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PREFÁCIO

Esta é a Publicação Avulsa nº 2 da ABEQUA, contendo parte dos trabalhos apresentados à reunião de Mérida (Venezuela), do Projeto 201 (Quaternário da América do Sul) do Programa Internacional de Correlação Geológica (PICG:UNESCO/UICG), realizada entre 5 e 8 de dezembro de 1986.

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Editores:
Kenitiro Suguio
Moysés G. Tessler

São Paulo, Setembro de 1987

PREFACE

This is the Occasional Publication nº 2 of ABEQUA containing part of the papers submitted to the Mérida (Venezuela) meeting of the International Geological Correlation Programme (IGCP:UNESCO/IUGS) Project 201 (Quaternary of South America), held from December 5 to 8, 1986.

The editors acknowledge Dr. Carlos Schubert and Dr. Leonel Vivas, for the organization of the meeting, as well as the Universidad de Los Andes (Mérida), for the necessary infrastructure for the meeting. Finally, they are also grateful to the authors, for interesting contributions, to Mrs. Maria Lucia Belisario Cicconi for careful typewritting, and to the Printing Section of Instituto de Geociências (University of São Paulo) for good workmanship.

Editors:
Kenitiro Suguio
Moysés G. Tessler

São Paulo, September 1987

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PALEOENVIRONMENTAL STUDIES IN THE VENEZUELAN GUAYANA SHIELD: PROGRESS REPORT

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ABSTRACT

During the Late Pleistocene, northern South America supported an arid climate which coincided temporally with glaciation in the middle and high latitudes. Evidence for this aridity in the Guayana Shield can be found in: 1. the begining of peat deposition in the Guayana Highlands in the Early Holocene, coinciding with a more humid, post-Pleistocene climate; and 2. alluvial sediments, mainly consisting of cobble to boulder gravel, in the piedmont areas of the highlands, which suggest a deposition under a former, more arid, climate (Late Pleistocene?), with less extensive vegetation cover and predominance of mechanical erosion. This evidence does not support the existence of a Pleistocene biological refuge in the Guayana region.

INTRODUCTION

The northern part of the Guayana Shield in Venezuela occupies the region south of the Orinoco River (Figure 1) and a few scattered outcrops to the northwest and west of that river. It consists of Precambrian rocks which range between more than 3.5 and 0.9 G_a (GIBBS & BARRON, 1983). Geomorphologically, the Guayana Shield can be broadly subdivided into two provinces: a northern province, developed on Precambrian igneous-metamorphic rocks (GONZÁLEZ DE JUANA et al., 1980) and dominated by inselbergs, and a southern province, developed in

Proceedings of the IGCP Project 201 Mérida (Venezuela) meeting: p. 1-12.

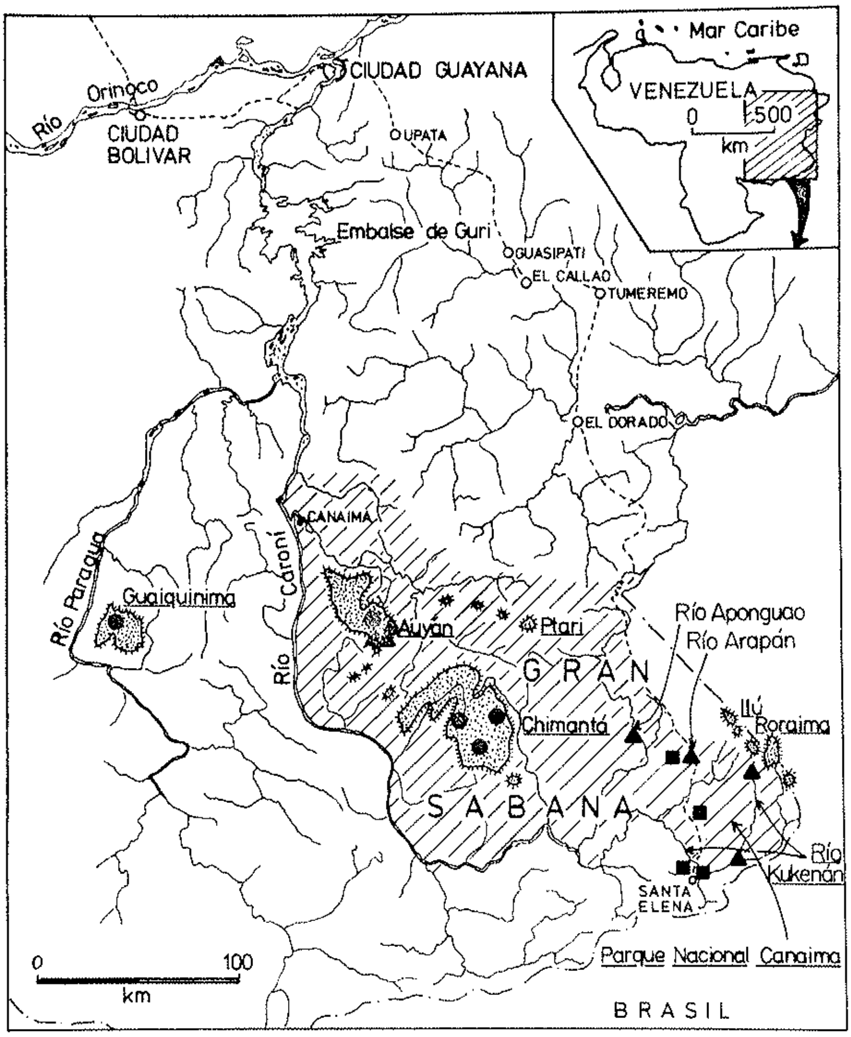
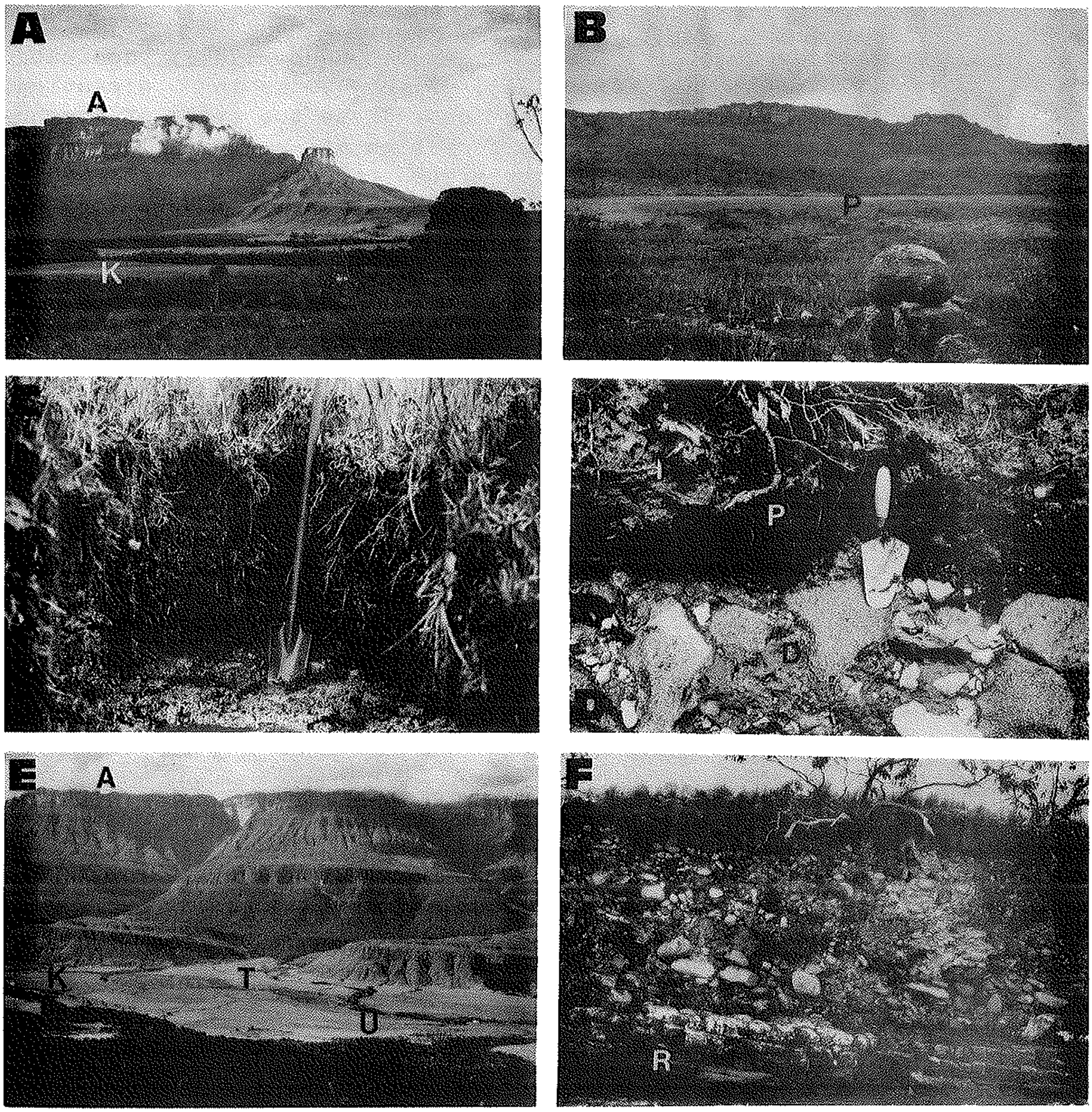


Figure 1 - Index map of southeastern Venezuela (Guayana Shield) showing the location of the study areas. Stippled areas are table mountain complexes (1600-2400 m elevation); these are surrounded by areas of tropical forest and savanna (900-1000 m; hatched areas). Circles: sites of highland peat collection; squares: sites of lowland peat collection; triangles: sites of alluvial deposits.

Precambrian quartzite (Roraima Group; GHOSH, 1985), dominated by table mountains (Figura 2A), up to 2900 m in elevation, and broad anticlines and synclines. These two types of morphologies are the result of the formation of several erosional surfaces, which have been correlated throughout the whole Guayana Shield by some authors (see summary in SCHUBERT et al., 1986). Figure 3 shows a highly speculative and schematic model of the evolution of these surfaces since the Precambrian. Uplift of the Guayana Shield must have been at least of the order of 30-40 km, because the highest metamorphic grade found in the Precambrian rock outcrops is the granulite facies (MENDOZA, 1977). This uplift occurred before the formation of the Imataca and Caroní-Aro erosional surfaces (Early Tertiary?). Each of the erosional surfaces, once its formation began, continued to form during all subsequent surface formation events; they are "present-day" surfaces in that they are all still forming today. This is supported by mineralogical evidence that at least several thousands of meters of rock existed above the present-day highest level of the Roraima Group (URBANI, 1977). The younger two of the erosional surfaces (Llanos and Orinoco floodplain) are the only surfaces with reliable dates; the Llanos surface was developed on the Pleistocene Mesa Formation, and the Orinoco floodplain consists of Holocene alluvial sediments.

LATE QUATERNARY PALEOENVIRONMENTAL EVIDENCE

Quaternary glaciation in the middle latitudes and high mountains of all latitudes was accompanied by aridity in the tropical zone, with growth of deserts and savanna areas at the expense of forest (FAIRBRIDGE, 1970; CHORLEY et al., 1984: 539-542; TRICART, 1985). The main evidence of ice-age aridity in northern South America (see SCHUBERT, in press, for a review) consist of: inactive dune fields in the Venezuelan and Colombian Llanos, arkosic sand deposited by the Amazon River on the Brazilian continental shelf, palynological evidence in the Lake Valencia basin, Guyana, and Brazil, duricrusts underneath present-day tropical humid forest, alluvial fans and terraces, anomalous drainages, and others. This evidence led to the postulation of Late Pleistocene "refuges" of humid tropical flora and fauna during the ice-age aridity (see the volume edited by PRANCE, 1982). The few paleoecological studies undertaken so far in the postulated refuge areas have failed to document their existence (ABSY, 1982; VAN DER HAMMEN, 1972;


A
A
K
B
P
P
D
E
A
K
T
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F
R

Figure 2 - A. Table mountain topography, eroded in Precambrian quartzite (Roraima Group), showing two prominent erosional surfaces: the Auyán-tepui surface (A; 2000-2800 m) and the Kamarata surface (K; 900-1200 m). Shown is the southern flank of Churí-tepui (eastern Chimantá Massif). B. Peat deposit (P) on the central Chimantá Massif (background is Toronó-tepui), deposited within a broad depression, about 2 m thick. Notice the solution features in Quartzite in the foreground . C. Peat section exposed along a stream on Churí-tepui, resting unconformably on Precambrian quartzite (Shovel is about 1.2 m long). D. Peat (P) resting on a duricrust (D) composed of boulders and pebbles of Precambrian diabase, quartzite, and quartz in a ochre to brick-red ferruginous matrix. This is one of the best evidences of Late Pleistocene-Holocene climatic change. E. Southern flank of Auyán-tepui, showing the Auyán-tepui surface (A), the Kamarata surface (K), and the alluvial terrace complex (T) of the Uruyén River (U), flowing towards the reader. On the right margin there are at least four terraces, up to 30 m high, and on the left margin there is a series of terraces partially buried by younger alluvial sediments. F. Alluvial deposit along the upper Kukenán River, composed of compacted gravel overlying horizontal beds of Precambrian chert (Roraima Group; R). The deposit is about 5 m thick.

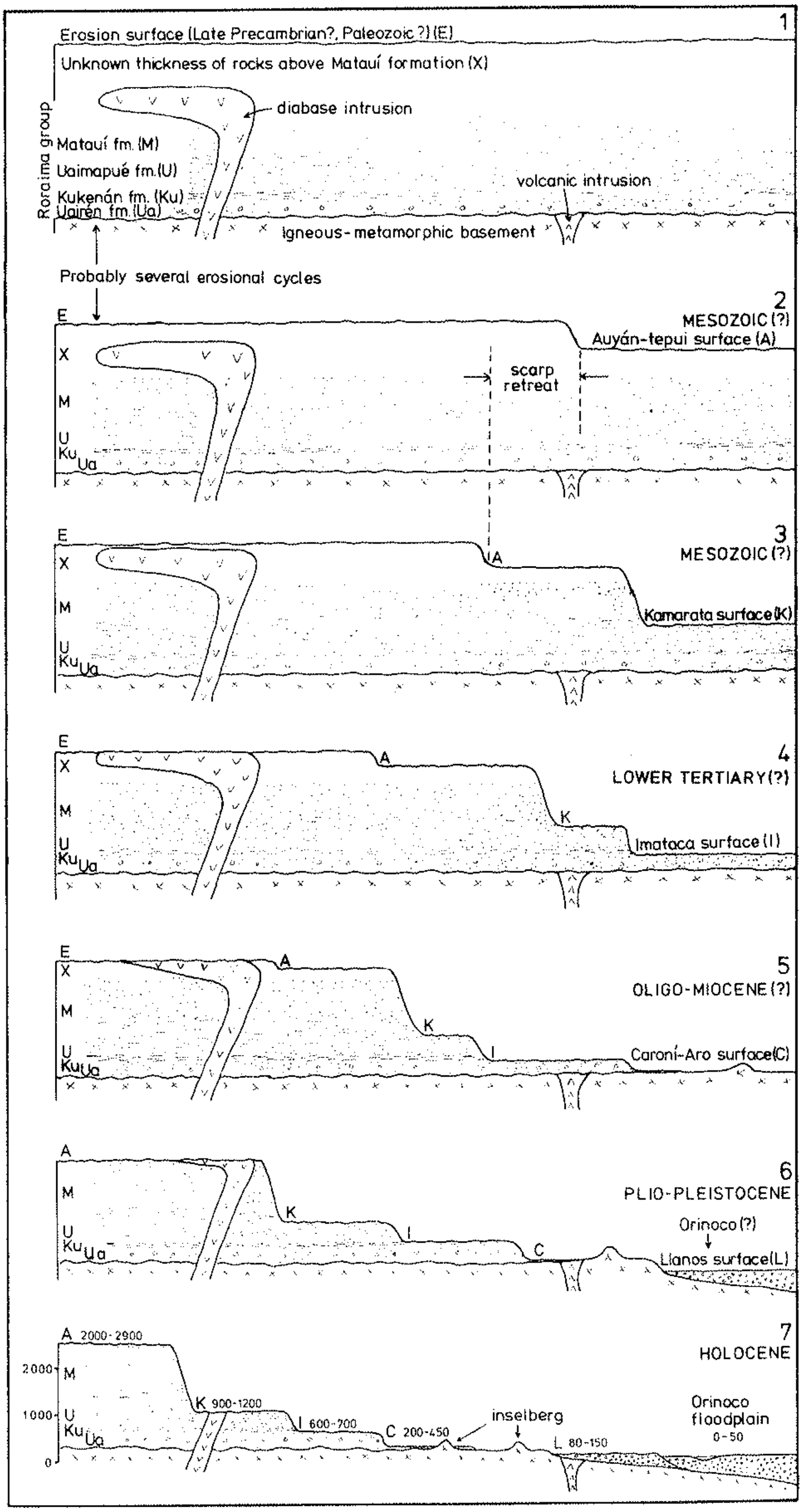
1
Erosion surface (Late Precambrian?, Paleozoic ?) (E)
Unknown thickness of rocks above Matauí formation (X)
diabase intrusion
Roraima group
Matauí fm. (M)
Uaimapué fm. (U)
Kukenán fm. (Ku)
Uairén fm. (Ua)
volcanic intrusion
Igneous-metamorphic basement
Probably several erosional cycles
2
MESOZOIC (?)
Auyán-tepui surface (A)
scarp retreat
3
MESOZOIC (?)
Kamarata surface (K)
4
LOWER TERTIARY (?)
Imataca surface (I)
5
OLIGO-MIOCENE (?)
Caroní-Aro surface (C)
6
PLIO-PLEISTOCENE
Orinoco (?)
Llanos surface (L)
7
HOLOCENE
A 2000-2900
K 900-1200
I 600-700
C 200-450
inselberg
L 80-150
Orinoco floodplain 0-50
2000
1000
0

Figure 3 - Schematic tentative formation of erosion surfaces in the Venezuelan Guayana Shield. The ages are all speculative, except for the lowermost two surfaces. Elevations are in meters above sea level. 1. In the Late Precambrian (?), there was sedimentation (Roraima Group and other rocks that may have existed on top of it), uplift brought the rocks to the surface, and erosion acted on them. Erosional surfaces were probably formed during the Paleozoic, but these have not been preserved, and an unknown thickness of rock was removed. 2. Formation of the Auyán-tepui surface (A). The pre-Auyán-tepui surface (E) continues to be eroded and lowered, and there is scarp retreat. 3. Formation of the Kamarata surface (K). Both surfaces E and A continue to be eroded and lowered. 4. Formation of the Imataca surface (I). All scarps retreat and surfaces E, A, and K continue to be eroded and lowered. 5. Formation of the Caroní-Aro surface (C). This surface is recognized only on the igneous-metamorphic basement. All previous surfaces continue to be eroded and lowered, and all scarps retreat. 6. Formation of the Llanos surface (L). This surface is cut into Plio-Pleistocene sediments of the Mesa and equivalent formations, and is partly aggradational. 7. Holocene situation: six erosional surfaces, all being eroded and the Orinoco River is building the lower surface on its flood plain.

SALGADO-LABOURIAU, 1980).

The Venezuelan Guyana Highlands were postulated as a Late Pleistocene refuge area (STEYERMARK, 1979). To test this possibility, a multidisciplinary project was started in early 1984, part of which consists of the study of Quaternary sediments. In particular, it focused on discontinuous peat deposits on the summits of the table mountains and surrounding savannas, and on alluvial deposits in their piedmonts.

Peat deposits

A discontinuous layer of herbaceous peat (Figure 2B) on the table mountain summits was sampled on the Chimantá and Guaiquinima Massifs and on the Auyán-tepui (Figure 1). It overlies pink, cross-bedded quartzite of the Mataui Formation (top unit of the Roraima Group). Samples were collected directly from peat outcrops along streams (Figure 2C) or from cores taken with a Hiller peat sampler. The peat consisted of root remnants and other plant material, and the maximum thickness encountered so far is 2 m.

Radiocarbon ages of seven peat samples (SCHUBERT & FRITZ, 1985; SCHUBERT et al., 1986) indicate that the age of the bottom of the peat deposits ranges from 3,120 ± 80 to 6,000 ± 80 radiocarbon years B.P. Radiocarbon ages of the top of the peat sequences range from 350 ± 60 radiocarbon years B.P. to 105.9% modern. Contamination by modern plant material was inevitable in spite of careful previous cleaning of the samples, and was estimated as between 10 and 30%. According to OLSSON (1974), adjustment of the radiocarbon ages for this amount of contamination (30%) will result in maximum ages ranging from 4,160 to more than 8,000 years B.P. The ultra-modern ages of the youngest peat in the sequences could be interpreted as due to the "bomb-effect" (^{14}C produced by nuclear explosions; McKAY et al., 1986). The latter effect could also increase the maximum radiocarbon ages by perhaps 1,000 years. Thus, the last peat-forming event seems to have begun in the Early Holocene, or earlier. Previous to that, ecological conditions (Late Pleistocene) probably were not favorable for peat deposition (which requires high humidity, rapid plant growth, and anaerobic conditions), and suggests a more arid climate. Independent evidence of this is found in the existence of a ferruginous duricrust underlying the peat on Apacará-tepui (Chimantá Massif; Figure 2D).

Lowland (savanna) peat (900-1,000 m elevation) was recently sampled at four localities (Río Arapán and in the Santa Elena area; Figure 1). At two sites, the peat is associated with permanent small lakes; it overlies an ochre, ferruginous sand, which is interpreted as a pre-Holocene duricrust, and its maximum thickness found so far is 2.5 m. Radiocarbon analyses are currently underway on this material.

The highland and lowland peat is the subject of palynological analyses which hopefully will generate more precise paleoecological data (SALGADO-LABOURIAU & VILLAR DE SEOANE, in press).

Alluvial deposits

Alluvial deposits in the Guayana Shield were first described in general by AGUERREVERE et al. (1939). In spite of their importance as gold- and diamond-bearing placers, few studies have been done on them. Recently, BRICEÑO (1985) determined an Early Holocene age for diamond-bearing alluvium in the middle Caroní River basin. GARNER (1966) suggested that rivers in the Guayana Shield reflected a geologically recent (Holocene) increase in water flow, which formed anastomosing and anomalous drainages, suggesting a previous more arid climate with concomitant alluviation.

In the piedmont areas of the table mountains, and along many rivers, there are alluvial deposits in the form of terraces and terrace-complexes (Figure 1; SCHUBERT, 1986).

In the Kukenán River, there are two main levels of alluvial terraces: 1-2 m, and 3-5 m above the river level. The lower terrace consists of dark brown sand with lenses of quartzite pebbles. The 3-5 m terrace consists of a fairly consolidated, subrounded to subangular boulder gravel(Figure 2F), of pink to white quartzite, green chert, and diabase in a ochre, ferruginous, sandy matrix. These rock types were derived from the Roraima Group in the adjacent table mountains (Kukenán-tepui and Roraima-tepui). The gravel forms a chaotic mixture with no sedimentary structures, which overlies unconformably horizontal to subhorizontal Roraima quartzite beds.

In the southern flank of Auyán-tepui (Figure 1), there are several alluvial terrace-complexes, located at two different levels: on the Kamarata erosional surface (Uruyén River, 450 m; Figure 2E) and on the first ledge of Auyán-tepui, formed by a more resistent quartzite unit (720 m). In the upper Uruyén River, there are four terrace levels (1-2 m, 5-10 m, 10-15 m, and 20-30 m). In general, they consist of rounded to subrounded cobble to boulder gravel, at places with rare incipient clast imbrication and crossbedding. The clasts consist of pink to white or greenish-gray quartzite, green chert, and diabase in an ochre, ferruginous matrix. Ferruginous duricrusts have formed sporadically on the terrace surfaces. Weathering of the clasts increases from pratically non-existent in the lower terrace to widespread in the highest; in fact, in the latter, clasts are only recognizable as a colored patch in a sandy, massive material. This reflects increase in age from the lowest to the highest terrace.

In the alluvial plain of the Uruyén River, along its lower left margin, there are numerous terraces, partially buried by younger alluvium, which rise 5 to 10 m above it (Figure 2E). They seem to represent former Uruyén River courses.

These alluvial sequences have been interpreted as the product of intermittent, torrential, chaotic sedimentation under a climate more arid than today (SCHUBERT et al., 1986). At present, the streams carry little sediment and most of the weathering is chemical.

CONCLUSIONS

Preliminary study of peat deposits of the Guayana Highlands and intervening savannas, and on alluvial deposits suggests that in the Late Pleistocene, this region supported a more arid climate than today, with a scarcer vegetation cover and, consequently, more mechanical erosion. Intermittent, torrential streams carried the products of this erosion from the table mountains to the savannas, and deposited them as extensive alluvial fans. In the Holocene, climate changed toward more humid conditions, and extensive chemical weathering took place; peat deposition began in small rock depressions, and the perennial streams dissected former alluvial deposits to form terraces. This evidence does not support the contention that ecological conditions remained stable during the Pleistocene, and that the Guayana region was a biological refuge.

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GEOMORFOLOGIA DEL PIEDMONTE DE PRECORDILLERA, SECTOR QUEBRADA DE ZONDA, PROVINCIA DE SAN JUAN, ARGENTINA

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ABSTRACT

Twenty kilometers to the west of the San Juan capital, the Zonda canyon lies. During the Early Quaternary, it was a valley through Oriental Precordillera, where the San Juan river ran. In that region various Quaternary units were identified, taking into account: origin and age of landforms, lithology, land use and vegetation. The knowledge of them allowed to obtain suggestions about the probable use of some land units and applied geomorphology to cave-in lands existing within the old alluvial cone of San Juan river. Pleistocene landforms such as levels of terraces and piedmont alluvial plains, and the great old San Juan river alluvial cone were identified in that area. On geomorphological view point, it was possible to recognize regional and local morphostructural units, and evidences of neotectonic phenomena affecting Quaternary landforms. On the other hand, in this sector, within the foothill deposits of cerro Zonda were recognized two areas with elevated potencial seismic hazard.

RESUMEN

La quebrada de Zonda se encuentra a 20 km hacia el oeste de la capital de San Juan. A principios del Cuaternario constituyó un valle a través de la Precordillera Oriental, lugar por donde corría el río San Juan. En la región se identificaron unidades cuaternarias en base a morfogénesis, morfocronología, litología, permeabilidad cualitativa, uso de la tierra y vegetación. El conocimiento de las mismas permitió arrojar recomendaciones sobre posibilidades de uso o forestación de tierras incultas y sobre la aplicación de la geomorfología a los problemas de revenición en el antiguo cono

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del río San Juan. Se identificaron geoformas pleistocenas tales como dos generaciones de conos aluviales, el gran cono antiguo del río San Juan y varios niveles de terrazas.

INTRODUCCION

Este trabajo constituye la primera etapa de un "Plan de Investigación Regional" acerca de las unidades morfoestructurales, desarrolladas en el área intermontana, existente entre la Precordillera Oriental, al oeste, y la sierra Pie de Palo, al este, denominada Valle de Tulum, en la provincia de San Juan. Se pretende identificar, clasificar y interpretar las unidades geomorfológicas del Cuaternario existentes tanto en el área piedemontana de Precordillera Oriental como en el valle propiamente dicho.

La provincia de San Juan se localiza en el centro-oeste de la República Argentina, entre los meridianos 70°35' y 66°40' de longitud oeste y entre los paralelos de 32°40' y 28°10' de latitud sur. Abarca una superficie que se estima aproximadamente en 93.650 km², donde prácticamente 2/3 de la misma están ocupados por macizos montañosos, de significativa jerarquía geomorfológica, y el tercio restante está representado por áreas tectónicamente deprimidas, de varias decenas de km de ancho y cubiertas en casi toda su extensión por sedimentos cuaternarios, comúnmente de varios centenares de metros de espesor. Las conexiones geomorfológicas entre las cadenas montañosas, de rumbo casi N-S, se establecen mediante las zonas deprimidas antes enunciadas que conforman extensos valles longitudinales, de relevante importancia en la Provincia de San Juan por constituir verdaderos "oasis" o sitios de mayor aptitud para los asentamientos humanos y el consecuente desarrollo agrícola-industrial.

El valle de Tulum, al sur de la provincia de San Juan, es una zona tectónicamente deprimida, ubicada entre dos provincias geológicas montañosas de la región occidental argentina: las Sierras Pampeanas Occidentales y la Precordillera Oriental (ORTIZ y ZAMBRANO, 1981).

Prácticamente, un 90% de la población sanjuanina se asienta en este valle de ínteres.

El posible aumento de problemas de índole ecológica, algunos en parte ya existentes, tales como contaminación con nitratos del agua circulante por el subálveo de la quebrada, ante nuevas construcciones de viviendas y balnearios, o la contaminación atmosférica producida por fábricas existentes, o la destrucción de geoformas y formaciones geológicas ante la apertura de huellas mineras y explotaciones de canteras, motivó la realización de este estudio. Se trata de conocer entonces, las diferentes unidades geoambientales y el comportamiento dinámico de las mismas, estableciendo la asociación entre las geoformas, los suelos o litologías y la vegetación natural o uso de la tierra.

ANTECEDENTES

En la provincia de San Juan, tanto en las Sierras Pampeanas como en la Precordillera, se han efectuado investigaciones geológicas desde hace ya mas de un siglo.

En años recientes, principalmente debido a las actividades de diversos organismos estatales y empresas petroleras privadas, se han compilado muchos de estos resultados en mapas e informes. El Centro Regional de Agua Subterránea (CRAS) ha realizado numerosos estudios de borde de cuenca en el valle de Tulum y de Ullum-Zonda, uno de cuyos resultados principales fue la obtención de un mapa geológico del área, a escala 1:100.000 (ROCCA, 1970).

Con posterioridad al trabajo de Rocca, comenzaron a utilizarse imágenes satelitarias. Además se realizaron numerosos estudios adicionales en las zonas de borde y de piedemonte, en gran parte como trabajos finales de licenciatura y tesis doctorales de la Universidad Nacional de San Juan. No obstante, no ocurre lo mismo con referencia a la información geomorfológica, área en donde se nota un cierto déficit.

CONSIDERACIONES GEOMORFOLÓGICAS REGIONALES

Los distintos sistemas, procesos y agentes morfogenéticos que actuaron y que actúan, en la región, sobre los materiales rocosos muy heterogéneos, desde el punto de vista litológico, estratigráfico y estructural, han imprimido rasgos morfológicos particulares sobre cada una de las provincias geológicas creando, regionalmente, paisajes muy contrastados (DE-GAIRAZ y SUVIRES, 1984).

De tal manera se reconocen en el ámbito sanjuanino tres sectores: A) Hacia el oeste del territorio (región cordillerana): un dominio de relieves muy elevados con alturas superiores a los 5000 m. (Cerro Mercedario = 6770 m.s.n.m.)con un predominio de morfología glacial y periglacial.

B) Hacia el centro de la provincia (región de Precordillera): se desarrollan también, relieves significativos en altura, los cuales superan ampliamente los 3000m (Mogote, Vallecito, en la sierra la Invernada, con 3876m y la sierra de la Punilla con cerros que superan los 4500m.s.n.m.).

C) Hacia el este del territorio (región de Sierras Pampeanas): aparecen relieves en correspondencia a unidades geológicas muy antiguas referidas al "basamento metamórfico precámbrico", y cuyas alturas medias oscilan entre los 1500 y 2000 m. Se destaca entre estos últimos relieves a la sierra Pie de Palo, con una altura máxima de 3162 m.s.n.m.(Mogote Los Corralitos).

Se puede señalar, con referencia al grado de erosión a que han sido sometidas las unidades morfoestructurales, que la Cordillera Jóven, al oeste, (Cordillera Principal o del Límite y Cordillera Frontal) es afectada por un proceso erosivo incipiente pero intenso; la Cordillera antigua, al centro, (Precordillera) por un proceso erosivo de grado más avanzado y más prolongado que ha arrasado y en parte peneplanizado a este tronco montañoso principalmente paleozoico, y finalmente en el "área de los troncos de montañas del basamento pampeano", al este, el proceso de erosión ha sido mayor que en las dos unidades antes citadas (REGAIRAZ *et al*., 1987).

UBICACIÓN DEL SECTOR DE ESTUDIO: QUEBRADA DE ZONDA

Se decidió comenzar con la quebrada de Zonda para el presente estudio, por considerarla como un área clave, para el estudio de la geomorfología local y para lograr el discernimiento de la historia geológica de la región.

La zona de estudio, quebrada de Zonda y alrededores, se encuentra a 20 km hacia el oeste de la ciudad capital de San Juan. Se accede a la misma por la ruta Nacional Nº 20 o por ruta Provincial Nº 14 (Av. Libertador Gral San Martín).

La quebrada de Zonda representa, en ese sector, el último evento geomórfico en la compleja historia del río San Juan, a principios del Cuaternario (SUVIRES, 1985).

UNIDADES GEOMORFOLÓGICAS LOCALES

La quebrada de Zonda es un antiguo cauce, actualmente seco y cultivado, del río San Juan, que tiene una dirección SO-NE y que atraviesa la sierra Chica de Zonda, por su extremo norte, perteneciente al Sistema de Precordillera Oriental, y comunica el valle de Ullum-Zonda, hacia el oeste, con el valle del Tulum, hacia el este.

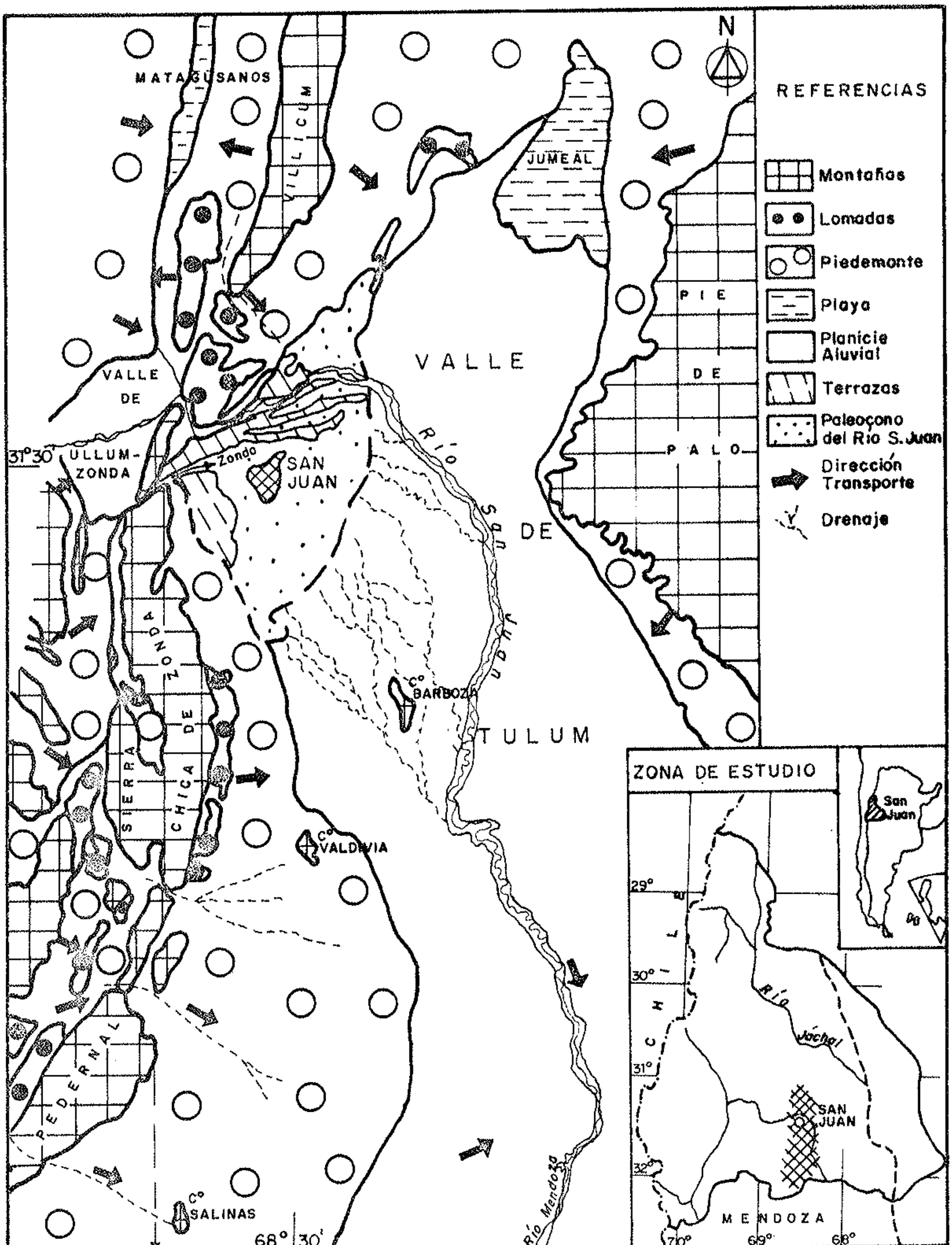
Es también denominada "Estero de Zonda" y alcanza tres kilómetros de longitud desde su entrada en la sierra Chica de Zonda, a la altura del dique Soldano, hasta su salida del área serrana, en el Jardín de Los Poetas. La quebrada tiene anchos variables entre 150 hasta 500 m. Es utilizada, por la proximidad a la ciudad de San Juan y por su vegetación arbórea abundante, como zona balnearia turística.

A lo largo de este antiguo valle se presentan relictos del nivel de terraza superior (T1), apoyados sobre afloramientos calcáreos del Cámbrico (BORDONARO, 1980), sobre los cuales se han construido hoteles y viviendas. Existen cavidades de disolución, de diferentes tamaños, en las rocas calcáreas que limitan a la quebrada y algunas de ellas estan ocupadas por material de terraza, rodados de rocas ígneas y de vulcanitas provenientes tanto de la Cordillera Jóven como de la Antigua.

La figura 1 muestra la disposición y ubicación de las unidades morfoestructurales que circunvecinan al valle de Tulum, área objeto de estudio.

Las geoformas pertenecen, sinteticamente, a dos categorías regionales de máxima jerarquización: A) Formas "heredadas o precuarternarias" y B) Formas cuaternarias. Entre las primeras se encuentran los niveles de superficies casi planos, denominados penillanuras o peneplanos, elaborados sobre los relieves elevados y montañosos de las sierras Chica de Zonda, Villicum, Pedernal y Pie de Palo. La ubicación de estos niveles no han sido mapeados en la Fig. 1.

Por otro lado, las unidades geomorfológicas cuaternárias (B) se desarrollan al pie de los frentes montañosos ocupan



Unidad Montañosa	Area Pedemontana	Planicie Aluvial Antigua de los Ríos San Juan y Mendoza	Escala gráfica
PALEOZOICO	CUATERNARIO		0 5 10 Km

UNIDADES MORFOESTRUCTURALES EN EL VALLE DE TULUM

Fig. Nº 1

do las áreas tectonicamente deprimidas.

En esta región sanjuanina, desarrollada bajo condiciones climáticas semiáridas con precipitaciones menores a los 100 mm/año, las geoformas típicas de ciclos áridos son abundantes, tales como los diferentes niveles de pedimentos o glacis de erosión y de acumulación, las playas (barreales y salinas), como por ejemplo la playa El Jumeal inmediatamente al norte de la depresión del Tulum y la de Matagusanos, al oeste de la sierra de Villicum. Las geoformas se disponen en una sucesión altimétrica desde el "knick point" de la sierra Chica de Zonda, a los 1000 m.s.n.m. hasta el nivel de base local, el cauce actual del río San Juan, a los 550 m.s.n.m.. En una transecta oeste-este se destaca la presencia del piedmonte con unidades geomórficas menores, la planicie aluvial antigua y abandonada del río San Juan, también con unidades menores (meandros, cauces abandonados y médanos) y finalmente las playas y el cauce actual del río San Juan (Fig. 1).

A) Formas precuaternarias

El arco constituido por las sierras de Zonda y de Villicum pertenece a la Precordillera Oriental, y tiene un estilo estructural que lo caracteriza, de fallas inversas de alto ángulo en superficie que limitan a las sierras por el oeste y las vuelca hacia el este (BALDIS et al., 1981). Está formado hacia el sur por la sierra Chica de Zonda, al centro por el cerro de Zonda y termina hacia el norte con la sierra de Villicum. El cerro de Zonda es un cordón montañoso, norte-sur, de 11 km de longitud y alturas superiores a los 1100 m. En toda la longitud del cordón serrano de Zonda se localizan superficies casi planas de 1 a 2 km de largo que constituyen presumiblemente relictos de penillanuras. Se ubican en diferentes cotas pero preferiblemente a los 1900, 2000 y 2200 m.s.n.m.

El control de la estructura y de los esfuerzos compresivos andinos se visualiza rapidamente en algunas características de la morfología serrana, como puede ser la asimetría de las vertientes occidental y oriental, ésta última de mayor desarrollo lateral.

B) Formas cuaternarias

Se procedió al mapeo de las unidades geomórficas cuaternarias, mediante la fotointerpretación de fotogramas a escala 1:10,000 y las posteriores comprobaciones de campo, obteniendo la Fig. 2.

Las unidades observadas a la salida de la quebrada de Zonda indican procesos alternantes de agradación y degradación originando formas de acumulación o de erosion, respectivamente. Entre las primeras merecen citarse los conos aluviales y los conos de deyección. En cambio el talud existente entre la terraza superior T1 y la terraza inferior T3, señala un vaciamiento y destrucción de la morfologia o superficie del antiguo y gran cono del río San Juan. Las unidades locales se disponen en el siguiente orden altimétrico:

860m hasta 800m: conos de deyección o de derrubios.
800m hasta 755m: cono aluviales antiguos de arroyos efímeros (C)
755m hasta 735m: conos más modernos coalescentes o bajada (B)
740m hasta 735m: talud entre terraza superior y terraza intermedia.
730m hasta 725m: terraza intermedia (T2).
725m: fondo de quebrada o paleovalle T3.

En el cuadro seguiente se presenta una síntesis de las unidades citadas.

CONOS DE DEYECCIÓN

En la margen noroccidental de la quebrada de Zonda (Fig. 2) se localizan depósitos de coluvios con forma de conos y dispuestos sobre afloramientos calcáreos de edad cámbrica. Hacia el oeste del Jardín de Los Poetas, nace un cono de deyección a los 860m, a partir de una falla, de rumbo NE-SO, que sobrepone afloramientos de sedimentitas del Terciario a calizas paleozoicas. Este cono tiene 49% de pendiente y se extiende hasta los 800 m. Contiene fragmentos subangulosos y angulosos de caliza gris y sedimento arenoso, claro, calcáreo, que cubre a la roca infrayacente, cabonática de la Formación La Laja, asignada al Cámbrico Inferior-Medio por BORDONARO en 1980. La vegetación en estos conos es principalmente de Bromeliáceas y de Larreas (nítida, divaricata y cuneifolia). Se encuentran además, Bulnesia remata, Gravowskya obtusa (oreja de gato) y Glandularia crithmifolia (té de burro). En esta geoforma no se observó drenaje superficial.

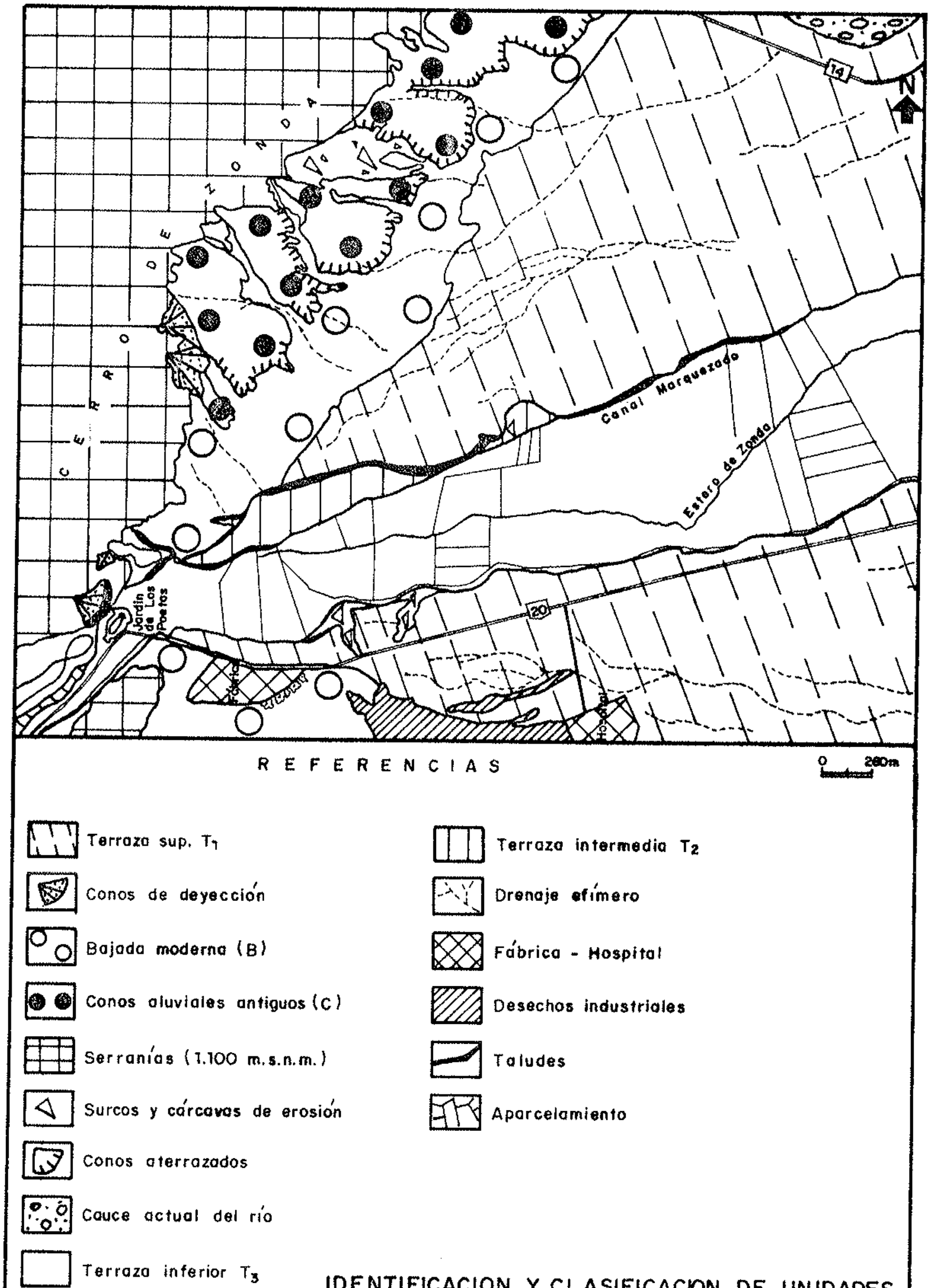


Fig. Nº 2 IDENTIFICACION Y CLASIFICACION DE UNIDADES GEOMORFOLOGICAS DE LA QDA. DE ZONDA

RELIEVE	UNIDADES GEOMORFOLÓGICAS		ESTRATIGRAFIA	EDAD	
BAJO	Cauce de inundación actual río San Juan (Ullum)		Rodados gruesos con arena intersticial	actual ↓	CUATERNARIO ↓
	Cono aluvial antiguo del río San Juan (Quebrada de Zonda)		Rodados de rocas igneas y de vulcanitas cubiertos por barniz.		
		T1: Terraza superior	Rodados de grauvacas, riolitas, granitos, arcosas y calizas.		
		T2: Terraza intermedia			
		T3: Terraza inferior	Suelos franco-arcillosos y limosos (cultivado).		
INTERMEDIO	Sectores de bajada del cono antiguo del río San Juan contaminados con desechos industriales.		Materiales finos, blancos que cubrem a conos y a afloramientos terciarios.	Pleistoceno ? ↑	CUATERNARIO ↑
	Bajada pedemontana (cubre en sectores a la terraza superior T1).		Depósitos coluviales y aluviales, al pie del Cerro de Zonda.		
	Conos de derrubios o de deyección		Coluvios sobre calizas paleozoicas.		
	Conos aluviales antiguos		Rodados fluviales provenientes del cerro de Zonda.		
	Lomadas con cubierta cuaternaria	bajas, redondeadas.	Limolitas y areniscas rosadas de la Formación Ullum, con intercalaciones conglomerad.	Mio.-Plioc.	TERCIARIO
		con abarrancamientos.			
ALTO	Montañas de un sector de la Sierra Chica de Zonda.		Rocas carbonáticas del Grupo Marquesado. (Bordonaro, 1981).	Cám. inf-sup	PALEOZOICO INFERIOR

CONOS ALUVIALES ANTIGUOS DE ARROYOS TEMPORARIOS DEL CERRO DE ZONDA

Los espesos depósitos de rodados, provenientes de la margen oriental del cerro de Zonda, forman distintos conos aluviales. Estos sobresalen de la morfología local porque no presentan una fase transicional, en su porción distal, a la bajada más moderna, sino que terminan en forma lobulada-abarrancada, elevándose en unos 15 a 20 m por encima del nivel de bajada.

Son, en general, geoformas heredadas que formaron una bajada pleistocena, actualmente desconectada y desmenbrada.

Los rodados integrantes de su cubierta son de caliza, margas, pedernal y cuarcitas (WEIDMANN, 1983).

También se hace presente, en estos conos, la acción tectónica moderna interrumpiendo la continuidad de los conos en sus porciones proximal y media. Como resultado de esta actividad neotectónica se forman zonas con mayor vulnerabilidad a la erosión hídrica, originando surcos y cárcavas de erosión, afectando tanto a sedimentitas terciarias como a la cubierta cuaternaria de los conos.

Es muy posible que estos conos de primera generación se hayan formado simultáneamente con el cono antiguo del río San Juan a la salida por la Quebrada de Zonda.

CONOS ALUVIALES COALESCENTES (BAJADA) DE SEGUNDA GENERACIÓN (B)

Forman una suave y amplia planicie entre los conos antiguos (C) y al pie de los mismos, y cubren partes de la primera superficie de terraza T1 y a veces T2. Están formados por rodados de caliza, areniscas y conglomerados.

En cuanto a vegetación se refiere, existen _Larreas_ sp., _Bulnesia retama_ y _Geoffroea decorticans_ (chañar).

El drenaje en esta unidad presenta mayor densidad que en la anterior (C).

CONO ALUVIAL DEL ANTIGUO CAUCE DEL RIO SAN JUAN

El río San Juan, antiguamente, comunicaba el valle de Ullum-Zonda con el Tulum, al oeste, a través de la quebrada de Zonda. El cauce de agua favoreció la formación de geoformas de acumulación y de erosión, terrazas y taludes respectivamente, observables en las márgenes y salida de la quebrada. Las terrazas se elevan por sobre el fondo de la quebrada en alrededor de 15 m. El tamaño de los rodados, medianos y gruesos, señalan la considerable competencia de la corriente de agua, que depositó esa carga.

La dirección SO-NE de la quebrada de Zonda influyó en la disposición del eje del cono aluvial que se formó a la salida de la misma, también SO-NE.

Este cono, desarrollado a la manera de abanico de explayamiento, alcanza en sentido radial O-E, 18 km, y 25 km en sentido N-S. Su porción proximal o apical está conformada por rodados gruesos y medianos de grauvacas, riolitas, granitos, andesitas, conglomerados, areniscas, arcosas y escasas calizas. La mayoría de los clastos y rodados superficiales están cubiertos por una pátina gris azulada llamada barniz del desierto. En cambio, la porción media del cono está formada por arenas sobre rodados o en parte conglomerados. Finalmente, la parte distal se extiende a más de 25 km de la quebrada de Zonda y tiene sedimentos finos, arenosos y arcillo-limosos.

El cauce actual del río San Juan bordea al antiguo cono por el extremo norte y atraviesa partes con los sedimentos finos distales.

En la parte media del cono antiguo se sitúa el núcleo urbano de San Juan y, en cambio, en el tramo medio-distal comienzan las zonas con cultivo intensivo.

Quedan, en el valle de Tulum, evidencias de antiguos cursos del río San Juan que ahora actúan como drenes naturales, parcialmente reguladores de la alta freática o fenómeno de revenición. Pueden señalarse a la manera de ejemplo los arroyos Agua Negra y de Los Tapones (Fig. 1).

El cono en cuestión posee tres niveles de terraza, dos de extensión regional (T1 y T3).

El río San Juan nace a más de 150 km del área en estudio y es alimentado por el derretimiento de nieves y glaciares. La presencia de dos a tres niveles de terraza en su curso inferior, sugeriría la idea de cambios en la competencia y cau dales del río, a través del tiempo, controlados muy posiblemente por alguna variación en el suministro o régimen de alimentación en Alta Cordillera.

CAUCE DE INUNDACION ACTUAL DEL RIO SAN JUAN

Se observa una mínima parte del mismo en el sector norte de la Fig. 2. Es una amplia planicie de inundación estacional surcada por numerosos brazos del río que se anastomosan. Está rellena por rodados medianos y gruesos provenientes tanto de Alta Cordillera como de Precordillera. Esta unidad, por el momento, no ha sido investigada.

GEOMORFOLOGIA APLICADA

Geomorfología como apoyo al estudio de uso de la tierra y forestación

Las distintas entidades geomórficas reconocidas, tales como conos, abanicos y terrazas, poseen diferentes usos de la tierra. Los conos de derrubios y los conos aluviales tanto antiguos (C) como modernos (B) están incultos, con vegetación natural arbustiva. En cambio, la terraza T3, o de nivel inferior, está cultivada con viñedos y olivares. La terraza T2 es de reducida extensión areal y en parte está cubierta por derrubios y rocas en superficie. No obstante, eliminando la pedregosidad puede transformarse en área útil. Asi también, el techo de la terraza T1 puede ser aprovechado para la plantación de árboles de raíz profunda.

Geomorfología como apoyo a los problemas de revenición

Los sectores cultivados del antiguo cono que coinciden con las porciones distales del mismo son afectados temporariamente por la alta freática. En estas regiones el nivel freático del agua subterránea se situa próxima a la superficie del terreno. Son zonas topográficamente bajas, casi planas, de escasa pendiente y con sedimentos finos. La revenición deteriora los cultivos, muriendo los de raíces profundas y dañando seriamente a las hortalizas, como asi también saliniza los suelos y afecta la estructura de los peds (SUVIRES *et al*.1986). La dinámica y mecanismo de la revenición es bien conocido en la provincia de San Juan y ha sido estudiado por entes estatales y privados.

Una de las soluciones a este problema consistiría en la limpieza y profundización de algunos paleocauces del río San Juan, con el fin de que actuaram como drenes reguladores naturales, caso Arroyo Tapones y de Agua Negra.

Geomorfología como apoyo a los problemas ecológicos

A la salida de la quebrada de Zonda, pese a ser una zona turística, los problemas de contaminación se agravan y aumentan, sin tomarse, por el momento, medidas preventivas algunas. Basureros y desechos industriales son frecuentes en el área. Especialmente estos últimos que provienen de los residuos de una fábrica de cemento y que, en días de viento, levantan nubes de polvo blanco, irritando la vista y ocasionando problemas alérgicos. Este desecho cubre una amplia superficie en la margen oeste del hospital allí existente y, con las lluvias torrenciales y esporádicas locales, es arrastrado hasta las zonas cultivadas o urbanizadas más próximas.

Por lo que se recomienda evitar la instalación de basureros municipales, de industrias y fábricas en la zona proximal del cono de Zonda y ubicar los parques industriales y fábricas en sitios claves que no sean muy afectados por la circulación de los vientos locales.

Geomorfología como apoyo a los estudios de neotectónica

En el área de estudio se encuentran dos zonas de fracturación moderna, detectadas en 1970 por ROCCA, una próxima al hospital y la otra al E-NE del cerro de Zonda. En estos dos sectores se observó, en el campo, la presencia de cárcavas y surcos de erosión elaborados sobre afloramientos terciarios, que fueron ascendidos, y sobre rodados más modernos. Se destaca lo citado en último término dado que, al generarse un nuevo desnivel topográfico se desata una onda erosiva retrocedente. La posterior acción eólica y fluvial se ha encargado de atenuar los rasgos del plano de falla y del escarpe (REGAIRAZ *et al.*, 1986).

SÍNTESIS

Del análisis realizado en la zona, hasta el presente, se recomienda, en forma suscinta, tener en cuenta el ambiente geomorfológico natural existente en el valle de Tulum para poder planificar adecuadamente los sitios para planeamiento urbano, para instalación de parques industriales y la elección de tierras para zonas agrícola-ganadero.

Evitar la proliferación de industrias y de fuentes contaminantes en el sector apical del cono, de mayor permeabilidad e infiltración, para prevenir la contaminación de las aguas.

Utilizar los paleocauces o paleoarroyos del río San Juan para regular parcialmente o, en todo caso, atenuar los efectos de la revenición.

Aprovechar la terraza T1 para plantación de árboles y de este modo contrarrestar los efectos de contaminación fabril y asi también comenzar a proteger el suelo de la erosión eólica y antrópica.

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NOVAS EVIDÊNCIAS DE ATIVIDADE TECTÔNICA MODERNA NO SUDESTE BRASILEIRO: OS DEPÓSITOS FALHADOS DA FORMAÇÃO PARIQUERA-AÇU

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ABSTRACT

The Pariquera-Açu Formation constitutes the substrate for the late Pleistocene Cananéia Formation and other Quaternary coastal deposits and is assumed to be Pliocene-Pleistocene in age according to preliminary palynological data. However, this must be considered as its minimum age, because it was accepted due to the absence of miofloristic assemblages indicative of older ages. On the other hand, Cananéia Formation is recording the homonymous transgressive episode, which occurred during the Sangamon interglacial period (about 120,000 years B.P.).

Preliminary surveys on the Pariquera-Açu Formation in the Ribeira de Iguape river valley (southern State of São Paulo, Brazil) have revealed a set of mesoscopic, predominantly normal post-sedimentary faults affecting the sediments. Systematic measurements of the fault planes, in an outcrop situated 23.9 km south of Biguá, in the road to the town of Iguape, showed that they are related with older structures as joints and meta-

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morphic foliations of different origins which are present in the Precambrian basement rocks. Computer geometric analysis of fault planes and slickenside lineations indicated a subvertical maximum shortening axis (Z), a subhorizontal NNE-SSW intermediate axis (Y), and a subhorizontal WNW-ESE maximum extension axis (X). In a pure shear regime, σ_1, σ_2 and σ_3 stress axes can be associated respectively with the above mentioned axes.

The Cenozoic tectonic events registered in southeastern Brazil are related to the evolution of the Serra do Mar Continental Rift System. The first one, active during the Tertiary at least until the Eocene, of tractional character, is believed to be the generator of the deformational structures measured in the Pariquera-Açu Formation. On the other side, possible compressive structures (mesoscopic reverse faults) affecting the Cananéia Formation deposits near the homonymous island could be interpreted as a product of a second tectonic event, believed as a right-lateral convergent transcurrence along ENE-WSW to E-W directions, caused by transpression which took place probably from Miocene until possibly Pleistocene times.

The correlation of the observed structures with regional tectonic events represents a first attempt to date these features, but the possibility of younger ages are not to be discarded.

RESUMO

A Formação Pariquera-Açu constitui o substrato para a Formação Cananéia, do Pleistoceno Superior, e outros depósitos costeiros do Quaternário, sendo considerada de idade pliocênica-pleistocênica segundo dados palinológicos preliminares. Entretanto, esta deve ser considerada como idade mínima, porque ela foi admitida em virtude da ausência de assembléias miofloristicas indicativas de idades mais antigas. Por outro lado, a Formação Cananéia registra o episódio transgressivo homônimo, que ocorreu durante o período interglacial Sangamoniano (cerca de 120.000 anos A.P. = Antes do Presente).

Os levantamentos preliminares realizados sobre a Formação Pariquera-Açu no vale do Rio Ribeira do Iguape (sul do Estado de São Paulo) revelaram um conjunto de falhas pós-deposicionais predominantemente normais afetando os sedimen-

tos. Medidas sistemáticas dos planos de falha, em um afloramento localizado 23,9 km ao sul de Biguá, na estrada para Iguape, mostrou que eles estão relacionados com estruturas mais antigas como juntas e foliações metamórficas de diferentes origens que estão presentes nas rochas pré-cambrianas do embasamento. Análise geométrica dos planos de falha e lineações de estrias de atrito em computador indicaram um eixo máximo de encurtamento (Z) subvertical, um eixo intermediário (Y), orientado NNE-SSW, e um eixo máximo de alongamento (X), orientado WNW-ESE, ambos subhorizontais. Em um regime de cisalhamento puro, os eixos de tensão σ_1, σ_2 e σ_3 podem ser associados respectivamente com os acima mencionados.

Os eventos tectônicos cenozóicos registrados no sudeste brasileiro estão relacionados à evolução do Sistema de "Rifts" Continentais da Serra do Mar. O primeiro, que atuou durante o Terciário pelo menos até o Eoceno, de caráter tracional, teria sido o gerador das estruturas deformacionais medidas na Formação Pariquera-Açu. Por outro lado, estruturas possivelmente compressionais (falhas inversas mesoscópicas), afetando os depósitos da Formação Cananéia próximo à ilha homônima, poderiam ser interpretadas como um produto do segundo evento tectônico, que teriam resultado de transcorrências dextrais convergentes de direção ENE-WSW para E-W, causadas por transpressão, que ocorreu provavelmente a partir do Mioceno e ativa até o Pleistoceno.

A correlação das estruturas observadas com os eventos tectônicos regionais representa uma primeira tentativa para se datar essas feições, sem descartar a possibilidade de que elas sejam de idades mais novas.

INTRODUÇÃO

Os aluviões terraceados existentes no baixo vale do Rio Ribeira de Iguape, no sul do Estado de São Paulo, foram reconhecidos pela primeira vez por SILVEIRA (1952), tendo sido posteriormente denominados de Formação Jacupiranga (ALMEIDA, 1964). BIGARELLA e MOUSINHO (1965) designaram esses depósitos de Formação Pariquera-Açu, nome que foi mantido em todos os estudos subseqüentes (FRANZINELLI, 1970; PONÇANO, 1981, *in* ALMEIDA *et al.*, 1981).

Embora muita dissensão tenha sido suscitada entre os primeiros estudiosos da formação, quanto ao número e posi ção topográfica dos terraços que constituiriam esta unidade litoestratigráfica, a questão parece ter sido solucionada por proposta de PONÇANO (1981, in ALMEIDA, et al., 1981). Este autor limitou-os a dois referindo-os a cotas relativas ao nível de base local (Rio Ribeira de Iguape), diferentemente do que vinha sendo feito anteriormente, quando eram relacionados ao nível do mar.

A Formação Pariquera-Açu é predominantemente composta por sedimentos finos, com alternâncias irregulares de siltitos arenosos e arenitos arcosianos, associados a camadas conglomeráticas pouco espessas (BIGARELLA & MOUSINHO, op.cit.). O mecanismo de deposição foi principalmente do tipo movimento de massa, que teria ocorrido sob condições de paleoclima semiárido.

A idade neocenozóica já era admitida pelos pesquisadores como BIGARELLA & MOUSINHO (op. cit.) e PONÇANO (1981, in ALMEIDA et al., 1981), com base em correlações geomorfológicas. SUNDARAM & SUGUIO (1985) atribuiram-lhe idade provável pliocênica baseada em estudo de palinomorfos.

A formação assenta-se discordantemente sobre rochas cristalinas pré-cambrianas, ocorrendo freqüentemente depósitos conglomeráticos basais. Na planície costeira ela forma o substrato de sedimentos marinhos da Formação Cananéia (SUGUIO & PETRI, 1973), que representaria o registro da transgressão homônima relacionada ao período interglacial Sangamoniano, há cerca de 120.000 anos A.P. (SUGUIO & MARTIN, 1978).

Os depósitos da Formação Pariquera-Açu têm sua área de ocorrência situada a meio caminho entre as bacias de São Paulo e Curitiba, ambas integrantes do Sistema de "Rifts" Continentais da Serra do Mar (Fig. 1). Entretanto, suas relações com esse sistema ainda não foram estudadas.

Embora diversos autores (SILVEIRA, op.cit.; BIGARELLA & MOUSINHO, op. cit.; PETRI & SUGUIO, 1973; HASUI et al., 1978; PRESSINOTTI & PRESSINOTTI, 1980, entre outros) tenham aventado a hipótese da influência do tectonismo, no entalhamento e preservação dos seus depósitos, nenhuma falha ou outros tipos de evidências diretas haviam sido relatadas.

Falhas mesoscópicas pós-deposicionais, com rejeitos decimétricos e caráter predominantemente normal, foram pela

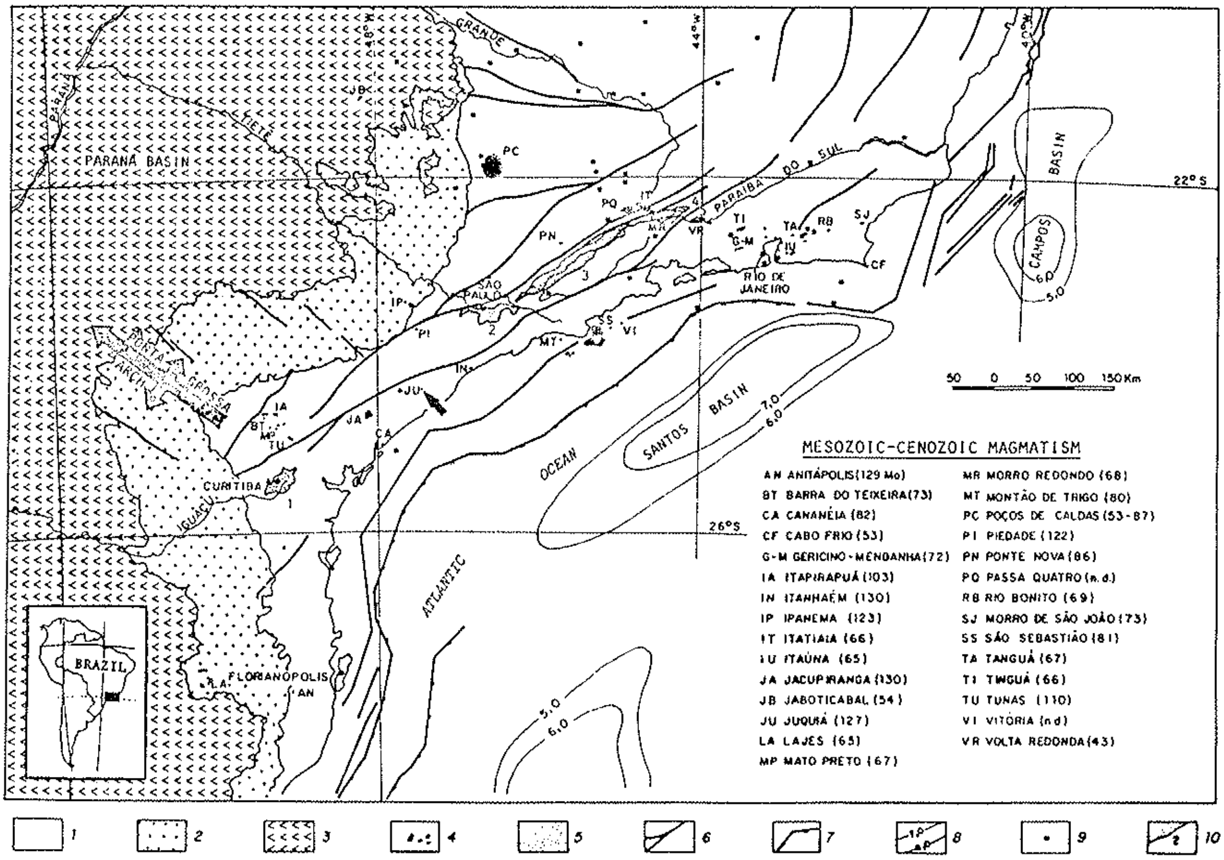


Figura 1 - Contexto geológico regional do sudeste brasileiro. A seta indica o local estudado na Formação Pariquera-Açu. 1 - embasamento pré-cambriano; 2 - sedimentos paleozóicos e mesozóicos da Bacia do Paraná; 3 - derrames basálticos mesozóicos da Formação Serra Geral, em parte recobertos por sedimentos; 4 - rochas relacionadas ao magmatismo do Mesozóico-Cenozóico (ver quadro no interior da figura; idades em Ma entre parênteses); 5 - sedimentos terciários; 6 - zonas de cisalhamento no embasamento; 7 - zonas de flexura; 8 - isópacas, em quilômetros, dos sedimentos das bacias costeiras; 9 - epicentros de terremotos; 10 - bacias do sistema de "rifts" (1 - Curitiba; 2 - São Paulo; 3 - Taubaté; 4 - Resende; 5 - Volta Redonda). Modificado de MELO et al. (1985).

primeira vez reconhecidas em afloramentos da Formação Pariquera-Açu na região entre Biguá e Iguape. Elas não são muito comuns nos afloramentos visitados, com exceção de um corte na rodovia Biguá-Iguape, onde sua freqüência permitiu uma análise preliminar.

O reconhecimento, pela primeira vez, dessas falhas cortando os sedimentos da Formação Pariquera-Açu, além de constituir-se no primeiro registro direto de atividade tectônica afetando esta unidade, poderá abrir novas perspectivas para uma melhor compreensão da evolução geológica do sudeste brasileiro, durante o Cenozóico.

DADOS DE CAMPO

O afloramento estudado situa-se do lado direito da SP-222, rumo a Iguape, onde ocorrem camadas métricas de sedimentos argilosos arroxeados com grânulos esparsos de quartzo, além de depósitos arenosos conglomeráticos amarelados com abundante matriz argilosa. Os rejeitos das falhas, bem como as lineações de atrito dos seus planos, revelam movimentação relativa predominantemente normal, pois as estrias dispõem-se segundo a reta de maior declive. Secundariamente há também lineações que acusam rejeitos oblíquos, mas ainda com predomínio da componente normal. A ausência de estrias em alguns planos de falha pode ser atribuida à natureza dos sedimentos. Fraturas sem rejeitos também estão presentes. As relações entre as estruturas observadas estão esquematicamente representadas na Fig. 2.

As informações obtidas foram tratadas de modo a deduzir os eixos médios principais de deformação e esforços que afetaram os sedimentos. Os diagramas foram construidos com base no estereograma de Schmidt-Lambert, usando-se como referência o hemisfério inferior. Os planos de falhas e fraturas medidos exibem uma distribuição preferencial segundo as direções NNW e NE e, secundariamente, ENE. Por outro lado, há uma nítida concentração dos polos das lineações de estrias de atrito segundo a direção EW com mergulhos médios a altos para W (Fig. 3).

ANÁLISE DOS DADOS ESTRUTURAIS

Na análise do padrão de fraturamento foram utiliza-

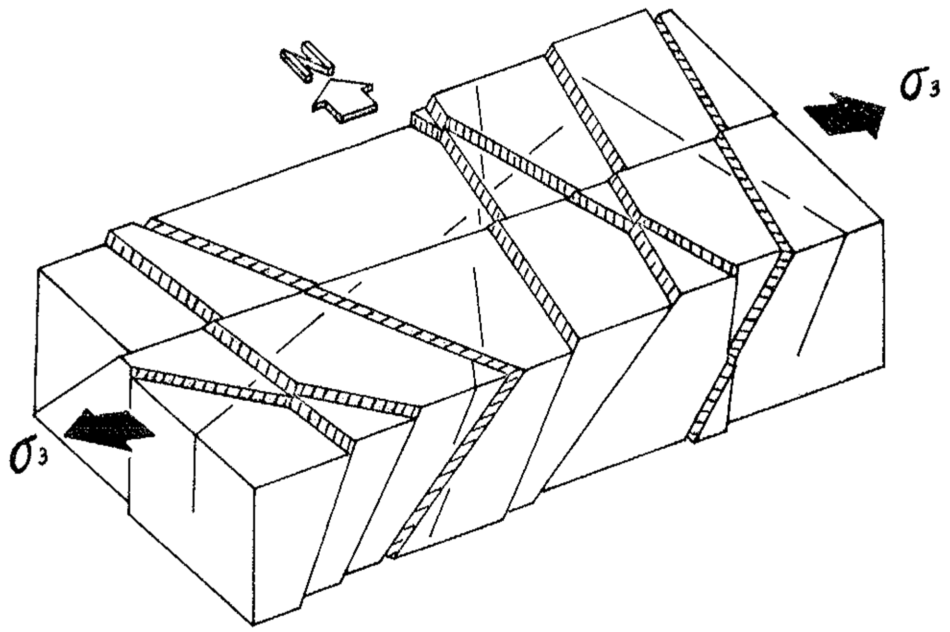


Figura 2 - Bloco-diagrama esquemático mostrando a relação entre as estruturas observadas (Km 23,9 da SP-222).

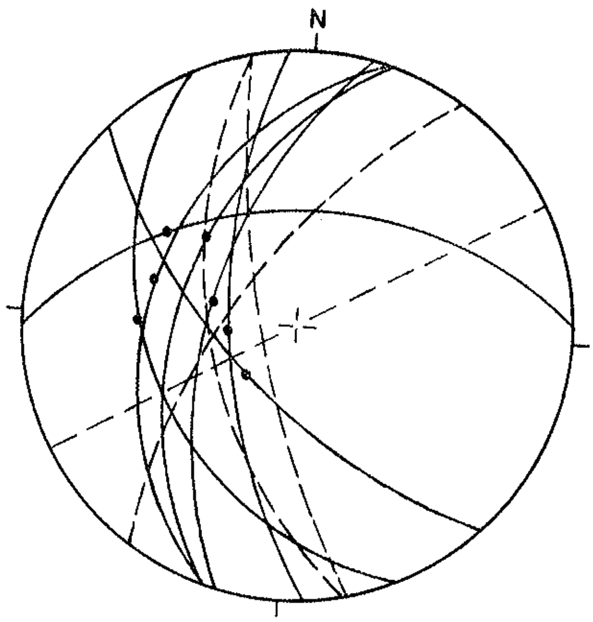


Figura 3 - Planos de falhas (círculos máximos) e estrias de atrito medidas. As falhas sem estrias e fraturas estão representadas pelos círculos máximos tracejados.

dos os dados referentes a falhas em escala de afloramento, afetando unicamente sedimentos, caracterizadas por superfícies discretas, polidas e estriadas, valendo-se de programas desenvolvidos em "Basic" para microcomputador gráfico.

Foram utilizados os métodos de análise desenvolvidos por ARTHAUD (1969), ANGELIER e MECHLER (1977) e ANGELIER (1979), já empregados anteriormente em estudos de estruturas semelhantes da região sudeste (CAMPANHA et al., 1985).

RESULTADOS OBTIDOS

Embora tenha sido pequeno o número de planos de falhas disponíveis para a análise, os polos de planos de movimento obtidos pelo método de ARTHAUD (op. cit.) apresentam certa concentração segundo a guirlanda horizontal (Fig. 4), com polo vertical. O polo vertical da guirlanda indica uma das direções principais de deformação. Como a população de falhas analisadas apresenta caráter predominantemente normal esta é a direção de maior encurtamento (Z). Nessa guirlanda horizontal ocorre concentração dos polos de planos de movimento na direção NNW e NNE. A direção intermediária (Y) é indicada pela concentração de polos na guirlanda, ou seja, segundo NNW/SSE a NNE/SSW. Por conseguinte, a direção de maior extensão (X), ortogonal às outras duas, estaria alojada segundo WNW/ESE a WSW/ENE. Em regime de cisalhamento puro, os eixos de maior encurtamento, intermediário e de maior compressão podem ser associados, respectivamente a σ_1, σ_2 e σ_3. Naturalmente, a precisão das direções obtidas não é grande, mas estas já mostram uma certa tendência.

Aplicando-se o método de ANGELIER (op. cit.) e ANGELIER e MECHLER (op. cit.), pode-se obter no diagrama de Schmidt-Lambert as áreas de maior probabilidade de localização dos maiores esforços de tração e compressão (Fig. 5), respectivamente na direção WNW/horizontal e vertical.

POSSÍVEIS RELAÇÕES DAS ESTRUTURAS DA FORMAÇÃO PARIQUERA-AÇU COM A TECTÔNICA REGIONAL

CAMPANHA et al. (op. cit.) analisaram o padrão de distribuição das estruturas mesozóico-cenozóicas em algumas bacias integrantes do Sistema de "Rifts" da Serra do Mar (área

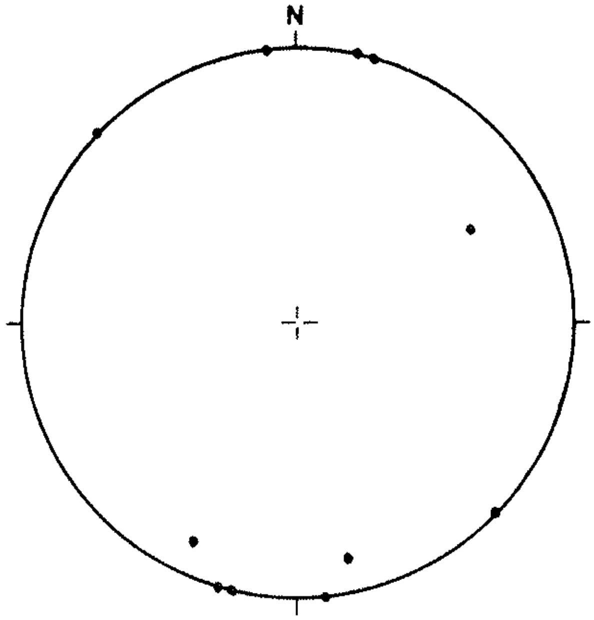


Figura 4 - Polos de planos de movimento (ARTHAUD, 1969).

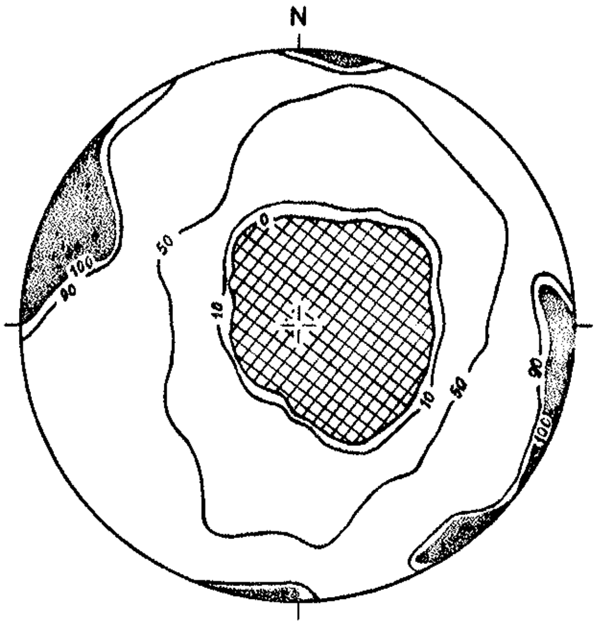


Figura 5 - Resultado da aplicação do método de ANGELIER (1979). As isolinhas de menor porcentagem delimitam as áreas de maior probabilidade de conter o esforço principal compressivo (σ_1), e as de maior porcentagem o esforço principal distensivo (σ_3).

de Itaquaquecetuba na Bacia de São Paulo, extremo leste da Bacia de Taubaté, Bacia de Resende e Bacia de Volta Redonda). Os dados obtidos (Fig. 6) mostraram grande identidade entre os padrões de fraturamentos, o que levou os autores a concluirem por uma similaridade e postularem um provável sincronismo entre os regimes de esforços atuantes nas diferentes bacias. Estes regimes apresentam caráter tracional, com eixo de estiramento segundo NW-SE, encurtamento vertical e eixo intermediário NE-SW. Suas relações com o preenchimento sedimentar das bacias permite datá-los como ativos até pelo menos o Eoceno.

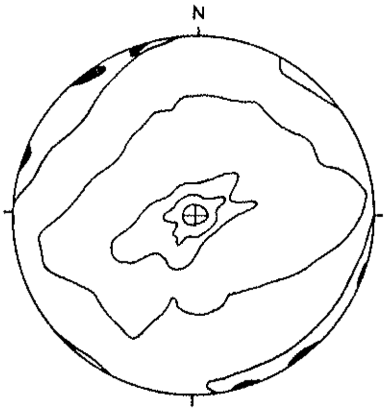
Um segundo evento tectônico vem sendo caracterizado na área do sistema de "rifts", o qual parece ter envolvido transcorrência dextral convergente, causada por transpressão, segundo ENE-WSW a E-W, de idade provável miocênica a possivelmente pleistocênica, a julgar pelas suas relações com a sedimentação.

Os dados obtidos para a Formação Pariquera-Açu mostram certa identidade com aqueles do primeiro evento tectônico obtidos para as outras bacias. Tal situação, embora recue substancialmente no tempo a época de sedimentação em relação a que hoje é admitida, é perfeitamente plausível. A única inferência de idade, feita em bases mais concretas (palinologia), apontou idade pós-pliocênica a pré-holocênica (SUNDARAM e SUGUIO, 1985) pela diferença da assembléia analisada, tanto em relação à zona mioflorística pliocênica de REGALI *et al.*(1974), como à assembléia holocênica da planície costeira de Santos, caracterizada por ABSY (1975). Entretanto, o elemento polínico de maior valor cronológico analisado corresponde à gramíneas, com registro de ocorrência desde o Paleógeno (Murilo R. de Lima, informação verbal). Desta forma, a idade pós-pliocênica a pré-holocênica deve ser entendida como mínima.

Por outro lado, já foram registrados indícios de atividade tectônica perturbando os sedimentos da Formação Cananéia, nas vizinhanças da ilha homônima, representados por falhas inversas de pequeno rejeito (centimétricos), que poderiam estar relacionados à segunda fase tectônica. Tais estruturas serão brevemente objeto de estudo mais detalhado. Esta associação das estruturas observadas com eventos tectônicos regionais representa a primeira tentativa para datá-las, mas não se pode descartar a possibilidade de serem muito mais jovens.

Bacia de São Paulo

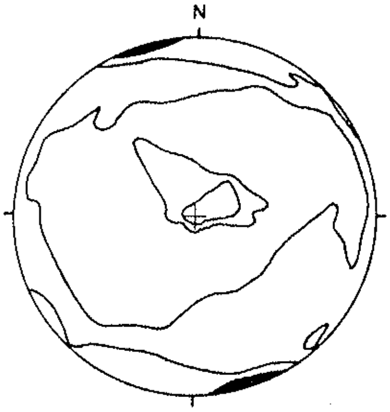
(área de Itaquaquecetuba)



Isolinhas (%) a partir do centro:
0 - 5 - 15 - 50 - 85 - 95

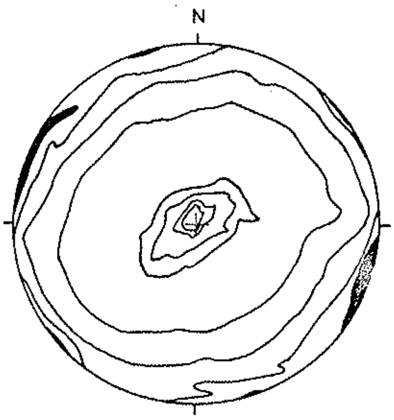
Bacia de Taubaté

(área de Cruzeiro)



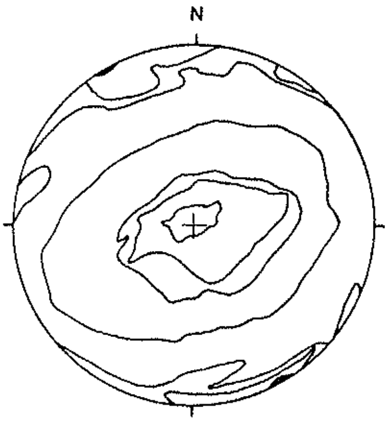
Isolinhas (%) a partir do centro:
0 - 15 - 50 - 80 - 90

Bacia de Resende



Isolinhas (%) a partir do centro:
0 - 3 - 5 - 10 - 15 - 50 - 65 - 75
80

Bacia de Volta Redonda



Isolinhas (%) a partir do centro:
0 - 10 - 15 - 50 - 85 - 90 - 95

Figura 6 - Resultados do método de ANGELIER (1979) para algumas bacias do Sistema de "Rifts" Continentais da Serra do Mar. As isolinhas de menor porcentagem delimitam as áreas de maior probabilidade de conter σ_1 e as de maior porcentagem σ_3 (CAMPANHA et al., 1985).

CONSIDERAÇÕES FINAIS

A análise de padrão de falhamentos presentes em sedimentos da Formação Pariquera-Açu revelou semelhança com os resultados obtidos para bacias integrantes do Sitema de "Rifts" Continentais da Serra do Mar.

Se a hipótese formulada em termos de correlação com os eventos tectônicos regionais for verdadeira, a região poderia representar o elo de ligação entre as bacias situadas mais a nordeste e a de Curitiba, integrando portanto o sistema de "rifts".

Não se descarta, entretanto, a possibilidade de existência de tectônica mais jovem, pós-sangamoniana, o que viria a trazer implicações no estudo do Quaternário Costeiro.

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CARACTERÍSTICAS SEDIMENTOLÓGICAS DA FORMAÇÃO CANANÉIA (PLEISTOCENO SUPERIOR) NA ÁREA PARANAGUÁ-ANTONINA (ESTADO DO PARANÁ, BRASIL)

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ABSTRACT

In continuation to the Iguape-Cananéia coastal plain of southernmost State of São Paulo, the Cananéia Formation is also very conspicuously developed in the Paranaguá-Antonina area (State of Paraná).

Grain size analysis of these sandy deposits showed that they are formed of well sorted, fine (0.250-0.125 mm) to very fine (0.125-0.062 mm) sands. Their non-magnetic heavy minerals are dominantly composed of stable minerals (ZTR index changes from 40 to 65%). Opaque heavy minerals, mostly composed of magnetite and ilmenite are very often hydrodynamically concentrated, giving origin to horizontal and cross-laminations.

Abundant parallel-horizontal and low-angle cross-laminations associated with channel fillings, and scarce herring-bone cross-laminations, *Callichirus* burrows and mud-cracked clay layer intercalations characterize the upper portion of the Cananéia Formation. These sands have been deposited in a foreshore, during the regressive phase of the Cananéia transgression (Sangamon = Riss/Würm interglacial stade).

Proceedings of the IGCP Project 201 Mérida (Venezuela) meeting: p. 43-54.

The lower portion of this formation is in general formed of grayish clayey-silty fine sands with wavy and lenticular laminations, sometimes loadcasted and/or bioturbated by *Callichirus* burrows. This portion of the Cananéia Formation corresponds to the upper shoreface related to the transgressive phase of the Cananéia transgression.

RESUMO

Em continuação à planície costeira Iguape-Cananéia, do extremo sul do Estado de São Paulo, a Formação Cananéia é também muito conspicuamente desenvolvida na área Paranaguá-Antonina (Estado do Paraná).

Análises granulométricas desses depósitos arenosos mostraram que eles são formados de areias bem selecionadas e finas (0,250-0,125 mm) a muito finas (0,125-0,062 mm). Os seus minerais não-magnéticos são compostos principalmente de minerais estáveis (índice ZTR varia de 40 a 65%). Minerais pesados opacos, compostos principalmente de ilmenita e magnetita são muitas vezes concentrados hidrodinamicamente, dando origem a laminações horizontais e/ou cruzadas.

Abundantes laminações paralelas-horizontais e cruzadas-de-baixo ângulo associadas com preenchimentos de canais e escassas laminações cruzadas tipo espinha-de-peixe, tubos de *Callichirus* e intercalações de camadas argilosas com gretas de contração caracterizam a porção superior da Formação Cananéia. Estas areias foram depositadas em uma antepraia, durante a fase regressiva da Transgressão Cananéia (Sangamoniana = estádio interglacial Riss/Würm).

A porção inferior desta formação é em geral formada de areias finas argilo-sílticas, de cor cinzenta, com laminações onduladas e lenticulares, algumas vezes com estruturas de sobrecarga e/ou bioturbações de *Callichirus*. Esta porção da Formação Cananéia corresponde a face praial superior relacionada à fase transgressiva da Transgressão Cananéia.

INTRODUÇÃO

As baías de Paranaguá-Antonina, com extensão aproximada de 46 km e largura máxima de 10 km, são feições praticamente perpendiculares à linha de costa atual, circundadas por áreas baixas ocupadas por manguezais, ilhas arenosas e canais lagunares. Esta área constitui a extensão sudoeste da planície costeira Cananéia-Iguape, Estado de São Paulo e, portanto, guarda grandes semelhanças entre si. Desta maneira, estão presentes as formações Cananéia e Santos, de idades pleistocênica e holocênica, já caracterizadas por SUGUIO & MARTIN(1978) no Estado de São Paulo.

Nas margens dos canais lagunares próximos à cidade de Paranaguá ("rios" Itiberê, dos Correias, dos Almeidas e do Maciel) ocorrem, com grande freqüência, cortes de 3 a 9 m de altura acima do nível de maré alta, formados por sedimentos pleistocênicos. Nestes afloramentos, bem como nas margens das ilhas arenosas situadas no interior da baía, foram descritas 15 seções e coletadas mais de 50 amostras para análises de laboratório (Figura 1).

CARACTERÍSTICAS SEDIMENTOLÓGICAS

As análises granulométricas das amostras coletadas nas seções descritas (Tabela 1) indicaram que os sedimentos são predominantemente areias finas (valor médio dos diâmetros médios = 2,8 Ø), bem selecionadas, aproximadamente simétricas e com curtoses entre platicúrtica e mesocúrtica. Essas areias exibem cores variáveis entre branca, amarelada e castanha clara a escura.

Os afloramentos dos "rios" Itiberê e dos Correias, em Paranaguá, apresentam as maiores alturas em relação ao nível do mar atual (7 a 9 m). Em apenas duas seções do "rio" Itiberê (seções 4 e 5: Figuras 2 e 3), na base da seqüência, ocorrem níveis argilosos e/ou argilo-arenosos correlacionáveis aos referidos por SUGUIO & PETRI (1973) e descritos em maior detalhe por SUGUIO & TESSLER (1987), na região de Cananéia (SP). Esses sedimentos cinza-esverdeados são intercalados por lentes centimétricas de areias argilosas e micáceas definindo estratificações onduladas (wavy bedding). Rumo ao topo, o material argiloso diminui rapidamente e passa para areias finas (0,250 a 0,125 mm) bem selecionadas, onde são freqüentes estratificações plano-paralelas sub-horizontais, em geral bioturbadas por estruturas de escape. Aparecem também raras estratificações cruzadas acanaladas de pequeno porte. Os tubos de <u>Callichirus major</u>, tão abundantes nas planícies costeiras do sul Paulista

Amostra	média	desvio padrão	assimetria	curtose	% grânulo	% areia	% silte	% argila	classificação textural de Shepard 1954
3.1	2.72	0.42	0.06	0.77	-	99.8	0.2	-	areia
3.2	2.80	0.34	-0.17	0.89	-	99.9	0.1	-	areia
3.3	2.63	0.38	0.08	0.81	-	99.9	0.1	-	areia
3.4	2.64	0.41	0.07	0.78	-	99.9	0.1	-	areia
3.5	2.60	0.37	0.20	0.84	-	99.9	0.1	-	areia
3.6	2.74	0.33	0.02	0.75	-	100.0	-	-	areia
3.7	2.73	0.34	0.03	0.80	-	100.0	-	-	areia
3.8	2.75	0.34	-0.03	0.81	-	99.9	0.1	-	areia
4.1	3.28	0.80	0.37	3.46	-	89.6	6.7	3.7	areia
4.2	2.95	0.32	-0.07	1.03	-	99.1	0.9	-	areia
4.3	3.01	0.31	-0.16	1.04	-	100.0	-	-	areia
4.4	2.90	0.37	-0.37	1.04	-	100.0	-	-	areia
4.5	2.80	0.41	-0.20	0.97	-	99.9	0.1	-	areia
4.6	2.92	0.32	-0.23	1.02	-	99.8	0.2	-	areia
5.1	3.42	1.52	0.23	3.48	-	82.1	9.2	8.7	areia
5.2	3.42	0.76	0.21	2.40	-	88.7	8.3	3.0	areia
5.3	3.34	0.65	0.22	2.64	-	93.3	3.5	3.2	areia
5.4	2.87	0.51	-0.42	1.02	-	100.0	-	-	areia
5.5	2.33	0.77	-0.22	0.81	-	99.9	0.1	-	areia
5.6	2.80	0.45	-0.33	0.90	-	99.8	0.2	-	areia
6.	2.90	0.35	-0.38	1.04	-	99.9	0.1	-	areia
7.1	2.91	0.39	-0.37	1.02	-	99.9	0.1	-	areia
7.2	2.73	0.39	-0.14	0.81	-	100.0	-	-	areia
7.3	2.28	0.67	-0.17	1.07	-	99.9	0.1	-	areia
7.4	2.75	0.34	0.01	0.77	-	99.9	0.1	-	areia
7.5	2.79	0.36	-0.12	0.84	-	100.0	-	-	areia
8.1	2.85	0.35	-0.26	0.92	-	100.0	-	-	areia
8.2	2.60	0.47	-0.06	0.89	-	100.0	-	-	areia
8.3	2.71	0.37	0.00	0.75	-	100.0	-	-	areia
8.4	2.72	0.34	0.05	0.79	-	99.8	0.2	-	areia
9.1	2.95	0.35	-0.29	1.01	-	100.0	-	-	areia
9.2	2.63	0.62	-0.34	1.08	-	99.9	0.1	-	areia
9.3	2.41	0.53	0.01	1.03	-	99.9	0.1	-	areia
9.4	2.81	0.35	-0.15	0.83	-	99.9	0.1	-	areia
9.5	2.82	0.32	-0.13	0.86	-	100.0	-	-	areia
10.1	2.76	0.48	-0.33	1.05	-	99.9	0.1	-	areia
10.2	2.81	0.36	-0.19	0.88	-	99.9	0.1	-	areia
10.3	2.90	0.30	-0.20	0.92	-	99.9	0.1	-	areia
11	2.55	0.43	0.07	0.90	-	99.9	0.1	-	areia
12.1	3.03	0.37	-0.42	1.47	-	99.9	0.1	-	areia
12.2	1.67	1.12	0.26	0.62	0.2	99.7	0.1	-	areia
12.3	1.87	1.22	-0.38	0.58	0.1	99.8	0.1	-	areia
12.4	2.55	0.86	-0.36	1.44	0.1	99.9	-	-	areia
13.1	2.97	0.33	-0.32	1.09	-	99.9	0.1	-	areia
13.2	2.63	0.51	-0.10	0.93	-	99.9	0.1	-	areia
13.3	1.76	0.86	-0.01	0.77	0.1	99.9	-	-	areia
14.1	2.84	0.58	-0.48	1.16	-	99.8	0.2	-	areia
14.2	2.81	0.48	-0.34	0.87	-	99.8	0.2	-	areia
14.3	2.82	0.39	-0.22	0.79	-	100.0	-	-	areia
14.4	2.81	0.37	-0.02	0.80	-	99.6	0.4	-	areia

Tabela 1 - Características granulométricas das amostras analisadas.

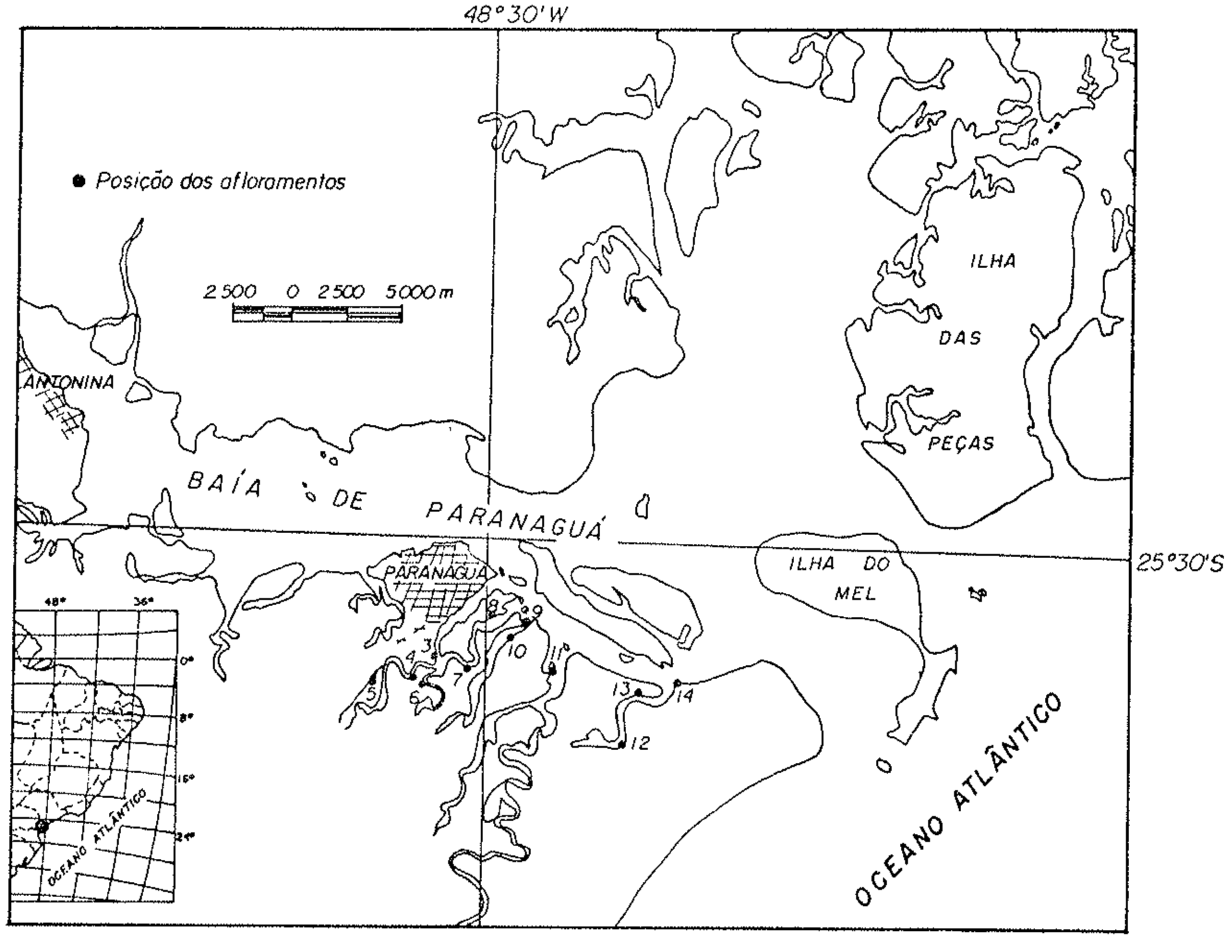


Fig. 1 - Mapa geral da área e localização dos afloramentos amostrados.

FIG. 2: Rio Itiberê – a montante da confluência com o Rio dos Correias. (7,40 m)

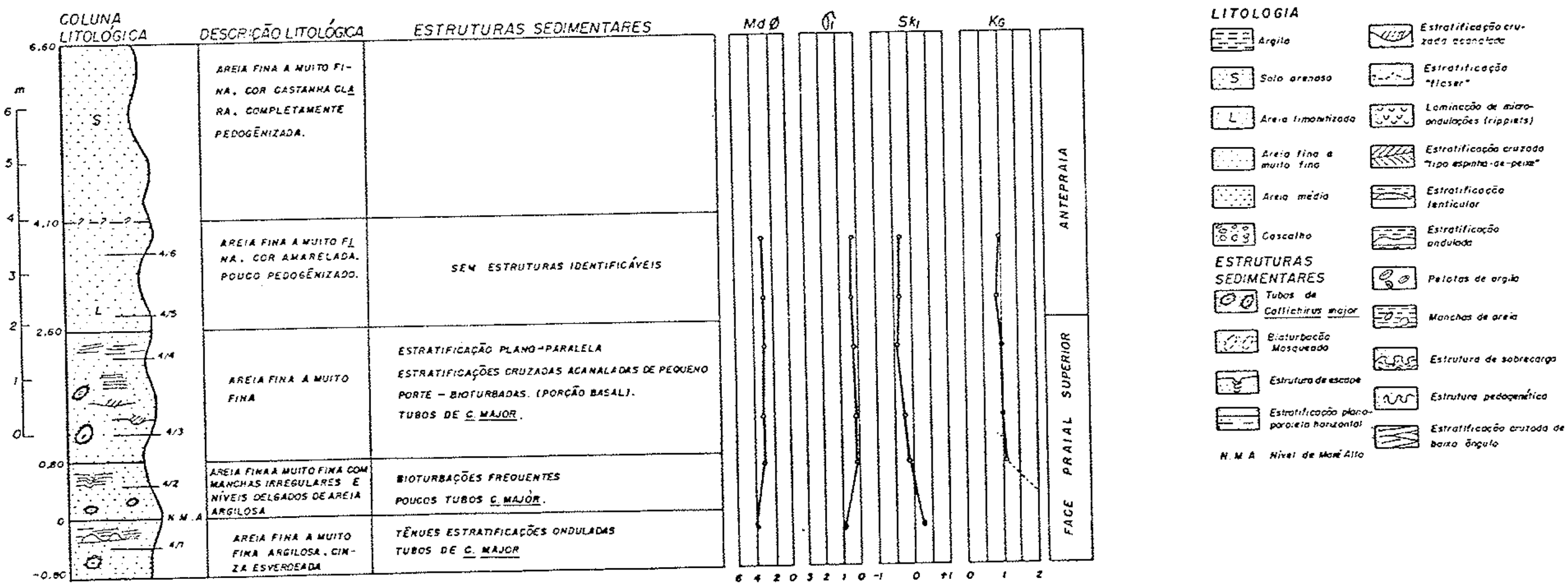
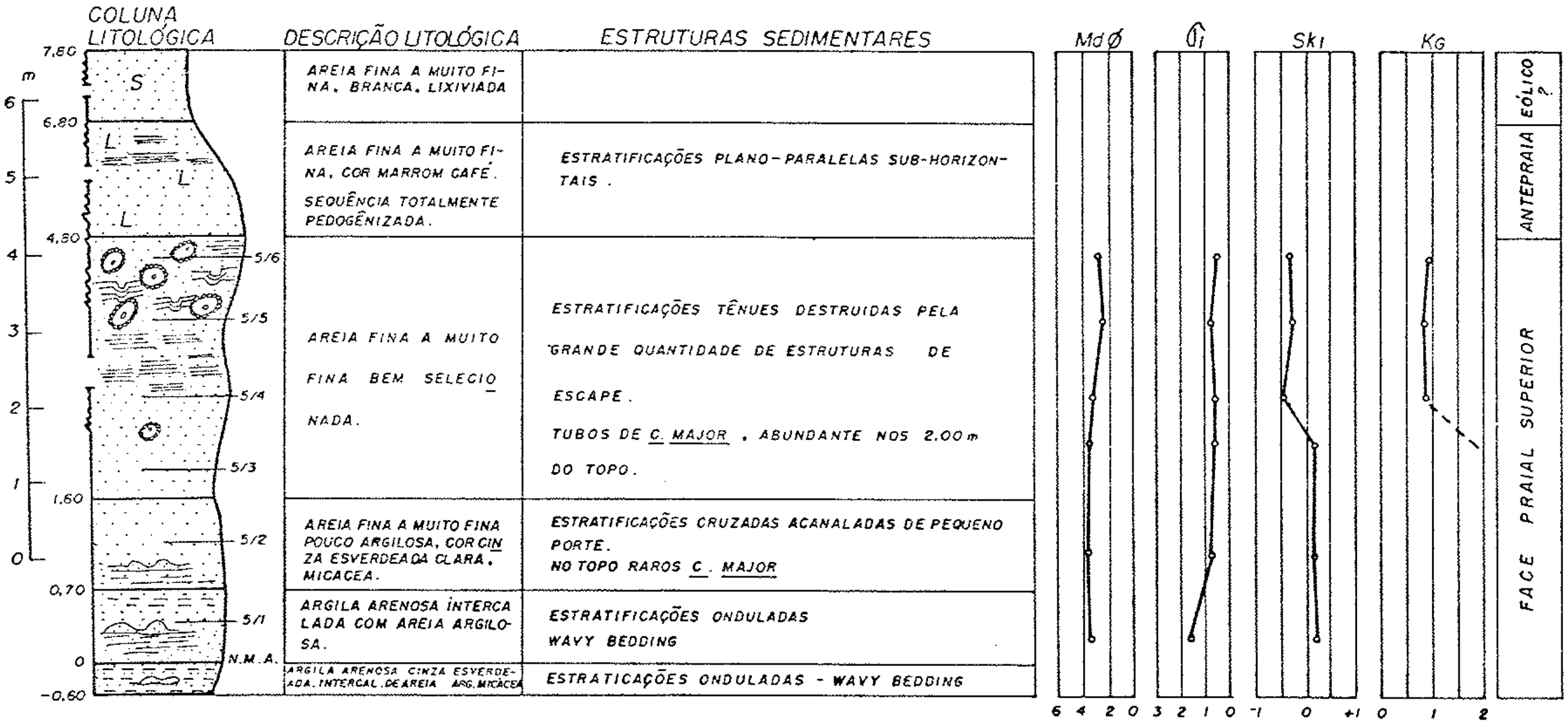


FIG. 3: Rio Itiberê (8,40 m)



(SUGUIO & MARTIN, 1976; SUGUIO *et al.*, 1984), são bastante raros na área de Paranaguá.

As características topográficas locais e a pequena amplitude das marés (cerca de 1,2 m) fazem com que os afloramentos permaneçam sempre expostos à ação intempérica, que resulta em cobertura superficial arenosa e branca, localmente acastanhada, onde são verificadas laminações plano-paralelas horizontais e sub-horizontais bastante obliteradas.

No "Rio" do Maciel, também próximo à Paranaguá, os afloramentos da Formação Cananéia apresentam alturas inferiores a 4 m, sendo toda a seqüência exposta representada por areias marinhas (Figuras 4, 5 e 6). Na base desses afloramentos são encontradas areias mais grossas intercaladas com areias fina a média. Esses níveis mais grossos exibem também estruturas sedimentares mais variadas, tais como, estratificações cruzadas de pequeno e médio porte (tabulares e acanaladas), tipo espinha-de-peixe, microondulações, bioturbações, etc.

Comum a todas as seqüências descritas é a ocorrência de estratificações plano-paralelas horizontais e sub-horizontais, ressaltadas por minerais pesados opacos, que são constituidos principalmente por ilmenita ($\geq$ 90%) e magnetita. O teor médio de ilmenita leucoxenizada é inferior a 5%, sendo mais freqüentes rumo ao topo (5 a 10%) e pouco freqüentes na base (1 a 2%).

Os minerais pesados transparentes não-micáceos aparecem em teores muito reduzidos, com valores em torno de 1,5% do concentrado obtido da amostra total. Os minerais predominantes (> 10%), no intervalo areia fina (0,250-0,125 mm), dos concentrados são hornblenda, zircão, turmalina e epídoto, que são seguidos pela sillimanita, granada, rutilo, cianita, andaluzita e estaurolita.

Os concentrados dos minerais leves são compostos quase que integralmente ($\geq$ 95%) de quartzo. Os raros grãos de feldspato estão quase sempre superficialmente caolinizados.

AMBIENTES DE SEDIMENTAÇÃO

As unidades III (transicional) e IV (marinha), descritas pela primeira vez por SUGUIO & PETRI (op.cit.), foram posteriormente reunidas para constituir a Formação Cana-

FIG. 4: Margem direita do Rio do Maciel - Paranaguá (3,80 m)

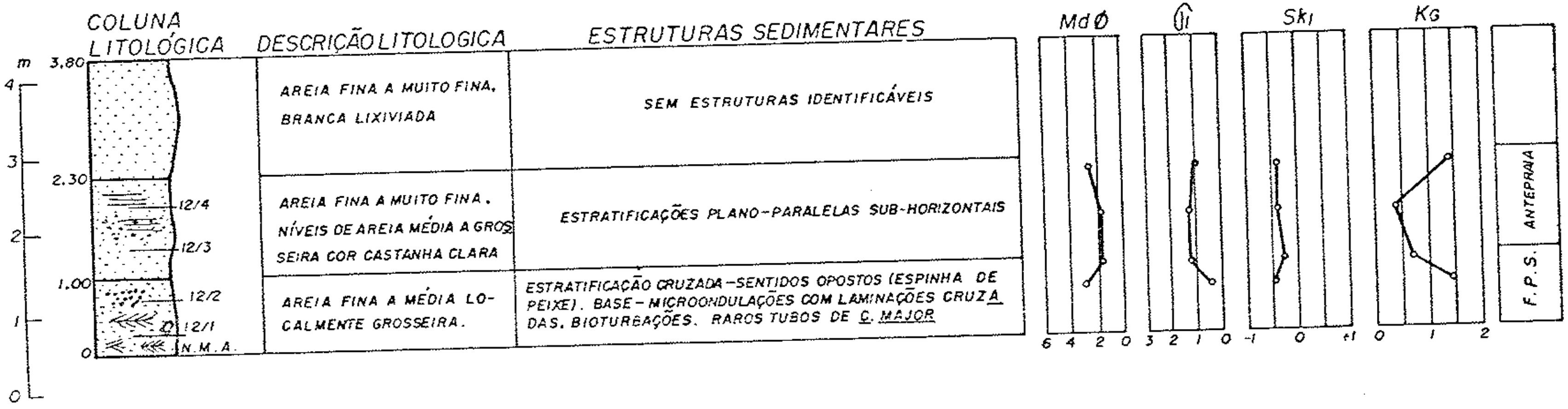


FIG.5: Rio do Maciel margem esquerda (Paranaguá)

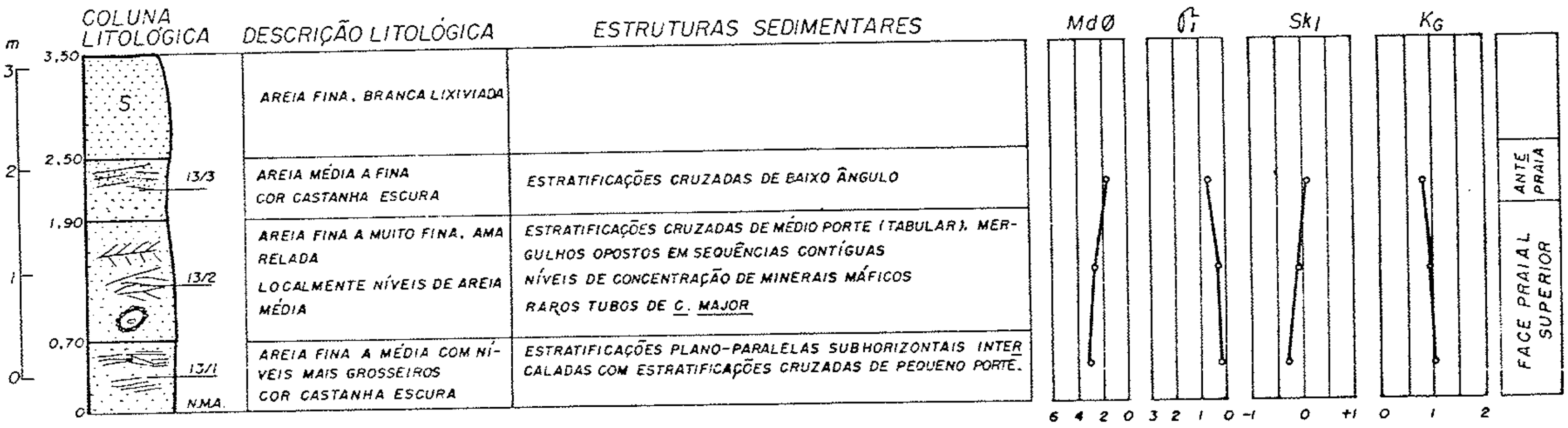
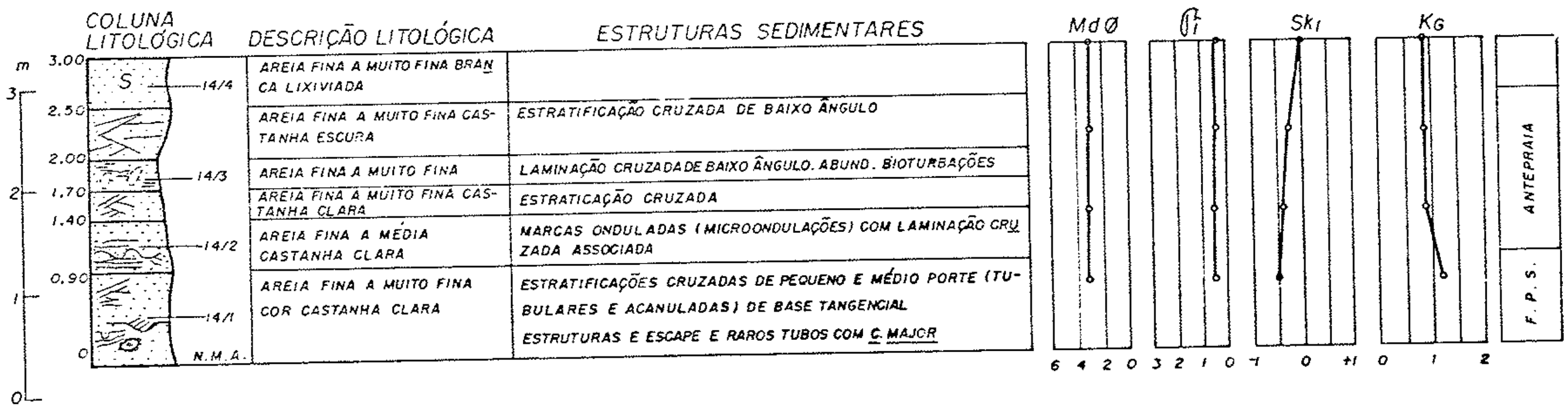


FIG. 6: Barra do Rio Maciel - margem direita (3,0 m)



néia por SUGUIO & MARTIN (1978). Os aspectos sedimentológicos detalhados desta formação foram estudados, pela primeira vez, por SUGUIO & TESSLER (op.cit.) que, na região de Cananéia-Iguape (SP), lhes atribuiram ambiente de face praial para a porção inferior mais argilosa e de antepraia para a parte superior de composição essencialmente arenosa.

Estudos sedimentológicos pormenorizados, nos mesmos moldes dos efetuados em Cananéia-Iguape (SP), vieram demonstrar que os mesmos ambientes deposicionais podem ser atribuidos para os depósitos pleistocênicos da Formação Cananéia da região de Paranaguá-Antonina.

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SEDIMENTOLOGY AND STRATIGRAPHY OF THE HOLOCENE FORMATIONS OF THE FRENCH GUIANA COASTAL PLAIN

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ABSTRACT

The Holocene coastal plain of French Guiana is a chenier plain. The shoreline is composed of extensive shoreface-attached mudflats and characterized by waterfront mangroves and by sub-coastal swamps and marshes. The cheniers, recording former coastlines, form a series of elongated narrow sandy ridges across the inner portions of the coastal plain.

The analysis of the present-day morphodynamic conditions brings to light the significance of Holocene evolution. Its major stages are presently well-known particularly thanks to the sedimentological research and radiocarbon dating that have been carried out in Suriname. In French Guiana there are only very scarce absolute datings.

The Holocene sediments belong to the Demerara Series. The deposits are composed of the Mara Phase (Early to Middle Holocene), the Moleson Phase (Late Holocene) and the Comowine Phase (Recent to Present). These phases, composed of fine grained marine and fluvio-marine deposits, are separated each other by the chenier sandy ridges.

RÉSUMÉ

La plaine côtière holocène de la Guyane française, ouverte vers l'Atlantique équatorial, est une vaste plaine à cheniers. La ligne du rivage est caracterisée par la présence de grands bancs de boue qui migrent vers l'Ouest sous l'action des courants et des vagues. Cette côte, basse et uniforme, est bordée par la mangrove de front de mer derrière laquelle s'ouvrent

Proccedings of the IGCP Project 201 Mérida (Venezuela) meeting: p. 55-83.

d'immenses espaces amphibies. Les cheniers, témoins d'anciennes lignes de rivage, forment un système de rides sableuses disposées, grosso modo, parallèlement à la côte actuelle. Ils s'étendent par des dizaines de km, interrompus seulement par les estuaires et, beaucoup plus rarement, par des affleurements du socle.

L'analyse de la dynamique côtière actuelle éclaire celle du passé holocène. Les etapes majeures de cette évolution sont connues, grâce notamment aux recherches surinamiennes, appuyées sur des datations absolues. En Guyane française, par contre, ces datations restent très rares.

Les sédiments holocènes appartiennent à la série Demerara composée des différentes phases: la phase Mara (Holocène Inférieur et Moyen), la phase Moleson (Holocène Supérieur) et la phase Comowine (Récent et Actuel). Ces phases de sédimentation fine sont séparées les unes des autres par les cheniers.

RESUMO

A planície lamosa holocênica da Güiana Francesa é baixa e uniforme. A monotonia da paisagem só é quebrada pela presença de cheniers que constituem uma das feições morfológicas fundamentais. Imensos manguezais emolduram a fachada atlântica da planície; grandes espaços palustres seguem aos mangues para o interior das terras.

Os cheniers, testemunhos de antigas linhas da costa, formam sistemas de cristas arenosas espaçadas e retilíneas, cuja base encontra-se próxima ao nível do mar atual e está em contato com um substrato argiloso. Parte integrante do sistema de acreção e de abrasão costeiras, os cheniers acompanham a direção da costa atual por dezenas de quilômetros, só sendo interrompidos pelos estuários ou, muito mais raramente, pelos afloramentos do escudo cristalino quando este aproxima-se do mar.

A análise da dinâmica atual esclarece a evolução holocênica pré-atual. As etapas principais desta última são conhecidas sobretudo graças às pesquisas feitas em Suriname com base em datações absolutas. Na Güiana Francesa este tipo de datação ainda é muito raro.

Os sedimentos holocênicos pertencem à Série Demerara, formada pelas seguintes fases de acumulação: fase Mara (Holoceno Inferior e Médio), fase Moleson (Holoceno Superior) e fase Comowine (Recente e Atual).

Os depósitos marinhos e flúvio-marinhos são predominantemente lamosos e são separados uns dos outros pelos cheniers.

INTRODUCTION

The coastline in French Guiana is low-lying and homogeneous for 320 km from the Oyapock River in the east to the banks of the Maroni in the west (fig. 1). Bordered by the waterfront mangrove it formes a part of the extensive mudflats and sub-coastal swamp-lands of the Guianas' region (fig.2).

The Quaternary littoral formations generally separate the crystalline basement from the ocean all along the Atlantic coast, the only discontinuity being composed of basement rocks just out between Cayenne and Organabo. These lowlands are only a small fraction (3,700 km^2) of the total surface area of French Guiana (90,000 k^2). Their width varies between a maximum of 50 km at Pointe Behague and a minimum of 5 km east of Cayenne. The slopes are very low and these lowlands play in part the role of intercepting fluvial deposits under the coupled effect of the diminished river slopes and a lower speed of flow.

Two important morphological units have been distinguished between the ocean and the shield (CHOBERT, 1957; BOYE, 1959; BRINKMAN & PONS, 1968; TURENNE, 1978) (fig. 3), namely:

- the "Young Coastal Plain" (Holocene) situated roughly between 0 and 5 m and composed of saline marine clays, waterfront mangrove and swampland. The latter are crossed by straight narrow sandy ridges having one or several sandy crests and more or less parallel to the shoreline. These ridges are separated from each other by phases of fine-grained sedimentation and sit upon marine clays, their base being very close to the present-day average sea level.

- the "Old Coastal Plain" (Pleistocene), situated roughly

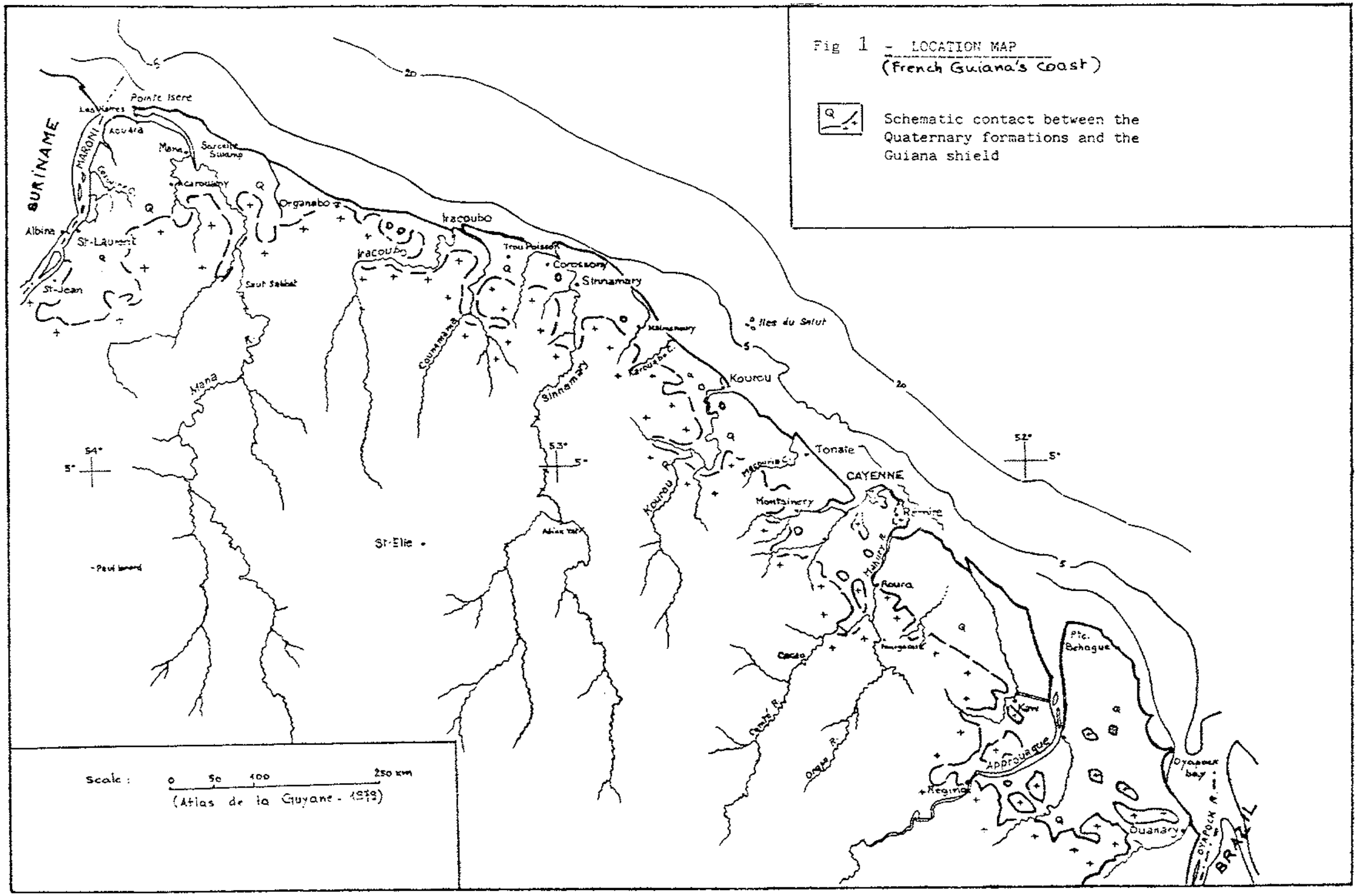


Fig 1 - LOCATION MAP
(French Guiana's Coast)

Q — Schematic contact between the Quaternary formations and the Guiana shield

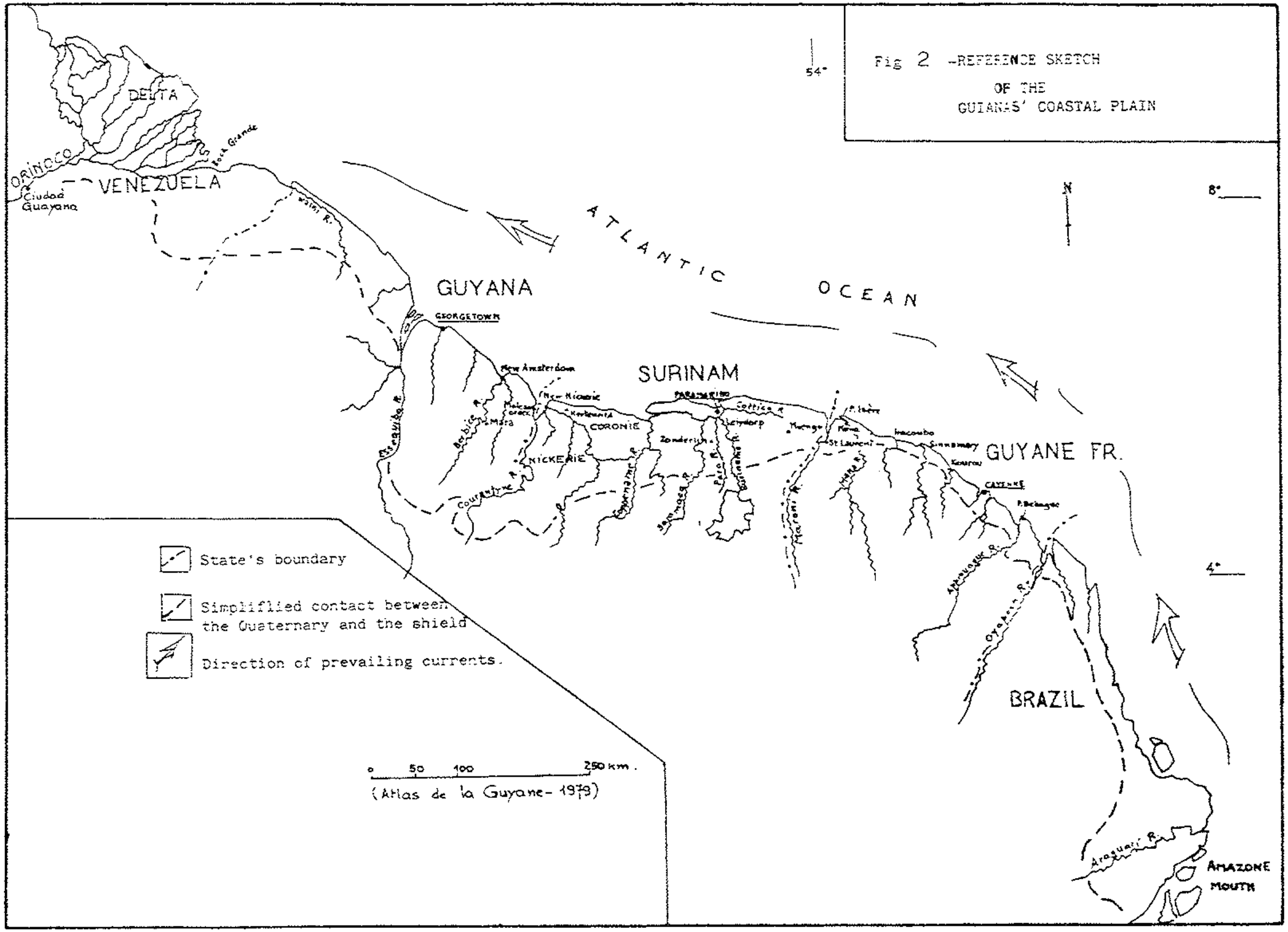
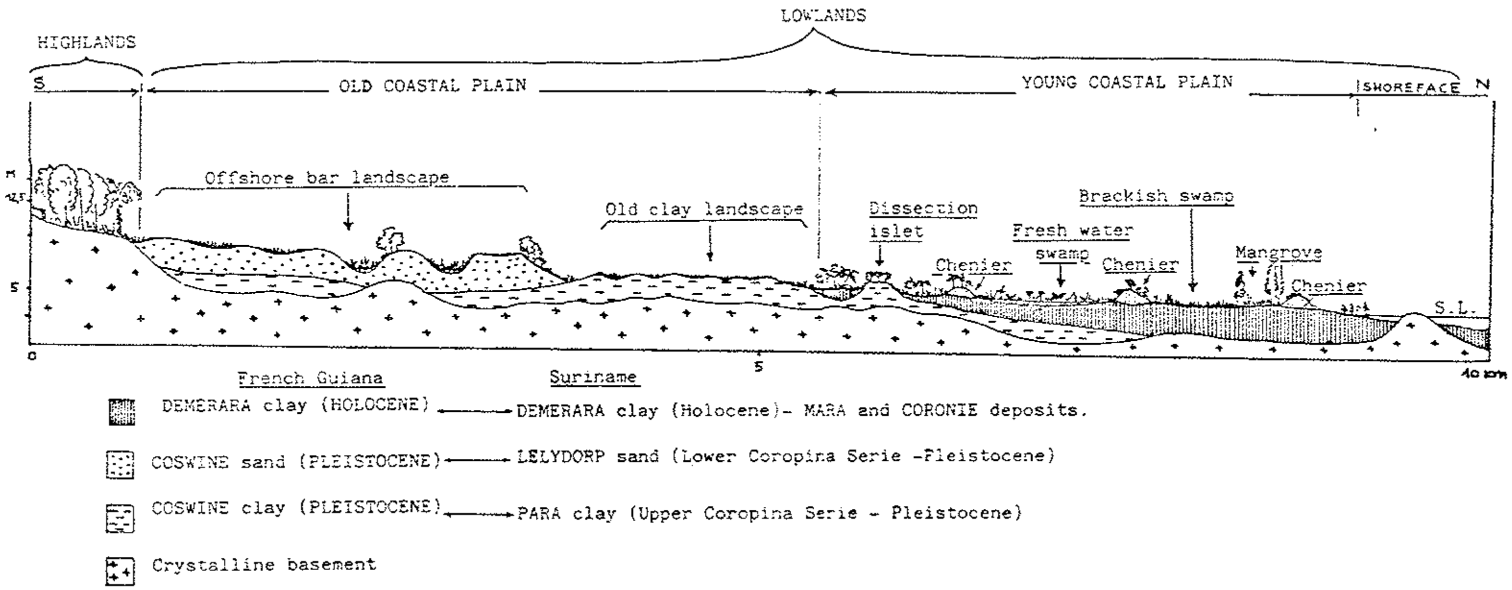


Fig 2 - REFERENCE SKETCH OF THE GUIANAS' COASTAL PLAIN

Fig 3 - Diagrammatical section of the French Guianas coastal plain.



between 5 to 25/30 m, is composed of savannas and some swamps. The plain is also marked by sandy ridges, wider and flatter than those of the Holocene plain. These ridges, with multiple crests, are found in close proximity to each other and are separated by narrow hydromorphic depressions; these ridges represent an old offshore bar landscape which sits on a substratum of developped desalinated marine clays.

This study concerns the Holocene plain. After a brief look at the present-day coastal dynamics, which sheds a light on those of the recent past, an analysis of the sedimentation and stratigraphy of the Holocene formations will be presented allowing somme concluding comparisons with the neighboring regions.

PRESENT-DAY CHANGES OF THE SHORELINE

Unerstanding of the dynamics in the present coastal environment is important for two reasons: the obvious relation to the economic interest of the countries concerned on the one hand; and the lights it sheds on the changes in the recent past long-term evolution, on the other hand.

During the last 20 years, research done on the Guianas' shoreline attained considerable progress. It has become clear that there are extremely active coastal dynamics. The major factors responsible for morphological modifications have been defined. However, the problem has arisen to determine the range of these variations as well as the critical values of activity and a total assessment of sedimentation. Another problem concerns the correlation of results within the region: although many studies have been done in Suriname and French Guiana, but there is little data for the Brazilian territory of Amapá, where such studies are much fragmented.

Given points

The most striking phenomenon influencing the coastal evolution is the longshore supply of the enormous mass of fine-grained sediments discharged by the Amazon River (100 to 200 million tons per year),carried steadily westward by the combined action of waves and currents (Guiana Current and longshore current created by trade-wind driven waves). Clays, silts and fine-grained sands are transported partially in suspension by the current and partially by means of westward migrating shoreface-attached mudbanks. The tidal currents (ebb and flow tides at river mouths) also play an important role in the transportation of sediments. However, the amount of sediment load carried down by the rivers in French Guiana is very small in comparison with that from the Amazon River.

The French Guiana coastline is presently constituted by 6 large mudflats 20 to 40 km long (fig. 4) prograding towards the ocean and forming an oblique angle to the coast. They are separated from each other by deeper parts: the troughs (or inter-bank zones) where erosion is dominant.

These banks migrate westward owing to the abrasion of the flat eastern border and the accretion of the west side (fig. 5). Accumulation is due to the presence of a semi-fluid mud, "slingmud"(1), which causes wave dampening, particularly during the low water slack, when the silt concentration in the seawater is the highest(2). During the next flood, "slingmud" may be transported in a fluidized state but only for short distances and always in the immediate environment. After the tide has receded once more the soft silt is exposed to the air and the consolidation accelerated (AUGUSTINUS, 1978). These events may be repeated several times.

The accumulation diminishes towards the middle and eastern flank of the mudbanks with increasing consolidation of mud and the emergence of sediments. Little by little, they lose their original capacity to subdue wave action, because there is hardly any "slingmud" in this sector. The energy of the waves is greater and they acquire an increased power of erosion. For this reason, in contrast with the smooth surfaces of the west side the eastern flank appears in aerial photos as an irregular and discontinuous surface, marked by a system of gullies. Finally, in the interbank zones where the water is

(1) "Slingmud" is a gelatinous agglomerate of clayed particles in water which develops when concentrations exceed a critical value (between 5,00 and 10,0 mg/l) (AUGUSTINUS, 1982).

(2) "Slingmud" deposition takes place especially during periods of strong winds and during low tide (AUGUSTINUS, 1986 - in press).

Fig 4 - POSITION OF THE MUD BANKS AND THE INTER-BANK ZONES (1985/86) along the French Guiana's coastline.

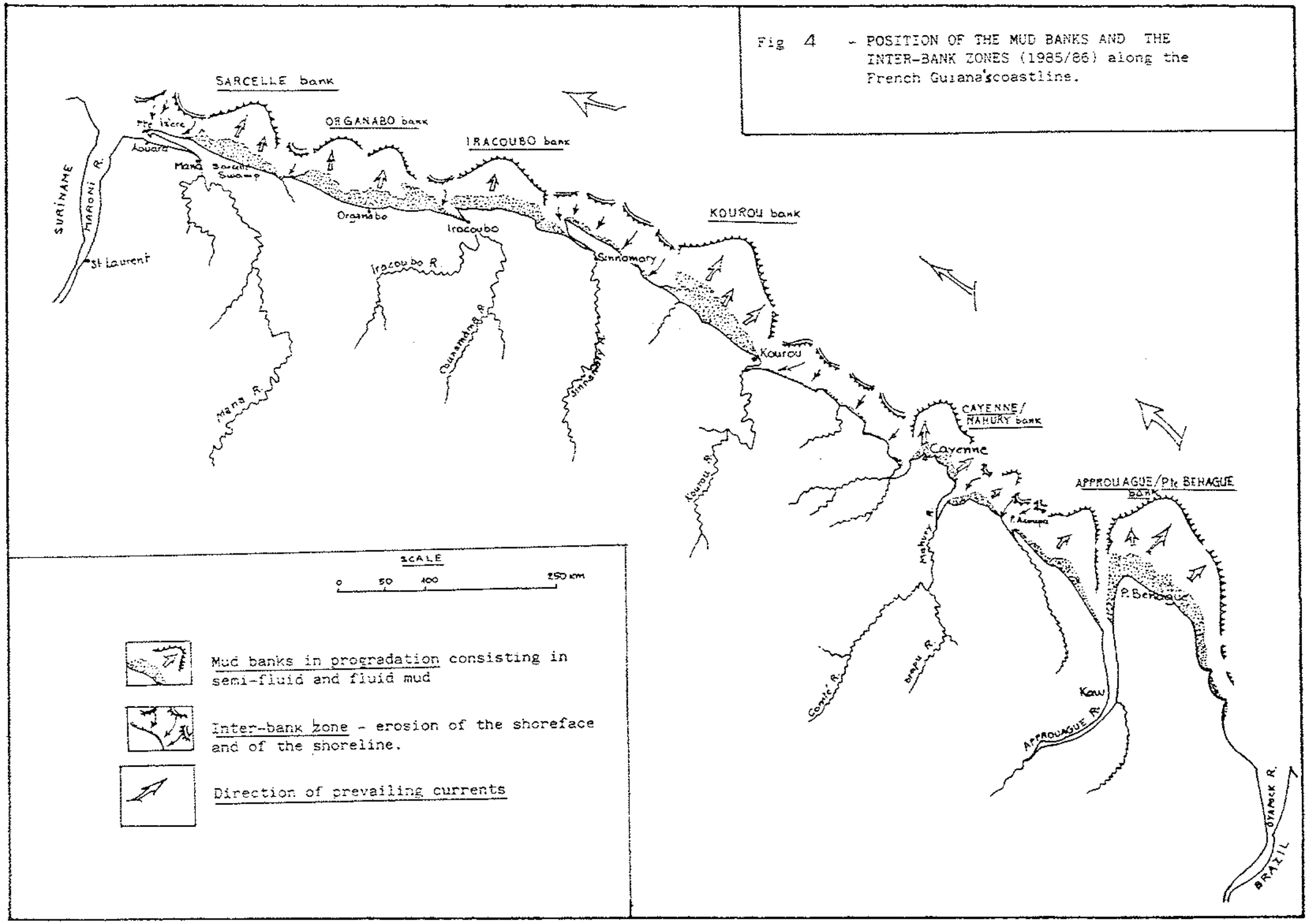
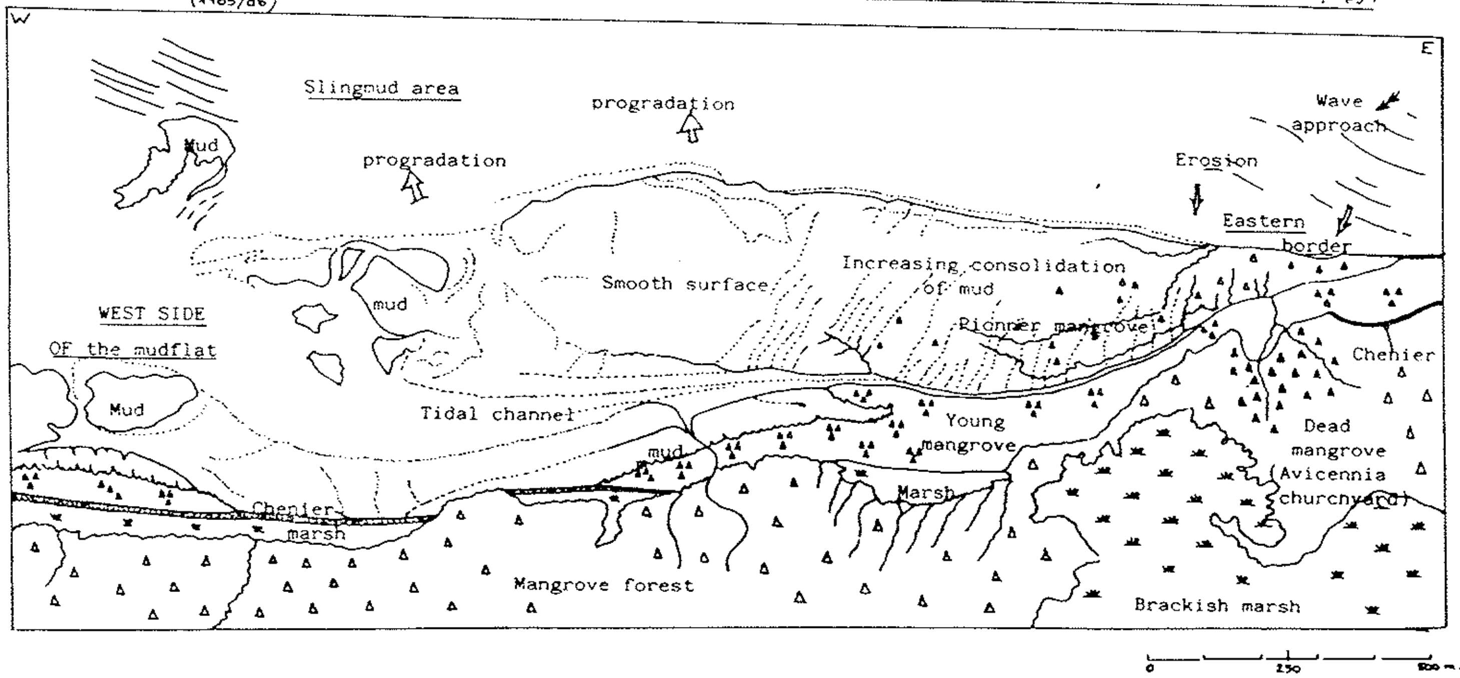


Fig 5 -Westward migrating shoreface-attached mudbank - East of the Sarcelle Swamp (zone of Mana-Iracompapy) (1985/86)



deeper and where the substratum is composed of more consolidated mud, erosion takes over and the shoreline recedes. On the whole, these dynamic processes take place in a relatively high energy environment, as noted by RINE and GINSBURG (1985), muds are accumulated by high current and wave activities. In the interbank zones, the waves not only erode the eastern flank of the mudflat but also cause the shoreline to recede. In other words, at the same time, there are as many sectors under accumulation as under recession along the coastline (fig. 6).

Measurements have been taken of the rate of migration of mudbanks and interbank zones. In French Guiana, it averages 900 m annually (between 300 and 1200 m/year - CORDET Report, 1985). In Suriname, it varies between 0,5 and 2,5 km/year (NEDECO, 1968; ALLERSMA, 1971; AUGUSTINUS, 1978, 1980, 1982, 1985). On the Guyana coast, the average rate of propagation is 1,3 km/year (DELFT, 1962). The differences emphasize the greater angle between the coastline and the direction of the prevailing winds (AUGUSTINUS, 1985). Lastly, the average period of mudbank migration along a given point of shoreline is about 30 years (DELFT, 1962; BOYE, 1962; TURENNE, 1978; AUGUSTINUS, 1978;RINE & GINSBURG, 1985; historical information, etc.).

Then, it is possible to reach the conclusion that:

a) The source of the considerable amount of sediment transported alongshore in suspension or by migrating shore-attached mudflats is related to argillaceous muds supplied by the Amazon River in striking contrast with the small supply from the local rivers.

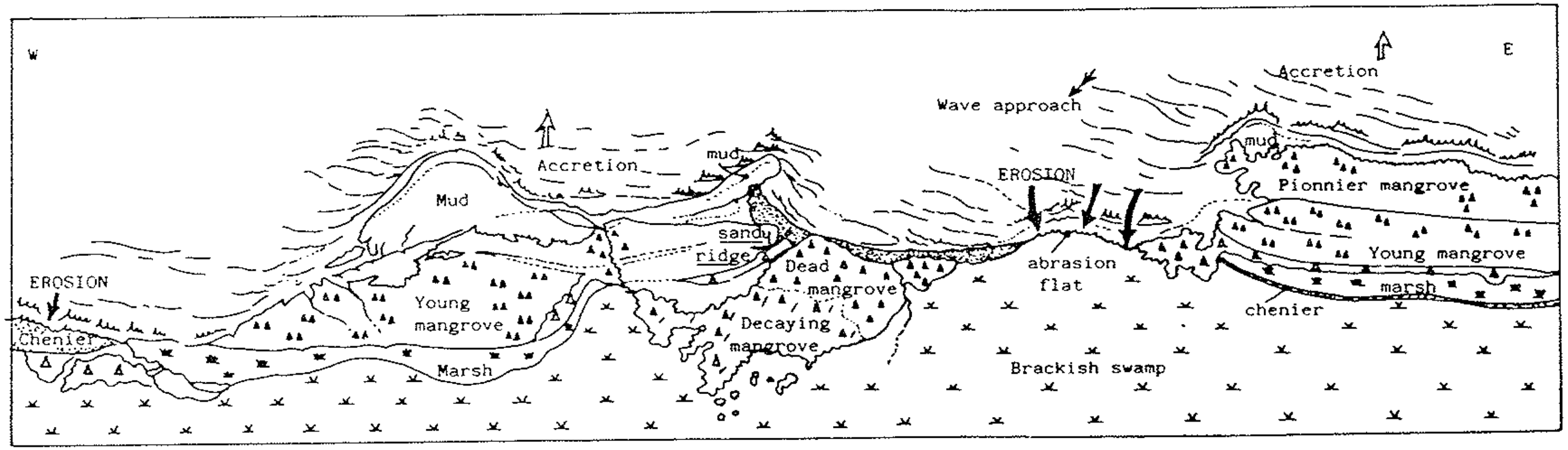
b) The littoral morphogenetic processes take place in a relatively high energy environment.

Controversial points

We will introduce only the three following qustions:

- What is the role played by estuaries in the transport of sediment along the coast?
- What is the origin of the sand composing beaches and present-day sandy ridges?
- What are the repercussions of coastal dynamics on the paralic sub-coastal environment?

Fig 6 - Accretion/erosion coastline east of the Sarcelle Swamp (Mana-Iracompapy zone. 1985)



Scale: 0 250 500

a) The role played by estuaries

The relative importance of estuaries in the transportation of coastal sediments is still unclear. Some believes that they play an important role; others, only a lesser one. Do local river mouths check the passage of fine-grained sediment?

AUGUSTINUS (1978) observed that the advance and retreat of the 2 m isobath in the western part of the Suriname estuaries does not appear to have a direct connection with the westward shifting mudbanks; the 2-m depth contour seems to change very little over the years. This stability is possibly due to the higher current velocities on the west side of estuaries and caused by river discharge during the ebb tide which prevents the silt from settling down. Research done in Suriname therefore also shows a differential behaviour of river mouths; when they are large, the pressure exerted by the supplied water is too high to introduce major changes. For example, in the case of the Essequibo River, the discharge causes perturbations in the Guiana Current and introduces changes in the transport of sediments (DELFT, 1962).

When river mouths are smaller they are deflected by the coastal sedimentary transport. AUGUSTINUS (1978) has shown that at the Mana River (French Guiana) this development started in the 18th century; in 1785, the river mouth was much further east than at present. After 1865, it began deviating westward and Pointe Isère began to take form. At present, the Mana and the Maroni Rivers share a common mouth, with Pointe Isère became the principal morphological feature of this part of the coast. The same process has resulted in a common river mouth for the Counamama and the Iracoubo Rivers. Several examples of deflection of river mouths can be found in the Young Coastal Plain of Suriname (for instance, the Cottica, Commewijne, Saramacca and Nickerie Rivers).

At which moment and under what conditions are river mouths affected by the westward transport of sediment? Until now, no comprehensive study of the processes has been published. Further information is necessary concerning the hydrological, sedimentary and morphogenetic processes involved particularly when we attempt to assess their critical values of activity. Moreover, observations have been random and local conditions cannot be easily generalized. Although some tendencies can be detected, their extent is still unknown.

b) Origin of sandy beaches and ridges

Sandy material is rather rare in this mud-dominated environment(3). Sand accumulates as cheniers and small beaches. But, from the geomorphological point of view, the sandy material is of a major importance, correlated with a type of coastal landscape defined by AUGUSTINUS (1978). But where do these sands originate?

Researches in Guyana and Suriname are in agreement on two possible sources:

- That of an Amazon-born fine and very fine-grained sands is uphold by KROOK (1976) and by AUGUSTINUS (1978, 1980, 1982, 1985). Accumulated at the mouth of the Amazon, they would be held in suspension and carried along with the pelitic particles by the Guyana Current (MILLIMAN, 1975; EISMA and VAN DER MAREL, 1971). As the result of the erosion of the mudflats, the sands are "washed out" of the muddy sediments. The muds are then carried further and the sands remain as beaches and coastal ridges.

According to KROOK (1976), the heavy mineral association is dominated by epidote and hornblende(20 to 40%). AUGUSTINUS (1978) emphasizes that these sands occurs only at west of the Suriname River.

- Medium and coarse sands are accepted by the majority of authors as river-born. JEANTET (1982) considers it obvious "even if their zone of influence slightly exceeds the estuary or strictly coastal areas". The river-born source is also shared by LEVEQUE (1962), BLANCANEAUX (1981) and FROIDEFOND (1985).

The heavy mineral assemblage is dominated by the staurolite (45/75%). The riverain-supplied sand is not brought far outside the river mouths or estuaries. Some deposits in Suriname seem to be supplied by the Mana and the Maroni Rivers, the latter carrying weathered products of the highly metamorphosed schists of the Armina Formation in Suriname (correlated with the schists of the Orapu Formation in French Guiana).

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(3) Only 2% of the total amount of the pelitic sediments (AUGUSTINUS, 1986, in press).

However, the hypothesis concerning the present-day river supply comes up against the problem of the small quantities of suspended load in French Guiana rivers (ORSTOM/ Cayenne, 1985-86). The load of colloids is very constant, at about 10 mg/l. Furthermore, the bed load affects only a thin few cm thick layer of the bed. Under these conditions, the solid load is insufficient to nourish and maintain the sandy accumulations along the coast. All the more so as the slopes are extremely small: on the Sinnamary River, for example, the river slopes is 0,90 m for the last 30 km (LOINTIER, 1984).

Subject to new observations and data, river transport of solid matter seems to be very small. This point reveals the complex problem of the present and past causes of the coastal sand accumulations.

c) Repercussions of coastal dynamics on paralic environments

Vast amphibious spaces occupy a very large part of the Younger Coastal Plain and constitute a privileged zone of action of marine and continental processes. They are the object of a recent study in the Sarcelle Swamp zone (LOINTIER & PROST, 1986). Two distinct units have been identified:

- The first, regularly covered by the tide, extends over a very limited area. Occupied by the waterfront mangrove and crossed by tidal channels, it evolves according the rhythm of the ocean (semi-diurnal tides and cycles between the syzygies).

- The second is a marshy area formed by vast depressions of brackish swamps and low vegetation, with little or practically no water circulation. Its evolution depends primarily of rainfall and evaporation.

LOINTIER shows a clear limit between the two units: as a general rule, there is no intrusion of sea water into the brackish water basins. But, when the rainfall exceeds 30 to 50 mm, the overflow of the brackish swamp fills the network of tidal channels which slowly drain the water towards the sea. Thus, at this time - and only under these conditions - a one way connection is established.

The paralic environment under consideration is influenced more greatly by continental rather than marine conditions. Notably, when dry season is more intense or lasts longer than three months, the central basin dries out and become a vast surface of cracked clay, a "dry tanne"(4).

As for the reprecussions of recent coastal dynamics on the evolution of sub-coastal swamps and marshes, it appears that:

- On the one hand, soil development, linked to recent phases of accretion and abrasion of the coast, explains the high salinity of the sub-littoral marsh as there is no saline intrusion into the brackish basins;

- On the other hand, a comparative study done in a neighboring freshwater marsh situated further inland and having developed soils proves the persistance of littoral conditions and the phenomena of the accretion/abrasion cycle.

On the whole, the sub-coastal environment also appears to be very dynamic. If the marine environment appears to be relatively unstable, there is no proof that once the mudbank has migrated westward, the evolution of this environment, as well as the beaches and sandy ridges, will not be modified (LOINTIER, 1986). Actually, it is more than likely. The brackish swamp appears to be rather more stable but this stability is very precarious; only slight modifications are sufficient to change the brackish swamp into a "dry tanne" or a stretch of open water. Finally, the freshwater marsh seems to be the most stable of the three, with developed soils and a dense cover of vegetation.

The enlargement of one unit in the detriment of another has also changed on time, as has been shown by sedimentological and stratigraphic data.

STRATIGRAPHY AND SEDIMENTOLOGY OF THE HOLOCENE FORMATIONS AND SHORELINE CHANGES

Stratigraphy of the Quaternary formations

The stratigraphy of the Guianese coastal plain has

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(4) Tanne: expanses with no vegetation or a herbaceous carpet, and situated in the depths of the mangrove.

been object of several studies (BOYE, 1963; MONTAGNE, 1964; BRINKMAN & PONS, 1968; VEEN, 1971; CHOUBERT, 1973; TURENNE, 1978, etc.). The simplified table below is based on research carried out in Suriname and indicates the corresponding series in French Guiana (TURENNE, 1978)

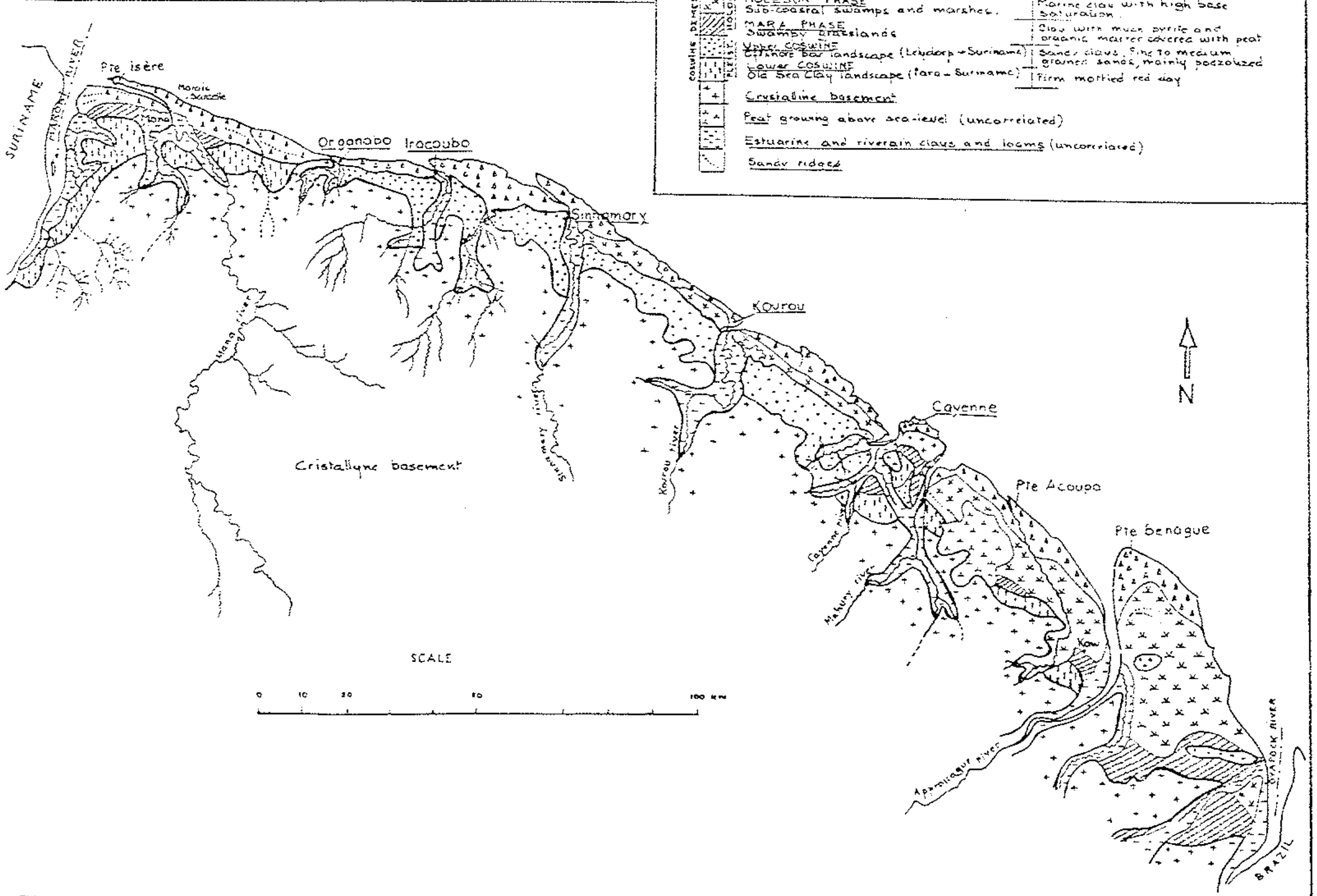
Age	Stratigraphy		Landscape
	Suriname	French Guiana	
Holocene	Demerara series (Coronie)	Demerara series	Young Coastal Plain
Pleistocene	Coropina series (Upper Coropina) (Lower Coropina)	Coswine series Fine-clayey sands Mottled and silty clays	Old Coastal Plain
Pliocene	Coesewijne series (Upper Coesewijne)	Detritic series (S.D.B.)	Precambrian shield edge

- The "Old Coastal Plain" spreads out between the "Young Coastal Plain" in the north and the outcropping shield in the south (Fig. 7). The Pleistocene deposits are not very thick, at most 16/18 m in French Guiana; they are, on the contrary, very wide and cover a larger area in Suriname and Guyana. They form the Coswine series in French Guiana and the Coropina series in Suriname.

Two levels are easily distinguished in French Guiana (see fig.3)
. At about 15 m of altitude they form a system of sandy ridges in close proximity to each other, between 400 to 600 m wide and generally lying in a SE/NW direction; these are old off-shore bars formed in deep water off the shoreline (SOURDAT/DELAUNE, 1970).
The sediment has a good sorting in contrast with the Holocene sands.
. At about 5 m of altitude appears the "Old Sea-Clay Landscape", formed by a mottled, desalinated and consolidated clay undergoing pedogenesis. Erosion has cut this landscape: small "islets of dissection" have been formed among the Holocene marshes. This

Fig. 7

SEDIMENTOLOGY AND STRATIGRAPHY OF THE QUATERNARY FORMATIONS OF THE FRENCH GUIANA'S COASTAL PLAIN.



type of morphology is clearly seen in the region of Mana and also in the Cayenne area.

- Holocene deposits (fig. 7), composed mainly of fine-grained marine sediments, occur since 8000 BP up to the present. Stratigraphic data based on studies carried out in Suriname (^{14}C dating, pedological research, pollen analyses, studies on mollusks, etc.) and are presented below in a simplified form.

Serie	Deposit	Phases	Sediments
Demerara	Coronie	Comowine	Saline to brackish marine clay with or without vague or brown mottles.
		Comowine/Moleson	Sandy ridges
		Moleson	Partially desalinated, yellow and brown mottled marine clay
		Moleson/Mara	Sandy ridges
		Mara	Heterogenous clays with organic matter and sand layers.
		Non-correlated	Peat

The Wanica phase (yellow mottled marine clays) - post-Mara and pre-Moleson - decribed in Suriname is not recognized in French Guiana.

The Mara Phase is the oldest, dating to 8,000/6,000 years BP (BOYE, 1959; LEVEQUE, 1962; VAN DER HAMMEN, 1963; ROELEVELD, 1968; BRINKMAN and PONS, 1968; TURENNE, 1978, etc.).

The peat from the Mara phase has been the object of age dating. It is accepted that peat from this period was formed very close to sea-level, frequently in brackish marshes of Rhyzophora. The pollen analyses carried out by ROELEVELD indicated nearly 100% of Rhyzophora pollen. Based on this data, VAN DER HAMMEM accepts a transgressive maximum of +3 m towards 6,000 BP. However, BRINKMAN and PONS believe that this type of deposit precedes the marine maximum of 6,000 BP and that it corresponds to the "Old Mara Phase". In other words, the old Holocene deposits have appeared in several stages and their summits are not found at the same altitude everywhere in relation to present-day sea level. Other studies will be necessary to determine these differences, especially in light of the fact that the littoral sea board has been subjected to subsidence.

The Moleson and Comowine Phases are dated respectively as being 2,600/1,300 BP and 1,000 BP to the present. In Suriname and Guyana, the Wanica/Moleson/Comowine sediments correspond to the Coronie deposits.

BRINKMAN & PONS (1968) estimated that the Wanica phase started about 6,360 BP. This age is based in a layer of a old peat (Mara phase) of a meter in thickness found in the zone of Nickerie; it is situated 1.50 m below average present-day sea level and lies on Pleistocene clays. A 4-m high sandy ridge containing shell fragments sits on top of the peat; it was therefore formed after 6,360 BP, and has been recognized as Wanica phase by the nature and degree of soil developement in the ridge. The end of the Wanica phase is dated at 3,500/3,000 BP.

The beginning of the Moleson Phase in Suriname can be estimated as about 2,800 BP thanks to the ^{14}C analyses of shells in the Hertenrits archeological site situated north of Wageningen (Nickerie). The end of the phase is placed at 1,000 BP (PONS, 1966). Pollen analyses at the Hertenrits site as well as new ^{14}C data permitted the definition of several stages within the Moleson phase and linked them with the advance and retreat os swampland in relation to changes of the shoreline. A few minor differences appear in the ages proposes by BRINKMAN & PONS (1968): beginning of Moleson at 2,500 BP (Old Moleson); intermediate stage at 2,000/1,500 BP (Middle Moleson); end of the phase at 1,300 BP (Young Moleson).

The Comowine Phase is the most recent. Towards 1,055 BP flooding left accumulations of marine clay at the foot of the Hertenrits amerindian mounds, where the Avicennia grow. The amerindians were forced to leave the site; they probably moved to the ridges. GEYSKES (1961) found a radiocarbon age of 480 $\pm$ 150 years BP at an amerindian site north of Paramaribo situated in the center of the belt of Comowine sediments.

Geographical maps of the 17th century show Paramaribo as much closer to the sea than at present. Progradation of the coast near the Coronie continued until 1914 (REYNE, 1961). As a matter of fact, the Comowine phase of sedimentation has therefore continued up until present times.

The stratigraphy here presented formed the basis for the identification of the phases of fine sedimentation - and the sandy ridges which separate them - within the three Guianas. In French Guiana, absolute datings are rare and the stratigraphy has been done mainly by analogy with that of Suriname and thanks to pedological studies. Only a few radiocarbon dates exist, taken during the CORDET Project. They show that the coast between Mana and the Maroni River prograded during 3,500 years oceanward while during the same period, it was in regression towards the Sinnamary (CORDET Report, 1985).

Sedimentology of the Holocene formations

a) Fine-grained sediments

The Holocene sediments are composed mostly of marine clays (fig. 7).

The grey clays of the Mara Phase are the most heterogeneous, accumulated in a brackish and/or in a marine environment (TURENNE, 1978) with a transgressive event and sedimentation in the estuaries. They have been accumulated within brackish lagoons and marshes situated behind coastal sandy ridges and in rias. For this reason, these clays contain organic matter and sandy layers. Further inland from the coast (zone of Mana-Iracompapay; Kaw marshes; Pointe Behague)appears a type of loose, acidic spongy and/or fibrous peat, the "pégasse". The soils developed in the Mara sediments are very rich in pyrites (pyrite clay or sulfurous clay) and would give rise to "cat clays" or "acid sulphate clay" after oxidation.

The Mara sediments cover only a small area in French Guiana, especially at the west coast (region of Mana-Iracompapay). Between Organabo and Cayenne, they are scarce and between the Mahury and the Oyapock Rivers, they appear only in small areas. They occur, on the contrary, in large areas in Suriname and especially in Guyana.

The Moleson sediments are composed of soft,brown and yellow-mottled, greyish-blue clays, superficially desalinized. They occur mainly to the east of Cayenne. These sediments correspond partially to the site of brackish marshes and are most frequently located above the highest tide level. BRINKMAN & PONS (1968) observed that in certain cases the Moleson sediments in Suriname occur approximately one meter lower than the present high-tide level. Moreover, no erosion of the surface has been observed in this phase (in contrast with the Mara phase) which indicates that after deposition,the sea level must have remained essentially constant (BRINKMAN & PONS, 1968).

The Comowine Phase, however, is composed of highly saline, blue marine clays, covered by normal high tides. It constitutes the waterfront mangrove landscape and the present-day shoreline which is being subjected to the most striking morphological changes.

b) Peat

Peat has not been found in the Holocene deposits. It should, however, be noted that a large majority of these peat swamps covered mainly the Mara deposits. However, BRINKMAN & PONS point out that besides the "eustatic" peat of the Mara Phase, there exist another kind of peat mounds growing above sea level, known as "ombragenous peat" from their appearence on aerial photos. They correlate these peats with the Wanica/ Moleson phase. At present, they continue to grow.

Because of the great difficulty of access, peat swamps in French Guiana have not been object of systematic studies and dating. However, we hope that radiocarbon dating will be done in future research.

c) Sandy ridges

The perched sandy ridges interspersed within different phases of the fine-grained sedimentation are cheniers ("ritsen" in Suriname and in Guyana). They rest on a substratum of marine clays and their base is very near the present-day sea level.

Cheniers are essentially built up of medium to coarse sand in French Guiana, and by sand and shell fragments in Suriname and Guyana with a small proportion of fine-grained sediments. Sandy ridges have been studied in French Guiana by SOURDAT and MARIUS (1964). According to these authors grain size varies between 0.1 and 1.0 mm although coarser sand (1 to 2 mm) is not uncommon. It is marine, "essentially composed of quartz and rare heavy minerals, containing mica and occasionally shell clastics" (TURENNE, 1978).

These ridges are straight and narrow (width between 70 to a maximum of 200 m) with one or several crests (see fig. 3). They occur mainly east of Cayenne. In the Mana-Aouara-Les Hattes region, they form complex systems curved toward the Maroni's mouth, the same feature occurring at the Suriname bank towards Pointe Galibi.

The cheniers spread out widely in Suriname and Guyana. AUGUSTINUS consecrated a large amount of his research to them from 1978 until 1986. He distinguished two types of cheniers along the Suriname coast; those formed by medium and coarse sands from the Maroni to the Mara River, and cheniers on the west coast, composed of fine grained sand and shell clastics. The fine-grained sands are carried from the Amazon. The author defines a typology of the erosion and accumulation coasts of Suriname; this typology is based largely on chenier development.

The cheniers need further studies in French Guiana, particularly concerning their ages. Until now, we used only relative ages ("old", "recent", "present-day" cheniers), based on their geomorphological position and on their degree of pedogenesis. But such an interpretation is insufficient and imprecise and must be replaced by a more accurate research especially in complex formations of sandy ridges, as often observed in the field.

In general, the cheniers are considered as built up on a relatively stable coast (AUGUSTINUS, 1978), shoreline changes occurring by progradation and retreat as at present. It is certain that they serve as a barrier for the brackish marshes developing behind the sandy ridges. AUGUSTINUS recalls that their development has many consequences for the geomorphology, drainage and the development of soils and vegetation in the coastal zone. He presents a diagram showing a synthesis of these interactions (fig. 8). RINE & GINSBURG (1985) have also emphasized the role of cheniers in the morphodynamic sequences of the French Guianese coast.

The Holocene coastal plain of the Guianas is one of the longuest continuous "open ocean" chenier plain, similar to the one in southwestern Louisiana. It is the result of a continuous and abundant supply of fine-grainde sediments and of the

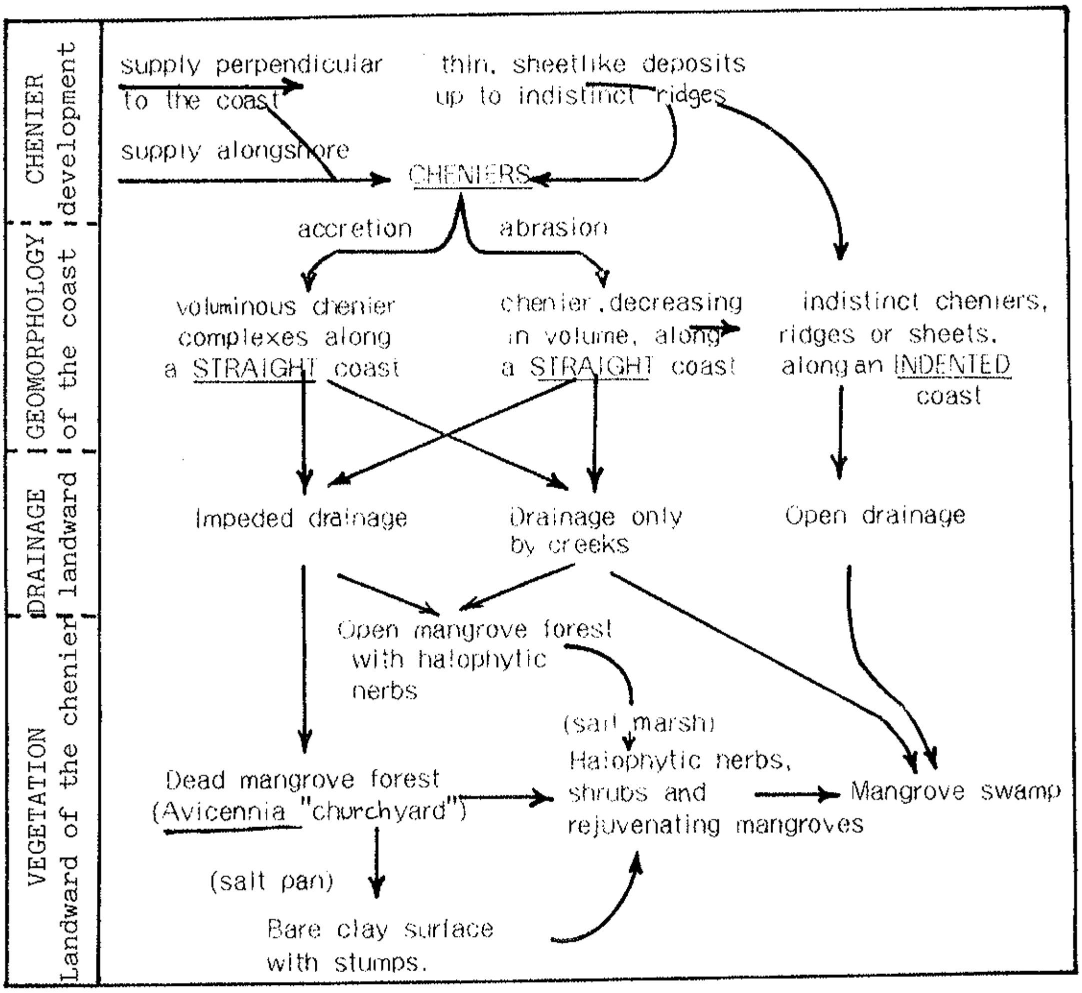


Fig. 8 - Influence of chenier formation on the coastal geomorphology, on the drainage of the adjacent area and the related development of the vegetation (form AUGUSTINUS, 1978).

development of sandy ridges which rest on clay and insert themselves between fine deposits.

Considering the Holocene as a whole, progradation is dominant; in the past 6,000 years the Surinamese coastline advanced seaward for approximately 30 km (RINE & GINSBURG, 1985). However, during this time interval, depositional phases are separated by periods of prevailing erosion or non-deposition (BRINKMAN & PONS, 1968; ROELEVELD & VAN LOON, 1979).

CONCLUSION

We have shown that the Guianas' coast is composed of immense amphibious space situated behind the waterfront mangrove, where cheniers are, apart from a few exceptions, often the only prominent landform. The coastline is generally low-lying and homogeneous. However, the morphogenic processes are not tediously invariable: on the contrary, coastal dynamics are very active and characterized by large accumulations of argillaceous mud supplied from the Amazon and carried westward by currents and waves. Vast mudflats prograde into the ocean and are separated by interbank zones where the coast is undergoing erosion. Mudbanks and interbank zones migrate westward; the intensity and frequency of this migration are variable according to location and time period.

These dynamics have several repercussions in the present coastal environment. However, the paralic space is partially free of the direct influence of the ocean and evolves according to continental conditions. A limited relationship has been observed between these two types of evolution at the Sarcelle Swamp and a comparison was made with neighboring fresh-water marshes.

All the elements show that conditions of "stability" and "instability" can be defined; however, the concept of landscape "stability" is very precarious. In order to provide a better understanding of the evolution of this natural environment, a synthesis of studies on stratigraphy and sedimentology of the Quaternary formations has been made. The aim was to provide the ages of the global changes affecting coastal areas (sedimentation, peat development, etc.). The different phases of sedimentation have been the object of radiocarbon dating establishing a chronology of the main events.

Subject to new data and observations, the behaviour of the Holocene littoral dynamics appears to be similar to those of the present time. It is certain that there was a regular rise in sea-level between 10,000 and 6,000 BP, the maximum transgressive coinciding with the Mara Phase. But - at least up to present day - there is no evidence of any subsequent vertical oscillation in sea level. The chenier characteristics argue in favor of progradation and recession similar to that of the present coastal dynamic. The Guiana's open ocean chenier plain does not seem to have undergone an evolution analogous to that of the Brazilian coastline, where a high number of detailed surveys indicate Holocene sea-levels higher than today.

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ENVIRONMENTAL GEOLOGY IN THE GUANARE PIEDMONT, VENEZUELA

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INTRODUCTION

As it is worldwide known, the landforms where a city is placed and those in the surrounding areas are important elements in an environmental evaluation for supporting urban policies. They display to us different possibilities and problems to be solved.

In Guanare city, capital of the Portuguesa state, one of the traditional problems was to preview how deep had to be an excavation for the location of domestic sewers in the old mansions. In the present time the same problem appears when it is necessary to extract groundwater. Why some areas inside the bedrock have better permeability than inside others in the beginning of the alluvial plain?

In addition to it, other elements need to be better known as are those concerned with the detritus that come from the closed hills, which combined with the bad external drainage in some sectors in the downtown, limits the transit in the city during the wet season. Some other erosional processes have their source outside the urban areas, but affect them indirectly generating an overload of solid charge in the creeks that pass by the city. What are the nature of these processes?

In the next pages, product of a short field review, we emphasize the importance of the Holocene history in the identification of those conditions.

Proceedings of the IGCP Project 201 Mérida (Venezuela) meeting: p. 85-100.

THE LOW PIEDMONT: A COMPLEX LANDSCAPE

Our study area is located on the south of the "Sierra de Portuguesa" piedmont, low slopes of the Andes mountains (Republic of Venezuela, Fig. 1). This zone is part of a vast region defined as one of very active streams discharged from the mountains into the alluvial plain.

The rainfall is of about 1,600 mm with a seasonal distribution typical of a tropical wet-dry (savanna) climate. The wet season is marked by short and intense heavy showers that accelerate slope erosion.

Here does not exist primary vegetation. The human intervention has been the most important factor in the regional ecology since the XVIth century (RENGEL-AVILES _et_ _al_., 1983).

The general landscape is very undulated, with altitudes ranging from 150 to 230 m.a.s.l. The dominant landforms, mesas, trenched cuestas and hills are separated by valley lowlands (Fig. 2). The mesas are old horizontal terraces (three different levels, horizontal surface with 1 to 2% slope). The trenched cuestas are old sloping terraces with their backslope (10% slope) toward the alluvial plain, over these surfaces lays part of Guanare city. The upper part of cuestas and mesas in Guanapa Formation (Qgp), detritic accumulation possibly developed as a depositional belt during the Pleistocene period as an agglomeration of granitic blocks and gravel inside a body of sand and clay (GONZALEZ DE JUANA _et_ _al_., 1980). This depositional belt in the piedmont was affected by a tectonic event: the Guanapa fault activation (RONDON, 1976), which originated the initial cuestas by differential uplift; its upper lip corresponds with the original scarp, parallel to the piedmont and possibly correspondent to late Pleistocene tectonic event (Fig. 3).

The high hills (25 to 45% slope) are mainly residual landforms on Rio Yuca Formation (Tpmy), Mio-Pliocene sediments now affected by gullies, and the low hills (10 to 30% slope) are developed on Parangula Formation (Tmp), Miocene sediments. Both formations consist of conglomerate, sandstone, siltstone and clay layers.

The valley lowlands were produced by alluvial accumulation (Qal) of sediments from hills and mesas. This

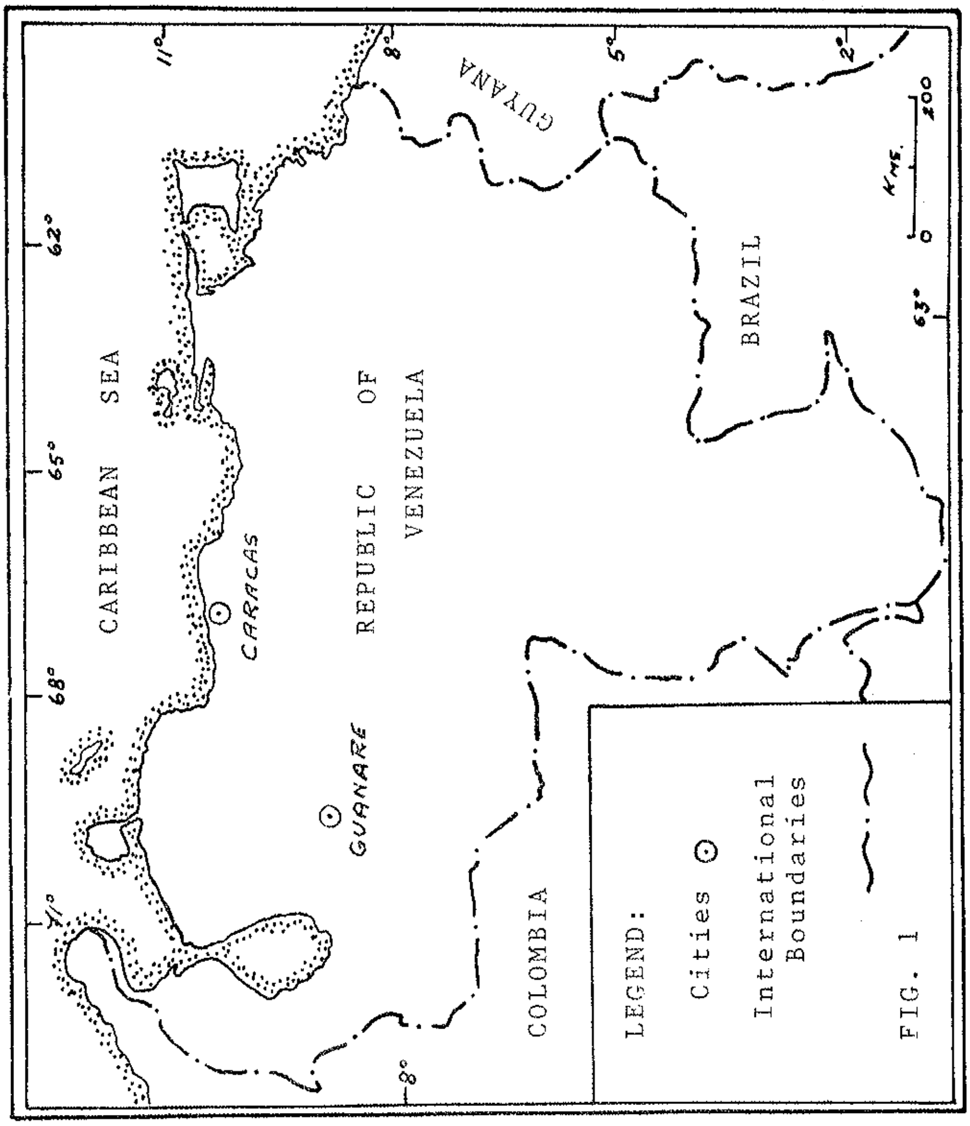
CARIBBEAN SEA
CARACAS
GUANARE
REPUBLIC OF VENEZUELA
COLOMBIA
GUYANA
BRAZIL
11°
8°
5°
2°
71°
68°
65°
62°
63°
KMS.
0
200
LEGEND:
Cities
International Boundaries

FIG. 1

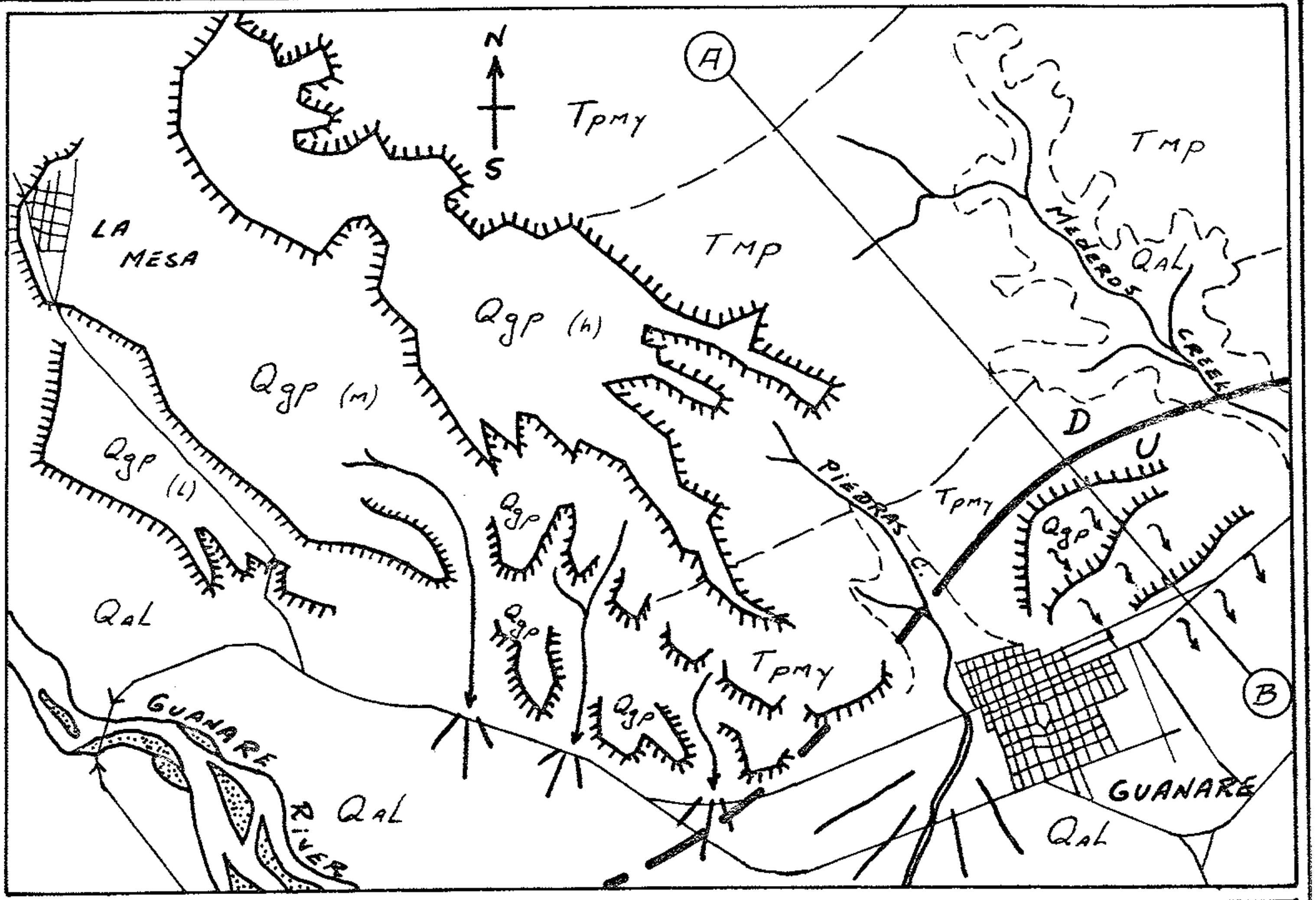

FIG. 2 GEOLOGY IN GUANARE / Adapt. from Rondon76 0 1 2 Kms.

GEOLOGY IN GUANARE PIEDMONT

TEMATIC LEGEND

Urban Area

Road

GEOLOGIC LEGEND

Parangula Formation	Tmp
Rio Yuca Formation	Tpmy
Guanapa Formation	Qgp (high, middle or Low)
Holocenic Sediments	QaL

Terrace Scarps

Creeks

Alluvial Fans

Sheet Flow

Fault — D → Down, U → Up

Formation Limits

GUANARE PIEDMONT

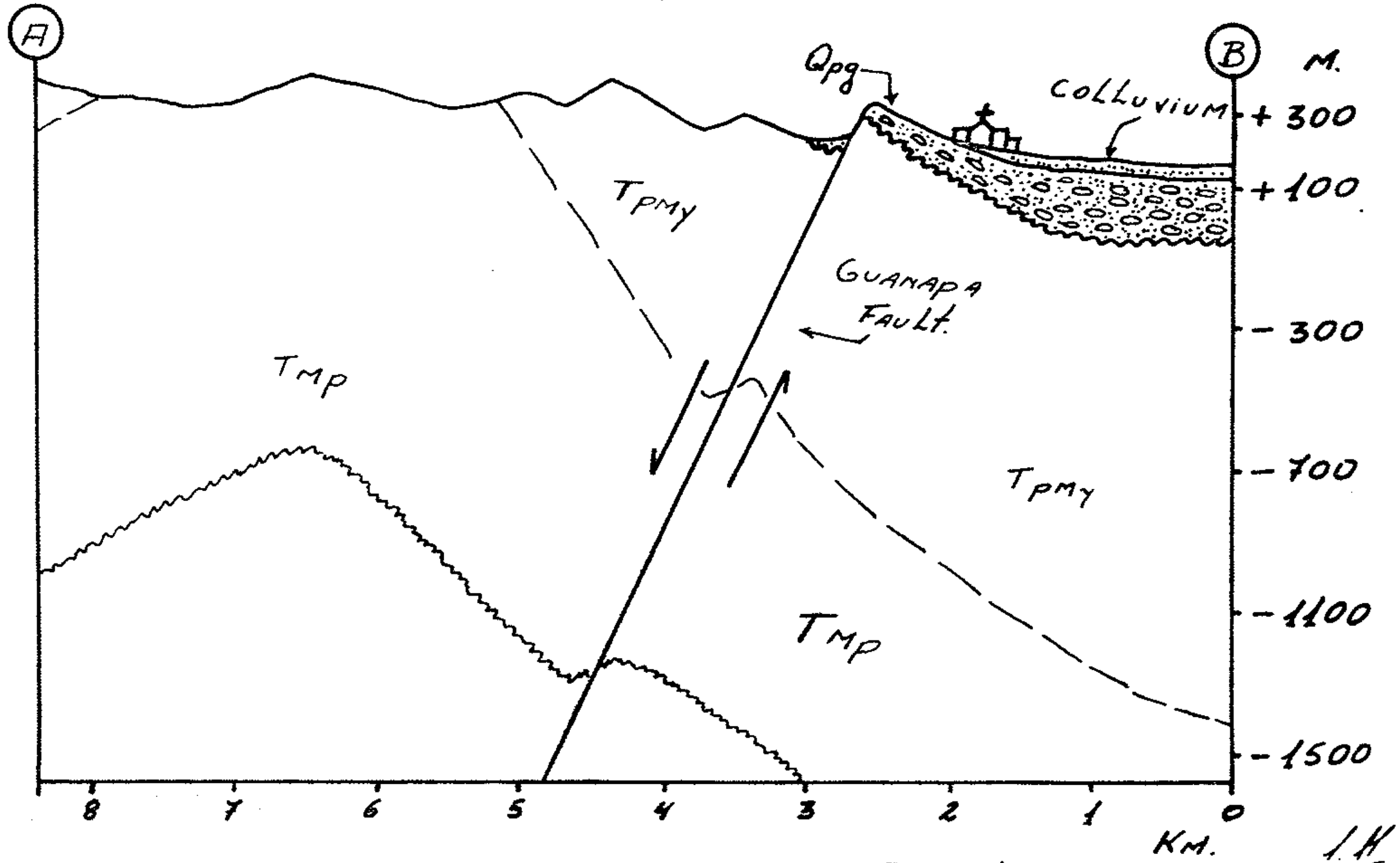

FIG. 3 GEOLOGICAL PROFILE -Tentative-

accumulation spread like fans into the alluvial plain.

THE HOLOCENE PROCESSES IN GUANARE

A research group of the "Universidad Ezequiel Zamora" (Unellez, Venezuela) and the "Centre d'Études de Géographie Tropicale" (C.E.G.E.T., France) published in 1982 the results of an investigation consisting in the comparison of sediments in this area by using grain size curves and other numerical indices.

Two selected curves from two different samples (Fig. 4 and 5) show a clear change of dynamic. The logarithmic curves correspond to the Guanapa Formation, describing its character of torrential accumulation due to stream erosion that predominated during Pleistocene period. The hyperbolical curves show a predominance of mud and clay, typical of a colluvial accumulation.

Numerical indices in micra obtained from grain size curves:

Samples	Median	Qd (Ø)	Heterometry
A	170	0.92	0.78
B	180	1.37	0.70
C	95	0.42	0.30
D	112	0.66	0.43

On the field it is evident the presence of old and stable alluvial fans constructed by erosion from Guanapa Formation, that means that an accelerated erosion by trenching continued during the Holocene, over the previous torrential deposits after their accumulation. These fans have been covered by the colluvium identified in the second group of samples. So, a sheet flow substituted the previous process, but when and how?

We can explain these buried landforms only by considering Holocene climatic changes, while the Pleistocene epoch were characterized by intense aridity. CHORLEY et al. (1984:358) stated that "during Wisconsin maximum 18,000 years B.P.)... the tropics were particularly drier than today". Thus the depositional belt of Guanapa Formation was constructed

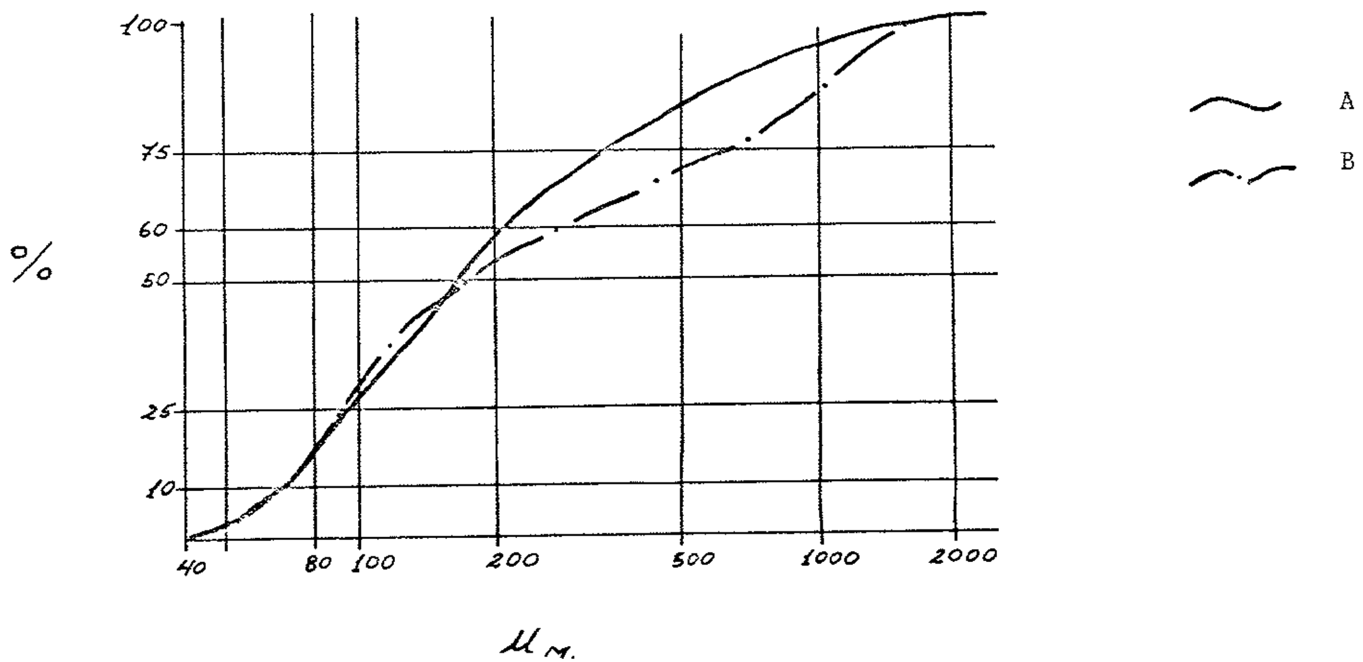

FIG. 4. GUANAPA FORMATION (Qpg). High Level.
(Source: UNELLEZ - CEGET, 1982)

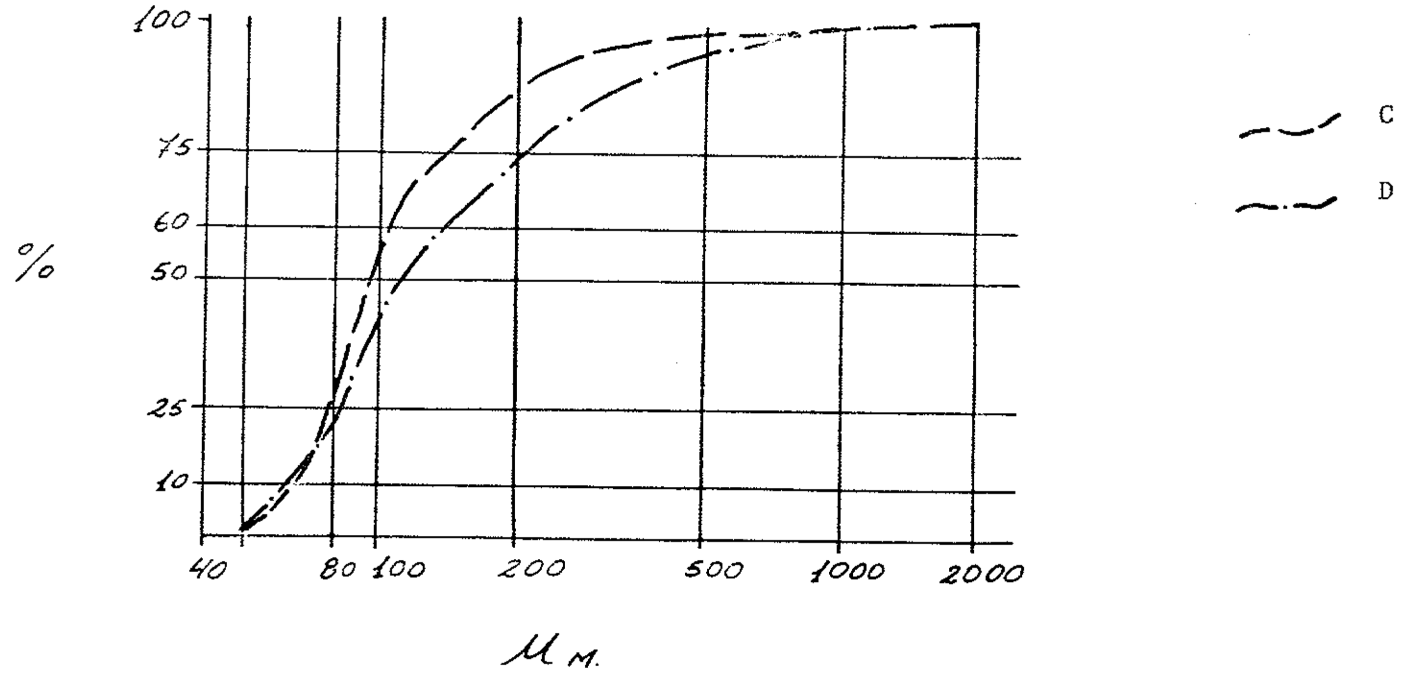

FIG. 5. HOLOCENIC SEDIMENTS (Qal).
(Source: UNELLEZ - CEGET, 1982)

under arid or semi-arid conditions, at least in its last phase of accumulation. This idea is supported by the poorly sorted material, typical of torrential activity. At the same time the tectonic action modified this landform by differential uplift.

We consider as a hypothesis the existence of two phases of Holocene erosion that crumbled the Guanapa depositional belt. The first phase just began with the climatic changes immediately after the last glacial age. With the deglaciation the piedmont started to suffer a sharp and sustained increase of precipitation, which according to FOX (1972; cited by CHORLEY et al., 1984:553) can "cause higher slope and channel erosion until the vegetation cover can improve", when the process declines. CHORLEY et al. (1984:542) also stated that "In the tropics there was a time of maximum precipitation about 9,000 - 7,000 years B.P., during which rainfall in the southern Sahara and most of Tropical Africa was 25 - 85 per cent greater than at present". If these conditions existed in our piedmont at the beginning of this pluvial period of very active denudation, the deposition of alluvial fans, possibly combined with debris flow, was the dominant process. The low gradients in the fans could be explained by the high clay/sand ratio in the Guanapa Formation (Fig. 6). When vegetation cover reduced this incisional process, it was substituted by a more controlled degradation, a superficial sheet flow that buried the previous fans (Fig. 7).

This buried topography, established on poorly sorted coarse-grained deposits, covered irregularly by layers of clay and silt, can help us to understand the location of places with different internal drainage in this area.

How many times it happened during the Holocene epoch? the climatic oscillation during this time is unknown in the area, but in tropical area near this place, VAN DER HAMMEN (1979) detected the existence of two "Climatic Optima", whose average temperature was 2°C higher than the present and happened from 7,000 to 3,000 BC., being also wetter periods than the present (LAUER, 1979). Thus, the previously defined climatic changes could have being reactivated many times, beginning with a trenching erosion that gradually changed to one more superficial.

Finally, we have to consider that the lack of evidence

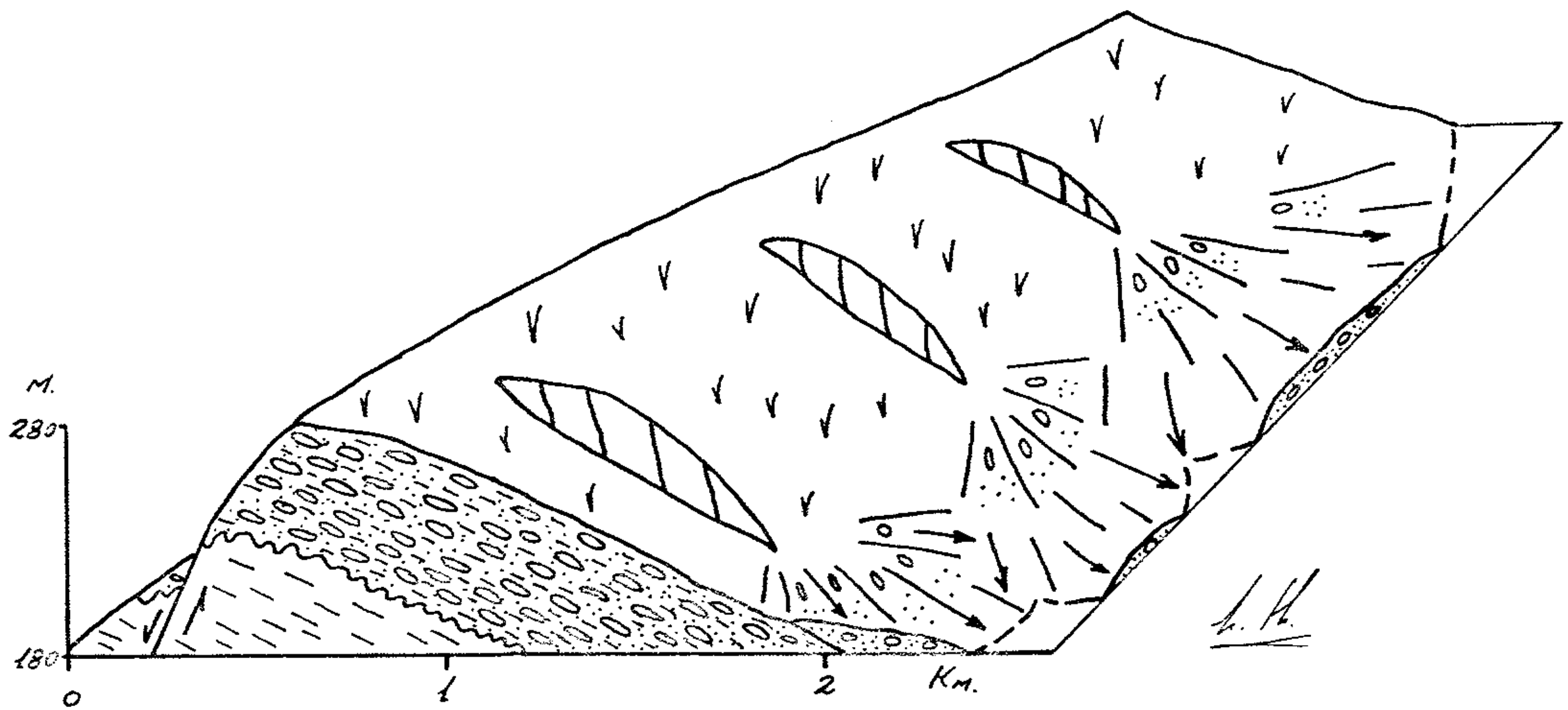

FIG. 6. GUANARE PIEDMONT.

EARLY HOLOCENE: DRY FANS & DEBRIS FLOW

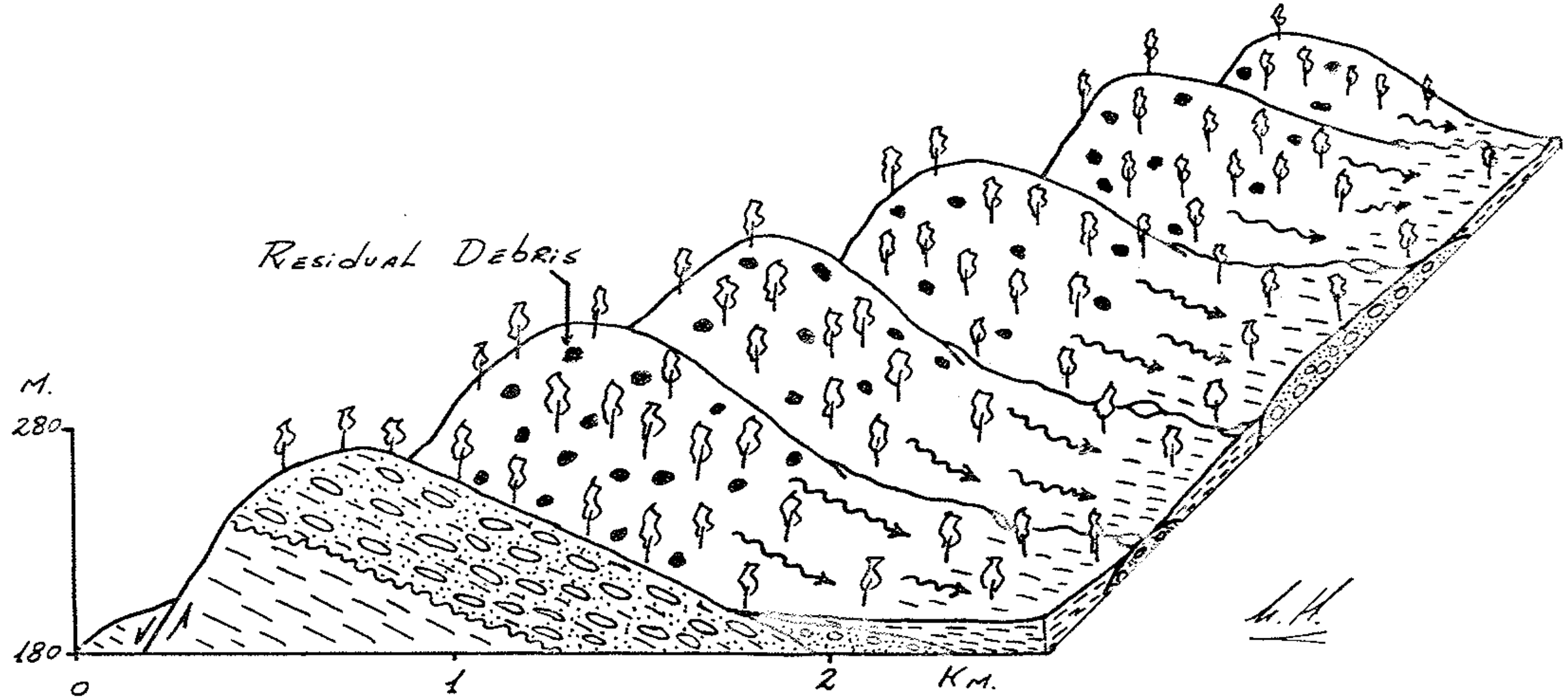

FIG. 7. GUANARE PIEDMONT.
LATE HOLOCENE (BEFORE COLUMBUS): SHEET FLOW

of segmented fans could mean they were not affected by Holocene tectonic uplift.

Also it is interesting to remark that the final phase of generalized sheet flow had a long time to act, so that it could leave a widely scattered residual debris (small stones and gravels) on the ground, covering the Guanapa Formation.

PRESENT SOURCES OF DETRITUS

After the spanish conquest and subsequent removal of the vegetation cover by human influence, a third phase of Holocene erosion took place. In the present time, this accelerated erosion appears as a reactivation of debris flow, in localities closed to the downtown mainly due to urban marginal occupation of Guanapa cuestas (Fig. 8), that generates the detrital accumulation during wet season.

Another important process of active sedimentation is related to the debris load in the creeks closed to the city. Its sources are some gullies grown on Rio Yuca Formation. These deep (until 10 m) and narrow gullies show evidence of a subsurface wash action. In some localities this process acts as an initial lateral eluviation, while in some others as advanced tunnelling. RUBEY (1928; cited by YOUNG, 1972:71) suggested that certain gullies in the Great Plains "were formed by the washing out of fine particles along seepage lines". It is quite possible that in our case exists an additional process of solution due to the presence of small quantities of limestone in Rio Yuca Formation. As this process is not evident in Parangula Formation, we consider its best explanation the fact that Rio Yuca Formation beds are more persistent than in the Parangula Formation (Fig. 9). So it facilitated the throughflow inside Rio Yuca sandstone layers transporting fine particles, and undermining this material.

FINAL CONSIDERATIONS

It is evident that the processes here described need a deeper research. About control policies of the active present processes, even though it has been considered the importance

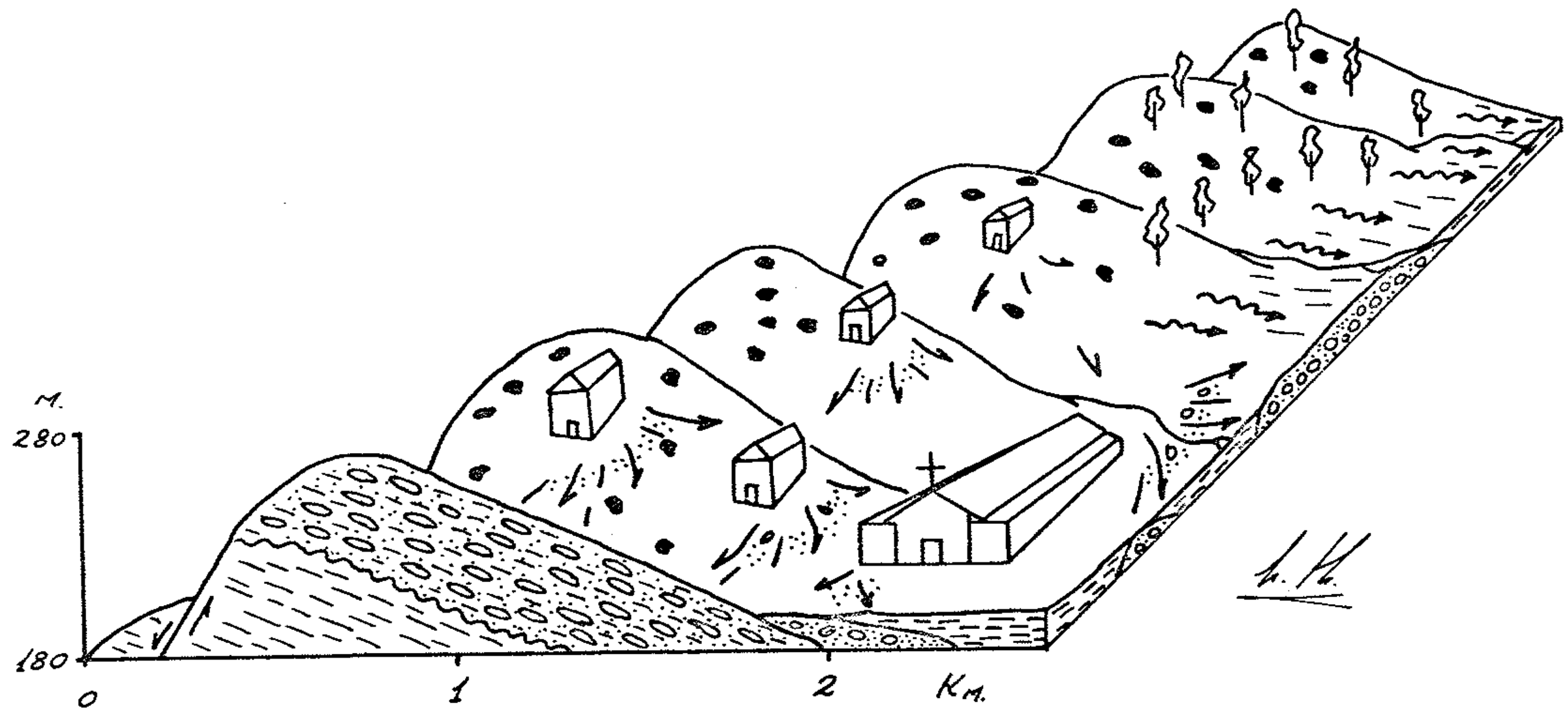

FIG. 8. GUANARE PIEDMONT.
PRESENT HOLOCENIC PROCESSES: URBAN IMPACT

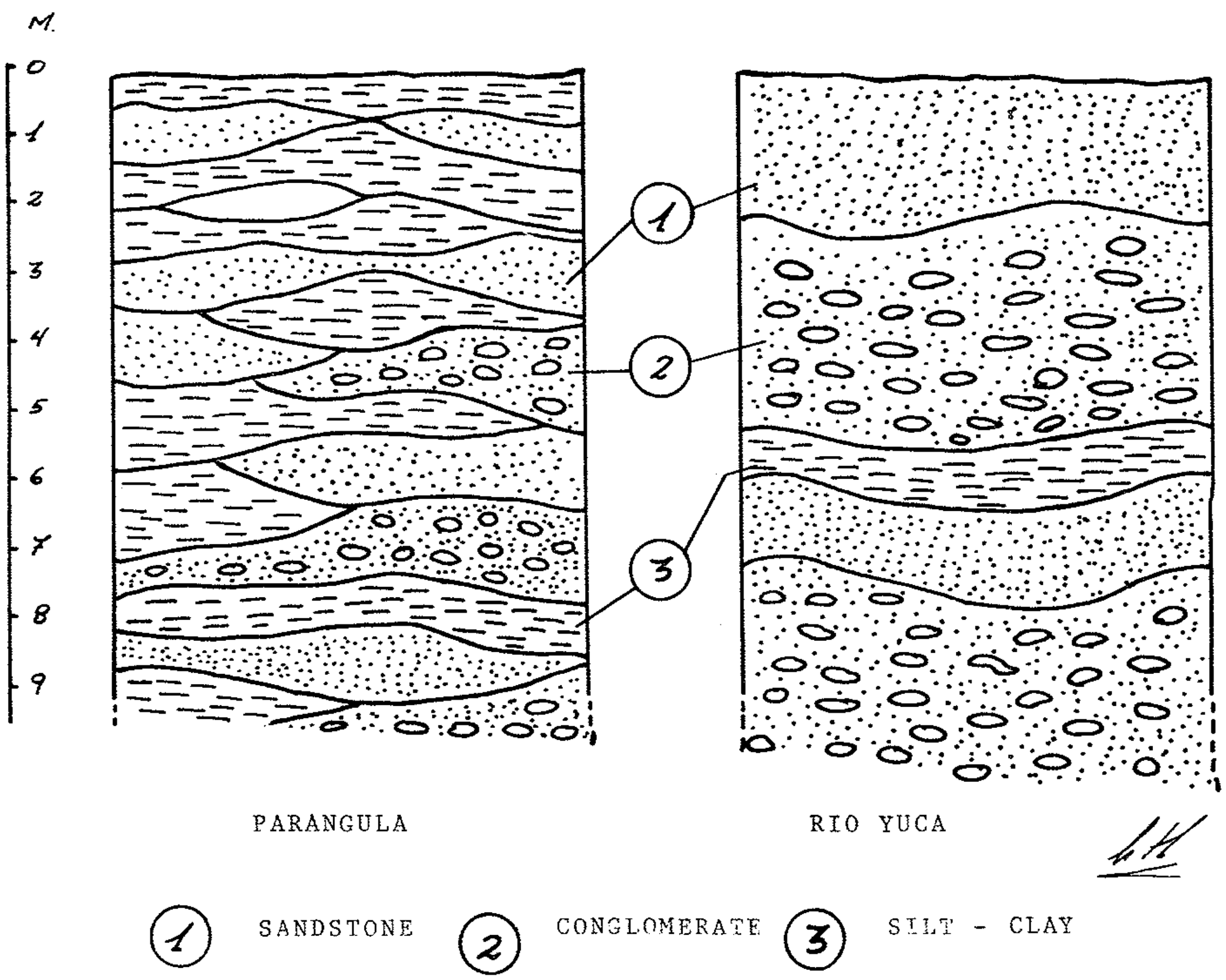

FIG. 9. COMPARISON OF FORMATIONS

of biological controls mainly in the gullies (RENGEL-AVILES _et al_., 1983), it is also important a change of attitude.

We need to live with these processes, and future field reconnaissance will tell us -with a better theoretical support- the landscape elements that may adapt to us, and the others to which we have to adapt our urban conceptions.

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EL CUATERNARIO CONTINENTAL DEL NORTE DEL URUGUAY: UNA APROXIMACIÓN A SU GEOCRONOLOGÍA Y RECONSTRUCCIÓN PALEOAMBIENTAL

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ABSTRACT

Paleontological research of the Uruguayan Quaternary has some inadequacies because of historical and methodological difficulties in the discrimination of the lithostratigraphic units. As a means of approaching a more rigorous paleontological characterization of the Quaternary, we have iniciated an analysis with strict stratigraphical control, of the fossil molluscs and mammals from the Pleistocene sediments of northern Uruguay. The objective of these research is mainly to clarify locally the paleoecological and geochronological questions and if possible regionally too. The first conclusions about local paleoenvironmental reconstruction suggest for the Sopas Formation the presence of water systems with different attributes, from large and speedy to little and lenticular. On the other hand, some mammals allow us to suggest the presence of open areas and arid plains.

With respect to the geochronology, the integrated analysis of the fossil mammals allow us to infer the Lujanian mammal-age (Upper Pleistocene) to the studied sediments. The conclusions are congruent with previous studies in Southern Brazil.

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INTRODUCCIÓN

La investigación paleontológica del cuaternario continental del Uruguay muestra rasgos de incertidumbre bastante marcados. Son varios los factores actuantes: las peculiaridades deposicionales de los afloramientos, los instrumentos metodológicos usados para diferenciar unidades formacionales introduciéndose aspectos sedimentológicos, estructurales, geomorfológicos, cronoestratigráficos y un gran cúmulo de fósiles continentales (en especial vertebrados) prospectados y recogidos la mayor parte con carencias metodológicas (referencias geográficas y estratigráficas imprecisas) y inadecuada orientación para su aprovechamiento en un contexto geocronológico.

Esta problemática se agudiza en relación con los sedimentos cuaternarios del Norte del Uruguay, debido a la escasas investigaciones geológicas y paleontológicas realizadas en esa área. Estos sedimentos son denominados Formación Sopas por ANTON (1975) y consiste de limo pardo claro, enriquecido con elementos groseros, con arcillas y arenas locales pasando de textura limo-arcillosa a franco-limosa. Incluye niveles con $CaCO_3$ como concreciones y muñecos de dureza variable. Esta unidad litológica no ha sido reconocida explicitamente por trabajos posteriores (PRECIOZZI *et al.*, 1985), pero tampoco identificada o correlacionada con formaciones cuaternarias definidas para el sur del Uruguay (Formación Libertad y Formación Dolores).

Desde el punto de vista regional, BOMBIN (1975, 1976) e PROST (1982) la correlacionan con depósitos de Rio Grande do Sul (Formación Touro Passo), Brasil.

Mediante la interrelación de estudios paleomastozoológicos y paleomalacológicos se ha buscado un mayor grado de formalización en la caracterización paleontológica de estos sedimentos. Esto permite lograr una mayor precisión geocronológica y establecer hipótesis paleoambientales. En esta primera etapa se ha realizado un relevamiento primario de un número limitado de localidades geográficas (Fig. 1) y de material fósil, depositado en el Museo Histórico Departamental de Artigas, lo que ha posibilitado la realización de este artículo.

Fig. 1 - Procedencia geográfica del material fósil estudiado.

PALEOFAUNA REGISTRADA

La continuación se presenta la lista de taxones determinados hasta el momento pertenecientes a la Formación Sopas.

La descripción del tipo de material, procedencia estratigráfica y geográfica, medidas y comentarios sistemáticos en relación con los taxa mencionados se encuentran en OLAZARRI (1981), UBILLA (1986) y MARTÍNEZ (ms).

Clase Bivalvia

Veneroida

Corbiculidae

Neocorbicula limosa

Unionoida

Hyriidae

Diplodon peraeformis

Clase Gastropoda

Mesogastropoda

Hydrobiidae

Potamolithus sp.

Basommatophora

Planorbidae

Biomphalaria tenagophila

Chilinidae

Chilina fluminea fluminea

Clase Mammalia

Tardigrada

Megatheriidae

Megatherium cf. *americanum*

Mylodontidae

Glossotherium robustum

Lestodon cf. *armatus*

Cingulata

Dasypodidae

Pampatherium humboldti

Glyptodontidae

Panochthus tuberculatus

Glyptodon clavipes

Carnivora

Felidae

Felis concolor

Rodentia

Cricetidae

Holochilus sp.

Caviidae

Cavia sp.

Hydrochoeridae

Hydrochoerus sp.

Myocastoridae

Myocastor coypus

Notoungulata

Toxodontidae

Toxodon sp.

Proboscidea

Gomphotheriinae

Gomphotheriinae indet.

Perissodactyla

Equidae

?Hippidion- Onohippidion

Tapiridae

Tapirus sp.

Artiodactyla

Tayassuidae

Catagonus sp.

Camelidae

Palaeolama paradoxa

Cervidae

Ozotocerus bezoarticus

Antifer cf. ultra

Morenelaphus brachyceros

Morenelaphus cf. lujanensis

GEOCRONOLOGIA

Los sedimentos estudiados corresponden al Pleistoceno tardío, de acuerdo con la información que brinda el análisis del conjunto de taxa de mamíferos registrados (UBILLA, op.cit.). Esta asociación de géneros y especies sugiere la existencia de la Edad-mamífero Lujanense (Pleistoceno superior) a juzgar por la presencia de formas extinguidas y formas con representantes en la actualidad. El registro de G. clavipes, característica del Lujanense (PASCUAL et al., 1966), G. robustum, frecuente en sedimentos cuaternarios terminales (FIDALGO y TONNI, 1983), Panochthus tuberculatus, L. armatus entre otros, asociados a M. coypus, Cavia sp., Holochilus sp. y F. concolor sustentan esta hipótesis. Esta proposición es congruente con la correlación propuesta por BOMBIN (1976) entre la Formación Touro Passo (Rio Grande do Sul, Pleistoceno superior: C^{14}: 11.010 ± 190 años A.P.) y la Formación Sopas del Uruguay.

Por otra parte, los taxa identificados para esta formación están compartidos con la Formación Touro Passo, aunque existen algunas diferencias atribuíbles a deficiencias del registro fósil y no a mutaciones distribucionales.

La fauna malacológica no permite inferir edad alguna con precisión, hallándo-se ésta acotada entre el Pleistoceno s.l. y el Reciente (MARTÍNEZ, m.s.)

PALEOAMBIENTES

Las inferencias de paleoambientes locales realizadas se apoyan fundamentalmente en una metodologia empírica taxonómica, asumiendo una correlación entre la función ecológica y el paleoambiente (VALENTINE, 1973). Tales proposiciones tienen mayor rango de certidumbre cuando se trata de taxa con representación en la actualidad. Por otra parte, las adaptaciones morfofuncionales que puedan ser discriminadas en restos de mamíferos constituyen una fuente de inferencia paleoambiental (SHOTWELL, 1955). Sin embargo, existe un conjunto de restricciones metodológicas que condiciona la generalización de las propuestas: características ecológicas del taxón considerado, nivel taxonómico discriminado, información relativa proporcionada por las formas extinguidas, etc. (TONNI y FIDALGO, 1979).

Respecto a los mamíferos, la información más relevante la brindan los siguintes taxa: M. coypus - requiere cuerpos de agua lénticos y lóticos (WALKER, 1975; MARES y OJEDA, 1982); Holochilus - semiacuático, requiere cuerpos de agua o áreas húmedas (WALKER, op. cit.); Hydrochoerus - las especies actuales son semiacuáticas (WALKER, op. cit); Ozotocerus bezoarticus - planicies abiertas y secas (WALKER, op. cit.). Una información de caráter más relativa la brindan las formas extinguidas consistente en la existencia de ámbitos secos,abiertos y de pastizal: M. americanum; G. clavipes, G. robustum, L. armatus, P. humboldti, Toxodon sp., P. paradoxa (PAULA COUTO, 1979; FIDALGO y TONNI, 1983; HOFFSTETTER, 1952).

Las características de la fauna mamiferológica estudiada sugierem indirectamente la existencia de condiciones de benignidad climática, posibilitando el desarrollo de distintos tipos de hábitats. Tal hipótesis es congruente con las propuestas de ANTÓN (1975) y BOMBIN (1976), así como con la tendencia a acentuarse las condiciones climáticas benignas en el Pleistoceno superior de Sudamérica a medida que se avanza hacia el E y NE (TONNI, 1984).

En cuanto a los moluscos, indican en su totalidad un ambiente dulceacuícola, viviendo sus representantes recientes en las cuencas de los ríos Uruguay y Paraná. Dentro de este ambiente se evidencian una pluralidad de hábitats, tal como sucede actualmente en la zona mencionada. Así, B. tenagophila vive en remansos poco profundos y charcos, pudiendo suportar períodos de desecación (OLAZARRI, 1981); N. limosa, Ch. fluminea y D. peraeformis prefieren ríos y arroyos de mediano caudal y también mediana velocidad de corriente (OLAZARRI, 1980; PARODIZ, 1970) en tanto que Potamolithus se encuentra en corrientes de agua grandes y rápidas (PARODIZ, (1965).

Problemas metodológicos ya mencionados han impedido por el momento la profundización en estudios tafonómicos, siendo de especial interés la futura estimación de la representatividad de la fauna hallada (cf. CUMMINGS et al., 1986).

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