Coastal Quaternary Formations of the Southern Part of the State of Espírito Santo (Brazil)

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ABSTRACT

A preliminary geologic map of the Quaternary deposits, situated at the southern half of the State of Espírito Santo coastal plain, is presented in this paper. They are represented by two generations of wave-built terraces, which have been originated after 123,000 years and 5,100 years B.P., by paleolagoonal deposits related to the last high sea-level period and by alluvial, coastal marsh and mangrove deposits of Holocene age. The evolutionary model valid for this sector of coast is quite similar to that previously established for other sectors of the Brazilian coast.

Key words: Quaternary coastal deposits, geological evolution, State of Espírito Santo, relative sea-level changes.

INTRODUCTION

With the exception of the Rio Doce mouth coastal plain, Quaternary deposits of the remaining State of Espírito Santo coast were never submitted to a systematical geological study. On the other hand, the Rio Doce coastal plain between Conceição da Barra and Barra do Riacho (Fig. 1) has been studied by several authors (Bacoccoli, 1971; Bandeira Júnior *et al.*, 1975 and 1979; Suguio *et al.*, 1982; Dominguez, 1987 and 1989; Dominguez *et al.*, 1987; Martin *et al.*, 1989). Works accomplished during the last decade, based on detailed geological mapping, radiocarbon dating and vibracorer samplings allowed to reconstruct the evolutionary history of the Rio Doce coastal plain with a good precision (Fig. 2). Then, it was proved that it is not entirely of Holocene age, and that its origin was strongly controlled by relative sea-level changes, fluvial sedimentary supply, longshore drift, as well as its reversals as a consequence of changes in the atmospheric circulation (Martin *et al.*, 1993).

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THE GEOMORPHOLOGICAL SCENARIO OF THE STATE OF ESPÍRITO SANTO COAST

The landward boundaries of the State of Espírito Santo coast Quaternary deposits are constituted by two distinct geomorphological units.

A *Tertiary plateau* formed of Barreiras Formation continental deposits, whose surface is slightly sloping oceanward. It is dissected by a subparallel hydrographic net, frequently characterized by the presence of wide valleys with flat bottoms, presently silted up by Quaternary sediments. They are drained by insignificantly sized water courses in completely incompatible relation-

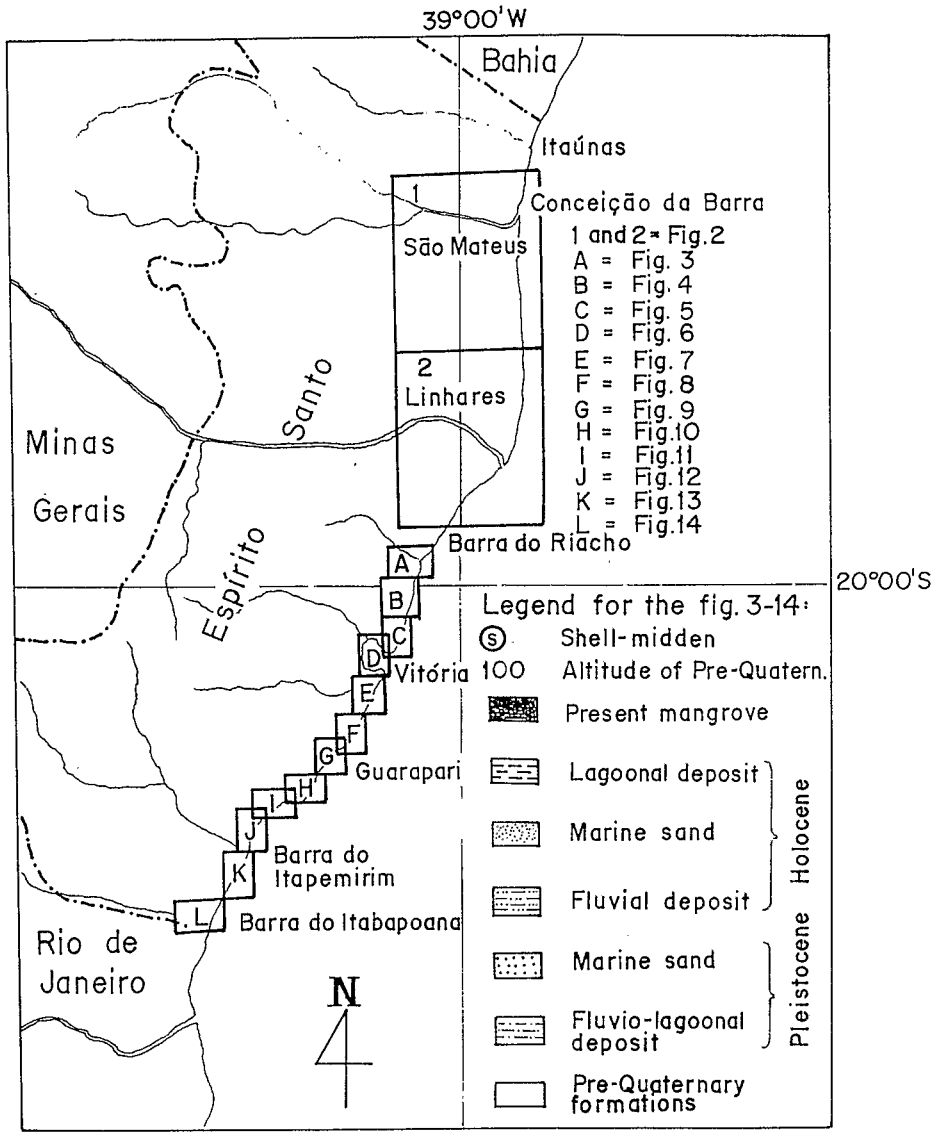


Fig. 1 — Location map of the studied area with articulation and legend of the maps (Fig. 3 to 14).

ship with the valley dimensions. Probably, they were excavated under paleoclimatic conditions different from the present ones.

A *mountainous area* composed of Precambrian crystalline rocks with an uneven relief, which is drained by a very dense dendritic hydrographic net.

According to the geomorphological unit forming its landward boundary, the State of Espírito Santo coastline can be divided into three sectors:

a) *Northern littoral*, going from the limit with the State of Bahia until the Vitória bay entrance, where the Quaternary coastal deposits are delimited by the Barreiras Formation just as in the southern State of Bahia.

b) *Central littoral*, which goes from the Vitória bay entrance until the Rio Itapemirim mouth. It is characterized by Precambrian crystalline rocks in direct contact with the Quaternary deposits, practically without Barreiras Formation deposits.

c) *Southern littoral*, extending from the Rio Itapemirim mouth at north until the State of Rio de Janeiro limit, where the Barreiras Formation pla-

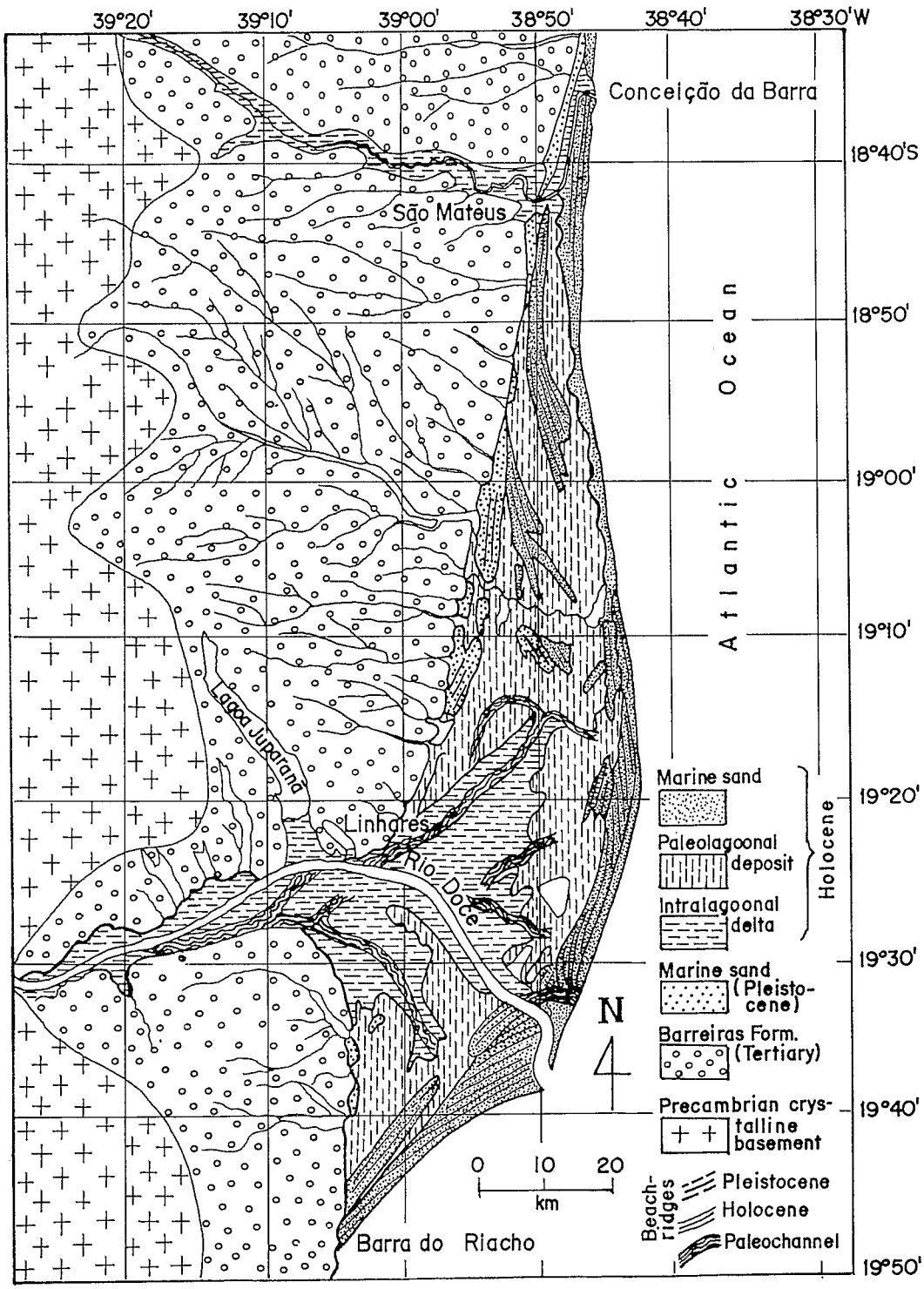


Fig. 2 — Schematic geologic map of the Rio Doce coastal plain.

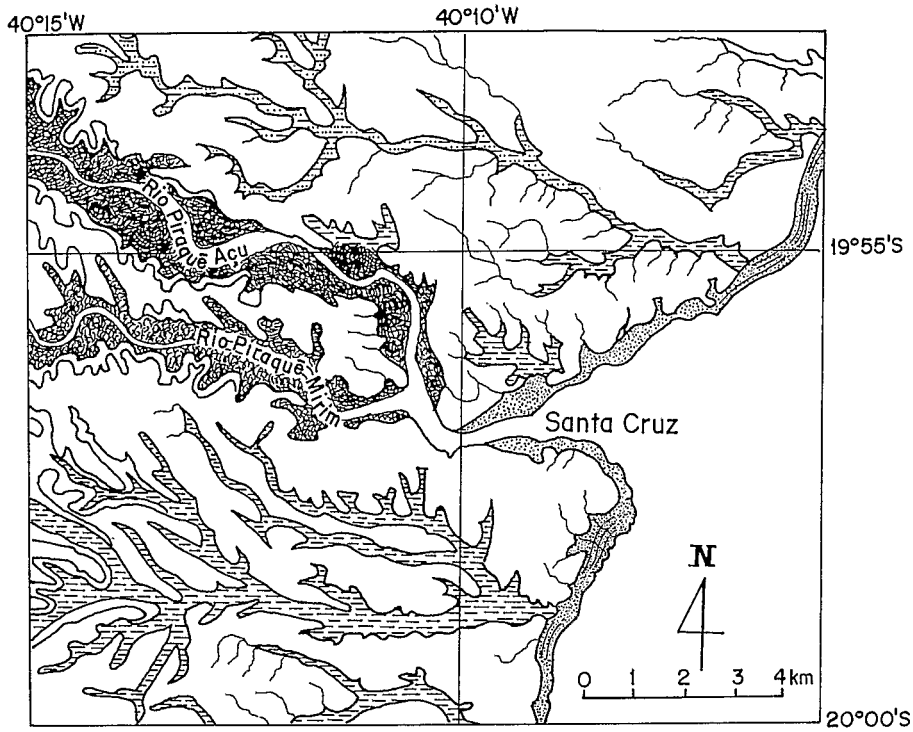


Fig. 3 — Schematic geologic map of the Santa Cruz region.

teaus are again in contact with the Quaternary deposits.

On the other hand, using only the Quaternary deposits, the State of Espírito Santo coastline can be divided into the following six sectors:

Sector 1, from the State of Bahia limit until the village of Conceição da Barra, characterized by very poor development of the Quaternary deposits situated at the foot of the Barreiras Formation cliffs.

Sector 2, corresponding to the Rio Doce coastal plain between Conceição da Barra and Barra do Riacho. In this sector, Quaternary deposits attain their maximum development (Fig. 2).

Sector 3, extending from Barra do Riacho to the Vitória bay entrance, where the Quaternary deposits, at the foot of the Barreiras Formation cliffs, are again poorly developed. However along some valleys as Piraquê, Piraquê Mirim and Reis Magos rivers mouths, Quaternary deposits are more extensively distributed (Figs. 3, 4 and 5).

Sector 4, which goes from Vitória bay entrance until the Rio Itapemirim mouth, corresponding to a sector characterized by outcrops of Crystalline Precambrian rocks in direct contact with the Quaternary deposits. Due to its morphological characteristics, being rather dissected, the areas occupied by the Quaternary deposits are very changeable, that is well developed within concave portions and almost absent within convex parts (Figs. 6 to 12).

Sector 5, which extends from the Rio Itapemirim mouth until the north of the ample Rio Itabapoana valley. It is characterized by Quaternary deposits poorly represented at the foot of cliffs carved into the Barreiras Formation. On the other hand, Quaternary deposits have considerable extent within large valleys dissected on the Barreiras Formation deposits (Fig. 13).

Sector 6, corresponding to the Rio Itabapoana valley external portion, is characterized by very important Quaternary deposits (Fig. 14).

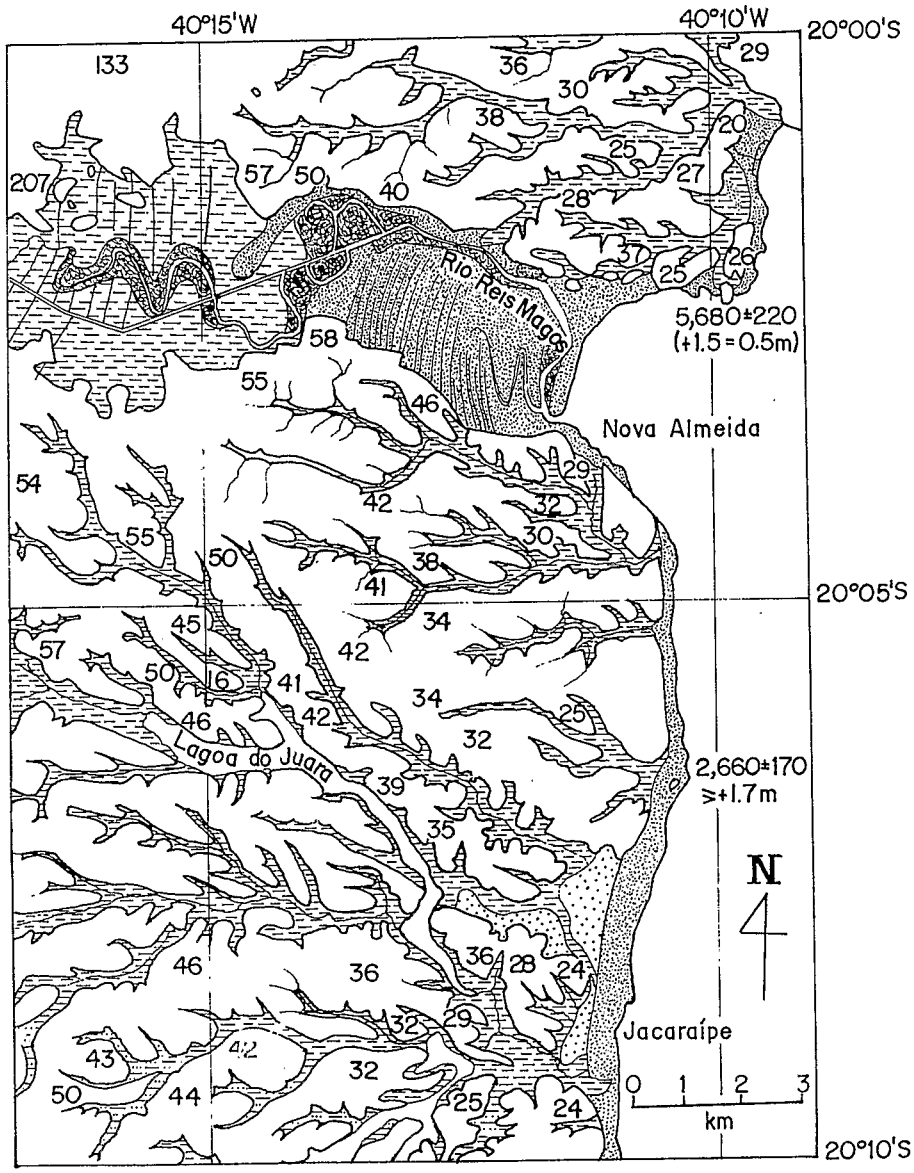


Fig. 4 — Schematic geologic map of the Nova Almeida region.

QUATERNARY SEA-LEVELS HIGHER THAN THE PRESENT ALONG THE STATE OF THE ESPÍRITO SANTO COAST

Studies performed during the last 15 years, along the eastern and southeastern Brazilian coast, mostly in the Rio Doce coastal plain (Suguio *et al.*, 1982, 1985 and 1988; Martin *et al.*, 1987) showed the existence of records of two sea-levels higher than the present. The last one is well known thanks to numerous radiocarbon datings, which allowed to delineate sea-level curves for several sectors of the Brazilian coast during the last 7,000 years. They indicated that this coastline was in submersion until about 5,100 years B.P., followed by an emersion episode intercalated by short duration submersions.

From a chronological viewpoint, the older high sea-level is much less known. In fact, samples suitable for radiocarbon dating indicated ages older than the limit of the method (about 30,000 years B.P. in available equipments). Nevertheless, coral

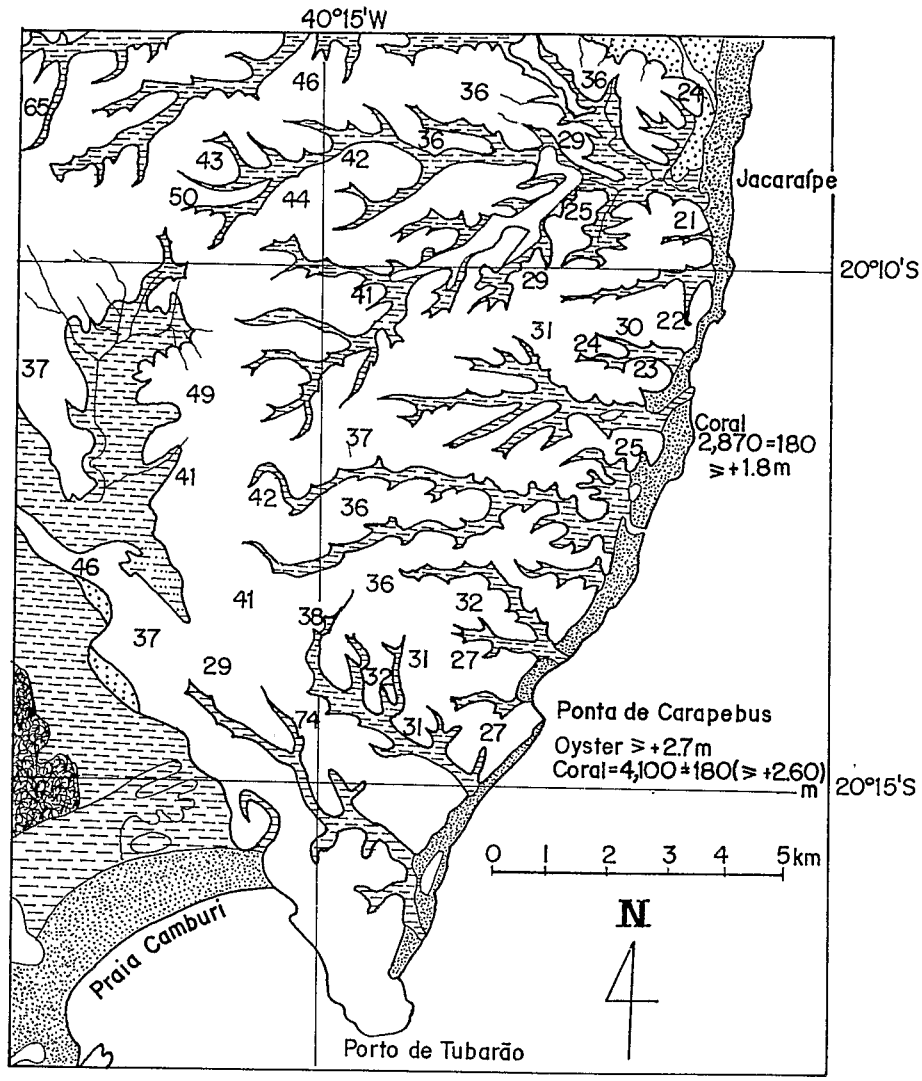


Fig. 5 — Schematic geologic map of the Jacaraípe-Tubarão region.

samples older than the above mentioned age (30,000 years), have been dated by the uranium/ionium method. These corals belong to a reef of southern State of Bahia, which developed during that high sea-level (Martin *et al.*, 1982). From eight samples randomly collected, three have been recrystallized from aragonite to calcite, and consequently were discarded and five remained samples with 100% of aragonite were dated. The obtained data showed that this high sea-level occurred about 123,000 years B.P., which is in perfect agreement with the penultimate high sea-level age (Bloom *et al.*, 1974; Chappell & Veeh, 1978). At that moment, the relative sea-level along the Brazilian coast was 8 ± 2 m above the present.

These two high sea-levels left numerous records along the State of Espírito Santo coastline. Presently, some datings corresponding to the last high sea-level period have been obtained, but just now it is still impossible to delineate a relative sea-level curve for the last 7,000 years. However, it was confirmed that the relative sea-level was certainly higher than the present one during the Holocene, with some oscillations after the 5,100 years B.P. culmination stage, as demonstrated by the second lagoonal phase of the Rio Doce coastal plain,

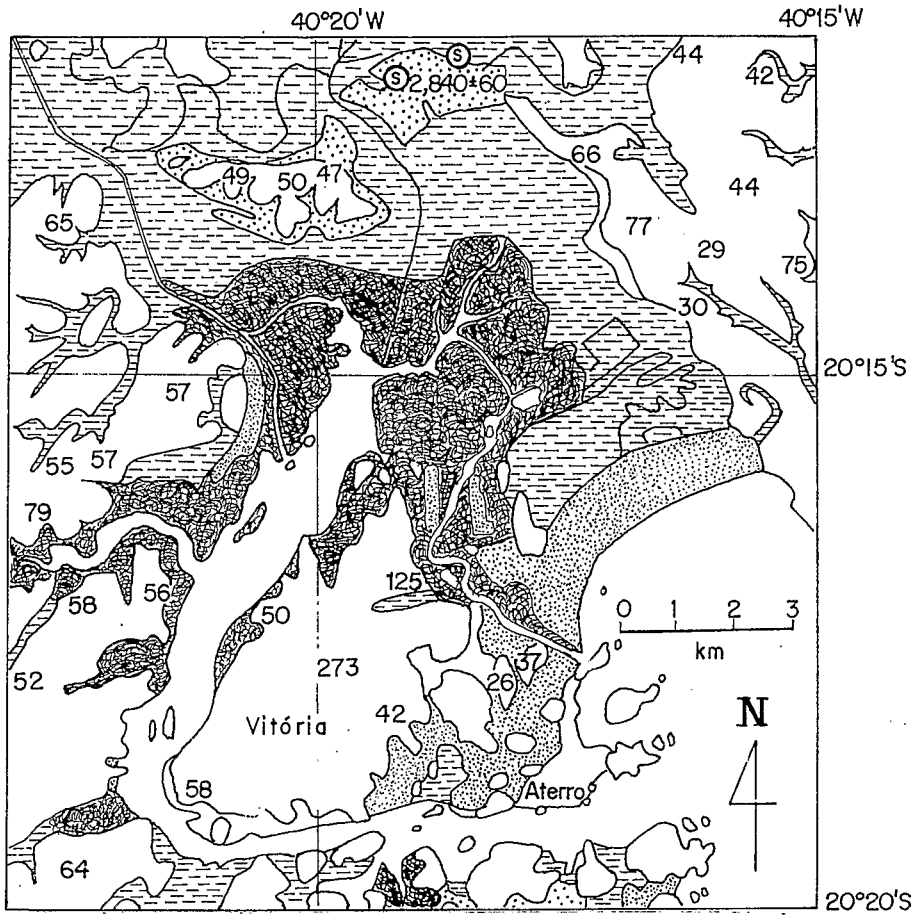


Fig. 6 — Schematic geologic map of the Vitória region.

occurred between 3,600 and 3,000 years B.P. Then, in a first approximation, it is possible to assume that the relative sea-level changes, during the last 7,000 years, were quite similar to which were recorded along the State of Bahia coastline.

Even if absolute ages, for the older high sea-level, were not obtained until the moment, the continuity of the outcrops with the State of Bahia permit to assume an age of about 123,000 years B.P.

QUATERNARY COASTAL DEPOSITS ALONG THE SOUTHERN STATE OF ESPÍRITO SANTO

a) Sandy Marine Terraces

Even in a preliminary geological mapping, it was possible to make clear the existence, along the southern State of Espírito Santo coastal plain, of two distinct generations of marine sandy deposits. The most external constitutes an almost continuous band along the coastline, while the most internal are very discontinuous because they have been intensively eroded when the sea-level was lower than the present. The surface morphological features of these sandy terraces, especially that associated which the beach-ridges, show some differences which allow to distinguish at least two distinct generations of sandy terraces on aerial photos (Martin *et al.*, 1981). The ages from the external terraces are older than 30,000 years B.P. On the other hand, mollusk shells are completely absent in the internal terraces, probably dissolved by humic and/or fulvic acids, frequently borrowing a pecu-

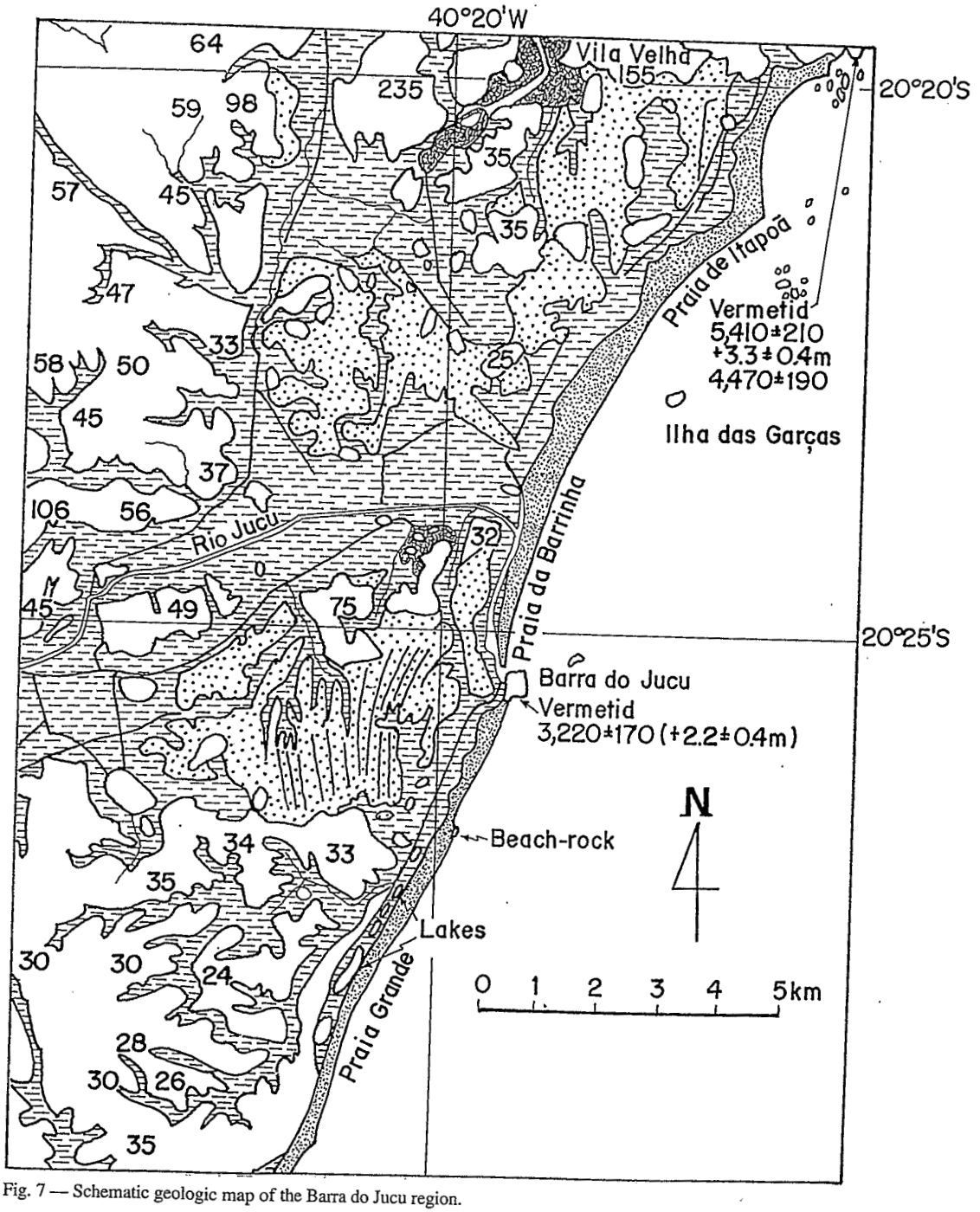


Fig. 7 — Schematic geologic map of the Barra do Jucu region.

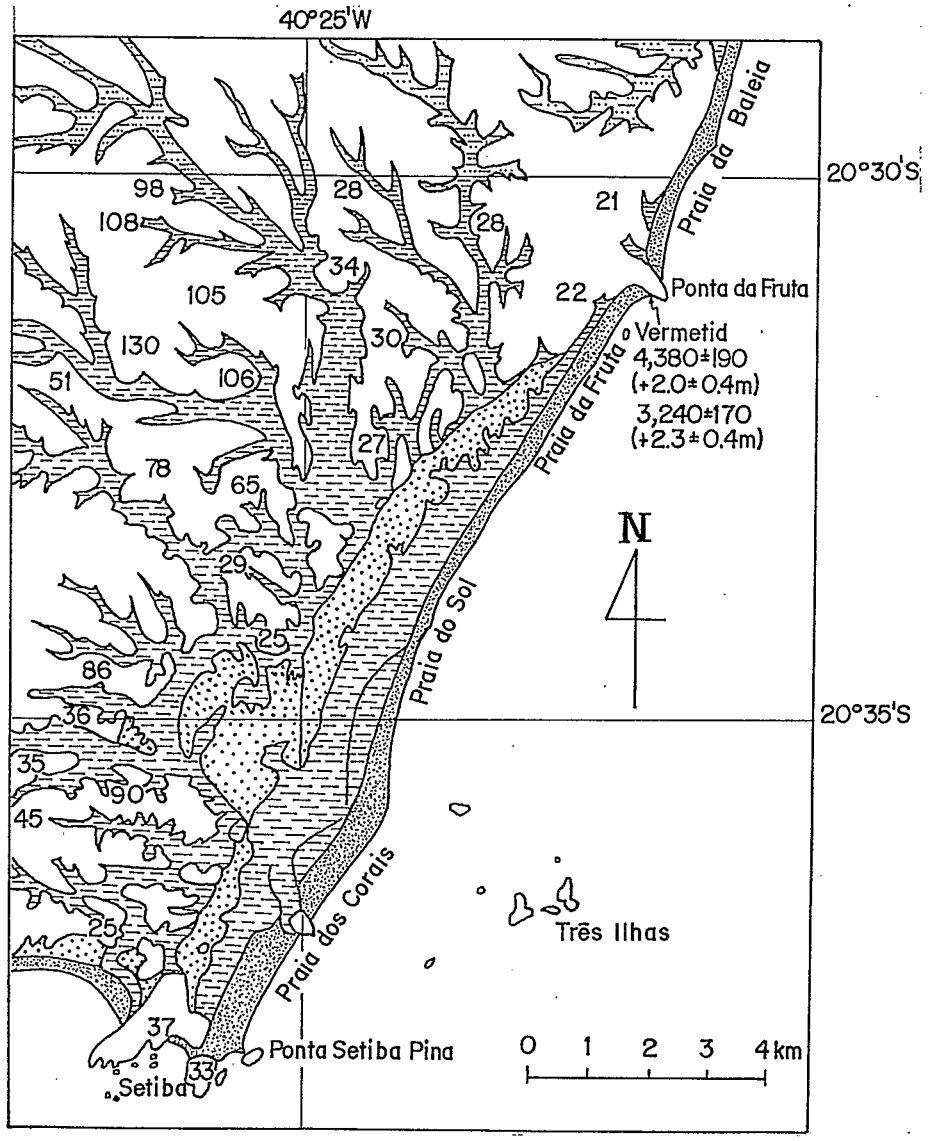


Fig. 8 — Schematic geologic map of the Setiba region.

liar roasted coffee-like colour and some degree of cohesion.

b) LAGOONAL AND PALUDAL DEPOSITS

They are composed of organic clays or peats occupying the lowlands separating Pleistocene from Holocene marine terraces, and along the lower courses of river valleys still not fulfilled by alluvial deposits. Frequently it is possible to observe that the paludal deposits are represented only by a thin layer covering organic matter rich shallow marine or lagoonal deposits with shell debris. These paleolagoons occupied an important portion of the coastal plain, being formed during a submersion episode, whose maximum sea-level occurred about 5,100 years B.P. Subsequently, as a consequence of relative sea-level drop, most of these lagoons was desiccated and replaced by freshwater swamps.

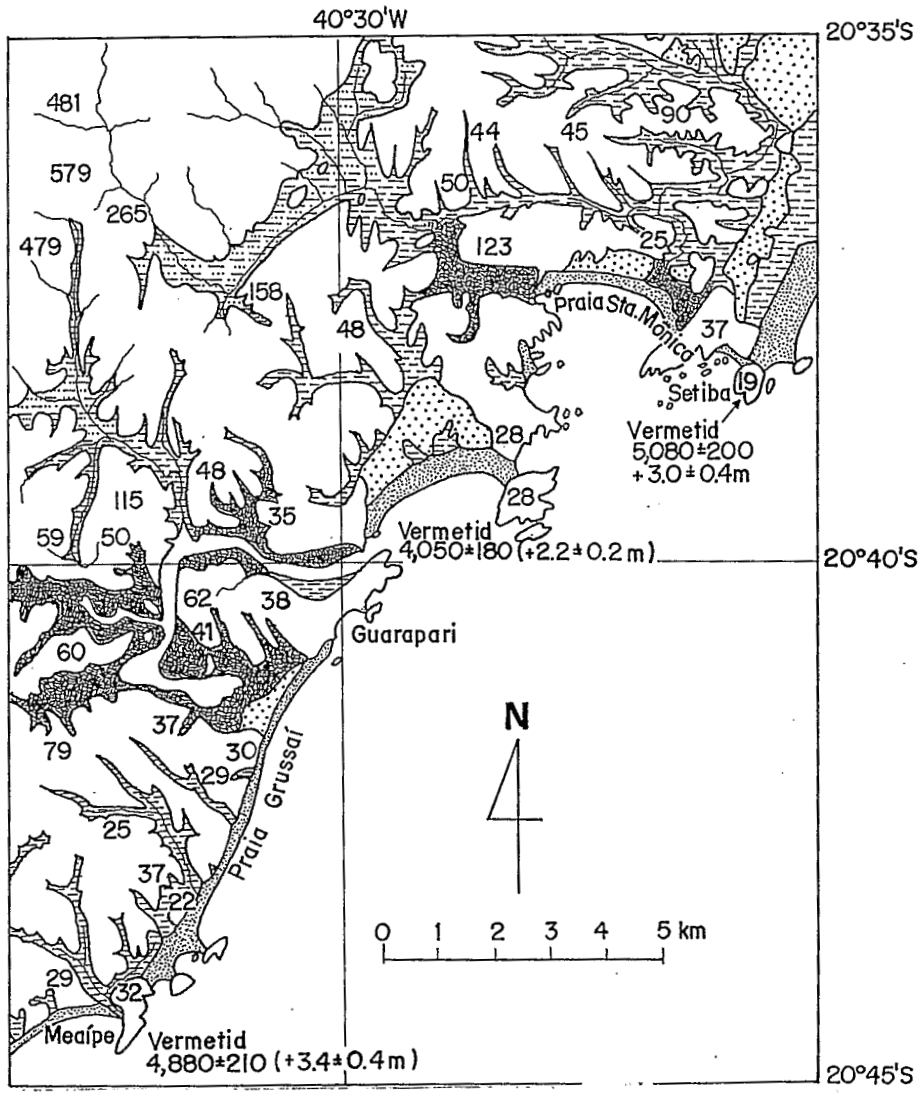


Fig. 9 — Schematic geologic map of the Guarapari region.

c) MANGROVE DEPOSITS

In several sectors of the coast, corresponding to bayhead areas, tidal channel margins and downstream courses of certain valleys, there are mangrove swamps. These deposits are essentially composed of locally sandy clayey-silty sediments and, in general, very rich in organic matter and containing also wood fragments and mollusk shell debris. Mangroves are particularly developed at north in the Santa Cruz area (Fig. 3), occupying part of the Piraquê and Piraquê Mirim rivers in the Vitória bay (Fig. 6), in the Guarapari (Fig. 9), and Anchieta (Fig. 10) regions.

d) FLUVIAL DEPOSITS

They are composed of sands with variable grain sizes or silty-clayey deposits, which occupy the upstream courses of the river valleys. In fact, at external portions of the coastal plain they are covering paleolagoonal sediments of the last submersion episode.

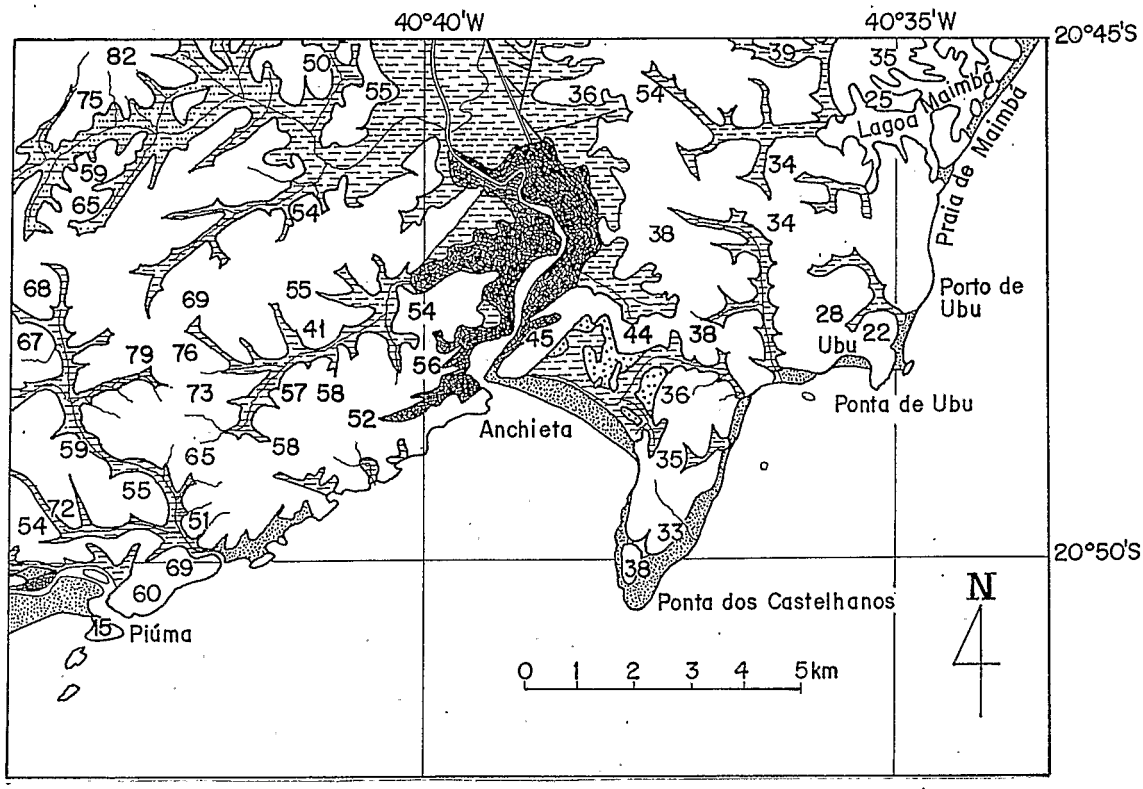


Fig. 10 — Schematic geologic map of the Anchieta region.

e) BEACH ROCKS

At south of the Rio Jucu mouth (Fig. 7), there is an outcrop of beach rocks resembling to the northeastern coast occurrences. Another beach rock bank has been observed immediately to the north of the Rio Itabapoana plain (limit between Figs. 13 and 14). This bank is presently covered by Holocene terrace sands, but it is outcropping on the streambed of a creek draining the Lagoa Boa Vista. There are other outcrops, also within the sector 3, and along the downstream course of the Rio Ipiranga in the Rio Doce coastal plain.

f) CALCAREOUS ALGAE, CORAL AND VERMETID CRUSTS

The incrustations occur along the rock coasts of the State of Espírito Santo and, frequently, they are furnishing evidence of past sea-levels higher than the present and some of them have been subjected to radiocarbon dating (Tab. I).

CONCLUSIONS

The evolutionary history, during the Quaternary, of the State of Espírito Santo coastal plain is similar to the previously studied sectors of the Brazilian coast. There are two distinct generations of Quaternary sandy marine terraces. The older one is attributable to a maximum sea-level occurred about 123,000 years B.P., represented by sandy terraces situated 8 ± 2 m above present level. The more recent one is related to a maximum sea-level occurred about 5,100 years B.P., represented by sandy terraces, lagoonal and paludal deposits, besides algal, coral and vermetid incrustations and beach rocks.

REFERENCES

BACOCCOLI, G., (1971), Os deltas marinhos holocênicos brasileiros: uma tentativa de classificação. *Boletim Técnico da Petrobrás,* **14:** 5-38.

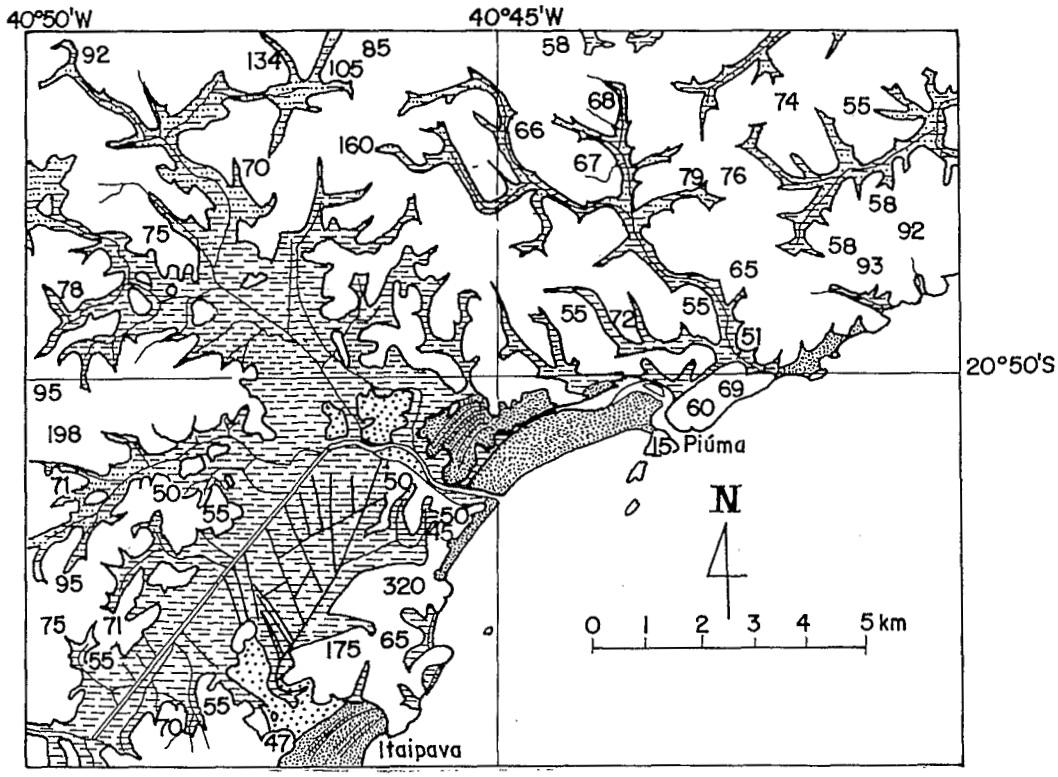


Fig. 11 — Schematic geologic map of the Piúma region.

BANDEIRA JÚNIOR, A. N.; PETRI, S. & SUGUIO, K., (1975), *Projeto Rio Doce* (relatório final). Petróleo Brasileiro S/A, Relatório Interno, 203p.

BANDEIRA JÚNIOR, A. N.; PETRI, S. & SUGUIO, K., (1979), *Doce river delta: an example of a "high wave-dominated" Quaternary delta on the Brazilian coastline, State of Espírito Santo.* 1978 International Symposium on Coastal Evolution in the Quaternary Proceedings: 275-295, São Paulo.

BLOOM, A. L.; BROECKER, W. S.; CHAPPELL, J. & MESOLELLA, K. J., (1974), Quaternary sea-level fluctuations on a tectonic coast: New 230Th/234U dates from the Huon Peninsula, New Guinea. *Quaternary Research,* **4:** 185-205.

CHAPPELL, J. & VEEH, H. H., (1978), Late Quaternary tectonic movements and sea-level changes at Tumor and Atauro island. *Geological Society of America Bulletin*, **89:** 356-368.

DOMINGUEZ, J. M. L., (1987), *Quaternary sea-level changes and depositional architecture of beach-ridges strandplains along the east coast of Brazil.* PhD dissertation, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, U.S.A., 288p.

DOMINGUEZ, J. M. L., (1989), *Ontogeny of a strandplain: evolving concepts on the evolution of the Doce river beach-ridge plain (East coast of Brazil).* International Symposium on Global Changes in South America during the Quaternary Special Publication nº **1:** 235-240.

DOMINGUEZ, J. M. L.; MARTIN, L. & BITTENCOURT, A. C. S. P., (1987), *Sea-level history and Quaternary evolution of river mouth associated beach ridge plains along the east-southeast Brazilian coast: a summary.* In: D. NUMMEDAL; O. H. PILKEY; J. D. HOWARD (eds.) Sea-level rise and coastal evolution. Society of Economic Paleontologists and Mineralogists Special Publication nº **41:** 115-127.

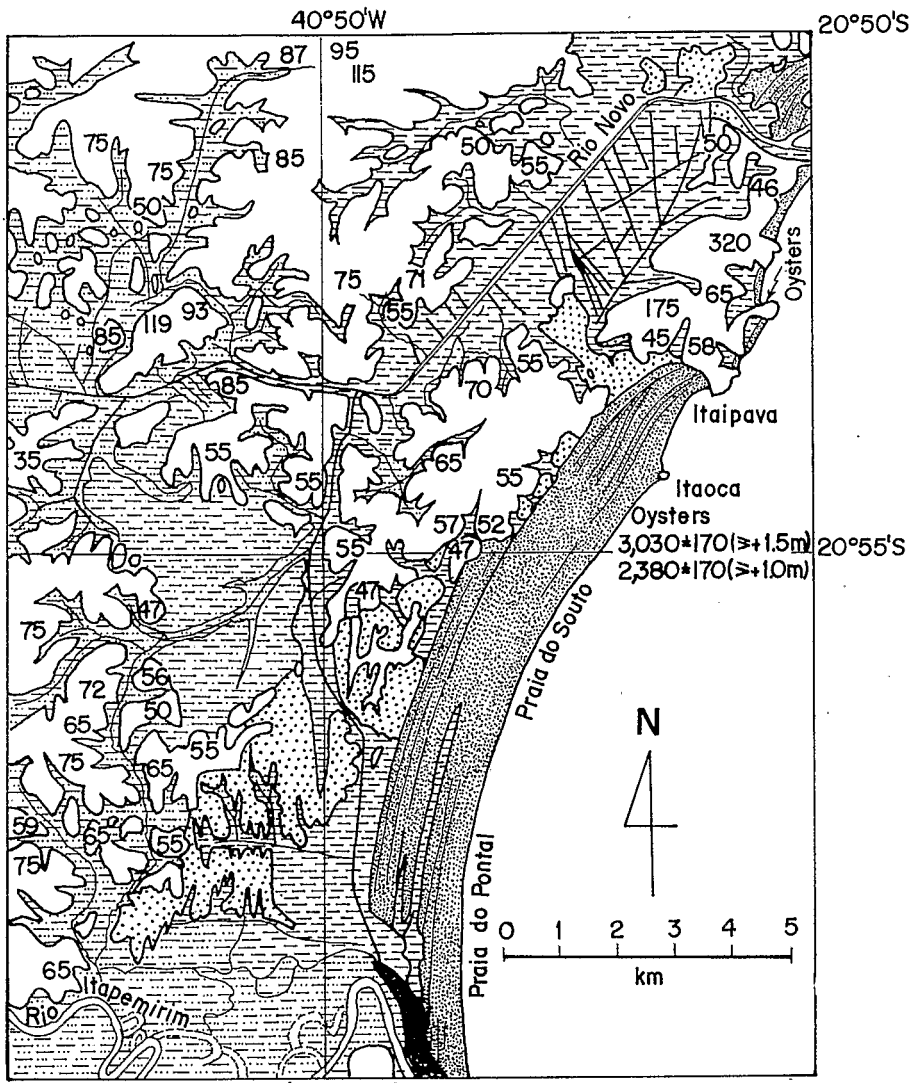


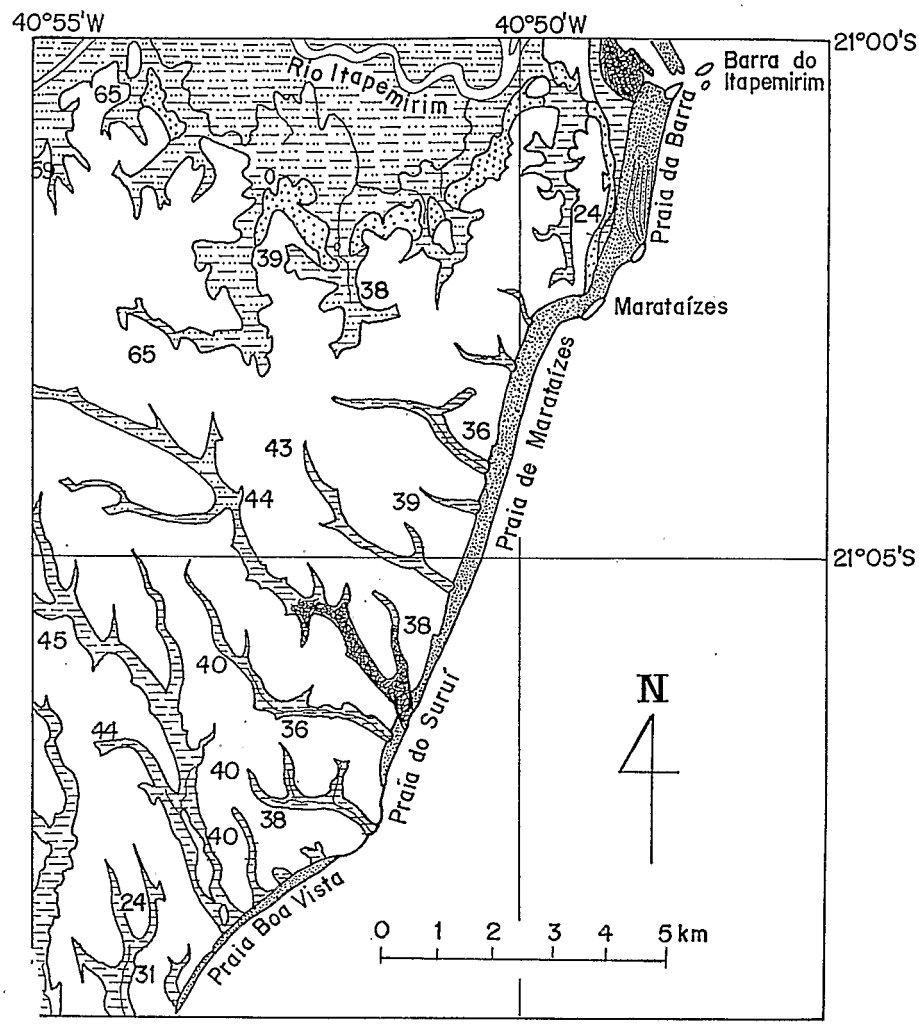
Fig. 12 — Schematic geologic map of the Itaõca region.

MARTIN, L.; BITTENCOURT, A. C. S. P. & VILLAS-BOAS, G. S., (1981), Differentiation sur photographies aériennes des terrasses sableuses pléistocènes et holocènes du littoral de l'Etat de Bahia (Brésil). Photointerpretation, **3**, fasc. 4/5, Paris.

MARTIN, L.; BITTENCOURT, A. C. S. P. & VILLAS-BOAS, G. S., (1982), Primeira ocorrência de corais pleistocênicos da costa brasileira: Datação do máximo da penúltima transgressão. *Ciências da Terra,* **1:** 16-17.

MARTIN, L.; SUGUIO, K.; FLEXOR, J. M.; DOMINGUEZ, J. M. L. & BITTENCOURT, A. C. S. P., (1987), Quaternary evolution of the central part of the Brazilian coast. The role of relative sea-level variations and the shoreline drift. *UNESCO Reports in Marine Science,* **43:** 97-145.

MARTIN, L.; DOMINGUEZ, J. M. L.; SUGUIO, K. & FLEXOR, J. M., (1989), Estudo detalhado da evolução da planície costeira do rio Doce durante o Holoceno. I Simpósio de Geologia do Sudeste (SBG), Resumos, Rio de Janeiro.



ig. 13 — Schematic geologic map of the Marataízes region.

MARTIN, L.; FLEXOR, J. M. & SUGUIO, K., (1991), Possible changes in the Holocene wind pattern recorded on southeastern Brazilian coast. *Boletim IG-USP, Publ. Esp.*, **8:** 117-131.

MARTIN, L.; SUGUIO, K. & FLEXOR, J. M., (1993), As flutuações do nível do mar durante o Quaternário superior e a evolução de "deltas" brasileiros. *Boletim IG-USP, Publ. Esp.*, **15:** 1-186.

SUGUIO, K.; MARTIN, L. & DOMINGUEZ, J. M. L., (1982), *Evolução do delta do Rio Doce (ES) durante o Quaternário: influência das variações do nível do mar*. Atas do IV Simpósio do Quaternário do Brasil (SBG): 93-116, Rio de Janeiro.

SUGUIO, K.; MARTIN, L.; BITTENCOURT, A. C. S. P.; DOMINGUEZ, J. M. L.; FLEXOR, J. M. & AZEVEDO, A. E. G., (1985), Flutuações do nível relativo do mar durante o Quaternário superior ao longo do litoral brasileiro e suas implicações na sedimentação costeira. *Revista Brasileira de Geociências,* **15** (4): 273-286.

SUGUIO, K.; MARTIN, L. & FLEXOR, J. M., (1988), Quaternary sea-level of the Brazilian coast: recent progress. *Episodes,* **11** (3): 203-208.

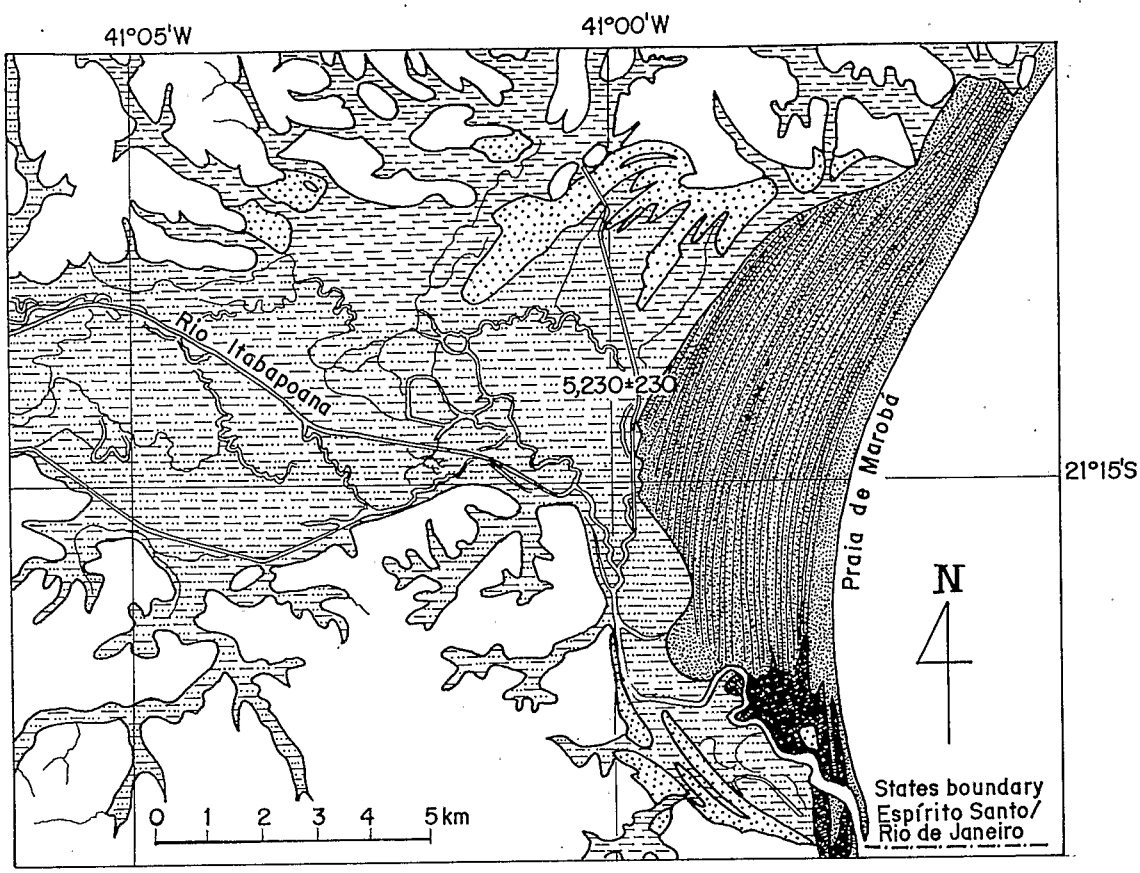


Fig. 14 — Schematic geologic map of the Rio Itabapoana region.

TABLE I

Radiocarbon ages of mollusk shells and wood fragments sampled from deposits of the coast between Itabapoana and Barra do Riacho.

Location	Coordinates	Nature	14C Age	Labo. Nr.	Sea-level
ES.42	20°12.2'S 40°22.0'W	Shell	7,080±280	Bah.1727	Rising sea-level
ES.47	20°02.2'S 40°09.7'W	Vermetidae	5,690±220	Bah.1586	+1.5±0.5 m
ES.44	20°19.6'S 40°16.1'W	Vermetidae	5,410±210	Bah.1585	+3.3±0.5 m
ES.10	20°52.1'S 40°48.0'W	Shell	5,400±210	Bah.1731	> 0.0 m
ES.01	21°14'S 41°00'W	Shell	5,220±220	Bah.1315	> 0.0 m
ES.17	20°38.2'S 40°26.1'W	Vermetidae	5,080±200	Bah.1580	+3.0±0.5 m
ES.07	20°44.4'S 40°16.1'W	Vermetidae	4,880±210	Bah.1548	+3.4±0.5 m

(to be continued)

TABLE I (Continuation)

Location	Coordinates	Nature	14C Age	Labo. Nr.	Sea-level
ES.43	20°19.6'S 40°16.1'W	Vermetidae	4,410±190	Bah.1585	≥ +1.4 m
ES.18	20°31.1'S 40°21.2'W	Vermetidae	4,380±190	Bah.1581	≥ +2.0 m
ES.03	20°56.8'S 40°49.3'W	Wood	4,140±200	Bah.1725	≥ 0.0 m
ES.11	20°50.6'S 40°46.6'W	Oyster crust	4,130±190	Bah.1732	Falling sea-level
ES.38	20°14.2'S 40°12.9'W	Coral	4,150±180	Bah.1588	≥ +2.6 m
ES.16	20°39.4'S 40°28.5'W	Vermetidae	4,050±180	Bah.1579	+2.2±0.5 m
ES.12	20°50.2'S 40°46.7'W	Shell	3,880±190	Bah.1723	> 0.0 m
ES.09	20°50.8'S 40°46.9'W	Shell	3,870±180	Bah.1730	> 0.0 m
ES.14	20°44.1'S 40°39.7'W	Shell	3,560±140	Bah.1735	> 0.0 m
ES.20	20°26.7'S 40°19.8'W	Calc. algae	3,440±190	Bah.1728	≥ +0.3 m
ES.19	20°31.1'S 40°21.2'W	Vermetidae	3,240±170	Bah.1582	≥ +2.3 m
ES.22	20°25.6'S 40°19.2'W	Vermetidae	3,220±170	Bah.1583	+2.0 m
ES.05	20°54.3'S 40°46.6'W	Oyster crust	3,030±170	Bah.1590	≥ +1.5 m
ES.39	20°12.3'S 40°19.2'W	Shell	2,930±200	Bah.1722	> 0.0 m
ES.34	20°11.5'S 40°11.4'W	Coral	2,870±180	Bah.1587	≥ +1.3 m
ES.45	20°06.4'S 40°10.3'W	Coral	2,660±170	Bah.1589	≥ +1.7 m
ES.06	20°54.3'S 40°46.6'W	Oyster crust	2,380±170	Bah.1591	≥ +1.0 m
ES.35	20°11.5'S 40°11.4'W	Calc. algae	2,380±170	Bah.1729	≥ +1.3 m
ES.36	20°11.5'S 40°11.4'W	Shell	2,020±170	Bah.1721	+1.2±0.5 m
ES.04	20°56.9'S 40°48.8'W	Wood	1,410±150	Bah.1726	> 0.0 m