A PALYNOLOGICAL STUDY OF SAMPLES FROM THREE WELLS OF THE BOSCAN FIELD, VENEZUELA

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ABSTRACT: The results of the palynological analysis of 71 core samples from 3 wells of the Boscan Field are discussed. The palynological assemblages were determined as middle Eocene in age. The results also indicate the presence of a mixed-type plant community at the moment of deposition. The fluctuations of the percentages of the palynomorph groups defined in this paper, as well as the position of the different clustered samples within the sequences under consideration, indicate the transition from low delta plain to upper delta plain deposits, as well as other possible paleoenvironmental changes that could have taken place at the time of deposition.

RESUMEN: Se discuten los resultados del análisis palinológico de 71 muestras de núcleos provenientes de 3 pozos del Campo Boscán. Los conjuntos de palinomorfos son característicos del Eoceno medio. Los resultados también indican la presencia de una paleocomunidad mixta de plantas en el momento de depositación. Fluctuaciones de las frecuencias de los diferentes grupos de palinomorfos definidos en este estudio, así como la posición dentro de las secuencias bajo consideración de los grupos de muestras determinados por análisis de agrupación, indican la transición de secuencias características de un plano deltaico bajo a depósitos de un plano deltaico alto, así como otros cambios paleoambientales que pudieron estar ocurriendo en el momento de depositación.

1. INTRODUCTION

The palynological analysis of outcrop and well samples have been of significant importance for the exploration activity of the oil industry in Venezuela since the middle of the 1940's. In spite of the extensive research in this field, the amount of information available is scarce, most of it being in propietary files of oil companies. Publications of van der Hammen and Wijmstra [1], González [2], Germeraad *et al.* [3], Wijmstra [4], Regali *et al.* [5-6] and Muller *et al.* [7] are important references for the palynological research of the northern area of South America. Local palynological studies, such as the one presented in this paper about the palynological analysis in three wells from the Boscan Field (Figure 1), are contributions not only for the information produced but also for the methodology used.

Geologic framework

The studied sequences are included within the Misoa Formation, whose geologic characteristics indicate deposition in a deltaic environment during the middle Eocene in the Lake Maracaibo Basin area [8]. Previous studies done by Azpiritxaga [9] pointed out the environmental change in the sequence under study, from characteristic deposits of a low deltaic plain to deposits likely to have been deposited on an upper deltaic plain environment. Figures 2,3 and 4 present an outline of the lithology and environments of deposition reported by Azpiritxaga [9].

The Lake Maracaibo Basin is located in a tectonic depression in northwestern Venezuela (Figure 1). The basin is limited to the west by the Sierra de Perijá, and to the south and east by the Venezuelan Andes.

The deposition in the Lake Maracaibo Basin during the Paleocene was characterized by the presence of three

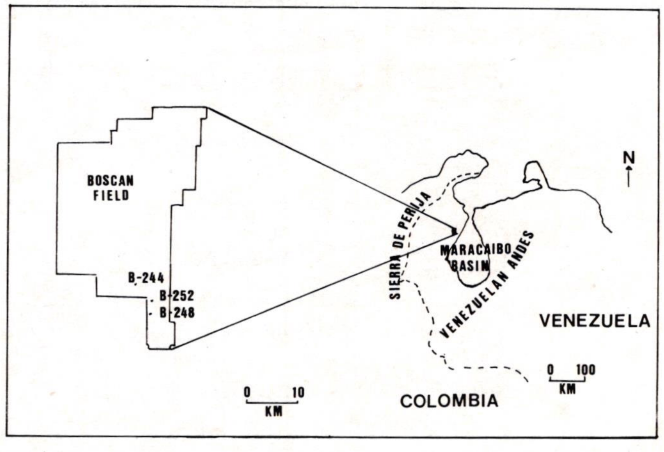

Fig. 1. Locations of the Boscan Field and wells B-244, B-248 and B-252 in western Venezuela.

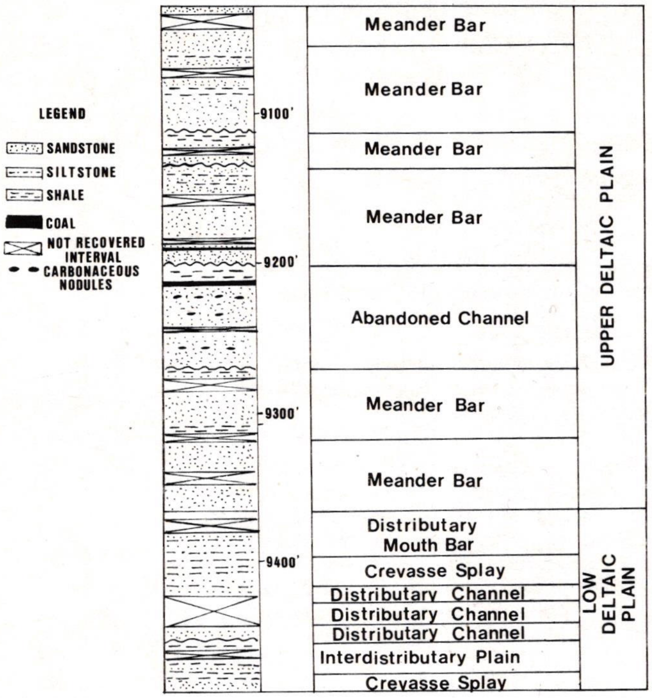

Fig. 2. Lithology and paleoenvironments of deposition inferred by Azpiritxaga [9] : Well B-244.

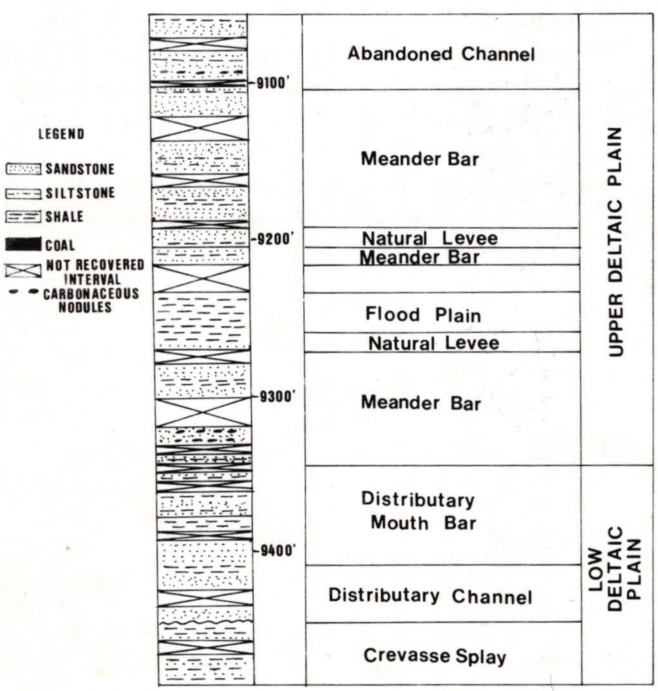

Fig. 3. Lithology and paleoenvironments of deposition inferred by Azpiritxaga [9] : Well B-248.

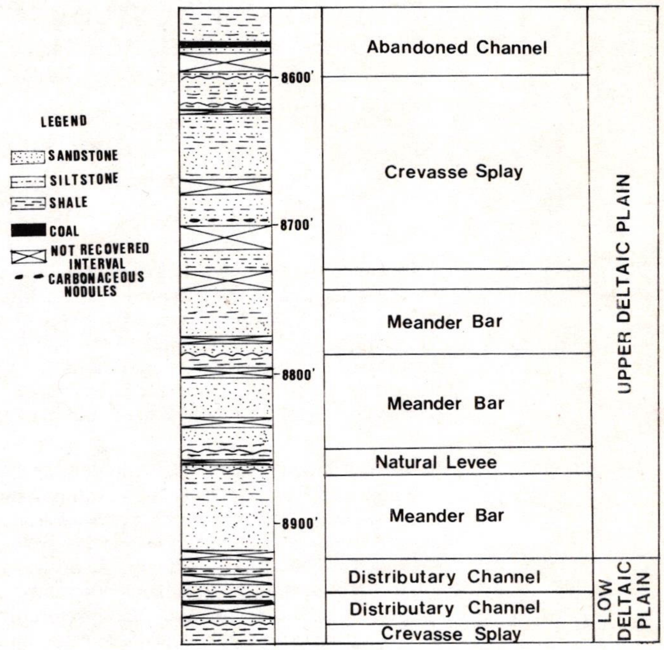

Fig. 4. Lithology and paleoenvironments of deposition inferred by Axpiritxaga [9] : Well B-252.

sedimentary provinces with a southwest to northeast trend, according to the model proposed by Zambrano *et al.* [10]. These authors state that during the Eocene, the progradation of the fluvial-deltaic province into the area currently occupied by the Lake Maracaibo caused the deposition of the Mirador Formation fluvial deposits [8] to the southwest of the basin, and the Misoa Formation deltaic deposits in the area occupied by the Lake Maracaibo. Some authors such as Zambrano *et al.* [10] and Bockmeulen *et al.* [11] have proposed a high subsidence rate for the central and southern zones of the basin, causing the significant thicknesses reported for the Misoa Formation in some areas of the Lake Maracaibo [9]. Zamora [12], based on the characteristics of well log responses, suggested a cyclic nature for the deposition of the Misoa Formation, inferring minor cycles of regressions and transgressions. Bockmeulen *et al.* [11] proposed that rapid and continuous subsidence of the area caused the significant thickness of sediments without major seaward progradation.

The uplifts of the Venezuelan Andes and of the Sierra de Perijá seem to have begun during the Oligocene [13-14] and continued into the Miocene and the Pliocene to complete the present configuration of the Maracaibo Basin.

Objectives

This paper presents the results of the palynological analysis of 71 core samples from wells B-244, B-248 and B-252 from the Boscan Field (Figure 1). The analyses were undertaken with the purpose of determining the age for the different studied sections, and generating information on the paleoecology and community structure of plants comprising the floras at the time of deposition. The variations of the characteristics of the palynofloras along the studied sequences under study should reflect evolutive and paleoecological changes that will be analyzed in this paper.

2. METHODS

Sample maceration and palynomorph counting

A total of 71 core samples were selected according to their lithology (silt, shale, very fine-grained sandstone and lignites).

The samples were processed following the standard palynological maceration techniques [15-16], and special care was taken in aspects such as the initial amount of sample used for the maceration, their careful oxidation using the Schulze reagent and the sieving of the organic residue left after the chemical maceration. The final residues were stained using Safranin "O" (1%). The stained residues were mounted on permanent microscope slides using Cellosize and Kleermount resin as mounting media and sealing agent respectively. A total of 3 slides were prepared for each sample.

The identification and counting of the different palynomorphs were perfomed using a Leitz-Wetzlar Ortholux microscope. The whole cover slip area was scanned. In the case of samples with a limited amount of residue, all three slides were used for the counting. The scanning of the slide was performed using a 12.5X objective lens, whereas the identification of palynomorphs was done with the 54X and 95X oil immersion objective lenses. The counting of fungal remains, such as spores and fructifications mainly, was kept appart from the total counting of land plant pollen and spores, and phytoplankton cysts and spores.

Because of the highly variable number of palynomorphs in the different samples, it was decided to count up to a number of palynomorphs at which no new type was recognized for the next 60 palynomorphs observed.

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

Palynomorph diagrams

The results of the counting of palynomorphs are presented in palynomorph diagrams. Previous papers by van der Hammen and Wijmstra [1] and Wijmstra [4] have presented a type of approach for the use of pollen diagrams, the so-called PAF (Palm-Angiosperm-Fern spores) diagrams to evaluate the nature of environmental changes in the sequences they studied. Frederiksen [17] also pointed out the use of grouping palynomorphs for evaluating environmental variations. A similar approach is used in this paper, using the following 6 different palynomorph groups, based on the botanical and the paleoenvironmental affinities of the palynomorphs:

1) Mangal Group: consisting of those palynomorphs that have been characterized as being produced by plants inhabiting environments with brackish water influence. Muller [18] and Blasco and Caratini [19] defined the mangrove community as vegetation and fauna growing in environments subjected to tidal influence. Chapman [20] preferred to use the word Mangal to define these communities, leaving the term mangrove for the *Rhizophora* and *Avicennia* species. Based on the definition and on the information from previous work on tropical paleofloras, it was decided to include the following palynomorphs as components of this group:

-*Echitriporites trianguliformis* van Hoeken-Klinkenberg [21], common in coastal type of environments [3].

-*Retibrevitricolpites triangulatus* van Hoeken-Klinkenberg [22], a possible ecological equivalent during the Eocene of Colombia to the current *Rhizophora* communities, because of the abundance peaks of this type of palynomorph in transgressive sequences [2].

-*Psilatricolporites crassus* van der Hammen et Wijmstra [1], whose botanical affinity has been related to plants of the genus *Pelliceria* (Theaceae), a plant associated to coastal settings [23-24]. This type of plant is currently restricted to areas in the Pacific coast of Costa Rica, Panama and Colombia, as well as some areas of the Caribbean coast of Colombia [25]. During the early Tertiary this type of palynomorph showed a braad distribution in the Caribbean area [23].

-*Spinizonocolpites*, whose botanical affinity has been related to the genus *Nypa*, very common in mangrove communities in Asia.

2) *Peltandripites* Group: comprising triporate echinate pollen grains of unknown affinity, that were found to be conspicuous in some samples.

3) Palmae Group: including those palynomorphs that were related to this family.

4) Fern Spore Group: including all the monolete and trilete fern spores identifies in this study. Great abundances of fern spores have been related to swamp type of environments [4-17].

5) Dinoflagellate Cysts Group, including cyst of the genus *Operculodinium* Wall [26], the only type of dinoflagellate cysts observed in this study.

6) Freshwater Phytoplankton Group: including the spores of fresh water algae *Pseudoschizea* sp. and the fresh water desmid *Micrastheria* sp.

It should be mentioned that Colmenares [27] used a seventh group, the so-called General Group, that included all the palynomorphs that were not included in the previous categories. This group is not now considered for the discussion in this paper; however, some of the components of this group such as those related to the families Bombacaceae and Chenopodiaceae, will be used in the general discussion on the paleocommunities present at the moment of deposition.

Some of the previously mentioned palynomorphs are shown in plates 1 and 2.

Numerical analysis

Using the relative frequencies of the previously defined palynomorph groups, calculations of the Similarity Index (S.I.) used by Jameossanaie [28] were performed. The calculations involve two-by-two comparisons of the different samples under study, and the determination of a chi-square value as follows:

Sample	Group A	Group B	...	Group K	Total
1	X_{a1}	X_{b1}	...	X_{k1}	N_1
2	X_{a2}	X_{b2}	...	X_{k2}	N_2
Total	X'_a	X'_b	...	X'_k	N_t

were X_{a1}, X_{a2}... X_{k2} are the percentages of the different palynomorph groups (Group A, B ... and K).

$$X^2 = \left(\frac{X^2_a/N}{P_a} + \frac{X^2_b/N}{P_b} + \dots + \frac{X^2_c/N}{P_c} \right) - N_t \quad (1)$$

where:

$$X^2_a/N = \left(\frac{X^2_{a1}}{N_1} + \frac{X^2_{a2}}{N_2} \right)$$

$$X^2_b/N = \left(\frac{X^2_{b1}}{N_1} + \frac{X^2_{b2}}{N_2} \right)$$

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$$X^2_k/N = \left(\frac{X^2_{k1}}{N_1} + \frac{X^2_{k2}}{N_2} \right)$$

and

$$Pa = X'_a/N', P_b = X'_b/N', \dots \text{ and } P_k = X'_k/N'.$$

For the purposes of this study the chi-square values obtained from the two-by-two comparison of samples were considered as S.I. values regardless of their level of significance. The chi-square values were transformed into S.I. values by using:

$$S.I. = 1 - X^2 / X^2_{max} \quad (2)$$

where X^2 is the calculated value of chi-square from the two-by-two comparison and X^2_{max} represents the highest value of all the comparisons done. This index ranges from 0 to 1 (1 indicating the maximum similarity).

The calculations of the cluster analysis were performed using a Basic program implemented by Dr. A. Jameossanaie for personal computers. The results of the cluster analysis are presented in the form of a dendrogram that was performed by using the weighed averaged clustering technique [29].

3. RESULTS

Out of the 71 samples that were prepared, 6 were barren of palynomorphs and only 63 samples were considered for the cluster analysis previously defined.

Age determination

Zambrano *et al.* [10] have calculated the total thickness of the Misoa Formation at about 20000 feet (6096 m) in some areas of the Lake Maracaibo, a fact that clearly indicates the limited time interval considered in this study in core sequences of about 440-470 feet (134-147 m).

The presence of the species *Echitriporites trianguliformis* and *Retibrevitricolpites triangulatus* throughout all the sequences clearly indicates that the sections under study are not younger than the Eocene [3-7].

The additional occurrences of *Bombacacidites soleaformis* Muller *et al.* [7] and *Psilatricolporites operculatus* van der Hammen et Wijmstra in the deepest parts of the cores corresponding to wells B-244 and B-248 and the absence of *Cicatricosisporites dorogensis* Potonie et Gelletich, *Perisyncolporites pokornyi* Germeraad *et al.* and *Retitricolporites quianensis* van der Hammen et Wijmstra restrict the age range of the sequences under study to the palynological zone of *Bombacacidites soleaformis* of Muller *et al.* [7], corresponding to the middle part of the middle Eocene of northern South America.

Paleoclimate

In general, some of the palynomorphs identified in the present paper have been identified in other publications dealing with nearly contemporaneous tropical to subtropical palynological assemblages, such as those described by González

[2] in Colombia, Germeraad *et al.* [3] in northern South America, Africa and Asia, Frederiksen [30] in southern United States and more recently by Graham [31] in Panamá.

Fluctuations of the palynomorph groups: Well B-244.

In general, the recovery, diversity and preservation of the palynomorphs were better in the deepest part of the section, fact that was also observed for the two other well sections under consideration in this study. It was especially observed that the preservation of the palynomorphs was much better in those deposits characterized as being laid down in a low deltaic plain, according to Azpiritxaga [9].

As it is shown in Figure 5, the percentages of the Mangal palynomorph group tend to decrease from the deepest part towards the middle of the section, passing from 29 to 39% to only 1 to 2% at 9266'5", 9217'1", 9209'1" and 9210'2", whereas the percentages of the Spore and Palmae groups tend to increase in the same interval. Towards the top of the sections, the percentages of the Mangal palynomorph group and the *Peltandripites* group begin to increase again, reaching values up to 21% (for the Mangal palynomorph group) and up to 50% (for the *Peltandripites* group). That decrease of the percentages of the Mangal group roughly occurs at the approximate level at which deposits corresponding to an upper deltaic plain were inferred by Azpiritxaga [9]; that is, at 9364'6". It has to be noted that most of the phytoplankton observed in various samples corresponding to this section are characteristic of fresh water environments (*Micrastherias* sp. and *Chomotriletes* sp.), and only one cyst of *Operculodinium* sp. was observed at 9111'2". In general the occurrence of grass pollen was very low throughout all the section and the occurrences of different species of palynomorphs related to the families Bombacaceae and Chenopodiaceae were observed in the intervals inferred to be low deltaic plain deposits.

Fluctuations of the palynomorph groups: Well B-248

As it was mentioned for well B-244, the percentages of the Mangal palynomorph group in the section corresponding to well B-248 (Figure 6) are larger towards the bottom of the surveyed section, with values going from 18 to 45% (at

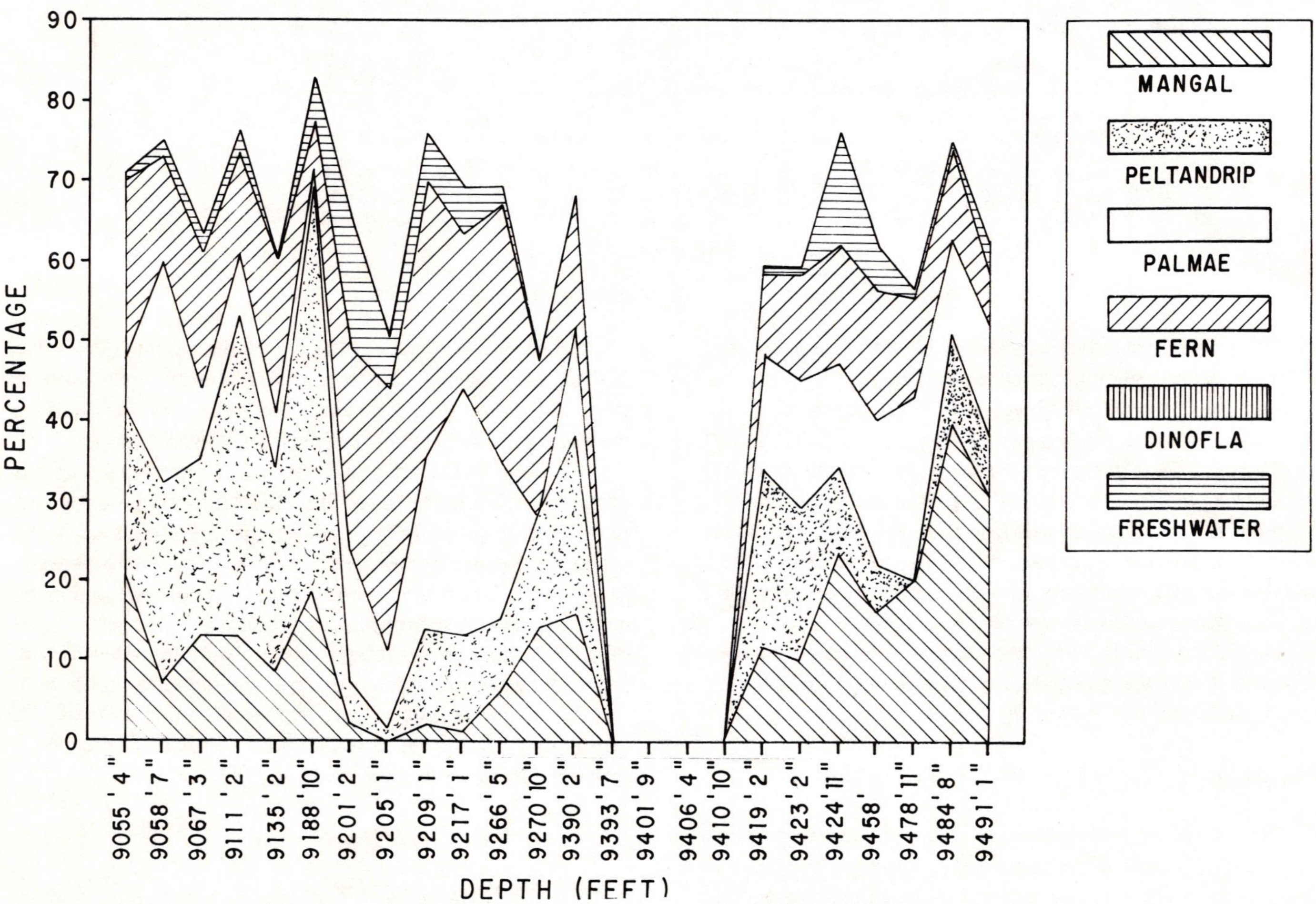

Fig. 5. Percentages of the palynomorph groups: Well B-244.

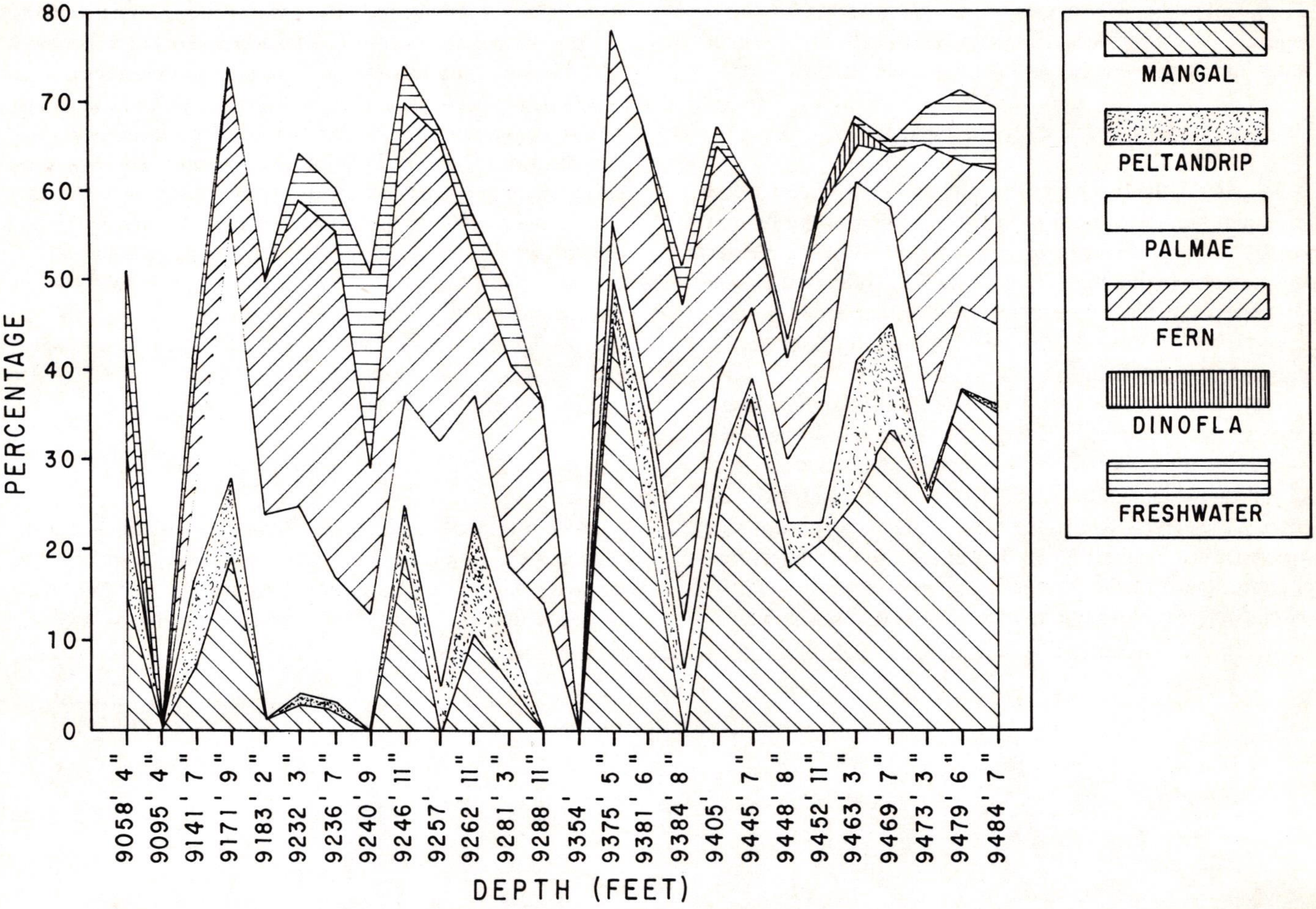

Fig. 6. Percentages of the palynomorph groups: Well B-248.

9375'5"). Then, towards the middle of the section, a significant decrease in the percentages of this group is observed, that roughly coincides with the level at which upper deltaic plain deposits were inferred by Azpiritxaga [9]; that is, at 9353'. The tendencies of the percentages of other palynomorph group are more erratic in this section than those discussed in well B-244.

It has to be mentioned that freshwater phytoplankton was observed in most of the samples, in very fluctuating percentages, and that the only occurrence of dinoflagellates corresponding to genus *Operculodinium* was observed at 9463'3". As it was mentioned for well B-244, the occurrences of palynomorphs related to Bombacaceae and Chenopodiaceae were observed mainly at the deepest part of the section.

Fluctuation of palynomorph groups: Well B-252

Of the three sections under study, the section corresponding to well B-252 yielded the less amount of palynomorphs and their preservation was not as good as that observed for the palynomorphs identified in wells B-244 and B-248.

In general, the tendency shown by the percentages of the Mangal palynomorph group is erratic, with high percentages towards the bottom and the top of the section. However, in the middle part of the section (at 8867'4", 8861'7" and 8857'5", Fig. 7), there is a drastic decrease of the percentages of this group, coinciding with the occurrence of upper deltaic deposits in the section [9] at 8921'. Towards the top of the section the percentages of the Mangal palynomorph group tend to increase, but show marked fluctuations, a fact that is not observed in the deepest part of the section under consideration. The percentages of the *Peltandripites* group also show a similar tendency, with the tendency of high values towards the top of the section.

The occurrences of freshwater phytoplankton are observed throughout all the section and the only occurrence of a dinoflagellate cyst was observed at 8573'10".

Cluster analysis

The dendrogram shown in Figure 8 indicated 4 main clusters, whose characteristics are as follows:

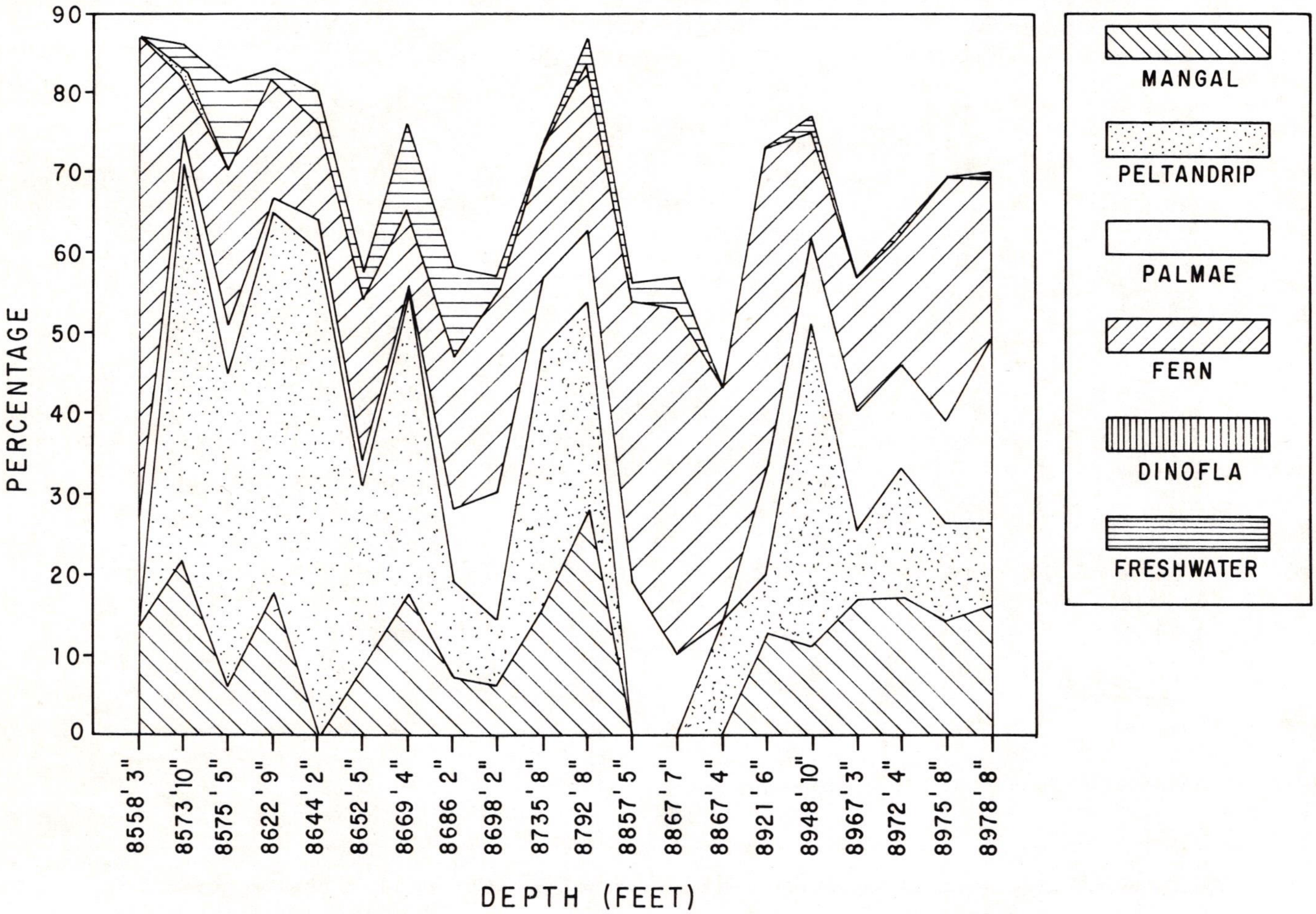

Fig. 7. Percentages of the palynomorph groups: Well B-252.

1- Cluster I; characterized by samples with very low percentages of the Mangal palynomorph group (0-2%). It has to be noted that all of them, except one, 9384'8" of well B-248, are located at intervals at which the transition from a low deltaic to an upper deltaic plain was inferred to have occurred in the three wells (Table 1).

2- Cluster II; characterized by moderate frequencies of the Mangal group (3-22%), Palmae and Spore group (8-40%) and a large proportion of palynomorphs with unknown botanical or paleoenvironmental association. The location of the samples included in this cluster is observed to be distributed in both low and upper deltaic plain deposits, but they are mostly located towards the middle of the three sections under consideration.

3- Cluster III; characterized by samples presenting the highest percentages of the Mangal group. This cluster includes only samples from wells B-244 and B-248, located at the deepest parts of the surveyed sections of these two wells.

4- Cluster IV; characterized by samples presenting relatively high percentages of the Peltandripites group (14-60%). Samples of this cluster are observed mainly in sections corresponding to wells B-244 and B-252, and are located mostly towards the top of the surveyed sections.

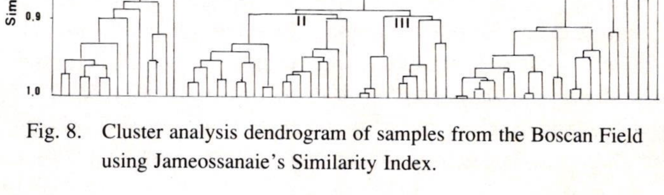

Fig. 8. Cluster analysis dendrogram of samples from the Boscan Field using Jameossanaie's Similarity Index.

WELL B-244		WELL B-248		WELL B-252	
Depth (Feet)	CLUSTER	Depth (Feet)	CLUSTER	Depth (Feet)	CLUSTER
9055'4"	IV	9058'4"	II	8573'10"	IV
9058'7"	II	9141'7"	II	8575'6"	IV
9067'3"	IV	9171'9"	II	8622'9"	IV
9111'2"	IV	9198'3"	I	8644'2"	IV
9135'2"	IV	9232'3"	I	8652'5"	IV
9188'10"	IV	9236'7"	I	8669'4"	IV
9201'2"	I	9240'9"	I	8686'2"	-
9205'1"	I	9246'11"	II	8698'2"	-
9209'1"	I	9257'1"	I	8735'8"	IV
9213'1"	-	9262'11"	II	8792'8"	IV
9217'1"	I	9281'3"	II	8857'5"	I
9266'5"	II	9288'11"	I	8861'7"	I
9270'10"	-	9375'5"	III	8921'6"	II
9390'2"	IV	9381'6"	II	8948'10"	IV
9419'2"	IV	9384'8"	I	8967'3"	II
9423'2"	IV	9405'	II	8972'3"	IV
9424'11"	II	9445'7"	II	8975'8"	II
9458'	II	9448'8"	II	8978'8"	II
9478'8"	III	9452'11"	III		
9484'8"	III	9463'3"	III		
9491'9"	III	9469'7"	III		
		9473'3"	III		
		9479'6"	III		
		9484'7"	III		

Table 1. List of the samples of each well that were considered for the cluster analysis, and the type of cluster which they were included in.

Paleoenvironmental and paleoecological interpretations

The dominant abundance of terrestrially derived palynomorphs and the occurrence of marine phytoplankton in very low percentages and in scattered samples throughout the studied sections indicate that these sediments were deposited under minor marine influences. However, the fluctuating percentages of the Mangal palynomorph group indicates tidal or at least brackish water influence in the depositional environments at the time of deposition, as it is inferred from the definition of this group based on the characteristics given by Muller [18] in regard to the mangrove type community.

In order to discuss the nature of the observed fluctuations of the different groups of palynomorphs, it is important to mention some of the factors that affect the distribution of plant communities, and indeed, of the palynomorphs they produce in deltaic and coastal environments. Chapman [20] and Jimenez [25] discussed the importance of soil salinity gradients on the distribution of plant communities, reaching the conclusion that there is a significant distinction between the types of plants inhabiting environments with different salinity gradients. Muller [32] clearly distinguished at least 7 different types of vegetational zones in the Orinoco Delta, from the mangrove type community on the coastal region of the delta and along channels subjected to tidal influence, dominated mainly by *Rhizophora* and *Avicennia*, the mixed-swamp and *Erythrina* swamp forest, with plants related to the family Bombacaceae (located in the low delta plain), to the palm, herbaceous swamps and rain forest communities located on the upper delta plain. It has to be noted that authors, such as West [33], distinguished a further zonation within the mangrove zone, inferring a *Rhizophora* belt in soils with higher salinity than those of the *Avicennia* belt, located in areas behind the *Rhizophora* belt. Blasco and Caratini [19] also observed at least three types of plant communities; the mangrove belt (dominated by *Rhizophora* and *Avicennia*), in areas with significant tide influence; a vegetational belt, characterized by the occurrence of plants of the Chenopodiaceae and Palmae families located in areas with occasional tidal influence or marine immersion; and a third vegetational belt, located in areas lacking tidal or marine influence, dominated mainly by palms.

Based on the fluctuations of the percentages of the palynomorph groups and on the results of the cluster analysis, it can be inferred that the plant communities existing at the time of deposition represented a mixed type of plant community at the oldest part of the three studied sections. The occurrence of palynomorphs related to coastal environments or plants inhabiting those environments in relatively high proportions, and the occurrences of palynomorphs related to the Bombacaceae and Chenopodiaceae, seems to suggest that the environments of deposition were located in or near areas subjected to permanent or occasional marine immersion. In wells B-244 and B-248, the palynological assemblages contained cysts of *Operculodinium*, clearly indicating marine water inflow. The presence of grass pollen (*Monoporites* sp.) in very low percentages seems to corroborate that open grass swamps, characteristic of the upper deltaic plain [32], were not close to the environments of deposition.

Wijmstra [4] noted that high percentages of *Rhizophora* indicated sedimentation in the mangrove belt area and thus the position of the coast line. For the purposes of this study, it is difficult to infer the position of the coast line, since *Rhizophora* was not present in northern South America until the late Eocene-Oligocene. González [2] proposed that *Retibrevitricolpites triangulatus* could be an ecological equivalent to the mangrove communities currently present in South America. The low percentages of this type of pollen, as well as the moderate percentages of the Mangal palynomorph group in the present study seems to indicate that deposition of the sequence under consideration took place in an area behind the coast line. Then the samples included in cluster III, could correspond to environments where a mixed-type of community including Mangal plant elements (*Pelliceria* and *Nypa* for example) and plants of the families Bombacaceae, Chenopodiaceae and Palmae were also present. On the other hand, samples included in cluster I seem to represent plant communities characteristic of areas lacking tide influence, located on the upper delta plain, where the low salinity of the soils did not allow the growth of the Mangal type or mixed-type community previously discussed. As it was mentioned before, the occurrence of the samples included in cluster I coincided with the levels at which the transition from a low delta plain to an upper delta plain was inferred by Azpiritxaga [9].

The paleoecological significance of cluster II seems to indicate a transitional nature between clusters I and III, in the sense of the intermediate percentages of the Mangal group and the position of the samples included in this cluster within the sections under consideration (towards the middle and top of the sections). However, it can also represent the mixing of the different palynomorphs in high energy environments. Blasco and Caratini [19] observed that palynological assemblages recovered from river channel samples usually yielded a large amount of allochthonous pollen (palynomorphs related to plants located away from the definite site of deposition), because of the energy of the water flow that allowed the transport and mixing of different palynomorphs. This effect can also be expected in environments subjected to inflow of fresh or marine water, such as the crevasse splay, distributary channel, distributary mouth bar and natural levee environments inferred by Azpiritxaga [9]. Therefore, the representation of allochthonous palynomorphs in the palynological assemblages observed in this study can be significant and can indeed obscure the real proportion of autochthonous pollen in the samples under study.

In regard to cluster IV, since the botanical affinity of *Peltandripites* sp. is unknown, it is difficult to elaborate on the paleoecological significance of this cluster. However, a preliminary inferrence in this study seems to indicate that this type of pollen is also associated to coastal environmental settings, because it tends to occur in high percentages at the same levels where the Mangal palynomorph group also showed high to moderate percentages.

As it was mentioned in the previous discussion, towards the top of the three sections under study, the percentages of the Mangal group and of the *Peltandripites* group tended to increase, as well as a very occasional presence of a dinoflagellate cyst (well B-252), indicating a major marine or brackish water influence in the environments of deposition. This fact can be related to the model proposed by Zamora [12] and Bockmeulen *et al.* [11], for some areas of the Lake Maracaibo Basin during the Eocene, of high subsidence rates, causing the piling up of deltaic sequences. Therefore, a transition from an upper delta plain to a low delta plain could have been taking place, with increasing marine or brackish water influence resulting in increasing representation of Mangal palynomorphs towards the top of the sections.

4. CONCLUSIONS AND RECOMMENDATIONS

The palynological analysis of 71 core samples from three wells of the Boscan Field was performed. The palynological assemblages, as a whole, were mainly dominated by angiosperm pollen and fern spores, besides freshwater phytoplankton. Scattered occurrences of dinoflagellate cysts were observed, indicating some marine or brackish water influence in the paleoenvironments of deposition.

The palynological assemblages were characterized to be of middle Eocene age, specifically within the middle Eocene *Bombacacidites soleaformis* palynological zone of Muller *et al.* [7].

The occurrence of palynomorphs related to plants characteristic of coastal environments or associated to those types of environments in relatively high to moderate percentages, as well as the occurrences of palynomorphs related to the families Bombacaceae and Chenopodiaceae, indicate the presence of a mixed-type community in the environments of deposition, that were probably located behind the coastline in areas subjected to marine or brackish water influence. Since the characteristic mangrove community currently existing in tropical coastal areas (dominated by *Rhizophora* and *Avicennia*) did not exist until the late Eocene, it can be assumed that a mixed community of plants inhabited this type of environment and was later gradually replaced by the *Rhizophora-Avicennia* community after the late Eocene.

Significant variations of the nature of the flora, related to environmental changes, were observed. Samples, whose palynological assemblages showed high to moderate abundance of Mangal palynomorphs, were observed towards the bottom of the three sections (clusters II and III), whereas samples, whose palynological assemblages were characterized by the low percentages of the Mangal palynomorph group (cluster I), were located at the approximate level at which the sedimentary model proposed by Azpiritxaga [9] predicted the transition from low delta plain to upper delta plain deposits. Towards the top of the three sections, the percentages of the coastal palynomorph and the *Peltandripites* groups tended to increase (clusters II and IV), indicating more marine or brackish water influence. This fact was related to the geological model of a rapid subsidence in some areas of Lake Maracaibo, proposed by Zamora [12] and Bockmeulen *et al.* [11], that could have caused the piling up of deltaic sequence. The increasing marine or brackish water influences, then, could represent part of a transition from upper delta plain deposits to lower delta plain deposits towards the top of the sections.

From the evolutionary point of view, the Eocene communitites have been a difficult topic to study in northern South America, because of the isolation of South American floras from those of Africa and North America (Graham, personal communication). Therefore, future studies, considering the botanical affinities of the observed palynomorphs or numerical analyses that can provide an insight view of the associations of certain types of palynomorphs to specific sets of environments, can be helpful to provide a reliable framework for future research on palynological studies of Eocene paleofloras.

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PLATE 1. (All magnifications X1000)

1. *Micrastherias* sp. Sample B-248 9463'3". 119.0 x 45.1 (L-1). Fresh water desmid algae.
2. *Chomotriletes* sp. Sample B-248 9463'3". 125.5 x 30.9 (L-1). Fresh water algae.
3. *Polypodiisporites* sp. Sample B-248 9257'. 112.9 x 42.7 (L-1). Related to the fern family Polypodiaceae.
4. *Mauritiidites* sp. Sample B-244 9390'2". 122.1 x 34.3 (L-1). Related to the *Mauritia* (Morichal palm), a genus of palms commonly found in the Venezuela and Colombia Llanos.
5. *Spinizonocolpites* sp. Sample B-248 9246'11". 123.8 x 23.4 (L-1). Related to the mangrove palm *Nypa*.
6. *Retibrevitricolpites triangulatus* van Hoeken-Klinkenberg. Sample B-248 9463'3". 122.6 x 41.4 (L-1). Unknown botanical affinity, but proposed by González [2] as a possible Eocene ecological equivalent to the mangrove type vegetation.
7. *Retitricolpites magnus* Gonzalez. Sample B-248 9463'3". 125.6 x 21.4 (L-1). Unknown botanical affinity.
8. *Psilatricolporites crassus* van der Hammen et Wijmstra. Sample B-248. 9246'11". 117.0 x 44.1 (L-1). Related to *Pelliceria* (Theaceae).
9. *Retitricolporites irregularis* van der Hammen et Wijmstra. Sample B-248 9448'8". 115.7 x 37.0 (L-1). Related to plants of the genus Amanoa (Euphorbiaceae).
10. *Psilatricolporites operculatus* van der Hammen et Wijmstra. Sample B-248 9448'8". 115.7 x 37.0 (L-1). Related to plants of the genus Alchornea (Euphorbiaceae).

PLATE 1

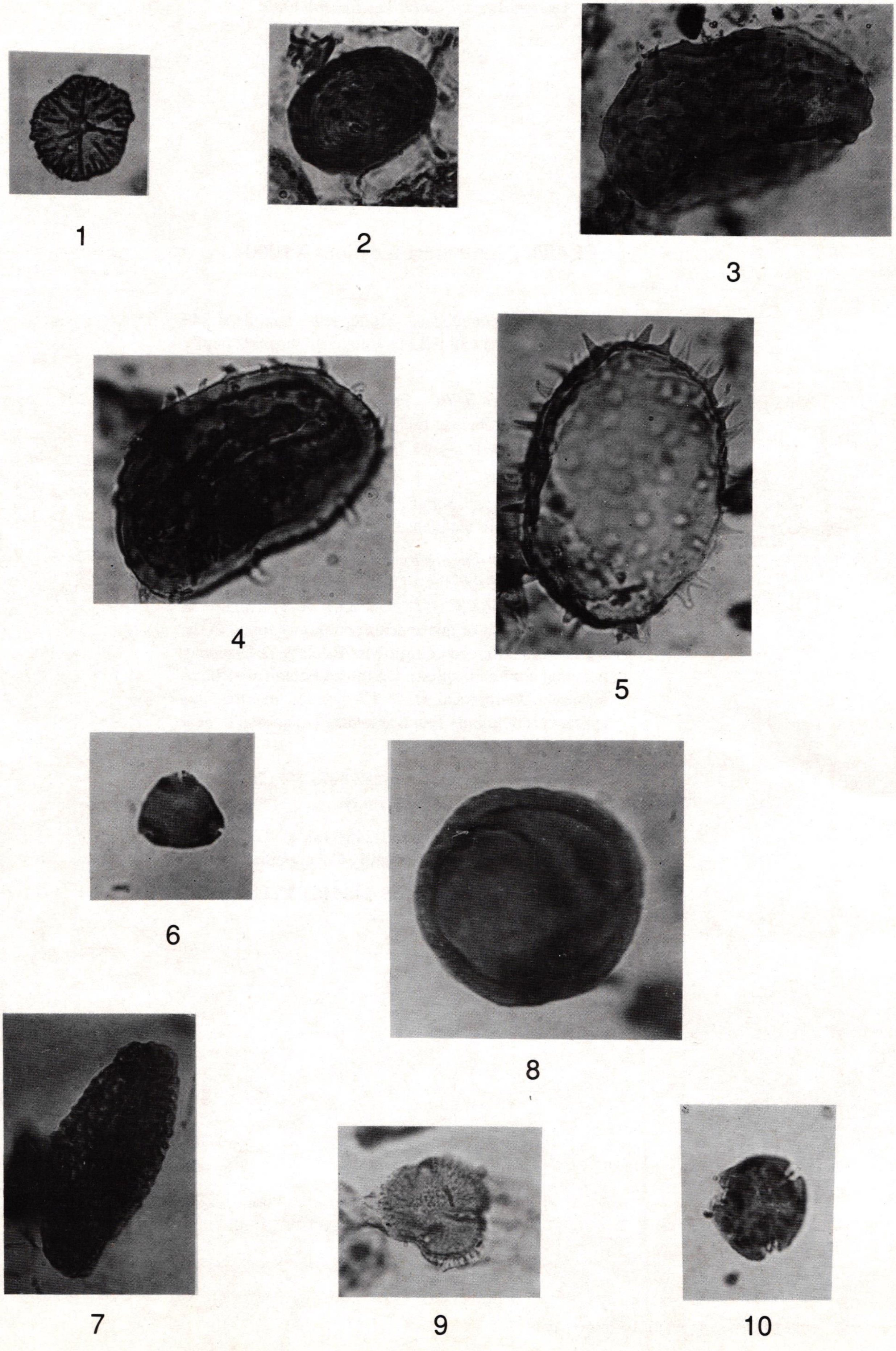


PLATE 2. (All magnifications X1000)

1. *Bombacidites soleaformis* Muller *et al.* Sample B-248 9246'11". 127.0 x 38.0 (L-1). Related to the plant family Bombacaeae.

2-3. *Bombacacidites bellus* Frederiksen. Samples B-248 9262'. 119.0 x 38.7 (L-1) (Figure 2) and B-248 9375'5". 127.0 x 23.9 (L-1) Figure 3). Related to the plant family Bombacaeae.

4. *Bombacacidites* sp. Sample B-248 9232'3". 112.9 x 98.0 (L-1). Related to the plant family Bombacaeae.

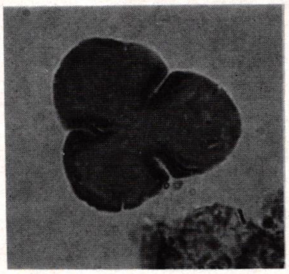
5-6. *Echitriporites trianguliformis* van Hoeken-Klinkenberg. Samples B-248 9463'3". 126.5 x 26.3 (L-1) (Figure 5) and B-248 9463'3". 118.5 x 35.1 (L-1) (Figure 6, tetraporate form of this species commonly found in the Misoa Formation according to Mrs. Estela de Di Giacomo, personal communication). Unknown botanical affinity. However, Germeraad *et al.* [3] pointed out that this species is commonly found associated to coastal or near shore sedimentary deposits.

7. *Peltandripites* sp. Sample B-252 8978'8". 126.9 x 38.9 (L-1). Unknown botanical affinity.

8. *Psilaperiporites* sp. Sample B-248 9488'8". 127.7 x 25.7 (L-1). Related to the plant family Chenopodiaceae.

9. *Operculodinium* sp. Sample B-248 9463'3". 115.0 x 41.7 (L-1). Dinoflagellate cyst.

PLATE 2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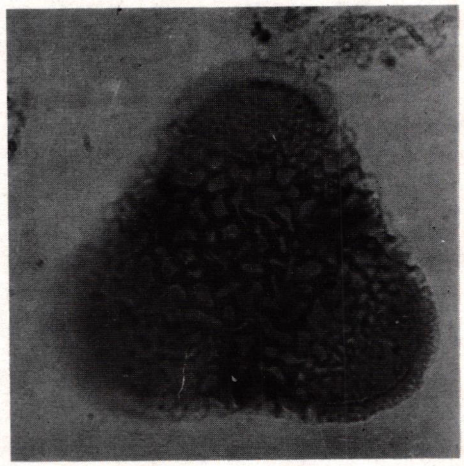
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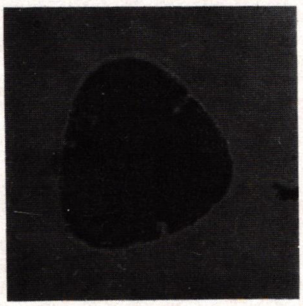
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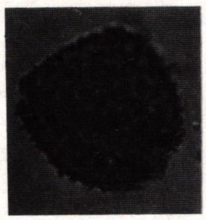
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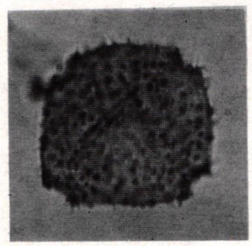
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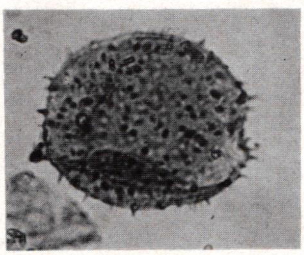
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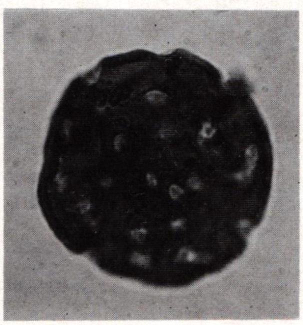
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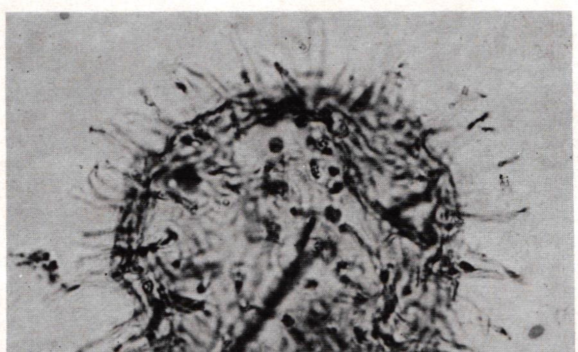
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