QUATERNARY OF SOUTH AMERICA AND ANTARCTIC PENINSULA

With selected papers of the special session on the Quaternary of South America XIIth INQUA International Congress Ottawa, 31 July-9 August 1987

Edited by
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VOLUME 5 (1987)

OFFPRINT

A.A.BALKEMA / ROTTERDAM / BROOKFIELD / 1987

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Characteristics of a Pleistocene nearshore deposit: An example from southern São Paulo State coastal plain

ABSTRACT

Cananéia Formation, occurring almost continuously at least in the southern half of the State of São Paulo coastal plain, is overlying continental Tertiary deposits of Pariquera Açu Formation or crystalline rocks of Precambrian age. Its basal portion, in general, with a sandy-clayey composition is superimposed by essentially sandy sediments, both representing the Pleistocene Cananéia Transgression (=Sangamon) in the area.

A detailed study of this formation in Comprida and Cananéia Islands, as well as in neighboring coastal plain in the continent, allowed us to recognize an assemblage of sedimentary structures representative of shallow marine depositional environments.

The fine sands with heavy mineral laminations and sandy-clayey intercalations, exhibiting wavy, lenticular and flaser beddings associated with intensive bioturbations and load-casts, are probably related to upper shoreface. These sediments are overlain by purer fine sands with parallel horizontal to sub-horizontal laminations and low-angle cross-beddings and mudcracks, representing a shallower sub-environment subjected to periodical subaerial exposures in a foreshore, indicate the end of the Cananéia Transgression.

RESUMO

A Formação Cananéia, que ocorre mais ou menos continuamente pelo menos na metade sul da planície costeira do Estado de São Paulo, é superposta aos depósitos terciários continentais

da Formação Pariquera Açu ou as rochas cristalinas de idade pré-cambriana. A sua porção basal apresenta, em geral, uma constituição areno-argilosa, sendo encimada por depósitos essencialmente arenosos, ambos representando a Transgressão Cananéia (= Sangamoniana) de idade pleistocênica na área.

Um estudo detalhado desta formação nas ilhas Comprida e Cananéia, bem como na planície costeira adjacente do continente, permitiu-nos reconhecer um conjunto de estruturas sedimentares representativas de ambientes deposicionais de mar raso.

As areias finas com laminações de minerais pesados e intercalações areno-argilosas, exibindo acamamentos ondulados, lenticulares e flaser associados a intensas bioturbações e estruturas de sobrecarga, são provavelmente relacionadas a face praial superior. Estes sedimentos são superpostos por areias finas mais puras com laminações horizontais e sub-horizontais paralelas e com estratificações cruzadas de baixo ângulo e gretas de contração, representando um sub-ambiente mais raso submetido a exposições sub-aéreas periódicas em uma antepraia, indicativas de fim da Transgressão Cananéia.

INTRODUCTION

Cananéia-Iguape coastal plain, situated in the southern part of the State of São Paulo, has an area of about 2,500 km^2, with a roughly half-moon shape of 130 x 40 km (Figure 1). Its northeastern and southwestern extremities are constituted by Precambrian crystalline rock headlands which reach the sea. This area is dissected by lagoonal channel systems delineating three islands, the first two essentially formed by Quaternary deposits (Cananéia and Comprida Islands) and the last one by Precambrian crystalline rocks (Cardoso Island).

Comprida Island is a barrier-island mostly related to sea-level fluctuations of the last 7,000 years (Martin and Suguio, 1978). It is about 70 km long and 3 - 5 km wide. A lagoonal channel 400 to 1,200 m wide, locally named "Mar Pequeno", separates this island from the continent. Southward, "Mar Pequeno" is divided into two lagoonal channels ("Mar de Cubatão" and "Mar de Cananéia"), around the Cananéia Island.

In Cananéia Island and in the neighboring coastal plain in the continent, the Quaternary shallow-marine and lagoonal (or bay bottom) sediments of Pleistocene Cananéia Formation are dominant. This formation was, for the first time,

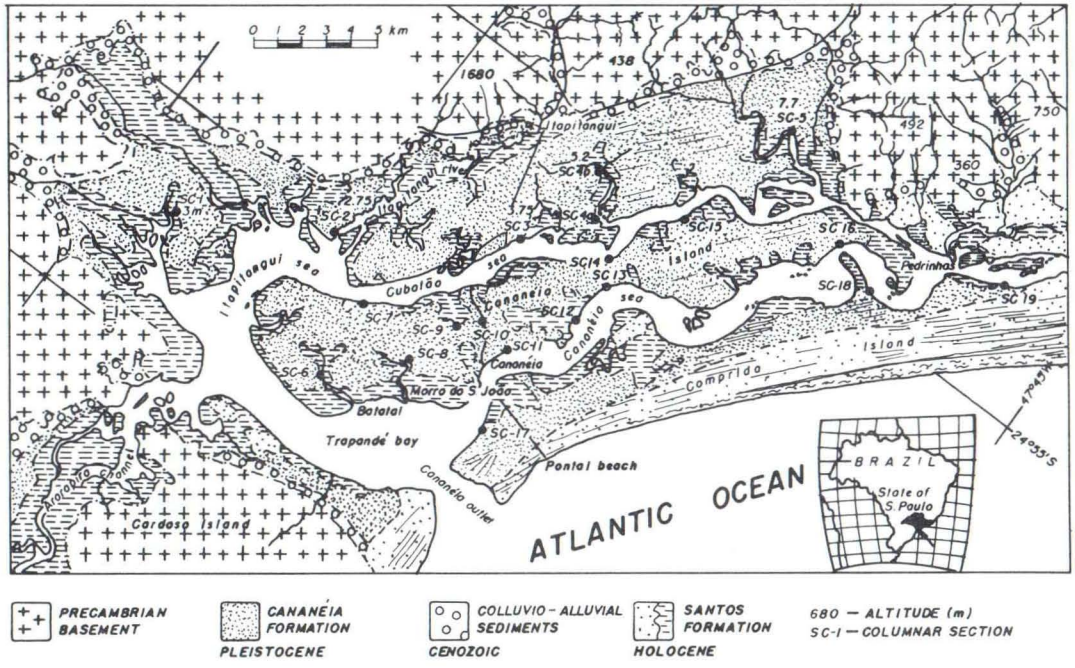

Figure 1. Geologic map of the studied area.

recognized and described by Suguio and Petri (1973). Its minimum age was obtained by Suguio and Martin (1978a), by dating wood fragments contained in basal clayey-sandy sediments. This formation has been correlated with the Pleistocene deposits in the State of Bahia coastal plains, dated by Martin **et al.** (1982) as 120,000 years BP.

The surface of Cananéia Formation was intensively dissected, during the following low sea-level period (Northern Hemisphere glacial period), by drainage net established at that time. During the last 6 - 7,000 years, sea-level surpassed the present sea-level, when the eroded portions of the Cananéia Formation have been occupied by the Holocene Santos Formation.

Suguio and Martin (1978a, b) reported the results of a detailed study, based on the interpretation of aerial photos, field surveys, and radiocarbon dating of these Quaternary sediments. They established the following evolutive model (Figure 2), valid for the Cananéia-Iguape coastal plain:

First stage - During the maximum of Cananéia Transgression the sea reached the foot of the Serra do Mar. In this period, clayey-sandy and transgressive marine sands covered the Pariquera Açu Formation.

Second stage - With the regressive phase, beach-ridges began to be deposited on the top of sandy sediments.

Third stage - During this phase sea-level was always lower than the present one (about 18,000 years BP the sea-level was about - 110 m below present level), and the rivers deeply eroded the sedimentary deposits of Cananéia Transgression. Valleys were formed similar to those in the Barreiras Formation, observed along the coastline of the State of Bahia.

Fourth stage - During the last transgressive phase the sea encroached upon lower zones at the beginning forming an extensive lagoonal system where clayey-sandy deposits, frequently very rich in organic matter, were deposited. In the meantime, the sea eroded the higher-lying parts of Cananéia Formation and redeposited the eroded sands to form the Holocene sandy marine deposits.

Fifth stage - During the return of the sea-level toward the present level, regressive beach-ridges were formed. The fluctuations of the sea-level during the final part of Santos Transgression produced several generations of beach-ridges. Thus, on Comprida Island we can see at least two generations of beach-ridges separated by a rather swampy, low-lying zone that can be followed over aproximately 50 km.

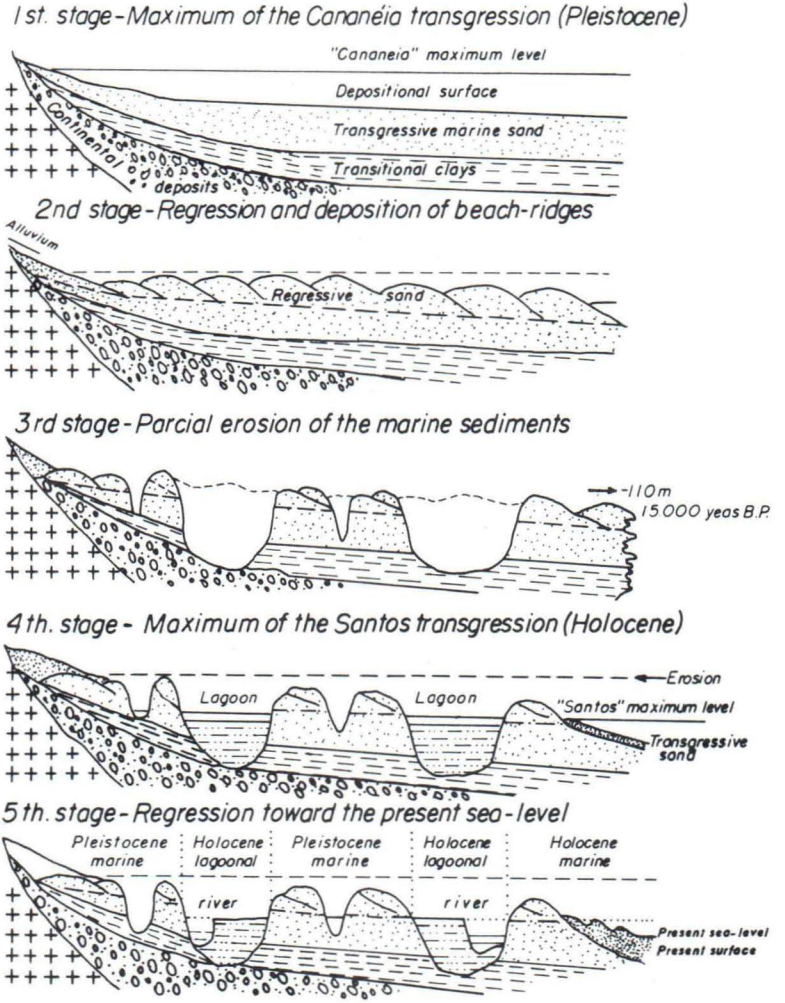

Figure 2. Evolutive stages proposed to explain the origin of the Cananéia-Iguape coastal plain (Suguio & Martin, 1978a).

CANANÉIA FORMATION SEDIMENTARY STRUCTURES

Outcrops of Cananéia Formation, whose summits are situated about 6 to 8 m above present high-tide level, are very frequently found in the studied area. They are always associated with erosional margins of present lagoonal channels.

Many kinds of sedimentary structures have been observed by

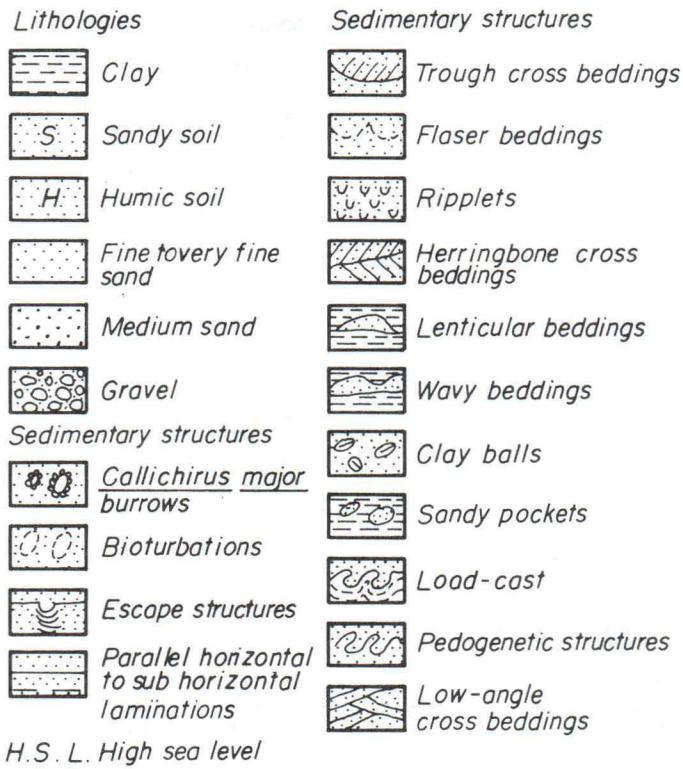

Figure 3. Legend for lithologies and sedimentary structures.

previous authors but they have never been studied in detail. Thirty six local columnar sections were measured and described in detail which allowed us to recognize the following features (Figure 3):

1. Biogenic structures - **Callichirus major** burrows, bioturbations (distinct and indistinct mottled structures), and escape structures. They have been described and interpreted previously by Suguio and Martin (1976), Suguio **et al.** (1984), and Rodrigues **et al** (1985).

2. Hydrodynamic structures - parallel horizontal and sub-horizontal laminations, trough cross-beddings, flaser beddings, ripple-drift cross-laminations, herringbone cross-bedding, lenticular beddings, wavy beddings and low-angle cross-beddings. These and some other miscellaneous structures, like load casts, clay galls and clay balls, mudcracks have been

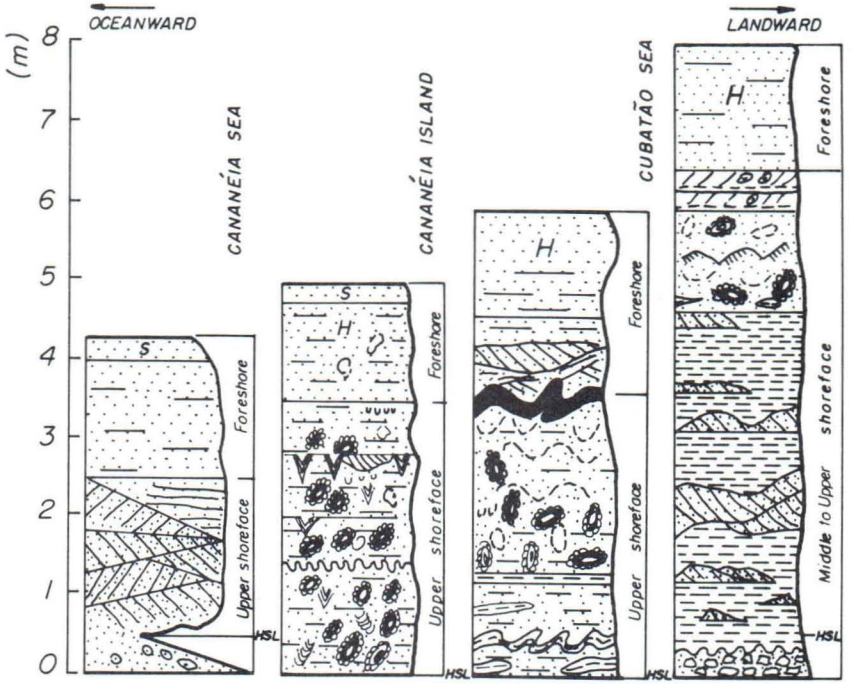

Figure 4. Integrated columnar sections of the Cananéia coastal plain showing the most important lithologies and sedimentary structures.

observed in Cananéia Formation. Some of them have been reported previously by Suguio and Petri (1973), and the meaning of hydrodynamic structures are explained in many text books on sedimentary structures.

Many of these sedimentary structures (**Callichirus major** burrows, flaser beddings, etc.) are very useful for the sedimentary environmental interpretation of Cananéia Formation.

COLUMNAR SECTIONS

Thirty six local columnar sections, representing outcrops of Comprida and Cananéia Islands, as well as the neighboring coastal plain in the continent, have been integrated into four composite sections, which give an idea of the general trend of facies changes from the open-sea toward the continent (Figure 4).

COLUMNAR SECTION REPRESENTING COMPRIDA ISLAND

The outcrop representative of the Comprida Island inner portion is located in southernmost extremity of the island (Picarro do Morrete) and is only 4 m high, because it is a wave-cut terrace built on Cananéia Formation.

It is entirely composed of fine to very fine sand without sandy-clayey layers. Abundant **Callichirus major** burrows, observed at present high-tide level, have been studied in detail by Suguio **et al.** (**op. cit.**) and Rodrigues **et al.** (**op. cit.**). Toward the top there is a sandy layer about 2 m thick with abundant herringbone cross-beddings, followed by sands with parallel horizontal to sub-horizontal laminations and low-angle cross-laminations.

COLUMNAR SECTIONS REPRESENTING CANANÉIA ISLAND

Cananéia Island outer portion - The most representative outcrop of this part of the island is found northward of Hotel Glória (Cananéia town). About lower 2/3 of this 5 m high outcrop constitutes the bed rich in **Callichirus major** burrows and escape structures, which are completely obliterating the primary hydrodynamic sedimentary structures. These tubes may be observed in longitudinal, transversal and diagonal sections, which give a good idea of their morphology. Horizontal parallel laminations, ripple-drift cross-laminations and trough cross-beddings have been observed in some places. About 1.5 m of its uppermost portion is characterized by parallel horizontal laminations and indistinct mottled structures.

Clayey-sandy intercalations are not observed in this portion of Cananéia Island, but they are present in some places in the inner part of the island, like in a sand quarry near the ferry-boat pier to the continent.

Cananéia Island inner portion - It is well represented by outcrops situated in front of the Iririaia-Açu River mouth. The outcrops are 5 to 6 m high, and about 1.5 m basal portion is very rich in load-casted clayey-sandy intercalations. This is followed toward the top by 2 m thick sand bed characterized by frequent **Callichirus major** burrows, indistinctly mottled structures and common flaser beddings. The top of these outcrops are also characterized by parallel horizontal to sub-horizontal and some trough cross-beddings.

COLUMNAR SECTIONS REPRESENTING THE CONTINENT

As the outcrops heights and the level of **Callichirus major** burrows increase landward, here are situated the highest outcrops in the studied area, wll represented by the one situated in the left margin of the Iririaia-Açu River.

About 6 m of its basal portion is dominantly constituted by greenish-grey argillaceous sediments intercalated by fine to very fine sand layers. These sands occur in association with wavy and lenticular beddings and some sandy patches filling organism burrows forming distinct mottled structures. In some places of the coastal plain in the continent, as in the Itapitangui River mouth, Cananéia Formation is underlain by oxidized pebbly muds, probably representing Pariquera Açu Formation, continental deposits, which according to Sundaram and Suguio (1985), is of Pliocene age.

About 1.5 m thick sandy layer with **Callichirus major** burrows are, in the area, found about 5 m above the present high-tide level.

The uppermost 1.5 m is formed of fine to very fine sand with parallel horizontal to sub-horizontal laminations and low-angle cross-laminations.

DEPOSITIONAL ENVIRONMENTS

According to Petri and Suguio (1973), Cananéia Formation represents a transgressive episode, beginning with transitional (brackish water) clayey-sandy sediments, followed by shallow-marine sands in its upper portion. This interpretation was based on microorganisms (foraminifera and diatoms) and grain size analysis.

Lithological characteristics, mostly sedimentary structures here analysed in some detail, are very important to understand the depositional environments of the Cananéia Formation. The lower portion characterized by an abundant hydrodynamic and biogenic structures could be suitably attributed to upper shoreface sub-environment. Lenticular, wavy and flaser beddings are suggestive of an environment where tidal currents played a very important role during sedimentation. The heights of the levels with abundant **Callichirus major** burrows, increasing from present shoreline toward the continent, and the anomalously higher density of burrows found by Suguio **et al.** (**op. cit.**) in "Costeira da Barra" area (Ribeira de Iguape

River) suggest sea-level rising during its deposition. About 1.5 to 2 m uppermost portion of Cananéia Formation outcrops, with only few structures and in some places exhibiting evidence of reworking by wind, could have been deposited in a foreshore sub-environment. The sedimentary structure most typical of foreshore is the low-angle cross-bedding (Thompson, 1937; McKee, 1957).

Therefore, sediments deposited in deepest water within the sequence must be represented between the above mentioned sub-environments, but this evidence is not clear. On the other hand, the striking difference between the columnar sections representing Cananéia Island, and the neighboring coastal plain in the continent, could indicate a much quieter water (lagoonal channel?) during the deposition of sediments outcropping in the Iririaia Açu River. This fact would suggest that Cananéia Island was a barrier-island during the Pleistocene originating a protected area at its backside similar to the present situation.

ACKNOWLEDGEMENTS

This work has been made possible thanks to financial support from FAPESP (Fundação de Amparo a Pesquisa do Estado de São Paulo) for field surveys (Processo 84/0271-0).

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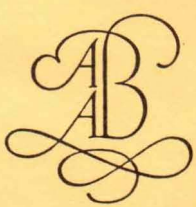

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