A PALYNOLOGICAL STUDY OF THE SOUTH-EAST REGION OF THE BOSCAN FIELD, VENEZUELA

By

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ABSTRACT

A PALYNOLOGICAL STUDY OF THE SOUTH-EAST REGION OF THE BOSCAN FIELD, VENEZUELA

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The palynological study of 71 core samples from the Boscán Field was performed. The main purposes of this study were the dating and the biostratigraphic and paleoecological characterization of the sedimentary sequences under study.

The palynological assemblage was determined to be Middle Eocene in age, according to the recent zonation published by Muller et al. (1985). In general, sedimentological and palynological results indicate environmental changes within a deltaic complex existing at the time of deposition. An approximate biozonation, based on the results of the cluster analysis and the fluctuations of the relative abundances of the different groups of palynomorphs, indicates a transition from a low deltaic plain to an upper deltaic plain in the 3 subsurface sections under study. A mixed plant community, with coastal and mixed-swamp vegetational components, is inferred to have been present at the time of deposition.

A la Memoria de mi Padre
A mi Madre y a mi Hermano

Por todo lo grande que me han enseñado
Por todo lo significativo que son para mí

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I. INTRODUCTION

I-1. Objectives.

The objectives of this research are:

a) Identify and describe the palynological assemblage from sediments of the Boscán Field, Venezuela.

b) Correlate comparable biostratigraphic zones in three subsurface wells.

c) Date different stratigraphic sections on the basis of biostratigraphic zonations.

d) Achieve the biostratigraphic integration of the subsurface sections by the use of palynological correlation and preparation of charts showing these correlations.

e) Develop information on the paleoecology and community structure of plants comprising these floras.

I-2. Geological evolution of the Lake Maracaibo Basin.

The Lake Maracaibo Basin is one of the twelve geomorphological provinces of Venezuela (Figure 1), as defined by Feo-Codecido et al. (1984). It is located in a tectonic depression in northwestern Venezuela, and encompasses a surface area of approximately 52,000 km^2. The basin is limited to the west by the Sierra de Perijá, and to the east and south by the Venezuelan Andes.

Since the beginning of this century, the basin has been one of the main oil producing regions of the world. After

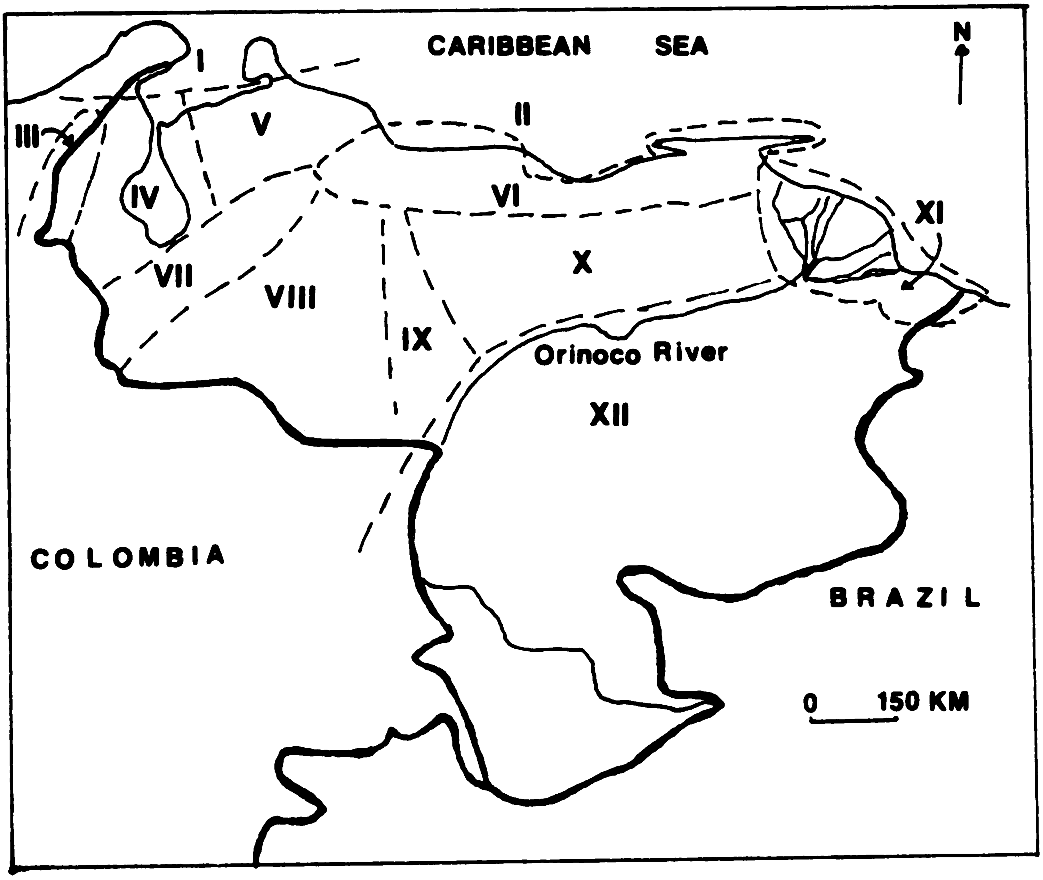


Figure 1. Geomorphological provinces of Venezuela: I- Guajira-Paraguana; II- Venezuelan-Caribbean Islands; III- Sierra de Perijá; IV- Lake Maracaibo Basin; V- Falcón and Lara Region; VI- Caribbean Mountains; VII- Venezuelan Andes; VIII-Barinas and Apure Basin; IX- El Baul Swell; X- Eastern Venezuela Basin; XI- Orinoco Delta Region; XIII- Guayana Shield. (After Feo-Codecido et al., 1984).

limited discoveries in the southern area of the basin, the Venezuelan government granted the first concessions for oil exploration in 1909 (Coronel, 1983). By the middle 1910's, exploratory wells had been drilled in the eastern part, Zumaque-1 being the first significant and productive discovery. In 1917, well Los Barrosos-2, also located in the eastern shore of Lake Maracaibo, blew out producing nearly 100,000 barrels per day. This series of discoveries led to intense activity of exploration and exploitation of oil, especially in the eastern shore area of the Lake Maracaibo, in the Bolívar Coastal Fields, considered to be one of the three largest oil fields of the world (Coronel, 1983). Exploration in the western area of the basin began in the early 1920's, leading to the discoveries of the Concepción, La Paz and the Boscán Fields (Figure 2).

The intensive exploratory activity developed since then, has generated important publications summarizing the geological evolution of the basin. By the middle 1940's and 1950's, papers by Sutton (1946), Schaub (1948) and Mencher et al. (1953) presented detailed descriptions of the geology and stratigraphy of the area. More recently, and based on new evidence and data, Zambrano et al. (1971), González de Juana et al. (1980), Bockmeulen et al. (1983), Kellogg (1984) and Talukdar et al. (1985), have presented new interpretations on the evolution of the basin.

Case et al. (1984) pointed out that the basin contains Jurassic red beds, Cretaceous marine carbonates and Cenozoic

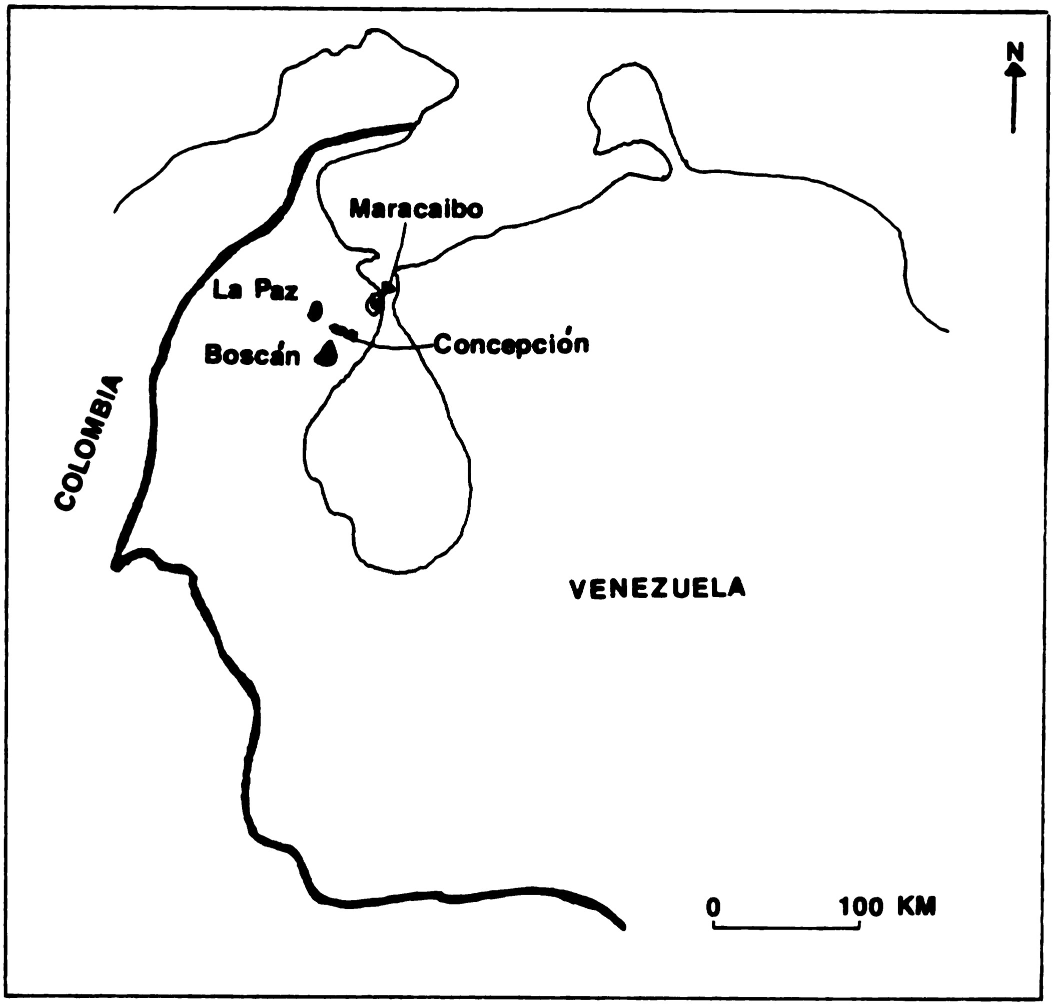


Figure 2. Location of the Boscán Field in western Venezuela. (After Bockmeulen et al., 1983).

deltaic, fluviatile, marine and lacustrine deposits. Since the main events related to the geological evolution of the basin, as well as to oil generation in the basin, occurred after the Jurassic, the following discussion will present a synopsis of the evidence describing and interpreting the history of the basin, from the Cretaceous to the Pliocene.

Mencher et al. (1953) and Zambrano et al. (1971) pointed out that during the Early Cretaceous, a shallow epicontinental sea covered not only the current Lake Maracaibo, but also most of the northern part of Venezuela, leaving the Guayana Shield as the only positive area. Talukdar et al. (1985) presented a detailed analysis of the types of organic matter contained in different formations of the Lake Maracaibo Basin. They concluded that the Early Cretaceous Rio Negro Formation was deposited in continental environments, being followed by the Apón, Lisure and Maraca Formations, deposited in a shallow marine platform. This transgression extended into the Cenomanian-Coniacian, reaching its maximum with the deposition of La Luna Formation. According to Talukdar et al. (1985), this calcareous shale-limestone constitutes the main source rock for hydrocarbons generated in the Lake Maracaibo Basin. Zambrano et al. (1971) described the existence of three sedimentary provinces during the Cretaceous. These were the coastal, neritic and pelagic provinces, which were roughly parallel to the northwestern edge of the Guayana Shield (Figure 3).

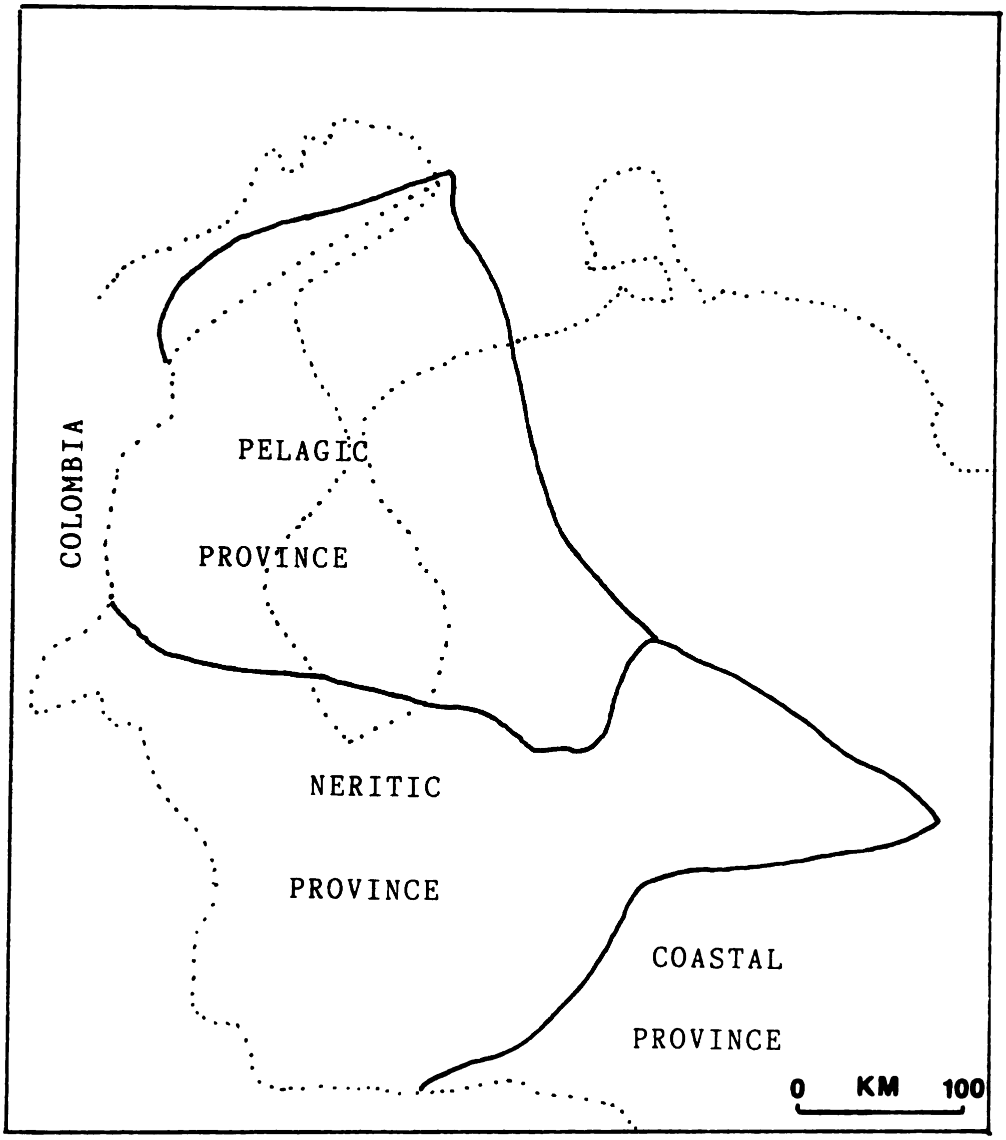


Figure 3. Sedimentary provinces in northwestern Venezuela during the Cenomanian-Coniacian. Dotted line shows the current coastline and international border for reference (After Zambrano et al., 1971).

González de Juana et al. (1980), in their important review "Geología de Venezuela y de sus cuencas petrolíferas" (Geology of Venezuela and its oil basins), pointed out that a gradual period of regression followed the maximum transgression of the Cenomanian-Coniacian. This fact is evidenced by the gradual transition between La Luna Formation and the overlying Colón Formation. The latter is characterized as a thick shale sequence, deposited in an open marine environment. Towards the top of the Colón Formation, it becomes sandier, with intercalated coal layers, indicating the regressive nature of the sequence. González de Juana et al. (1980) also noted the presence of faunal indicators of shallow water in the upper section of this Formation.

Beginning in the Cenozoic, a significant change took place to the southwest of the basin area. Zambrano et al. (1971) and González de Juana et al. (1980) distinguished three sedimentary provinces, that unlike those described for the Cretaceous, have their zones in a southwest-northeast trend (Figure 4). This fact seems to suggest an incipient uplift to the southwest, in Colombia. Shagan et al. (1984) postulated that the incipient orogeny of the Central Cordillera in Colombia occurred at this time, caused by the relative motions of the Caribbean and the South American plates.

Bockmeulen et al. (1983) postulated that the sea re - treated from the southwestern area of the basin. González de Juana et al. (1980) pointed out the existence of a fluvial province in this area. The Catatumbo, Barco and Los Cuervos

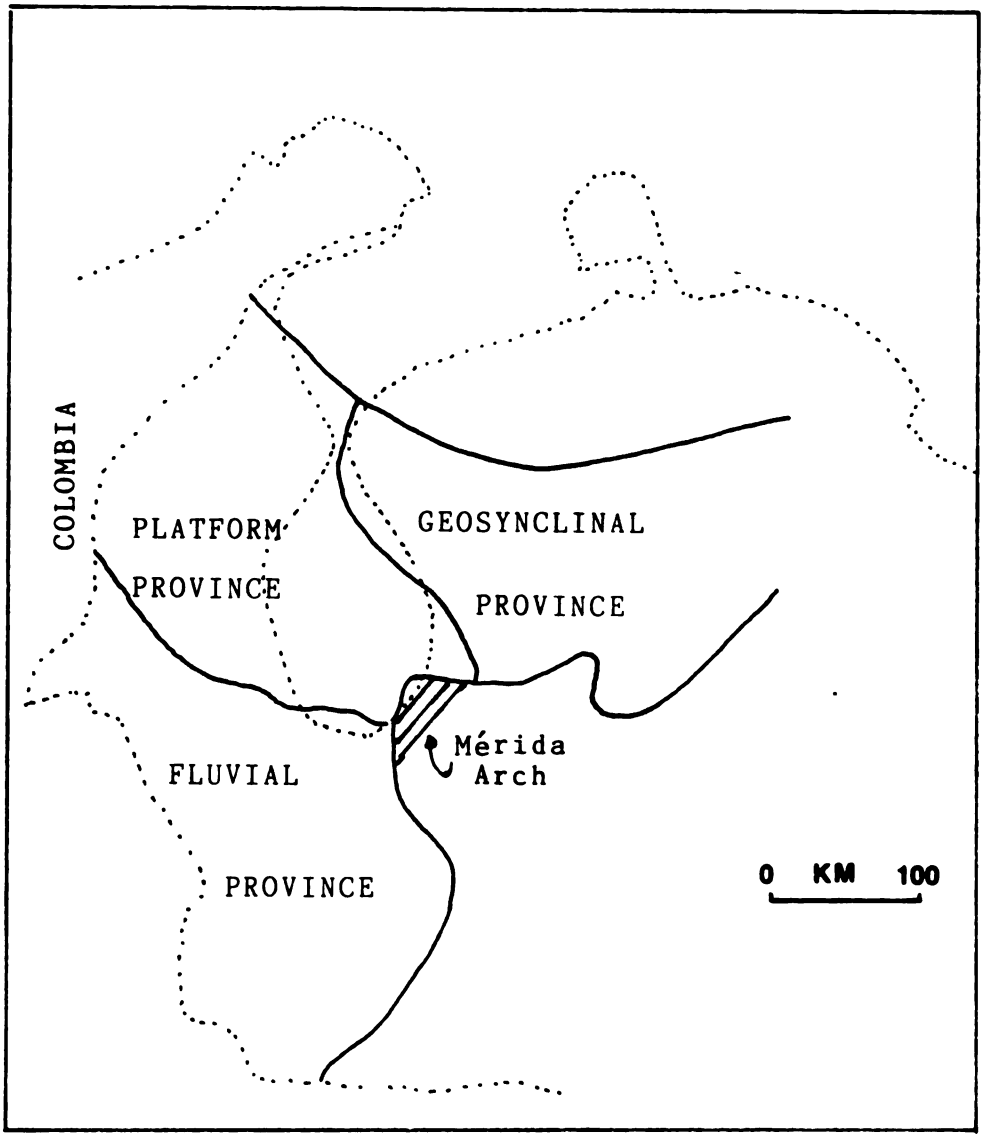


Figure 4. Sedimentary provinces in northwestern Venezuela during the Paleocene. Dotted line shows the current coastline and international border for reference (After Zambrano et al., 1971).

Formations, comprising the Orocue Group (Figure 10), are characterized as being deposited in continental (fluvial) conditions. To the northeast of this area, marine and brackish conditions were still present. The so-called platform province (González de Juana et al., 1980) was limited to the southeast by the Mérida arch (a prolongation of the Guayana Shield present since pre-Cretaceous times). The Guasare Limestone was deposited in this province. A third province, located to the northeast of the platform province, is the geosynclinal province, characterized by deep water sediments, such as those of the Trujillo Formation (González de Juana et al., 1980).

During the Eocene, the location of the sedimentary provinces remained the same as in the Paleocene. However, the first signs of the incipient orogenies of the Venezuelan Andes and of the Sierra de Perijá are postulated to have occurred during the Middle Eocene (Kellogg, 1984). Kellogg (1984) proposed significant tectonic deformation of the basin, with the formation of a series of anticlines with northeast-southwest axes, and large unconformities, that are observed in the oil fields of the Lake Maracaibo and in the Boscán Field. Shagan et al. (1984) seem to support this hypothesis in regard to the timing of this event, based on fission-track age determinations, made in rocks of western Venezuela and eastern Colombia. These events, as it will be pointed out later in this discussion, will be important for defining the evolution and configuration of the basin.

Bockmeulen et al. (1983) suggested that the coastline of the Caribbean Sea was located on what is now the Lake Maracaibo during the Early Eocene (Figure 5). The fluvial-deltaic province in the southwest was still developing. The Mirador (fluvial) and the Misoa (deltaic) Formations were deposited in this province. Shallow and deep marine sedimentation took place in the northeast area of the basin. Zambrano et al. (1971) noted that the thickness of the Misoa and the Trujillo Formations increases towards the northeast, reaching a total of 20,000 feet (approximately 6,096 m) of Eocene deposits. On the basis of the analysis of electric and radioactivity logs, Zamora (1977) noted that the sedimentation of the Misoa Formation had a cyclic nature, with minor deltaic regressions and transgressions. Bockmeulen et al. (1983) proposed that rapid and continuous subsidence of the area caused the significant thickness of the sediments, without major seaward progradation. This fact suggests the formation of many superimposed deltas, as it was proposed by Zambrano (1977).

By the Middle Eocene, tectonic deformation in the area is proposed by Zambrano et al. (1971) and Kellogg (1984). This deformation is evidenced by the formation of the Macoa arch (Figure 6), unconformities in the Lake Maracaibo oil fields and, according to Zambrano et al. (1971), a hiatus in the deposition of the Mirador Formation in the southwest of the Basin. However, González Guzmán (1967), based on palynological evidence, did not find evidence of this hiatus in eastern Colombia. Continuous sedimentation has been

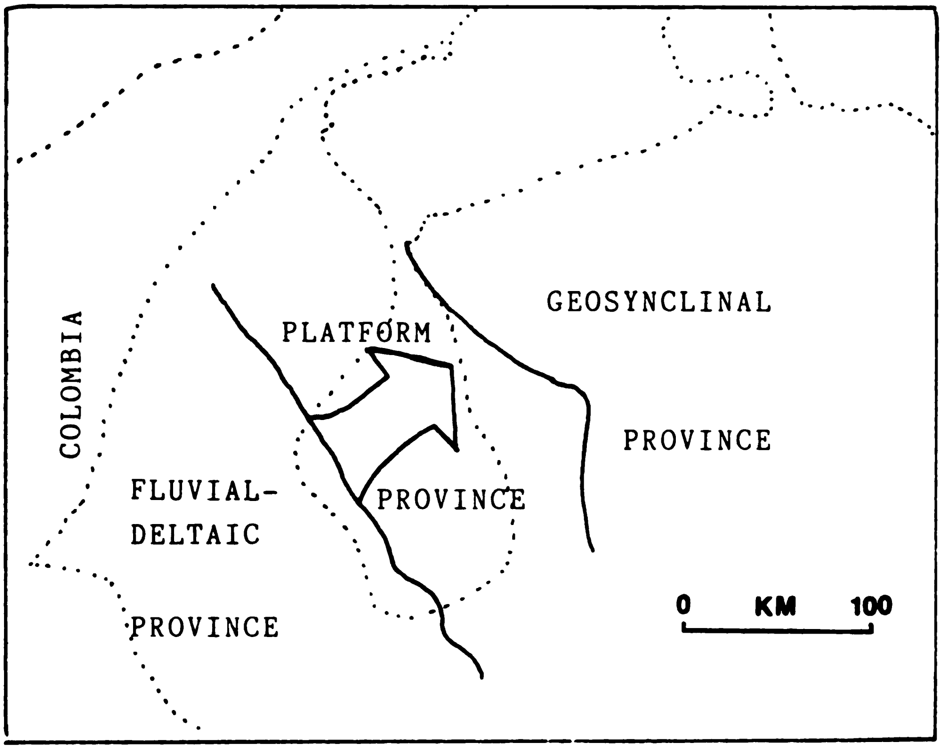


Figure 5. Sedimentary provinces in northwestern Venezuela during the Early Eocene. Arrow indicates direction of progradation of the Fluvial-Deltaic Province. Dotted line shows the current coastline for reference (After González de Juana et al., 1980).

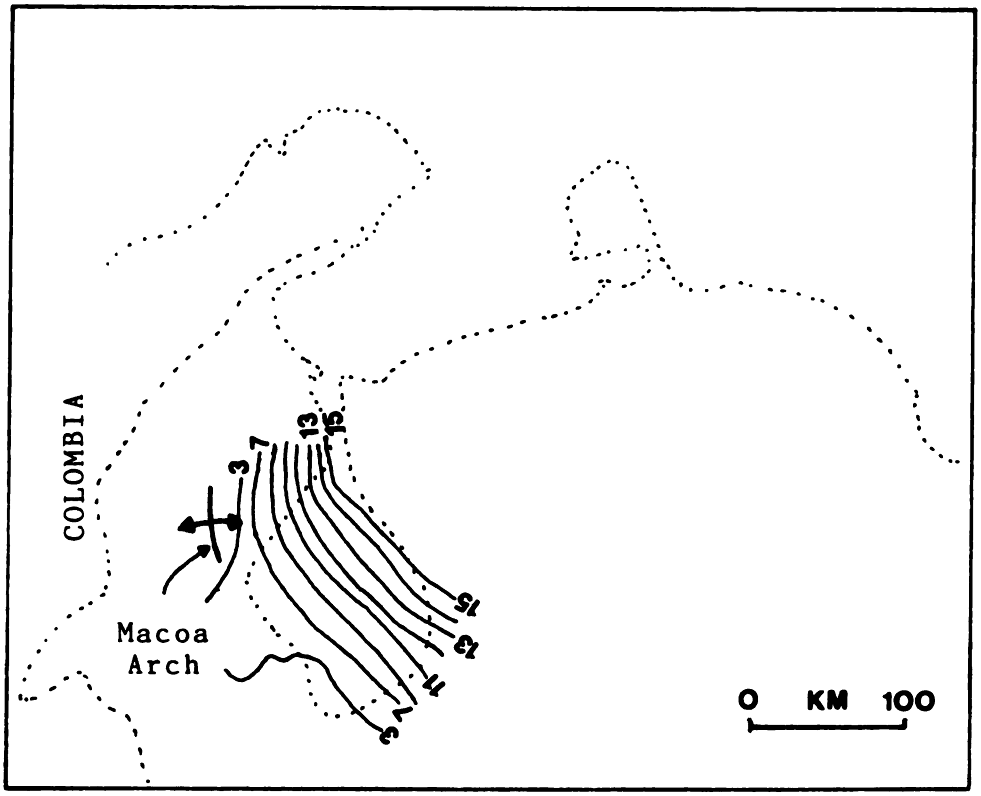


Figure 6. Location of the Macoa Arch (Middle Eocene). The tectonic reconstruction includes Eocene isopachs (Contour interval is 1,000 feet). Dotted line shows the current coastline and international border for reference (After Kellogg, 1984).

assumed for the rest of the basin. The Paují Formation was deposited in relatively deep water in the northeastern area of the basin. These shaly deposits are considered to be the marine equivalent to the Misoa Formation (González de Juana, et al., 1980). During the Late Eocene, the sea covered most of the basin area, except the southwestern part. In this area, the deposition of the Mirador and Carbonera Formations (Figure 10) had minor marine influence overall. In the west, La Sierra Formation (Figure 10) was deposited in brackish water conditions.

The pronounced subsidence in the northeastern area of the basin during the Middle and Late Eocene, has been proposed by Bockmeulen et al. (1983) and Talukdar et al. (1985), to have caused the generation of oil, in zones buried deeply enough, and the primary migration of hydrocarbons towards the thick Eocene sandstones, located up-dip in the central area of the basin (Figure 7).

In the Early Oligocene, the tectonic deformation in the basin area continued. In the central part of the basin, in what is now the Lake Maracaibo, a series of anticlines and closely spaced faults, with north-south trend, began to develop (Figure 8). Zambrano et al. (1971) and Bockmeulen et al. (1983) noted that the erosion undergone by Eocene sediments was severe, with estimates of nearly 9,000 feet (2,743 m) of Eocene sediments being removed in the central part of the basin. Continuous sedimentation, as proposed by Zambrano et al. (1971), Bockmeulen et al. (1983) and Kellogg (1984),

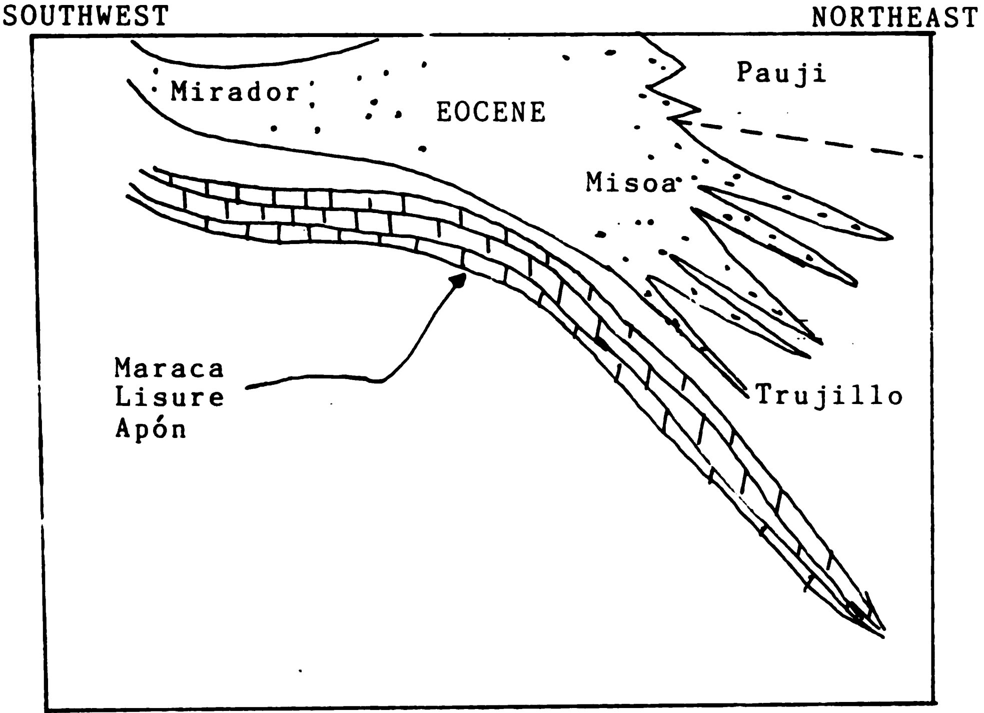


Figure 7. Location of sandstone accumulation in the Lake Maracaibo Basin during the Eocene (After Bockmeulen et al.,1983).

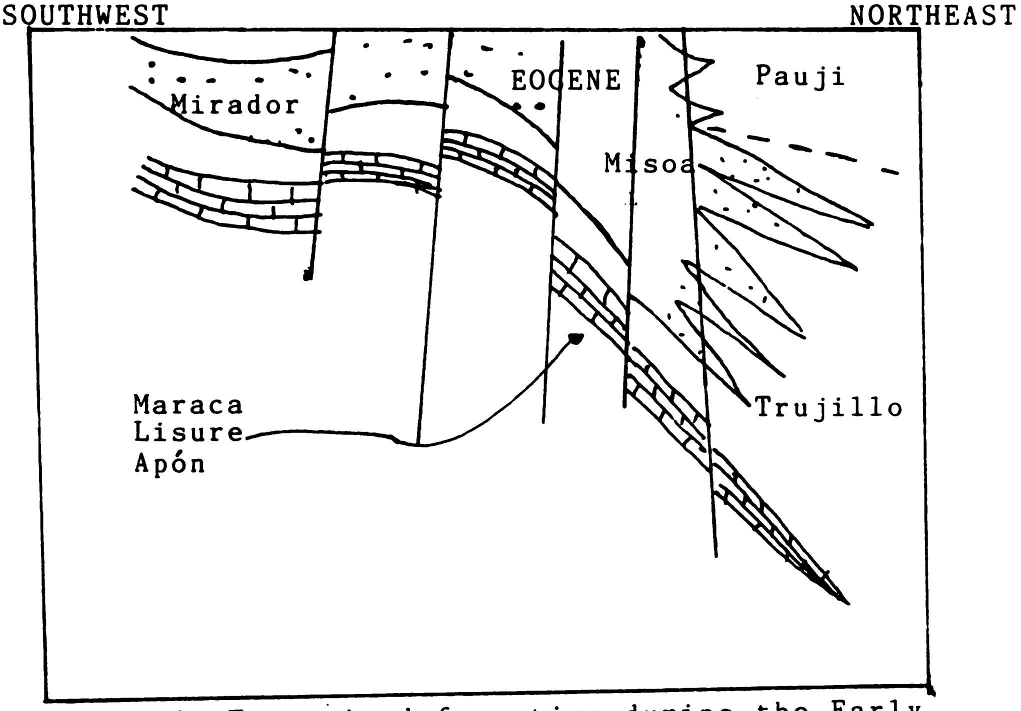


Figure 8. Tectonic deformation during the Early Oligocene (After Bockmeulen et al., 1983).

took place in most of the western-southwestern area of the basin. The Peroc Formation, part of El Fausto Group (Figure 10), was deposited in this area under non-marine conditions. To the east of the basin, the effects of the incipient orogeny of the Venezuelan Andes began to be noted, with the erosion of Eocene sediments, but without the significance previously noted for the central area of the basin. The only Oligocene marine sediments are found to the north of the basin. This fact seems to suggest a significant regressive period, suggested by Bockmeulen et al. (1983) as part of a worldwide event taking place at that time.

In zones where erosion and removal of sediments took place, the central and eastern areas of the basin, are characterized by a marked unconformity between the Misoa Formation and the Oligocene Icotea Formation. This unconformity has also been described in the Boscán Field, in the northwestern area of the basin, by Sutherland (1964) and Azpiritxaga (1985). The age and environment of deposition of the Icotea Formation have not been precisely determined. The sediments contain only reworked Eocene foraminifera (Lexíco Estratigráfico de Venezuela, 1970) and lack palynomorphs (Kuyl et al., 1955). Interpretations concerning the environment of deposition are varied. Sutton (1946), based on grain size distribution, proposed an eolian origin for these sediments. Talukdar et al. (1985) reported a fluvial environment. Azpiritxaga (1985) reported that these sediments were deposited in a continental environment during a regressive cycle in the Oligocene. The age of the Icotea Formation has been proposed to be Oligocene-Miocene (Léxico Estratigráfico de Venezuela, 1970 and Kellogg, 1984).

By the Late Oligocene, the definite orogeny of the Venezuelan Andes began (Kohn et al., 1984). In terms of the geology of Venezuela, this event is important because it marks the total separation of the Lake Maracaibo Basin and the Barinas Basin (provinces IV and VIII,respectively, Figure 1) (Zambrano et al., 1971). Contemporaneous with the uplift, that extended into the Miocene, marked subsidence occurred to the southeast and to the east of the basin, along the incipient orogenic belt. Bockmeulen et al. (1983) noted important structural changes as having taken place during the Late Oligocene and Early Miocene, such as the tilting of the basin to the west (Figure 9), and marked subsidence throughout most of the basin. La Rosa Formation, composed of basal sands followed by marine shales, was deposited during a transgressive period. Zambrano et al. (1971) noted that Miocene sediments commonly become thicker towards the southwestern area of the basin, evidence of the rapid uplift of the Venezuelan Andes to the east.

The main uplift of the Sierra de Perijá occurred during the late Miocene and extended into the Pliocene (Shagan et al., 1984). Bockmeulen et al. (1983) pointed out that subsidence continued throughout most of the basin during the Pliocene. Bockmeulen et al. (1983) and Talukdar et al. (1985) pointed out that the directions of maximum subsidence changed

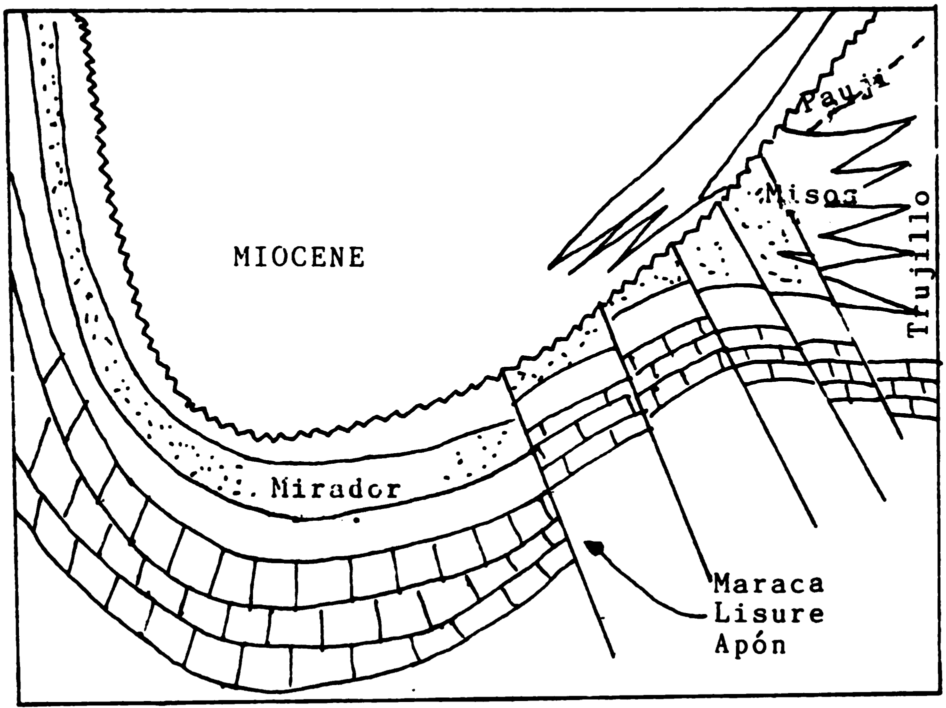


Figure 9. Tectonic deformation during the Late Miocene and the Pliocene (After Bockmeulen et al., 1983).

from the southwest (Late Oligocene-Early Miocene) to the south (Late Miocene-Pliocene). This period is characterized by a regression, observed in the transition between the marine La Rosa Formation and the overlying Lagunillas Formation, deposited in subaerial conditions (Zambrano et al., 1971). In the southwest, continental deposits of El Fausto Group and Los Ranchos Formation were laid down. A synopsis of the stratigraphy of the basin is presented in Figure 10.

I-3. The Boscán Field: Stratigraphy and sedimentary models.

The Boscán Field is located about 25 miles (40 km) southwest of the city of Maracaibo, in a low-lying flat area (Sutherland, 1964). By the late 1920's, exploratory wells had been drilled in the area, without any comercial success. By the middle 1940's, Richmond Exploration Company (former Chevron Oil Company of Venezuela) performed seismic surveys in areas located to the west of the Lake Maracaibo, including the Boscán Field. The results led to the drilling of new wells in the eastern area of the field. The results at this time were productive and by the late 1940's, the importance and size of the Boscán Field were known. Later, in 1951, former Shell Oil Company of Venezuela, and in 1963, the former Corporación Venezolana del Petróleo (CVP), extended their operations in the area. Currently, the field is operated by CORPOVEN s.A..

The field covers an area of approximately 102,502 acres (414 km^2), produces oil with an average of 10.4°. Since 1946,

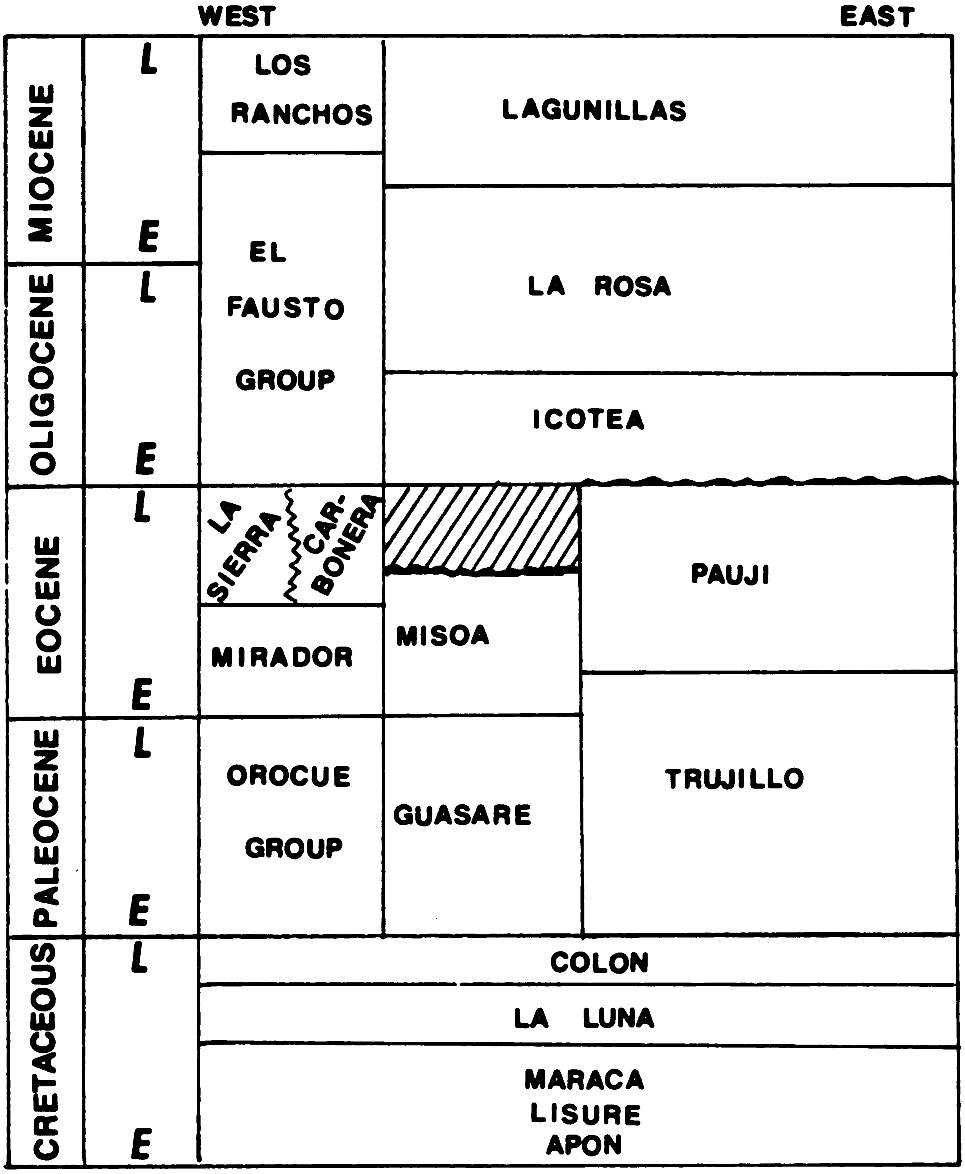


Figure 10. Abbreviated stratigraphic column of the Lake Maracaibo Basin.

a total of 651 million barrels have been produced, with proven reserves of 26,363,758 barrels (Azpiritxaga, 1985).

As most of the oil fields of the Lake Maracaibo Basin, the Boscán Field has the Eocene Misoa Formation and the basal Oligocene Icotea Formation, as the main reservoirs (Miller, 1958 and Azpiritxaga, 1985). Sutherland (1964) cited the relative isolation of the Boscán Field from other fields to the east of the Lake Maracaibo, as the reason for the development of an informal stratigraphic nomenclature. This nomenclature is poorly related to that of other areas of the basin. Zambrano et al. (1971) summarized the subdivisions of the Misoa Formation into the B and C sands in the Bolívar Coastal Fields (Figure 11). Sutherland (1964) referred to the producing horizons in the Boscán Field as the lower and the upper Boscán sands, with Las Flores Shales in between. Germeraad et al. (1968) reported that the Misoa Formation can be correlated with the B sand of the Bolívar Coastal Fields and to La Sierra Formation in the Sierra de Perijá. These authors limited the deposition of this formation to their _Retibrevitricolpites_ _triangulatus_ and _Retitricolporites guianensis_ palynological zones (Lower to Middle Eocene).

As it was previously summarized, the Misoa Formation is characterized as a part of a vast deltaic complex existing in the Eocene of western Venezuela. The Misoa Formation was initially described by Garner in 1926. However, the lack of precision of the original description led Bronijk (1967) to redefine it. It is characterized by sands intercalated with

MAJOR DIVISIONS	SUB DIVISION	THICKNESS	LITHOLOGY
B SAND	Upper Unit	2,900' (883.9 m)	Predominantly shales
	Lower Unit	1,200' (365.8 m)	Sand and shales
C SAND	Upper Unit	700' (213.4 m)	Predominantly shales
	Middle Unit	1,500' (457.2 m)	Shales and sand
	Lower Unit	2,600' (792.5 m)	Massive sand and shale

Figure 11. Characteristics of the subdivisions of the Misoa Formation in the Bolívar Coastal Fields (After Zambrano et al., 1971).

shales and limestone. van Veen (1977) studied the lithologic characteristics of the Mirador and the Misoa Formations, and recognized a fluvial environment for the deposition of the Mirador Formation. For the Misoa Formation, van Veen (1977) recognized transgressive-regressive sequences, with increasing marine influence towards the central and northern areas of the Lake Maracaibo. Based on lithologic features, van Veen (1977) recognized different types of deposits:

a) Pointbar
b) Filling of distributary channels
c) Coastal barrier.

In general van Veen (1977) described a decrease in grain size towards the top of the section, as well as from the south to the north of the Lake Maracaibo.

Zamora (1977) recognized several cycles of sedimentation, that have been attributed to a prograding delta in an area undergoing extensive subsidence. Based on electric and gamma ray logs, Zamora (1977) recognized at least five different categories of sand deposits:

a) Delta front
b) Filling of distributary channels
c) Overbank
d) Meander
e) Transgressive sequences.

The deltaic model proposed by Zamora (1977) is shown in Figure 12.

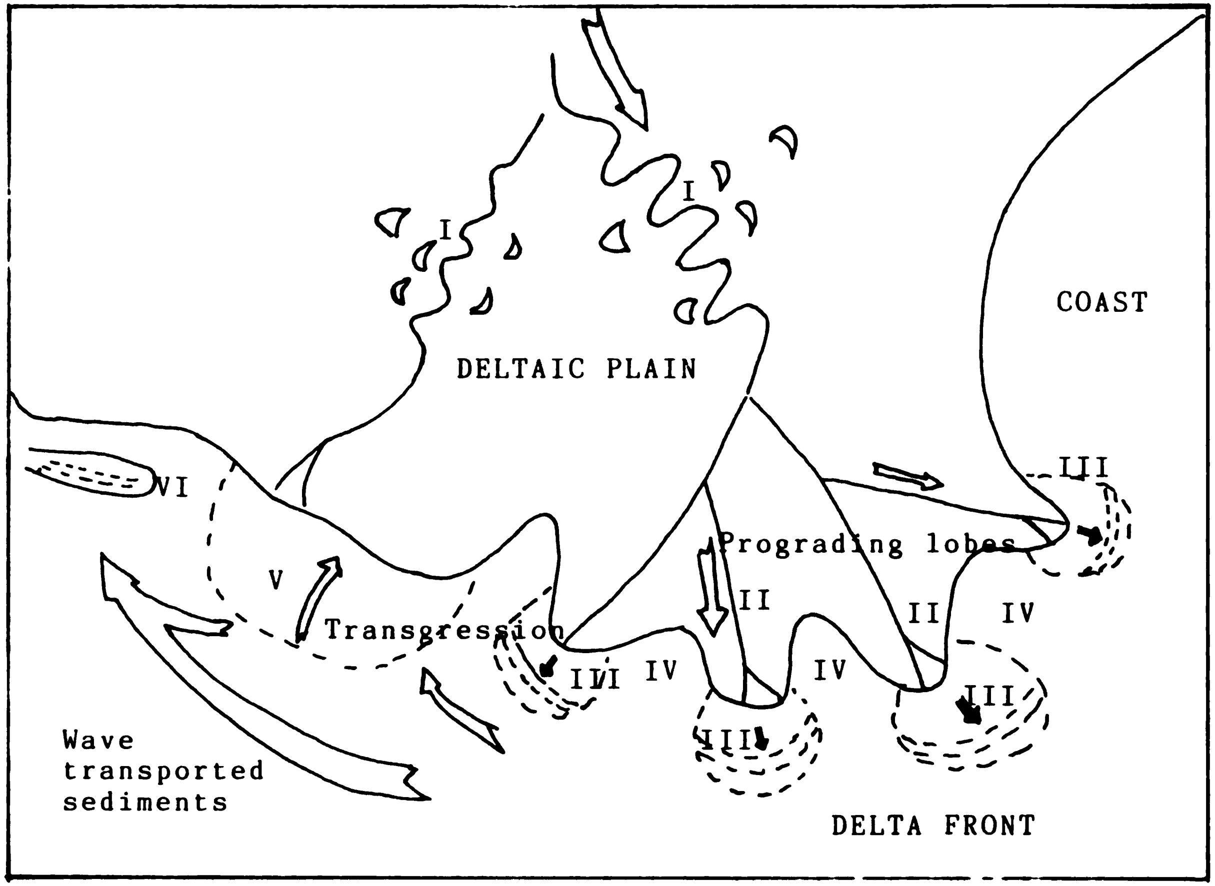


Figure 12. Deltaic model and different sedimentary facies: I- Meandering river, II- Distributary channels, III- Mouth bar, IV- Interdistributary bay, V- Transgressive deposits and VI- Coastal or litoral barrier (After Zamora, 1977).

Three sedimentological models for the Boscán Field are discussed in the following paragraphs.

Sutherland (1964) reported that erosion of Eocene sediments was more pronounced towards the northern area of the field. Sutherland (1964) also noted that the grain size tends to decrease towards the north, whereas coarse-grained sands with relatively high porosity are located in the southern part of the field. Sutherland (1964) also reported that the dipping direction of the strata in the field area is towards the west-southwest (approximately 25 feet/mile or 7.6 m/Km).

Sutherland (1964) and Azpiritxaga (1985) noted that the main structural features of the field are caused by normal faulting. These authors reported that the fault trend is north-northwest (N 18° W) and that the relative displacement along the fault planes is more pronounced towards the south of the field. Both authors agreed that tectonic events taking place during the Oligocene caused these faults.

Reservoir Inc., in 1983, prepared a report on the geology and sedimentology of the Boscán Field. This report, as well as the information reported by Azpiritxaga (1985), concluded that the sediments of the Boscán Field were laid down in a vast deltaic system, probably similar in extent to the Missisippi Delta. Reservoir Inc. reported that the lower Boscán sands appear to have been deposited in a low deltaic plain, with minor marine influence. As the delta prograded, a gradual transition to an upper deltaic plain occurred. For the purposes of this study, low deltaic deposits are those laid down in environments of a delta subjected to tidal influence. Busch and Link (1985) defined the low deltaic plain as that area of the delta extending from the highest zone of marine influence or tidal influence, to the low tide line. On the other hand, upper deltaic deposits are those laid down in environments with none or minor tidal influence. Busch and Link (1985) considered it as the continuation of the fluvial valley into the delta.

Azpiritxaga (1985) proposed a sedimentary model, in which she recognized seven informal stratigraphic intervals for the Misoa Formation in the Boscán Field. The opinions of Azpiritxaga coincides with the interpretations made by Reservoir Inc. in regard to the main genetic units of sedimentation; that is, the low and the upper deltaic plains.

Azpiritxaga (1985) observed that deposits of the low deltaic plain are characterized as those of distributary channels, overbank, delta front and interdistributary plain sediments. On the other hand, the upper deltaic plain deposits are those of channels, meander pointbars, flood plains, ox-bow lakes and natural levees.

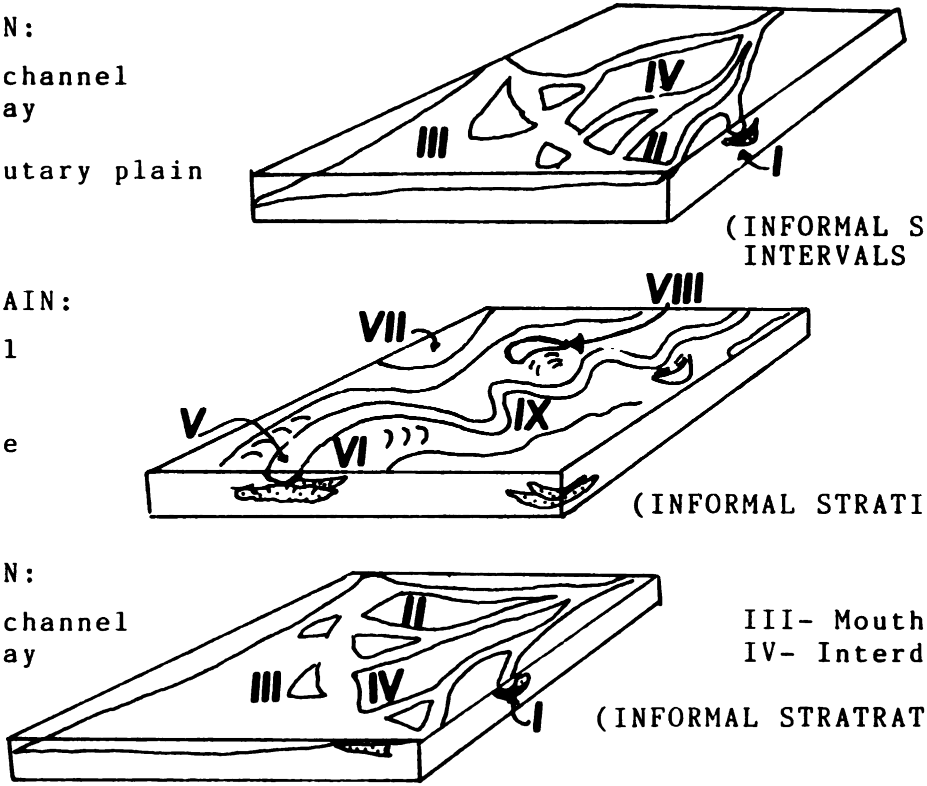
In the deepest cores surveyed by Azpiritxaga (1985), she observed the first two informal intervals (corresponding to low deltaic deposits). These two intervals are overlaid by a sequence characteristic of an upper deltaic plain. Finally, towards the top of the surveyed cores, characteristic deposits of a low deltaic plain were observed. An illustrated model of these observations is shown in Figure 13.

I-4. Palynological studies in northern South America.

Palynology has been widely used in northern South America since the middle 1940's. Its principal application, in the specific case of Venezuela, has been in petroleum geology, as reviewed by Kuyl et al. (1955). In spite of the extensive research carried out, the amount of information that is available is scarce; most of it being in propietary files of oil companies.

Among the few publications available, that of Germeraad et al. (1968) reveals important aspects of the palynology of tropical areas. These authors pointed out the high diversity of the palynological assemblages, estimating at 800-1,000 different types of palynomorphs in an average collection. Of this number, less than 20% is of importance for stratigraphical purposes. Graham (1985) pointed out that the Eocene vegetation of northern South America is still largely unknown, a fact that constrains paleoecological reconstructions. Frederiksen (1985) pointed out that the palynological information for most of the environmental suites observed in tropical areas is incomplete.

In order to organize the available information, the following discussion will be divided into two main categories. The first part will be related to the stratigraphical uses of palynology in northern South America. This part will review the main publications containing zonations, based on palynological determinations. The second part will deal with



LOW DELTAIC PLAIN:

I- Distributary channel
II- Crevasse splay
III- Mouth bar
IV- Interdistributary plain

(INFORMAL STRATIGRAPHIC
INTERVALS 5-6 and 7)

UPPER DELTAIC PLAIN:

V- Active channel
VI- Point bar
VII- Flood plain
VIII- Ox-bow lake
IX- Leveé

(INFORMAL STRATIGRAPHIC INTERVALS 3-4)

LOW DELTAIC PLAIN:

I- Distributary channel
II- Crevasse splay
III- Mouth bar
IV- Interdistributary plain

(INFORMAL STRATRATIGRAPHIC INTERVALS 1-2)

Figure 13. Sedimentary model proposed for the Boscán Field (After Axpiritxaga, 1985).

an overview of the methodology used for the characterization of the paleoecology and paleoenvironments of Tertiary palynological assemblages in this area.

I-4-1. Stratigraphic applications.

Three main publications are considered to provide an useful insight view of the stratigraphic applications of palynology in northern South America.

The first publication is that of Germeraad et al. (1968), that compiles almost 20 years of experience in the field, not only in South America, but also in Asia and Africa. The information reported in this paper is highly diverse and points out the different aspects to be considered in a palynological study. The main result of this publication is related to the establishment of three major zone categories for Late Cretaceous-Tertiary-Quaternary tropical sediments. The first major zone is the Pantropical zone, defined by those palynomorphs that have widespread distribution in all the areas of the study. The second major zone, the Transatlantic zone, is defined by those palynomorphs found in South America and Africa. Unlike the palynomorphs used for the definition of the third type of zone, these two categories are defined based on palynomorphs with significant stratigraphical importance. Finally, the third type of zone, the Intracontinental or local zones, are defined based on the local occurrence of palynomorphs. In total, these authors defined a total of 6 Pantropical zones, 5 Transatlantic zones and numerous local zones.

Regali et al. (1974a) defined a zonation for Mesozoic and Cenozoic sediments from Brazil. The zonation has been used as reference in palynological work in other areas of northern South America.

Muller et al. (1985) reported a detailed zonation for the Cretaceous-Tertiary-Quaternary sediments of northern South America, including Brazil. These authors recognized a total of 10 Superzones and 31 zones that, when compared to the number of zones recognized by Germeraad et al. (1968), represent a continual refinement due to the experience accumulated since the middle 1940's. These authors also recognized 8 zones for the Eocene, 5 of which have been determined in the Misoa Formation, beginning with the Rugotricolporites felix (Lower Eocene) up to the Retitricolporites guianensis (Middle Eocene) zones. The scope of this publication, however, is still limited, pending more complete analyses yet to be published.

I-4-2. Paleoecological applications.

As previously noted, the unknown nature of the floras existing during the Early Tertiary in northern South America limits paleoecological studies. Flenley (1979) noted that tropical floras are highly diversified and consist mostly of angiosperms. This author, as well as Graham (1985), noted the lack of extensive studies in the area, or at least, of available information. Frederiksen (1985) and Flenley (1979) described different types of vegetation and correlated these with the environments where they occurred. Frederiksen (1985) acknowledged that for Early Tertiary palynological studies, only two types of paleocommunities have been characterized; a brackish water assemblage and peat forming swamps. The principal factor permitting such a detailed characterization is the high proportion of autochthonous palynomorphs present in the sediments deposited in these environments. An excellent illustration of this fact was presented by Cohen and Spackman (1972). For other types of environments, the interpretation becomes more difficult, due to a higher proportion of allochthonous palynomorphs. Graham (1985) pointed out the transport of large numbers of allochthonous pollen to different environments due to the significant runoff present in tropical areas.

Paleoecological analyses involving paleoenvironmental interpretations have been reported in various publications by Thomas van der Hammen, Thomas Wijmstra, Enrique González Guzmán and Alan Graham. The following discussion will consider some important aspects of paleoecological interpretations in tropical areas.

van der Hammen and Wijmstra (1964), on their study of Cretaceous and Tertiary sediments from British Guiana, observed that marked fluctuations in the percentage of the Rhizophora pollen were good indicators for the identification of transgressive and regressive cycles. A diminution of this type of pollen indicates regressive sequences, in which inland vegetation (swamp forest dominated by palms) becomes more conspicuous.

González Guzmán (1967), in a palynological study of the Upper Los Cuervos and the Mirador Formations in eastern Colombia, was able to distinguish the transgressive sequences, characterized by high proportions of the *Brevitricolpites* group. This observation led González Guzman to con sider this group as an ecological equivalent, in a broad sense, to the mangrove community. On the other hand, regressive sequences were characterized by the dominance of the *Psilamonocolpites* group, or palms in general, as well as other angiosperm pollen types and fern spores.

Wijmstra (1969), in a detailed study of Cretaceous, Tertiary and Quaternary sediments from Surinam, used a similar approach for the determination of environments. The resulting pollen diagrams reflected changes through all the section, such as:

a) Towards the top of the section (mainly Pliocene-Pleistocene), Wijmstra recognized the dominance of grass pollen types corresponding to *Byrsonima* and *Curatella*, indicating an open savanna-type of environment.

b) Below the sediments containing high proportions of grass pollen types, Wijmstra noted sequences with marked changes in the proportions of *Rhizophora* and palm pollen types. These sequences contain minor amounts of grass pollen, indicating a mangrove forest and swamp forest. The relative proportions of each one are dependent on the transgressive or regressive nature of these sediments.

c) Towards the lower part of the surveyed section, the palynological assemblages were observed to be dominated by palm pollen types, other types of angiosperm pollen and fern spores.

Due to the absence of the typical mangrove representatives, such as Rhizophora or Avicennia, in the lower part of the section, the paleoenvironmetal interpretation was more difficult. Wijmstra (1969) used the so-called PAF (Palmae-Angiosperm-Fern spores) diagram to infer the transgressive and regressive cycles based on the variations of the proportions of the palm pollen types. Regressive sequences were observed to follow periods with maxima of palm pollen types. Similar observation was made by González Guzmán (1967). The general model proposed by González Guzmán is shown in Figure 14.

Other studies that have been done in Recent sediments, include those by Wijmstra and van der Hammen (1966) in the tropical savannas of northern South America, and by Salgado-Laboriau (1979 and 1980) in the Venezuelan Andes and in the Lake Valencia (central Venezuela). Graham and Jarzen (1969) and Graham (1985) have also reported the results of studies of neotropical communities in the Caribbean area and in Central America.

Numerical clustering techniques have not been used for the study of palynological assemblages of northern South America. Due to the high diversity of the flora, these types of technique can be useful for the better understanding of the paleoecology and community structure.

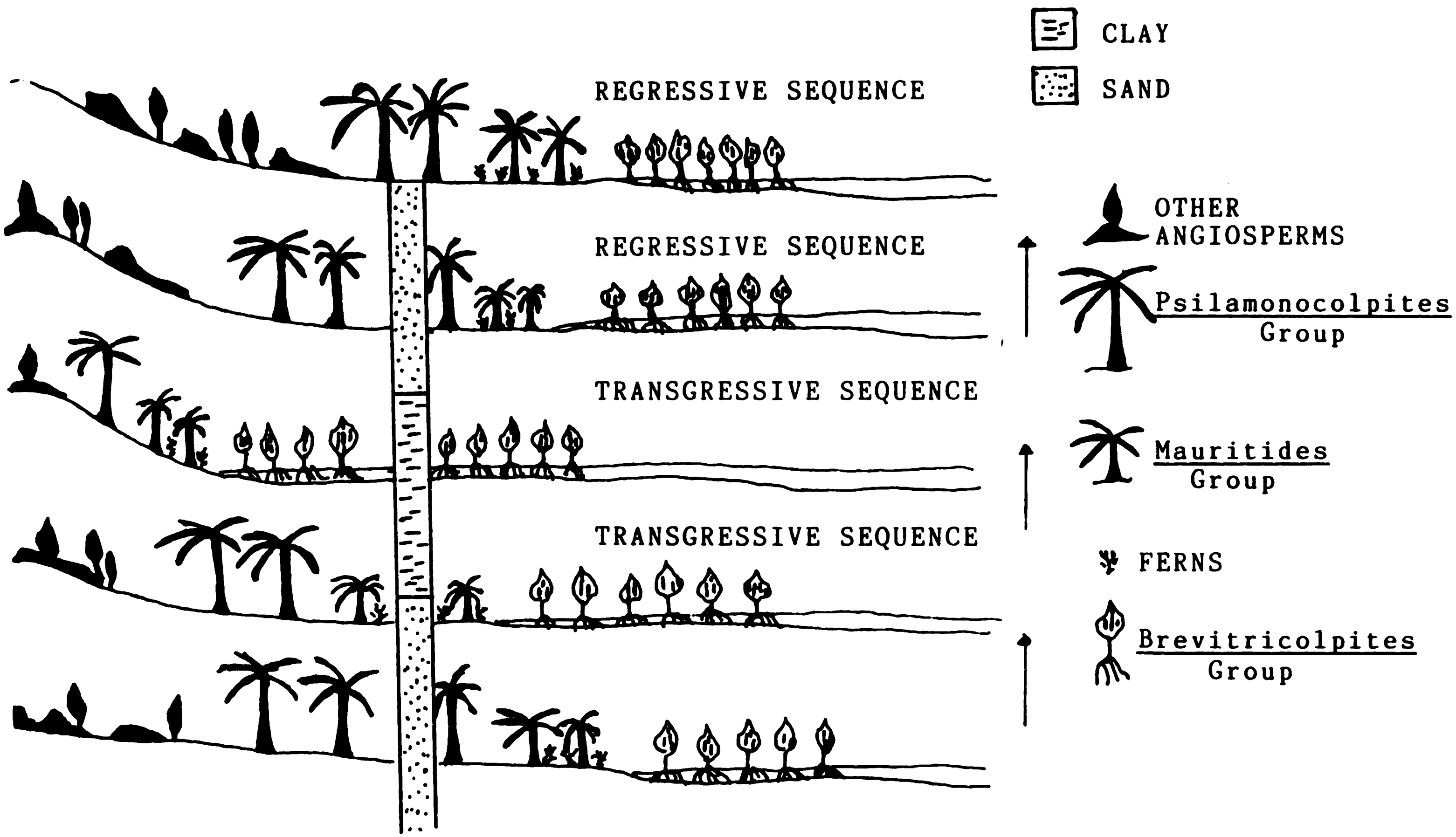


Figure 14. Model of sea level fluctuation and shore vegetation changes (After González Guzmán, 1967).

II. MATERIALS AND METHODS

II-1. Samples.

A total of 71 core samples from 3 wells of the Boscán Field were selected by the Section of Biostratigraphy of the Venezuelan Institute for Petroleum Research (INTEVEP S.A.). The samples were selected according to their lithology (very fine-grained sand and siltstone). The 3 wells are located in an approximately NW-SE traverse in the southeast area of the Boscán Field (Figure 15).

INTEVEP S.A. also provided electric well logs and lithologic descriptions of the 3 cores. It should be noted that there is no regularity on the sampled intervals.

The samples were tightly wrapped in plastic bags, packed and sent to the author of this study in July, 1984. The samples were assigned a maceration number and were transferred to plastic containers.

II-2. Maceration procedure.

All samples were treated with the same general method. The time of reaction varied for various samples. Lignite and carbonaceous siltstone required longer time of reaction with the Schulze's reagent. The procedure is as follows:

1) A brief lithologic description was obtained, taking into consideration the presence of relevant sedimentological fea-

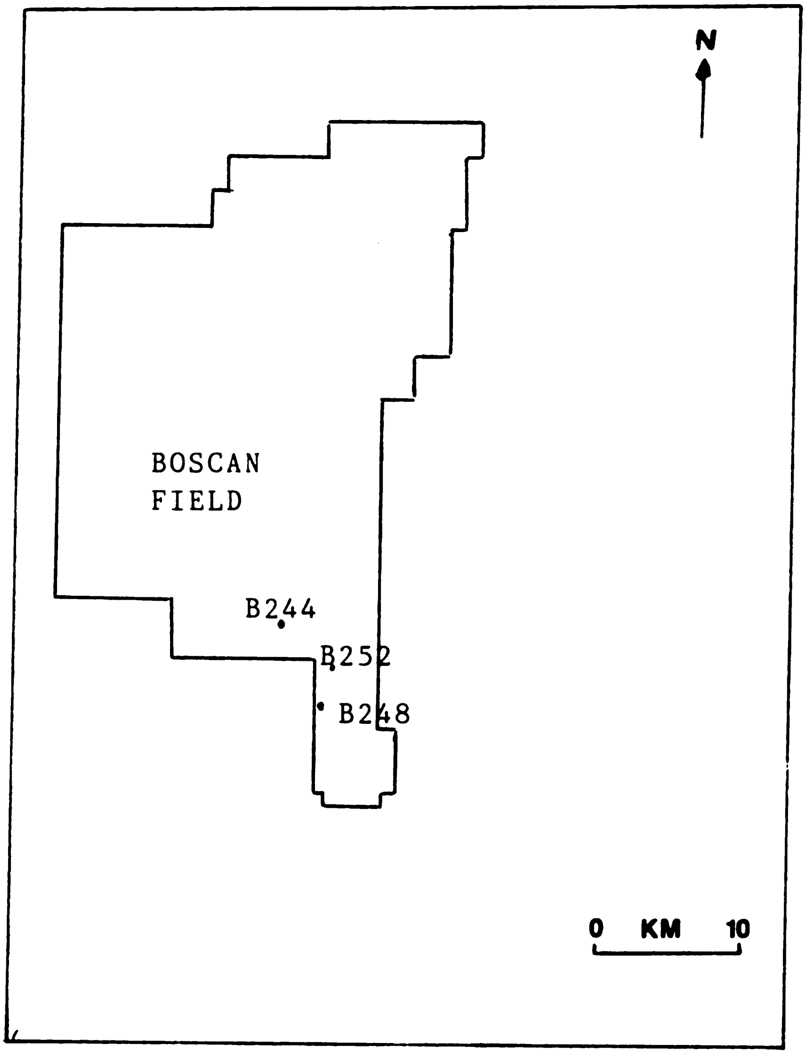


Figure 15. Location of the three wells under study in the Boscán Field (After Axpiritxaga, 1985). The location of the field within the area of the Lake Maracaibo Basin is seen in figure 2.

tures. These observations were later complemented with the lithologic information provided by INTEVEP S.A..

2) The drilling mud was removed by scrubbing the surface of the sample with a hard brush.

3) Before crushing and weighing the sample, it was dispersed on paper and divided into numerous pieces. Some of these pieces were randomly selected for the maceration.

4) The pieces were crushed in a clean metallic mortar, until fragments of 2-3 mm were obtained.

5) Using a balance, 5 gms of each sample were obtained and placed in a previously washed 25 ml plastic tube, marked with the maceration number of the sample. In the cases of samples yielding very low amounts of palynomorphs, 15 gms were used.

6) Approximately 15 ml of hydrochloric acid (HCl, 10%) was added to each sample. The samples were frequently stirred. The reaction time was 1 hour and 30 minutes at room temperature.

7) After this period, the samples were centrifuged at 2,000 rpm for approximately 5 minutes. After the centrifugation, the supernatant liquid was discarded and distilled water was added to wash out the remaining HCl. This process was repeated 3 times for each sample.

8) After rinsing free of HCl, the samples were treated with hydrofluoric acid (HF, 52-55%) for nearly 18 hours at room temperature.

9) A similar procedure to the one described in step 7 was used to wash out the HF from the samples. However, the sample

was rinsed with HCl (10%) once, and with distilled water 3 times.

10) During the last rinse with distilled water, the samples were transferred to glass tubes, taking care to transfer all the residue.

11) The samples were then left to react with the Schulze's reagent, 5 parts of nitric acid (HNO_3) and 1 part of potassium chlorate ($KClO_3$). The amount of reagent that was used was determined by using a fixed liquid/residue height ratio of 2. This ratio was used in order to maintain uniformity in the treatment of all the samples. The time of reaction varied, as it was previously noted, from 1 hour 30 minutes to 6 hours, at room temperature.

12) Step 7 was repeated in order to remove the excess reagent.

13) Using the same liquid/residue height ratio mentioned in step 11, potassium hydroxide (KOH, 5%) was added to the samples and left to react for 5 minutes. The samples were then rinsed with distilled water.

14) Before using the heavy liquid, zinc bromide (ZnBr, specific gravity 1.91), the residues were rinsed with HCl (10%). After discarding the excess of HCl, ZnBr was added to the samples using a liquid/residue height ratio of 3:5. The sample and the liquid were thoroughly mixed and centrifuged for 2 minutes at 2,000 rpm. The supernatant liquid containing the organic fraction was collected and diluted in HCl (10%)

in order to concentrate the organic residue. The excess HCl, was removed by rinsing with distilled water.

15) 1 or 2 drops of ammonium hydroxide (NH_4OH) were added to each residue, in order to make it basic for the staining procedure.

16) 2 or 3 drops of Safranin O (1%) were added and left to react for 5 minutes at room temperature. Excess stain was removed by successive rinses with distilled water.

17) The stained residues were sieved through a 10 μm mesh, in order to remove undesired particulate material from the final residue. Microscopic observation were done on the material that passed through the mesh, in order to verify that no palynomorphs were present.

18) The residues were transferred to vials and stored until the moment of preparing the microscope slide.

II-3. Preparation of microscope slides.

In order to prepare microscope slides, each residue was diluted in distilled water to a concentration that was determined to be suitable for avoiding any excess of organic residue in the final slide. The total number of drops of this dilution was determined by using a Pasteur pipette. The dilution was evenly mixed in order to get an uniform suspension. Using the same pipette, an aliquot of the suspension was obtained, and a given number of drops was added to a previously cleaned cover slip, placed on a hot table. Using a toothstick, the suspension was dispersed on the glass cover slip as uniformily as possible. The excess solvent was evaporated, leaving a thin film of organic residue adhering to the cover slip. Microscope slides were prepared by turning the cover slip over and placing it on the glass microscope slide, using Kleermount resin as the sealing agent. 3 slides were prepared for each sample.

By determining the total number of drops of the dilution (D_t) and the number of drops placed on the cover slip, an estimation of the absolute number of palynomorphs can be made, using the following relation:

- Since the number of drops per slide is known, and depending on how many slides per sample were counted, a total number of drops that were used (D_c) is obtained. Using the absolute frequency of the different palynomorphs (A_c), an extrapolation to the absolute number of palynomorphs in each sample can be calculated by:

$$\frac{A_c}{D_c} = \frac{A_t}{D_t} \quad (1) \quad \text{or} \quad A_t = \frac{A_c \times D_t}{D_t} \quad (2)$$

where A_t is the absolute number of palynomorphs in the sample. By dividing A_t by the weight of sample used for the maceration, the absolute frequency of palynomorphs per gram of sample can be estimated.

II-4. Counting of palynomorphs.

The counting was done using a Leitz-Wetzlar Ortholux microscope. The whole cover slip area was observed, in most of the cases.

It was determined that by using the 12.5 X objective lens, one division of the coordinate scale of the microscope was equal to a field of view. The counting of each slide was always started at the upper left corner of the cover slip, using the 12.5 X objective lens for the scanning. Detailed morphological observations and identification of palynomorphs were done with the 54 X and the 95 X oil immersion objective lenses.

Because the highly variable abundance of palynomorphs in the different samples (see next chapter), it was decided to count up to a number at which no new type was recognized for the next 60 palynomorphs observed. Counting of fungal spores, hyphae and fructifications was kept separated from the total of other palynomorphs.

II-5. Photographic material.

Photographs of the different palynomorphs were obtained by using a Leitz-Wetzlar Orthomat automatic microscope camera. The developing and printing were done at facilities existing at Michigan State University, using standard techniques.

II-6. Palynomorph diagrams.

The result of the tabulation of palynomorphs are presented in palynomorph diagrams. These diagrams show the main trends of the relative frequencies of the different groups of palynomorphs.

Grouping of palynomorphs into different categories per-

mitted a better evaluation for paleoenvironmental interpretations. The approach used in designing the diagrams was similar to those mentioned in the previous chapter. However, based on the results obtained, a different type of diagram was used. The palynomorphs were included in 6 main categories:
a) Mangrove group; consisting of those palynomorphs that have been typically characterized as being produced in brackish water swamps. Muller (1964) defined the mangrove communtity as the vegetation growing under tidal influence, in water of fluctuating salinity. Similar definition was used by Blasco and Caratini (1973), in their study of the mangrove of Pichavaran, India.

Using the important information provided by Frederiksen (1985), it was decided to include the following palynomorphs as components of this mangrove group:
Echitriporites triangulifornis, *Psilatricolporites crassus*, (*Pelliceria*, Theaceae), the *Spinizonocolpites* (*Nypa*) group, and the *Brevitricolpites* group.

The description of these palynomorphs, as well as illustrations of all the palynological assemblage, are presented in Appendices A and B.

b) *Peltandripites* sp. group; formed by a triporate, echinate pollen grain of unknown botanical affinity, that was found to be very conspicuous in some samples.

c) Palmae group; including those pollen grains that were attributed to this family.

d) Spore group; including fern and other types of plant spores.

e) Dinoflagellate-Algae-Foraminifera group; formed by the following palynomorphs:

The dinoflagellate cyst identified as belonging to the genus *Operculodinium* (Dr. J. Wren, personal communication), the fresh water algae cf. *Micrasterias* sp., the fresh water algae cf. *Pseudoschizaea* sp., and unidentified chitinous inner linings of foraminifera.

f) General group; including those palynomorphs that were not grouped in the previously defined categories.

A phylogenetic list of the palynological assemblage is presented in Appendix B.

II-7. Cluster analysis.

Using the relative frequencies of the previously defined groups of palynomorphs, calculations of the Similarity Index used by Jameossanaie (1983) were performed. The calculations involve two-by-two comparisons of the different samples under study, and the determination of chi-square values as follows:

SAMPLE No.	GROUP A	GROUP B	......	GROUP K	ROW TOTAL
1	X_{a_1}	X_{b_2}	......	X_{k_1}	N_1
2	X_{a_2}	X_{b_2}	......	X_{k_2}	N_2
COLUMN TOTAL	X'_a	X'_b	......	X'_k	N'

where X_{a_1}, X_{b_1},... and X_{k_2} represent the relative frequencies of the different groups of palynomorph in each sample.

$$\chi^2 = \left(\frac{X_a^2/N}{\hat{P}_a} + \frac{X_b^2/N}{\hat{P}_b} + \ldots + \frac{X_k^2/N}{\hat{P}_k} \right) - N'$$

where:

$$X_a^2/N = \left(\frac{X^2_{a_1}}{N_1} + \frac{X^2_{a_2}}{N_2} \right)$$

$$X_b^2/N = \left(\frac{X^2_{b_1}}{N_1} + \frac{X^2_{b_2}}{N_2} \right)$$

$$\vdots$$

$$X_k^2/N = \left(\frac{X^2_{k_1}}{N_1} + \frac{X^2_{k_2}}{N_2} \right)$$

and

$$\hat{P}_a = X'_a/N' \; ; \; \hat{P}_b = X'_b/N' \; ; \; \ldots \; \hat{P}_k = X'_k/N'$$

In this analysis, the chi-square values are considered as coefficients of similarity, regardless their level of significance. Then, the values of chi-square were converted into Similarity Index (S.I.) values by:

$$\text{S.I.} = 1 - \frac{\chi^2}{\chi^2_{max}}$$

where χ^2 is the calculated value of chi-square for each two-by-two comparison, and χ^2_{max} is the highest value of chi-square among all possible comparisons. This index ranges from 0 to 1 (1 indicating maximun similarity).

The calculations were performed using a BASIC program, implemented for personal computers by Dr. A. Jameossanaie. The results are presented in a dendrogram showing the different clusters.

III. RESULTS

III-1. Abundance of palynomorphs.

A general clasiffication was used to describe the approximate abundance of palynomorphs in the different samples:

- Very low abundance; 1-100 counted palynomorphs per sample
- Low abundance; 101-200 counted palynomorphs per sample
- High abundance; 201-300 counted palynomorphs per sample
- Very high abundance; 301 or more counted palynomorphs per sample.

Out of the 71 samples studied, 6 (8%) were barren of palynomorphs, 27 (38%) were found to have very low abundance, 17 (24%) had low abundance, 15 (22%) had high abundance and only 6 (8%) had very high abundance.

The absolute abundance or number of palynomorphs per gram of sample was calculated according to equation 2 (refer to page 39). The values for the different samples in each well are presented in Tables 1, 2 and 3. The absolute number of palynomorphs per gram of sample is quite variable, as evidenced in the large values of standard deviation presented for each well in Tables 1-3. Larger number of palynomorphs seem to have been recovered in wells B244 and B248 (see calculated averages of the number of palynomorphs for each well).

SAMPLE DEPTH (FEET)	NUMBER OF COUNTED PALYNOMORPHS (A_c)	# OF DROPS OF INITIAL SUSPENSION (D_t)	# OF DROPS USED (D_c)	GRAMS OF SAMPLE USED	ABSOLUTE NUMBER OF PALYNOMORPHS (A_t)
9055'4"	90	78	21	15	23
9058'7"	174	71	30	15	27
9067'3"	139	75	30	15	23
9111'2"	240	110	21	15	84
9135'2"	87	60	30	15	12
9188'10"	223	157	15	15	156
9201'2"	100	89	30	15	20
9205'1"	110	70	30	15	17
9209'1"	65	64	30	15	9
9213'1"	5	36	30	15	< 1
9217'1"	155	123	15	15	131
9266'5"	240	148	24	15	280
9270'10"	29	46	30	15	3
9390'2"	230	138	30	15	71
9393'7"	0	35	30	35	0
9401'9"	0	33	30	15	0
9406'4"	0	32	30	15	0
9410'10"	0	37	30	15	0
9419'2"	126	66	30	15	18
9423'2"	207	89	30	15	41
9424'11"	175	78	30	15	30
9458'	162	143	30	15	52
9478'11"	83	66	30	15	12
9484'8"	259	126	30	15	76
9491'4"	350	128	5	5	1,792

Table 1. Absolute number of palynomorphs per gram of sample (A_t) for well B244. ($\overline{X}$= 114.3 and σ= 352.2)

SAMPLE DEPTH (FEET)	NUMBER OF COUNTED PALYNOMORPHS (A_c)	# OF DROPS OF INITIAL SUSPENSION (D_t)	# OF DROPS USED (D_c)	GRAMS OF SAMPLE USED	ABSOLUTE NUMBER OF PALYNOMORPHS (A_t)
9058'4"	75	71	30	15	12
9095'4"	0	37	30	15	0
9141'7"	71	69	30	15	11
9171'9"	82	74	30	15	13
9198'3"	140	75	30	15	23
9232'3"	256	89	30	15	51
9236'7"	248	97	30	15	53
9240'9"	103	69	30	15	17
9246'11"	360	77	10	5	698
9257'	164	53	30	15	25
9262'11"	218	77	18	15	62
9281'3"	65	53	30	15	8
9288'11"	14	37	30	15	1
9354'	0	37	30	15	0
9375'5"	332	98	10	5	651
9381'6"	452	93	10	5	841
9384'8"	49	71	30	15	8
9405'11"	414	92	10	5	762
9445'7"	139	78	30	15	24
9448'8"	292	107	10	15	208
9452'11"	210	93	24	15	54
9463'3"	439	97	5	5	1,703
9469'7"	270	91	15	15	109
9473'3"	72	71	15	15	23
9479'6"	87	72	15	15	28
9484'7"	145	81	15	15	52

Table 2. Absolute number of palynomorphs per gram of sample (A_t) for well B248.
($\bar{X}$= 209.1 and σ= 401.8)

SAMPLE DEPTH (FEET)	NUMBER OF COUNTED PALYNOMORPHS (A_c)	# OF DROPS OF INITIAL SUSPENSION (D_t)	# OF DROPS USED (D_c)	GRAMS OF SAMPLE USED	ABSOLUTE NUMBER OF PALYNOMORPHS (A_t)
8558'	8	34	30	15	< 1
8573'10"	107	76	30	15	18
8575'6"	16	40	30	15	1
8622'9"	225	116	30	15	58
8644'2"	25	36	30	15	2
8644'2"	49	69	30	15	8
8652'5"	92	85	30	15	17
8669'4"	43	68	30	15	7
8686'2"	49	69	30	15	8
8792'8"	225	109	30	15	62
8857'5"	52	79	30	15	9
8861'7"	21	40	30	15	2
8867'4"	7	33	30	15	< 1
8921'6"	15	34	30	15	1
8948'10"	204	118	30	15	53
8967'3"	65	75	30	15	11
8972'4"	112	80	30	15	20
8975'8"	140	93	30	15	29
8978'8"	140	92	30	15	29

Table 3. Absolute number of palynomorphs per gram of sample (A_t) for well B252. ($\bar{X}$= 17.1 and σ= 19.6)

III-2. Sedimentological and palynological results.

In this section, detailed descriptions of the sedimentological and palynological characteristics of each well are presented. The lithologic descriptions, as well as the determinations of the different intervals corresponding to each sedimentary environment, are based on the information provided by INTEVEP S.A. and the characteristics of the SP curves for each well.

Well B244.

a) Sedimentology.

In this well, as in the others, two genetic sedimentary units were recognized. In the lower part of the recovered core, from 9492' to 9364'6", deposits are characteristic of a low deltaic plain. Overlying them, deposits characterized as being deposited in an upper deltaic plain occur (9364'6" to 9026").

In each genetic sedimentary unit, it was possible to identify different sedimentary facies:

- Low deltaic plain deposits;

Crevasse splay deposits (9492' to 9486' and 9415' to 9396'), characterized by fine-grained sandstone with laminations of silt. Laminations are irregular (not parallel) for most of these intervals. Sideritic nodules and zones occur. Sandstone is oil impregnated and relatively massive.

Interdistributary plain deposits (9486' to 9475'), characterized by dark siltstone, with laminations of fine-grained sandstone.

Distributary channel deposits (9475' to 9456'4"; 9456'4" to 9424' and 9424' to 9414'), characterized by basal sandstone showing erosional contact with underlying fine-grained sediments. The three intervals seem to represent sequences of abandoned distributary channels, because of the continuous and significant decrease in grain size towards the top of each interval. High-angle cross bedding (20° to 30°), ripple marks and some carbonaceous laminations also occur.

Distributary mouth bar deposits (9396' to 9364'6"), characterized by the transition from fine-grained sand and siltstone, to massive coarse-grained sandstone towards the top of the interval. As Coleman (1982) noted, deposits of a distributary mouth complex show a tendency of becoming coarser towards the top, resulting in the typical "bell" shape of the SP curve. This feature is shown in Figure 16, that presents the SP curve of this well.

- Upper deltaic plain deposits;

Meander bar deposits (9364'6" to 9308'4"; 9308'4" to 9270'; 9200' to 9134'7"; 9134'7" to 9110'; 9110' to 9051'6" and 9051'6" to 9026'), characterized by relatively massive sandstone, with decreasing grain size towards the top of the sequences. Cross-bedding (10° to 30°), ripple marks and silt clasts are the most evident sedimentological features.

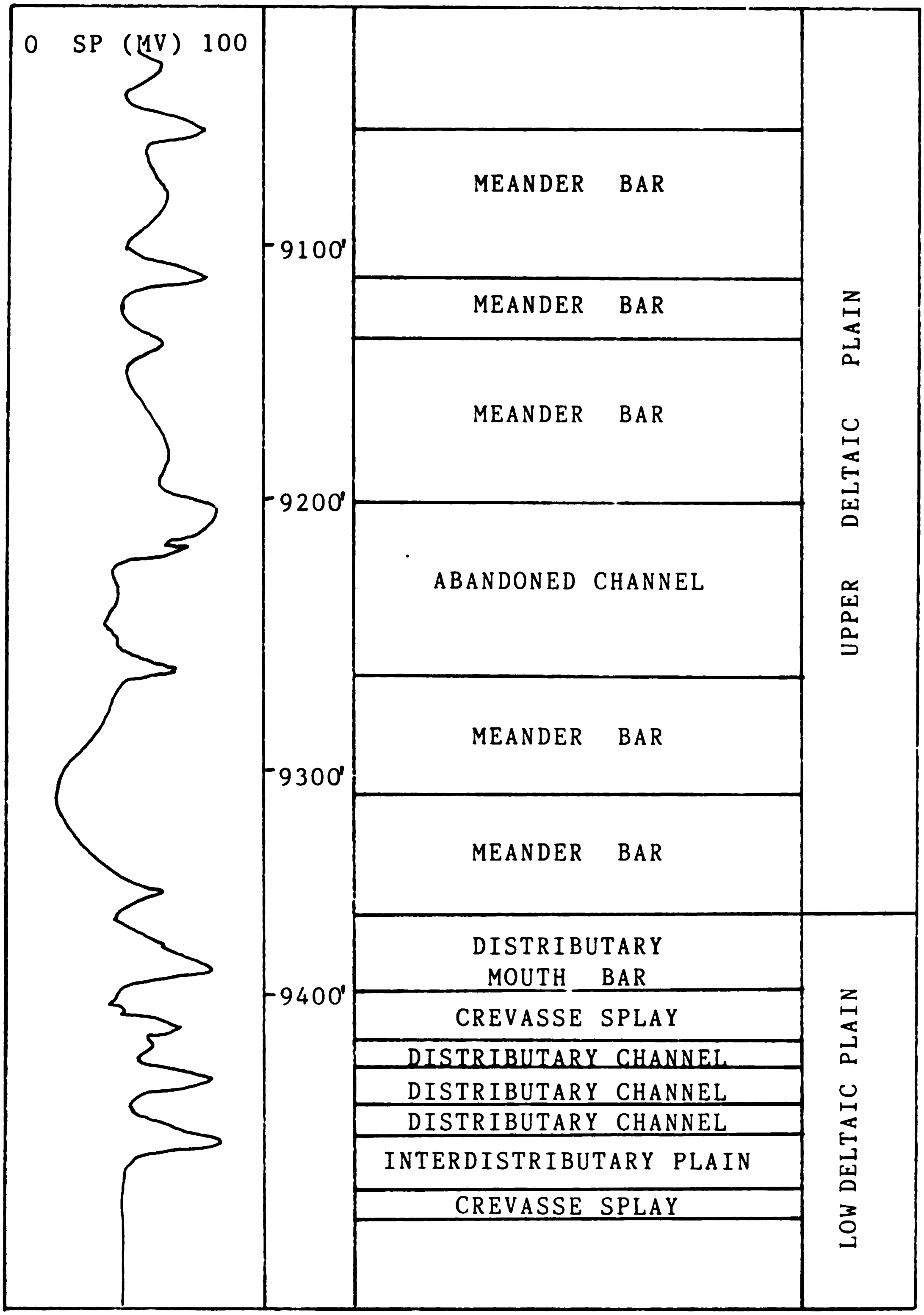


Figure 16. SP curve and environments of sedimentation-
Well B244.

Sideritic nodules and zones, bioturbation (mostly burrowing) also occur. This type of deposit constitutes the largest proportion of the sediments inferred to have been deposited in an upper deltaic plain. The SP curve clearly shows the thick sequence of sandstone in this interval.

Abandoned channel deposits (9270' to 9200'), characterized by sandstone sequences, with progressively decreasing grain size towards the top of the interval. At the bottom, the sandstone is relatively massive, with high-angle cross-bedding (25° to 30°). Laminated siltstone and layers of lignite occur towards the top, indicating the progressive abandonment of the channel. Sideritic zones and nodules also occur in this interval.

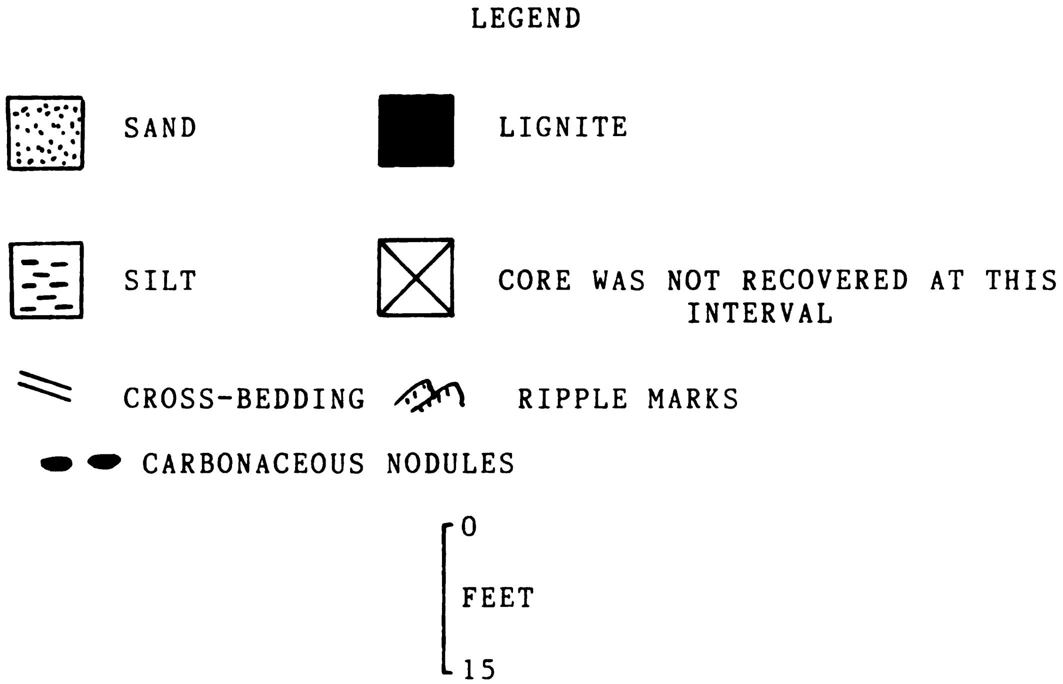
Figure 17 presents the lithology of the surveyed core and the locations of the samples that were processed for the palynological study.

b) Palynology.

In general, the palynological assemblages observed in samples of this well are relatively homogeneous. There is a tendency for larger recovery of palynomorphs and more diverse assemblages (roughly measured by the number of different types identified) in samples of the lower part of the section under study.

Table 4 shows the percentages of the different palynomorph groups, and Figure 18 presents the palynomorph diagram for well B244. Important trends to be noted are those of the Mangrove group, the Spore group and the Palmae group.

Figure 17. Lithology of the core of well B244



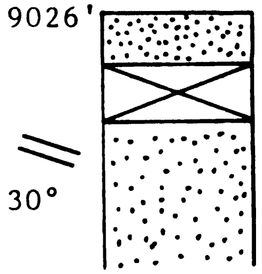
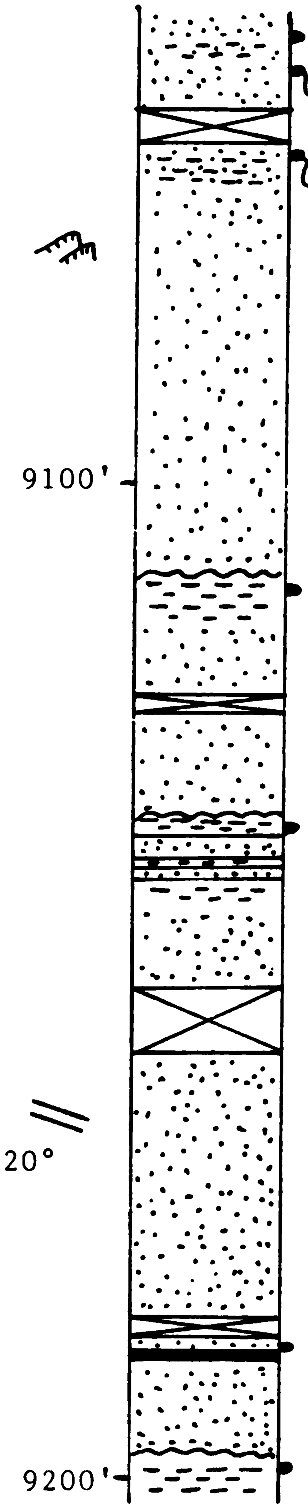


Figure 17-a. Lithology of the core of well B244
(continued)



PB14239 (9055'4"); fine-grained sand with carbonaceous material and micaceous plates.

PB13994 (9058'7"); fine-grained sand intercalated with silt.

PB13980 (9076'3"); fine-grained sand intercalated with silt and carbonaceous material.

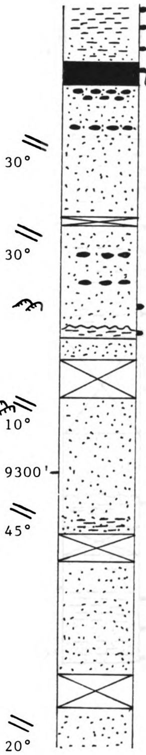
PB14238 (9111'2"); massive gray silt with carbonaceous material.

PB14237 (9135'2"); fine-grained sand intercalated with silt.

PB14236 (9188'10"); fine-grained sand with carbonaceous nodules (fusain and resinite present).

PB14233 (9201'2"); massive gray silt.

Figure 17-b. Lithology of the core of well B244
(continued)



PB13995 (9205'1"); massive gray silt.

PB14232 (9209'1"); gray silt intercalated with fine-grained sand.

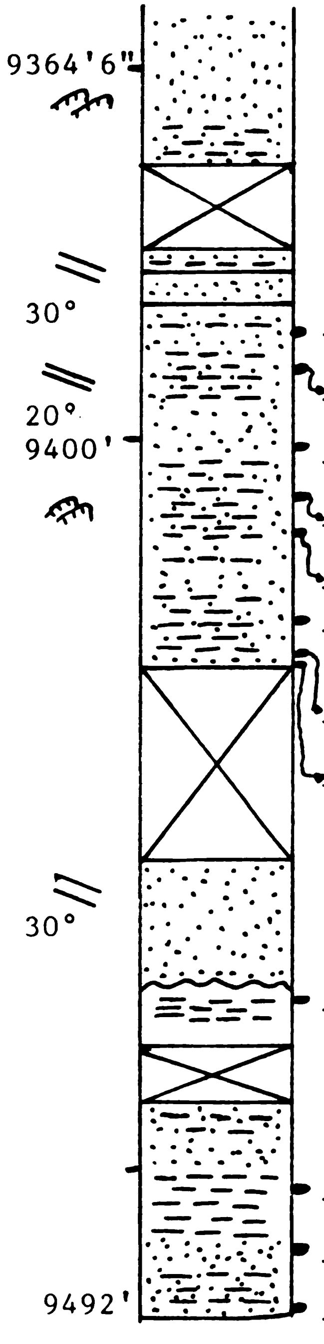
PB14231 (9213'1"); fine-grained sand intercalated with gray silt.

PB13996 (9217'1"); lignite.

PB13998 (9266'5"); massive fine-grained sand with carbonaceous nodules.

PB14234 (9270'10"); massive gray silt with carbonaceous nodules.

Figure 17-c. Lithology of the core of well B244 (continued)



PB14230 (9390'2"); fine-grained sand intercalated with silt. Sideritic nodules occur.

PB13999 (9393'7"); laminated gray silt.

PB14222 (9401'9"); fine-grained sand intercalated with silt.

PB14223 (9406'4"); fine-grained sand intercalated with gray silt.

PB14224 (9410'10"); laminated gray silt.

PB14225 (9419'2"); gray silt intercalated with fine grained sand. Sideritic nodules occur.

PB14226 (9423'2"); gray silt intercalated with fine-grained sand.

PB14227 (9424'11"); fine-grained sand with carbonaceous nodules.

PB13981 (9458'); laminated gray silt with carbonaceous material.

PB14228 (9478'11"); massive dark-gray silt.

PB14229 (9484'8"); massive dark-gray silt.

PB13997 (9491'4"); relatively massive dark-gray silt.

Figure 17-d. Lithology of the core of well B244.

SAMPLE DEPTH (FEET)	MANGROVE GROUP	PELTAND- RIPITES SP. GROUP	GENERAL GROUP	PALMAE GROUP	SPORE GROUP	DINO-ALGAE FORAM. GROUP
9055'4"	21	20	19	7	22	1
9058'7"	6	25	26	28	13	2
9067'3"	13	22	37	9	17	2
9111'2"	12	40	24	8	13	2
9135'2"	8	25	40	8	19	0
9188'10"	16	50	20	3	5	6
9201'2"	2	5	35	17	25	16
9205'1"	0	1	50	10	33	6
9209'1"	2	12	24	21	35	6
9213'1"*	0	0	60	40	0	0
9217'1"	1	12	31	31	19	6
9266'5"	3	9	34	20	32	2
9270'10"	14	14	52	0	20	0
9390'2"	16	22	32	14	16	0
9393'7"	0	0	0	0	0	0
9401'9"	0	0	0	0	0	0
9406'4"	0	0	0	0	0	0
9410'10"	0	0	0	0	0	0
9419'2"	11	22	42	14	10	1
9423'2"	9	19	42	16	13	1
9424'11"	18	10	30	13	15	14
9458'	15	6	43	18	16	6
9478'11"	29	0	45	23	12	1
9484'8"	39	11	26	12	11	1
9491'4"	29	7	40	14	6	4

Table 4. Percentages of the different groups of palynomorphs in the core samples of well B244 (* this sample only contained 5 specimens).

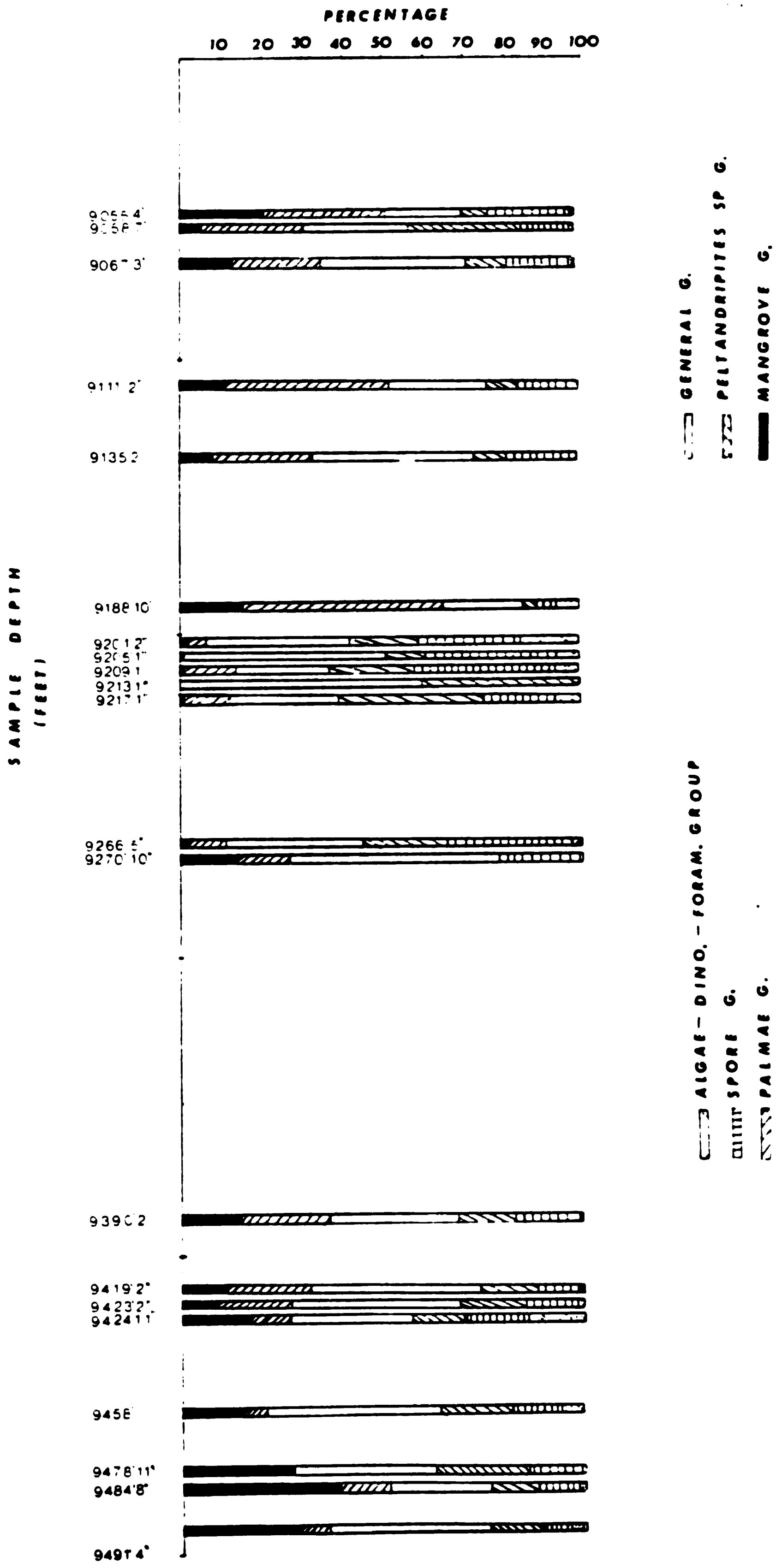


Figure 18. Well B244. Palynomorph diagram

In general, the percentages of the Mangrove group tend to decrease towards the middle of the section, passing from 29-39% to only 1-2% at 9266'5", 9217'1", 9209'1" and 9210'2". It can also be observed that the proportions of the Spore and the Palmae groups, relatively constant towards the bottom of the section, increase in the same interval at which the percentages of the Mangrove group decrease. An opposite tendency is observed at the top of the section. It should be noted that the drastic decrease of the Mangrove group occurs at the approximate level at which deposits corresponding to an upper deltaic plain begin to be observed.

The percentages of the Dinoflagellate-Algae-Foraminifera group varied throughout the section, but they are a very small part of the total assemblage, both in absolute number and in the number of different types. The main palynomorphs included in this group and found in this section are the fresh water algae Micrasterias sp. and Pseudoschizaea sp.. The dinoflagellate cyst Operculodinium sp. was observed in only one sample (9111'2").

The number of different types and absolute number of pollen grains related to grasses is very low in all the samples.

Well B248.

a) Sedimentology.

As in the case of well B244, two genetic sedimentary units were recognized:

- Low deltaic plain deposits (9485' to 9355");

Crevasse splay deposits (9485' to 9445'6"), characterized by relatively fine-grained sandstone with laminations of siltstone and carbonaceous material.

Distributary channel deposits (9455'6" to 9407'), characterized by relatively massive fine-grained sandstone, showing an erosional contact with the underlying fine-grained sediments. Cross-bedding (20°) occur. Unlike the sequence of well B244, the diminution of grain size is not as great, suggesting that this sequence represents deposits of an active distributary channel.

Distributary mouth bar deposits (9407 to 9353'), characterized by the transition from fine-grained sediments (siltstone) to laminated sandstone-siltstone towards the top.

Meander bar deposits (9348' to 9264'; 9215' to 9203' and 9181' to 9104'), characterized by relatively massive sandstone with high-angle cross-bedding (20°), intercalated with siltstone laminations. A sequence characteristic of an ox-bow lake occurs in the interval 9299'-9281'. This sequence consists of massive basal sandstone, exhibiting decreasing grain size towards the top. Well-laminated siltstone occurs at the top of the interval, suggesting the progressive abandonment of the meander channel and the progressive isolation of the ox-bow lake.

Natural leveé deposits (9264' to 9259' and 9203' to 9195'), characterized by fine-grained sandstone with intercalated siltstone, clay clasts, sideritic nodules and ripple marks.

Flood plain deposits (9259' to 9230'), characterized by gray siltstone showing convolute bedding in the lower part of the interval; becoming more massive towards the top. Abandoned channel deposits (9100' to 9056'), characterized by sandstone sequences, with decreasing grain size and bioturbation towards the top. Laminations of carbonaceous material and cross-bedding (10°) occur in the basal part.

The SP curve is shown in Figure 19 and the lithology of the recovered core is presented in Figure 20.

b) Palynology.

As in well B244, the assemblages throughout the section are relatively homogeneous. The same tendency for more diverse assemblages towards the lower part of the section was also observed.

Table 5 and Figure 21 present the fluctuations of the percentages of the different groups of palynomorphs. As in well B244, the percentages of the Mangrove group decrease drastically towards the middle of the section. Again, this dimunution of the abundance of this group roughly coincides with the approximate level at which characteristic deposits of an upper deltaic plain begin to be observed.

The percentages of the Palmae group and the Spore group are more variable than in well B244 and do not show similar tendencies to those noted in well B244. However, the Palmae group seems to increase in frequency in the interval at which the Mangrove group abundance diminishes. The Spore

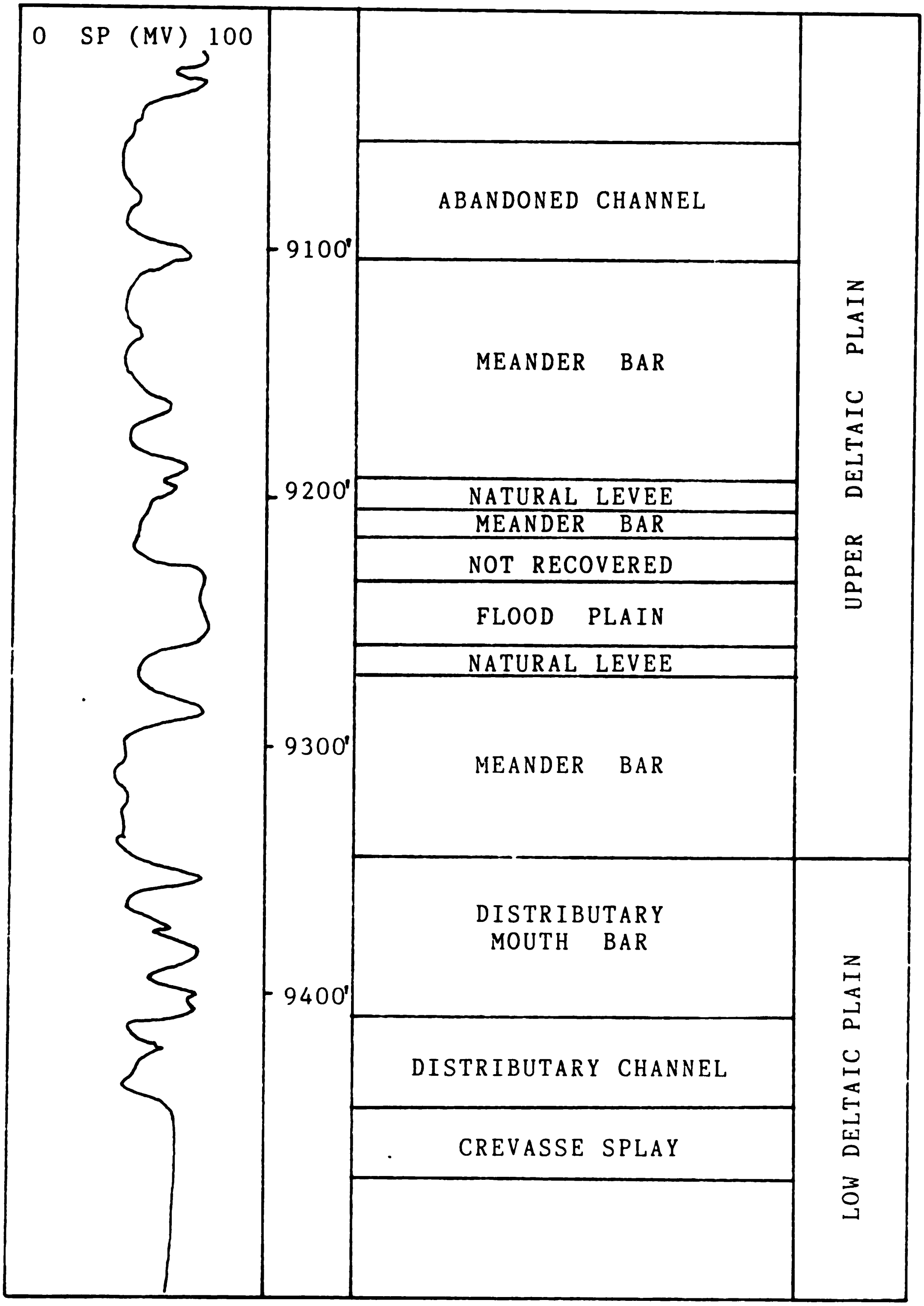
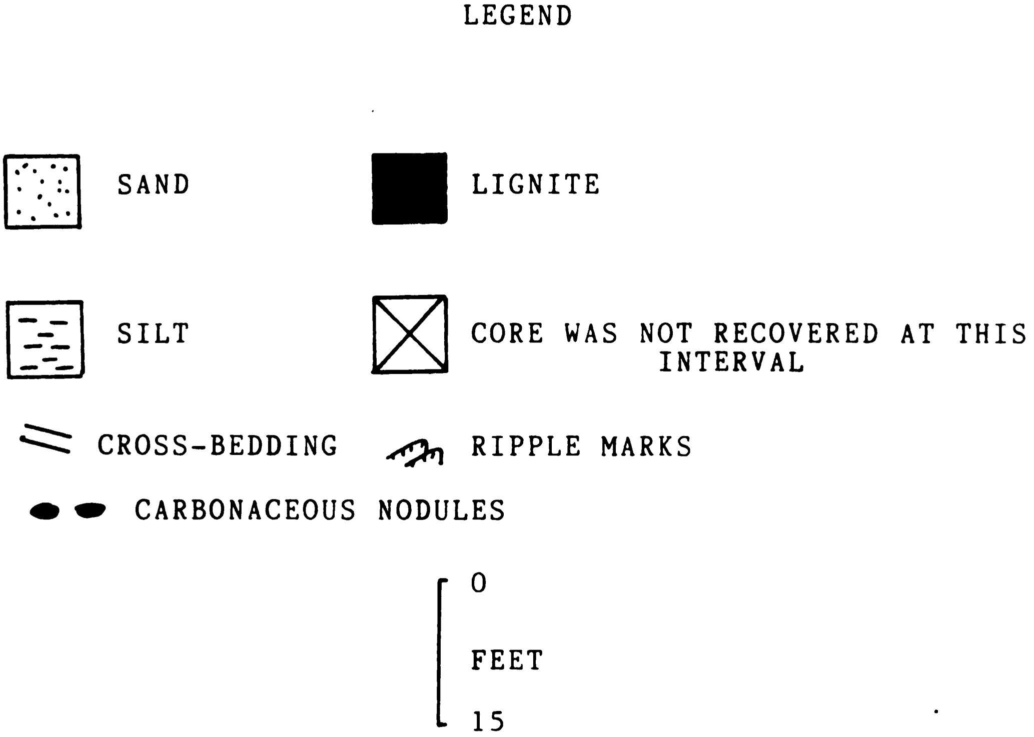
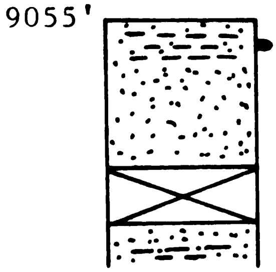


Figure 19. SP curve and environments of sedimentation-Well B248.

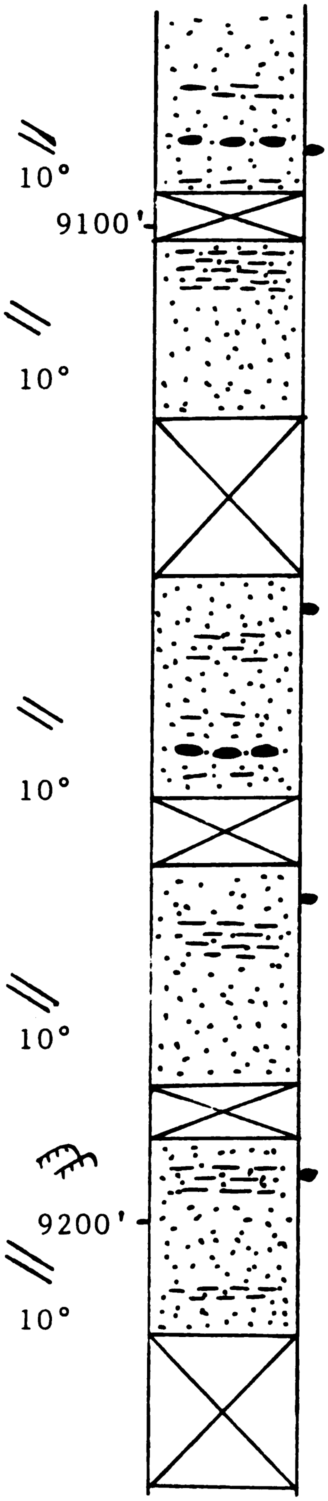
Figure 20. Lithology of the core of well B248.





PB14128 (9058'4"); gray silt intercalated with fine-grained sand and carbonaceous material.

Figure 20-a. Lithology of the core of well B248 (continued)



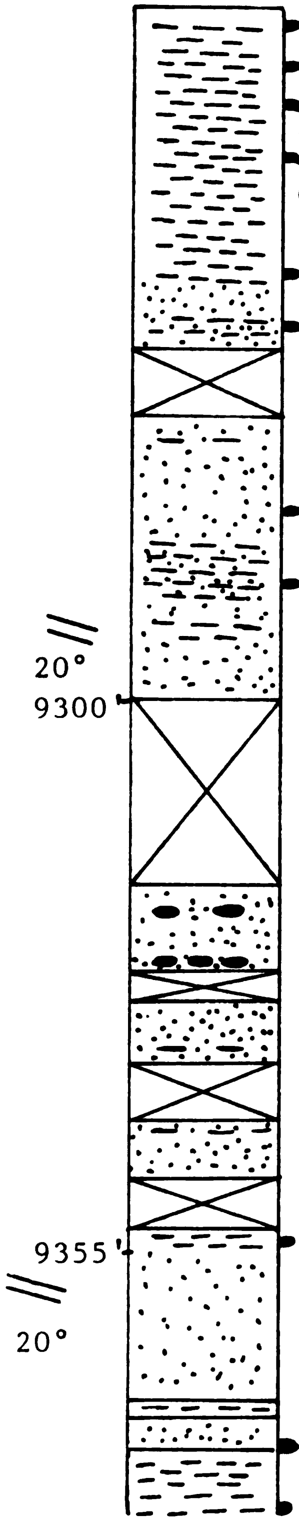
PB13982 (9095'4"); fine-grained sand intercalated with carbonaceous nodules.

PB14000 (9141'7"); fine-grained sand intercalated with gray silt.

PB14129 (9171'9"); fine-grained sand with carbonaceous material.

PB14127 (9198'3"); gray silt with sideritic nodules.

Figure 20-b. Lithology of the core of well B248 (continued)



PB14001 (232'3"); massive gray silt with carbonaceous material and sideritc nodules.

PB14186 (9236'7"); massive dark-gray silt with carbonaceous material.

PB14187 (9240'9"); massive dark-gray silt with sideritic nodules.

PB14188 (9246'11"); massive dark-gray silt.

PB14189 (9257'); dark gray silt intercalated with fine-grained sand.

PB14002 (9262'11"); fine-grained sand with carbonaceous material.

PB14190 (9281'3"); fine-grained sand intercalated with gray silt. Sideritic zones occur.

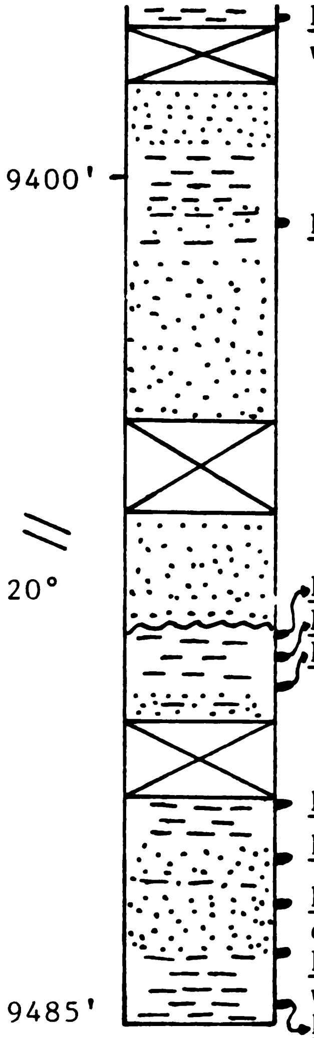
PB14003 (9288'11"); massive dark-gray silt.

PB14191 (9354'); massive gray silt.

PB14004 (9375'5"); dark-gray silt.

PB14198 (9381'6"); massive dark-gray silt with sideritic nodules.

Figure 20-c. Lithology of the core of well B248 (continued)



PB14197 (9384'4"); massive dark-gray silt with sideritic nodules.

PB14192 (9405'11"); dark-gray silt.

PB14193 (9445'7"); massive gray silt.

PB14194 (9448'8"); massive gray silt.

PB14005 (9452'11"); massive gray silt.

PB14195 (9463'3"); massive gray silt

PB14196 (9469'7"); dark-gray silt.

PB13983 (9473'3"); fine-grained sand with carbonaceous material.

PB14199 (9479'6"); gray silt intercalated with fine-grained sand.

PB14200 (9484'7"); gray silt.

Figure 20-d. Lithology of the core of well B248.

SAMPLE DEPTH (FEET)	MANGROVE GROUP	PELTAND-RIPITES SP. GROUP	GENERAL GROUP	PALMAE GROUP	SPORE GROUP	DINO-ALGAE FORAM. GROUP
9058'4"	12	9	52	9	8	10
9095'4"	0	0	0	0	0	0
9141'7"	7	10	56	9	14	4
9171'9"	20	8	26	29	17	0
9198'3"	1	0	50	23	25	1
9232'3"	3	1	36	21	34	5
9236'7"	2	1	40	14	38	5
9240'9"	0	0	49	13	16	22
9246'11"	19	5	27	12	33	4
9257'	0	4	33	28	34	1
9262'11"	6	12	48	14	16	4
9281'3"	5	5	51	8	23	8
9288'11"	0	0	64	14	22	0
9354'	0	0	0	0	0	0
9375'5"	45	5	22	7	21	0
9381'6"	23	9	35	4	28	1
9384'8"	0	6	49	6	35	4
9405'	22	6	34	10	26	2
9445'7"	37	2	40	8	13	0
9448'8"	17	5	58	7	11	2
9452'11"	21	2	41	13	22	1
9463'3"	25	15	33	20	4	3
9469'7"	33	11	36	13	6	1
9473'3"	24	1	32	10	29	4
9479'6"	35	0	32	9	16	8
9484'7"	32	1	34	9	17	7

Table 5. Percentages of the different palynomorphs groups in the core samples of well B248.

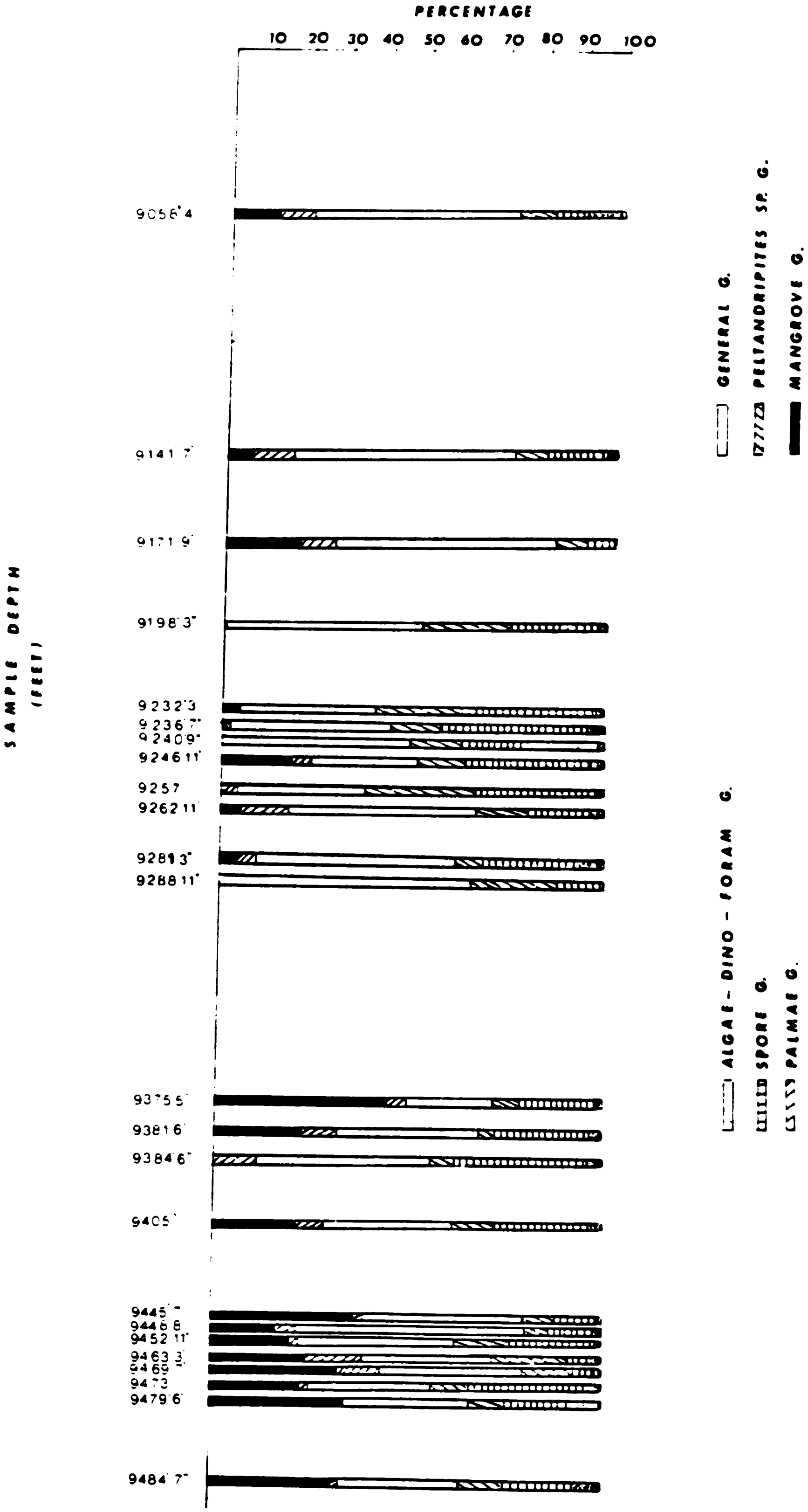


Figure 21 Well B248; Polynomorph diagram

group is more erratic, but there is some increase in its abundance towards the middle-top parts of the section.

The abundance of the Dinoflagellate-Algae-Foraminifera group is quite variable for most of the section. The maximum value of abundance of this group, was observed at 9240'9" (23%). At that level, it is composed of only the fresh water algae Micrasterias sp.. The only dinoflagellate cyst in this well was that of Operculodinium sp., at 9463'3".

Well B252.

a) Sedimentology.

As in the other two wells, two genetic sedimentary units were distinguished:

-Low deltaic plain deposits (8979'5" to 8921');

Crevasse splay deposits (8979' to 8967'), characterized by laminated fine-grained sandstone and siltstone, with irregular laminations and ripple marks.

Distributary channel deposits (8967' to 8948' and 8948' to 8921'), characterized by basal sandstone showing erosional contact with the underlying fine-grained sediments. As in well B248, the decrease in grain size towards the top is small, suggesting that these deposits represent sequences of active distributary channels.

- Upper deltaic plain deposits (8921' to 8555');

Meander bar deposits (8921' to 8869'/ 8852' to 8788' and 8788' to 8753'), characterized by sandstone with high-angle cross-bedding (20° to 30°), ripple marks and some intercalations of gray siltstone. The sequences contain sideritic zones and nodules, and bioturbation by rootlets and burrowing.

Natural leveé deposits (8869' to 8856'), characterized by gray siltstone, intercalated with laminations of fine-grained sandstone. The sequence contains sideritic zones and nodules, ripple marks and bioturbation.

Crevasse splay deposits (8735'6" to 8600'), characterized by intercalated fine-grained sandstone and siltstone. Sandstone is relatively massive and shows sideritic nodules. Bioturbation by rootlets and burrowing occur. Sandstone sequences are thicker in this sequence than in those described for the low deltaic plain deposits.

Abandoned cahnnel deposits (8600' to 8551'), characterized by basal sandstone with distinctive erosional contact with the underlying sediments. Basal sandstone is mostly massive, showing high-angle cross-bedding. Grain size decreases markedly towards the top. A lignitic layer occurs near the top of the section, indicating the progressive abandonment of the channel. A clear indication of the low energy environment is provided by a dicotyledon leaf compression, that is undistorted at 8644'2". Siltstone towards the top is well-laminated.

The SP curve and the lithology of the recovered core of this well are presented in Figures 22 and 23.

b) Palynology.

Table 6 and Figure 24 show the fluctuations of the relative abundances of the different groups of palynomorphs. Similar tendencies to those reported for well B244 and B248, in regard to recovery and diversity of assemblages, were observed. However, the recovery and preservation were the poorest of the three wells under study.

Unlike tendencies observed for the other two wells, the percentages of the Mangrove group shows a more erratic distribution. In the lower part of the section, the abundance remains relatively constant, and decreases drastically at 8867'4" and 8857'5". Towards the top, the abundances of this group tend to increase, with maximun values at 8792'8" and 8622'9". Those were also the samples with the largest amount of palynomorphs recovered in this well.

Another important tendency is shown by the so-called _Peltandripites_ sp. group, that is observed to be very abundant towards the top of the section.

The Dinoflagellate-Algae-Foraminifera group also shows significant variation, composed mainly by the fresh water algae _Micrasterias_ sp.. The only specimen of _Operculodinium_ sp. was observed at 8573'10".

Unlike those tendencies observed for the other two wells, the abundances of the Spore group and the Palmae group were observed to decrease towards the top of the section.

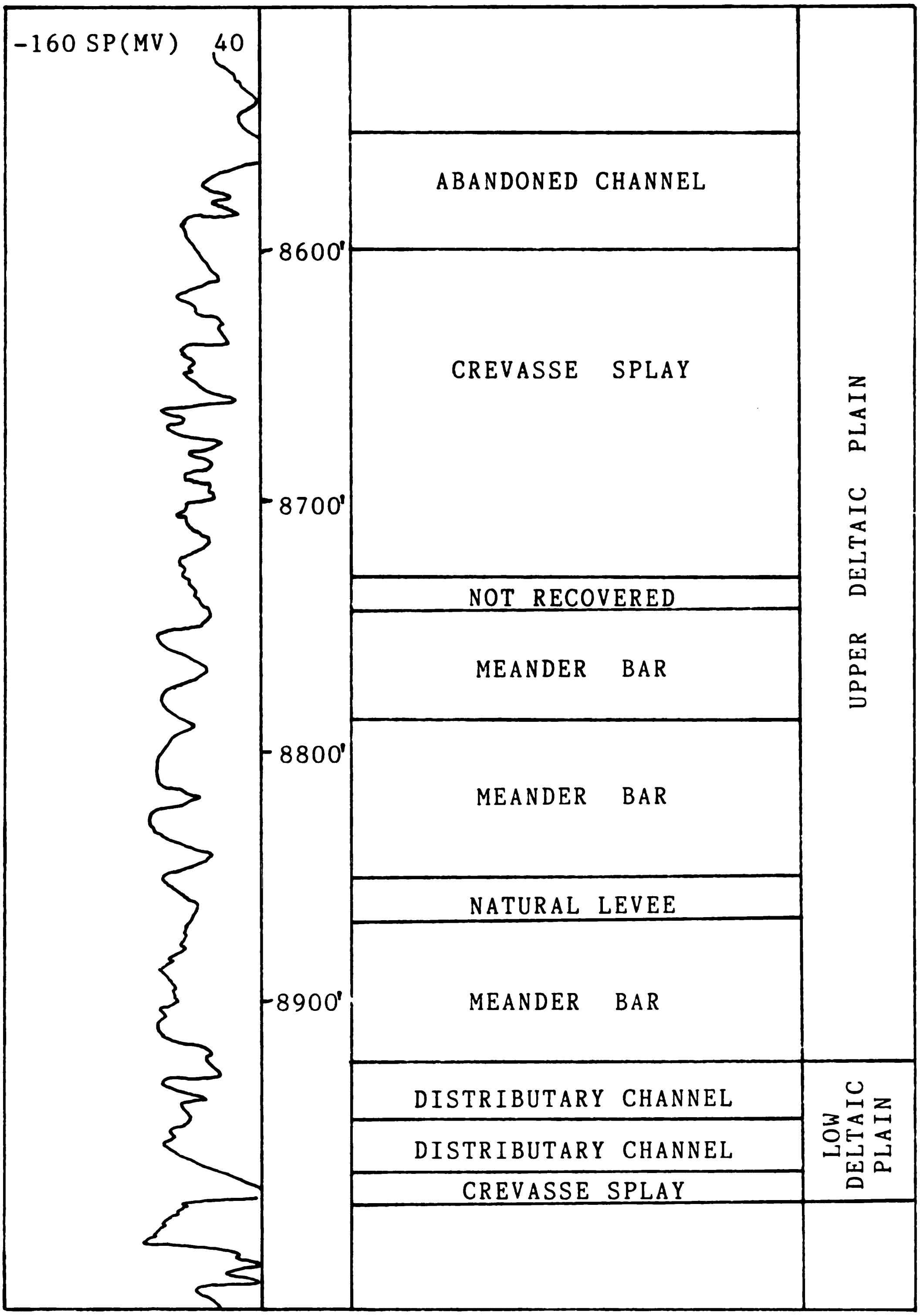


Figure 22. SP curve and environments of sedimentation-
Well B252.

Figure 23. Lithology of the core of well B252.

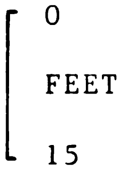
LEGEND

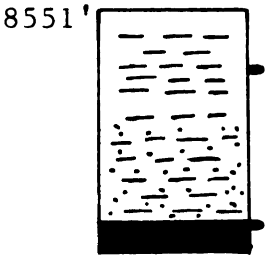
▨ SAND ■ LIGNITE

☰ SILT ☒ CORE WAS NOT RECOVERED AT THIS INTERVAL

⫽ CROSS-BEDDING ∿ RIPPLE MARKS

● ● CARBONACEOUS NODULES

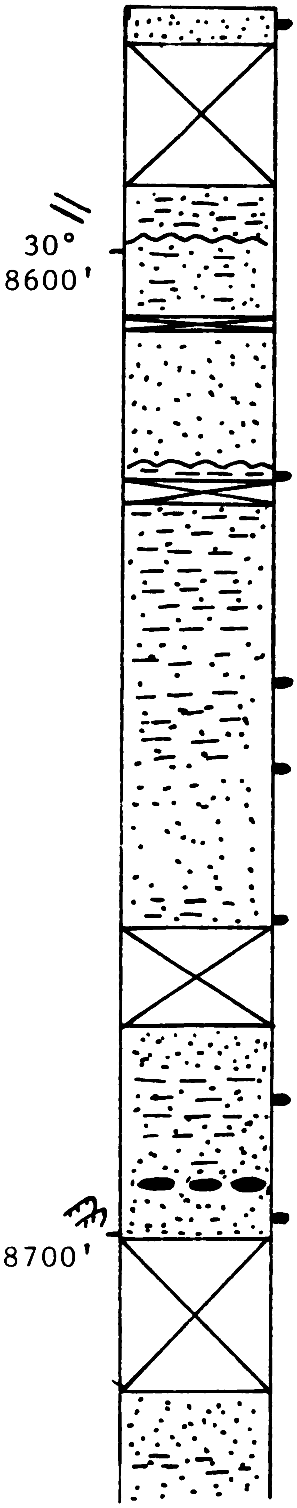




PB14041 (8558'); gray silt with sideritic zones.

PB14042 (8573'10"); lignite.

Figure 23-a. Lithology of the core of well B252



PB13984 (8575'6"); dark colored fine-grained sand.

PB13978 (8622'9"); dark-gray silt.

PB14043 (8644'2"); fine-grained sand intercalated with silt. Carbonaceous material and leaf compression occur.

PB14044 (8652'5"); fine-grained sand intercalated with silt.

PB13985 (8669'4"); fine-grained sand intercalated with silt. Organic nodules occur.

PB14045 (8686'2"); dark-gray silt with carbonaceous material.

PB13986 (8698'2"); fine-grained sand with carbonaceous material.

Figure 23-b. Lithology of the core of well B252 (continued)

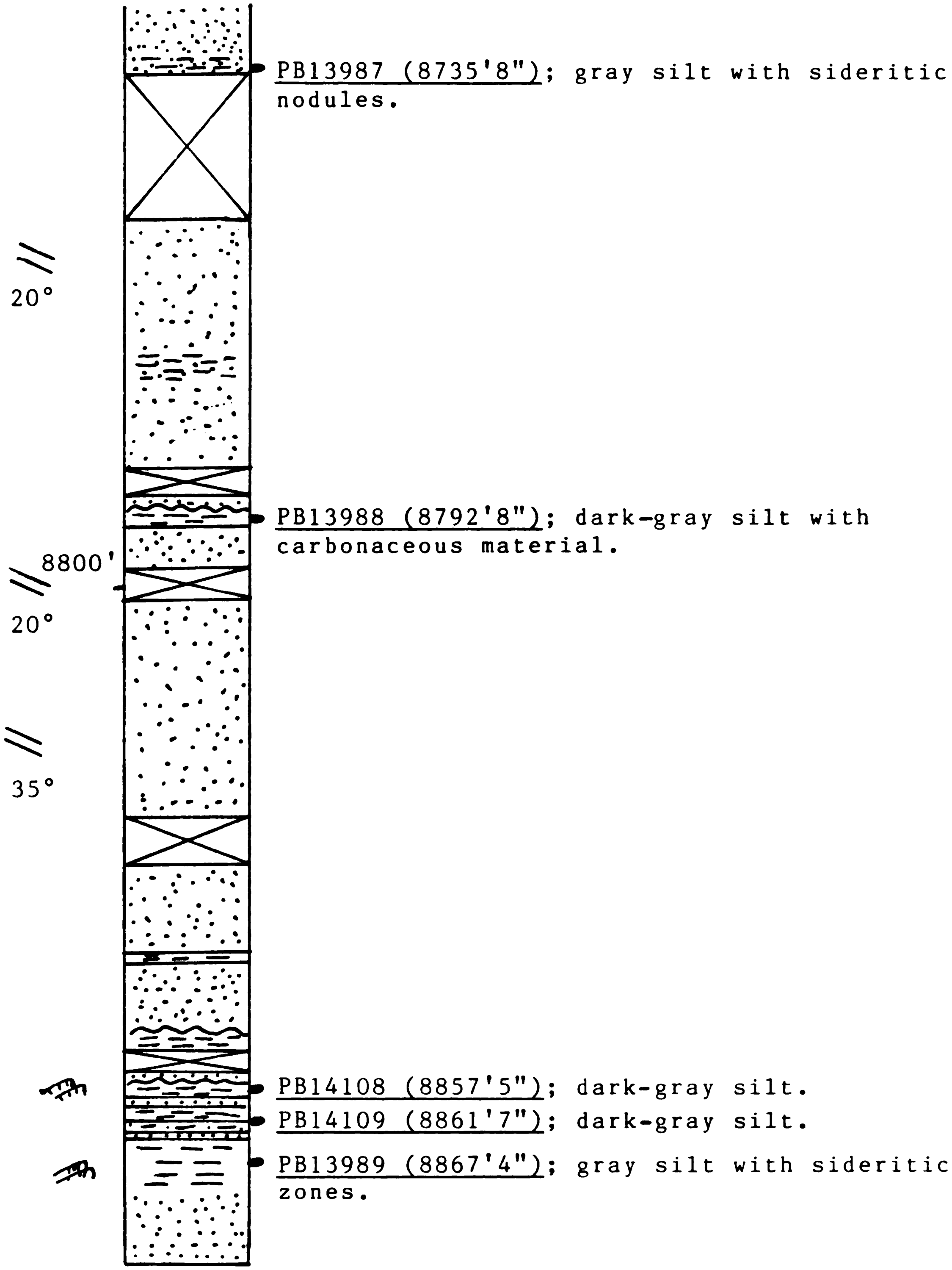
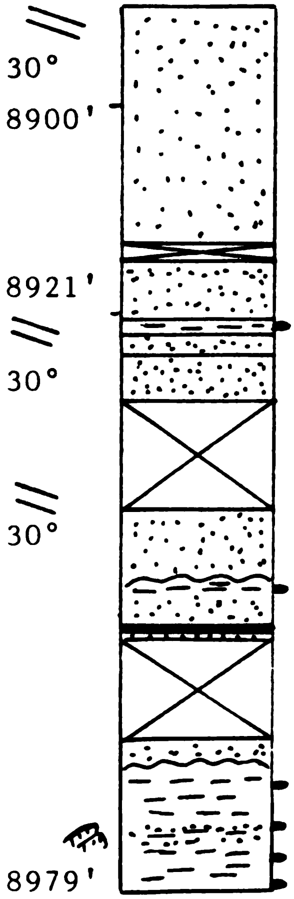


Figure 23-c. Lithology of the core of well B252
(continued)



PB14122 (8921'6"); dark-gray silt.

PB14123 (8948'10"); gray silt intercalated with fine-grained sand.

PB14124 (8967'3"); laminated gray silt with sideritic nodules.
PB14125 (8972'4"); fine-grained sand with intercalated silt.
PB13979 (8975'8"); dark-gray silt.
PB14126 (8978'8"); gray silt intercalated with fine-grained sand.

Figure 23-d. Lithology of the core of well B252.

SAMPLE DEPTH (FEET)	MANGROVE GROUP	PELTAND-RIPITES SP. GROUP	GENERAL GROUP	PALMAE GROUP	SPORE GROUP	DINO-ALGAE FORAM. GROUP
8558'3"*	13	0	13	13	61	0
8573'10"	21	49	15	4	7	4
8575'6"	0	38	25	7	19	11
8622'9"	17	47	18	2	15	1
8644'2"**	0	60	20	4	12	4
8652'5"	8	22	43	4	20	3
8669'4"	17	37	25	1	9	11
8686'2"	7	12	42	9	19	11
8698'2"	6	8	43	16	25	3
8735'8"	16	32	27	9	16	0
8792'8"	28	26	13	9	21	3
8857'5"	0	0	44	19	35	2
8861'7"	0	0	43	10	43	4
8867'4"***	0	14	57	0	29	0
8921'6"	13	7	27	13	40	0
8948'10"	11	40	23	11	13	2
8967'3"	17	8	43	15	17	0
8972'3"	17	16	37	13	16	1
8975'8"	14	12	31	13	30	0
8978'8"	15	10	31	23	20	1

Table 6. Percentages of the different groups of palynomorphs in the core samples of well B252 (*This sample only contained 8 specimens; ** this sample contained only 25 specimens; *** this sample contained only 7 specimens).

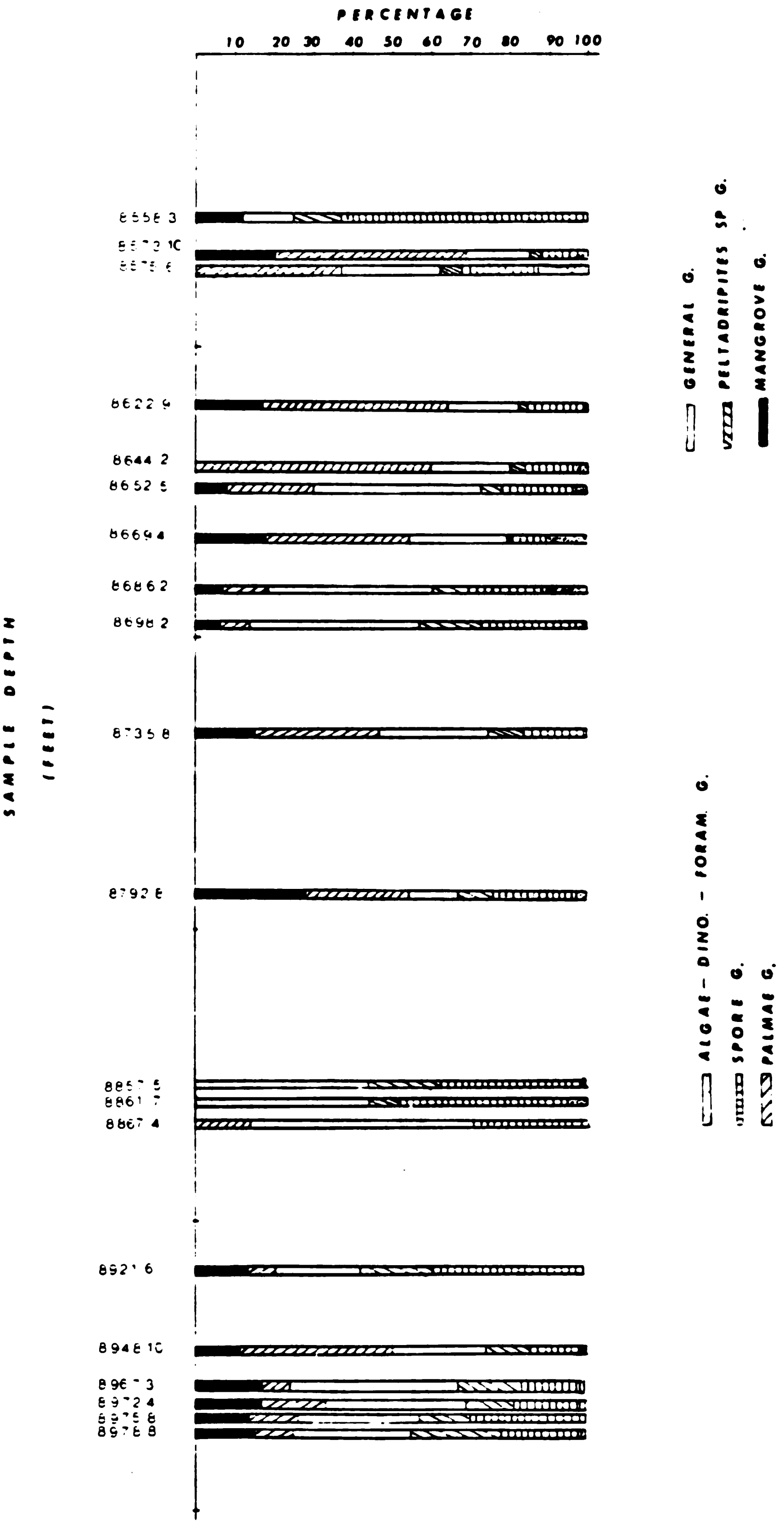


Figure 24. Well B252. Palynomorph diagram

III-3. <u>Cluster analysis results</u>.

The dendrogram of the clustering of the different samples under study is shown in Figure 25.

As seen, four principal clusters resulted. It should be noted that for the purposes of this study, the chi-square values obtained from two-by-two comparison of samples are considered as coefficients of similarity, regardless of their significance.

The characteristics of these four cluster elements are as follows:

1) Cluster I; characterized by very low relative abundances (0-2%) of the Mangrove group and high abundances of the General group and the Spore group. It is important to note that all the samples of this cluster, except one (9384'8" of well B248), correspond to sediments of an upper deltaic plain, and are located at the approximate level at which the transition from a low deltaic plain to an upper deltaic plain was inferred in the three wells.

2) Cluster II; characterized by high frequencies of the General group and by relatively moderate abundances of the Mangrove group (3-22%), of the Spore and the Palmae groups (8-40%). The location of the samples included in this cluster element was observed to be distributed in both the low and the upper deltaic plain deposits, with certain tendency towards the middle part of the sections.

3) Cluster III; characterized by the highest abundances of the Mangrove group. Samples of this cluster were observed

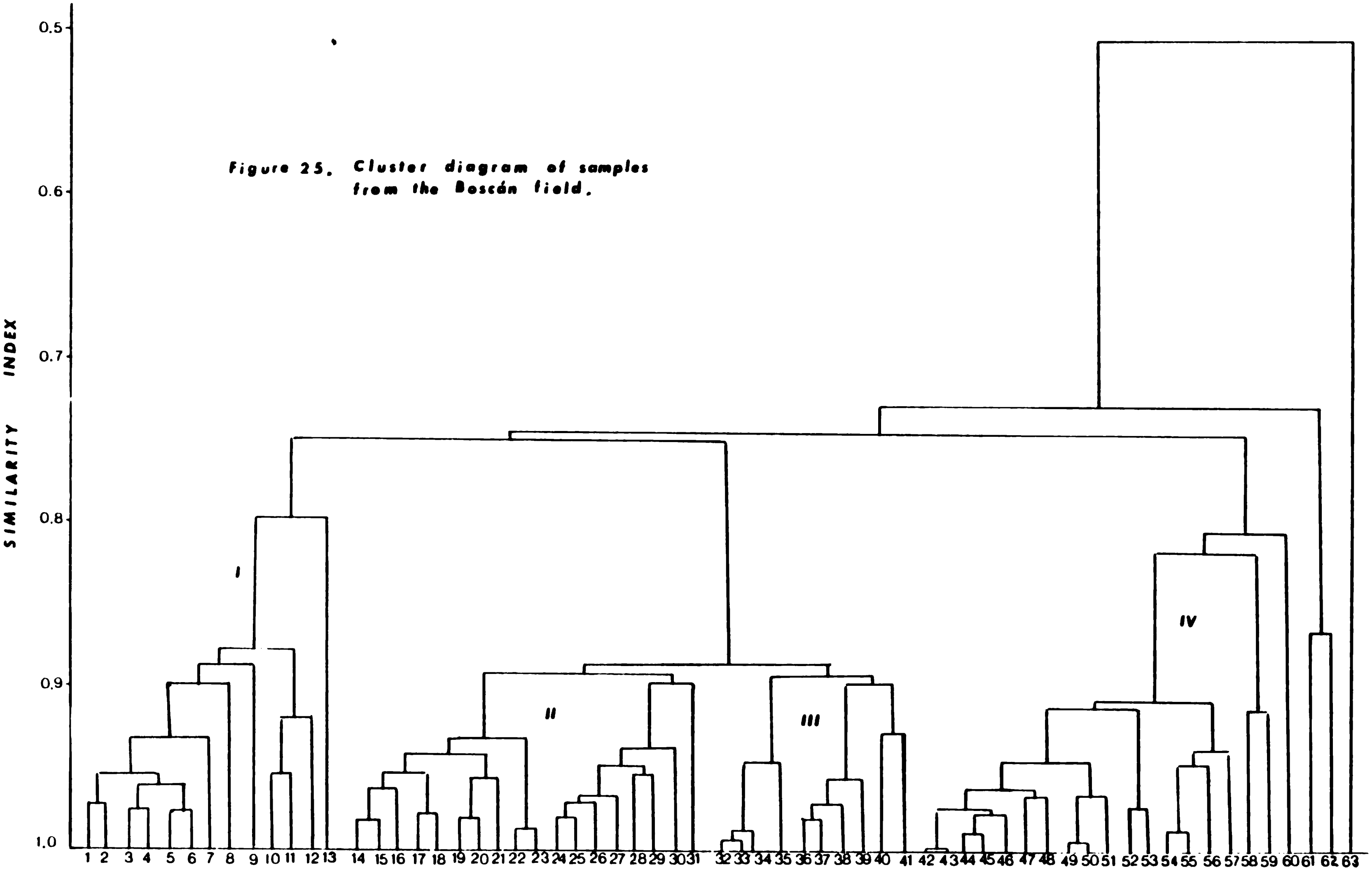


Figure 25. Cluster diagram of samples from the Boscán field.

in wells B244 and B248 only, at the lowest parts of the surveyed cores.

4) Cluster IV; characterized by samples with relatively high proportions of the so-called Peltandripites sp. group (14-60%) and variable relative abundances of other groups. Samples of this cluster were observed in wells B244 and B252. Their distribution corresponds mostly towards the top of the surveyed sections of these wells but also in the middle part.

IV. DISCUSSION

IV-1. Geological age range.

As mentioned in the introduction, the thickness of Eocene sediments is calculated at about 20,000 feet (6,096 m) in some areas of the Lake Maracaibo Basin. The recovered cores used in this study have lengths of about 440-470 feet (134-143 m), a fact that clearly indicates the limited time interval under consideration.

For the determination of geological time range, the recent zonation of Muller et al. (1985) was used. Fortunately, some of the palynomorphs with significant stratigraphic importance were easily identified in the palynological assemblages of the Boscán Field sediments. The presence of *Retibrevitricolpites triangulatus* and *Echitriporites trianguliformis* throughout all the sections under study clearly indicates that these sections are not younger than Late Eocene. The range distribution of *R. triangulatus* is restricted to the Eocene in northern South America (Muller et al., 1985), whereas that of *E. trianguliformis* extends from the Cretaceous to the late Eocene.

In addition, the presence of *Retitricolpites magnus*, *Psilatricolporites operculatus* and *Retitricolporites irregularis*, seems to delimit the age range of these assemblages to the Middle Eocene. As noted, the presence of these palynomorphs were recognized in the Misoa Formation by Muller et al. (1985).

A final point should be made in regard to the existence of an Eocene-Oligocene unconformity in the sections under study. Studies made by CORPOVEN S.A. and Swanson (Azpiritxaga, personal communication) reported the existence of this unconformity at the following depths:

WELL	CORPOVEN S.A.	SWANSON
B244	9213'	9050'
B248	9036'	9036'
B252	8861'	8600'

However, according to the results obtained in this study, there is not an abrupt change of the flora that could indicate the existence of this unconformity at the levels predicted by CORPOVEN S.A. in the three sections under study or in well B252, at the level predicted by Swanson. The palynological assemblages of the Oligocene are considered to be very different to those of the Eocene, due to climatic changes (Germeraad et al., 1968). Therefore, it can be stated that the absence of characteristic flora of the Oligocene in the samples under study seems to negate the existence of the Eocene-Oligocene boundary in the sections under study.

IV-2. Abundance of palynomorphs.

As previously mentioned, the absolute abundances of palynomorphs per gram of sample showed marked variations throughout the sections under study. Unfortunately, palynological studies reporting absolute abundances, were not found for comparison. Frederiksen (1985, p. 27) pointed out the fact that few palynologists working on Early Tertiary palynological assemblages, used this type of data for their paleoecological interpretations.

The marked fluctuations in the abundance of palynomorphs per unit of sediment may be attributed to several different factors. The principal ones considered to be important in the samples studied are briefly reviewed below.

The first is the preservation of organic matter in the sediments after deposition. This fact is related to the oxidation of the organic matter, due to the interaction with fungi-bacteria and the atmosphere. Since sideritic zones and nodules occur in all the sections under study, this interaction could have played a significant role in causing the observed fluctuations. These sideritic zones and nodules can be formed in the sediments in periods between flooding, when the sediments are left exposed to the atmosphere because variations in the water table level. The interaction of oxygen with minerals containing iron, leads to the oxidation of these minerals, forming Fe^{+3} (very insoluble) as the dominant form of iron in the sediments.

It should be noted that the largest recoveries of palynomorphs were obtained in dark-gray sediments, with abundant carbonaceous material. Because of the characteristic color and the absence of sideritic nodules and zones, these sediments seem to have undergone no oxidation. Therefore, it can stated that the oxidation of organic matter after deposition is one of the main factors causing the observed fluctuations in the samples under study.

A second important factor is the supply of palynomorphs into a particular type of environment. Muller (1959) noted that the abundances of palynomorphs varied due to local shifting of sedimentary environments in the Orinoco River Delta. Muller (1959) observed that the local transport of palynomorphs can be reduced in some areas of the delta. For example in the back-swamp area, water movement is restricted to the periods of flood stage, affecting the supply, and therefore, the amount of palynomorphs in a given sedimentary environment.

It should be recalled that the more diverse assemblages in the samples studied were found in the interval characterized as a low deltaic plain. This fact can be related to the role of sorting and mixing of the palynological assemblage, not only in the distributary channels, but also in distributary mouth bar complex, where the palynomorphs undergo hydraulic sorting along with the clastic sedimentary particles. Moreover, tidal influence also causes mixing of the assemblage in different environments, especially in the low deltaic plain.

Other factors, such as distance of the source plants from the sites of deposition and long-shore currents, also have noticeable effects not only in the composition of the palynological assemblages, but also in the abundance of the different types of palynomorphs in different environments of deposition.

IV-3. Paleoenvironmental and paleocommunity inferences.

The absence of significant amounts or of high frequencies of marine elements clearly indicates that the sediments under study were deposited under minor marine or tidal influence. Except for the dinoflagellate cyst of *Operculodinium* sp. (found in very low frequencies), the rest of the palynological assemblage has a clear terrestrial origin.

The frequencies of the Mangrove group, especially in the lower part of the surveyed cores, also seem to indicate minor marine or tidal influence. It should be recalled that the general definition of the mangrove community (Muller, 1964) includes the estuarine vegetation growing under tidal influence and in environments with variable salinity.

Using the results presented for the fluctuations of the different groups of palynomorphs, and the results of the cluster analysis, two extreme situations are observed. One, in which the relative abundance of the Mangrove group is relatively high, and in the other, in which the relative abundance of this group is very low. In between, the other two cluster elements seem to represent a kind of transitional situation.

Before going into the discussion of the results of this study, a brief review of the factors affecting the relative abundances of the different types of palynomorphs, in deltaic and swampy environments, is presented.

Muller (1959), in a detailed study of the dispersal patterns of palynomorphs, noted that the relative frequencies of different types of pollen were significantly affected by the type of vegetation located in the proximity of the environment of deposition. This fact becomes quite important in a deltaic environment, in which several vegetational belts or zones have been described by different authors. For example, Allen (1965) distinguished two main vegetational belts in the Niger Delta; that of mangrove dominated vegetation and the other dominated by more inland vegetation. Muller (1959) clearly distinguished at least 7 different types of vegetational zones in the Orinoco Delta, going from the mangrove forest, mixed-swamp forest and <u>Erythrina</u> swamp forest (located mainly in the low deltaic plain), to the palm and herbaceous swamps and rain forest, located towards the higher plains and leveés of the upper delta. Blasco and Caratini (1973) distinguished three different types of plant communities, the distribution of which were affected by tidal influence in a mangrove swamp. The first, near to the coast, is the mangrove-type community, subdivided into two zones; one that was continuously immersed by salt-water and that was dominated mainly by <u>Rhizophora</u>, and the other that was variably immersed, dominated by <u>Avicennia</u>. The second belt of vegetation that Blasco and Caratini distinguished was found in terrains with occasional tidal or marine immersion. This vegetational belt was characterized by the presence of plants of the family Chenopodiaceae and Palmae.

Finaly a third type of vegetational belt was observed to be found in areas that lacked tidal or marine influence, and it was mainly dominated by palms. These authors determined that the frequencies of the different palynomorphs had high variability, depending on the location of the collecting spot within the swamp.The palynological spectra clearly reflected the influence of the nearby vegetation. The percentages of autochthonous pollen were significantly higher in flood plain and swamp environments than those of allochthonous pollen. These authors, on the other hand, observed that allochthonous pollen became more significant in samples collected in river channels. These observations clearly agree with the main tendencies observed by Muller (1959) in regard to the effects of the dispersal patterns of the palynomorphs on the palynological spectra found in different environments. Other factors affecting the distribution of palynomorphs, such as the grain size of the palynomorphs, are discussed by Muller (1959) and will not be repeated here. The effect of the vegetation located in proximity to the environments of deposition, on the abundances of palynomorphs, was also discussed by Cohen and Spackman (1972) and Cohen (1975) in their studies of the Okefenoke Swamp and Everglades of Florida.

Returning to the results obtained in this study, it is clear that an established dominance by a given type of palynomorph or group of palynomorphs, such as those reported by van der Hammen and Wijmstra (1964), González Guzmán (1967) and Wijmstra (1969), was not observed. Muller (1959) and

Blasco and Caratini (1973) noted that mixing of the palynological assemblage was more efficient in channel samples. It should be noted that most of the sequence under study comprises distributary channels (in the low deltaic plain) and meander bar deposits (in the upper deltaic plain). Therefore, it seems reasonable to suggest that the type of sedimentary environment is one of the factors controlling the relative abundances of the different groups of palynomorphs. The lack of dominance by any group of palynomorph in this study can be caused in part by the mixing of the assemblage in channels of the deltaic system, where the proportions of the allochthonous pollen should be found in higher proportions than autochthonous pollen.

As mentioned in the results, the tendencies shown by the relative abundances of the different groups of palynomorphs seem to suggest a transition from a low deltaic plain to an upper deltaic plain. Based on the results obtained in the cluster analysis, it can be inferred that such changes occurred accordingly.

In the lower part of the surveyed cores, specifically in wells B244 and B248, samples clustered under III (characterized by relatively high frequencies of the Mangrove group) were observed to be common. Then, a gradual decline in the frequencies of this group was noted. This decline was noted in samples clustered under II and IV, characterized by samples containing moderate frequencies of the Mangrove group. In well B252, the lower part of the surveyed core was also characterized by samples containing moderate frequencies of the Mangrove group (clusters II and IV). Towards the middle part of the three sections under study, a significant decrease in the frequency of the Mangrove group was observed. In wells B244 and B252, these samples were observed to be restricted to the middle part of the sections, whereas in well B248, they were observed to occur in the middle and in the upper parts of the sections. Finally, towards the top of the three sections under study, samples clustered under II and IV were observed to be common.

This type of distribution seems to suggest environmental changes, that are reflected in the changes of the distribution and relative frequencies of the different groups of palynomorphs.In the three wells, it was observed that the range of Juglanspollenites sp. (Chenopodiaceae) goes from the middle of the section to the upper parts, and tends to disappear in the uppermost samples. Blasco and Caratini (1973) noted that several species of this family were observed in swampy terrains subjected to occasional immersion. This occurrence was observed to happen at the same intervals at which the relative abundances of the Mangrove group show a gradual decline. These two facts; therefore, seems to suggest the prograding nature of the deltaic system under study, and the gradual transition towards an upper deltaic plain.

A further vegetational change is observed at the level at which the sedimentological model proposed by INTEVEP S.A. predicted the transition from sediments of a low deltaic plain to those of an upper deltaic plain. This change is characterized by the drastic decrease in the frequencies of the Mangrove group, and in some cases, of the Peltandripites sp. group. As noted in the previous chapter, the relative frequencies of the Palmae group, General group and the Spore group, tend to increase at this level, also indicating the transition from a low deltaic plain to an upper deltaic plain. For example, in sample 9217'10" of well B244, a lignite, the frequencies of the Palmae group and the Spore group totalled almost 50% of the total palynological assemblage, with the frequencies of the Mangrove group characterized by a very low value.

Towards the top of the sections under study, samples clustered under II and IV were observed to be common. As previously mentioned, these types of cluster elements seem to represent transitional palynological assemblages. In these samples, the frequencies of the Mangrove group were observed to be moderate. This fact could indicate that towards the top of the sections, there was minor tidal influence and that a kind of transition to a low deltaic plain could have been taking place. This inference would agree with the sedimentological model proposed by Azpiritxaga (1985) for other areas of the Boscán Field (refer to pages 25 and 27 of the introduction). This transition could also be related to the significant subsidence proposed by Zamora (1977) and Bockmeulen et al. (1983) for some areas of the Lake Maracaibo Basin. It should be recalled that according to these authors, the significant subsidence caused the piling up of deltaic sequences without major transgressive and regressive cycles.

A final point should be made in regard to the transitional clusters II and IV. The latter, as mentioned before, is characterized by relatively high frequencies of the so-called Peltandripites sp. group. This fact seem to suggest that the environments of deposition under study in wells B244 and B252 were closer to places where plants producing this palynomorph were growing. Besides this difference, other elements of the assemblage observed in these two cluster elements were quite similar to each other.

Figure 26 presents the proposed biozonation for the three wells under study. The type of biozone used for this purpose is the Assemblage-zone (International Stratigraphic Guide, 1976, p.50-52). The different Assemblages-zones were recognized based on the components of the palynological assemblages of the Boscán Field sediments, as well as on the results of the cluster analysis. Assemblages-zones are particularly significant as indicators of environments at the local level.

In regard to the type of community present at the time of deposition, one limitation should be emphasized. As in other publications dealing with the palynology of Tertiary tropical sediments, the interpretations of this study were made based on few taxa. Graham (1985) pointed out that most of the elements of the palynological assemblages of tropical areas lack defined botanical affinities. He also noted that

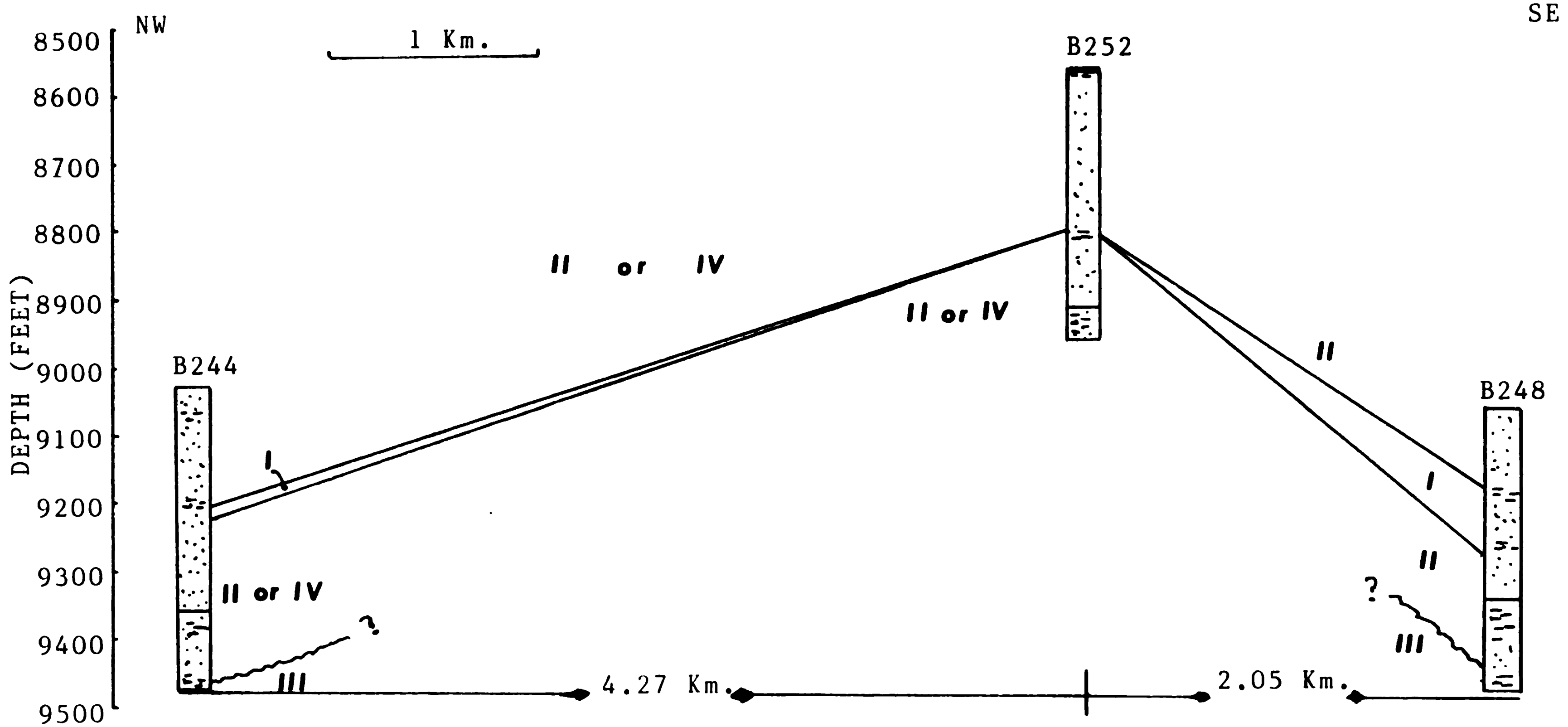


Figure 26. Cross section of the southeast corner of the Boscán field, along a traverse striking N28°W. The proposed biozonation for the sections under study is shown. Roman numerals correspond to the different types of cluster discussed in the text.

the definition of these affinities in Eocene palynomorphs is made more difficult by the fact that at that time transition to modern floras was taking place, and that the morphologies of numerous taxa do not match those of current ones.

Based on the results obtained in this study, it can be stated that the type of plant paleocommunity existing at the time of deposition seems to be characterized by the following attributes:

1) The lack of dominance by any group of palynomorphs, that is caused by the influence of the sedimentary environment or by a mixed and diverse community.

2) The very low frequencies of the Brevitricolpites group, proposed by González Guzmán (1967) as an ecological equivalent to the mangrove community in Eocene sediments of Colombia, seems to indicate that the environments of deposition under study could have been located behind the vegetational belt located closer to the coast.

3) The presence of various species of the genus Bombacacidites (Bombacaceae) and Juglanspollenites (Chenopodiaceae), seems to suggest the presence of a mixed-swamp vegetation, such as those described by Muller (1959, p. 4) and Blasco and Caratini (1973). Frederiksen (1985) also documented the main components of this type of mixed or marsh-swamps, noting the presence of specimens of the genus Bombacacidites.

4) The nearby presence of mangrove-type community can be inferred from the presence of the following palynomorphs:

a) Brevitricolpites group (discussed before)

b) *Psilatricolporites crassus* (*Pelliceria*, Thaceae), reported by Wijmstra (1968) as presently associated to mangrove communities occurring in the Pacific coasts of Central America and Colombia. According to Wijmstra (1968), the distribution of this palynomorph showed a wider range, including the Caribbean area during the Tertiary.

c) *Nypa* pollen types, reported by Muller (1964 and 1968) as being related to mangrove palms.

d) *Echitriporites trianguliformis*, that was associated with coastal vegetation by Germeraad et al. (1968).

According to Frederiksen (1985), the first three palynomorphs constitute valuable indicators of salt-water coastal environments. Frederiksen also mentioned the genus *Proxapertites* as another possible indicator of coastal environments. However, Thanikaimoni et al. (1985) reported that this palynomorph is associated with some climbers in evergreen forests of tropical regions. Therefore, for this study, this palynomorph was not used for this type of interpretation.

This set of observations seems to suggest that the plant paleocommunities existing at the time of deposition were relatively diverse. The palynological assemblages seem to include elements of characteristic coastal vegetation and elements of mixed-swamp vegetation. This interpretation seems to agree with the inferences of the sedimentological model and the vegetational changes inferred from the fluctuations of the proportions of the different groups of palynomorphs.

IV-4. Comparison to other palynological assemblages.

Due to the lack of complete and detailed published information from palynological studies in northern South America, limited comparison can be done at this moment. Only two palynological assemblages of similar age and geographical proximity were found in the literature. The first is the one described by González Guzmán (1967), from the Paleocene-Eocene Upper Los Cuervos and Mirador Formations in eastern Colombia. Some of the palynomorphs described by González Guzmán were also observed in the palynological assemblages from the Boscán Field; however, the similarity is less than expected in sediments believed to be of the same age. Two possible explanations can be postulated for explaining the observed differences:

1) Geographical distance between zones under study.
2) Differences in the sedimentary environments. The Mirador Formation was deposited in a fluvial environment, whereas the Misoa Formation was deposited in a deltaic complex.

The second palynological assemblage is the one described by Graham (1985) from the Late Eocene of Panama. Again, some similarity was observed.

As seen in Appendices A and B, some of the palynomorphs identified in this study have been described in other publications dealing with tropical palynological assemblages (Graham, 1985) or subtropical palynological assemblages (Frederiksen, 1980). This fact clearly indicates that tropical or subtropical conditions existed existed at that time.

IV-5. Limitations of this study.

There are two principal factors limiting the interpretations previously presented. The first is the limited knowledge on Tertiary floras of northern South America. As Graham (1985) noted, more extensive studies are necessary for the understanding and characterization of Tertiary tropical floras and their paleocology.

The second factor is related to the types of lithology considered for this study and the type of sampling used. Fisk (1986) pointed out that palynomorphs undergo hydraulic sorting, as clastic sedimentary particles do. Therefore, a more detailed sampling, comprising different types of lithology, would have provided a more complete paleoecological view, avoiding the possible bias caused by considering only a restricted range of lithologies.

V. CONCLUSIONS AND SUMMARY

The palynological analysis of 71 core samples from three wells of the Boscán Field, Venezuela, was performed.

As described, the palynological assemblage, as a whole, was mainly composed of angiosperm pollen, fern spores, fresh water algae, a species of a dinoflagellate cyst, and abundant fungal spores and fructifications. The low abundance of gymnosperm pollen has also been noted by other authors, and according to Penny (1969, p. 349), it is due to the significant replacement of gymnosperms by angiosperms during the Paleocene in South America. Comparison to other palynological assemblages is still superficial and inconclusive. In general, it reveals a subtropical or tropical paleoclimate at the time of deposition.

The palynological assemblage is characterized to be of Middle Eocene age. The presence of *Echitriporites trianguliformis*, *Retibrevitricolpites triangulatus*, *Psilatricolporites operculatus*, *Retitricolporites irregularis* and *Retitricolpites magnus*, delimit the assemblage to zones 19 and 20 of the recent palynological zonation published by Muller et al. (1985). Future characterization will be done as soon as the complete information of this zonation is published. The results of this study also show that an Eocene-

Oligocene unconformity, previously proposed by other workers, does not occur in the sections studied.

The absence of abundant marine elements in the palynological assemblages clearly indicates that the sediments under study were deposited in environments with minor marine influence. Based on the lithologic characteristics, it was concluded that the general environment was a deltaic complex.

Throughout the sections under study, environmental changes were noted. Lithologic information clearly indicates the existence of two genetic sedimentary units; a low deltaic plain and an upper deltaic plain. The SP logs clearly indicates the different nature of the curves for these two main sedimentary units.

Palynological results agree with the interpretation mentioned in the previous paragraph. By using the fluctuation of the relative frequencies of the different groups of palynomorphs, a gradual transition from a low deltaic plain to an upper deltaic plain is apparent. This transition is characterized by the gradual decrease of the relative frequencies of the so-called Mangrove group, and the increase of the frequencies of the Palmae group and the Spore group. A similar tendency was reported by other authors as indication of regressive periods. In the case of this study, however, the author would like to relate this tendency to the prograding nature of the delta complex (there is not enough evidence in the sections under study for complete regressive-transgressive cycles).

A difference of the results of this study and those reported by van der Hammen and Wijmstra (1964), González Guzmán (1967) and Wijmstra (1969) is the lack of dominance (very high abundances) by any group or type of palynomorph. In the case of this study, this fact is attributed to the types of environment of deposition. They were mostly deposits associated to channels (either distributary or meander). According to Muller (1959) and Blasco and Caratini (1973), allochthonous pollen were observed to be in larger proportions in channel samples than in samples taken directly in the swamp, that reflected more the nearby vegetation.

The gradual transition from a low deltaic plain to an upper deltaic plain is also verified by the different cluster groups obtained using the Similarity Index of Jameossanaie (1983). As extensively described in the previous chapter, those samples showing relatively high frequencies of the Mangrove group (cluster type III) were observed to be located in the lower parts of the sections corresponding to wells B244 and B248. Then, samples with moderate frequencies of this group were observed to begin in the middle part of the sections of the three wells (cluster types II and IV). A more drastic decrease was then observed in the middle part of the sections (cluster type I), whereas transitional situations (clusters II and IV) were also observed towards the top of the three sections. This transitional situation seems to suggest incipient tidal or marine influence in the area at that time, and a probable transition towards a low deltaic environment, as it was postulated by Azpiritxaga (1985). Future evaluations of samples above and below the depths included in this study would provide evidence for a more complete view of environmental changes in the area and the subsequent changes of vegetation. Based on these results, the biozonation of the three subsurface sections was accomplished, using the results of the cluster analysis and the fluctuations of the relative abundances of the different groups of palynomorphs (Figure 26).

Finally, in regard to the paleocommunities of plants present at the time of deposition, a mixed community, with a coastal vegetational component (the so-called Mangrove group) and a mixed-swamp vegetational component, growing under minor or no tidal influence, existed. This inference agrees with the sedimentological model proposed by INTEVEP S.A.. Future research in areas near the zone under study, would provide a better paleogeographical view of the distribution of the vegetation in the area. Future characterization of the botanical and paleoecological affinities of the taxa found in sediments of the Boscán Field, will help to improve the knowledge in regard to the types of plant paleocommunities existing in the Middle Eocene of northwestern Venezuela.

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APPENDIX A

Appendix A

Alphabetical list of the Boscán palynomorphs

TAXA	PLATE	FIGURE
Aglaoreidia sp. 1	X	8
Anacolosidites sp. 1	XI	6
Bombacacidites sp. 1	IX	8
Bombacacidites sp. 2	IX	9
Bombacacidites sp. 3	IX	10
Bombacacidites sp. 4	IX	11
Cingutriletes sp. 1	III	2
Cingutriletes sp. 2	III	3
Cingutriletes sp. 3	III	4
Classites sp. 1	XIII	1
Clavatricolpites sp. 1	VII	1
Clavastephanocolporites? sp. 1	XI	8
Cricotriporites sp. 1	XI	5
Curvimonocolpites sp. 1	IV	11
Echimonocolpites sp. 1	V	7
Echimonocolpites sp. 2	V	8
Echimonocolpites sp. 3	V	9
Echiminocolpites sp. 4	V	10
Echitricolpites sp. 1	VII	2
Echitriletes sp. 1	II	10
Echistephanoporites sp. 1	XI	9
Echitriporites trianguliformis	X	11
Echitriporites sp. 1	X	12
Equisetosporites sp. 1	IV	1
Fungal fruit-body (Acrostoma)	I	5
Fungal Spore Type A	I	1
Fungal Spore Type B	I	2
Fungal Spore Type C	I	3
Fungal Spore Type D	I	4
Graminidites sp. 1	X	7
Gemmamonocolpites sp. 1	V	2
Gemmatriletes sp. 1	II	7
Gemmatriletes sp.2	II	8
Gemmatriletes sp. 3	II	9
Juglanspollenites sp. 1	XI	7
Laevigatosporites sp. 1	II	3
Longapertites sp. 1	IV	7
Longapertites sp. 2	IV	8
Longapertites sp. 3	IV	9
Longapertites sp. 4	IV	10
Micrasterias sp.	I	6
Margocolporites sp. 1	X	1
Margocolporites sp. 2	X	2
Operculodinium sp.	XIII	6
Peltandripites sp. 1	XIII	2
Perfotricolpites digitatus	VI	1
Proteacidites sp. 1	X	13
Proxapertites sp. 1	V	3

TAXA	PLATE	FIGURE
Pseudoschizaea sp.	I	7
Psilabrevitricolpites? sp. 1	X	3
Psilamonocolpites sp. 1	V	1
Psilastephanocolpites sp. 1	VII	4
Psilastephanocolporites sp. 1	X	5
Psilastephanocolporites sp. 2	X	6
Psilatricolpites sp. 1	VII	1
Psilatricolporites crassus	VII	6-7
Psilatricolporites obscurus	VIII	1
Psilatricolporites operculatus	VII	8
Psilatricolporites sp. 1	VIII	2
Psilatricolporites sp. 2	VIII	3
Psilatricolporites sp. 3	VIII	4
Psilatricolporites sp. 4	VIII	5
Psilatricolporites sp. 5	VIII	6
Psilatricolporites sp. 6	VIII	7
Psilatriletes sp. 1	II	11
Psilatriletes sp. 2	II	12
Psilatriletes sp. 3	III	1
Retibrevitricolpites triangulatus	VI	3
Retidiporites sp. 1	X	9
Retidiporites sp. 2	X	10
Retimonocolpites sp. 1	IV	2
Retimonocolpites sp. 2	IV	3
Retimonocolpites sp. 3	IV	4
Retimonocolpites sp. 4	IV	5
Retimonocolpites sp. 5	IV	6
Retitricolpites antonii	VI	6
Retitricolpites clarensis	VI	5
Retitricolpites magnus	VI	4
Retitricolpites simplex	VI	7
Retitricolpites sp. 1	VI	8
Retitricolpites sp. 2	VI	9
Retitricolporites irregularis	VIII	8
Retitricolporites quadrosi	VIII	9
Retitricolporites sp. 1	VIII	10
Retitricolporites sp. 2	IX	1
Retitricolporites sp. 3	IX	2
Retitricolporites sp. 4	IX	3
Retitricolporites sp. 5	IX	4
Retitricolporites sp. 6	IX	5
Retitricolporites sp. 7	IX	6
Retitricolporites sp. 8	IX	7
Retitriletes sp. 1	III	6
Retitriporites sp. 1	XI	1
Retitriporites sp. 2	XI	2
Retitriporites sp. 3	XI	3
Retitriporites sp. 4	XI	4
Spinizonocolpites baculatus	V	4
Spinizonocolpites echinatus	V	5-6
Spyrosyncolpites spiralis	VII	5
Striatricolpites catatumbus	VI	2
Syncolporites sp. 1	X	4

TAXA	PLATE	FIGURE
Tetrad Type A	XII	1
Tetrad Type B	XII	2
Tetrad Type C	XII	3
Tilia sp. 1	IX	12
Undulatisporites sp. 1	III	3
Unidentified chitinous foram.	XIII	7
Unknown Type 1	XIII	3
Unknown Type 2	XIII	4
Unknown Type 3	XIII	5
Verrucatosporites *usmensis*	II	1-2
Verrucatriletes sp. 1	II	4
Verrucatriletes sp. 2	II	5
Verrucatriletes sp. 3	II	6

APPENDIX B

Appendix B

Phylogenetic list of the Boscán palynomorphs

This list also includes information regarding the groups of palynomorphs that were used in the palynomorph diagrams. Each palynomorph was included in a given group and this list provides information into which group they were included, according to the following legend:

-Mangrove Group: MG

-*Peltandripites* sp. Group: PSP

-General Group: GG

-Palmae Group: PG

-Spore Group: SG

-Dinoflagellate-Algae-Foraminifera Group: DAF.

TAXA	PLATE	FIGURE	PALYNOMORPH GROUP
DIVISION EUCOMYCOPHYTA			
Fungal Spore Type A	I	1	-
Fungal Spore Type B	I	2	-
Fungal Spore Type C	I	3	-
Fungal Spore Type D	I	4	-
Fungal fruit-body (Acostroma)	I	5	-
SUBKINGDOM ALGAE			
Micrasterias sp.	I	5	DAF
Psedoschizaea sp.	I	6	DAF
SPORES			
Verrucatosporites usmensis	II	1-2	SG
Laevigatosporites sp.1	II	3	SG
Verrucatriletes sp. 1	II	4	SG
Verrucatriletes sp. 2	II	5	SG
Verrucatriletes sp. 3	II	6	SG
Gemmatriletes sp. 1	II	7	SG
Gemmatriletes sp. 2	II	8	SG
Gemmatriletes sp. 3	II	9	SG
Echitriletes sp. 1	II	10	SG

TAXA	PLATE	FIGURE	PALYNOMORPH GROUP
Psilatriletes sp. 1	II	11	SG
Psilatriletes sp. 2	II	12	SG
Psilatriletes sp. 3	III	1	SG
Cingutriletes sp. 1	III	2	SG
Cingutriletes sp. 2	III	3	SG
Cingutriletes sp. 3	III	4	SG
Undulatisporites sp. 1	III	5	SG
Retitriletes sp. 1	III	6	SG
POLYPLICATE GYMNOSPERM POLLEN			
Equisetosporites sp. 1	IV	1	GG
ANGIOSPERM POLLEN			
MONOCOLPATES			
Retimonocolpites sp. 1	IV	2	PG
Retimonocolpites sp. 2	IV	3	PG
Retimonocolpites sp. 3	IV	4	GG
Retimonocolpites sp. 4	IV	5	GG
Retimonocolpites sp. 5	IV	6	GG
Longapertites sp. 1	IV	7	PG
Longapertites sp. 2	IV	8	PG
Longapertites sp. 3	IV	9	PG
Longapertites sp. 4	IV	10	PG
Curvimonocolpites sp. 1	IV	11	PG
Psilamonocolpites sp. 1	V	1	GG
Gemmamonocolpites sp. 1	V	2	PG
Proxapertites sp. 1	V	3	GG
Spinizonocolpites baculatus	V	4	MG
Spinizonocolpites echinatus	V	5-6	MG
Echimonocolpites sp. 1	V	7	PG
Echimonocolpites sp. 2	V	8	PG
Echimonocolpites sp. 3	V	9	PG
Echimonocolpites sp. 4	V	10	PG
TRICOLPATES			
Perfotricolpites digitatus	VI	1	GG
Striatricolpites catatumbus	VI	2	GG
Retibrevitricolpites triangulatus	VI	3	MG
Retitricolpites magnus	VI	4	GG
Retitricolpites clarensis	VI	5	GG
Retitricolpites antonii	VI	6	GG
Retitricolpites simplex	VI	7	GG
Retitricolpites sp. 1	VI	8	GG
Retitricolpites sp. 2	VI	9	GG
Psilatricolpites sp. 1	VII	1	GG
Clavatricolpites sp. 1	VII	2	GG
Echitricolpites sp. 1	VII	3	GG
STEPHANOCOLPATES			
Psilastephanocolpites sp. 1	VII	4	GG

TAXA	PLATE	FIGURE	PALYNOMORPH GROUP
SYNCOLPATES			
Spyrosyncolpites spiralis	VII	5	GG
TRICOLPORATES			
Psilatricolporites crassus	VII	6-7	MG
Psilatricolporites operculatus	VII	8	GG
Psilatricolporites obscurus	VIII	1	GG
Psilatricolporites sp. 1	VIII	2	GG
Psilatricolporites sp. 2	VIII	3	GG
Psilatricolporites sp. 3	VIII	4	GG
Psilatricolporites sp. 4	VIII	5	GG
Psilatricolporites sp. 5	VIII	6	GG
Psilatricolporites sp. 6	VIII	7	GG
Retitricolporites irregularis	VIII	8	GG
Retitricolporites quadrosi	VIII	9	GG
Retitricolporites sp. 1	VIII	10	GG
Retitricolporites sp. 2	IX	1	GG
Retitricolporites sp. 3	IX	2	GG
Retitricolporites sp. 4	IX	3	GG
Retitricolporites sp. 5	IX	4	GG
Retitricolporites sp. 6	IX	5	GG
Retitricolporites sp. 7	IX	6	GG
Retitricolporites sp. 8	IX	7	GG
Bombacacidites sp. 1	IX	8	GG
Bombacacidites sp. 2	IX	9	GG
Bombacacidites sp. 3	IX	10	GG
Bombacacidites sp. 4	IX	11	GG
Tilia sp. 1	IX	12	GG
Margocolporites sp. 1	X	1	GG
Margocolporites sp. 2	X	2	GG
Psilabrevitricolpites? sp. 1	X	3	GG
SYNCOLPORATES			
Syncolporites sp. 1	X	4	GG
STEPHANOCOLPORATES			
Psilastephanocolporites sp. 1	X	5	GG
Psilastephanocolporites sp. 2	X	6	GG
MONOPORATES			
Graminidites sp. 1	X	7	GG
Aglaoreidia sp. 1	X	8	GG
DIPORATES			
Retidiporites sp. 1	X	9	GG
Retidiporites sp. 2	X	10	GG
TRIPORATES			
Echitriporites trianguliformis	X	11	MG
Echitriporites sp. 1	X	12	GG
Proteacidites sp. 1	X	13	GG

TAXA	PLATE	FIGURE	PALYNOMORPH GROUP
Retitriporites sp. 1	XI	1	GG
Retitriporites sp. 2	XI	2	GG
Retitriporites sp. 3	XI	3	GG
Retitriporites sp. 4	XI	4	GG
Cricotriporites sp. 1	XI	5	GG
STEPHANOPORATES			
Anacolosidites sp. 1	XI	6	GG
Juglanspollenites sp. 1	XI	7	GG
Clavastephanocolporites? sp. 1	XI	8	GG
Echistephanoporites sp. 1	XI	9	GG
TETRADS			
Tetrad Type A	XII	1	GG
Tetrad Type B	XII	2	GG
Tetrad Type C	XII	3	GG
INCERTAE SEDIS			
Classites sp. 1	XIII	1	GG
Peltandripites sp. 1	XIII	2	PSP
Unknown Type 1	XIII	3	GG
Unknown Type 2	XIII	4	GG
Unknown Type 3	XIII	5	GG
DIVISION PYRROPHYTA			
Operculodinium sp.	XIII	6	DAF
PHYLUM PROTOZOA			
Unidentified foram. inner chitinous linnings	XIII	6	DAF

PLATES

PLATE I

(All illustrations 1000X)

FIGURE

1 Fungal Spore Type A
Figured specimen: PB14186 (126.0 x 31.0);
50 µm x 20 µm.
Note: Multicellate, septate, psilate spores. Two apical pori.

2 Fungal Spore Type B
Figured specimen: PB14195 (123.1 x 44.6);
43 µm x 14 µm.
Note: Multicellate, septate, psilate spores.

3 Fungal Spore Type C
Figured specimen: PB14004 (126.8 x 29.0);
65 µm x 14 µm.
Note: Multicellate, septate, psilate spores. At least one apical pore.

4 Fungal Spore Type D
Figured specimen: PB13995 (128.0 x 41.6);
62 µm x 16 µm.
Note: Tetracellate, septate, psilate spores. Size of the cell decreasing towards the endings. Each septum with a septal pore with annulus. Distinct median septum. Two apical pori.

5 Fungal Fruit-body (Acrostoma)
Figured specimen: PB14001 (116.7 x 22.4);
43 µm x 43 µm.
Note: According to Elsik (1978), this specimen could be included within the genus *Microthallites*, because of the absence of a central ostiole or of a dense knob.

6 *Micrasterias* sp.
Figured specimen: PB14195 (119.0 x 45.1);
19-25 µm.
Note: Deeply lobed circular flattened cells.

PLATE I (Cont.)

FIGURE

7 *Pseudoschizaea* sp.

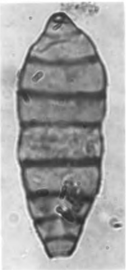
Figured specimen: PB14195 (125.5 x 30.9); 27-29 μm.

Note: Ovoidal-circular test with complex muri in concentric ribs. Similar to some specimens described by Christopher (1976).

PLATE I

1

2



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10 µm

4

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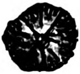

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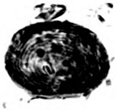


7

PLATE II

(All illustrations 1000X)

FIGURE

1-2 *Verrucatosporites usmensis* (van der Hammen, 1956-b) Germeraad, Hopping and Muller, 1968.
Figured specimens: PB14195 (124.1 x 29.3) (Fig. 1) PB14189 (112.9 x 42.7) (Fig. 2); 30-40 μm and 48-55 μm.
Note: Two size ranges were observed.

3 *Laevigatosporites* sp. 1
Figured specimen: PB14195 (119.0 x 13.4); 37-41 μm.
Note: Botanic affinities to Polypodiaceae.

4 *Verrucatriletes* sp. 1
Figured specimen: PB14001 (112.7 x 39.6); 32-37 μm.
Note: Rounded-triangular amb. Verrucae, 3-6 μm. wide.

5 *Verrucatriletes* sp. 2
Figured specimen: PB14195 (128.2 x 17.4); 27-30 μm.
Note: Radially symmetrical amb. Verrucae, 2-3 μm. wide.

6 *Verrucatriletes* sp. 3
Figured specimen: PB14001 (126.9 x 36.8); 26-29 μm.
Note:Rounded triangular amb with slightly undulating laesurae. Verrucae, 1-2 μm wide, in cases with spiny ends.

7 *Gemmatriletes* sp. 1
Figured specimen: PB14127 (126.4 x 14.5); 26-29 μm.
Note: Radially symmetrical amb. Gemmae, 2-3 μm wide.

8 *Gemmatriletes* sp. 2
Figured specimen: PB14194 (120.0 x 41.0); 30-34 μm.
Note: Trilete mark not very conspicuous.

PLATE II (Cont.)

FIGURE

9 Verrucatriletes sp. 3
Figured specimen: PB14001 (120.4 x 22.0);
36 μm x 29 μm.
Note: Only one specimen was observed.

10 Echitriletes sp. 1
Figured specimen: PB14232 (113.8 x 22.9);
22-31 μm.
Note: Circular amb. Echinae, 1-2 μm long. Similar to some spores of Selaginella, identified by Graham (1985) from the Late Eocene of Panama.

11 Psilatriletes sp. 1
Figured specimen: PB13998 (113.0 x 27.4);
30-38 μm.
Note: The rounded-triangular amb, with characteristic concave sides, seems to suggest some similarity to the spores of Microlepia (Pteridaceae) described by Erdtman (1957).

12 Psilatriletes sp. 2
Figured specimen: PB14195 (124.8 x 41.4);
37-45 μm.
Note: Circular amb, with laesurae extending to the margins.

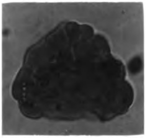
PLATE II

10 µm


1


2


3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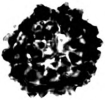
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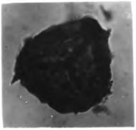
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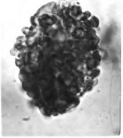
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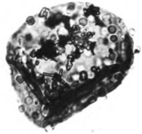
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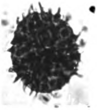
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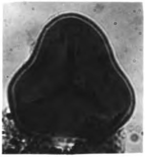
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12

PLATE III

(All illustrations 1000X)

FIGURE

1 _Psilatriletes_ sp. 3

Figured specimen: PB14189 (125.3 x 37.7);

41-60 μm.

Note: Circular amb. Laesurae do not extend to the spore margins.

2 _Cingutriletes_ sp. 1

Figured specimen: PB14227 (120.3 x 24.0);

35-42 μm.

Note: Graham (1985) identified specimens similar to those observed in this study, as belonging to the genus _Pteris_ (Polypodiaceae).

3 _Cingutriletes_ sp. 2

Figured specimen: PB14009 (118.2 x 38.7);

40-47 μm.

4 _Cingutriletes_ sp. 3

Figured specimen: PB14189 (125.3 x 37.8);

50 μm. x 45 μm.

Note: Only one specimen was observed.

5 _Undulatisporites_ sp. 1

Figured specimen: PB14001 (122.9 x 15.4);

20 μm x 18 μm.

Note: Only one specimen was observed.

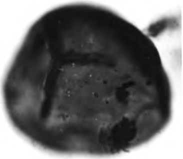
6 _Retitriletes_ sp. 1

Figured specimen: PB14001 (113.1 x 14.9);

26-28 μm.

Note: Rounded triangular amb, finely reticulate.

PLATE III



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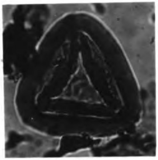
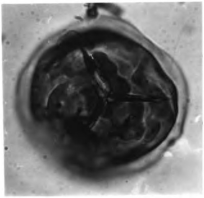


2

10 µm



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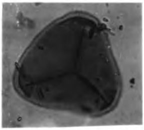

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PLATE IV

(All illustrations 1000X)

FIGURE

1 *Equisetosporites* sp. 1
Figured specimen: PB13998 (127.9 x 37.0);
40-42 μm.
Note: Polyplicate gymnosperm pollen. Affinities to *Ephedra* (Gnetopsida).

2 *Retimonocolpites* sp. 1
Figured specimen: PB14195 (127.3 x 37.0);
30-35 μm.
Note: Prolate,reticulate,monocolpate pollen grains. Size of the lumina, uniform (1.0μm). Intectate, exine 1.0 μm. Probably related to Palmae.

3 *Retimonocolpites* sp. 2
Figured specimen: PB14195 (125.5 x 16.9);
28-31 μm.
Note: Globular-ovoidal reticulate pollen grains. Size of the lumina, 2-3 μm. Intectate, exine 1-2 μm.

4 *Retimonocolpites* sp. 3
Figured specimen: PB14198 (123.0 x 32.0);
30-34 μm.
Note: Prolate, reticulate monocolpate pollen grains. Size of the lumina, 2.5-3.0 μm. Intectate, exine 1.2 μm.

5 *Retimonocolpites* sp. 4
Figured specimen: PB14188 (113.0 x 23.7);
46-49 μm.
Note: Prolate, reticulate, monocolpate pollen grains. Size of the lumina, 3-4 μm, decreasing towards the colpus.

6 *Retimonocolpites* sp. 5
Figured specimen: PB14195 (127.3 x 23.7);
25-29 μm.

PLATE IV (Cont.)

FIGURE

7 *Longapertites* sp.1
Figured specimen: PB14195 (126.8 x 16.9); 25-28 μm.
Note: Prolate, psilate monocolpate pollen grains. Colpus dividing the grains in two halves. Related to Palmae.

8 *Longapertites* sp. 2
Figured specimen: PB14195 (125.9 x 23.9); 17-23 μm.
Note: Similar to *Longapertites* sp. 1, but differs in range of size and the reticulate sculpture. Related to Palmae.

9 *Longapertites* sp. 3
Figured specimen: PB14187 (114.0 x 30.5); 47-52 μm.
Note: Globular shape, reticulate. Colpus dividing the grain in two unequal halves. Related to Palmae.

10 *Longapertites* sp. 4
Figured specimen: PB14188 (117.3 x 30.4); 23-27 μm.
Note: Reticulate, monocolpate pollen grains. Colpus dividing the grain in two halves. Related to Palmae.

11 *Curvimonocolpites* sp.
Figured specimen: PB14189 (124.0 x 39.9); 36-41 μm.
Note: Kidney-bean shaped pollen grain, with colpus in the convex side of the grain. Psilate.

PLATE IV


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10 µm


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PLATE V

(All illustrations 1000X)

FIGURE

1 *Psilamonocolpites* sp. 1
Figured specimen: PB13998 (128.8 x 37.2); 26-33 μm.
Note: Psilate, monocolpate pollen grains.

2 *Gemmamonocolpites* sp. 1
Figured specimen: PB14005 (116.1 x 25.8); 42 μm x 22 μm.
Note: Prolate, Only one specimen was observed. Prolate, gemmate, monocolpate pollen grain. Wall, finely perforate.

3 *Proxapertites* sp. 1
Figured specimen: PB14188 (115.1 x 31.3); 20-23 μm.
Note: Circular monocolpate pollen grains. The wide colpus divides the grain in two halves. Germeraad et al. (1968) suggested some similarities to the pollen of *Astrocaryum*. Thanikaimoni et al. (1985) related it to unnamed climbers in evergrenn forests.

4 *Spinizonocolpites* *baculatus* Muller, 1968
Figured specimen: PB14196 (117.9 x 38.4); 30 μm x 15 μm.
Note: Only one specimen was observed. Related to the mangrove palm *Nypa*.

5-6 *Spinizonocolpites* *echinatus* Muller, 1968
Figured specimens: PB14004 (115.5 x 41.4) (Fig. 5) and PB14188 (123.8 x 23.4) (Fig. 6); 40-50 μm.
Note: Related to mangrove palm *Nypa*.

7 *Echimonocolpites* sp. 1
Figured specimen: PB14186 (122.4 x 40.9); 32-36 μm.
Note: Probably related to Palmae.

PLATE V (Cont.)

FIGURE

8 Echimonocolpites sp. 2
Figured specimen: PB13998 (113.1 x 22.7);
29-34 μm.
Note: Probably related to Palmae.

9 Echimonocolpites sp. 3
Figured specimen: PB14124 (121.1 x 46.7);
17-20 μm.

10 Echimonocolpites sp. 3
Figured specimen: PB14230 (122.1 x 34.3);
52 m x 33 μm.
Note: Only one specimen was observed. Characteristic thick exine (4.0 μm).

PLATE V

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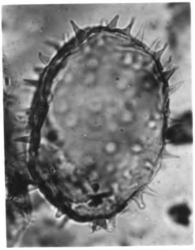

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10 µm

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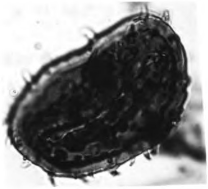

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PLATE VI

(All illustrations 1000x)

FIGURE

1 *Perfotricolpites digitatus* González Guzmán, 1967
Figured specimen: PB14195 (118.6 x 16.5);
39-55 μm.
Note: Germeraad et al. (1968) related it to pollen of *Merremia* (Convolvulaceae). González Guzmán (1967) observed this species in the Eocene of Colombia. In this study, it was mainly observed in samples clustered under III.

2 *Striatricolpites catatumbus* González Guzmán, 1967
Figured specimen: PB14195 (126.4 x 21.5);
33-35 μm.
Note: Related to *Crudia* (Fabaceae). González Guzmán (1967) observed this species in the Eocene of Colombia.

3 *Retibrevitricolpites triangulatus* van Hoeken-Klinkenberg, 1966
Figured specimen: PB14195 (122.6 x 41.4);
15-22 μm.
Note: González Guzmán (1967) observed this species in the Eocene of Colombia. In this study, it was mainly observed in samples clustered under III.

4 *Retitricolpites magnus* González Guzmán, 1967
Figured specimen: PB14195 (125.6 x 21.4);
45-50 μm.
Note: González Guzmán observed this species in the Eocene of Colombia. In this study, it was mainly observed in samples clustered under III.

5 *Retitricolpites clarensis* González Guzmán, 1967.
Figured specimen: PB14195 (124.0 x 31.0);
27-35 μm.
Note: González Guzmán (1967) observed this species in the Eocene of Colombia.

PLATE VI (Cont.)

FIGURE

6 *Retitricolpites antonii* González Guzmán, 1967
Figured specimen: PB14195 (125.7 x 21.1);
30-34 µm.
Note: González Guzmán (1967) observed this species in the Eocene of Colombia.

7 *Retitricolpites simplex* González Guzmán, 1967
Figured specimen: PB14188 (115.0 x 34.0);
40-50 µm.
Note: González Guzmán (1967) observed this species in the Eocene of Colombia.

8 *Retitricolpites* sp. 1
Figured specimen: PB14188 (117.3 x 45.2);
43-49 µm.
Note: Prolate, reticulate, tricolpate pollen grains. Size of the lumina, 1-1.5 µm.

9 *Retitricolpites* sp. 2
Figured specimen: PB14195 (123.2 x 24.2);
40-47 µm.
Note: Prolate, reticulate, tricolpate pollen grains. Reticulum arranged in such a way that it looks like forming striae on the grain surface.

PLATE VI

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10 µm

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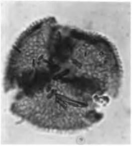

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PLATE VII

(All illustrations 1000X)

FIGURE

1 *Psilatricolpites* sp. 1
Figured specimen: PB14195 (127.0 x 16.2);
22-27 µm.
Note: Prolate, psilate, tricolpate pollen grains.
Costae colpi.

2 *Clavatricolpites* sp. 1
Figured specimen: PB14195 (121.9 x 18.3);
13-17 µm.
Note: Prolate, clavate, tricolpate pollen grains.
Clavae, 1.0 µm long.

3 *Echitricolpites* sp. 1
Figured specimen: PB14238 (123.2 x 40.3);
19-26 m.
Note: Prolate, echinate, tricolpate pollen grains.
Echinae, 1.0 µm, evenly dispersed on the grain
surface.

4 *Psilastephanocolpites* sp. 1
Figured specimen: PB13988 (121.0 x 15.3);
32-42 µm.
Note: Prolate-ovoidal, stephanocolpate (8-10 colpi),
psilate pollen grains.

5 *Spyrosyncolpites spiralis* González Guzmán, 1967
Figured specimen: PB14189 (25.6 x 112.9);
30-50 µm.
Note: González Guzmán (1967) observed this species
in the Eocene of Colombia.

6-7 *Psilatricolporites crassus* van der Hammen and Wijmstra,
1964
Figured specimens: PB14188 (117.0 x 44.1) (Fig. 6)
and PB14195 (127.0 x 23.4) (Fig.7);
30-35 µm and 42-50 µm.
Note: Two size ranges were observed. In this study,
it was mainly observed in samples clustered under III.

PLATE VII (Cont.)

FIGURE

Wijmstra (1968) related it to *Pelliceria* (Thaceae).

8 *Psilatricolporites operculatus* van der Hammen and Wijmstra, 1964

Figured specimen: PB14194 (115.7 x 37.0); 17-25 µm.

Note: Germeraad et al. (1968) related it to pollen of *Alchornea* (Euphorbiaceae). González Guzmán (1967) observed this species in the Eocene of Colombia.

PLATE VII

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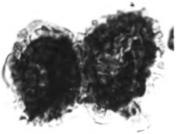

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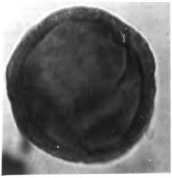

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PLATE VIII

(All illustrations 1000X)

FIGURE

1 *Psilatricolporites obscurus* González Guzmán, 1967
Figured specimen: PB14195 (125.7 x 41.3);
35-45 µm.
Note: González Guzmán (1967) observed this species in the Eocene of Colombia. In this study. it was mainly observed in samples clustered under III.

2 *Psilatricolporites* sp. 1
Figured specimen: PB14195 (126.3 x 33.5);
29-35 µm.
Note: Approximately circular limb. Large polar area. Exine, 3-4 µm. In this study, it was mainly observed in samples clustered under III.

3 *Psilatricolporites* sp. 2
Figured specimen: PB14195 (127.2 x 33.4);
27-31 µm.
Note: Globular, psilate, tricolporate pollen grains. Exine, 2.0 µm.

4 *Psilatricolporites* sp. 3
Figured specimen: PB14195 (125.9 x 32.2);
27-31 µm.
Note: Prolate, psilate, tricolporate pollen grains. Exine, 1.0 µm.

5 *Psilatricolporites* sp. 4
Figured specimen: PB14195 (124.7 x 23.6);
17-19 µm.
Note: Sub-prolate, psilate, tricolporate pollen grains. Equatorial lalongate pori. Costae colpi.

6 *Psilatricolporites* sp. 5
Figured specimen: PB14195 (119.4 x 16.7);
26 µm x 16 µm.
Note: Only one specimen was observed. Prolate, psilate tricolporate pollen grains. Costae colpi. Equatorial pori.

PLATE VIII (Cont.)

FIGURE

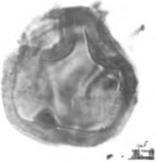
7 *Psilatricolporites* sp. 6
Figured specimen: PB14234 (116.0 x 39.2);
25-29 μm.
Note: Prolate, psilate, tricolporate pollen grains. Slightly aspidate equatorial pori.

8 *Retitricolporites irregularis* van der Hammen and Wijmstra, 1964
Figured specimen: PB14194 (115.7 x 37.0);
19-21μm.
Note: Germeraad et al. (1968) related it to pollen of *Amanoa* (Euphorbiaceae).

9 *Retitricolporites quadrosi* Ragali, Uesugui and da Silva Santos, 1974-b
Figured specimen: PB14189 (114.8 x 41.0);
52-59 μm.
Note: Observed mainly in samples clustered under III in this study.

10 *Retitricolporites* sp. 1
Figured specimen: PB14195 (127.0 x 16.9);
40-43 μm.
Note: Prolate, finely reticulate, tricolporate pollen grains. Exine, 2.0 μm.

PLATE VIII



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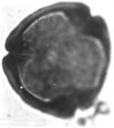

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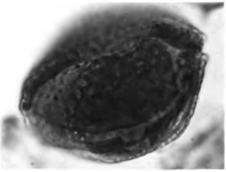

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PLATE IX

(All illustrations 1000X)

FIGURE

1 *Retitricolporites* sp. 2
Figured specimen: PB14195 (127.0 x 16.9);
15-20 μm.
Note: Prolate, finely reticulate, tricolporate pollen grains. Lalongate equatorial pori. Costae colpi. Thin exine.

2 *Retitricolporites* sp. 3
Figured specimen: PB14195 (126.3 x 37.1);
30-37 μm.
Note: Prolate, reticulate, tricolporate pollen grains. Equatorial pori. Costae colpi. Exine, 2.0 μm.

3 *Retitricolporites* sp. 4
Figured specimen: PB14186 (118.2 x 40.2);
47 μm x 35 μm.
Note: Only one specimen was observed. Prolate, reticulate, tricolporate pollen grains. Equatorial pori. exine, 2.0 μm.

4 *Retitricolporites* sp. 5
Figured specimen: PB14002 (124.8 x 30.7);
18 μm x 17 μm.
Note: Only one specimen was observed. Circular equatorial limb, reticulate (size of the lumina increasing towards the equatorial area), tricolporate pollen grain. Distinctive foot layer. Exine, 3.0 μm.

5 *Retitricolporites* sp. 6
Figured specimen: PB14230 (125.9 x 22.4);
26 μm x 15 μm.
Note: Only one specimen was observed. Prolate, finely reticulate, tricolporate pollen grain. Exine, 1.0 μm.

PLATE IX (Cont.)

FIGURE

6 Retitricolporites sp. 7
Figured specimen: PB14195 (120.1 x 26.4);
19-24 µm.
Note: Roughly circular outline, reticulate, tricolporate pollen grains. Exine, 2.0 µm.

7 Retitricolporites sp. 8
Figured specimen: PB14123 (111.2 x 29.1);
40 µm x 40 µm.
Note: Only one specimen was observed. Circular equatorial outline. Reticulate, tricolporate pollen grain. Exine, 1.0 µm.

8 Bombacacidites sp. 1
Figured specimen: PB14004 (127.0 x 23.9);
46-50 µm.
Note: Rounded-triangular polar view. Reticulate, size of the lumina decreasing from the polar area (2-4 µm) to the equatorial area (less than 1.0 µm). Planaperturate, tricolporate. Exine, 2.0 µm. Related to Bombacaceae.

9 Bombacacidites sp. 2
Figured specimen:PB14002 (119.0 x 38.7);
28-33 µm.
Note: Similar to Bombacacidites sp. 1, but differs in size range. Related to Bombacaceae.

10 Bombacacidites sp. 3
Figured specimen: PB14001 (112.9 x 38.0);
23-28 µm.
Note: Rounded-triangular polar view. Reticulate, size of the lumina decrasing from the polar area (1.0 µm) towards the equatorial area (less than 1.0 µm). Planaperturate, tricolporate. Exine, 1.0 µm. Related to Bombacaceae.

PLATE IX (Cont.)

FIGURE

11 *Bombacacidites* sp. 4

Figured specimen: PB14188 (127.0 x 38.0); 24 μm x 22 μm.

Note: Only one specimen was observed. The preservation was not good. Planaperturate, tricolporate. Exine, 1.0 μm. Probably reticulate with decreasing size of the lumina towards the equatorial area. Related to Bombacaceae.

12 *Tilia* sp. 1

Figured specimen: PB13994 (127.1 x 22.7); 34 μm x 34 μm.

Note: Only one specimen was observed. Rounded-triangular polar view. Reticulate-foveolate, size of the lumina decreasing towards the equatorial limb. Exine, 2-2.5 μm. Planaperturate, tricolporate.

PLATE IX


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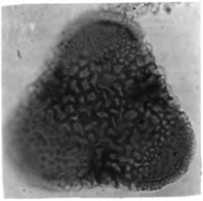
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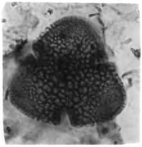
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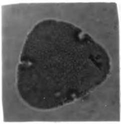
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PLATE X

(All illustrations 1000X)

FIGURE

1 *Margocolporites* sp. 1
Figured specimen: PB14195 (126.9 x 35.4);
29 μm x 19 μm.
Note: Only one specimen was observed. Circular polar view. Reticulate, size of the lumina tends to decrease towards the polar area. Psilate margo.

2 *Margocolporites* sp. 2
Figured specimen: PB14190 (114.3 x 22.5);
34 μm x 31 μm.
Note: Only one specimen was observed. Circular polar view. Reticulate, size of the lumina relatively uniform, except at margo, where smaller. Exine, 2.0 μm.

3 *Psilabrevitricolpites*? sp. 1
Figured specimen: PB14195 (125.3 x 44.2);
33 μm x 27 μm.
Note: Only one specimen was observed. Globular-oblate. Psilate, finely perforate. Brevitricolporate, with lolongate pori. van Hoeken-Klinkenberg (1966) described the genus *Psilabrevitricolpites*. Even though the specimen found in the samples in this study is clearly brevicolporate, it is still uncertain that if it can be included in this genus.

4 *Syncolporites* sp. 1
Figured specimen: PB14195 (120.9 x 13.5);
15-19 μm.
Note: Rounded-triangular outline. Reticulate. Syncolporate, pori located at the equator. Exine, 1.0 μm.

5 *Psilastephanocolporites* sp. 1
Figured specimen: PB14188 (119.7 x 52.2);
21 μm x 17 μm.

PLATE X (Cont.)

FIGURE

Note: Only one specimen was observed. Prolate, stephanocolporate (6-8 apertures), with equatorial pori. Exine, 1.0 µm.

6 Psilastephanocolporites sp. 2

Figured specimen: PB14239 (114.7 x 34.6); 34 µm x 26 µm.

Note: Only one specimen was observed. Circular polar view. tetracolporate, with thickened margins. Exine, 2.0 µm. Psilate. Some similarity is observed with the specimens of Dysoxylum malabaricum (Meliaceae) described by Thanikaimoni et al. (1985).

7 Graminidites sp. 1

Figured specimen: PB14188 (124.7 x 22.1); 55 µm x 30 µm.

Note: Only one specimen was observed. Prolate, monoporate. Probably psilate (the only specimen that was observed was not well-preserved). Related to pollen of Gramineae.

8 Aglaoreidia sp. 1

Figured specimen: PB14195 (126.4 x 22.1); 20 µm x 16 µm.

Note: Only one specimen was observed. Ovoidal to circular equatorial outline. Reticulate, size of the lumina relatively uniform. Exine, 1.5 µm. Related to Ruppiaceae (Frederiksen, 1980).

9 Retidiporites sp. 1

Figured specimen: PB14195 (120.5 x 33.6); 18-25 µm.

Note: Elongated ellipsoid. Diporate. Finely reticulate. Exine, 1.0 µm. In this study, it was mainly observed in samples clustered under III.

PLATE X (Cont.)

FIGURE

10 *Retidiporites* sp. 2

Figured specimen: PB14195 (121.0 x 14.1); 15-22 μm.

Note: Similar to *Retidiporites* sp. 1, but more finely reticulate. Very thin exine. In this study, it was mainly observed in samples clustered under III.

11 *Echitriporites triangulifomis* van Hoeken-Klinkenberg, 1964

Figured specimen: PB14195 (126.5 x 26.3); 19-23 μm.

Note: In this study, it was mainly observed in samples clustered under III.

12 *Echitriporites* sp. 1

Figured specimen: PB13988 (118.6 x 20.7); 42 μm x 32 μm.

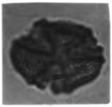
Note: Only one specimen was observed. Almost circular polar view. Echinae, 2-3 μm. long. Exine, 1.0 μm. Wall, finely perforate or reticulate.

13 *Proteacidites* sp. 1

Figured specimen: PB14189 (119.1 x 35.3); 30 μm x 29 μm.

Note: Triangular outline, triporate. Roughly concave sides. Reticulate-foveolate. Costae pori. Exine, 1.5 μm. Related to Proteaceae.

PLATE X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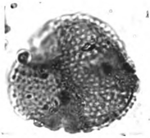
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10 µm


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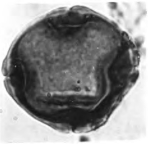
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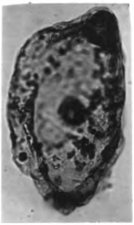
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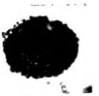
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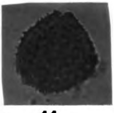
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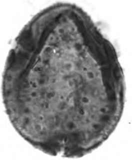
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PLATE XI

(All illustrations 1000X)

FIGURE

1 Retitriporites sp. 1
Figured specimen: PB14195 (125.5 x 38.0);
57 µm x 52 µm.
Note: Only one specimen was observed. Circular polar view. Coarsely reticulate. Triporate, thickened pori. Exine, 3-3.5 µm. Similar to Foveotriporites hammenii described by González Guzmán (1967) in the Eocene of Colombia.

2 Retitriporites sp. 2
Figured specimen: PB13997 (127.0 x 34.6);
35-39 µm.
Note: Circular polar view. Triporate, probably lalongate pori. Finely reticulate. Exine, 1.0 µm.

3 Retitriporites sp. 3
Figured specimen: PB13997 (115.1 x 22.9);
20-25 µm.
Note: Roughly circular polar view. Triporate. Pori are not located at the equator. Reticulate. Exine, 1.0 µm.

4 Retitriporites sp. 4
Figured specimen: PB14126 (125.3 x 33.2);
38 µm x 31 µm.
Note: Almost circular outline. Triporate, pori with distinctive annulus. Reticulate. Exine, 2.0 µm.

5 Cricotriporites sp. 1
Figured specimen: PB14195 (126.6 x 21.3);
15-20 µm.
Note: Circular outline. Triporate, psilate. Exine, 1.2 µm.

6 Anacolosidites sp. 1
Figured specimen: PB13981 (123.4 x 41.0);
18-25 µm.
Note: Rounded-triangular outline. Hexaporate, with

PLATE XI (Cont.)

FIGURE

3 pori in each face. Exine, 1- 1.5 μm. Wall, finely perforate. In this study, it was mainly observed in samples clustered under II and IV. **Related** to Olacaceae.

7 _Juglanspollenites_ sp. 1

Figured specimen: PB14194 (127.7 x 25.7); 29-35 μm.

Note: Circular outline, polyforaminate. Exine, 1.5 μm. In this study, it was mainly observed in samples clustered under II and IV.

8 _Clavastephanocolporites_ ? sp. 1

Figured specimen: PB14230 (113.2 x 25.9); 24 μm x 23 μm.

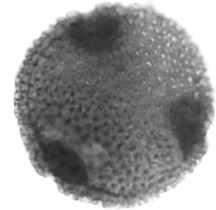
Note: Only one specimen was observed. Circular outline. Clavae, 1.5 μm. long. The author of this study considers that the type of apertures are similar to those described by Leidelmeyer (1966) for the genus _Clavatricolporites_. However, the author of this study thinks that the apertures of the specimen found in this study are porate rather than colporate.

9 _Echistephanoporites_ sp. 1

Figured specimen: PB13988 (118.6 x 20.7); 30 μm x 30 μm.

Note: Only one specimen was observed. Circular equatorial outline, tetraporate. Pori, with annulus. Exine, 1.0 μm. Echinae, 1.0 μm long.

PLATE XI



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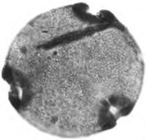

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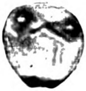

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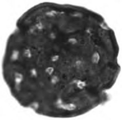

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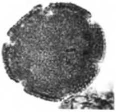

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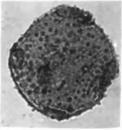

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PLATE XII

(All illustrations 1000X)

FIGURE

1 Tetrad Type A

<u>Figured specimen</u>: PB14186 (125.7 x 17.0); 68-71 μm.

<u>Note</u>: Tetrad of echinate pollen grains. Wall, finely perforate. Apertures were not observed. Exine, 2.0 μm. Echinae, 6-7 μm long. It was only observed in this sample.

2 Tetrad Type B

<u>Figured specimen</u>: PB14001 (122.0 x 26.4); 32-37 μm.

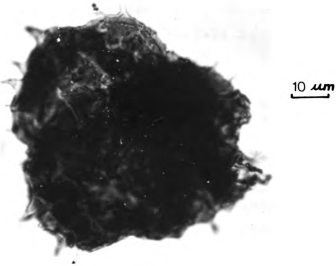
<u>Note</u>: Prolate individual grains. Tricolporate. Wall, psilate or finely perforate. Exine, 2.0 μm. It was mainly observed in samples clustered under II and IV.

3 Tetrad Type C

<u>Figured specimen</u>: PB14108 (116.0 x 34.8); 55 μm x 45 μm.

<u>Note</u>: Only one specimen was observed. Tetrad of coarsely reticulate pollen grains. Exine, 2-3 μm. Apertures were not observed.

PLATE XII



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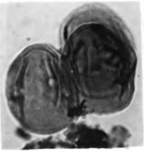

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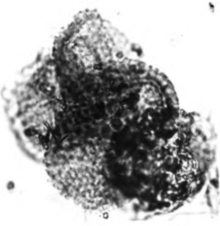

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PLATE XIII

(All illustrations 1000X)

FIGURE

1 Classites sp.

Figured specimen: PB14195 (12.8 x 17.5);

30-32 μm.

Note: Inaperturate grains, with circular outline. Exine is clearly divided in two layers. Psilate. Similar specimens were described by González Guzmán (1967) in the Eocene of Colombia.

2 Peltandripites sp. 1

Figured specimen: PB14126 (126.9 x 38.9);

17-25 μm.

Note: Circular outline. Triporate, pori are not very distinct in some views. Echinae, approximately 1.0 μm long. Very thin and structureless exine. In this study, it was mainly observed in samples clustered under IV.

3 Unknown Type 1

Figured specimen: PB14195 (118.5 x 35.1);

20-27 μm.

Note: Rhomboidal-circular outline. Tetraporate, pori with some thickening. Echinate, echinae 1.0 μm long. Very thin and structureless exine. In this study, it was mainly observed in samples clustered under III.

4 Unknown Type 2

Figured specimen: PB14124 (109.9 x 26.1);

62 μm x 62 μm.

Note: Only one specimen was observed. Circular polar view. Probably tetracolporate. Exine, 3.0 μm. Semitectate,

5 Unknown Type 3

Figured specimen: PB14225 (126.9 x 33.9);

40 μm.

Note: Only one specimen was observed. Fragmented palynomorph, with large gemmae linked to a reticulate

PLATE XIII (Cont.)

FIGURE

wall. Gemmae, 10 µm wide.

6 *Operculodinium* sp.

Figured specimen: PB14195 (115.0 x 41.7); 41-46 µm.

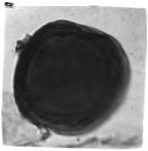
Note: Rarely found in the samples under study. Circular cysts, without any evident ornamentation or observable plates or sutures. Non-fibrous processes with bifurcate ends.

7 Unidentified chitinous inner linings of Foraminifera

Figured specimen: PB14195 (122.4 x 44.6); 23-34 µm.

Note: Generally, kidney-bean shaped, with chambers separated by septa.

PLATE XIII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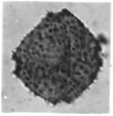
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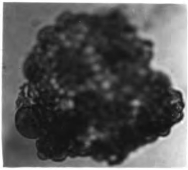
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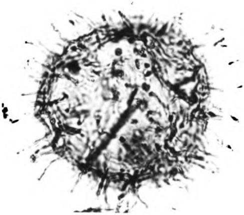
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