FOSSIL PLANTS FROM THE ITAQUAQUECETUBA FORMATION (CENOZOIC OF THE SÃO PAULO BASIN) AND THEIR POSSIBLE PALEOCLIMATIC SIGNIFICANCE[1]

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ABSTRACT

The fossil leaves of the Itaquaquecetuba Formation (Cenozoic, São Paulo Basin), although very abundant and reasonably well preserved, have not been the subject of study until now. The main purpose of this paper is to establish the possible paleoclimatic significance of these leaves on the basis of their description and taxonomic determination and the ecological relationships of similar living forms.

The plant association studied here indicates a tropical evergreen forest inasmuch as all the identified genera have similar forms that live at present within such a habitat. The following hypotheses are raised based on the analysis of this material: 1) The climate at the time of deposition of the sediments of the Itaquaquecetuba Formation was tropical and humid and not semiarid as suggested in previous papers; the braided type of sedimentation present in the formation, although characteristic of semiarid environments, is not exclusive to such environments. 2) The association of these plants with braided sediments could possibly be explained by tectonic reworking of previously lithified, fossiliferous sediments, in which large blocks (olistoliths) containing plant fossils were transported into the sedimentary basin.

RESUMO

As folhas fósseis da Formação Itaquaquecetuba (Cenozóico da Bacia de São Paulo), apesar de muito abundantes e razoavelmente bem conservadas, não foram, até o momento, objeto de qualquer estudo. O principal objetivo do presente trabalho é estabelecer o possível significado paleoclimático das folhas fósseis daquela unidade estratigráfica, através da determinação e descrição dos *taxa* ali presentes, e do estabelecimento de suas relações ecológicas com formas viventes.

A associação vegetal estudada é indicativa de uma mata tropical perenifólia, já que todos os gêneros identificados têm formas semelhantes que vivem atualmente neste tipo de vegetação. As seguintes hipóteses foram levantadas a partir da análise deste material: 1) o clima vigente à época de deposição dos sedimentos da Formação Itaquaquecetuba era tropical úmido e não semi-árido, como sugerido em trabalhos anteriores, considerando que a sedimentação do tipo "braided", observada naquela formação, apesar de típica de ambientes semi-áridos, não é exclusiva destes; 2) embora faltem provas conclusivas, a presença destes vegetais neste tipo de ambiente poderia ser explicada por retrabalhamento, de origem tectônica, através do qual

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grandes blocos de sedimentos já litificados ("olistolitos"), contendo estes fósseis, foram transportados para o interior da bacia de sedimentação.

INTRODUCTION

The deposits of the Itaquaquecetuba Formation - the formal title proposed by COIMBRA et al. (1983) - were initially studied by JUNQUEIRA (1969) and subsequently designated "ancient alluvia of the Tietê and Pinheiros Rivers" (SUGUIO & TAKAHASHI 1970; SUGUIO, 1971; SUGUIO et al., 1971) and "cross-bedded strata of the Butantã phase" (AB´SABER, 1978, 1980). These sediments occur beneath the present-day plains of the Tietê and Pinheiros Rivers and are best exhibited in the sand-pits of the Itaquaquecetuba and Carapicuíba region.

The paleontological evidence consists principally of plant remains. Amongst these can be distinguished variously fossilized trunks and carbonified leaves which are prolific in sandy and clayey strata respectively.

Using data based principally on the radiocarbon dating method, the sediments of the Itaquaquecetuba Formation were attributed to the Upper Pleistocene (BIGARELLA, 1971; SUGUIO, 1971). Results from paleomagnetic and palynological studies, however, have suggested a much greater age, probably Upper Eocene (MELO et al., 1985).

The paleoclimate in which the Itaquaquecetuba Formation sediments were deposited has been the subject of much controversy. BIGARELLA (1971), for example, suggests that the trunks were deposited during mass movement caused by change from a humid to a dry climate. SUGUIO (1971) and SUGUIO & MUSSA (1978), using paleoecological data from fossil wood studies, suggest a tropical humid type of climate. AB´SABER (1978, 1980) and SUGUIO (1980), on the other hand, acknowledge the possibility that the sediments might have been deposited in a semi-arid climate in which the fossil trunks could have derived from gallery forests. COIMBRA et al. (1983) similarly consider that the deposits might have been layed down under semi-arid conditions in which the vegetation responsible for the presence of the trunks shared little of the local climatic character. ARAI (1987) suggests, in turn, a temperate to tropical humid climate. COIMBRA et al. (op. cit.) emphasize accordingly that the increase in studies of a paleontological nature will eventually resolve the discussion.

GEOLOGY

In recent years, the geological aspects of the Itaquaquecetuba Formation have been studied principally by COIMBRA et al. (1983), ALMEIDA et al. (1984) and ATENCIO (1986). Its deposits are thought to be distributed beneath the present-day plains of the Tietê and Pinheiros Rivers in the São Paulo Basin region.

The Itaquaquecetuba Formation extends normally over the Precambrian basement, attaining a length of around 40 km, a breadth of 2 km and a maximum thickness of the order of 50 m in the Itaquaquecetuba - Carapicuíba area. It is composed mainly of coarse, poorly sorted sands with little clayey-silty matrix. Tabular and tangential cross-bedding of medium size are common in the sandy deposits. Statistical analysis of paleocurrents, based on cross-stratification and orientation of pebbles, shows the existence of paleocurrents coming from the east (COIMBRA et al., 1983).

Thin, lenticular conglomerate beds with clay pebbles characterise the base of the paleochannels. In the clayey fragments, plant remains are found, including entire leaves. A second type of conglomerate stratum is composed of clast-supported conglomerates which form detrital paleopavements from 10 cm to a little over 1 m in thickness consisting of pebbles of

up to 10-20 cm, locally imbricated and graded. Sand bars with cross-stratification develop upon these paleopavements. Such strata are thicker and more frequent and have larger pebbles, at the base of the sequence. On top, in turn, clayey layers and the cut-and-fill structures are frequently found which characterise the infill-facies of paleochannels (COIMBRA et al., 1983).

Normal faults with oblique displacement can be observed in the sediments of the Itaquaquecetuba Formation. Such faults are clearly evidenced by the disruption of sedimentary bads as well as by the abrupt contact between sediments and rocks of the Precambrian basement and by extensive fault surfaces (ALMEIDA et al., 1984).

ATENCIO (1986) points out that the Itaquaquecetuba Formation sediments show various similarities to the "roll" type of deposits, one of which being the presence of one portion sulphurised and the other oxidised. COIMBRA et al. (1983) emphasize that the type of deposit, the lithological types and the structures present are all key features for characterising a fluvial sedimentation of the braided type.

FOSSIL CONTENT

Amongst the various studies of the Cenozoic flora in Neotropical America, the ones that stand out are those analysing material from Bahia (HOLLICK & BERRY, 1924), from Trinidad (BERRY, 1937a, b), from Acre (BERRY, 1937c), from Bolívia (BERRY, 1939a), from Cuba (BERRY, 1939b) and from Venezuela (BERRY, 1939c). More recently, DUARTE and co-workers studied Cenozoic floras of various regions of Brazil, including the states of Pará (DUARTE, 1972, 1987), Ceará (DUARTE & NOGUEIRA, 1980), Paraíba (DUARTE & VASCONCELOS, 1980), Minas Gerais (DUARTE & MELLO FILHA, 1980) and São Paulo (DUARTE & REZENDE-MARTINS, 1983; DUARTE & MANDARIM LACERDA, 1987). For all these areas, the fossil forms were generally cited as extant genera with wide geographical distribution in the tropical region.

With regard to the Itaquaquecetuba Formation, few studies of paleobotanical significance have been undertaken. The paleontological evidence consists mainly of plant-remains which include trunks, leaves, fruits, seeds, pollen, spores and diatoms. Apart from these, ichnofossils are also relatively common.

The trunks constitute the most easily observed elements amongst the fossils of the Itaquaquecetuba Formation, reaching dimensions of the order of 4 m in length and 50 cm in diameter. Their predominant form of fossilisation is carbonification, but limonitisation and partial substitution by iron sulphide (marcasite) or silica can also occur. The presence of these fossil wood was first indicated by TOLENTINO (1965), who classified then on the basis of chemical analysis as xyloid lignite. However, the first study of a systematic and paleoecological nature was by SUGUIO (1971), who identified the presence of at least 5 genera: *Myrocarpus* sp., *Piptadenia* sp., *Centrolobium* sp., *Miconia* sp., *Sloanea* sp. - all still extant today in the tropical rain-forests. SUGUIO & MUSSA (1978), in a study of the anatomical and paleoecological aspects of those fossil wood, recognised 5 new genera and species: *Astronioxylon mainieri*, *Piptadenioxylon chimeloi*, *Myrocarpoxylon sanpaulense*, *Matayboxylon tietense* and *Qualeoxylon itaquaquecetubense*. The authors (SUGUIO & MUSSA, op. cit.) confirmed the presence of transitional stages between silicified and marcasitised, and marcasitised and carbonified fossilisation, suggesting that the three forms of fossilisation could occur simultaneously. The most recent study regarding these trunks was done by ARAI (1987) who, on the basis of studies of conventional organic petrography, found that the organic matter in the material was still at an early stage and thus should be classified as peat and not as lignite as had been proposed previously (TOLENTINO, op. cit.).

The palinological content of the Itaquaquecetuba Formation was only recently subjected to

study. MELO et al. (1985) examined a sample from the area of the type section of the formation and found a relatively rich assemblage in which the following pollen and spores could be identified: *Margocolporites vanwijhei*, *Podocarpidites* ? sp. 2 and *Polypodiaceoisporites potoniei*.

References to at least three types of seeds were made by ALMEIDA et al. (1984) although they were not figured or studied.

JACINTO & CAMPANHA (1986) noted the first occurrence of diatoms in the Itaquaquecetuba Formation, althought without paying regard to age and depositional environment. According to these authors, 3 genera were identified: *Pinnularia* cf. *P. brevicostata*, *Pinnularia* sp. and *Melosira* sp.

The presence of ichnofossils associated with the plant remains was confirmed by us in field studies in the area of the type section of the formation. According to the paleontologist, V.A. CAMPANHA (verbal communication), these represent worm perforations.

The fossil leaves, although very abundant and reasonably well preserved, have hitherto merited few references as they have not been the subject of any study.

PALEOCLIMATE

On the basis of sedimentological, paleontological, geomorphological and petrographical evidences, numerous authors have drawn the most diverse conclusions as to the paleoclimate prevailing at the time of deposition of the sediments of the Itaquaquecetuba Formation.

JUNQUEIRA (1969), on studying the "cross-bedded sands" in an outcrop on the São Paulo University campus, concluded that the differences between the sedimentary material found in these outcrops and the material deposited today in the Pinheiros River Valley indicate morphogenetic processes different from those today and associated with a drier climate, the result of a brief climatic fluctuation. This fluctuation, according to JUNQUEIRA (op. cit.), would have been the last dry period before the current very recently begun, wet period.

According to BIGARELLA (1971), the sedimentation of the sands on the São Paulo University campus occurred in a semi-arid type of climate characterised by the concentration of rain into a short period of the year.

Studying the fossil trunks in alluvial deposits of the Pinheiros River, SUGUIO (1971) identified the presence of an association suggestive of a wet tropical climate prevailing around 40,000 years ago, corresponding to the last glacial period of the northern hemisphere. SUGUIO's conclusions (1971) were confirmed by a further paleobotanical and paleoecological study of the fossil trunks (SUGUIO & MUSSA, 1978).

AB'SABER (1978, 1980) and SUGUIO (1980) accepted that these trunks were linked to gallery forests, with the possibility that the regional climate was semi-arid.

COIMBRA et al. (1983) suggested that vegetation developed in a semi-arid climate on sand bars stabilized by the deposition of finer sediments; in subsequent periods of flooding the trunks would have been uprooted, transported and buried.

On the basis of a petrographical study of the trunks of the Itaquaquecetuba Formation, ARAI (1987) suggests a temperate or humid tropical climate for the time of deposition. According to the author, the material studied was classified as peat which would have been formed in environments characterised by a temperate or humid tropical climate, and mild tectonics.

In view of the fact that, up to the present, few works touch on the paleoenvironmental aspects of the Itaquaquecetuba Formation, the object of the present study is to recognise the possible paleoclimatic significance of the fossil leaves by determining and describing the taxa present in this stratigraphic unit there and by establishing their ecological

relationships with living forms.

LOCATION OF THE STUDY AREA

The fossil material studied here originates from a sand pit on the right bank of the Tietê River (Fig. 1) in Itaquaquecetuba district, S.P. Access to the site is obtained by the "Via Dutra" or the "Rodovia dos Trabalhadores" approximately 35 km to the NE of the city of São Paulo.

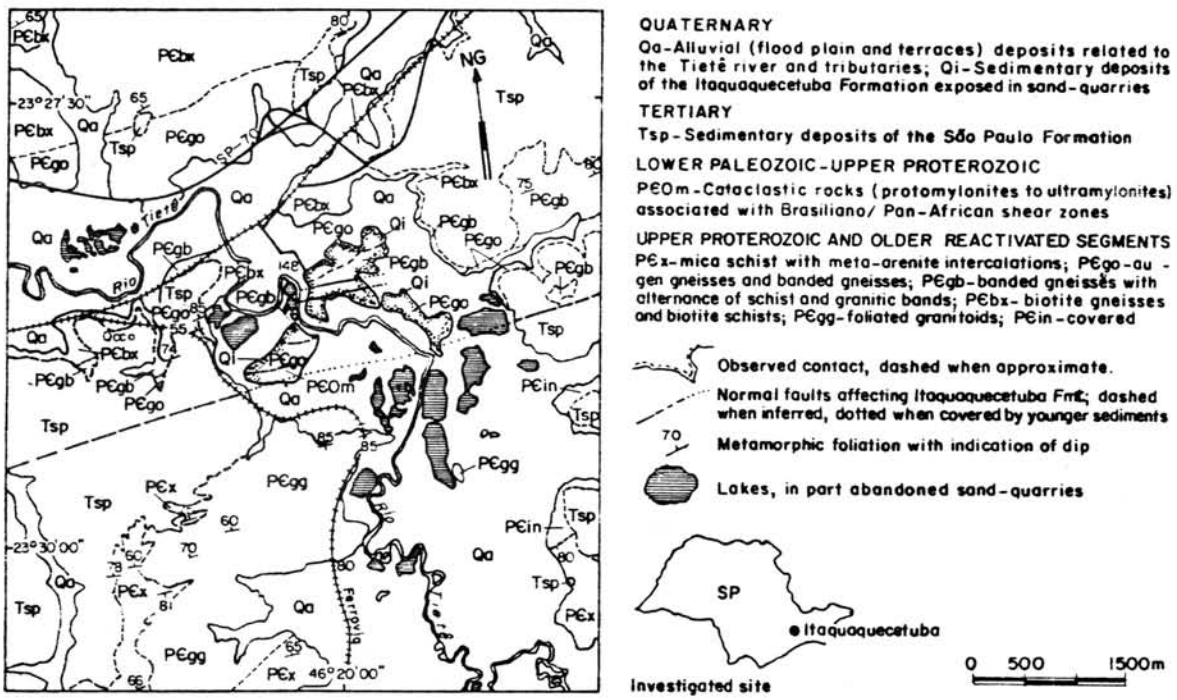

Fig. 1 - Geologic map of the type-area of the Itaquaquecetuba Formation (after ALMEIDA et al.1984).

MATERIAL AND METHODS

The material studied occurs in lenses of grey siltstone, very rich in organic material and with little lateral expression. The fossils are scattered randomly throughout the matrix and show no apparent orientation. The leaves are commonly fragmented although in some cases complete specimens can be observed. All the leaves are carbonified and the epidermic cuticle is only rarely preserved.

Reasonably well-preserved seeds and/or fruits occur in association with the leaves.

Approximately 100 specimens were collected at a single point in the sand-pit which probably corresponds to the upper portion of the Itaquaquecetuba Formation.

For identification, drawings of the fossils obtained with the use of a camera lucida coupled to a stereomicroscope were compared with material in the herbarium of the Botany Department at the Institute of Biological Sciences, University of São Paulo (SPF) and with specimens described and illustrated in the specialised literature.

The same methodology as described by BURNHAM (1986) for the Ulmaceae of the Tertiary Period was adopted when deciding whether to accept present-day genera or not.

The fossils are deposited in the Paleontology Collection of the Institute of Geological Sciences at São Paulo University.

SYSTEMATICS

I - LEAVES

Division ANGIOSPERMAE
Class MONOCOTYLEDONEAE
Family ARACEAE
Genus *Monstera* Adans

Monstera marginata sp. nov.
Figures 2, 19.

Holotype - GP/3T-1809; type locality: sand-pit in Itaquaquecetuba, SP (Itaquareia).
Specific epithet - *marginata* alludes to the characteristic marginal vein which runs along the entire limb.

Diagnosis - fragment of the lateral half of an apparently cordate leaf with entire margin, attenuate at the apex; venation probably camptodromous, formed by many arcuate-ascendent nerves without obvious anastomoses; an evident marginal nerve runs the length of the limb.

Discussion - The parallel-curved nerves point to the Monocotyledoneae; the shape together with the marginal nerve indicate that it is Araceae - *Monstera*.

Class DICOTYLEDONEAE
Family AQUIFOLIACEAE
Genus *Aquifoliphyllum* gen. nov.

Diagnosis - Leaf simple, margin dentate, venation probably semicraspedodromous with arcuate lateral nerves.

Derivatio nominis - refers to the similarity between the fossil and the leaves of present-day representatives of the family Arquifoliaceae.

Aquifoliphyllum ilicioides sp. nov.
Figure 3.

Holotype - GP/3T-1810; type locality: sand-pit in Itaquaquecetuba, SP (Itaquareia).
Specific epithet - *ilicioides* refers to the similarity with species of the present-day genus *Ilex*.

Diagnosis - This very incomplete fossil represents the lateral portion of a leaf with an oblong or lanceolate shape and dentate margin; venation probably semicraspedodromous with central nerve evident and secondary arcuate nerves leading from it (at an angle of approximately 50°), intersecondary venation inconspicuous.

Discussion - Although very incomplete, this fossil shows a very characteristic margin with obvious teeth reminiscent in many ways of the leaf-margins of both present-day Aquifoliaceae and some Moraceae (*Sorocea* St. Hil.); however the venation pattern on the margin is compatible with Aquifoliaceae, especially the genus *Ilex* L.

Family FLACOURTIACEAE
Genus *Casearia* Jacq.

Casearia serrata sp. nov.
Figure 4.

Holotype - GP/3T-1811; type-locality: sand-pit in Itaquaquecetuba, SP (Itaquareia).
Specific epithet - *serrata* alludes to the characteristic serrate margin of the leaf.

Diagnosis - Fragment of a median portion of a leaf, probably oblong or elliptic in shape with an irregularly serrate margin; venation apparently eucamptodromous; median nerve proeminent, rectilinear with secondary arcuate-ascendent nerves leading from it at an acute angle (approximately 70°), insconpicuous, disappearing before reaching the margin; intersecondary venation inconspicuous.

Discussion - The leaf-shape associated with this type of margin approximates to *Casearia commersoniana* Camb., a commmon species in the forests of São Paulo State.

Family LEGUMINOSAE
Subfamily CAESALPINIOIDEAE
Genus *Schizolobium* Vogel

Schizolobium inaequilaterum sp. nov.
Figures 5, 20.

Holotype - GP/3T-1812; type locality: sand-pit in Itaquaquecetuba, SP (Itaquareia).
Specific epithet - *inaequilaterum* refers to the asymmetric form of the leaflet.

Diagnosis - leaflet of oblong shape, c. 1.7cm long x 0.6 cm broad, apex obtuse, base subcordate; asymmetric, margin entire; venation brochidodromous with very prominent rectilinear median nerve diminishing in thickness towards the apex and straight to slightly arcuate, secondary nerves leading from it (at an acute angle of about 80°) which join in arcs submarginally, inconspicuous; intersecondary venation inconspicuous.

Discussion - This is certainly a leaflet from the Leguminosae. On comparing details of venation and shape in various genera, the conclusion was that it was most similar to *Schizolobium*, a very common genus in the rain-forests of São Paulo State.

Family MALPIGHIACEAE
Genus *Byrsonima* Rich. ex Juss.

Byrsonima bullata sp. nov.
Figures 6, 21.

Holotype - GP/3T-1813; type locality: sand-pit in Itaquaquecetuba, SP (Itaquareia).

Paratypes - GP/3T-1824, -1828.
Specific epithet - *bullata* refers to the raised aspect of the limb in the areas between the veins.

Diagnosis - Leaves elliptic in shape, 2.6 cm long x 1.6 cm broad, apex rounded, base obtuse, margin entire; venation brochidodromous with very proeminent rectilinear median nerve diminishing in thickness towards the apex and arcuate secondary nerves leading from it (at angles greather than 45° between the middle and the base and at angles of about 45° above the middle), which unite submarginally; intersecondary venation evident, impressed, giving the leaf a bullate appearance.

Discussion - This dicotyledon does not show many distinguishing features, but its leaf-shape, venation and especially texture are very reminiscent of some present day species of *Byrsonima*.

Family MYRTACEAE
Genus *Myrcia* DC. ex Guill.

Myrcia cf. *rostrataformis* Hollick & Berry, 1924
Figures 7a, b, 22 and 23.

Material - GP/3T-1814, -1815, -1816, -1829.

Description - Leaves narrowly oblong-lanceolate and slightly falcate, approximately 5-6 cm long x 0.9-1.2 cm broad, apex acute, attenuate, base acute, attenuate, margin entire; venation brochidodromous, central nerve prominent, rectilinear to slightly curved in the distal part with various inconspicuous pairs of secondary nerves leading from it (at an acute angle) and uniting close to the margin into an obvious "collecting nerve"; numerous minute glands are scattered uniformly over the limb; intersecondary nerves inconspicuous.

Discussion - Numerous fossils of this species can be identified, indicating that it was a common species. The type of venation together with the glands on the limb place this species in the family Myrtaceae. The species from amongst the representatives of this family which is very commonly found in the present-day flora of São Paulo city is *Myrcia rostrata* DC., a small, much-branched tree with lanceolate, long-acuminate leaves (ROSSI, 1987), which are very similar to the fossil under discussion.

HOLLICK & BERRY (1924) described *M. rostrataformis* from the Terciary of Bahia, mentioning its great similarity to the extant *M. rostrata*. Our material is quite similar to their drawings and photographs of *M. rostrataformis* but analysis of the type specimen is necessary in order to confirm this identification. G.M. BARROSO (personal comunication) considers this fossil to be also similar to *Gomidesia cambessedeana* Berg which is only known from material collected in the middle of the last century in Santa Anna, Rio de Janeiro province (BERG, 1857).

Genus *Psidium* L.
Psidium paulense sp. nov.
Figure 8.

Holotype - GP/3T-1817; type locality: sand-pit in Itaquaquecetuba, SP (Itaquareia).
Specific epithet - *paulense* refers to the São Paulo Basin, the place of origin of the fossil.

Diagnosis - Fragment of the basal half of an apparently obovate leaf with cuneate base and entire margin; venation brochidodromous, median nerve rectilinear, very prominent with various very evident secondary nerves leading from it at an acute angle and uniting submarginally into a distinct "collecting nerve"; numerous minute, circular glands are scattered over the limb.

Discussion - This species is typically Myrtaceous in having brochidodromous venation and a very evident "collecting nerve" together with glands on the limb. Amongst the genera in the family, it is similar to *Psidium*.

Family RHAMNACEAE?
Genus *Rhamniphyllum* gen. nov.

Diagnosis - Leaf simple, margin entire, venation brochidodromous with arcuate secondary nerves united just below the margin.
Derivatio nominis - relates to the similarity of the fossil leaf to the present-day representatives of the family Rhamnaceae.

Rhamniphyllum casearifórmis sp. nov.
Figures 9a, b, 24.

Holotype - GP/3T 1818; type locality: sand-pit in Itaquaquecetuba, SP (Itaquareia).
Specific epithet - *casearifórmis* suggests the appearance of the leaves of present-day species of *Casearia* in the family Flacourtiaceae.

Diagnosis - Fragment of the basal part of a leaf of oblong or lanceolate shape, base acute, margin entire, venation brochidodromous, median nerve rectilinear, very prominent, diminishing in diameter towards the apex; secondary nerves very arcuate (at an angle of approximately 50°), united submarginally; intersecondary venation evident and reticulate.

Discussion - This material was difficult to relate to present-day groups but the general pattern of secondary venation is reminiscent of existing species of the genus *Rhamnidium* Reisseck (Rhamnaceae), although the intersecondary nerves of this genus are more parallel to each other. This pattern of venation also occurs in species of the genus *Casearia* Jacq. (Flacourtiaceae), but the closest species consistently have serrate leaves. Specimen GP/3T 1825, which represents a median-terminal portion of a leaf, is probably of the same species as it shows the same arcuate pattern of secondary venation although its intersecondary nerves are more parallel to each other.

Family SAPINDACEAE
Genus *Serjania* Mill.

Serjania lancifolia sp. nov.
Figures 10, 25.

Holotype - GP/3T-1819; type locality: sand-pit in Itaquaquecetuba, SP (Itaquareia).
Specific epithet - *lancifolia* alludes to the lanceolate form of the leaflet.

Diagnosis - Probably a leaflet, lanceolate apex acute, base acute, margin irregularly serrate and lobes more or less rounded; venation craspedodromous, main nerve rectilinear, very

prominent with various pairs of ascendent lateral nerves, straight or slightly arcuate, very evident, the most distal being dichotomously branched close to the margin; intersecondary venation densely reticulate and evident.

Discussion - This material is morphologically compatible with the leaflets of present-day species of *Serjania*.

Serjania itaquaquecetubensis sp. nov.
Figures 11, 26.

Holotype - GP/3T-1820; type locality: sand-pit in Itaquaquecetuba, SP (Itaquareia).
Specific epithet - *itaquaquecetubensis* refers to the place of origin of the fossil.

Diagnosis - Fragment (central portion), probably of an oblong or lanceolate leaflet with irregularly serrate margin; venation craspedodromous with median nerve slightly curved, very prominent with various pairs of subrectilinear, ascendent, secondary nerves evident, some of them branched half-way to the margin; intersecondary venation inconspicuous.

Discussion - This material is more incomplete than that of *S. lancifolia*, but in this case also there is sufficient similarity to leaflets of present-day species of the genus *Serjania*.

Family RUTACEAE
Genus *Zanthoxylum* L.

Zanthoxylum glanduliferum sp. nov.
Figures 12, 27.

Holotype - GP/3T-1821; type locality: sand-pit in Itaquaquecetuba, SP (Itaquareia).
Specific epithet - *glanduliferum* alludes to the numerous oil glands on the limb.

Diagnosis - Fragment of the terminal half of an oblong leaflet approximately 1-2 cm broad, apex obtuse, margin entire; venation eucamptodromous, median nerve rectilinear, prominent with various pairs of ascendent secondary nerves leading from it (at an acute angle), curved near the margin of the limb, very evident; numerous circular glands are scattered uniformly over the limb; intersecondary nerves inconspicuous, reticulate.

Discussion - The venation pattern on the fossil together with the type of glands place it clearly in the family Rutaceae, within which the genus with the closest affinity is *Zanthoxylum*.

Family TILIACEAE
Genus *Luehea* Willd

Luehea divaricatiformis sp. nov.
Figures 13, 28.

Holotype - GP/3T-1823; type locality: sand-pit in Itaquaquecetuba, SP (Itaquareia).
Paratypes- GP/3T-1822, -1824.
Specific epithet - *divaricatiformis* alludes to the present-day species *Luehea divaricata* Mart., the leaves of which are very similar to those of the fossils.

Diagnosis - Fragment of the basal half of an apparently oval or elliptic leaf; base very asymmetric with the base of the limb acute on one side of the central nerve and rounded on the other; margin distinctly serrate from close to the base; venation basal actinodromous with 3 prominent primary nerves diverging at an acute angle from the base of the limb; secondary nerves numerous, more or less parallel across the limb uniting the primary nerves.

Discussion - The actinodromous venation with parallel secondary veins together with the asymmetric base and serrate margin place this specimen immediately in the Tiliaceae and in the genus *Luehea*. The present-day species with the greatest affinity is *L. divaricata* Mart., the "açoita-cavalo" ("horse-whip"), which is very common in the forests of São Paulo State.

DUARTE & VASCONCELOS (1980) mention in the "Flórula de Umbuzeiro", PB, that *Clusia paranemorosa* Duarte & Nogueira shows signs of possible galls resulting from insect or fungal attack. A similar occurrence was also observed in *Luehea divaricatiformis*.

II - SEEDS (?)
Figures 14 and 15.

Material: GP/3T-1826.
Description - Elliptic structure approximately 2 mm long, dark coloured and testa (?) smooth; in longitudinal section, the testa (?) and tegmen (?) can be seen, the latter well developed, and a loculus probably corresponding to the location of the embryo.
Commentary - These fossils appear in great quantity, located in sediments rich in organic material. The structures analysed were considered to be probable seeds, especially with the presence of a thick tegmen (?) with a small opening line in the distal portion, which could correspond to the fusion region of the integuments of the ovule and the micropilar channel.

III - FRUITS (?)
Figures 16-18.

Material - GP/3T-1827.
Description - From the front view these fossils appear to be triangular structures with two "sacs" on each side. In longitudinal section, each "sac" corresponds to at least two internal loculae which are covered by a pelicule of lighter, reticulate tissue.
Commentary - A preliminary analysis of the front view of these structures reminds one immediately of a Gymnosperm megasporophyl with two ovules, but closer examination reveals the presence of two lateral "sacs" and a longitudinal section shows the presence of various loculae. It is probable that this material belongs to the Angiospermae - Dicctyledoneae, but it was not possible to relate it to any present-day family.

DISCUSSION

As was seen in the introduction, various works have been written on the Cenozoic flora of Tropical America, which is generally represented as a flora rich in dicotyledons and predominantly of forest regions.

Analysis of the material from Itaquaquecetuba also showed a predominance of dicotyledons with just one monocotyledon in the family Araceae, this being the first reference to fossils of this family for Brazil. The presence of monocotyledon megafossils from the Cenozoic of Brazil has previously only been recorded by DOLIANITI (1955) in a description of palm fruits from Pernambuco, denominated *Nipa pernambucensis*, and by DUARTE (1972), who described *Rapatea*

from the Pirabas Formation in Pará.

As for the dicotyledons, it can be seen that one family which is present in almost all the Cenozoic formations is the Leguminosae with its three subfamilies. HOLLICK & BERRY (1924), BERRY (1937b), DUARTE & MELLO FILHA (1980) and DUARTE & REZENDE-MARTINS (1983) report a number of genera of this family from various parts of Brazil. In the material studied, only one leaflet from the Leguminosae was found, this being similar to the present-day genus *Schizolobium* and the first reference to this genus for the Cenozoic flora of Brazil, SUGUIO & MUSSA (1978) attributed fossilised trunks from São Paulo to Leguminous genera, calling them *Piptadenioxylon*, related to the present-day genus *Piptadenia*, and *Myrocarpoxylon*, related to *Myrocarpus*. Comparison of the fossil leaflet studied with these two genera of the Leguminosae did not permit its inclusion in either of the genera. As regards the other dicotyledons, the families and genera most commonly found in other deposits and which were identified in Itaquaquecetuba are: a) Rutaceae with the genus *Fagara* (= *Zanthoxylum*) for the Tertiary of Bahia (HOLLICK & BERRY, 1924), of Bolivia (BERRY, 1939a) and of Cuba (BERRY, 1939b); b) Myrtaceae with the genera *Myrcia* and *Psidium* from the Tertiary of Bahia (HOLLICK & BERRY, 1924), *Myrcia* and *Eugenia* from Bolivia (BERRY, 1939a) and *Myrcia* from Pará (DUARTE, 1972); c) Sapindaceae with the genera *Serjania* and *Sapindus* from Pará (DUARTE, 1972) and São Paulo (DUARTE & REZENDE-MARTINS, 1983). *Serjania lancifolia* sp. nov. and *S. itaquaquecetubensis* sp. nov., the two species studied in the present work, are different from the species previously described from this genus, specially from S. *mezzarilai* , a species from Vargem Grande do Sul, SP (DUARTE & REZENDE-MARTINS, 1983). The other fossils found, which could be refered to the present-day genera *Casearia* (Flacourtiaceae), *Byrsonima* (Malpighiaceae) and *Luehea* (Tiliaceae), are reported for the first time in the Cenozoic flora of Brazil.

Some species could not be refered to extant genera as they were incomplete fossils with leaf characteristics which prevented their inclusion in current taxa. Hence, the new genera *Aquifoliphyllum* and *Rhamniphyllum* have been described. Apart from this, it was only possible to assign the fruits and seeds encountered to the class Angiospermae.

Further collections will certainly bring to light other forms to increase the number of taxa listed here.

AGE & CORRELATION

The material under review did not permit any significant conclusions with regard to the age of the Itaquaquecetuba Formation as no forms have been found which are identical to those hitherto described for other Cenozoic deposits, except *Myrcia* cf. *rostrataformis* from the Tertiary of Bahia.

CONCLUSIONS

Following COIMBRA et al. (1983), the textural and mineralogical immaturity of the Itaquaquecetuba Formation deposits demonstrate conditions of rapid sedimentation and considerable transportation of detritus in a braided-type fluvial system. On the basis of such characteristics, COIMBRA et al. (op. cit.) acknowledged the possibility of these deposits having been formed under semi-arid conditions as had already been previously suggested by SUGUIO (1980) and AB'SABER (1978, 1980). None of these authors, however, made it clear what they meant by a semi-arid environment.

The plant association studied here indicates a tropical evergreen forest inasmuch as all the identified genera have similar forms that live at present within such a habitat. This

plant formation is characteristic of the more humid, wetter areas of the tropics, being generally dense and luxuriant, in contrast to the vegetation of semi-arid environments which, according to PENTEADO (1978), are characterised by having very high annual average temperature, scarce and irregular precipitation, impoverished vegetation and a lack of permanent rivers.

Some authors (AB'SABER, 1978, 1980; SUGUIO, 1980) acknowledged that the trunks present in these deposits could be related to the existence of gallery forests, even under arid conditions for the region as a whole. However, on the supposition that the regional climate was semi-arid, it is difficult to imagine the existence of a forest typical of a tropical humid climate, even if it were gallery forest, within the context of a region characterised by semi-aridity, since, as already pointed out, the irregularity and scarcity of rain in these environments does not favour the existence of permanent rivers except in rare circumstances. Moreover, the diversity of species in the plant association studied, allied to the abundance of the remains of certain species such as in the case of *Myrcia* cf. *rostratafomis*, suggest a more extensive forest which, owing to its geographical location, might have formed as an extension of the Atlantic Forest still existing today in the Planalto Atlântico.

On the basis of the above, two hypothesis are suggested to interpret the paleoclimate prevailing at the time of deposition of the sediments of the Itaquaquecetuba Formation.

According to the first hypothesis, the climate was tropical and humid and not semi-arid as previously suggested by COIMBRA et al. (1983); the braided type of sedimentation, although characteristic of semi-arid environments, is not exclusive to such environments.

The anomalous presence of these plants in sediments characteristic of semi-arid environments could possibly be explained by tectonic reworking, in which olistoliths containing these fossils (and representative of a fluvio-lacustrine phase under humid conditions of the São Paulo or Taubaté Basin) were transported into the interior of the sedimentary basin. The principal objections to this hypothesis are the occurrence of fossil trunks referable to tropical forest genera throughout the sedimentary deposit and the difficulty of identifying the structural highs which might have favoured this sort of reworking. It is also possible, however, that the fossil trunks together with the fragments of sediment rich in organic material could have been incorporated into the deposit as already carbonified fossil material reworked from other sediments (RICCOMINI, personal communication).

AKNOWLEDGMENTS

The authors wish to thank the geologists Armando Márcio Coimbra and Claudio Riccomini for their suggestions and collaboration in the field, Graziela Barroso for her aid in identifying assorted material, Genise V. Sommer and Simon Mayo for their help in identifying Sapindaceae and Araceae material respectively and Thomas R. Fairchild for correcting the abstract and reviewing the final English text. We specially thank Brian Stannard for translating the original Portuguese manuscript into English.

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PLATE I

Obs: Scale in the photographs = 1 cm

Fig. 2 - *Monstera marginata* - Showing the marginal vein; specimen GP/3T-1809 (holotype).

Fig. 3 - *Aquifoliphyllum ilicioides* - showing the dentate margins and nerves running into the teeth; specimen GP/3T-1810 (holotype).

Fig. 4 - *Casearia serrata* - showing the serrate margin and the central vein; specimen GP/3T-1811 (holotype).

Fig. 5 - *Schizolobium inaequilaterum* - showing the prominent central vein and assymetrical base; specimen GP/3-1812 (holotype).

Fig. 6 - *Byrsonima bullata* - specimen GP/3T-1813 (holotype).

Fig. 7 - *Myrcia* cf. *rostrataformis*; 7a - proximal portion with attenuate base and numerous minute glands; specimen GP/3T-1815; 7b - distal portion suggesting an attenuate apex; specimen GP/3T-1814.

Fig. 8 - *Psidium paulense* - showing the principal and marginal nerves and numerous glands; specimen GP/3T-1817 (holotype).

Fig. 9 - *Rhamniphyllum caseariformis*; 9a - showing the principal and secondary nerves; 9b - detail of the reticulation; specimen GP/3T-1818 (holotype).

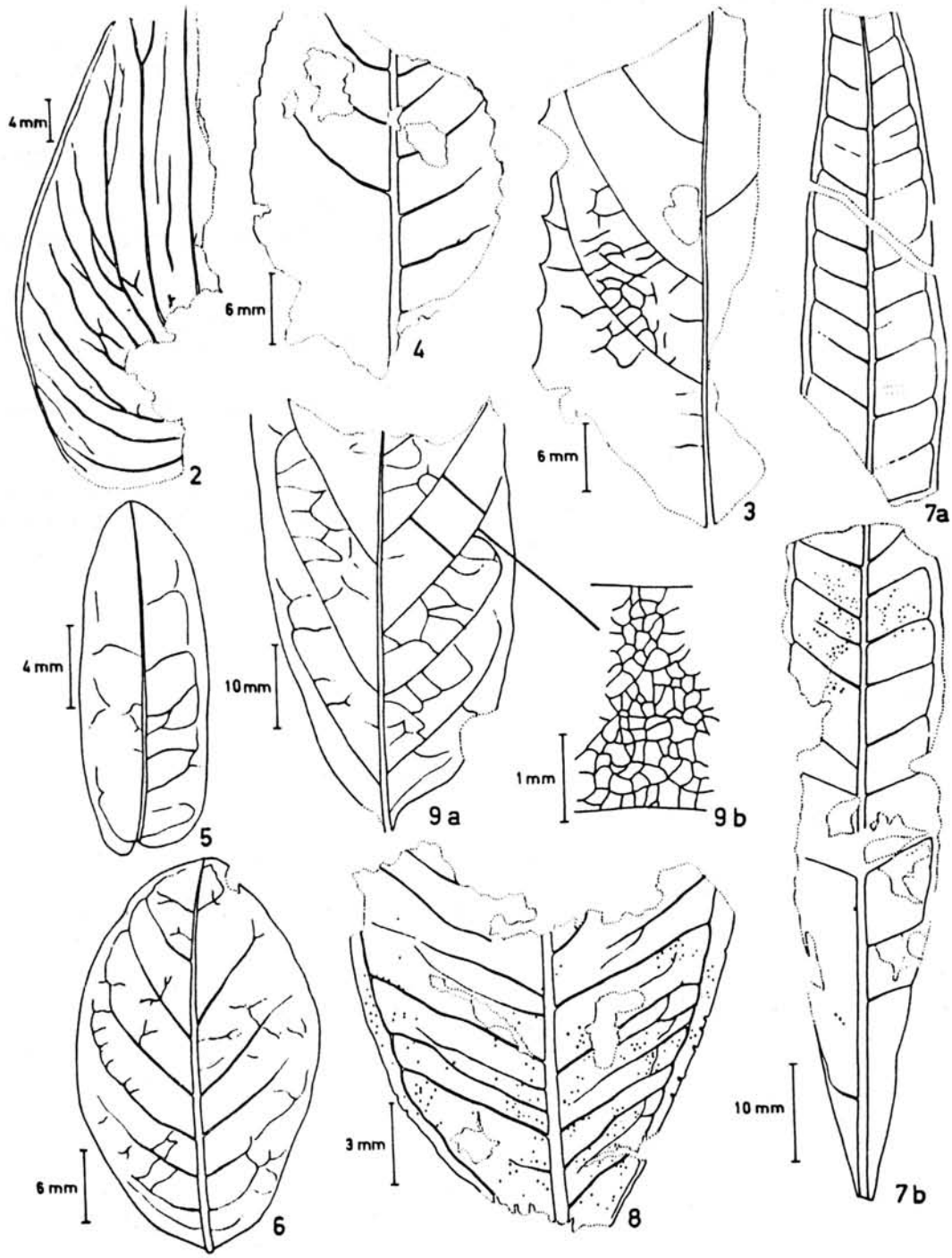
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PLATE II

Obs: Scale in the photographs = 1 cm

Fig. 10 - *Serjania lancifolia* - showing the principal and secondary nerves as well as the attenuate apex and base; specimen GP/3T-1819 (holotype).

Fig. 11 - *Serjania itaquaquecetubensis* - showing the irregularly serrate margin and craspedodromous venation; specimen GP/3T-1820 (holotype).

Fig. 12 - *Zanthoxylum glanduliferum* - showing the camptodromous venation and conspicuous glands; specimen GP/3T-1821 (holotype).

Fig. 13 - *Luehea divaricatiformis* - showing the three basal nerves, the subparallel secondary nerves and the circular marks of possible galls; specimen GP/3T-1823 (holotype).

Figs. 14, 15 - Seed (?); 14 - longitudinal section showing the probable micropilar area; 15 - transverse section; specimen GP/3T-1826.

Figs. 16-18 - Fruits (?); 16 - whole structure in front view showing two "sacs"; 17 - side view showing two "sacs"; 18 - longitudinal section of the "sac" region showing various inner loculi; specimen GP/3T-1827.

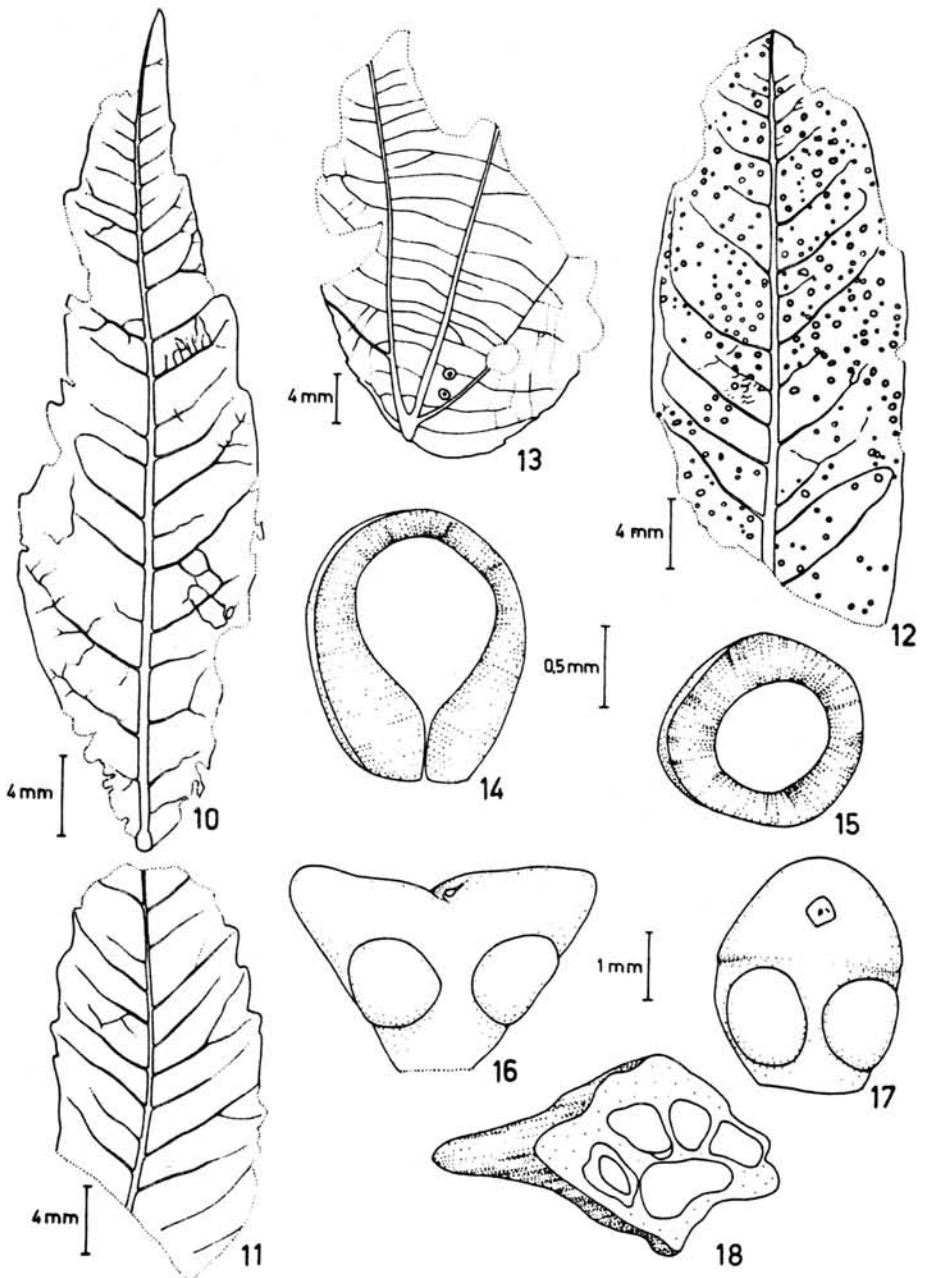
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PLATE III

Obs: Scale in the photographs = 1 cm

Fig. 19 - *Monstera marginata*; specimen GP/3T-1809 (holotype).

Fig. 20 - *Schizolobium inaequilaterum*; specimen GP/3T-1812 (holotype).

Fig. 21 - *Byrsonima bullata*; specimen GP/3T-1828 (paratype).

Fig. 22 - *Myrcia* cf. *rostrataformis*; specimen GP/3T-1816.

Fig. 23 - *Myrcia* cf. *rostrataformis*; specimen GP/3T-1829.

Fig. 24 - *Rhamniphyllum caseariformis*; specimen GP/3T-1818 (holotype).

Fig. 25 - *Serjania lancifolia*; specimen GP/3T-1819 (holotype).

Fig. 26 - *Serjania itaquaquecetubensis*; specimen GP/3T-1820 (holotype).

Fig. 27 - *Zanthoxylum glanduliferum*; specimen GP/3T-1821 (holotype).

Fig. 28 - *Luehea divaricatiformis*; specimen GP/3T-1823 (holotype).


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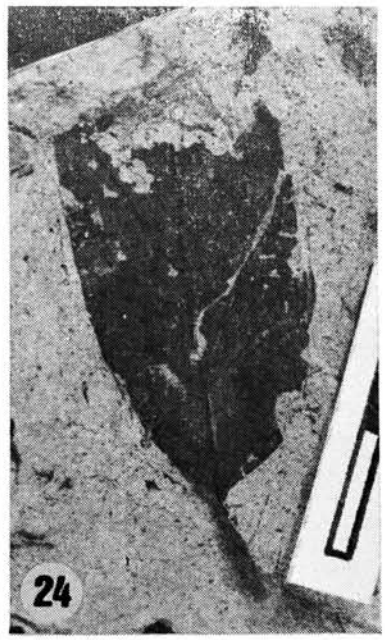
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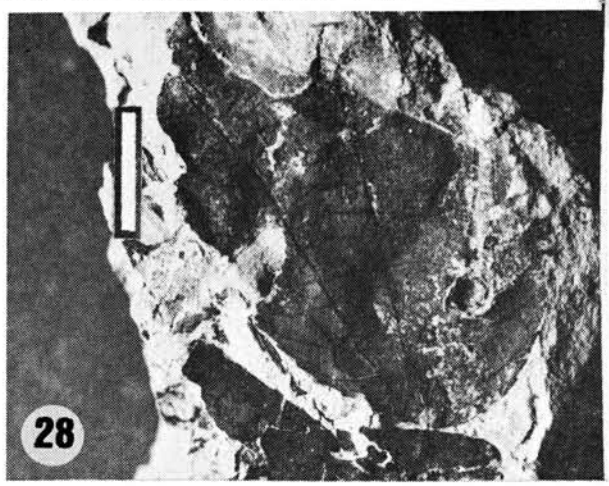
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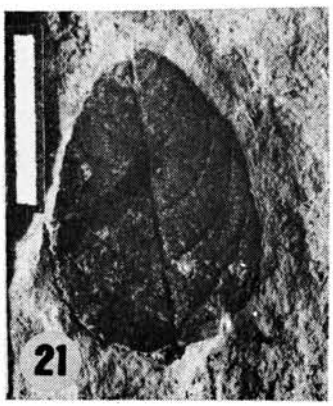
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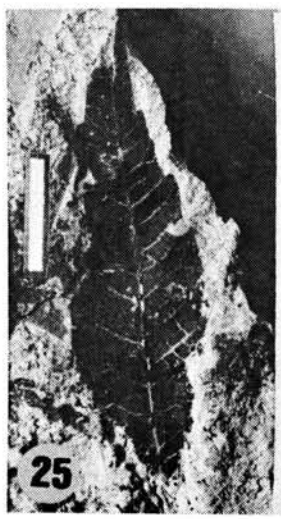
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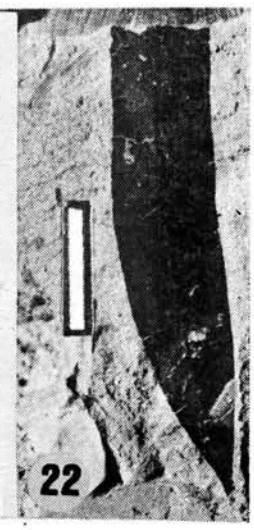
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