it's only been in the last ten years that attempts have been made to protect and conserve this scientific and cultural patrimony. At the end of the 1990s, environmentalist Tereza Kolontai Soldan undertook an excavation in the Reserva Tauá/Malhada Marsh area in order to protect the botanical garden on her property from the forest fires which frequently sweep the region. During this process, the removal of the topsoil revealed the excellently preserved coquina outcropping under discussion here (Fig. 7).

At the institutional level the first attempt to preserve the site was jointly developed by the owner of the Reserva Tauá and the *Projeto Caminhos Geológicos* coordinated by the *Departamento de Recursos Minerais do Estado do Rio de Janeiro* ( Department of Mineral Resources of the State of Rio de Janeiro - DRM /RJ). On this occasion, an aluminum plate was erected inscribed with information (in English and Portuguese) regarding the local and regional geology surrounding the coquina outcropping.

With the dawn of the new millennium, researchers from UFRJ, UNIRIO and UERJ visited the outcropping, seeking to develop sedimentology, paleo-ecology, taphonomy, estratigraphy and sea level studies centered on the Holocene period in the Malhada Marsh region. In 2005, the *Laboratório de Geologia Costeira e Sedimentologia do Departamento de Geologia e Paleontologia do Museu Nacional* (Coastal Geology and Sedimentology Laboratory of the Paleontology Department of the National Museum -

UFRJ) proposed to begin the process which would preserve the outcropping as part of the geological patrimony of humanity under the regulations of SIGEP. This proposal was supported by several professionals in the geosciences and the *Núcleo de Estudos Tafonômicos* (Nucleus for Taphonomic Studies) of UNIRIO.

The request to register this geological site as the patrimony of humanity was undertaken in order to protect one of the most important pieces of evidence regarding the Holocene sea-level changes (marine flooding and regression) which occurred all along the coastal zone of the Brazilian southeast.

The pressure of urban expansion in the areas around the outcropping is quite considerable, however and human occupation of the region could completely destroy this sight if the Reserva Tauá is split up and sold at some future date. The outcropping is also threatened by people and agents who are interested in mining it for its mineral value.

The owner of the Reserva Tauá maintains a corps of permanent guards in order to protect the area's biological and geological integrity. This, however, is not enough to guarantee the preservation of this important site. Other measures are necessary in order to establish the Reserva as an unquestionable part of the national and global geological patrimony.



**Figura 7** - Remoção da camada de solo, área do afloramento de coquina - Reserva Tauá.

**Figure 7** - Removal of the soil layer, area of the coquina outcrop - Tauá Reserve.

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