

**MIDDLE TO LATE EOCENE DINOFLAGELLATE CYSTS AND  
FUNGAL SPORES FROM THE EAST COAST OF THE  
MARACAIBO LAKE, VENEZUELA  
(BIOSTRATIGRAPHY, PALAEOECOLOGY AND TAXONOMY)**

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# MIDDLE TO LATE EOCENE DINOFLAGELLATE CYSTS AND FUNGAL SPORES FROM THE EAST COAST OF THE MARACAIBO LAKE, VENEZUELA: (BIOSTRATIGRAPHY, PALAEOECOLOGY AND TAXONOMY)

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Keywords: Dinocysts, fungal remains, eocene, palaeocology, taxonomy, eastern Zulia, palynology, biostratigraphy, Jarillal Formation, Pauji Formation, Caus Formation.

## Abstract

Palynological investigation (dinoflagellate cysts and fungal remains) of 155 samples from the two subsurface sections and three outcrop of the Middle-Upper Eocene siliciclastic-carbonate platform facies of the Jarillal, Pauji and Caus formations of the Eastern Zulia yield a total of 60 species of dinoflagellate cysts, 42 species of fungal remains, freshwater protists and acritarchs, and numerous phytoclasts. Five new species of fungal remains are described.

By means of characteristic dinoflagellate cysts, four assemblages zones were defined which led to the stratigraphic division of the profiles.

Comparative research on the stratigraphic distribution of Middle Eocene dinoflagellates in different geographical areas not only confirmed the stratigraphic distribution but also extended their stratigraphic range. This extension applies mainly to the dinocysts *Polysphaeridium subtile* and *Areoligera senonensis*. Therefore, their significance as a stratigraphic marker is limited.

The composition of the terrestrial palynoflora (fungal remains) is indicated of a general warm and climatic humid conditions during the Middle-Upper Eocene.

A comparison of characteristic taxa demonstrates the significance of the dinocysts as environmental indicators. Fluctuations in the concentration of palynomorphs suggest that the dinocysts/sporomorphs ratio (pollen, spores and fungi) is controlled by ecological events. The numbers of sporomorphs, which progressively decreases from on-to offshore, is paralleled with increase of diversity of dinoflagellate spectrum.

Monospecific dinoflagellate associations document a shallow water environment in the Middle Eocene of sites Quebrada Palma and Quebrada Honda, probably correlated with a drastic decline of the sea level.

The possible influence of oceanic current systems is evident in the distribution pattern of the dinoflagellate associations.

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## INTRODUCTION – OBJECTIVES

# 1

Biostratigraphical and paleoenvironmental analyses of the Eocene sediments from the East Coast of Lake Maracaibo are still mainly based on calcareous microfossils (foraminifers, nannofossils) and/or pollen and spores. Zonal schemes based on these groups of microfossils allow intrabasinal subdivisions and correlations, but their calibration with the international chronostratigraphic time scale is often somewhat problematic (Crux et al., 1997). This problem is common to several neotropical areas such as Brasil, Colombia and Venezuela (Jaramillo, 1999). Since many representatives of these microfossils are restricted to rather narrow facies realms, they are unsuitable for intrabasinal correlations between marginally marine and deeper marine deposits (Wilpshaar, 1995).

In order to overcome some of these restrictions, I have tried to use two groups of organic-walled microfossils, dinoflagellate cysts and fungal spores, in order to contribute to a better understanding of the stratigraphic correlations and paleoenvironmental interpretations within the Eocene of the Eastern part of Lake Maracaibo.

Dinoflagellate cysts have been used successfully as stratigraphic tools, particularly in hydrocarbon exploration in many parts of the world (e.g. Williams, G. & Brideaux, W., 1975; Staplin, 1976; Norris, 1986; Powell, 1988; Bujak & Mudge, 1994; Mudge & Bujak, 1994, 1996; Helenes et al., 1998; Helenes & Somoza, 1999; Torrecelli & Biffi, 2001). They are not only very useful for interregional correlations and chronostratigraphy, but also for paleoenvironmental determinations, such as the recognition of changes in sea level, sea surface temperature and productivity (e.g. Brinkhuis, 1988, 1992, 1994, Brinkhuis et al., 1998; Wilpshaar, 1995).

Due to the lack of published data, the biostratigraphical and paleoenvironmental use of fungal spores is considerably less established

(Elsik, 1978). However, in recent years, data on the diversity and on their value for environmental interpretations have increased rapidly (Kalgutkar & Sigler, 1995). They occur commonly associated with spores, pollen and algal remains, but they are generally better preserved and more resistant to destruction by oxydation.

I have tried to present an inventory of the dinoflagellate cysts and fungal spores of the Middle-Late Eocene Jarillal and Paují formations including their description, illustration, occurrence and a discussion of their stratigraphic and paleoecologic significance. In addition, the palynofacies of the organic matter contained in the studied samples has been analysed.

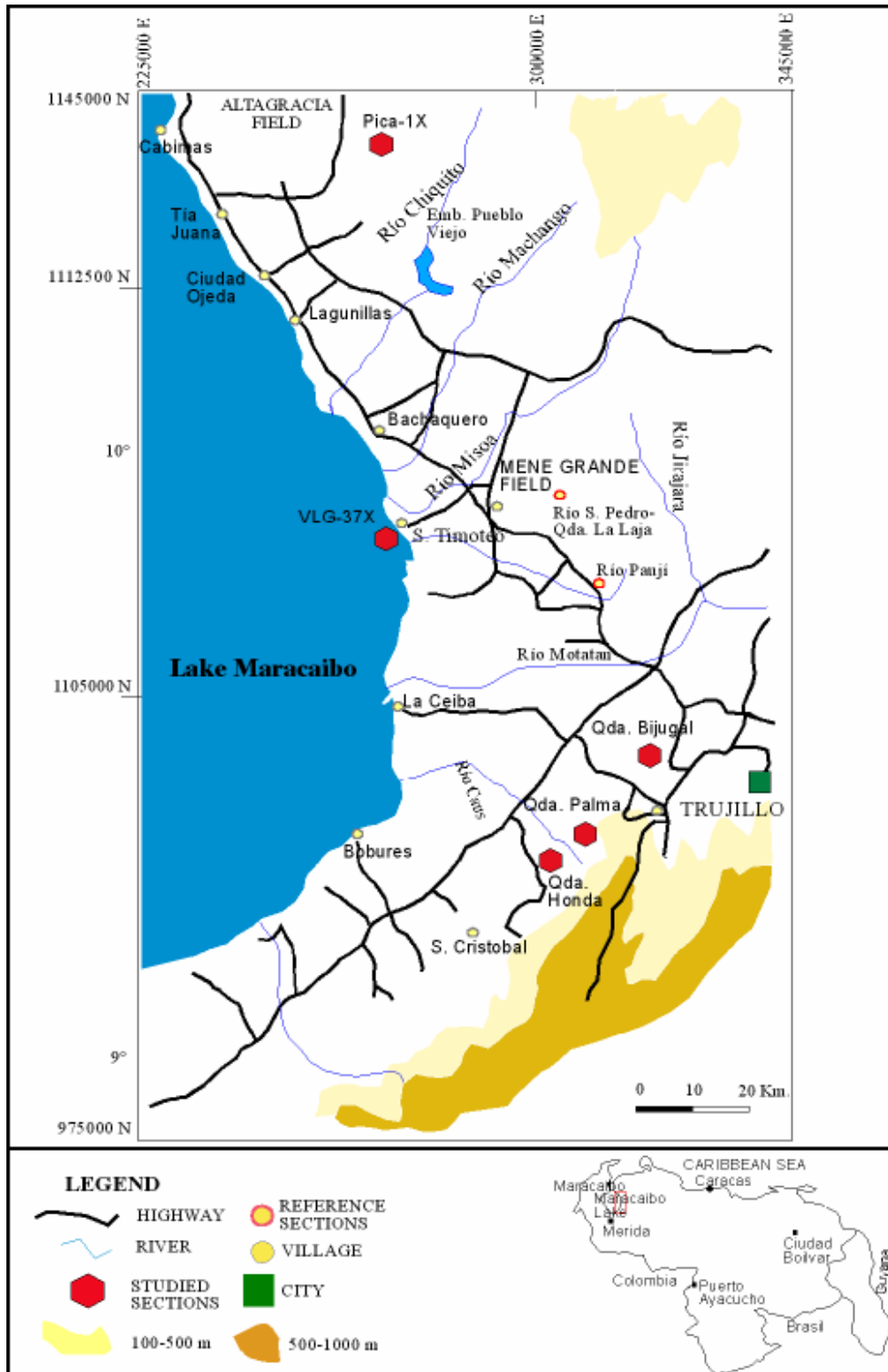
The present study of the biostratigraphy, palynostratigraphy and sequence stratigraphy of the five Middle-Late Eocene sections of the east coast of Lake Maracaibo consists of :

- Identification of fossil dinoflagellate cysts and fungal spores.
- Biostratigraphic subdivision of the Middle-Late Eocene interval based on the occurrence, diversity and abundance of palynomorphs.
- Reconstruction of the paleoenvironmental and paleoclimatic conditions during the deposition of Jarillal and Paují formations.
- Comparison of the observed distribution of palynomorphs with that in other regions in order to intergrate the regional subdivisions into the standard timescale.
- Integration of palynofacies and paleoecology based on palynomorphs into a tentative sequence stratigraphic framework.

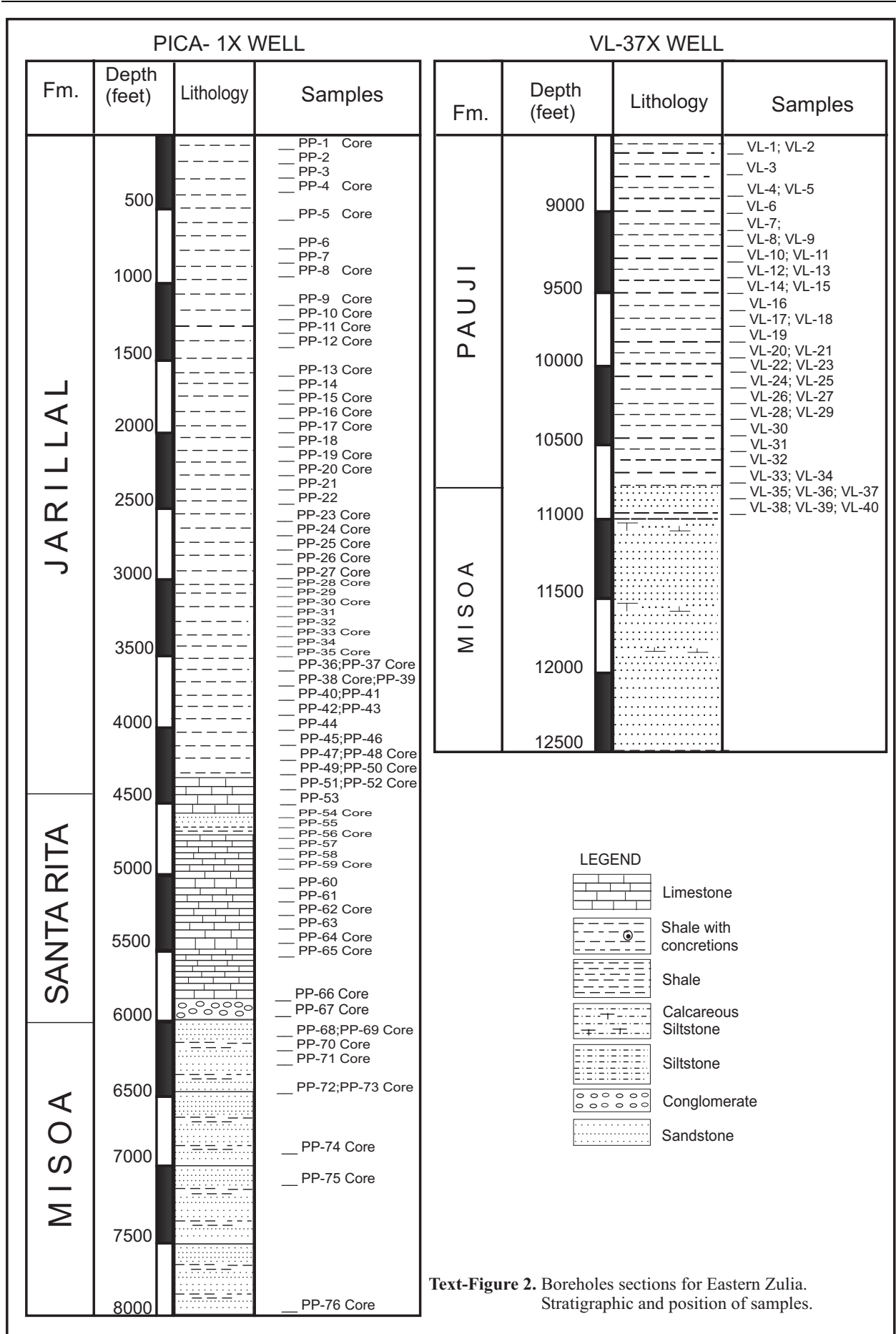
1.1 Location of study area

The area selected for the present study is located in northwestern Venezuela and covers approximately 9.648 Km<sup>2</sup> of the Eastern coast of the Maracaibo Lake. It is limited to the north by the Altagracia oil field, to the south by the La Ceiba field, the Mene Grande field to the east

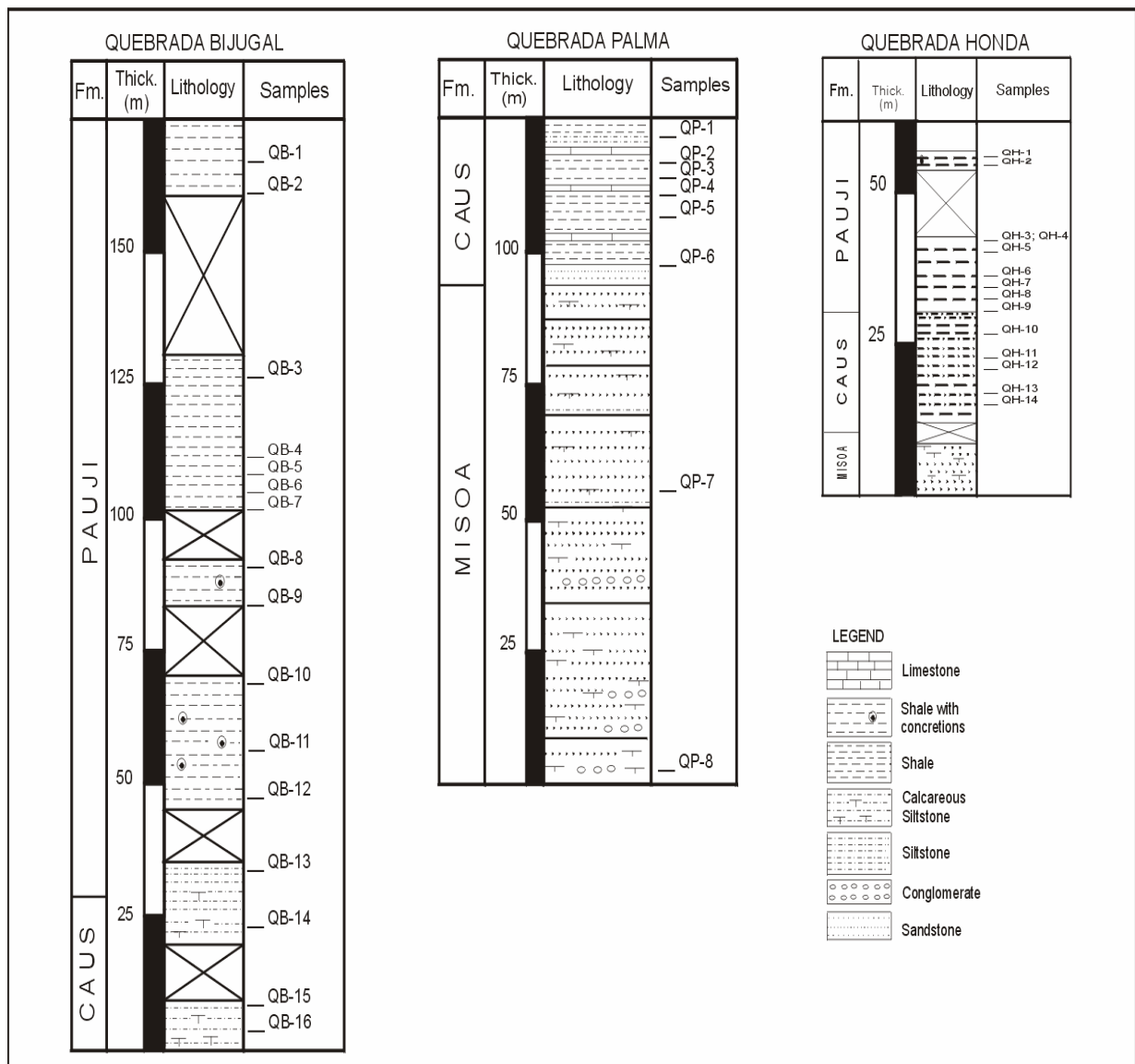
and the Ceuta field to the west. Traditionally, it is known as Zulia Oriental (see Text-Figure 1). Within this area, the study concentrates on the Middle to Late Eocene shales of the Jarillal and Pauji formations, and the carbonates of the Caus Formation which occurs only locally (see Text-Figure 2 and 3).



Text-Figure 1. Map of Eastern Zulia showing the location of studied sections.



Text-Figure 2. Boreholes sections for Eastern Zulia. Stratigraphic and position of samples.



Text-Figure 3. Outcrop sections for Eastern Zulia. Stratigraphic and position of samples.

Regional Geological Setting

2

2.1 Tectono-stratigraphic framework

Several regional studies mainly by foreign and Venezuelan oil companies have described the geological history of the sedimentary basins of western Venezuela in terms of a regionally consistent tectono-stratigraphic framework. The evolution of these basins is intimately related with the plate-tectonic history of South-America.

The geologic history comprises six supersequences (see Table 1) composed of small-scale depositional sequences and bounded by unconformities which can be recognised not only in Venezuela, but throughout sections and northern South America (Parnaud et al., 1995; BP & PDVSA., 1992).

Super Sequence	Intervals	Events	Sequence Boundary/ age in Ma
<b>E and F</b>	<b>Late Eocene to Middle Miocene</b>	Compressional deformation of the foreland basin caused by the collision of the Panama Arc against the South-American craton.	SB-15.5
		This episode is responsible for the separation of the Lake Maracaibo and Barinas basins.	SB-39.0
<b>D</b>	<b>Late Paleocene to Middle Eocene</b>	Collision and obduction of the Pacific Volcanic Arc with overriding by the South American Plate.	SB-45
		Emplacement of the Lara Nappes generates a major Eocene foredeep basins.	SB-58
<b>C</b>	<b>Late Cretaceous to Paleocene</b>	Transitional phase. Collision of the Pacific Volcanic Arc with the South American Plate transforms the passive margin into an active orogenic belt.	SB-66
			SB-74
<b>B</b>	<b>Cretaceous</b>	Passive margin. Widespread anoxic conditions and high organic productivity (period) resulted in the widespread development of source rocks.	SB-98
			SB-132
<b>A</b>	<b>Late Triassic to Jurassic</b>	System of basins interpreted as extensional rift. The formation of this rift was a response to north-west/south-east crustal stretching and the initiation of the continental breakup between North and South America (BP & PDVSA, 1992)	

Table 1. Summary chart of the tectono-stratigraphic framework (mainly based on Parnaud et al., 1995)

**2.2 Paleogene tectono - stratigraphic and depositional history in Eastern Zulia**

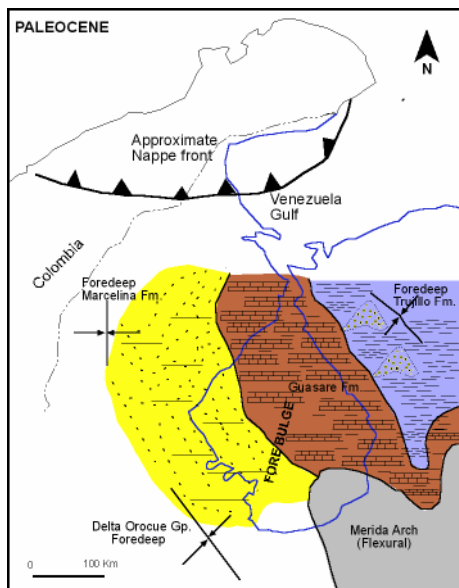
The tectono-stratigraphic evolution of Eastern Zulia is intimately linked to the regional geological development of the Maracaibo Basin which contains sediments deposited from Jurassic to Holocene times (Lugo, 1991; Lugo & Mann, 1995).

Paleogeographical maps of the Maracaibo Basin based on the sequence stratigraphic and plate-tectonic interpretations have been produced by Higgs & Pindell (1994), Higgs et al.(1995), Parnaud et al. (1995), Ghosh et al. (1997).

The following summary of the paleogeographical development emphasises the Paleogene (Paleocene-Middle Eocene) of Eastern Zulia, but considers also adjacent regions.

- **Early Paleocene**

The NW-SE orientation of the facies belts in the Cretaceous changes to NE-SW in the Early Paleocene. The Eastern Zulia is affected by the uplift of a fore bulge caused by the transpressive obduction of the eastward migrating Caribbean Arc. Uplift of the fore bulge is indicated by the shallowing upward trend within the bathyal shales of the Maastrichtian Colon Formation overlain by Early Paleocene shallow marine bioclastic limestones of the Guasare Formation. The open-marine muds and turbiditic sands of the Trujillo Formation accumulated northeast of the fore bulge (see Text-Figure4).



**Text-Figure 4.** Palaeogeographic map of the Paleocene (Parnaud et al., 1995; Ghosh et al., 1997)

- **Late Paleocene**

The gradual southwestward migration of the fore bulge is responsible for the regional Guasare-Misoa unconformity in the the Lake Maracaibo region. The age of this unconformity on top of the Guasare Formation is Late Paleocene (Zone P3, Lorente, 1996).

During this time, the depocenter of the Trujillo Formation migrates transgressively towards Eastern Zulia. There, Burro Negro-Paujil Fault controls the distribution and thickness of the bathyal and shallow marine facies of this formation (Leon et al., 1995).

The emplacement of the Lara Nappes started north of the Lake Maracaibo. These nappes gradually propagate eastward and originate to a new foreland basins (Parnaud et al, 1995).

- **Early Eocene**

The Misoa Formation conformably overlies the Paleocene-Early Eocene Trujillo Formation, however, west of the Burro Negro-Paujil Fault, Leon et al. (1995) recognized a major regional unconformity on seismic lines that separates the “neritic” Trujillo Formation from the Misoa Formation.

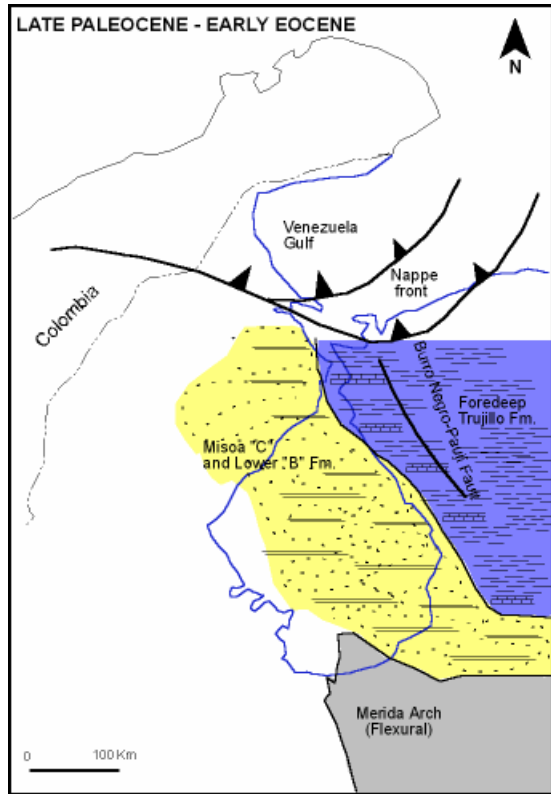
The flexure of the shelf leads to a second transgressive phase which starts with the deposition of the stacked Misoa “C” sandstone (see Text-Figure 5).

During the Early Eocene, the deep marine facies of the Trujillo Formation persist in the northern part of Eastern Zulia.

The sedimentation of the Misoa Formation culminates with the high-stand systems tract of the deltaic lower Misoa “B” (Parnaud et al., 1995).

- **Middle Eocene**

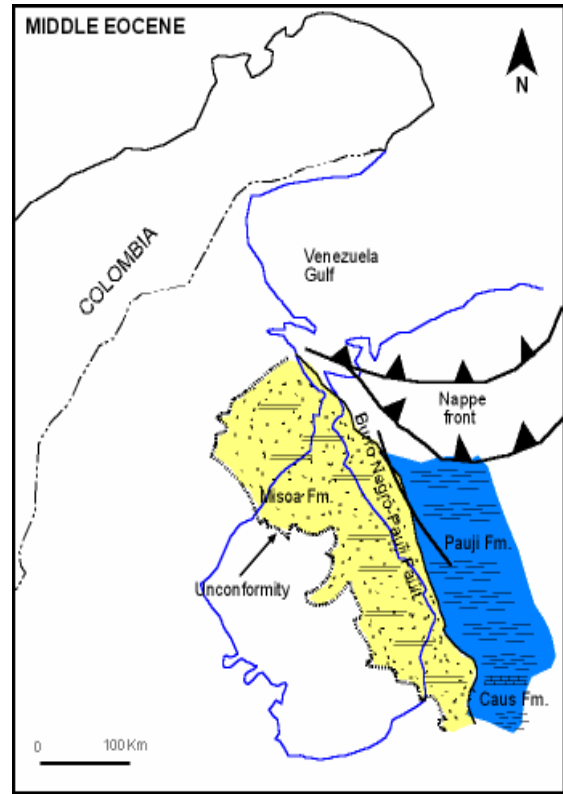
During the Early Eocene and at the beginning of the Middle Eocene (see Text-Figure 6), an extensional regime is predominant perpendicular to the compressional regime which persisted. This extension a regime leads to the development of the Orocué Foredeep (Colombia) as well as to the formation of an important depocenter in Eastern Zulia as result of the emplacement of Lara Nappes (Melendez et al., 1996).



**Text-Figure 5.** Palaeogeographic map of Late Paleocene-Early Eocene (Parnaud et al., 1995; Higgs & Pindell, 1994)

In this depocenter, the shallow marine shelf sediments of the upper Misoa "B" are overlain by the bathyal shales of the Pauji Formation (Parnaud et al., 1995). Even if an extensional style is predominant, a compressive phase in the central and Eastern part of the Lake Maracaibo Basin coincides with unconformity SB-44 ("base B-6" within the lake) which separates the lower Misoa "B" from the upper Misoa "B" (Leon et al., 1996; Melendez et al., 1996). SB-44 is the main intra-Eocene unconformity.

The start of the inversion in the Middle Eocene is related to the final phase of the emplacement of the Lara Nappes (Leon et al., 1996). Toward the end of the late Middle Eocene, uplift of the local graben due to inversion reaches its maximum at end of the sedimentation of the Pauji Formation and prior to the deposition of the Mene Grande Formation and its equivalent, the "Piedras Blancas" in the Burro Negro Graben. In the entire area corresponding to northwestern Venezuela and two different tectonic provinces can be recognized: the Lake Maracaibo Basin Province and the Falcon Basin Province separated by the Burro Negro-Pauji Fault and Valera Fault (see Text-Figure 7).



**Text-Figure 6.** Palaeogeographic map of the Middle Eocene (Parnaud et al., 1995; Higgs & Pindell, 1994; Pestman et al., 1996)

The post-Eocene led to a deformation and partial inversion of the basin removing parts of the Eocene sequence, particularly the Upper Eocene, in most parts of the basin (Melendez et al., 1996).

### 2.3 Structural style of the Maracaibo Basin

The different phases of deformation which affected the Lake Maracaibo Basin and particularly Eastern Zulia resulted in a complex polyphase tectonic history reflected by different structural styles (De Toni et al., 1994; Leon et al., 1996). However, structural styles are not well imaged on seismic lines and not clearly seen in the field. They underwent partial erosion during Late Eocene to Miocene, in particular by Late Eocene-Oligocene distensive and transtensive events (BP & PDVSA, 1992).

The Lake Maracaibo Basin and Eastern Zulia are characterised by a series of structural alignments which are predominantly NNW-SSE oriented (Text-Figure 7). They are related to the orientation deformation front of the Lara Nappes. Three structural provinces can be recognised (Melendez et al., 1996; Parnaud et al., 1994):

1. A foredeep in Eastern Zulia and the northEastern Lake Maracaibo Basin.
2. Reactivation of a NW-SE directed peripheral bulge in the central part of the Maracaibo Basin with local, the development of normal (NNE dipping) and listric faults towards the borders of the graben.
3. Reactivation of the extensional (Paleocene-Early Eocene) and the transpressional-transensional (Middle Eocene-Late Eocene) regimes reactivated the pre-existing main fault systems (e.g. Pueblo Viejo and Burro Negro-Paujil faults).

In the Lake Maracaibo Basin and Eastern Zulia, a large number of structures again experienced inversion due to compression.

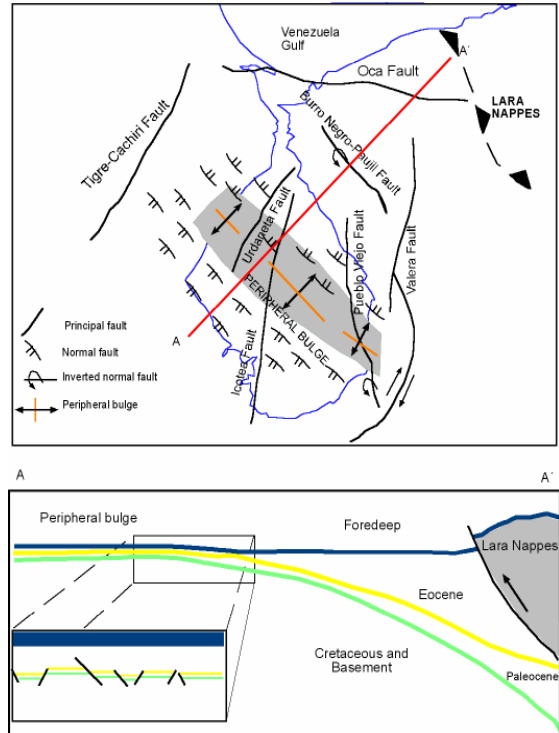
Compression led to reactivation of normal faults and resulted in deformation of the Tertiary sediment cover which became detached from its basement.

In Eastern Zulia, the major tectonic structure alignment is the NE-SW oriented Burro Negro-Paujil Fault. In its southern part the fault progressively bends eastward and joins the Valera Fault. From the late Middle Eocene to the Oligocene, these two faults separate Eastern Zulia in two tectonic provinces: the Falcon Basin and the Lake Maracaibo Basin (Leon et al., 1996).

## 2.4 Paleocene-Middle Eocene Stratigraphy of Eastern Zulia

The Paleocene-Eocene formations in Eastern Zulia are bounded by major local and regional unconformities. The facies of these formations are predominantly deltaic (Misoa Formation), nearshore shallow-marine (Caus Formation) and bathyal (Pauji, Jarillal and Mene Grande formations).

All stratigraphic units show a northward increase in thickness (Text-Figure 7 and 10), since the northEastern margin of the Lake Maracaibo Basin underwent strong subsidence caused by the emplacement of the Lara Nappes (Melendez et al., 1996; Pilloud et al, 1996; Parnaud et al., 1995).



**Text-Figure 7.** Regional structural map showing distribution of normal and listric fault in relation to the foredeep and peripheral bulge (Pestman et al., 1994; Melendez et al., 1996)

In addition, sedimentation is controlled by north-northeast striking fault systems of recurring syndimentary normal faults that were possibly controlled by strike-slip motions (Meyer, 1996).

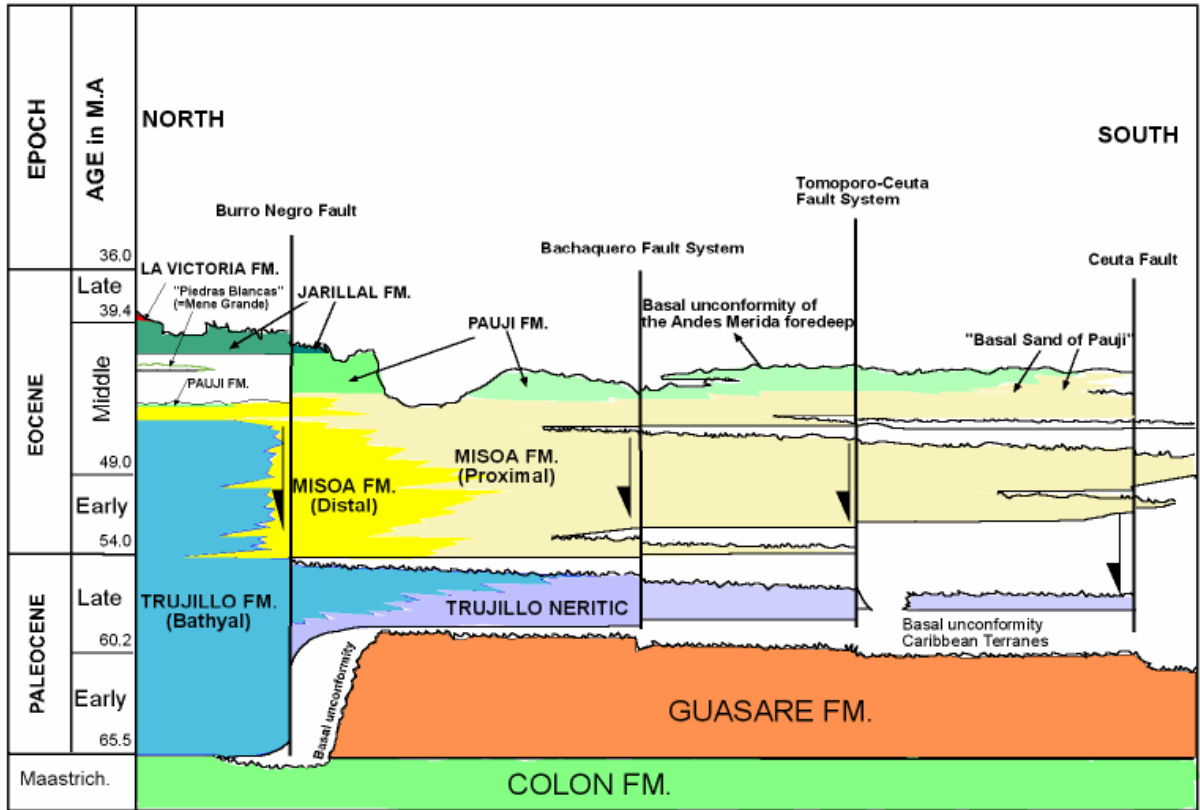
The chronostratigraphy of the Paleogene formations in Eastern Zulia is summarized in Text-Figures 8.

The Paleocene-Eocene in Eastern Zulia is divided from bottom to top into the following units (see Text-Figure 9):

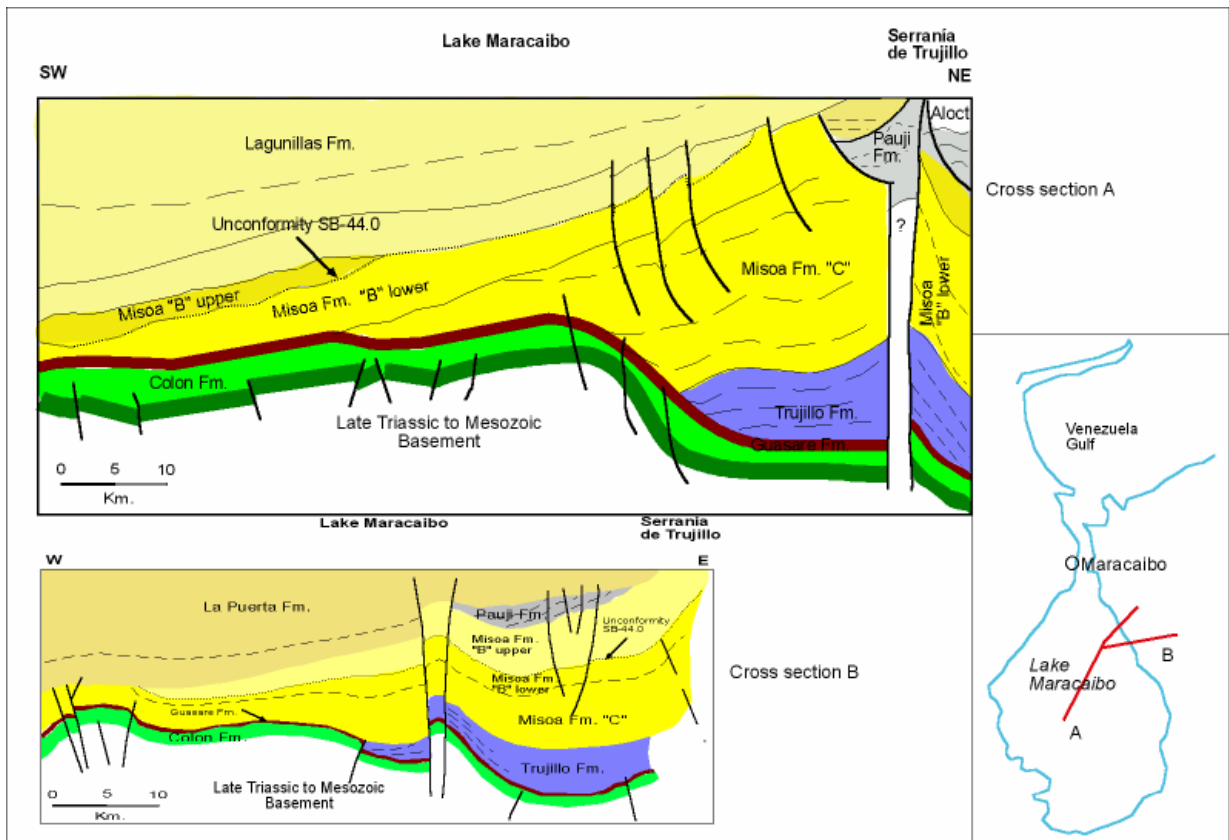
- **Trujillo Formation** (Hodson, F., 1926)

In the northEastern part of the Lake Maracaibo Basin, the Trujillo Formation is represented by turbiditic deposits (Brondijk, 1967; Ghosh & Zambrano, 1996; Zambrano, Melendez & Ghosh, 1996) which correspond to a prograding lowstand wedge. The predominantly sandy and shaly deposits accumulated in a bathyal environment. In the basal part of the formation, blocks of redeposited platform limestones occur (Brondijk, 1967; Canache, Crux & Gamarra, 1995).





Text-Figure 8. Stratigraphic chart of Eastern Zulia (western part; Leon et al., 1996)



Text-Figure 9. Cross sections: A Northwest-Southwest and B West-East (Parnaud et al., 1994)

The Trujillo Formation is dated as Early Eocene, but it probably covers the time span from Paleocene to Middle Eocene (L.E.V., 1999). Canache, Crux & Gamarra, (1995) dated this unit as Paleocene to Middle Eocene based on foraminifera from the platform limestones of the "Quebrada Totuche Section". They suggest that the Paleocene limestones have been redeposited during the Early to Middle Eocene based on the occurrence of larger foraminifera: (*Ranikothalia* sp. Paleocene, *Discocyclus* sp. Paleocene-Eocene, *Discocyclus* cf. *grimsdalei* Paleocene-Middle Eocene), the planktonic foraminifera (*Globigerina* cf. *triloculinoides* Paleocene) and nannofossils (*Coccolithus cavus* Paleocene-Eocene)

- **Misoa Formation** (Garner, H., 1926)

The Misoa Formation is a thick deltaic complex of consolidated clastic sediments. Predominant lithologies are sands and siltstones intercalated shales and some limestone beds. Depositional environments vary from coastal plain in the southwest and south to shallow-marine to the north and northeast (Pestman et al., 1994; Ghosh et al., 1997).

According to L.E.V.(1999), the age of the formation is Early to Middle Eocene based on palynological studies by Colmenares (1988). Colmenares identified *Echitriporites trianguliformis*, *Retibrevitricolpites triangulatus* and *Psilatricolporites crassus* which correspond to the palynological Zone 20 (*Bombacacidites soleaformis* Zone) of Muller et al. (1987). However, recent chronostratigraphic charts of the Maracaibo Basin (Pestman et al., 1994; Lugo & Mann, 1995; Parnaud et al., 1995) show significant differences in the age and duration of accumulation of the Misoa Formation.

Based on planktonic foraminifera, Pittelli (1991) dated marine sediments from more distal parts of the Misoa Formation as Early Eocene to Middle Eocene (Zones P9-P13).

- **Caus Formation** (Liddle, R., 1928)

The Caus Formation occurs at the base of the Pauji Formation in the southwest of Lake Maracaibo. This unit is the first

manifestation of marine facies in the Middle Eocene transgressive sequence (Gonzalez de Juana et al., 1980). The Caus Formation is conformably overlain by the Pauji Formation. The contact with the underlying Misoa Formation is conformable and transitional. This unit consists of carbonates, silty shales, siltstones and sandstones accumulated in an inner-shelf depositional environment (Higgs & Pindell, 1994).

Since the Caus Formation is overlying the Early-Middle Eocene Misoa Formation and overlain by the late Middle Eocene Pauji Formation, it has been assigned a Middle Eocene age (L.E.V., 1999).

- **Pauji Formation** (Tobler, A., 1922)

In the Lake Maracaibo Basin, the Pauji Formation represents the Middle to Late Eocene transgression. It is characterised by marine grey shales which clearly separate it from the sands of the underlying Misoa Formation. However, in the Motatan Field, a sandy lower unit is found (Delgado & Chacartegui, 1996; Pestman, Ghosh & Melendez, 1996).

Planktonic foraminifera occur throughout the Pauji Formation. The assemblage is diverse and characteristic of the late Middle Eocene *Truncorotaloides* Zone (Walton, 1966 in L.E.V., 1999). Recently, the contact of the Pauji Formation with the underlying Misoa Formation has been described as diachronous (Pestman, Ghosh & Melendez, 1996), but the examination of calcareous nannofossils by Crux et al. (1997) in two sections of the Rio San Pedro outcrop (reference section) and a well section on the Ceuta Field did not confirm the presence of such a diachronism. In the Río San Pedro Section, nannofossils indicate an undifferentiated Middle Eocene age (NP15-NP16) for the base of the Pauji Formation as based on the last occurrences of *Chiasmolithus gigas* and *Lophodolichus* sp. and below the first occurrences of *Reticulofenestra umbilicus* and *Pemma papillatum*.

- **Mene Grande Formation** (Gorter, N. & Van der Vlerk., 1932)

The Mene Grande Formation is a local unit to the east of Lake Maracaibo

composed of turbiditic sandstones and black shales with some lenses of limestone.

In the L.E.V.(1999), the Mene Grande Formation is dated as late Middle Eocene based on the association of *Pseudophragmina* (*Proporocyclina*) *flitensis*, *Discocyclina* (*Asterocyclina*) *georgiana*, *Lepidocyclina* (*Pliolepidina*) *kugleri* and other larger foraminifera as well as the planktonic foraminifera *Globigerina senni*, *Globorotalia centralis*, *G. crassata*, *G. spinuloinflata*, *G. lehner* indicative of the *Truncorotaloides rohri* Zone (Furrer, 1967).

NP17 as indicated by the presence of *Helicosphaera seminulum*, *Reticulofenestra reticulata* and *Discoaster saipanensis* above the last occurrence of *Chiasmolithus solitus*. However, this formation also contains the palynomorphs *Perisyncolporites pokorny*, *Retitricolporites guianensis* and *Echitriporites trianguliformis* that indicate a Middle to Late Eocene age (palyological zones 21 to 24, Muller et al., 1987).

- **Jarillal Formation** (Senn, A., 1935)

The Jarillal Formation is a thick shaly sequence with minor amounts of sand penetrated in the Pica-1X well (reference section). Its contact with the underlying Santa Rita Formation is transitional and conformable (Pittelli & Molina, 1989). This unit and the Pauji Formation represent the maximum extent of the Middle Eocene transgression in Eastern Zulia. The Jarillal Formation has been deposited in an inner to open and relatively deep shelf environment.

The Jarillal Formation is very fossiliferous with assemblages of arenaceous, larger and planktonic foraminifera similar to those of the Pauji Formation. Noteworthy is the presence some *Nummulites* in a few calcareous levels near the top (Pittelli, 1991). The fossil assemblages are characterised by the occurrence of *Textularia* spp., *Gaudryina* sp., *Cyclammia* sp., *Gyroidina soldanii*, *Lenticulina* spp., *Uvigerina peregrina*, *Uvigerina* spp., *Nummulites*, *Truncorotaloides rohri*, *Globigerina eocaena* and *Globigerina* spp.

Based on its flora and fauna, Pittelli & Molina (1989) attribute a late Middle to early Late Eocene age to the Jarillal Formation (palyological zones 21-23), *Retitricolporites guianensis* to *Janmulleripollis pentaradiatus* zones of Muller et al., 1987, and *Truncorotaloides rohri* Zone.

Crux et al., 1997 suggest that the Jarillal Formation is probably placed entirely in the Middle Eocene nannofossil Zone

## Biostratigraphy

# 3

### 3.1 Introduction

The Middle and Upper Eocene of the Eastern coast of Lake Maracaibo have a complex geological history (see Chapter 2). Biostratigraphic data are of key importance to resolve many stratigraphic and structural problems facing the explorationist. In Eastern Zulia, a series of exploration wells sunk during the last few years have provided a wealth of stratigraphic information. Biostratigraphic studies of the subsurface Tertiary which contains the main reservoirs dealt mostly with foraminifera and calcareous nannoplankton. However, some biostratigraphic data are rather complex and in part even contradictory. These unsatisfactory results may be caused by incomplete sampling, misidentifications and differences in species concepts and reworking. The resulting inconsistencies in the stratigraphic ranges attributed to species may be in part caused by these factors and not by facies changes.

In the same interval, palynomorphs have been studied less intensively. In order to contribute to an improved understanding of the age and paleoenvironment of the Lower Tertiary in Eastern Zulia, I present and discuss in this chapter the results of my study of the quantitative distribution of the dinoflagellate cysts and fungal spore assemblages in five sections.

### 3.2 Previous palynological studies in the Middle and Upper Eocene of the Eastern part of Lake Maracaibo

Palynological investigations in the Middle and Upper Eocene of the Eastern coast of Lake Maracaibo have concentrated mainly on pollen and spores. Only a single report by Norris & Velásquez (1994, unpublished report) deals with dinoflagellate cysts. In this report, the authors discuss the taxonomy and biostratigraphy of fossil dinoflagellates from the Maastrichtian to Pliocene in several sections in the Lake

Maracaibo Basin and adjacent areas, in the foothills of the Andes and the Perija Range (western Venezuela). In the Middle and Upper Eocene, Norris & Velásquez identify and describe the morphology of 35 dinoflagellate taxa. Based on the observed range tops (last appearance datums LAD) of selected dinoflagellate cysts they recognize four interval zones (EOM1-EOM4) in two subsurface sections (Pica-1X and 15-GU-507).

Several other palynological studies (Leon et al. 1996, Canache et al., 1995; Colmenares 1996) mention the presence of dinoflagellate cysts, but without illustrating them or discussing their taxonomy and biostratigraphic importance.

A significant number of publications deals with Cretaceous palynological assemblages (Helenes & Somoza, 1999; Helenes et al., 1999; Helenes, de Guerra & Vazquez, 1998; Colmenares, 1994; Fasola & Paredes, 1991), but do not cover the Middle to Upper Eocene interval.

However, the taxonomy, morphology and stratigraphic importance of Eocene dinoflagellates have been extensively documented in Europe, Australia and Canada where they are a very important tool in biostratigraphy, particularly in successions in which calcareous microfossils (planktonic foraminifera, calcareous nannoplankton) are lacking or giving only unsatisfactory results (see e.g. Brinkhuis, 1994; Bujak, 1976, 1980, 1994; Châteauneuf, 1980; Cookson & Eisenack, 1982; de Coninck, 1977, 1985, 1995a, b, 1999a, b; Eaton, 1971, 1976; Gocht, 1969; Jan du Chêne, 1984; Klump, 1953; Morgenroth, 1966; Sarjeant, 1986; Wilson, 1982, 1985, 1988).

To my knowledge, no investigations on Eocene fungal spores from Venezuela have been published. They have been studied in other areas, particularly in northern North America and India by several authors. Recent comprehensive papers on dispersed fungal remains in the

Tertiary have been published by Kalgutkar & Jansonius (2000), Parsons & Norris (1999), Kalgutkar (1997, 1993, 1985), Kalgutkar & Sigler (1995) and Norris (1986). The present study is mainly based on them, but the earlier pioneering studies by Elsik (1974, 1976, 1978), Dilcher (1965, biological aspects), Clarke (1965), Sheffy & Dilcher (1971), Elsik & Jansonius (1974, (first stratigraphic applications), Venkatachala & Kar (1969) and Kar, Singh & Sah (1972) have also been taken into account.

### 3.3 Problems of the dinoflagellate cyst zonation and provincialism

Dinoflagellate cysts are an important group of microfossils in petroleum exploration all over the world, due to their potential to resolve problems of age dating and correlation. The remarkable morphological diversity displayed by dinoflagellate cysts facilitates their identification. Most of them are short-lived and, geographically widespread in marine sediments thanks to their planktonic nature.

Several zonation schemes based on dinocysts have been proposed for the Eocene, but almost all of them have been established in high and middle latitudes, whereas data from tropical areas are scarce or even lacking. Zonal schemes established in the Northern Hemisphere (northwestern Europe and Canada) cannot be applied without modifications to the northern part of South America or the Caribbean region. This is probably due to the following reasons:

Water temperature and oceanic circulation patterns seem to constitute the two principal factors in the determination of provincialism in dinoflagellate cysts (e.g. Williams et al., 1990). Today, some species of dinoflagellate cysts are confined to the tropical/subtropical regions, while others are found exclusively in high latitudes.

During the middle to late Early Eocene, the oceans and seas are characterized by a rather uniform warm global climate ("greenhouse" conditions, Miller et al. 1987). Warm marine conditions are indicated by oxygen isotope ratios of planktonic and benthic foraminifera recovered worldwide from many locations (e.g. Sloan & Barron, 1992). Within the Middle Eocene, the climate started to deteriorate leading to a steeper temperature gradient from lower to higher latitudes. This climatic change was perhaps more pronounced in tropical regions (e.g. Sloan & Rea, 1995) and did lead to an increase in the differences between low

latitude and middle to high latitude assemblages.

The recognition of cosmopolitan and endemic species in the Tertiary is complicated by the increasing provincialism observed in dinoflagellate cysts (Stover et al., 1996). This affects the definition of the limits of biozones and other significant events as well as the chronostratigraphic correlation with the Eocene zonation established in NW Europe, Canada and Australia. These zonation schemes are mainly based on representatives of the genera *Apectodinium*, *Rhombodinium*, *Wetzeliella*, *Kisselovia*, *Gochtodinium*, *Wilsonidium* and *Dracodinium* (see Williams & Bujak, 1985). All these genera - except *Wetzeliella*, *Rhombodinium*, *Wilsonidium*, and *Apectodinium* (*Wetzeliella* Group) are good index-fossils in the Eocene of southern Brazil, but unfortunately, they are absent in the basins close to the equator in northern Brazil (Mitsuru, A., 2002, written communication) and also in the samples I have studied from Venezuela.

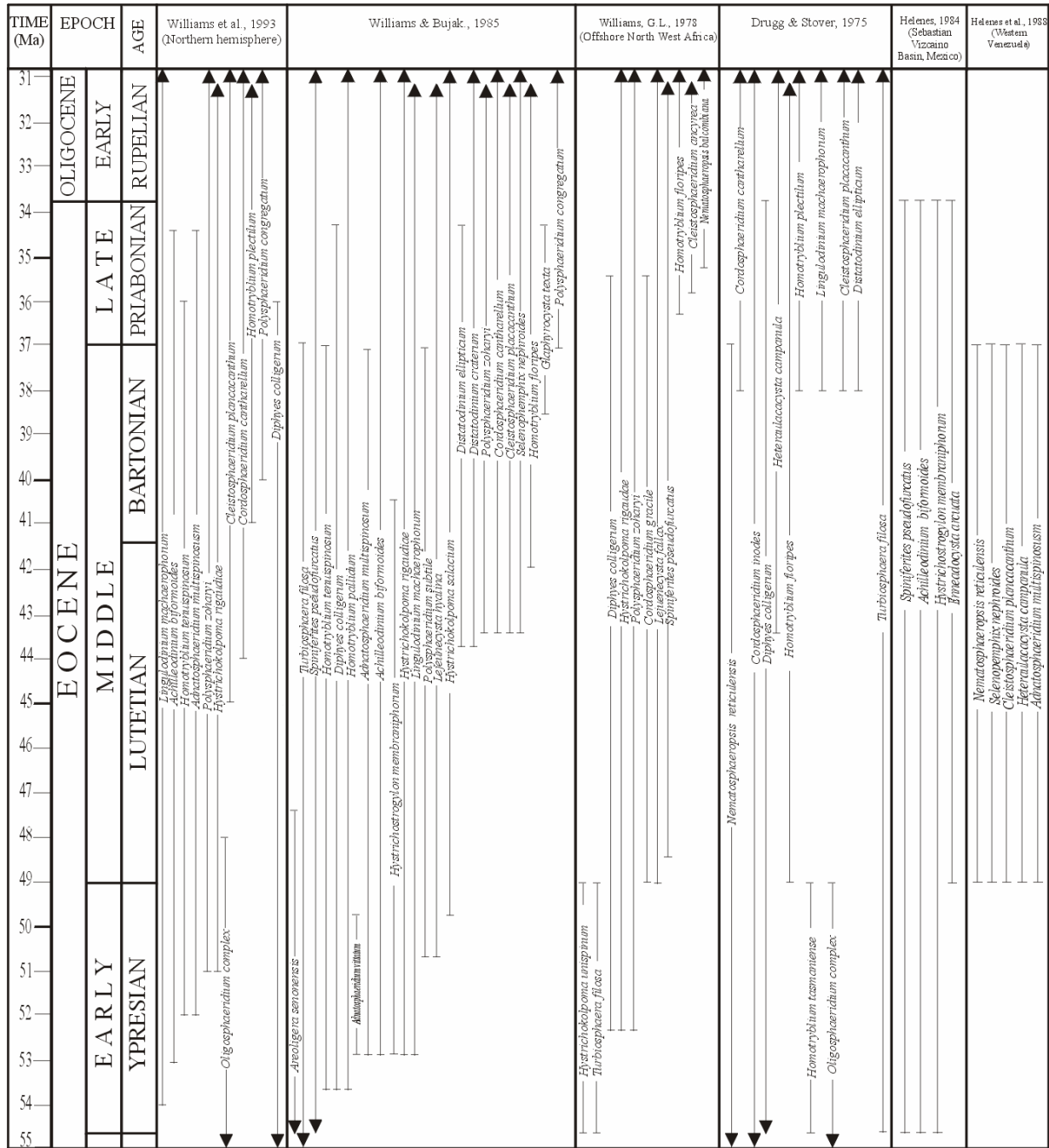
Text-Figure 10 shows the differences in the stratigraphic ranges attributed by different authors to selected Eocene taxa found in this study. They are arranged according to their last (LAD) and first appearances (FAD). The Eocene time scale considered as standard in this study that of Berggren et al. (1995).

Already Williams et al. (1990); Stover et al. (1996) stress that temporal and spatial distribution of most Mesozoic and Cenozoic dinoflagellate cysts are probably not uniform.

Patterns of provincialism have been proposed for this fossil group (e.g. Norris 1975; Williams & Bujak, 1977; Damassa & Williams, 1993, 1996, and Arai et al. 2000). These authors discuss and illustrate clearly the recognition of different provinces (boreal, arctic, "transitional", tethyan, tropical/subtropical) focusing on the distribution of selected dinoflagellate taxa restricted to specific geographic areas during a given interval of time.

Unfortunately, in low latitudes, much less information on the distribution patterns of Eocene dinoflagellate cysts is readily available.

Helenes (1984) and Helenes et al. (1988) report a total of 9 species from the Middle Eocene of Mexico and Venezuela, but did not discuss the significance of their distribution. All these species are also present in central and northern Europe.



Text-Figure 10. Stratigraphic ranges of selected Eocene dinoflagellate cyst taxa found in this study.

Williams & Bujak (1977) studied the affinities between selected species (*Areosphaeridium diktyoplokus*, *Areosphaeridium multicornutum*, *Distatodinium paradoxum*) in the Upper Eocene to Oligocene of the Grand Banks, England, the Scotian Shelf and offshore Florida. The authors discuss the variations in their distribution and suggest that they are controlled by local and regional variations of the paleoenvironmental conditions.

Williams et al. (1990) stress the differences between the Eocene dinoflagellate cyst assemblages from the Grand Banks (Williams & Brideaux, 1975) and those from southern

England (Bujak et al., 1980). During the Eocene, some subtropical to tropical species disappear from the Grand Banks.

Damassa & Williams (1993, 1996) explain differences in the distribution of dinoflagellate cysts during the Eocene-Oligocene distribution in six different regions (Gulf of Mexico, offshore New Jersey, Labrador Sea, Norwegian Sea, Rockall Plateau, and northwestern Africa) by latitude and the pattern of surface currents. They identify characteristic assemblages restricted to low or middle latitudes and only a small number of cosmopolitan species, whereas some species

have pronounced heterochronous stratigraphic ranges.

Variations in the biogeographical distribution and provincialism of dinoflagellate cysts are mainly caused by climatic changes and shifts in the pattern of oceanic currents (e.g. Williams et al., 1990), but they are modified by local and regional paleoenvironmental factors.

### 3.4 Results

#### 3.4.1 Analytical procedures:

The results exposed in this study are exclusively based on cuttings, outcrop and core samples of five sections in Eastern Zulia (see Chapter 5).

Two slides for each sample have been scanned in uniformly spaced traverses in order to count the number of specimens and to determine the species of dinoflagellate cysts present. If possible, an average of one hundred to one hundred fifty determinable specimens (75 grains on each slide) has been counted. According to Köthe (1990), Brinkhuis (1993), Pross (1997) and others, a count of 300 grains is necessary in order to include most species present in an assemblage. Due to the low recovery of dinoflagellate cysts, this number could not be reached and therefore, the statistical analysis is incomplete.

The representatives of each species have been described, sketched, measured and photographed. Their taxonomic status, morphological development, intraspecific variation, and paleoecology are discussed in the systematic part (see chapter 6). All these data are recorded in the data base TAXIS (*Taxonomic Information System*). The relative frequencies are indicated on the distribution charts (Tables 2-7) as follows: 1 specimen (trace); 2-5 specimens (rare); 6-15 specimens (common); 16-25 specimens (frequent); > 25 specimens (abundant).

The fungal spores were analysed only in the studied interval of the well Pica-1X and in the Quebrada Bijugal section, in which they are very frequent. The relative abundance of species was determined by systematically scanning four slides per sample (two unoxidized and two oxidized slides) and counting 100 specimens. This number of specimens is considered to yield a representative association. The relative abundance of each species in each sample is indicated in the same way as with the dinoflagellate cysts (see Table 2, 3 5; Appendix B). The described new species are based on a

minimum of 12 or more specimens of identical morphology.

#### 3.4.2 Stratigraphic subdivision of the sections

The subdivisions of the four sections investigated in Eastern Zulia are based mainly on the well represented marine dinoflagellate cysts and terrestrial fungal spores. The adopted bioevents are discussed in detail after presenting the main characteristics of the distribution of the two groups of palynomorphs in each of the studied sections.

##### 3.4.2.1 Pica 1X Well

The distributions of the dinoflagellate cysts and fungal remains recovered from the Jarillal Formation are presented in Appendix B (see Table 2 and 3). A total of seventy-six samples (core and cuttings) were collected from the Pica-1X well in the north of Eastern Zulia. The majority of the studied samples are from the Jarillal Formation (Samples PP-1 to PP-56). Preservation is generally good, but abundance and species diversity vary significantly throughout the studied section. Additionally, acritarchs and fresh water algae are recorded (see Chapter 4 Palynomorph ecostratigraphy).

#### *Distribution of palynofloras in the Jarillal Formation*

The palynological assemblages from the Jarillal Formation consist mainly of dinoflagellate cysts and fungal remains as well as of frequent occurrences of pteridophyte spores, gymnosperm and angiosperm pollen grains which have not been studied..

More than 45 different taxa of dinoflagellate cysts have been identified (see Table 2, Appendix B). Species recovered in the samples between -100 ft and -4720 ft, are characteristic for Late Eocene to late Middle Eocene assemblages in other areas. (e.g London Basin, Paris Basin, Grand Banks, U.S.A. Gulf Coast, western Nile Delta, Baja California and India). However, data on their stratigraphic distribution in these areas vary in detail and perhaps several of the species are only of regional biostratigraphic value, but more research is needed to establish firmly their significance. Generally, occurrences indicated on Table 2 (see Appendix B) do not correspond to the known entire range of the taxa.. The most frequent and significant taxa belong to the genera *Diphyes*, *Araneosphaera*, *Enneadocysta*,

*Adnatosphaeridium*, *Hystrihostrogylon*, *Lingulodinium*, *Homotryblium* and *Cordosphaeridium*. They are found in most of the samples, but their distribution in the section is not uniform.

Fungal remains have been found in almost all samples from the Jarillal Formation, but their composition varies from sample to sample. They are particularly frequent in the upper part of the formation (-100 ft to -460 ft). The quantitative distribution of fungal remains is shown in Table 3, Appendix B. The fungal remains include 33 described and 5 new species. The most dominant forms are ascostromata of the family Microthyreaceae viz. *Callimothallus assamicus*, *Callimothallus pertusus*, *Desmidiospora willoughbyi*. Fungal spores are represented mainly by the genera *Paragranatisporites*, *Dictyosporites*, *Fusiformisporites*, *Multicellites*, *Striadiporites*, *Brachysporisporites* and *Exisisporites*. Fungal hyphae are also widespread. Many of the fungi are similar to fungal remains recorded by Norris (1986) and Parsons & Norris (1999) from the Tertiary of the Mackenzie Delta in northern Canada, by Kalgutkar (1993) from the Paleogene of the Yukon Territory, by Ediger (1981) and Ediger & Alisan (1989) from the Tertiary of the Thrace Basin in Turkey, by Kemp (1978) from the Tertiary of the Ninetyeast Ridge in the Indian Ocean, by Lange (1978) from the Tertiary of Southern Australia and by Dilcher (1965) and Elsik & Dilcher (1974) from the Eocene of Tennessee.

#### Age-assessment of the palynoflora

The Pica-1X well is of primary importance in assessing the age suggested by the palynofloras, since it represents the most complete available section of the Jarillal Formation. Therefore, it is also the standard section for palynostratigraphical correlations.

The interval from -100 ft to -460 ft contains a rather uniform dinoflagellate cyst assemblage dominated by *Enneadocysta pectiniformis*, *Glaphyrocysta texta*, *Polysphaeridium congregatum* in co-occurrence with *Chiropteridium galea*.

*Enneadocysta pectiniformis* and *Glaphyrocysta texta* have both their first appearance at -460 ft (sample PP-4). According to Stover & Williams (1993), the range for *E. pectiniformis* in different European localities (e.g. Germany, Belgium, France and Italy) is from the late Middle Eocene (Bartonian) to the Early Oligocene (Rupelian). In terms of calcareous nannoplankton zones, the species ranges from Zone NP15 to Zone NP20

(Williams & Bujak, 1985). Likewise, *G. texta* has a range restricted to Zones BAR-3 to BAR-5 of the Barton Beds (Eaton et al., 1980). According to Williams & Bujak (1985), this interval of the Barton Beds is equivalent to the calcareous nannoplankton zone NP17. Recently, Torricelli & Biffi (2001) reported this species from the Upper Eocene of northern Tunisia.

The species *P. congregatum* (FAD in sample PP-3) has not been recorded from beds older than late Middle Eocene (Eaton et al. 1980; Williams & Bujak, 1985; Williams et al. 1993). This species has its first occurrence in the upper part of the calcareous nannoplankton zone NP17 (Williams & Bujak, 1985).

*Chiropteridium galea* was found only in the samples PP-2 and PP-3. This species has its youngest occurrence in the Oligocene of Europe, Africa and Canada (Williams, 1975; Williams, 1978; Biffi & Manum, 1988 and Köthe, 1990). However, it also has been reported from the Late Eocene deposits of offshore Eastern Canada (Williams & Brideaux, 1975) and of the North Atlantic (Damassa et al., 1990). The latter authors correlate the occurrence of *C. galea* in the North Atlantic with the nannofossil zones NP19/20 to 25 (late Priabonian to Chattian). The presence of *C. galea* in the samples PP-2 to PP-3 is a strong evidence for an early Late Eocene age of the corresponding interval (probably equivalent to calcareous nannoplankton zone NP18?).

A comparison with the dinoflagellate cyst zones of Eaton et al (1980) and Williams & Bujak (1985) shows that many representatives of the Middle to Late Eocene genera used in their zonations are also present in the Jarillal Formation, but a detailed correlation results to be difficult.

The fungal spores of the same interval are probably indicative of a broad Late Eocene age. *Fusiformisporites rugosus*, *Paragranatisporites vermiculus* (FAD in sample PP-3) are reported from the Thrace Basin (Turkey) with ranges not older than Late Eocene. The common presence of the species *Dictyosporites morularis* (FAD in sample PP-4) has been recorded in the Lower Miocene of Equatorial Africa (Kalgutkar & Jansonius, 2000). The new species *Brachysporisporites jarillalensis* is restricted to the upper part of this interval.

Microfloras extracted from the interval – 580 ft to – 3915 ft (samples PP-5 to PP-43) are rather diverse and contain a few marker species. Among the significant taxa are *Diphyes colligerum*, *Enneadocysta arcuata*,



*Araneosphaera consociata*, and *Adnatosphaeridium vittatum*.

Based on calcareous nannofossils, Crux et al. (1997) considered this interval to be entirely or nearly entirely of Middle Eocene age (calcareous nannoplankton Zone NP17 and within planktic foraminiferal zone P14-P15 of Blow 1969 = *Truncorotaloides rohri* to *Globigerinatheka semiinvoluta* zones of Toumarkine & Luterbacher, 1985). An exact correlation of my samples with those of Crux (1997) is difficult, but the dinoflagellate cyst assemblages recovered from this interval corroborate independently the age based on calcareous nannoplankton.

The LAD of *Diphyes colligerum* at -580 ft (sample PP-5) and of *Adnatosphaeridium vittatum* at -3940 ft (sample PP-44; -3940 ft) indicates an age not older than the upper part of calcareous nannoplankton zone NP 16.

*Diphyes colligerum* is restricted to the Late Eocene (Williams, 1975, 1978; Williams & Brideaux, 1975) and used worldwide to indicate the Eocene-Oligocene boundary (Williams et al., 1993). This species has also been reported in Late Eocene deposits of northern Tunisia (Torricelli & Biffi, 2001); the Western Desert (El-Bassiouni et al., 1988) and the Nile Delta in Egypt (El-Beialy, 1988; 1990). El-Beialy (1988) suggests that the range of *D. colligerum* in Egypt is probably equivalent to the planktonic foraminiferal *Globorotalia cerroazulensis* zone.

*Adnatosphaeridium vittatum* appears in the uppermost zone B-5 of the Bracklesham Beds (Bujak et al. 1980). On the basis of calcareous nannoplankton from the Bartonian type area, these beds are assigned to the Middle Eocene (Zone NP16). However, Williams & Bujak (1985) restrict the range of *A. vittatum* to the Early Eocene, but without giving conclusive support to their assumption.

Other indicators of a probable Middle Eocene age are the LAD of *Enneadocysta arcuata* at -2357 ft (sample PP-20) and the high abundance of *Araneosphaera consociata* in samples PP-12 and PP-17. It place the youngest occurrence in the Middle Eocene from southwestern Kutch, India (Zone IV; Jain & Tandon, 1981).

According to Williams & Bujak (1985), the oldest occurrence of *Enneadocysta arcuata* is within the Middle Eocene (calcareous nannoplankton zone NP 14). In the Barton Beds of the Isle of Wight the last occurrence of common *E. arcuata* is within the Zone BAR-5 of Eaton et al. (1980) which is assigned to the upper part of the calcareous nannoplankton zone NP17 by Aubry (1983, 1985). Most of the records are, however,

from the Middle Eocene Lutetian (e.g. Eaton, 1971; Williams, 1975; Bujak et al., 1980; Jain & Tandon, 1981; Helenes, 1984; Edwards, 1989; Köthe, 1990).

Based on the above discussion, I place the entire interval from -580 ft to -3915 ft into the Middle Eocene (more or less equivalent to the calcareous nannoplankton zone NP 17).

It is noteworthy that the lowermost samples from the Jarillal Formation between -3915 ft to -4440 ft (PP-43 to PP-53) contain common specimens of *Adnatosphaeridium vittatum*, *Adnatosphaeridium* cf. *multispinosum*, *Homotryblidium floripes*, and *Hystrichostrogylon membraniphorum*. The first two species are also known in many areas as the most dominant members of Middle Eocene assemblages. The ranges of most of these species reach into the Middle Eocene,

The youngest occurrence of *Hystrichostrogylon membraniphorum* has been reported in the Middle Eocene calcareous nannoplankton zone NP16 by Williams & Bujak (1985). The species is also known from the Middle Eocene of Baja California (Helenes, 1984) and the Eastern U.S.A (Edwards, 1989), where its range correlates with the upper part of the nannoplankton zone NP16. *H. membraniphorum* reaches its greatest abundance at -4157 ft (sample PP-48)..

The first occurrence of *Homotryblidium floripes* at -4035 ft (sample PP-45) could indicate an important palynological event, since it has been used in various zonations as an important zonal marker (Drugg & Stover, 1975; Williams et al., 2001). According to Williams et al. (2001) this species has its oldest occurrence in the Middle Eocene (Lutetian). However, Williams & Bujak (1985) place its oldest occurrence into the upper part of the calcareous nannoplankton zone of NP16 (topmost Lutetian to Bartonian).

Finally, the LAD of *Adnatosphaeridium vittatum* and the FAD *Adnatosphaeridium* cf. *multispinosum* suggest that the interval between -3915 ft to -4440 is not younger than the upper part of the calcareous nannoplankton zone NP16.

Fungal remains from the interval -580 ft to -4720 ft support a Middle Eocene age based on the presence of several fungal spores with known stratigraphic ranges. Among the species recorded from this interval are *Fusiformisporites crabii*, *Plochrompeltinites masonii* (LAD in sample PP-6), *Striadiporites* cf. *irregularis* (FAD in sample PP-51), *Dictyosporites odremanensis*, *Striadiporites crosstriatus* and

*Multicellites grandiusculus* (LAD in sample PP-10). Most of the species are present throughout the studied interval, but a few of them show a restricted occurrence. These restricted occurrences may provide a basis for correlations and age determinations in the studied area, but more complete sequences and more detailed observations are necessary to prove their stratigraphic significance. Peak abundances of fungal remains are scattered throughout the entire section, but the diversity may be either low or high in these levels (e.g. samples PP-7 and PP-35).

*Callimothallus assamicus*, and *C. pertusus* which are common throughout the section are known from the Middle Eocene of Tennessee (Dilcher, 1965), India (Kar, Singh & Sah, 1970), North Canada (Elsik, 1976), Southern Australia (Lange, 1977), the Indian Ocean (Kemp, 1978), northern Canada (Norris, 1986; Parsons & Norris, 1999), and Turkey (Ediger & Alisan, 1989).

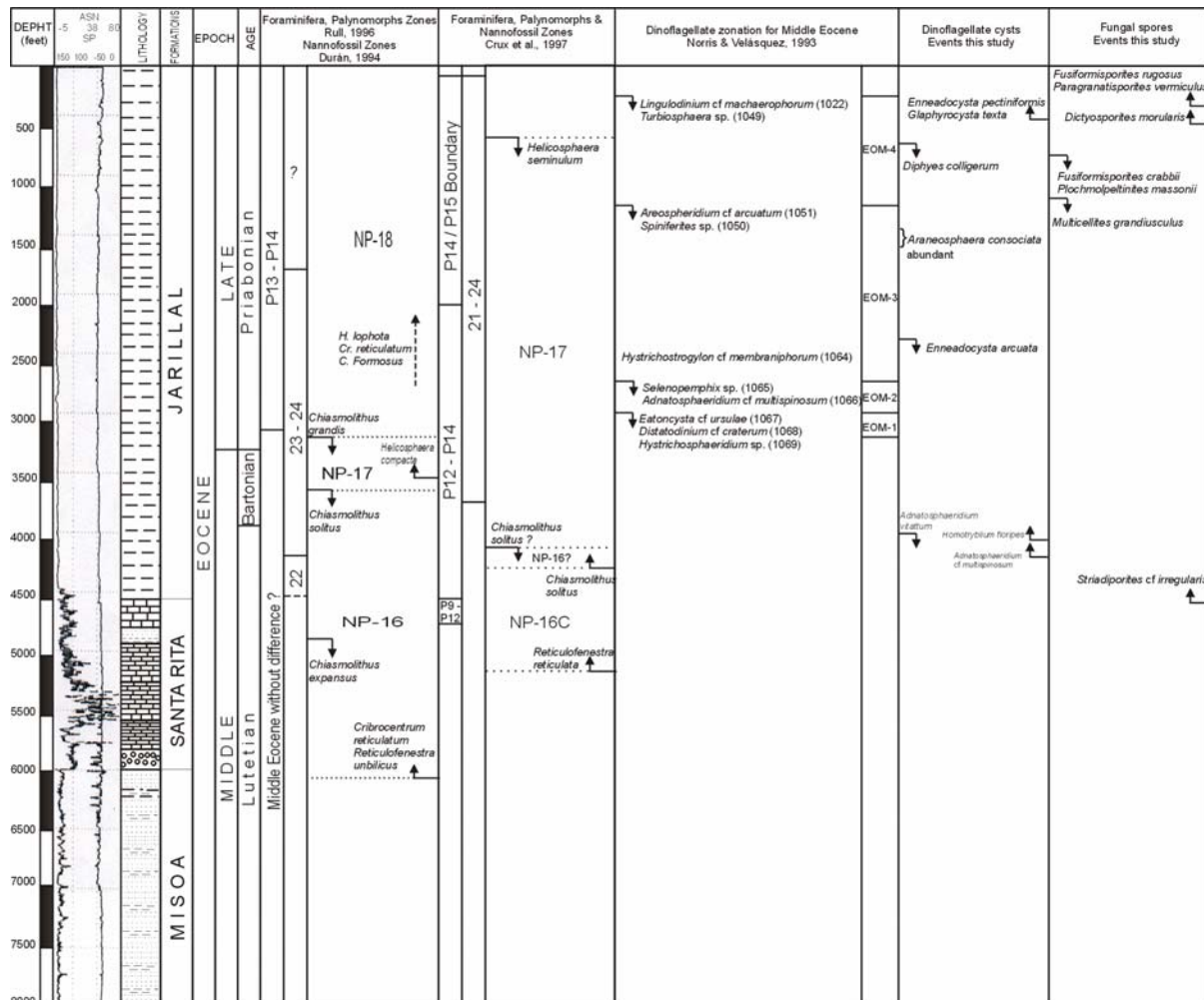
The presence in great numbers of *Fusiformisporites crabbii* in sample PP-7 (-820

ft) is another indication of a Middle Eocene age. Parsons & Norris (1999) have recorded this species in the Middle Eocene of the Mackenzie Delta where it occurs together with *Plochmopeltinites masonii*, *Striadiporites cf. irregularis* and other species. These three species are used, by these authors for the definition of the palynomorph zone CHF5 attributed to the younger part of the late Middle Eocene.

The only published record of *Multicellites grandiusculus* is from the Middle Eocene of Tennessee (Dilcher, 1965).

Additional evidence for an Eocene age comes from the conspicuous representatives of the genus *Striadiporites* which never has been recorded in beds older than Eocene in widely separated areas (India, Colombia, Alaska; see Elsik & Jansonius, 1974).

Text-Figure 11 shows some important dinoflagellate cysts and fungal spores events recognized in the studied interval of the Pica-1X well.



Text-Figure 11. Stratigraphic summary and biostratigraphic events recognized in the Pica-1X well.

### 3.4.2.2 VL-37X Well

Forty ditch samples covering the depth interval from -8700 ft to -10960 ft from VL-37X have been investigated for their content in palynomorphs. The samples belong to the Pauji Formation. Almost all of these samples are dominated by terrestrial pollen and spores, organic-walled cysts and algae (*Pediastrum*). The preservation of the microfossils is generally good.

#### **Distribution of the palynoflora in the Pauji Formation**

The dinoflagellate flora contains 22 species from 13 genera. Table 4 (see Appendix B) shows the distribution chart of the identified dinoflagellate cysts in the VL-37X well. Only a few taxa are common in all samples of the studied interval. Characteristic species include *Polysphaeridium subtile*, *Selenopemphix nephroides*, *Homotryblium tenuispinosum*, *Homotryblium pallidum*, *Homotryblium plectillum*, *Cordosphaeridium cantharellum*, *Lingulodinium polyedrum* and *Operculodinium centrocarpum*.

*Homotryblium pallidum* and *Homotryblium plectillum* are common mainly in the lowermost sample, whereas the remaining taxa are either relatively rare to common or have a more or less patchy occurrence.

Three samples from the upper part of the Pauji Formation (VL-1, VL-2, VL-3) are devoid of palynomorphs.

#### **Age-Assessments of Palynoflora**

The majority of dinoflagellate cysts recovered from VL-37X are essentially Middle Eocene taxa. The exact dating of the Pauji Formation is difficult due to the lack of additional biostratigraphic data. The known ranges of selected biostratigraphically significant taxa that occur in the productive interval (VL-4 to VL-40) are based on standard reference works (e.g. Williams & Bujak, 1985; Eaton et al., 1980 and others).

I hesitate to make statements regarding the interpretation of the distribution of dinoflagellate

cysts in well VL-37X for three reasons: (a), the sampling intervals are very large, and any analysis would probably be significantly modified by a more detailed study; (b) the stratigraphic ranges of a number of taxa are unknown in tropical areas; (c) many first occurrences of dinoflagellate cysts are based on ditch cuttings and the presence of down-hole contaminations cannot be excluded.

For these reasons, I prefer simply to plot the species distribution against independent age determinations and to postpone the interpretation until a more elaborate study is made. Only a few remarks on the probable age attributions are made.

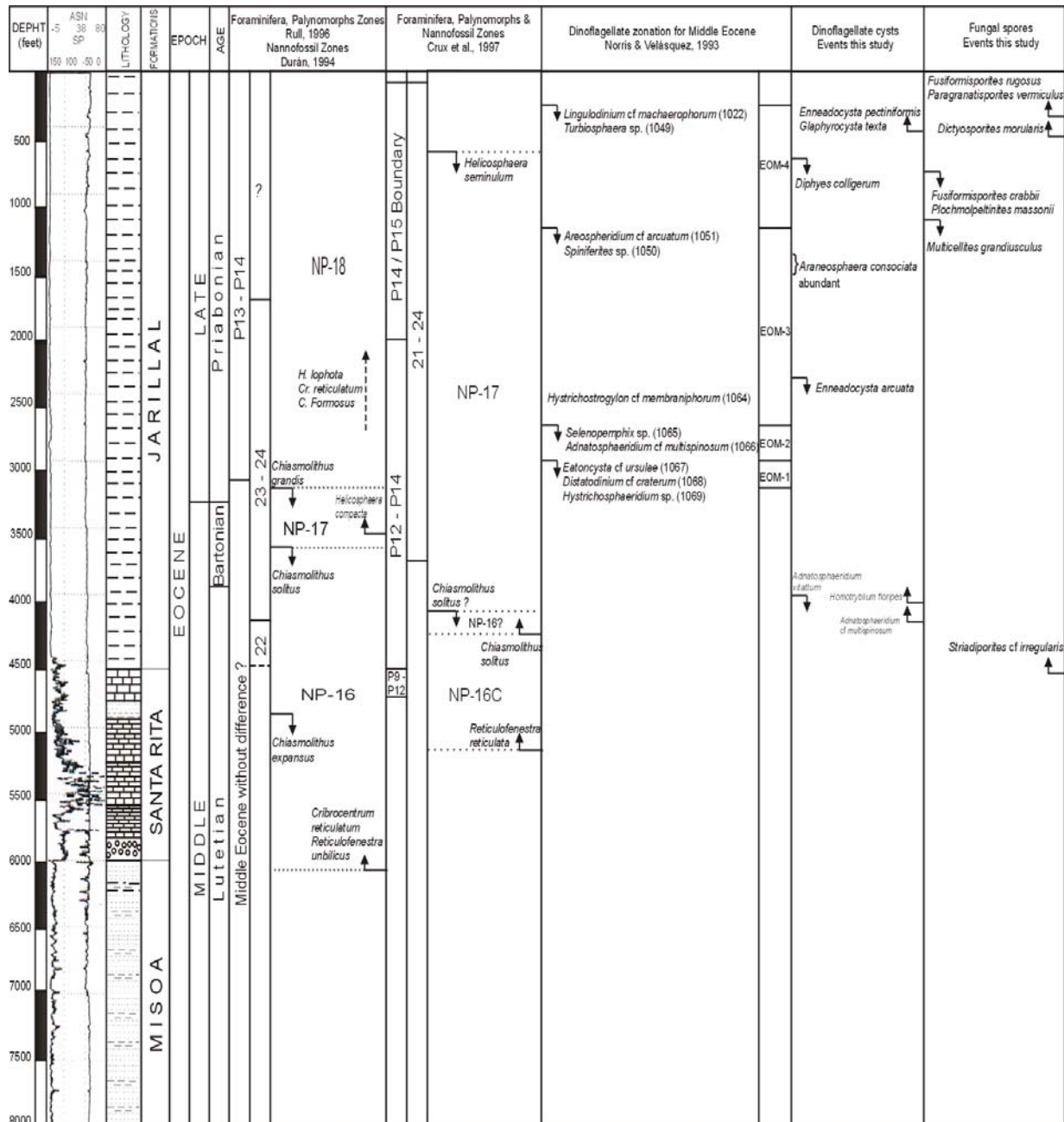
Two species *Polysphaeridium subtile* (LAD in sample VL-4) and *Homotryblium tenuispinosum* (FAD in sample VL-40) seem to be restricted to beds of Early to Middle Eocene age (calcareous nannoplankton zones NP12-NP17) according to Williams & Bujak (1985).

*Selenopemphix nephroides* found in samples VL-4 to VL-25) has its lowermost occurrence in the calcareous nannoplankton zone NP16 (Williams & Bujak, 1985).

The frequent occurrence of the species *Hystriochokolpoma salacium* from samples VL-6 to VL-9 is considered here as an important event. Data from the Bracklesham Beds (London Basin, Eaton et al., 1980) indicate that this species is restricted to the Middle Eocene, and correlates with calcareous nannofossil zone NP16.

*Clesitosphaeridium placacanthum* has its oldest occurrence in the Middle Eocene (Lutetian) of the Northern Hemisphere (Williams et al., 1993). Bujak & Mudge (1994) report that the range of this species is restricted to the calcareous nannoplankton zone NP15 in the North Sea.

All taxa indicate an undifferentiated Middle Eocene age (calcareous nannoplankton zone NP15-NP16). In VL-37X the Pauji/Misoa boundary is probably above the last occurrence of *C. placacanthum* and below the last occurrences of *P. subtile* and *H. tenuispinosum* (see Text-Figure 12).



Text-Figure 12. Stratigraphic summary and biostratigraphic events recognized in the VL-37X well.

3.4.2.3 Quebrada Bijugal outcrop section

A total of 16 samples collected from this outcrop of the Pauji and Caus formations yielded palynomorphs. These are mainly dominated by marine (dinoflagellate cysts) and terrestrial fungal remains. The preservation varies from generally good to very bad.

Palynoflora distribution in the Pauji and Caus formations

The samples from the Pauji Formation mainly contain dinoflagellate cysts and fungal remains (samples QB-1 to QB-10).

The dinoflagellate cyst assemblages are dominated by *Cleistosphaeridium diversispinosum*, *Distatodinium ellipticum*, *Diphyes colligerum*, *Homotryblum vallum* and *Cleistosphaeridium sp. A*.

Table 5 (see Appendix B) shows the distribution of the palynomorphs identified in this outcrop section.

Scarce to common fungal remains are found in some samples. The assemblages are of low diversity and dominated by abundant representatives of a restricted number of

species (e.g. *Dictyosporites odremanensis* and *Fusiformisporites crabbii*).

The interval between samples QB-11 and QB-16 is barren in palynomorphs.

**Age-assessments of the palynoflora**

The succession of dinocyst occurrences in the Pauji Formation in the Quebrada Bijugal outcrop section is quite similar to that in the interval -580 ft to -3878 ft of the Pica-1X well.

In both sections, the assemblages are diverse and contain distinctive species as *Diphyes colligerum*, *Diphyes spinulum*, *Turbiosphaera filosa*, *Selenopemphix nephroides*, *Cleistosphaeridium ancyrea*, *Distatodinium cf. tenerum* and *Homotryblium floripes*. In both sections *Diphyes colligerum*, and *D. spinulum* the upper part of the succession.

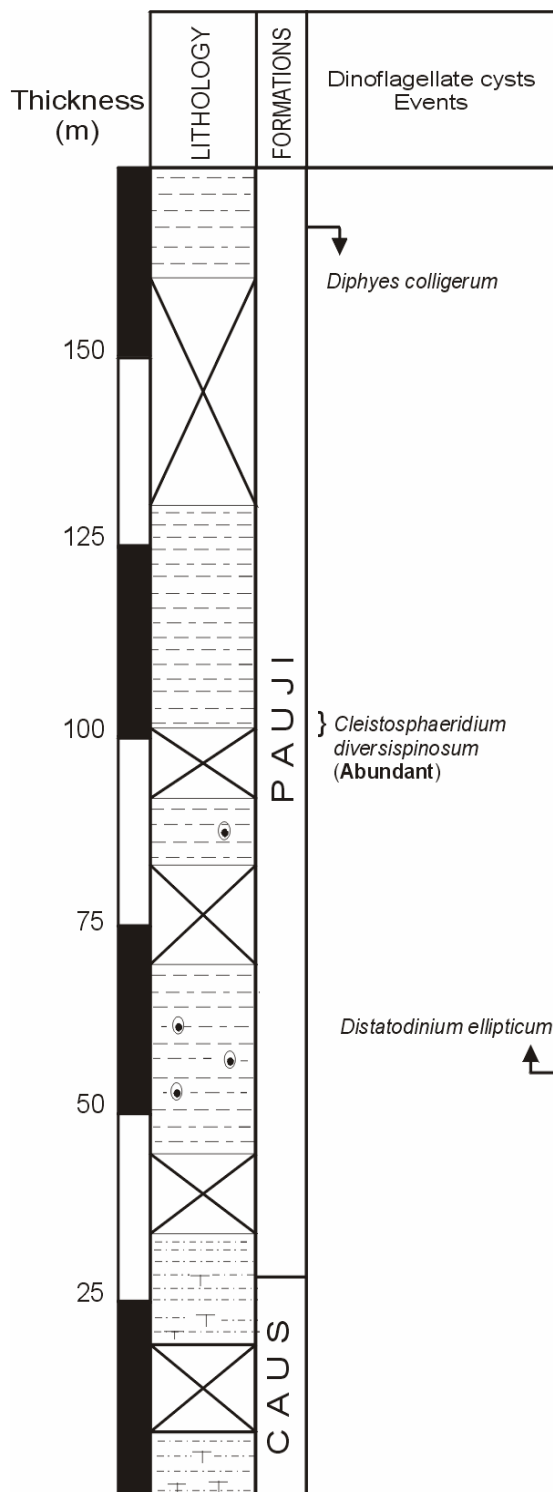
The dinocyst flora of the Pauji Formation indicates a Middle Eocene age with *Cleistosphaeridium diversispinosum*, and *Distatodinium ellipticum* as dominant species.

According to Eaton et al. (2001), *Cleistosphaeridium diversispinosum* has an Early Eocene to Early Oligocene range. However, in material from the Grand Banks (Williams & Brideaux, 1975), this species appears to be abundant in strata provisionally dated at least as young as Late Oligocene.

according to Williams & Bujak (1985) *Distatodinium ellipticum* has a range equivalent to the calcareous nannoplankton zone NP15-NP17. Damassa et al. (1990) indicate that the first occurrence of *D. ellipticum* is in the late Middle Eocene, and correlates with the calcareous nannoplankton zone NP17. Bujak et al. (1980); Mathur (1986) and Manum et al. (1989) report this species from in the Middle Eocene in England, India and Norway.

**3.4.2.4 Quebrada Palma outcrop section**

Eight samples were examined from the Middle Eocene sequence of the Quebrada. Palma section. Dinoflagellate cysts are general fairly to very badly preserved. Poor preservation prevented the determination of many specimens, but others could be identified reliably.



**Text-Figure 13.** Stratigraphic summary and biostratigraphic events recognized in the Quebrada Bijugal section.

**Palynoflora distribution of the Caus Formations**

Dinoflagellates present in the Quebrada Palma section are dominated mainly by representatives of the genera *Homotryblium* and *Areoligera*. Common to frequent species include

*Polysphaeridium subtile*, *Adnatosphaeridium vittatum*, *Operculodinium microtriainum*, *Homotryblum plectillum*, *Homotryblum pallidum*.

*Areoligera senonensis*, and *Homotryblum tasmaniense* are present in the majority of the samples. However, *A. senonensis* is more frequent in the middle part in contrast to *H. tasmaniense* which becomes more frequent up section.

*Selenopemphix nephroides*, *Lejuenecysta hyalina* occur only towards the top and bottom of the section. Species lists are show in the range chart Table 6 (see Appendix B).

**Age – Assessment of the palynoflora**

Samples QP-7 and QP-8 attributable to the Misoa Formation are very poor and do not allow an age determination.

Within the Caus Formation following succession of last and first occurrences is observed *Homotryblum tasmaniense* its last appearance in sample QP-1, while *Areoligera senonensis* has its youngest occurrence in samples QP-2. The first specie was originally reported from the Paleocene of Tasmania. It was subsequently recorded from strata as young as in Middle Eocene of Nigeria (Oloto, 1984), and Egypt (El-Beialy, 1990).

*A. senonensis* is very abundant in the Lower to Middle Eocene of Europe (Williams & Downie, 1966; Gruas-Cavagnetto, 1971). However Bujak et al. (1980) restrict its range to their zone B-1 which they correlate with the calcareous nannoplankton zone NP16.

*Polysphaeridium subtile* has its first occurrence in sample QP-7 near the base of the section. According to Williams & Bujak (1985), this species has its youngest occurrence in the calcareous nannoplankton zone NP17.

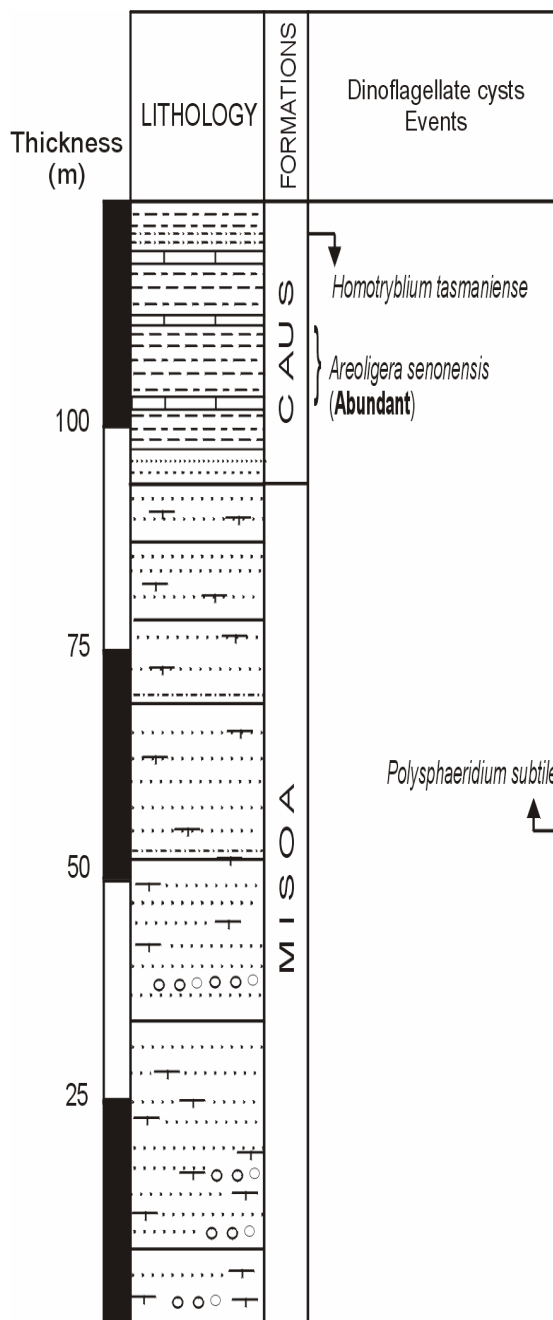
The age of the Caus Formation in the Quebrada Palma section is considered to be Middle Eocene (not older than equivalent to the calcareous nannoplankton zone NP 17). Because of the poor preservation of the dinoflagellate cysts and the absence of some key species, a more detailed age determination is not possible at present.

**3.4.2.5 Quebrada Honda outcrop section**

Of the 14 samples processed from the Middle Eocene of the Quebrada Honda outcrop section,

all except one (QH-2) are productive. Dinoflagellate cysts in particular are well represented in most of the samples, but the total number of palynomorphs is generally smaller than in the other sections. The species diversity of the assamblages is very variable. A total 21 dinoflagellate cyst species have been recovered from this section. Preservation of the dinoflagellate cysts is moderate to good in most samples.

The range chart (see Table 7, Appendix B) shows the stratigraphic distribution of the dinoflagellate cysts.



**Text-Figure 14.** Stratigraphic summary and biostratigraphic events recognized in the Quebrada Palma section.

### Distribution of palynomorphs in the Caus and Pauji formations

The most abundant dinoflagellate cysts belong to long-ranging species, including *Polysphaeridium subtile*, *Lingulodinium polyedrum*, and *Selenopemphix nephroides*. A few poorly represented species have rather patchy occurrences (e.g. *Turbiosphaera filosa*, *Spiniferites ramosus* and *Nematosphaeropsis balcombiana*).

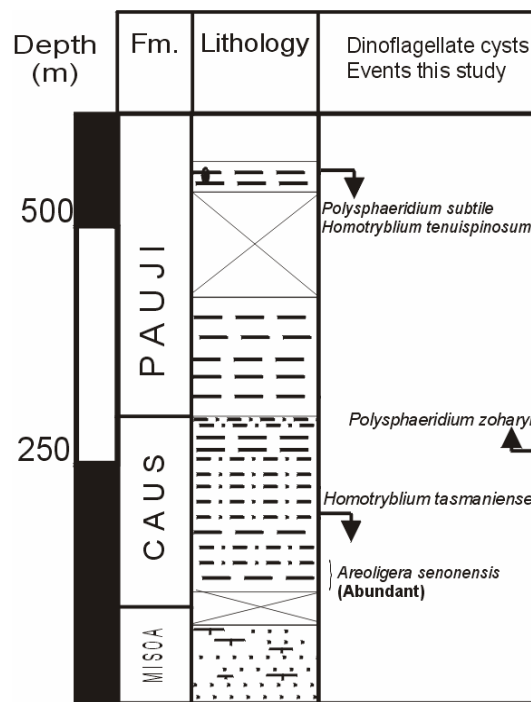
The four lowermost samples (QH-11 to QH-14) which are attributed to the Caus Formation contain well-preserved assemblages with the largest number of specimens of *Areoligera senonensis* and *Homotryblium tasmaniense*. The occurrence of the latter species is restricted to the Caus Formation (LAD in sample QH-12), whereas rare representatives of *A. senonensis* reach into the lower part of the Pauji Formation (LAD in sample QH-8).

In the upper part of the Quebrada Honda section, sample QH-1 contains abundant to frequent *Polysphaeridium subtile* and *Homotryblium tenuispinosum*.

### Age-Assessment of Palynoflora

Many of the dinoflagellate cyst species recorded in the Quebrada Honda section have ranges which are poorly established or which are not critical for a precise age determination of the section. Nevertheless, a late Middle Eocene age, is supported by the youngest occurrence of *Homotryblium tasmaniense* in sample QH-12 (equivalent to calcareous nannoplankton zone NP 16 or younger, and the highest occurrence of *Areoligera senonensis* in samples QH-8 (calcareous nannoplankton zone NP 16 or older). Perhaps the most significant biostratigraphic event within this interval is the FAD of *Polysphaeridium zoharyi* in sample QH-10. This species has its youngest occurrence in the calcareous nannoplankton zone NP16 (Williams & Bujak, 1985). Other events that may prove stratigraphically useful include the FAD of *Cleistosphaeridium* sp. A. in the sample QH-9, and the LAD of *Polysphaeridium subtile* and *Homotryblium tenuispinosum* in sample QH-1 (see discussion of the VL-37X subsurface section).

The LAD of *P. subtile* and *H. tenuispinosum* in sample QH-1 indicate that this sample is probably not younger than Middle Eocene (equivalent to the calcareous nannoplankton zone NP 16C).



**Text-Figure 15.** Stratigraphic summary and biostratigraphic events recognized in the Quebrada Honda section.

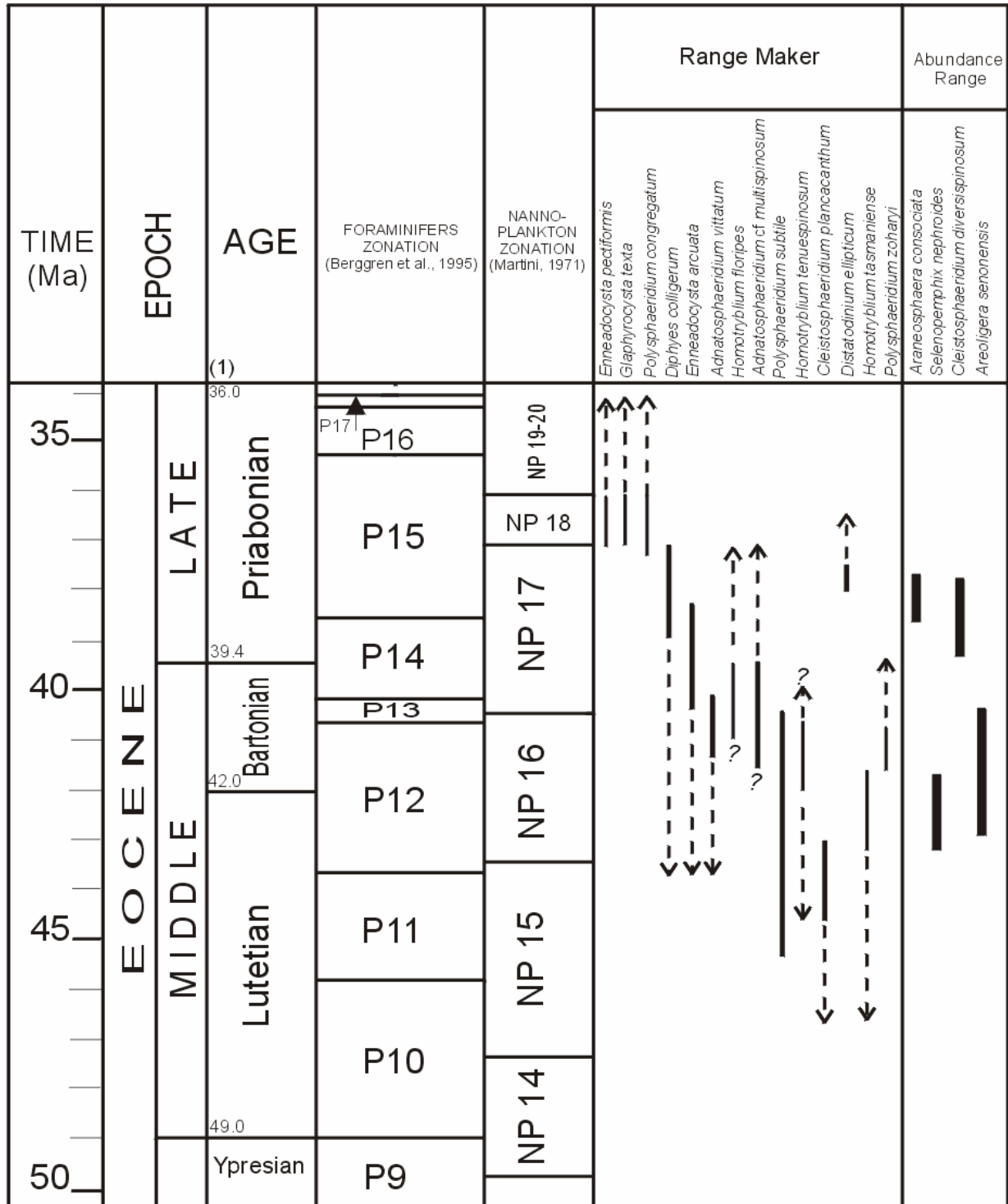
### 3.5 Palynological Zonation

The dinoflagellate assemblages recovered from the samples of Eastern Zulia do not allow to propose a formal zonation of the Middle Eocene. Many of the commonly occurring taxa are long-ranging forms (see Text-Figure 12). In addition, in ditch samples (Pica-1X and VL-37X) lowest occurrence may be blurred by cavings.

Nevertheless, a considerable number of range and abundance markers allow to recognise a provisional sequence of dinoflagellate events valid mainly for Eastern Zulia. Based on data in literature, a large number of taxa such as *Enneadocysta pectiformis*, *Glaphyrocysta texta*, *Polysphaeridium congregatum*, *Chiropteridium galea*, *Diphyes colligerum*, *Adnatosphaeridium vittatum*, *Enneadocysta arcuata*, *Araneosphaera consociata*, *Adnatosphaeridium* cf. *multispinosum*, *Hystrichostrogylon membraniphorum*, *Homotryblium floripes*, *Homotryblium tenuispinosum*, *Polysphaeridium subtile*, *Selenopemphix nephroides*, *Hystrichokolpoma salacium*, *Cleistosphaeridium placacanthum*, *Cleistosphaeridium diversispinosum*, *Homotryblium tasmaniense*, *Areoligera senonensis* and *Polysphaeridium zoharyi* are considered to be biostratigraphically significant (Table 8). Isolated occurrences have not been taken into account. Last and first appearances (LAD and FAD) of species listed above as well as the last or first

common occurrences (abundance events) of one or more dinocysts taxa have been compiled into a sequence of marker events shown in Text-Figure 16. This figure also includes the correlation of these events with standard the calcareous nannofossil zones of Martini (1971). The majority of these events are LAD which are

more appropriate for ditch samples since they are not affected by cavings. Further work probably will extend the range of some species.



(1) Haq et al. (1987)

Text-Figure 16. Ranges and abundances of selected dinoflagellate cysts in the Eocene of Eastern Zulia.



Specie	FAD	LAD	Autor
<i>Areoligera senonensis</i>	B-1 (NP16)	B-4 (NP16) NP14	Eaton et al., 1980 Williams & Bujak, 1985
<i>Homotryblium tasmaniense</i>		Middle Eocene (undifferentiated)	El-Beialy, 1990
<i>Polysphaeridium zoharyi</i>	NP16		Williams & Bujak, 1985
<i>Homotryblium tenuispinosum</i>	NP10	NP17 NP17	Stover (in Haq et al., 1988) Williams & Bujak., 1985
<i>Polysphaeridium subtile</i>	NP-16		Williams & Bujak., 1985
<i>Distatodinium ellipticum</i>	NP17 NP14	NP17	Damassa et al., 1990 Williams & Bujak, 1985
<i>Diphyes colligerum</i>		NP17 NP18	Williams et al., 2001 Williams et al., 1993
	NP10		Williams & Bujak., 1985 Bujak & Mudge, 1994
<i>Cleistosphaeridium placacanthum</i>	NP15		Williams et al., 1993 Bujak & Mudge, 1994
	NP16	NP15	Williams & Bujak, 1985
<i>Selenopemphix nephroides</i>	NP16		Williams & Bujak, 1985
<i>Hystrichokolpoma salacium</i>	NP13 B-2	B-5	Williams & Bujak, 1985 Eaton et al., 1980
<i>Adnatosphaeridium multispinosum</i>	NP11	NP17 NP17	Stover (in Haq et al., 1988) Williams et al., 1993
	NP11	NP17	Williams & Bujak, 1985
<i>Homotryblium floripes</i>	NP16 BAR-2	BAR-2	Williams & Bujak, 1985 Eaton et al., 1980
	Restricted range	Restricted range	
<i>Adnatosphaeridium vittatum</i>		NP15 NP16-NP17	Bujak & Mudge, 1994 Manum et al., 1989
	B-1	B-5	Eaton et al., 1980
<i>Enneadocysta arcuata</i>	NP14 NP14		Stover (in Haq et al., 1988) Williams & Bujak., 1985
		BAR-5 Middle-Late Eocene (NP16-NP17 ?)	Eaton et al., 1980 Manum et al., 1989
		NP16	Edwards, 1989
<i>Hystrichostrogylon membraniphorum</i>	NP14 Restricted range NP11	NP14 Restricted range NP16 NP16	Damassa et al., 1990 Williams & Bujak., 1980 Edwards, 1989
<i>Enneadocysta pectiformis</i>	NP18	Late Eocene	Williams et al., 2001 El-Beilay, 1988
	NP16 NP17? Restricted zone	NP17?	Köthe, 1990 Manum et al., 1989
		Restricted zone NP23/24	Torricelli & Biffi., 2001
<i>Glaphyrocysta texta</i>	BAR-3 Restricted zone NP17 NP19/20 Restricted zone	BAR-5 Restricted zone NP20 NP19/20 Restricted zone	Eaton et al., 1980 Williams & Bujak, 1985 El-Beily., 1988
<i>Polysphaeridium congregatum</i>	NP18 BAR-5 Restricted zone	NP24 BAR-5 Restricted zone	Williams & Bujak, 1985 Eaton et al., 1980

**Table 8.** Summary of some Dinoflagellate-events found in the Eocene of Eastern Zulia and their correlation with calcareous nannofossils according to literature.

**3.6 Palynostratigraphic correlations**

The correlations based on palynostratigraphy of sections measured in Eastern Zulia is show in Text-Figure 17.

Only part of the taxa recognized in the Pica-1X well are also found in the Quebrada Bijugal section located about 65 km to southeast. The top of the Jarillal Formation, in the well Pica-1X correlates with the top of the Pauji Formation in the Quebrada Bijugal section based on LAD of *Diphyes colligerum*. The very bad preservation of the palynoflora in the Quebrada Bijugal section does not allow to correlate the lower parts of these two formations.

The correlation between the well VL-37X and the Quebrada Honda Section is based on LAD of the species *Polysphaeridium subtile* and *Homotryblium tenuispinosum*. An exact correlation of the lower part of Quebrada Bijugal Section with this two sections is difficult. No diagnostic dinoflagellate cysts, have been recovered from the lower part of the Quebrada Bijugal section.

The two distinctive dinoflagellate cysts (*Homotryblium tasmaniense* and *Areoligera senonesis*) are common in the Caus Formation and allow a correlation with the Quebrada Honda and Quebrada Palma sections. In Eastern Zulia, the ranges of

these two species seem to be more restricted (See section 3.2.4.4 and 3.2.4.5). A more precise determination of FAD within the interval belonging to the Caus Formation was not possible. The LAD of *H. tasmaniense* and *A. senonesis* occur within the unit.

Correlations indicated in Text-Figure 18 are necessarily tentative and have to be detailed by the study of additional sections and samples and to be confronted and modified by additional data based on other palynomorphs (e.g. fungal remains) and other groups of microfossils.

**3.7 Comparison of dinoflagellate cyst assemblages with those from others areas**

Table 9 shows the percentages of dinocyst species common in the Middle Eocene in several European and Indian localities and Eastern Zulia. The lack of published data on well-dated dinoflagellate cysts from the Middle Eocene of Venezuela and northern South America forces me to rely on comparisons with occurrences in very distant areas. In general the percentages of shared dinoflagellate taxa fluctuate between 30 and 50%. These percentages are rather high and may also indicate similar paleoenvironments.

Locality	Stage	TSR	NSC	%SC <sub>1</sub>	%SC <sub>2</sub>
Southern England (Eaton et al., 1980)	Middle Eocene	145	30	20,7	50
Norwegian Sea (Manum et al., 1989)	Middle Eocene	129	27	20,9	45
Rogoznik section, Poland (Geld, 1995)	Middle Eocene	80	24	30,0	40
South western Kachchh, India (Jain & Tandon, 1981)	Middle Eocene	48	19	39,6	31,7
North Cambay Basin, Western India (Marthur, 1986)	Middle Eocene	49	15	30,6	25,0
Himachal Pradesh, India (Sarkar & Singh, 1988)	Middle Eocene	33	15	45,5	25,0
Morni Hills Haryana, India (Sarkar & Prasad, 2001)	Middle Eocene	38	22	57,9	36,7
West Nile Delta, Egypt (El-Beialy, 1988)	Upper Eocene	37	18	48,6	30,0

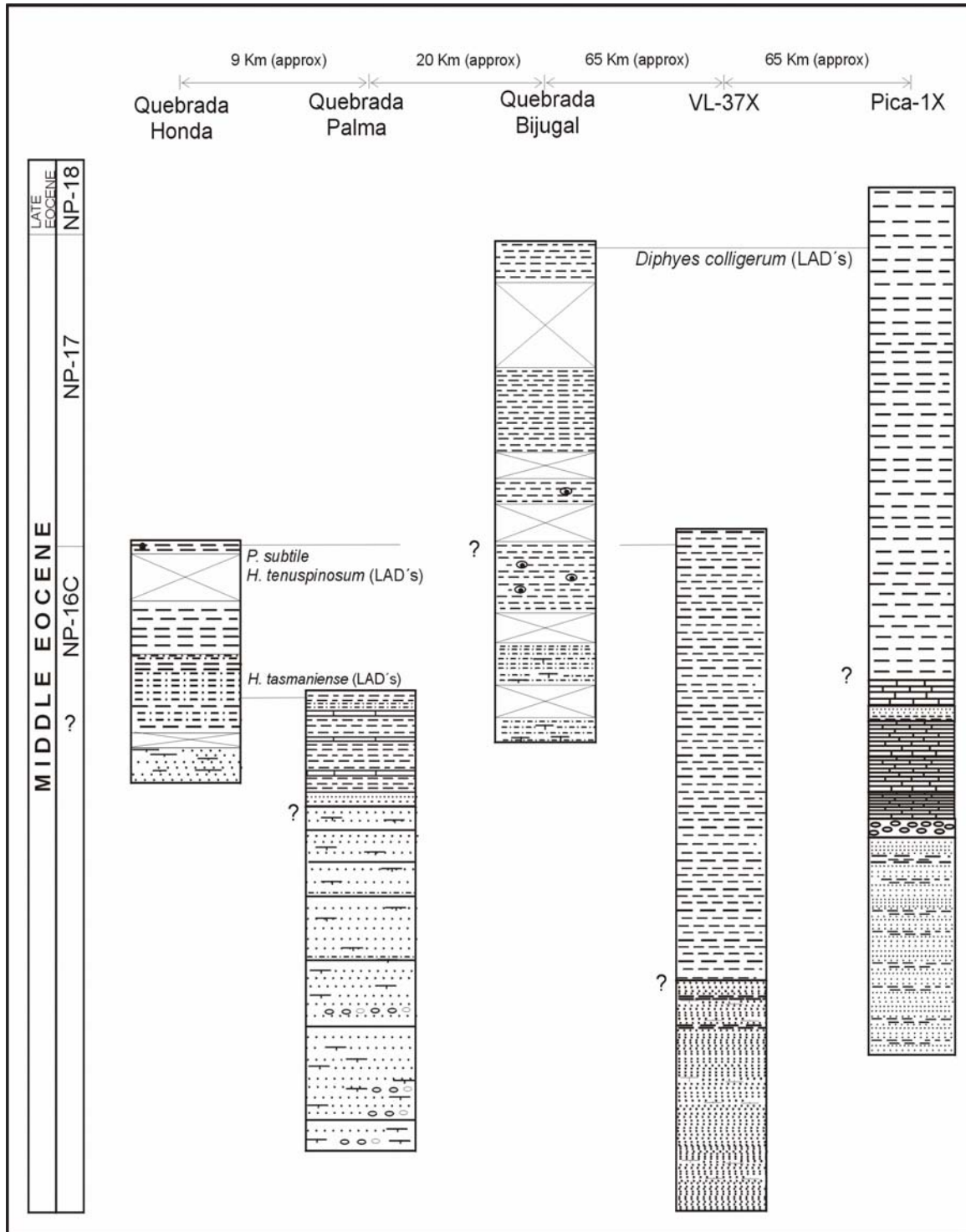
**Table 9.** Percentages of dinocyst species in common between compared localities and Eastern Zulia.

TSR Total number of dinocyst species reported for the compared locality.

NSC Number species in common between the compared locality and the Eastern Zulia.

%SC<sub>1</sub>= Percentage species in common calculated by (NSC \* 100)/TSR;

%SC<sub>2</sub>= Percentage species in common calculated by (NSC \* 100)/60.



**Text-Figure 17.** Correlation of Middle Eocene formations in Eastern Zulia, dated by dinoflagellate cysts and correlated with nanofossils zones (Martini, 1971; time scale after Berggren et al., 1995)

The dinoflagellate cyst assemblages studied from Eastern Zulia share a significant number of species with assemblages described from the Middle Eocene of southern England (Bartonian stratotype Eaton et al., 1980). The most significant species common to both areas are *Cordosphaeridium gracile*, *C. inodes*, *Diphyes colligerum*, *Lingulodinium polyedrum*,

*Homotryblium pallidum*, *H. tenuispinosum*, *Adnatosphaeridium multispinosum*, *A. vittatum*, *Polysphaeridium subtile*, *P. congregatum*, *Lejuenia hyalina*, *Enneadocysta arcuata*, *E. pectiniformis*, *Distatodinium ellipticum*, *Selenopemphix nephroides*, and *Cleistosphaeridium placacanthum*. The species in common is high (50%, see Table 9).

The following dinoflagellate cysts used as marker species in Eastern Zulia have also been recorded by Manum et al. (1989) from the Middle Eocene of the Norwegian part of North Sea: *Adnatosphaeridium vittatum*, *Enneadocysta arcuata*, *Enneadocysta pectiniformis*, *Distatodinium ellipticum*.

Similarities at the generic and specific level with coeval dinoflagellate assemblages of India seem to be more limited. Sarkar & Prasad (2001) reported dinoflagellate assemblages from the Subathu Formation in the Morni Hills (Haryana, India) include *Achilleodinium biformoides*, *Achomosphaera multifurcata*, *Adnatosphaeridium vittatum*, *A. multispinosum*, *Lingulodinium polyedrum*, *Operculodinium centrocarpum* known from Eastern Zulia.

Coeval assemblages from Himachal Pradesh, India (Sarkar & Singh, 1988) share even less species with those from Eastern Zulia: *Adnatosphaeridium vittatum*, *A. multispinosum*, *Cleistosphaeridium divesispinosum*, *Cordosphaeridium inodes* and *Homotryblium tenuispinosum*. The percentage of common species reported by Jain & Tandon (1981) from the Kutch is relatively low (25 %).

Upper Eocene dinoflagellate assemblages from Egypt and Tunisia have been described by El-Beialy (1988) and Toricelli & Biffi (2001). Only a few species are shared with the Eocene of Eastern Zulia: *Diphyes colligerum*, *Enneadocysta pectiniformis*, and *Glaphyrocysta texta*.

The albeit incomplete present analysis seems to indicate that dinoflagellate cysts reported from northwest Europe are also present in low latitude assemblages. This may indicate their adaptation to a broad spectrum of paleoenvironmental conditions. Others species, particularly *Homotryblium floripes* and *Polysphaeridium zoharyi* seem to be restricted to or are more common in lower latitudes Williams et al. (1990).

Palynomorph Ecostratigraphy and Paleocology

4.1 Data processing

All productive samples were analysed qualitatively and quantitatively. The quantitative analysis is made in two steps. In a first step, to up 100 specimens of palynomorphs have been counted and separated into seven groups with different paleoenvironmental (see e.g.. Van Mourik, Brinkhuis & Williams, 2001; Pross 1997; Brinkhuis & Biffi, 1993) These groups are (see Table 10):

- (a) terrestrial palynomorphs: pollen/spores, fungal remains.
- (b) aquatic palynomorphs: dinoflagellate cysts, acritarchs, foraminiferal linings, prasinophyte. algae, and colonial chlorococcales.

Aquatic Palynomorphs		
Category	Biological affinity	General ecology
Dinoflagellate cysts	Dinoflagellata	predominantly <b>marine</b> , sediments, although a few dinoflagellate cysts have been reported from freshwater sediments (Williams et al., 1999)
Acritarchs	Acritarcha	organic-walled microfossils of uncertain affinities, recent molecular studies indicate that some acritarchs may be dinoflagellate cysts or their phylogenetic precursors (Mullins, 2001): generally <b>marine to brackish</b> .
Foraminiferal lining	Foraminifera	organic remains of microforaminifera left after removal of the test, Stancliffe, 1989. Although not considered as palynomorphs <i>sensu strictu</i> , foraminiferal lining are found in many palynological preparations samples: generally <b>marine to brackish</b> .
Prasinophyte algae	Clorophyta	exact taxonomic uncertain, probably "primitive" green algae according to Guy-Ohlson, 1992: Recent prasinophycean algae are mainly marine, but have been recorded also in <b>brackish and freshwater</b> and show tolerance to increased salinity (Tyson, 1996)
Colonial chlorococcales	Clorophyta	<i>Pediastrum</i> and <i>Botryococcus</i> , colonial and unicellular green algae (Tyson, 1996): frequent in <b>freshwater</b> , but a few species tolerate higher salinity.
Terrestrial palynomorphs		
Pollen and spores	Pollenites and Sporites	Pollen: male productive bodies (microgametophytes) of seed plants (Heusser, 1998). They originate in the anthers of flowering plants, or angiosperms and in the microsporangia of gymnosperms. Spores are produced by "lower plants": dispersal into marine sediments mainly by <b>freshwater influx</b> and wind transport into <b>coastal</b> habitats.
Fungal Remains	Fungi imperfecti	dispersed spores no embryophytic as microscopic sporangia, hyphae or fragmented mycelia (Elsik, 1976): dispersal mainly by <b>freshwater</b> .

Table 10. Main groups of palynomorphs, their botanical affinity and general ecology.

In a second step, terrestrial and aquatic palynomorphs are counted separately. Since the number of specimens available for counting is

generally less than 120, no statistical analyses, which in order to be representative would

require a minimum of 150 specimens, have been attempted.

a) The **Palynological Marine Index** (PMI; Helenes et al., 1998; Helenes et al., 1999) is defined as:

$$PMI = (R_m/R_t + 1) * 100$$

where:

R<sub>m</sub>= number of aquatic palynomorphs (dinoflagellate + acritarchs + prasinophyte + foraminifera linings).

R<sub>t</sub>= number of terrestrial palynomorphs (Pollen + Spores + Fungal remains)

- Zero values of PMI indicate samples without marine palynomorphs and are interpreted as representative of **terrestrial or freshwater environments**.
- Low values of PMI are interpreted as indicative of **brackish-water** influence.
- Higher values of PMI are interpreted as indicative of **marine** conditions of deposition.

The PMI is used as a proxy for marine influence and its fluctuations may indicate changes of the depositional environments. The PMI curve is useful for the recognition of maximum flooding intervals which are usually located close or coincide with the maximum PMI values within a sequence (Helenes et al., 1998). As a general rule, sequence boundaries are found in intervals with upward-decreasing values of PMI.

#### b) **Diversity of the dinoflagellate cysts**

The quantitative measurement of flora and faunal diversity is another important paleoecologic parameter. I use the equation of Bradford & Wall (1984) for a complete expression of faunal diversity. The number of species observed in a fauna or flora is the most direct and simple measure of species diversity (Rosenzweig, 1995; Holland, 1995). The diversity is defined as:

$$D = \sum_{j=1}^m n_i \log n_i / N$$

where:

D= diversity  
 m= number of species  
 n<sub>i</sub>= number of individuals of species i  
 N= total count of individuals species for sample

Diversity and the occurrence of a particular taxa in recent dinoflagellate assemblages are functions of the salinity, currents, turbidity, temperature and distance from the shore (Wall et al 1977).

However, changes in diversity in fossil assemblages may also be affected by post-mortem changes (diagenetic alterations, variable preservation potential., e.g Fensome et al., 2000; Evitt, 1985; Gregory et al., 1995).

On the other hand, environmental conditions influence also the evolutionary diversification of dinoflagellates. The number of dinoflagellate taxa increases markedly from the Late Paleocene to Early Eocene. (e.g. Bujak & Williams, 1979), an interval which is characterised by considerable global warming (Early Eocene Thermal Maximum at approximately 55 Ma. (see Crouch et al., 2001). This event affected drastically not only the dinoflagellate assemblages (e.g. increase of representatives of the genus *Apectodinium*), but the entire surface-dwelling plankton.

Changes in the composition and diversity of dinoflagellate assemblages are useful in stratigraphic sequence analysis (e.g. Habib et al., 1992)

#### 4.2 **Remarks on the ecology and paleoecology of dinoflagellate cysts**

Dinoflagellate cysts are remains of unicellular biflagellate algae with a size from 5 to 200 µm. They belong to the Pyrrhophyta. Dinoflagellates have a relatively simple life cycle with a motile flagellate phase and an encysted phase (resting cyst). Only about 10 % of all living dinoflagellate species are known to form cysts (Evitt, 1985), and perhaps less than 70% of these may produce cysts that are preserved as fossils (Dale, 1976 in Tyson, 1996). Dinoflagellates are a significant part of primary planktonic production in both oceans and lakes.

The distribution of motile stage dinoflagellates, in modern oceans is controlled by several factors such as latitude, temperature, salinity and distance from the shore (Köthe 1990; Godmann, 1987; Harland 1983 and Wall et al., 1977)

The distribution of dinoflagellate cysts in sediments from middle and high latitudes of the Northern Atlantic and adjacent basins is relatively well documented (e.g. Ellegaard, 2000; Rochon et al., 1999; Dale, 1996; Mudie et al, 1992; Harland, 1983; Wall et al., 1977), but only few papers have been published on the

distribution of dinoflagellate cysts in tropical areas (Höll et al., 2000; Vink et al., 2000; Bradford & Wall, 1984).

The information obtained from the studies of the modern distribution patterns of dinoflagellate cysts is the base the understanding their potential in paleoenvironmental reconstructions. Of course, this 'actualistic' method has also serious drawbacks. Many genera and species abundant or even dominant in Middle Eocene assemblages have since become extinct. Other species belong to genera which are also known from recent sediments (e.g. *Lingulodinium*, *Polysphaeridium*, *Spiniferites* and *Nematosphaeropsis*), but their Middle Eocene representatives may not have had exactly the same ecological requirements. The uncritical transfer of ecologic parameters of modern analogues may lead to pitfalls.

The application of fossil dinoflagellate cysts assemblages in paleoenvironmental studies is a relatively young field. Characteristic associations of dinoflagellate cysts (ecogroups or ecoassemblages) which are potential indicators of inner neritic to oceanic environments have

been recognised by different authors (Van Mourik et al., 2001; Jaramillo & Obok-Ikuhenobe, 1999; Pross, 1997; Brinkhuis, 1994; Stover & Hardenbol, 1993 and Köthe, 1990; Wrenn & Kokinos, 1986). Indications by these authors and additional data have been used for the paleoenvironmental interpretation of the samples studied from Eastern Zulia. However, it has to be born in mind that these data are compiled from a considerable number of geographical areas and on assemblages of varying age.

Van Mourik et al. (2001) recognised five different associations characterised by the occurrence and abundance of some genera which are characteristic of marine environments (restricted neritic, inner neritic, outer neritic, neritic to oceanic and oceanic, see Table 11). These five generic assemblages have also been used for the paleoenvironmental interpretation of the Middle and Upper Eocene of Eastern Zulia, but some of the genera included by Van Mourik et al. (2001) have been replaced by others which are thought to have similar paleoecologic requirements.

Restricted neritic	Outer neritic	Neritic to Oceanic	Oceanic
<i>Homotryblium</i> spp.	<i>Cordosphaeridium</i> spp. <i>Diphyes</i> spp. <i>Enneadocysta</i> spp. <i>Turbiosphaera</i> spp.	<i>Distatodinium</i> spp. <i>Oligosphaeridium</i> spp. <i>Operculodinium</i> spp. <i>Spiniferites</i> spp. <i>Xenicodinium</i> spp. <i>Lejeunecysta</i> spp. <i>Selenopemphix</i> spp. <i>Achomosphaera</i> spp.	<i>Hystrichokolpoma</i> spp. <i>Nematosphaeropsis</i> spp.
<b>Inner neritic</b>			
<i>Achilleodinium</i> spp. <i>Areoligera</i> spp. <i>Glaphyrocysta</i> spp. <i>Lingulodinium</i> spp. <i>Systematosphora</i> spp. <i>Adnatosphaeridium</i> spp. <i>Cleistosphaeridium</i> spp. <i>Polysphaeridium</i> spp. <i>Chiropteridium</i> spp.			

**Table 11.** Generic associations typical of neritic to oceanic environments (After Van Mourik et al., 2001)

### 4.3 Ecology and paleoecology of fungal remains

The importance of fungal spores in paleoecological interpretations has been stressed by many authors (Jarzen & Elsik, 1986; Sherwood-Pike, 1988; Phatare, 1989). Changes in the diversity and relative abundance of fungal remains can be useful in helping to determine the evolution of depositional sequences (Elsik,

1996). However, fungal palynomorphs are generally treated merely as an accessory group and are not studied in detail.

The taxonomically highly divers fungal spores occupy a variety of ecological niches. Lange, (1978); Phadtare (1989); Ethridge et al., (1986); Kumar, (1990) and Kalgutkar & McIntyre, (1991) and others have tried to compare recent and fossil fungal remains. The paleoecological

interpretation of fungal remains is largely based on their investigations. However, the interpretation of fungal remains from the Eocene of Eastern Zulia meets with some restrictions, since several of them have no recent analogues.

Because of the low recovery, the confusing taxonomy and the lack of applicable of recent studies, no detailed paleoecological study of the fungal remains has been attempted. I have mainly tried to document the fungal remains encountered in my samples.

Representatives of the very frequent fungal family Microthyriaceae are widespread in the Tertiary (e.g. India: Rao, 1958, Phatadare, 1989; Turkey: Ediger, 1981; Australia: Lange, 1976; 1977; USA: Dilcher, 1965; Canada: Parsons & Norris, 1999; India Ocean: Kemp, 1978). The presence of abundant remains of the Microthyriaceae suggests uniform high humidity and warm temperature (Dilcher, 1965; Elsik, 1976; Phatare, 1989 and Kalgutkar, 1993). Microthyriacean fungi are most abundant in tropical and subtropical regions, generally with heavy rainfall and associated with broad-leaved angiosperms (Phatadare 1989). This restricted occurrence and their easy identification make them useful paleoecological indicators.

Elsik (1976) considered representatives of the fungal spore genus *Exisisporites* as typical for a warm climate.

Less than 2% of all known fungi from recent sediments are aquatic (freshwater). Therefore, most fungal remains are allochthonous showing a similar hydrodynamic behaviour as other terrestrial palynomorphs (e.g. pollen and spores, Tyson, 1996). Therefore, fungal remains in marine sediments are most abundant in proximal nearshore facies and show an inverse relationship with the marine microplankton (Elsik 1976).

In general, fungal palynomorphs have been included in several studies of modern or ancient sediments, but have not received due consideration. Frequently, they are treated merely as an accessory group and more comprehensive studies focus on other groups of palynomorphs.

#### 4.4 Paleocology of the Middle to Upper Eocene in the studied sections

##### 4.4.1 Pica-1X well

The Middle to Late Eocene palynomorph assemblages (fungal spores and dinoflagellate

cysts) of the Jarillal Formation show significant quantitative changes. The depositional environments fluctuate between inner and outer neritic with variable distance to shore. The other groups of organic-walled microfossils tend to confirm this interpretations.

Text-Figure 19 shows the relative percentages of marine and non-marine palynomorphs., notably the dinocysts, Throughout the entire well, marine palynomorphs, mainly dinoflagellate cysts, predominate. Percentages of fungal remains are highest at -340 ft and -3400 ft, while those of dinocysts peak at -3170 ft.

The relative percentages of generic associations typical of neritic to oceanic environments are represented in Text-Figure 20. They show a slight to significant terrestrial influence towards the top (-100- -340 ft), where palynological assemblages are dominated by fungal remains and percentages of marine phytoplankton are low.

Samples between -340 to -3390 ft are dominated by dinocyst assemblages thought to correspond to outer neritic to oceanic conditions. Downhole, dinocysts, acritarchs and foraminiferal linings are more frequent than fungal remains. The diversity of the dinocyst assemblages is increasing in this interval. Species of the genera of *Glaphyrocysta*, *Enneadocysta* and *Diphyes* are frequent. The occurrences of relatively well preserved pollen, spores and fungal remains suggest periods of increased inflow of terrestrial particles. The increase in the number of benthic foraminiferal linings might indicate intervals with higher nutrient levels.

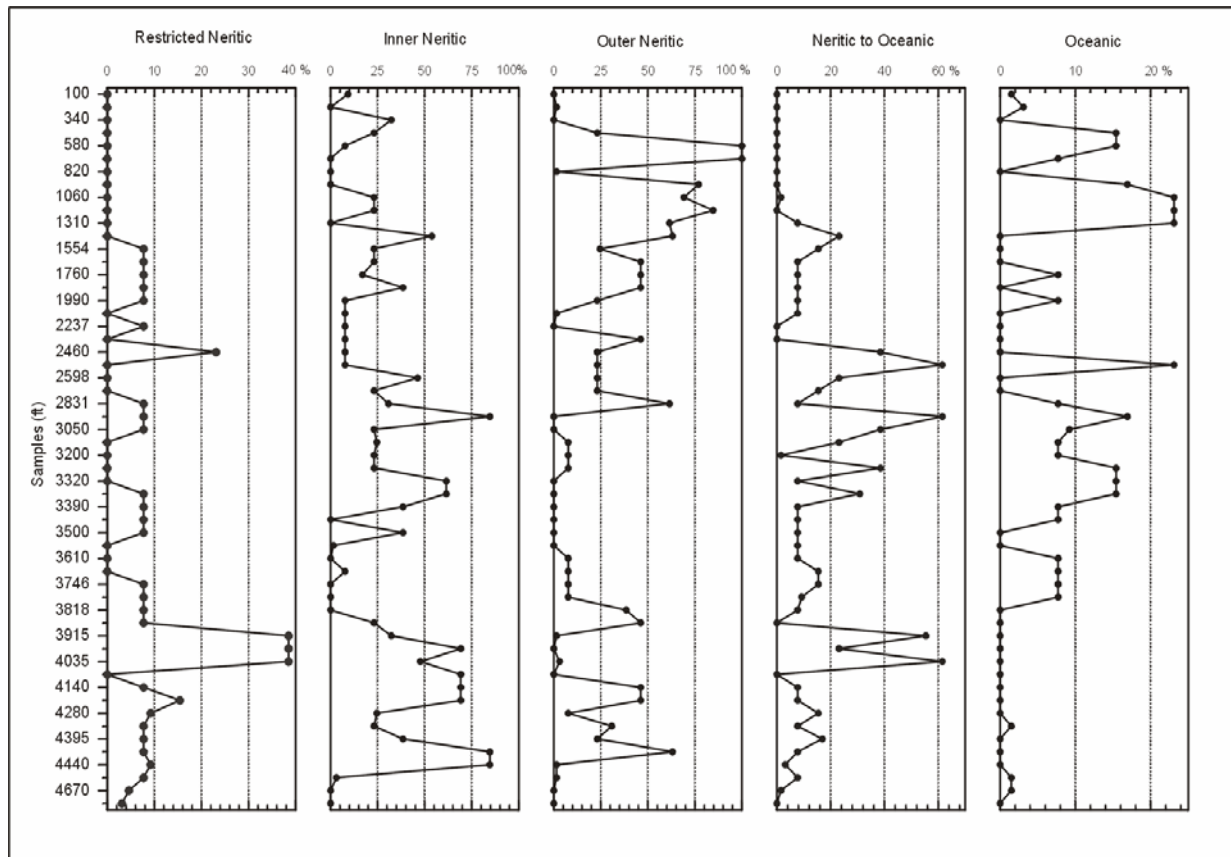
The interval -3390 to -4720ft is dominated by inner neritic dinocyst assemblages, the numbers of foraminiferal linings decreases, whereas those of pollen and spores increases. The generic and specific composition of the dinocyst assemblages shows only little variations (except ample -3915 ft).

The general composition of the phytoplankton and the fungal spores indicates the persistence of warm tropical conditions during the entire studied interval.

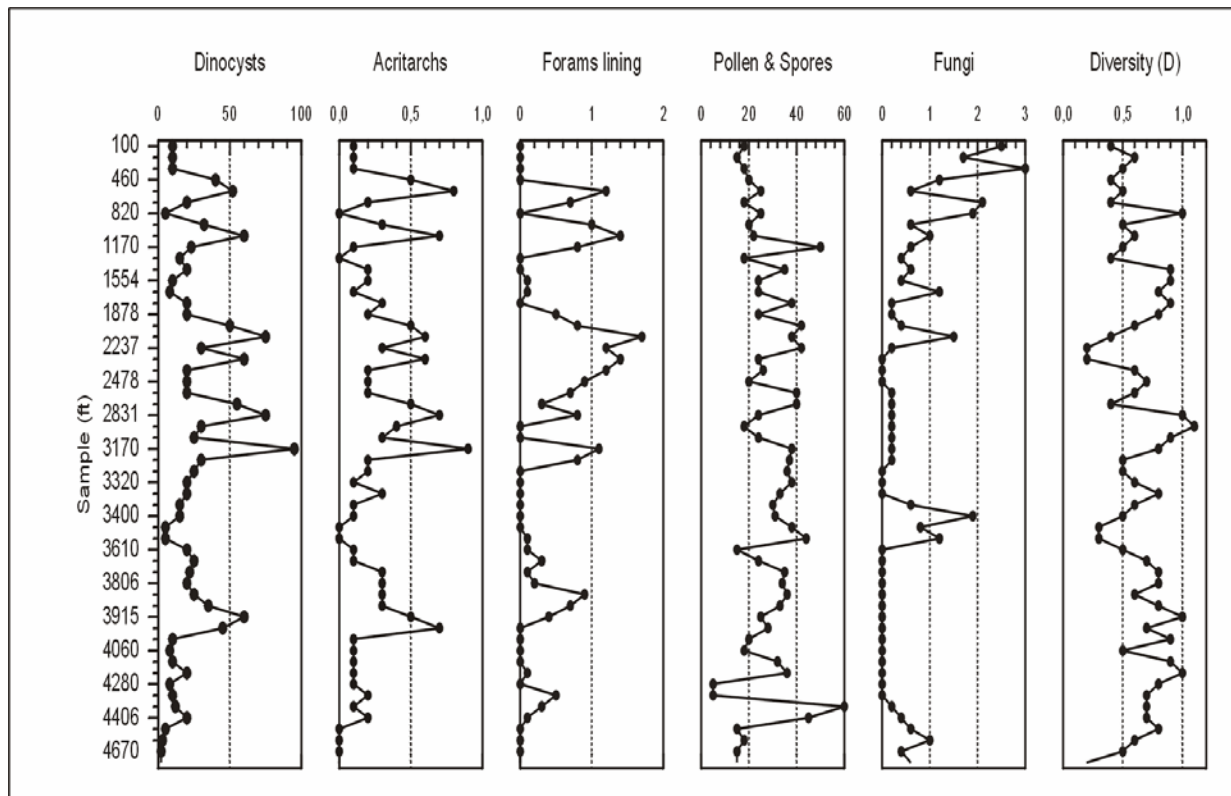
##### 4.4.2 VL-37X well

The common occurrence of dinoflagellate cysts throughout the studied interval suggests that the depositional environments of the Pauji Formation in well VL-37X were more marine than in the corresponding interval of the Pica-1X well.



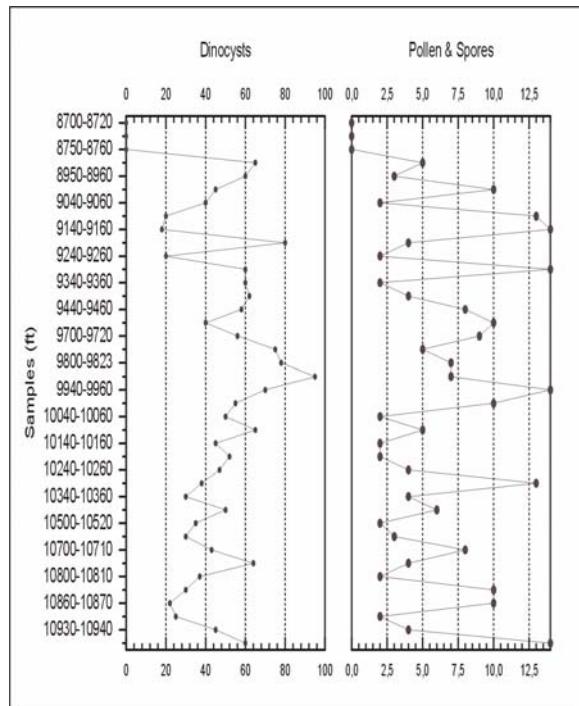


Text-Figure 18. Distribution relative percentages of marine and non-marine palynomorphs in the Pica-1X well.



Text-Figure 19. Distribution percentages of generic associations typical of neritic to oceanic environments in the Pica-1X well.

(see Text-Figure 21). Samples are richer mainly in dinoflagellate cysts as well as pollen and spores. Other groups of palynomorphs are absent.



**Text-Figure 20.** Distribution relative of percentages of marine and non-marine palynomorphs in the VL-37X well.

In the interval -8700 - -8760 ft, a change in paleoenvironmental conditions may be indicated by the very poorly preserved or even barren assemblages and the extensive growth of pyrite crystals..

In the topmost samples (-8900 - -9260 ft), the general composition of the microplankton assemblages, particularly the dominance of *Polysphaeridium subtile* and the presence of common *Selenopemphix nephroides* (high frequencies of peridinioid cysts) are suggestive of middle to outer neritic assemblages. The presence of *P. subtile* is indicative of restricted circulation. In the interval -9300 - -10120 ft, assemblages dominated by *Cordosphaeridium cantharellum* indicate similar conditions. The common *Polysphaeridium zoharyi* is a typical tropical species (Harland, 1984). In the assemblages of the lowermost interval (-10140 - -10960 ft), the most frequent species are *Homotryblium spp.*, *Spiniferites pseudofurcatus* and *Achomospaera cf. ramulifera*. This association indicates high- stress shelf conditions, perhaps caused by increased salinity (Brinkhuis, 1994). The other components of the assemblages support a neritic environment, although the frequency of peridinioid cysts decreases (see Table 4). The presence of

*Pediastrum spp.* in the same interval is indicative fresh water influence. This algae is often associated with estuarine conditions (Evitt, 1963).

#### 4.2.3 Quebrada Bijugal outcrop section

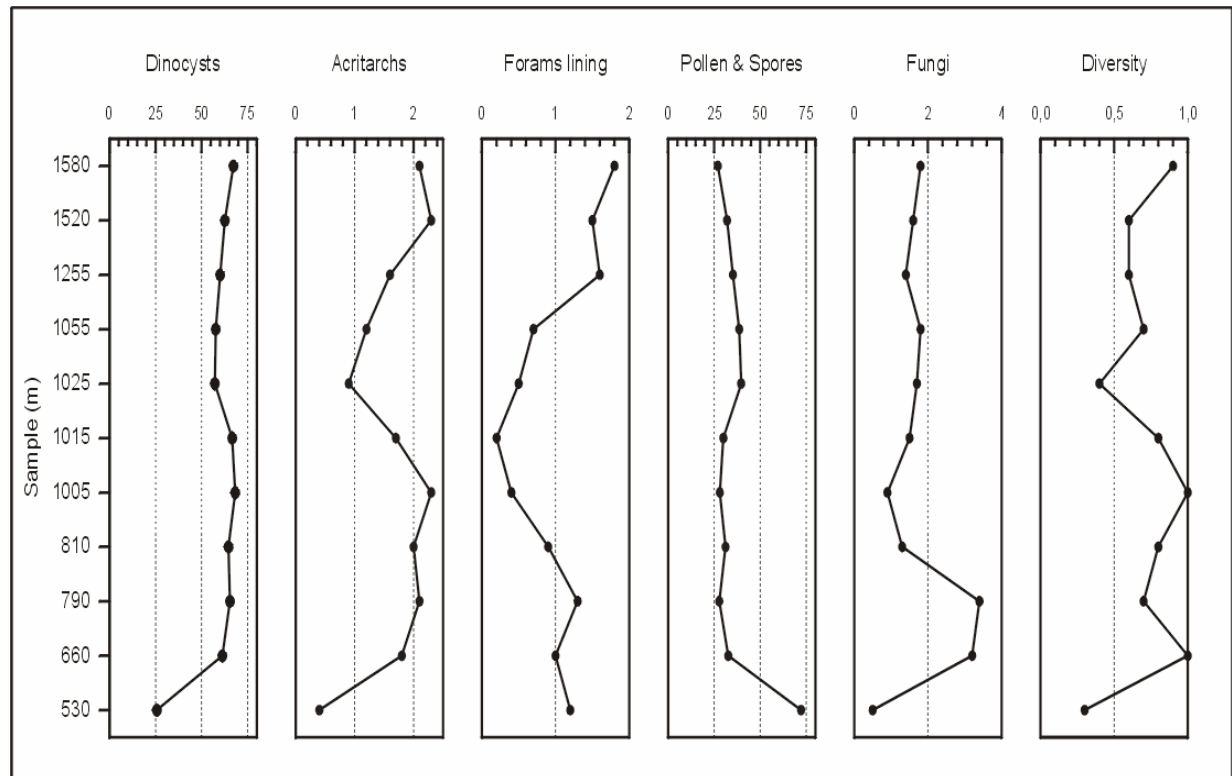
The distribution of the palynomorphs recognized in the Quebrada Bijugal section is shown in Text-Figure 21. Only five of total of 16 samples yield rich palynomorph assemblages. These assemblages are dominated by dinocysts such as *Diphyes spp.*, *Selenopemphix spp.*, *Nematosphaeropsis spp.*, and *Lejeunecysta spp.* This palynoflora indicates deposition in open marine conditions, but the presence of the land-derived fungal remains suggests terrigenous influx.

Foraminiferal linings are common from 1580 to 1025 m. The species common in this section have been grouped in one complex of morphologically and presumably ecologically closely related taxa: the *Nematosphaeropsis-Lejeunecysta* group. Recent representatives of *Nematosphaeropsis spp.* are mainly known from outer neritic to oceanic environments (Brinkhuis et al., 1992; Brinkhuis & Biffi, 1993; Zevenboom et al., 1994). The peridinioid dinoflagellate cysts of *Lejeunecysta spp.* are presumably derived from heterotrophic dinoflagellates (Schøiler et al., 1997). In the Cenozoic, assemblages dominated by peridinioid dinoflagellate cysts occur together with diatom-rich assemblages. This may imply that most dinoflagellate cysts of peridinioid affinity are derived from heterotrophs and can be used as paleoproductivity indicators (e.g. of upwelling systems bringing cold and nutrient-rich water masses to the ocean surface; Powell et al., 1990; Bujak, 1984). attributed high frequencies of heterotrophic peridinioids to areas with high primary production related to increased nutrient availability (upwelling areas, river mouths). Therefore, the intervals with high relative abundance of peridinioid cysts in the Quebrada Bijugal section may indicate times of high productivity during the Eocene. The common occurrence of terrestrial organic matter (pollen, spores and fungal remains) in the same samples suggests a continental source of the nutrients (e.g. river runoff) and probably also more proximal environments. Larger numbers of foraminiferal linings are generally found in shelf assemblages. The increase of their number observed in the upper part may indicate a trend towards outer shelf conditions. Muller (1959) indicates that the abundance of foraminiferal linings increases seawards in the modern sediments of the Orinoco Delta.

Pollen and spores are mainly represented by poorly preserved specimens of trilete spores. In contrast, fungal remains are well preserved.

The composition of the palynomorph assemblages from the interval between 1015 and 530 m is very different from the overlying interval. The number of acritarchs and fungi increases, whereas that of foraminiferal linings

decreases. Most assemblages of dinoflagellate cysts are characterized by high numbers of *Homotryblium* spp., *Cleistosphaeridium* spp., and *Distatodinium* spp. Therefore, sediments from this interval have been deposited in a shallow nearshore environment into which occasionally more open marine elements may have been washed during times of bad weather.



**Text-Figure 21.** Distribution relative percentages of marine and non-marine palynomorphs in the Quebrada Bijugal outcrop section.

The common occurrence of *Cleistosphaeridium* spp. is considered to indicate of 'normal' shallow marine conditions (Köthe, 1990), while that of *Homotryblium* spp. is typical of warm water masses of lower latitudes (Williams & Bujak, 1977). The fungal remains in the lower part of the section probably were washed in from fresh water habitats in the hinterland. The association of *Polyadosporites* sp. with *Fusiformisporites* sp. suggests an inner neritic environment.

#### 4.2.4 Quebrada Palma outcrop section

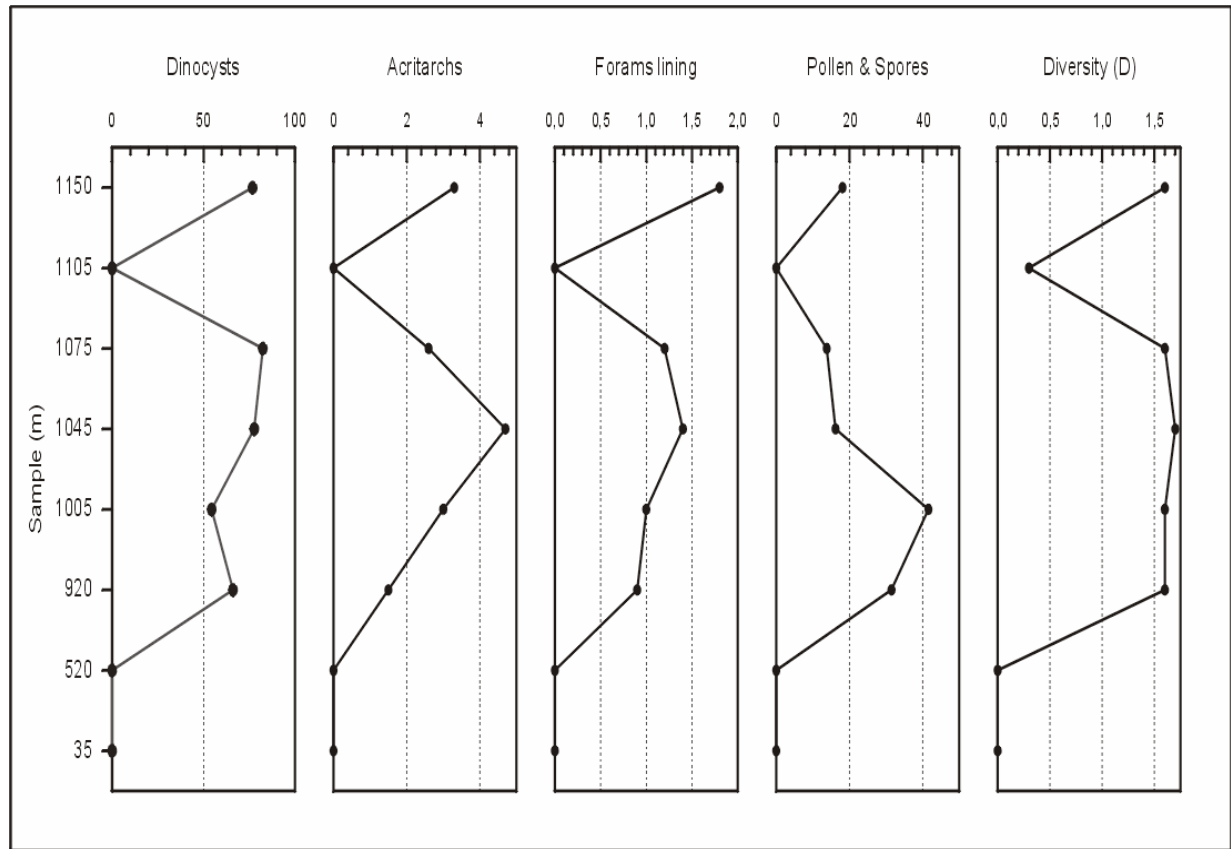
In this section, three samples are either barren or yield less than 50 specimens per sample. Palynological assemblages of the interval 1075 to 920 m show relatively rich assemblages (see Text-Figure 22). Dinocysts, acritarchs and foraminiferal linings are present in significant

percentages, except in sample 1045 m which yields an assemblage dominated by pollen and spores.

The dinocyst assemblages are dominated mainly by specimens of *Areoligera* spp., *Homotryblium* spp. and *Lingulodinium* spp. Five samples from the Caus Formation are dominated by *Areoligera* spp. Brinkhuis (1994) suggests that *Areoligera* associations represent marginally marine to inner neritic water masses in low to middle latitudes and possibly occur near foreslopes of carbonate platforms. The same samples are also rich in *Homotryblium* spp. and *Lingulodinium* spp. *Homotryblium* spp. may indicate restricted inner neritic environments (Van Mourik et al., 2001; Brinkhuis, 1994); while *Lingulodinium* spp. suggests euryhaline nearshore conditions (Islam, 1984; Brinkhuis et al., 1992). Therefore, the Caus Formation is likely to have been

deposited in an inner neritic environment. A decrease in the number of species in the

uppermost Caus Formation may indicate upwards shoaling (see Table 6).



**Text-Figure 22.** Distribution of the relative percentages of marine and non-marine palynomorphs in the Quebrada Palma outcrop section.

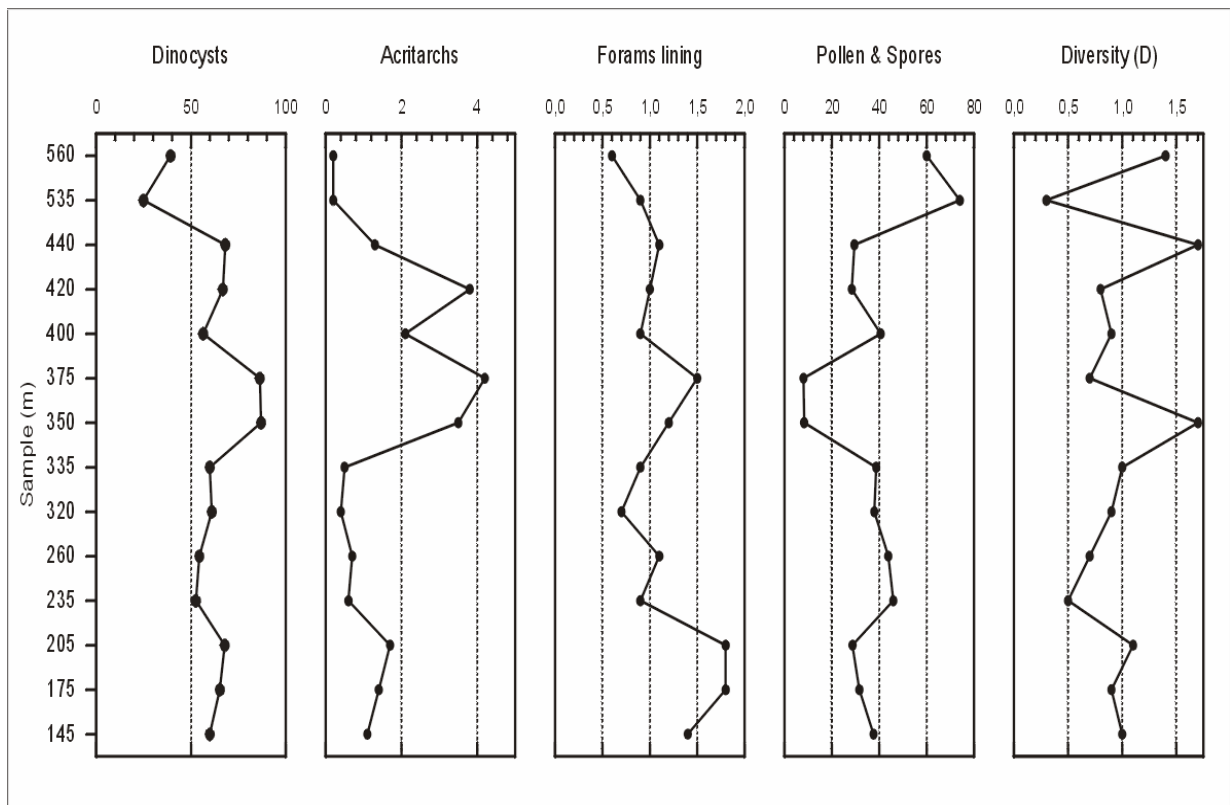
#### 4.2.5 Quebrada Honda outcrop section

Text-Figure 23 shows the distribution of the palynomorphs in the fourteen productive samples from the Quebrada Honda outcrop section including samples from the Caus Formation (145 to 235 m) and the Pauji Formation (260 to 560 m).

The palynological assemblages in the basal part of the section (Caus Formation) are characterized by good preservation and the occurrence of such dinoflagellate species as

*Areoligera* spp., *Homotryblum* spp., and *Ligulodinium* spp. This interval is rather rich in pollen and spores as well as foraminiferal linings. The number of acritarchs is small. As in the corresponding interval with similar dinocyst assemblages in the Quebrada Palma section, an inner neritic environment is inferred.

The samples from the Pauji Formation (260 to 560 m) are considerably more diverse than those from the Quebrada Bijugal section. *Polysphaeridium* spp., *Cordosphaeridium* spp. and *Homotryblum* spp. are the most frequent taxa.



**Text-Figure 23.** Distribution of the relative percentages of marine and non-marine palynomorphs in the Quebrada Honda outcrop section.

In this interval, *Polysphaeridium subtile* becomes the dominant species which may suggest shallow inner neritic conditions. The extant species *P. zoharyi* (see Table 7) is typical of tropical waters (Harland, 1984). The presence of *P. subtile* is also indicative of restricted circulation. Large numbers of representatives of the *Cordosphaeridium* group have been widely reported from Mesozoic to Miocene neritic sediments (Schjøiler et al., 1997). Possibly,

these assemblages indicate fluctuations in the local environmental conditions. The corresponding interval in the Quebrada Bijugal section has probably been deposited in a more offshore position, whereas the predominantly shallow neritic regime in the Quebrada Honda section is situated more inshore as indicated by the predominantly shallow inner neritic palynomorph assemblages.

## Material and methods

### 5.1 Provenance of material

The study of the Middle to Late Eocene dinoflagellate cysts and fungal remains is based on three surface and two subsurface sections from the East coast of Maracaibo Lake (Text-Figure 2). The three outcrop sections, Quebrada Bijugal, Quebrada Palma and Quebrada Honda are located south of the Ceuta Field and have been originally studied by H.W.Loser (1954) and O.Renz (1955). Well Pica-1X is located in the western part of Falcón (coordinates U.T.M. North: 1149318.60 and East: 268114.44). Well VL-37X is in the area of Ceuta (North: 1079887 and East: 271671).

A total of 357 outcrop, core and ditch samples have been collected, but unfortunately several samples are lacking palynomorphs, because of the strong degradation of the organic matter by weathering and carbonisation (Nijsen, 1965; Fuenmayor & Di Giacomo, 1976; Rull, 1997). Predominant lithologies are shales, mudstones and siltstones. The samples are numbered and their origin is indicated: QB = Quebrada Bijugal; QH = Quebrada Honda; QP = Quebrada Palma; PP= Pica-1X; VL= VL-37X.

### 5.2 Palynological Processing

A total of 155 samples were processed in mineral acids in several steps according to palynological standard methods (e.g. Kaiser & Ashraf, 1974; Traverse, 1988) (see Text-Figure 24):

1. The amount processed depends on the lithology: shales, mudstones and siltstone 20-25 grams; for limestone and calcareous shales, siltstone and mudstones 25-30 grams.
2. Cutting and core samples are scraped and washed in order to avoid contaminations by drilling mud. The

samples were then crushed to pieces of about 1 to 2 mm.

3. Approximately 20-30 grams of material are placed in 250 ml. polypropylene beakers. 250 ml. 30% hydrochloric acid (HCl) are added and left for at least 8 hours to remove any calcareous material. The acid is then decanted and the remaining residue is washed with distilled water and centrifuged three times in order to remove the calcium ions that can form unwanted  $\text{CaF}_2$  crystals when hydrofluoric acid (HF) is added.
4. 250 ml of hydrofluoric acid (HF) with a concentration of 70% are added cautiously and left for at least 1 hour. The polypropylene beakers are then hermetically sealed and agitated on a shaker at 1900 r.p.m. for 8 hours until digestion is completed.
5. The sample is allowed to settle for at least 24 hours for the settling of the finest fraction of sediment. Afterward, the acid is decanted and the samples are washed three times with distilled water and decanted.
6. After the final decantation, the samples are filtered with distilled water through a 10  $\mu$  sieve, poured into a 25 ml glass test tube and centrifuged for five minutes at 2000 r.p.m.
7. The remaining mineral particles are removed using a  $\text{ZnBr}_2$  solution (density 2.0). Twenty ml of  $\text{ZnBr}_2$  with five drops of concentrated HCl to improve better heavy liquid separation are added to the sample and agitated. The test tubes are placed in an ultrasonic bath for 10 seconds and subsequently centrifuged for 30 minutes at 1500 r.p.m.

8. The suspended fraction (organic matter) is again filtered through a 10  $\mu$  sieve, washed with water and poured into another tube. The remaining mineral fraction is discarded.
  9. The organic matter is transferred in test tubes with distilled water and centrifuged for 5 minutes at 2000 r.p.m.
  10. Subsequently, the organic matter is separated into two fractions, the first fraction is oxidized with HNO<sub>3</sub> (see 5.2.1 -oxidation method) for an improved recovery and concentration of palynomorphs (dinoflagellates and fungal spores), while the second fraction is not oxidized and used for the palynofacies analysis.
4. 10 % caustic potash solution is added to remove the oxidized humic compounds in solution, and the samples is then washed with distilled water and centrifuged at 1500 r.p.m. for 5 minutes. The procedure is repeated three times.
  5. Finally, the sample is filtered through a 20  $\mu$  sieve with distilled water and the slides are mounted.

### 5.2.1 Oxidation method

The oxidation method is used for the elimination of "nano-coals", such as wood, leaf cuticles, and amorphous organic matter (Traverse, 1988). This procedure must be applied with great care and caution, because sporopollenin is quite easily and irreversibly oxidated (Batten & Morrison, 1988). Type of oxidant and length of oxidation time chosen are dependent on the degree of diagenesis of the palynomorphs as indicated by the colour of the organic material.

All samples have been treated with concentrated nitric acid (HNO<sub>3</sub>) as justified by the generally poor recovery of dinoflagellate cysts and fungal spores as well as the coaly aspect of the organic matter. According to Kummel & Raup (1965), the concentration recommended for Eocene samples is 40 % HNO<sub>3</sub>. A series of tests have been run in order to determine the optimal time and temperature of oxidation.

1. A portion of the residue obtained in step 10 of the standard preparation is checked to determine the amount of oxidation required.
2. Five ml of nitric acid (63% HNO<sub>3</sub>) is poured in the test tubes with the residue and mixed carefully with the sample.
3. The test tube is placed in a hot water bath for 20-30 minutes which is agitated every 5 minutes and checked each 10 minutes.

### 5.2.2 Mounting

Approximately five to ten drops of glycerine jelly are added to the test tubes and thoroughly mixed with the organic matter. The mixture is transferred with a disposable graduated pipette on a slide and covered with a 24x32 mm coverslip. The slide is allowed to dry for 20-30 minutes, and after one week the excess glycerine is removed from the edge of the coverslip.

Four slides (two for palynofacies and two for determination and counting of the palynomorphs) were prepared from each sample.

### 5.2.3 Location of the slides

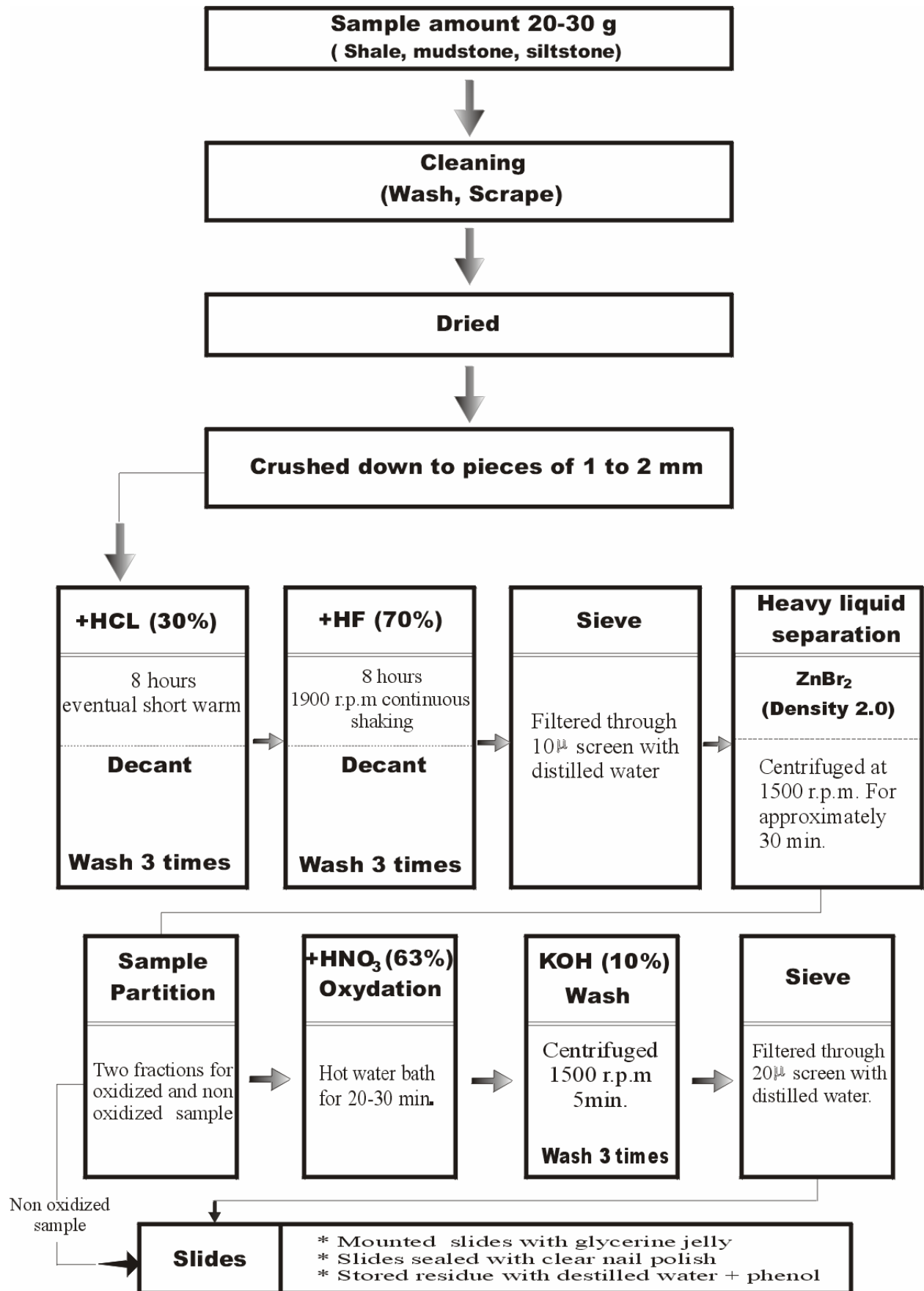
The slides are deposited in the micropaleontology collection of the Institute of Geological Sciences at the University of Tübingen.

### 5.3 Analytical Procedures

Description and counting of the different palynomorphs groups, and classes of particulate organic matter were done mainly with a Zeiss transmitted- light microscope, using interference contrast (IC). The slides are scanned with a 40x Zeiss planapochromatic objective, whereas a 100x objective is used for detailed descriptions and observations.

### 5.4 Photography

Light photomicrographs are produced with an Olympus BX-51 Axioplan microscope (IC) and a digital camera Olympus Camedia C-3030 zoom. The images are enhanced in brightness and contrast using Adobe Photoshop 5.5 and saved as TIF files. Specimens illustrated (Plates 1-13) on the slides are located by England Finder references.



Text-Figure 24. Flow chart for processing of palynological samples



## Systematic Palynology

# 6

This chapter presents the taxonomy of four groups: dinoflagellate cysts, acritarchs, prasinophytes, and fungal spores. In each group, genera are arranged in alphabetic order. One group of microfossils, foraminiferal linings

### Taxonomic approach

The fossil dinoflagellate, acritarchs, prasinophytes and fungal spores recovered in this study have been classified using several approaches. In the case of dinoflagellate cysts, the suprageneric classification of living and fossil dinoflagellates recently published by Fensome et al. (1991, 1993) has been adopted. These authors have proposed that at the subdivision and class levels, the characteristics of the nucleus (conventional eukaryotic nucleus or dinokaryon nucleus with condensed chromosomes present during the complete mitotic cycle) are of prime value. At the order and suborder levels, the pattern of tabulation or the structure of the amphiesma are the primary defining characters.

In the classification of fungal spores, two approaches have been proposed. They can be assigned to modern fungal taxa or they can be assigned to form taxa. The latter approach is predominantly used by authors dealing with fossil occurrences (e.g. Kalgutkar & Jansonius, 2000; Parsons & Norris, 1999; Kalgutkar, 1993; Norris, 1986; Elsik, 1968). The first approach would seem to have the advantage of providing ecological information but in practice, it is generally difficult to assign fungal remains to any but the broadest of natural groups.

is not treated in detail. The four other groups are treated according to the "*International Code of Botanical Nomenclature of Tokyo*" (Greuter et al., 1994).

The second approach, the use of form taxa, has been widely used by pre-Quaternary palynologists who have built on the original form genera introduced by Van der Hammen (1954, 1956a). This approach has the advantage of providing named taxa, some of which have quite distinctive morphologies, and may represent a single species. In this study, all fungi are assigned to form taxa. Taxa are grouped under the general categories - monocellate fungal spores, dicellate fungal spores, multicellate fungal spores, Fungal fruiting bodies and hyphae - rather than being classified under the so-called "Saccardoan System" for Fungi Imperfecti (Saccardo, 1899).

Acritarch genera will be listed alphabetically within the Group Acritarca (Evitt, 1963) as suggested by Mullins (2001).

Prasinophyte algae are a group of green algae. Their systematic position has been extensively discussed, but no agreement has been reached yet on their systematic position. Tappan (1980) has placed them in the Division Prasinophyta, but alternatively ranged them in the Division Chlorophyta within the Class Prasinophyceae. This latter approach has been adopted in this study.

## 6.1 Taxonomy of dinoflagellate cysts

Phylum *Pyrrophyta* PASCHER 1914  
 Division *Dinoflagellata* (BÜTSCHLI 1885) FENSOME et al. 1993  
 Class *Dinophyceae* PASCHER 1914  
 Order *Gonyaulacales* TAYLOR 1980

Suborder *Cladopyxiineae* FENSOME et al. 1993  
 Family *Cladopyxiaceae* STEIN 1883

Genus *Enneadocysta* STOVER & WILLIAMS 1995

1995: *Enneadocysta* n. gen.- STOVER & WILLIAMS 1995: 108-109.

Type species *Enneadocysta pectiniformis*.- (GERLACH 1961) STOVER & WILLIAMS 1995

*Enneadocysta arcuatum* EATON 1971  
 (Pl. 1/Fig.1; Pl. 2/Fig. 7)

1971: *Areosphaeridium arcuatum* n. sp.- EATON 1971: 360-361: Pl. 3/ 1-3, 5-9.  
 1995: *Enneadocysta arcuatum* comb. nov.- STOVER & WILLIAMS 1995: 109.  
 1980: *Areosphaeridium arcuatum*.- BUJAK, ET AL 1980: Pl. 2/6.  
 1981: *Areosphaeridium arcuatum*.- JAIN & TANDON 1981: Pl. 2/23-24.  
 1984: *Areosphaeridium arcuatum*.- HELENES 1984: Pl. 5/5-6.  
 1990: *Areosphaeridium arcuatum*.- KÖTHE 1990: Pl. 19/8,10.  
 1992: *Areosphaeridium arcuatum*.- POWELL 1992: Pl. 4.7/1.

Description: See STOVER & WILLIAMS (1995:109)

Dimensions: Ø central body=17-36 µm, Length of processes= 18-20 µm (n=3)

Stratigraphic range:

Upper Eocene- Lower Oligocene, NW Germany (Köthe, 1990)  
 Middle Eocene-Lower Oligocene, Norwegian Sea (Manum et al., 1989)  
 Middle Eocene, South England (Islam, 1983)  
 Middle-Upper Eocene, England (Bujak, et al., 1980)  
 Middle Eocene-Lower Oligocene, North France (Châteauneuf, 1979)  
 Lower Oligocene (Stover, 1977)  
 Middle Eocene, offshore East Canada (Williams & Brideaux, 1975)  
 Middle-Upper Eocene, England (Eaton, 1971, 1976)

*Enneadocysta pectiniformis* (GERLACH 1961) STOVER & WILLIAMS 1995  
 (Pl.1/Fig.1, 2; Pl. 2/Fig. 7)

1961: *Baltisphaeridium pectiniforme* n. sp.- GERLACH 1961: 195: Pl. 28/14.  
 1969: *Cleistosphaeridium pectiniforme* comb. nov.- DAVEY & DOWNIE in DAVEY et al. 1966: 170.  
 1971: *Areosphaeridium multicornutum* n. sp.- EATON 1971: 363-364: Pl. 4/1-7.  
 1972: *Cleistosphaeridium pectiniforme*.- BENEDEK 1972: 33: Pl. 10/5.  
 1978: *Areosphaeridium pectiniforme* comb. nov.- STOVER & EVITT 1978: 20.  
 1984: *Areosphaeridium pectiniforme* emend.- SARJEANT 1984: 83-84.  
 1990: *Areosphaeridium pectiniforme*.- KÖTHE 1990: Pl. 21/6a-b.  
 1993: *Areosphaeridium pectiniforme*.- STOVER & HARDENBOL 1993: Pl. 1/1a-2b.  
 1995: *Enneadocysta pectiniformis* comb. nov.- STOVER & WILLIAMS 1995: 114.  
 1997: *Areosphaeridium pectiniforme*.- PROSS 1997: 84: Pl. 1/7-8.

Description: See SARJEANT (1984: 83-85)

Dimensions: Ø central body=16-38 µm, Length of processes= 18-20 µm (n=5)

Stratigraphic range:

Upper Eocene, Egypt (El-Beialy, 1988b)  
 Upper Eocene, South England (Bujak et al., 1980)  
 Upper Eocene, England (Eaton, 1971, 1976)  
 Middle Oligocene, West Germany (Benedek, 1972)  
 Middle Oligocene, West Germany (Gerlach, 1961)

Suborder **Gonyaulacaceae** FENSOME et al. 1993 (AUTONYM)  
 Family **Gonyaulacaceae** LINDEMANN 1928  
 Subfamily **Leptodinioideae** FENSOME et al. 1993

**Genus *Oligosphaeridium* DAVEY & WILLIAMS 1966b emend. DAVEY 1982b**

1966: *Oligosphaeridium* n. gen.- DAVEY & WILLIAMS 1966b: 70-71.  
 1982: *Oligosphaeridium* emend.- DAVEY 1982b: 13.  
 Type species *Oligosphaeridium complex* (WHITE 1842) DAVEY & WILLIAMS 1966b

***Oligosphaeridium complex* (WHITE 1842) DAVEY & WILLIAMS 1966b emend.  
 DAVEY & WILLIAMS 1966b  
 (Pl. 2/Fig. 1)**

1842: *Xanthidium tubiferum complex* n. sp.- WHITE 1842: 39, Pl. 4/11.  
 1959: *Oligosphaeridium complex*.- GOCHT 1959: 66-67, Pl. 3/2-3, 7/5-6.  
 1966: *Oligosphaeridium complex* comb. nov. emend.- DAVEY & WILLIAMS 1966b: 71-74, Pl. 7/1-2, 10/3.  
 1975: *Oligosphaeridium complex* .- DRUGG & STOVER 1975: Pl. 5/11.  
 1978: *Oligosphaeridium complex*.- WILLIAMS 1978: 797, Pl. 5/7,10-11.  
 1985: *Oligosphaeridium complex*.- WILLIAMS & BUJAK 1985: Pl. 34/14.  
 1988: *Oligosphaeridium complex*.- SARKAR & SINGH 1988: Pl. 3/20.  
 1990: *Oligosphaeridium complex*.- KÖTHE 1990: Pl. 5/4.  
 1997: *Oligosphaeridium complex*.- PROSS 1997: 84.

Diagnosis: See DAVEY & WILLIAMS (1966b:71-74)

Dimensions: Ø central body= 30-48 µm, Length processes= 25-30 µm (n= 3)

Stratigraphic range:

Late Barremian-Middle Eocene, Venezuela (CORPOVEN, 1994)  
 Turonian-Coniacian, Colombia (Prössl, 1992)  
 Upper Paleocene-Upper Eocene, NW Germany (Köthe, 1990)  
 Eocene, North India (Sarkar & Singh, 1988)  
 Upper Berriasian-Middle Eocene, General (Williams & Bujak, 1985)  
 Valanginian-Cenomanian, offshore North West Africa (Williams, 1978)  
 Lower Paleocene-Lower Eocene, General (Drugg & Stover, 1975)  
 Barremian-Cenomanian, Lower Eocene, England (Davey & Williams, 1966b)

**Genus *Systematosphora* KLEMENT 1960 emend. BRENNER 1988  
 emend. STANCLIFFE & SARJEANT 1990**

1960: *Systematosphora* n. gen.- KLEMENT 1960: 61-62.  
 1988: *Systematosphora* KLEMENT 1960 emend.- BRENNER 1980: 83.  
 1990: *Systematosphora* KLEMENT 1960 emend.- STANCLIFFE & SARJEANT 1990: 207-208.

Type species *Systematosphora areolata* KLEMENT 1960

***Systematosphora ? varibilis* (COOKSON & EISENACK 1967a) STOVER & EVITT 1978  
 (Pl.1/Fig. 4,5)**

1967: *Cyclonephelium variabile* n. sp.- COOKSON & EISENACK 1967a: 134-135: Pl. 19/ 9-11.  
 1978: *Systematosphora ? varibilis*.- STOVER & EVITT 1978: 84.

Diagnosis: See EISENACK & KJELLSTRÖM (1972: 330a)

Dimensions: Ø central body= 70-75 µm, Length of processes= 25-30 µm (n= 3)

Stratigraphic range:

Paleocene, West Tasmania (Cookson & Eisenack, 1967)

**Subfamily *Cribroperidinioideae* FENSOME et al., 1993**

**Genus *Achilleodinium* EATON 1976**

1976: *Achilleodinium* n. gen.- EATON 1976: 234.

Type species *Achilleodinium biformoides* (EISENACK 1954b) EATON 1976

***Achilleodinium biformoides*** (EISENACK 1954b) EATON 1976  
(Pl. 1/ Fig. 3,6)

1954: *Hystrichokolpoma biformoides* n. sp.- EISENACK 1954b: 68, Pl. 16-20.  
1965: *Hystrichokolpoma biformoides* comb. nov.- EISENACK 1965: 3-4, Pl. 1/2.  
1966: *Hystrichokolpoma biformoides*.- MORGENROTH 1966a: 28, Pl. 6/9-10.  
1972: *Hystrichokolpoma cinctum*.- BENEDEK 1972: 28, Pl. 9/7a-b.  
1976: *Achilleodinium biformoides* comb. nov.- EATON 1976: 234-236, Pl. 1/1-6.  
1988: *Achilleodinium biformoides*.- WILSON 1988: 13, Pl. 1/1.  
1988: *Achilleodinium biformoides* .- JAN DU CHÊNE: 152, Pl. 6/3.  
1990: *Achilleodinium biformoides*.- KÖTHE 1990: Pl. 23/11-12.  
1997: *Achilleodinium biformoides*.- PROSS 1997: 85, Pl. 1/5-6.

Diagnosis: See EATON (1976:234-236)

Dimensions: LxB central body= 44x38 µm, L. antapical processes= 22 µm, L. processes= 18µm (n= 5)

Stratigraphic range:

Lower Eocene-Upper Oligocene, North West Germany (Köthe, 1990)  
Danian., Senegal (Jan du Chêne, 1988)  
Lower Miocener, North Egypt (El-Beialy, 1988a)  
Middle Eocene, North India (Mathur, 1986)  
Eocene, North California (Damassa, 1984)  
Middle Eocene, Mexico (Helenes, 1984)  
Lower-Upper Eocene, South England (Bujak et al., 1980)  
Upper Paleocene-Upper Eocene, offshore East Canada (Williams & Bujak, 1977a)  
Middle-Upper Oligocene, North Germany (Benedek, 1972)

Genus ***Araneosphaera*** EATON 1976

***Araneosphaera consociata*** JAIN & TANDON 1976  
(Pl. 1/ Fig. 10)

1976: *Araneosphaera consociata* n. sp.- JAIN & TANDON 1976: 7-8: Pl. 2/36-37; 3/47.

Diagnosis: See JAIN & TANDON (1976: 7-8)

Dimensions: LxB overall= 100x80 µm, Ø central body= 60 µm, Length of processes= 25 µm (n= 8)

Stratigraphic range:

Middle Eocene, West India (Jain & Tandon, 1981)

Genus ***Cordosphaeridium*** EISENACK 1963b emend. MORGENROTH 1968 emend. DAVEY 1969c  
emend. HE CHENGQUAN 1991

1963: *Cordosphaeridium* n. gen.- EISENACK 1963b: 261.  
1968: *Cordosphaeridium* EISENACK 1963b emend.- MORGENROTH 1968: 548-549.  
1969: *Cordosphaeridium* EISENACK 1963b emend.- DAVEY 1969C: 35.  
1991: *Cordosphaeridium* EISENACK 1963b emend.- HE CHENGQUAN 1991: 157-158.

Type species *Cordosphaeridium inodes* (KLUMP 1953) EISENACK 1963b emend. MORGENROTH 1968 emend. SARJEANT 1981

***Cordosphaeridium cantharellum*** (BROSIUS 1963) GOCHT 1969  
(Pl.1/ Fig.7,8,9)

1963: *Hystrichosphaeridium cantharellum* n. sp.- BROSIUS 1963: 41, Pl. 6/1.  
1969: *Cordosphaeridium cantharellum* comb. nov.- GOCHT 1969: Pl. 5/11-13, 6/10-11.  
1972: *Cordosphaeridium cantharellum*.- BENEDEK 1972: 26, Pl. 8/6.  
1975: *Cordosphaeridium cantharellum*.- DRUGG & STOVER 1975: Pl. 1/4.  
1980: *Cordosphaeridium cantharellum*.- CHÂTEAUNEUF 1980: 134, Pl. 20/6.  
1990: *Cordosphaeridium cantharellum*.- KÖTHE 1990: Pl. 24/4; 25/9.  
1988: *Cordosphaeridium cantharellum* .- BIFFI & MANUM: Pl. 105/14.  
1997: *Cordosphaeridium cantharellum*.- PROSS: 87, Pl. 15/3.

Diagnosis: See GOCHT (1969:45-46)

Dimensions: Ø overall= 45 µm, Length of processes= 25 µm (n= 2)

Stratigraphic range:

Upper Eocene-Upper Oligocene, North West Germany (Köthe, 1990)

Upper Oligocene-Lower Miocene, Italy (Biffi & Manum, 1988)

Lower Oligocene-Lower Miocene, Egypt (El-Beialy, 1988a)

Upper Eocene, South England (Bujak et al., 1980)

Upper Eocene-Lower Miocene, offshore East Canada (Williams & Bujak, 1977a)

Upper Middle Eocene-basal Miocene, General (Drugg & Stover, 1975)

Middle-Upper Oligocene, West Germany (Benedek, 1972)

Middle Oligocene, North West Germany (Gocht, 1969)

***Cordosphaeridium cf. gracile*** (EISENACK 1954) DAVEY & WILLIAMS 1966b  
(Pl.1/Fig.11)

1954: *Hystriochosphaeridium inodes subsp. gracile* n. subsp.- EISENACK 1954: 66-67, Pl. 8/17, 10/3-8, 12/7,21.

1963: *Cordosphaeridium inodes gracile* comb. nov.- EISENACK 1963b: 261, Pl. 29/2.

1966: *Cordosphaeridium inodes gracile*.- MORGENROTH 1966a: 23-24, Pl. 5/2-3.

1966: *Cordosphaeridium gracile* stat. nov.- DAVEY & WILLIAMS 1966b: 84-86, Pl. 3/8, 11/4, 6-7.

1969: *Cordosphaeridium inodes gracile*.- GOCHT 1969: 41-42, Pl. 1/1-9, 15.

1972: *Cordosphaeridium inodes gracile*.- BENEDEK 1972: 25, Pl. 7/11.

1990: *Cordosphaeridium gracile*.- KÖTHE 1990: Pl. 13/2-5.

1997: *Cordosphaeridium gracile* .- PROSS 1997: 87.

Diagnosis: See GOCHT (1969:41-42)

Dimensions: Ø overall= 90 µm, Length of processes= 38 µm (n= 1)

Stratigraphic range:

Upper Paleocene-Upper Eocene/Oligocene, North West Germany (Köthe, 1990)

Lower Eocene, New Zealand (Wilson, 1988)

Lower-Upper Eocene, South England (Bujak et al., 1980)

Middle-Upper Eocene, offshore North West Africa (Williams, 1978)

Upper Maastrichtian-Upper Eocene, offshore East Canada (Williams & Bujak, 1977a)

Middle-Upper Oligocene, Germany (Benedek, 1972)

Lower-Upper Eocene, North Germany (Gocht, 1969)

Lower Eocene, England (Davey & Williams, 1966b)

Lower Eocene, North Germany (Morgenroth, 1966b)

***Cordosphaeridium inodes*** (KLUMPP 1953) EISENACK 1963b emend. MORGENROTH 1968 emend.  
SARJEANT 1981  
(Pl. 2/Fig. 6)

1953: *Hystriochosphaeridium inodes* n. sp.- KLUMPP 1953: 391-392:Pl. 18/1-2.

1963: *Cordosphaeridium inodes* comb. nov.- EISENACK 1963b: 261.

1968: *Cordosphaeridium inodes* emend.- MORGENROTH 1968: 549-550:Pl. 4/9; 46/1-8.

1969: *Cordosphaeridium inodes inodes*.- GOCHT 1969: 41: Pl. 1/11-12; 4/14.

1972: *Cordosphaeridium inodes inodes*.- BENEDEK 1972: 25: Pl. 7/10.

1981: *Cordosphaeridium inodes* emend.- SARJEANT 1981: 102-105.

1984: *Cordosphaeridium inodes*.- JAN DU CHÊNE & ADEDIRAN 1984: 12: Pl. 12/5,7.

1988: *Cordosphaeridium inodes*.- SARKAR & SINGH 1988: 39-40: Pl. 1/14.

1990: *Cordosphaeridium inodes*.- KÖTHE 1990: Pl. 9/8,10.

1997: *Cordosphaeridium inodes*.- PROSS 1997: 87: Pl. 15/2.

Description: See SARJEANT (1981: 102-105)

Dimensions: Ø overall= 49-55 µm, Length of processes= 27-30 µm (n= 6)

Stratigraphic range:

Upper Paleocene-Upper Oligocene, North West Germany (Köthe, 1990)

Eocene, North India (Sarkar & Singh, 1988)

Oligocene-Lower Miocene, North East India (Saxena, Rao & Singh, 1987)

Upper Paleocene-Lower Eocene, South West Nigeria (Jan du Chêne & Adedirán, 1984)

Lower-Upper Eocene, South England (Bujak et al., 1980)

Lower Paleocene-Upper Oligocene, General (Drugg & Stover, 1975)

Middle-Upper Oligocene, West Germany (Benedek, 1972)

Lower-Upper Eocene, North West Germany (Gocht, 1969)

Upper Paleocene, West Australia (Cookson & Eisenack, 1967a)

Lower Eocene, Belgium (Davey & Williams, 1966b)

Middle-Upper Eocene, North Germany (Klumpff, 1953)

**Genus *Diphyes* COOKSON 1965a emend. DAVEY & WILLIAMS 1966b emend. GOODMAN & WITMER 1985**

1965: *Diphyes* n. gen.- COOKSON 1965a: 85.

1966: *Diphyes* COOKSON 1965a emend. DAVEY & WILLIAMS 1966b: 95-96.

1985: *Diphyes* COOKSON 1965a emend. – GOODMAN & WITMER 1985: 76.

Type species *Diphyes colligerum* (DEFLANDRE & COOKSON 1955) COOKSON 1965a emend. GOODMAN & WITMER 1985

***Diphyes* cf. *appendiculare* (COOKSON & EISENACK 1970a)  
(Pl. 2/ Fig. 2)**

1970: *Diphyes appendiculare* n. sp.- COOKSON & EISENACK 1970: 149, pl. 13/5.

1990: *Diphyes* sp. cf. *appendiculare*.- KÖTHE 1990: Pl. 4/6.

Diagnosis: See COOKSON & EISENACK (1970: 149)

Dimensions: Ø central body= 38-40 µm , Length of processes= 14-16 µm, L. antapical processe= 12 µm (n= 6)

Remarks: Cyst skolochorate, subspherical, with numerous nontabular, similar, long, hollow, fibriliar processes with expanded bases and a single larger antapical process. Endophragm and periphragm visible beneath and near bases of processes. Archeopyle apical.

Stratigraphic range:

Upper Paleocene-Lower Eocene (Köthe, 1990)

Lower Maastrichtian, Spain (Ashraf & Erben, 1986)

Senonian, West Australia (Cookson & Eisenack 1970)

***Diphyes colligerum* (DEFLANDRE & COOKSON 1955) COOKSON 1965a emend. GOODMAN & WITMER 1985  
(Pl. 2/ Fig. 5)**

1955: *Hystrochospaeridium colligerum* n. sp.- DEFLANDRE & COOKSON 1955: 178, Pl. 7/3.

1965: *Diphyes colligerum* comb. nov.- COOKSON 1965: 86, Pl. 9/1-12.

1966: *Diphyes colligerum* emend.- DAVEY & WILLIAMS 1966b: 96, Pl. 4/2-3.

1966: *Hystrochospaeridium colligerum* .- MORGENROTH 1966a: 29-30, Pl. 8/1-2.

1980: *Diphyes colligerum*.- BUJAK et al. 1980: Pl. 6/7-8.

1990: *Diphyes colligerum*.- KÖTHE 1990: Pl. 18/5.

1997: *Diphyes colligerum*.- PROSS 1997: 89.

Diagnosis: See DAVEY & WILLIAMS (1966b: 96)

Dimensions: Ø overall= 50-60 µm, Ø central body= 30-32 µm, L. antapical process= 10-13 µm (n= 8)

Stratigraphic range:

Lower Eocene (P-6)-Upper Eocene (P-17), Venezuela CORPOVEN, 1994

Lower Eocene-Lower Oligocene, North West Germany (Köthe, 1990)

Middle Eocene- Middle Miocene (Köthe, Khan & Ashraf, 1988)

Lower Eocene-Lower Oligocene, General (Williams & Bujak, 1985)

Maastrichtian., Mexico (Helenes, 1984)

Lower-Upper Eocene, South England (Bujak et al., 1980)

Middle-Upper Eocene, North France (Châteauneuf, 1980)

Middle Eocene-Upper Oligocene, offshore East Canada (Williams & Bujak, 1977a)

Lower Eocene, South England (Davey & Williams, 1966b)

Upper Eocene, Australia (Cookson, 1965)

***Diphyes spinulum* (DRUGG 1970b) STOVER & EVITT 1978  
(Pl. 3/ Fig. 3,4)**

1970: *Lingulaphaera spinula* n. sp.- DRUGG 1970b: 817-818, figs.10G,11D-E,12A-B.

1978: *Diphyes spinulum* comb. nov.- STOVER & EVITT 1978: 39.

1984: *Diphyes spinulum*.- JAN DU CHÊNE & ADEDIRAN 1984: Pl. 13/2; 14/5-7.

1988: *Diphyes spinulum*.- JAN DU CHÊNE 1988: 154-155: Pl. 5/9-10, 13-15; Pl. 27/4-5.

1990: *Diphyes spinulum*.- KÖTHE 1990: Pl. 4/7.

Diagnosis: See Eisenack & Kjellström (1972: 776b) & JAN DU CHÊNE (1988: 154-155)

Dimensions: Ø central body= 32-44 µm, L. processes= 12-20 µm, L. antapical process= 15-22 µm (n= 10)

Stratigraphic range:

Upper Paleocene.-Lower Eocene, North West Germany (Köthe, 1990)  
Danian, Senegal (Jan du Chêne, 1988)  
Paleocene-Lower Eocene, South West Nigeria (Jan du Chêne & Adediran, 1984)  
Upper Paleocene-Lower Eocene, Pakistan (Köthe, Khan & Ashraf, 1988)  
Lower Eocene, Gulf Coast US (Drugg, 1970)

Genus *Hystrichokolpoma* KLUMPP 1953 emend. WILLIAMS & DOWNIE 1966a

1953: *Hystrichokolpoma* n. gen.- KLUMPP 1953: 388.

1966: *Hystrichokolpoma* KLUMPP 1953 emend.- WILLIAMS & DOWNIE 1966a: 176.

Type species *Hystrichokolpoma cinctum* KLUMPP 1953

*Hystrichokolpoma* cf. *denticulata* MATSUOKA 1974  
(Pl. 2/Fig. 8)

1974: *Hystrichokolpoma denticulatum* n. sp.- MATSUOKA 1974: 330-331: Pl. 44/3-5.

1986: *Hystrichokolpoma denticulata*.- WRENN & KOKINOS 1986: Pl. 8/1-2.

Diagnosis: See MATSUOKA (1974: 330-331)

Dimensions: Ø central body= 40 µm, Length of processes= 16-20 µm (n= 5)

Remarks: Cysts skolochorate, subspherical body with granular surface. Processes are cylindrical to tubiform in shape, large, hollow and smooth with denticulate distal termination. Archeopyle apical.

Stratigraphic range:

Lower-Middle Miocene, Central Japan (Matsuoka, 1974)  
Middle/Upper Miocene-Pleistocene, Gulf of Mexico (Wrenn & Kokinos, 1986)

*Hystrichokolpoma elliptica* MATSUOKA 1974  
(Pl. 3/Fig. 1)

1974: *Hystrichokolpoma ellipticum* n. sp.- MATSUOKA 1974: 330: Pl. 44/2.

Diagnosis: See MATSUOKA (1974: 330)

Dimensions: LxB central body= 40-45 x 45-48 µm, Length of processes= 16-20 µm (n= 4)

Stratigraphic range:

Lower-Middle Miocene, Japan (Matsuoka, 1974)

*Hystrichokolpoma rigaudae* DEFLANDRE & COOKSON 1955  
(Pl. 3/Fig. 2)

1954: *Hystrichokolpoma rigaudae*.- DEFLANDRE & COOKSON 1954.

1955: *Hystrichokolpoma rigaudae* n. sp.- DEFLANDRE & COOKSON 1955: 279, Pl. 6/6-10.

1972: *Hystrichokolpoma rigaudae*.- BENEDEK 1972: 28-29, Pl. 8/9.

1980: *Hystrichokolpoma rigaudae*.- CHÂTEAUNEUF 1980: 141, Pl. 25/2.

1984: *Hystrichokolpoma rigaudae*.- JAN DU CHÊNE & ADEDIRAN 1984: 18: pl. 16/1-7.

1988: *Hystrichokolpoma rigaudae*.- BIFFI & MANUM 1988: Pl. 5/9.

1988: *Hystrichokolpoma rigaudae*.- JAN DU CHÊNE 1988: Pl. 6/9-10.

1990: *Hystrichokolpoma rigaudae*.- KÖTHE 1990: Pl. 13/6; 15/11.

1992: *Hystrichokolpoma rigaudae*.- BRINKHUIS, POWELL & ZEVENBOOM 1992: Pl. 8/5.

1997: *Hystrichokolpoma rigaudae*.- PROSS 1997: 90: Pl. 2/11-12

Diagnosis: See BENEDEK (1972: 28-29)

Dimensions: LxB overall= 50x45 µm, LxB central body= 35x 42 µm (n= 4)

Remarks: This species is characterized by an antapical process with a distinct and somewhat point-like termination which is larger than the other process.

Stratigraphic range:

Upper Oligocene-Lower Miocene Italy (Brinkhuis, Powell & Zevenboom, 1992)  
Lower Eocene, South West Nigeria (Oloto, 1992)  
Upper Paleocene-Upper Oligocene, North West Germany (Köthe, 1990)  
Oligocene-Lower Miocene, Italy (Biffi & Manum, 1988)

Upper Eocene-Lower Oligocene, Egypt (El-Bassiouni et al., 1988)  
 Danian, Senegal (Jan du Chêne, 1988)  
 Lower Eocene-Lower Pleistocene, General (Williams & Bujak, 1985)  
 Upper Paleocene.-Lower Eocene, South West Nigeria (Jan du Chêne & Adediran, 1984)  
 Eocene-Lower Oligocene, North France (Châteauneuf, 1980)

***Hystrichokolpoma salacium* EATON 1976**  
 (Pl. 3/Fig. 4)

1976: *Hystrichokolpoma salacium* n. sp.- EATON 1976: 271-272, pl. 11/1-3.  
 1986: *Hystrichokolpoma salacium*.- DE CONINCK 1986b: 14: Pl. 4/2-4, 6.  
 1988: *Hystrichokolpoma salacium*.- SARKAR & SINGH 1988: 47-48, Pl. 3/12.  
 1997: *Hystrichokolpoma salacium*.- PROSS 1997: 90, Pl. 2/5-6, 10.

Diagnosis: See EATON (1976: 271-272)

Dimensions: LxB central body= 50-52 x 46-48  $\mu\text{m}$ , L. antapical processes= 26-30  $\mu\text{m}$  (n= 5)

Stratigraphic range:

Middle Eocene, Somalia (Prössl, 1992b)  
 Eocene, North India (Sarkar & Singh, 1988)  
 Upper Eocene, South Netherlands (de Coninck, 1986b)  
 Lower Eocene-Upper Eocene, South England (Bujak et al., 1980)  
 Eocene, North India (Khanna, 1978)

***Hystrichokolpoma cf. unispinum* WILLIAMS & DOWNIE 1966a**  
 (Pl. 3/Fig. 5)

1966: *Hystrichokolpoma unispinum*.- WILLIAMS & DOWNIE 1966a: 179-180: Pl. 17/6-7.  
 1980: *Hystrichokolpoma unispinum*.- BUJAK et al. 1980: Pl. 3/1-3.  
 1981: *Hystrichokolpoma unispinum*.- JAIN & TANDON 1981: Pl. 4/65.  
 1998: *Hystrichokolpoma unispinum*.- DE CONINCK 1999a: Pl. 2/13, 3/7-9

Diagnosis: See WILLIAMS & DOWNIE (1966a: 179-180)

Remarks: Cyst skolochorate, subspherical, with large, hollow and cylindrical processes. Endophragm and periphragm smooth. Small processes in cingulum. Archeopyle apical

Dimensions: LxB central body= 25-28 x 38-40  $\mu\text{m}$ , Length processes= 15-18  $\mu\text{m}$  (n= 4)

Stratigraphic range:

Upper Eocene, Egypt (El-Bassiouni et al., 1988)  
 Middle Eocene, India (Jain & Tandon, 1981)  
 Lower Eocene, South England (Bujak et al., 1980)  
 Lower-Upper Eocene, North East India (Dutta & Jain, 1980)  
 Lower Eocene, offshore North West Africa (Williams, 1978)  
 Lower Eocene, offshore East Canada (Williams & Brideaux, 1975)  
 Lower Eocene, Belgium (de Coninck, 1972)  
 Lower Eocene, England (Williams & Downie, 1966a)

***Hystrichokolpoma sp. A***  
 (Pl. 3/Fig. 3)

Remarks: Cyst skolochorate, with a ellipsoidal body. Endophragm distinct, only process bases with periphragm. Processes are tubiform, hollow, slightly striate, distal termination subdivided by short tubules. Antapical process distinctly longer and bulbous shape with gradually tapering termination. Archeopyle apical with attached operculum. This species has some imilarity with the species described by JAN DU CHÊNE & ADEDIRAN (1985: 18, Pl. 16/8-12) as *Hystrichokolpoma ? fenestratum*.

Dimensions: LxB overall= 50-46 x 48-45  $\mu\text{m}$ , Length of processes= 15-18  $\mu\text{m}$ , L. antapical process= 25-30  $\mu\text{m}$  (n= 3)

Genus ***Lingulodinium* WALL 1967 emend. WALL & DALE in WALL et al. 1973 emend. DODGE 1989**

1967: *Lingulodinium* n. gen.- WALL 1967: 109.  
 1973: *Lingulodinium* WALL 1967 emend.- WALL & DALE in WALL et al. 1973: 23-24.  
 1989: *Lingulodinium* WALL 1967 emend.- DODGE 1989: 291.

Type species *Lingulodinium machaerophorum* (DEFLANDRE & COOKSON 1955) WALL 1967



***Lingulodinium polyedrum*** (DEFLANDRE & COOKSON 1955) WALL 1967  
(Pl. 3/Fig. 6,7,10)

- 1955: *Hystrichosphaeridium machaerophorum* n. sp.- DEFLANDRE & COOKSON 1955: 274, Pl. 9/4,8.  
1961: *Baltisphaeridium machaerophorum* comb. nov.- GERLACH 1961: 191-192, Pl. 28/11.  
1967: *Lingulodinium machaerophorum* comb. nov.- WALL 1967: 109, Pl. 15/16-17.  
1972: *Lingulodinium machaerophorum*.- BENEDEK 1972: 49-50, Pl. 11/10a-b.  
1975: *Lingulodinium machaerophorum*.- DRUGG & STOVER 1975: Pl. 4/7.  
1986: *Lingulodinium machaerophorum*.- BUJAK & MATSUOKA 1986b: 2/13  
1986: *Lingulodinium machaerophorum*.- WRENN & KOKINOS 1986: Pl. 8/3,6.  
1988: *Lingulodinium machaerophorum*.- BIFFI & MANUM 1988: Pl. 14/9.  
1988: *Lingulodinium machaerophorum*.- SAKAR & SINGH 1988: 48, Pl. 3/11.  
1989: *Lingulodinium machaerophorum*.- EDWARDS 1989: Pl. 2/11.  
1997: *Lingulodinium machaerophorum*.- PROSS 1997: 91, Pl. 3/3.

Diagnosis: See EISENACK & KJELLSTRÖM (1972: 775)

Dimensions: Ø central body= 48-50 µm, Length of processes= 12-14 µm (n= 12)

Stratigraphic range:

- Upper Paleocene-Lower Miocene, Virginia (Edwards, 1989)  
Oligocene-Lower Miocene, Central Italy (Biffi & Manum, 1988)  
Eocene, North India (Sarkar & Singh, 1988)  
Middle Eocene, Egypt (El-Beialy, 1988c)  
Miocene-Upper Pleistocene, West & North Pacific (Bujak & Matsuoka, 1986)  
Miocene-Pleistocene, Gulf of Mexico (Wrenn & Kokinos, 1986)  
Lower Eocene-Upper Pleistocene, General (Williams & Bujak, 1985)  
Lower-Upper Eocene, South England (Bujak et al., 1980)  
Middle-Upper Oligocene, North Germany (Benedek, 1972)  
Upper- Middle Eocene-Holocene, General (Drugg & Stover, 1975)  
Eocene-Upper Miocene, offshore South East Canada (Williams, 1975)  
Pleistocene, Caribbean (Wall, 1967)

***Lingulodinium pycnospinosum*** (BENEDEK 1972) STOVER & EVITT 1978 emend. BENEDEK & SARJEANT 1981  
(Pl. 3/Fig. 8,9)

- 1972: *Impletosphaeridium pycnospinosum* n. sp.- BENEDEK 1972: 32, Pl. 12/14.  
1978: *Lingulodinium? pycnospinosum* .- STOVER & EVITT 1978: 172.  
1981: *Lingulodinium pycnospinosum* .- emend BENEDEK & SARJEANT 1981: 343-344, Pl. 10/1.  
1988: *Lingulodinium pycnospinosum*.- BIFFI & MANUM 1988: Pl. 10/14.

Diagnosis: See BENEDEK (1972: 32)

Dimensions: Ø central body= 48-52 µm, Length processes= 14-18 µm (n= 4)

Stratigraphic range:

- Middle-Upper Oligocene, West Germany (Benedek, 1972)  
Oligocene-Lower Miocene, Central Italy (Biffi & Manum, 1988)

**Genus *Operculodinium* WALL 1967 emend. MATSUOKA et al. 1997**

- 1967: *Operculodinium* n. gen.- WALL 1967: 110-111.  
1997: *Operculodinium* emend.- MATSUOKA et al. 1997: 22.

Type species *Operculodinium centrocarpum* (DEFLANDRE & COOKSON 1955) WALL 1967

***Operculodinium centrocarpum*** (DEFLANDRE & COOKSON 1955) WALL 1967  
(Pl. 3/Fig. 11, 12)

- 1955: *Hystrichosphaeridium centrocarpum* n. sp.- DEFLANDRE & COOKSON 1955: 272-273, Pl. 8/3-4.  
1961: *Baltisphaeridium centrocarpum* comb. nov.- GERLACH 1961: 192-193, Pl. 28/9.  
1967: *Operculodinium centrocarpum* comb. nov.- WALL 1967: 111, Pl. 16/1-2, 5.  
1986: *Operculodinium centrocarpum*.- WRENN & KOKINOS 1986: Pl. 8/5,8.  
1986: *Operculodinium centrocarpum*.- BUJAK & MATSUOKA 1986: Pl. 2/15.  
1988: *Operculodinium centrocarpum*.- SARKAR & SINGH 1988: 50, Pl. 2/16; 3/7-8.  
1988: *Operculodinium centrocarpum*.- KÖTHE, KHAN & ASHRAF 1988: Pl. 17/10.  
1988: *Operculodinium centrocarpum*.- JAN DU CHÈNE 1988: 162-163: Pl. 8/5-14.  
1997: *Operculodinium centrocarpum*.- MATSUOKA, McMINN & WRENN 1997: 22-24, Pl. 1/1-6; Pl. 2/1-9.  
1997: *Operculodinium centrocarpum*.- PROSS 1997: 92: Pl.3/5-6.

Diagnosis: See MATSUOKA et. al (1997: 22-24)

Dimensions: Ø central body= 48-50 µm, Length of processes= 10-12 µm (n= 3)

Stratigraphic range:

Oligocene-Holocene, Venezuela (CORPOVEN, 1994)

Upper Eocene, Pakistan (Köthe, Khan & Ashraf, 1988)

Eocene, North India (Sarkar & Singh, 1988)

Danian, Senegal (Jan du Chêne, 1988)

Lower Miocene-Holocene, West North Pacific (Bujak & Matsuoka, 1986)

Middle/Upper Miocene-Pleistocene, Gulf of Mexico (Wrenn & Kokinos, 1986)

Lower Miocene, West India (Kar, 1985)

Lower-Upper Eocene, South England (Bujak et al., 1980)

Lower Paleocene-Pleistocene, offshore South East Canada; offshore Florida (Williams & Bujak, 1977a)

Lower Eocene.-Pleistocene, offshore West Africa (Williams, 1978)

Lower Eocene-Pleistocene, offshore East Canada (Williams & Brideaux, 1975)

***Operculodinium microtrainum* (KLUMPP 1953) ISLAM 1983a**  
(Pl. 4/Fig.1,2)

1953: *Hystrichosphaeridium microtriaina* n. sp.- KLUMPP 1953: 390:Pl. 17/6-7.

1963: *Cordosphaeridium microtriaina* (Klumpp).- EISENACK 1963: 263.

1979: *Polysphaeridium microtriaina* (Klumpp.- KAR 1979: 33: Pl. 4/63a-65.

1981: *Achomosphaera microtriaina* (Klumpp).- SARJEANT 1981: 110-112.

1983: *Operculodinium microtrainum* (Klumpp).- ISLAM 1983a: 241: Pl. 4/1.

1988: *Operculodinium microtrainum*.- RAUCHER & SCHULER 1988: Pl. 2/12.

1990: *Operculodinium microtrainum*.- KÖTHE 1990: Pl. 22/10,14.

Diagnosis: See KLUMPP (1953: 390)

Dimensions: Ø central body= 46-50 µm, Length of processes= 12-15 µm (n= 5)

Stratigraphic range:

Upper Eocene-Lower Oligocene, North West Germany (Köthe, 1990)

Lower Oligocene, North East France (Rauscher & Schuler, 1988)

Eocene, South England (Islam, 1983a)

Upper Paleocene, Morocco (Prössl, Lucas & Doubinger, 1979)

Oligocene, West India (Kar, 1979)

Upper Eocene, Germany (Klumpp, 1953)

**Genus *Turbiosphaera* ARCHANGELSKY, 1969a**

1969: *Turbiosphaera* n. gen.- Archangelsky 1969: 408.

Type species *Turbiosphaera filosa* (WILSON 1967a) ARCHANGELSKY 1969a

***Turbiosphaera filosa* (WILSON 1967a) ARCHANGELSKY 1969a**  
(Pl. 4/Fig. 3)

1967: *Cordosphaeridium filosum* n. sp.- WILSON 1967a : 66: Pl. 2b/31-32, 34.

1969: *Turbiosphaera filosa* n. comb.- ARCHANGELSKY 1969a : 408-411: Pl. 1/1-4.

1975: *Turbiosphaera filosa*.- DRUGG & STOVER 1975: Pl. 7/7.

1988: *Turbiosphaera filosa*.- WILSON 1988: 32: Pl. 23/3a-b-4a-b.

Diagnosis: See EISENACK & KJELLSTRÖM (1972: 255) & WILSON (1988: 32)

Dimensions: LxB overall= 70-90 x 65-78 µm, Length of processes= 20-28 µm (n= 4)

Stratigraphic range:

Paleocene-Lower Eocene, New Zealand (Wilson, 1988)

Lower Eocene, offshore North West Africa (Williams, 1978)

Upper Maastrichtian-Upper Paleocene, offshore East Canada (Williams & Bujak, 1977a)

Lower Paleocene-Lower Oligocene, General (Drugg & Stover, 1975)

Upper Maastrichtian-Paleocene, offshore East Canada (Williams, 1975)

Subfamily Gonyaulacoideae FENSOME et al. 1993 (AUTONYM)

Genus Achomosphaera EVITT 1963

1963: *Achomosphaera* n. gen.- EVITT 1963: 163

Type species *Achomosphaera ramulifera* (DEFLANDRE 1937b) EVITT 1963

***Achomosphaera cf. multifurcata* JAIN & TANDON 1981**  
(Pl. 4/Fig. 4)

1981: *Achomosphaera multifurcata* n. sp.- JAIN & TANDON 1981: 7: Pl. 1/10.

1990: *Achomosphaera multifurcata*.- KÖTHE, KHAN & ASHRAF, 1988: Pl. 14/2; Pl. 16/2.

Diagnosis: See JAIN & TANDON (1981: 7)

Dimensions: Ø central body= 42-44 µm, Length of processes= 14-18 µm (n= 4)

Remarks: Cysts skolochorate, subspherical body, with sutural processes in gonal and intergonal positions. Processes hollow bifurcate or trifurcate to the second order. Periphragm–endophragm separation visible beneath process bases, periphragm surface mikrosulptured. Archeopyle precingular.

Stratigraphic range:

Middle Eocene, West India (Jain & Tandon, 1981)

Upper Paleocene-Middle Eocene, Pakistan (Köthe, Khan & Ashraf, 1988)

Genus Hystrichostrogylon AGELOPOULOS 1964 emend. STOVER AND EVITT 1978

1964: *Hystrichostrogylon* n. gen.- AGELOPOULOS 1964: 673-674.

1978: *Hystrichostrogylon* emend.- STOVER & EVITT 1978: 164.

Type species *Hystrichostrogylon membraniphorum*.- AGELOPOULOS 1964 emend. STOVER & EVITT 1978

***Hystrichostrogylon membraniphorum* AGELOPOULOS 1964 emend.**  
**STOVER & EVITT 1978**  
(Pl. 4/Fig. 5)

1964: *Hystrichostrogylon membraniphora* n. sp.- AGELOPOULOS 1964: 674: Figs. 1-2.

1976: *Achomosphaera membraniphora* nov. comb. emend.- EATON 1976: 237.

1978: *Hystrichostrogylon membraniphorum* emend.- STOVER & EVITT 1978: 164.

1989: *Hystrichostrogylon membraniphorum*.- EDWARDS 1989: Pl. 4/6.

1984: *Hystrichostrogylon membraniphorum*.- HELENES 1984: Pl. 5/13-14.

1984: *Hystrichostrogylon membraniphorum*.- BUJAK 1984: 186: Pl. 2/2.

1990: *Hystrichostrogylon membraniphorum*.- KÖTHE 1990: Pl. 7/7; 11/7; 16/5.

Description: See AGELOPOULOS (1964: 674)

Dimensions: Ø central body= 38-45 µm, Length of processes= 20-26 µm, Height pericoel 10-18 µm (n= 2)

Stratigraphic range:

Upper Paleocene-Upper Eocene/basal Oligocene, North West Germany (Köthe, 1990)

Middle Eocene, Virginia (Edwards, 1989)

Lower-Middle Eocene, General (Williams & Bujak, 1985)

Lower Oligocene, offshore SW Africa (Bujak, 1984)

Middle Eocene, Mexico (Helenes, 1984)

Upper Lower-Lower Middle Miocene, Central Japan (Matsuoka, 1983)

Middle-Upper Eocene, South England (Bujak et al., 1980)

Upper Eocene, India (Dutta & Jain, 1980)

Middle-Upper Eocene, South England (Eaton, 1976)

Upper Eocene, Germany (Agelopoulos, 1964)

Genus Nemosphaeropsis DEFLANDRE & COOKSON 1955 emend. WILLIAMS & DOWNIE 1966c  
emend. WRENN 1988

1954: *Nemosphaeropsis*.- DEFLANDRE & COOKSON 1954: 1237.

1955: *Nemospharopsis* n. gen.- DEFLANDRE & COOKSON 1955: 268.

1966: *Nematosphaeropsis* DEFLANDRE & COOKSON 1955 emend.- WILLIAMS & DOWNIE 1966c: 222.  
 1988: *Nematosphaeropsis* DEFLANDRE & COOKSON 1955 emend.- WRENN 1988: 137.

Type species *Nematosphaeropsis balcombiana* DEFLANDRE & COOKSON 1955

***Nematosphaeropsis balcombiana* DEFLANDRE & COOKSON 1955**  
 (Pl. 4/Fig. 6)

1955: *Nematosphaeropsis balcombiana* n. sp.- DEFLANDRE & COOKSON 1955: 268-269: Pl. 8/5.  
 1988: *Nematosphaeropsis balcombiana*.- WRENN 1988: 139-140: Pl. 7/3.

Diagnosis: See WRENN (1988: 139-140)

Wrenn (1988) indicated that this species should be restricted to the type material, and that other reports of it probably represent other species.

Dimensions: LxB central body= 45-50 x 38-40  $\mu\text{m}$ , Length processes= 18-20  $\mu\text{m}$  (n= 8)

Stratigraphic range:

Lower Eocene, England (Williams, 1966)

Lower Eocene, England (Williams & Downie 1966c)

Middle Miocene, Australia (Deflandre & Cookson, 1955)

***Nematosphaeropsis reticulensis* (PASTIELS 1948) SARJEANT 1986 emend. SARJEANT 1986**  
 (Pl. 4/Fig. 7)

1948: *Cannosphaeropsis reticulensis* n. sp.- PASTIELS 1948: 49: Pl. 5/7-10.  
 1966: *Cannosphaeropsis reticulensis*.- MORGENROTH 1966a: 19: Pl. 4/2-3.  
 1969: *Adnatosphaeridium reticulense* comb. nov.- GOCHT 1969: 64: Pl. 8/13-14.  
 1972: *Adnatosphaeridium reticulense*.- BENEDEK 1972: 22: Pl. 4/10; 7/1.  
 1980: *Adnatosphaeridium reticulense*.- CHÂTEAUNEUF 1980: 132: Pl. 19/2.  
 1986: *Nematosphaeropsis reticulense* comb. nov. emend.- SARJEANT 1986: 9.  
 1988: *Adnatosphaeridium reticulense*.- BIFFI & MANUM 1988: Pl. 1/3.  
 1988: *Adnatosphaeridium reticulense*.- RAUCHER & SCHULER 1988: Pl. 2/1-2; 10-11.  
 1997: *Nematosphaeropsis reticulensis*.- PROSS 1997: 95: Pl. 10/5; Pl. 14/1.

Diagnosis: See SARJEANT (1986: 9-11) & GOCHT (1969: 64)

Dimensions:  $\emptyset$  overall= 65-70  $\mu\text{m}$ ,  $\emptyset$  central body= 32-36  $\mu\text{m}$ , Length of processes= 12-14  $\mu\text{m}$  (n= 4)

Stratigraphic range:

Upper Eocene-Lower Oligocene, Central Italy (Biffi & Manum, 1988)

Lower Oligocene, North East France (Rauscher & Schuler, 1988)

Middle Eocene-Lower Oligocene, North France (Châteauneuf, 1980)

Lower Eocene, offshore North West Africa (Williams, 1978)

Upper Paleocene-Upper Eocene, offshore East Canada (Williams & Bujak, 1977a)

Upper Paleocene-Middle Eocene, General (Drugg & Stover, 1975)

Middle-Upper Oligocene, West Germany (Benedek, 1972)

Lower Eocene, North West Germany (Gocht, 1969)

Genus ***Spiniferites* MANTELL 1850 emend. SARJEANT 1970**

1850: *Spiniferites* n. gen.- MANTELL 1850: 191.  
 1970: *Spiniferites* MANTELL 1850 emend.- SARJEANT 1970: 75.  
Type species *Spiniferites ramosus* (EHRENBERG 1838) MANTELL 1854

***Spiniferites bulloideus* (DEFLANDRE & COOKSON 1955) SARJEANT 1970**  
 (Pl. 4/Fig. 8)

1955: *Hystriosphera bulloidea* n. sp.- DEFLANDRE & COOKSON 1955: 264: Pl. 5/3-4.  
 1961: *Hystriosphera bulloidea*.- GERLACH 1961: 12: Pl. 6/7.  
 1970: *Spiniferites bulloideus* DEFLANDRE & COOKSON 1955 comb. nov.- SARJEANT 1970: 75.  
 1986: *Spiniferites bulloideus*.- BUJAK & MATSUOKA 1986: Pl. 2/11.

Diagnosis: See EISENACK & KJELLSTRÖM (1972: 533)

Dimensions:  $\emptyset$  central body= 24-26  $\mu\text{m}$ , Length of processes= 10-14  $\mu\text{m}$  (n= 6)

Stratigraphic range:

Upper Miocene-Upper Pleistocene, West North Pacific (Bujak & Matsuoka, 1986)

Middle Oligocene-Middle Miocene, North West Germany (Gerlach, 1961)

Eocene-Middle Miocene, Australia (Deflandre & Cookson, 1955)

***Spiniferites mirabilis*** (ROSSIGNOL) SARJEANT 1970  
(Pl. 4/Fig. 9)

1962: *Hystriosphera mirabilis* n. sp.- ROSSIGNOL 1962; p. 132.  
1963: *Hystriosphera mirabilis*.- ROSSIGNOL 1963: Pl. 2/16-21.  
1970: *Spiniferites mirabilis*.- SARJEANT 1970: 76.  
1975: *Spiniferites mirabilis*.- DRUGG & STOVER 1975: Pl. 6/10.  
1980: *Spiniferites mirabilis*.- BUJAK et al. 1980: Pl. 21/10.  
1986: *Spiniferites mirabilis*.- BUJAK & MATSUOKA 1986: Pl. 2/7.  
1986: *Spiniferites mirabilis*.- WRENN & KOKINOS 1986: Pl. 6/4.

Description: See ROSSIGNOL (1962: 132)

Dimensions: Ø central body= 30-35 µm, Length of processes= 12-15 µm (n= 8)

Stratigraphic range:

Miocene, Virginia (Edwards, 1989)  
Lower Oligocene-Pliocene, Egypt cf. (El-Beialy, 1988a)  
Danian, Senegal cf. (Jan du Chêne, 1988)  
Lower Miocene-Upper Pleistocene, West North Pacific (Bujak & Matsuoka, 1986b)  
Middle Miocene-Pleistocene, Gulf of Mexico (Wrenn & Kokinos, 1986)  
Lower-Upper Oligocene, Venezuela (Fasola et al., 1985)  
Upper Eocene, South England (Bujak et al., 1980)  
Lower-Upper Miocene, offshore East Canada (Williams & Bujak, 1977a)  
Lower Oligocene-Pleistocene, General (Drugg & Stover, 1975)  
Pleistocene, Israel (Rossignol, 1962)

***Spiniferites cf. multibrevis*** (DAVEY & WILLIAMS 1966 in DAVEY et. al. 1966) BELOW 1982c  
(Pl. 4/Fig.10)

1966: *Hystriosphera ramosus* var. *multibrevis* n. sp.- DAVEY & WILLIAMS 1966a:35-36: pl. 1/4; pl. 4/6.  
1971: *Spiniferites ramosus* var. *multibrevis* DAVEY & WILLIAMS 1966a.- DAVEY & VERDIER 1971: 33.  
1973: *Spiniferites ramosus* subsp. *multibrevis* DAVEY & WILLIAMS 1966a.- LENTIN & WILLIAMS 1973.  
1985: *Spiniferites ramosus* var. *multibrevis*.- JAN DU CHÊNE & ADEDIRAN 1985: 24: Pl. 17/8-10.  
1988: *Spiniferites. multibrevis*.- JAN DU CHÊNE 1988: 165-166: Pl. 24/4,7-8.

Diagnosis: See DAVEY & WILLIAMS (1966a: 35-36)

Remarks: Cysts proximo-chorate, subspherical, with strong thick sutures and short gonial and intergonial processes. Very short processes are subconical, the length and breadth of the processes are rather similar. Endophragm and periphragm distinct beneath processes. Archeopyle no discernable.

Dimensions: Ø central body= 30-35 µm, Length processes= 12-14 µm (n= 8)

Stratigraphic range:

Lower Eocene, South West Nigeria (Oloto, 1992)  
Danian, Senegal (Jan du Chêne, 1988)  
Upper Paleocene/Lower Eocene, South West Nigeria (Jan du Chêne & Adediran, 1985)  
Hauterivian-Lower Eocene, England (Davey & Williams, 1966a)  
Oligocene, West India (Kar, 1979)

***Spiniferites cf. ovatus*** MATSUOKA 1983  
(Pl. 4/Fig. 11, 12)

1983: *Spiniferites ovatus* n. sp.- MATSUOKA 1983: 134-135: Pl. 3/ 1-4.  
1984: *Spiniferites ovatus*.- BUJAK 1984: 192: Pl. 3/15-18.

Diagnosis: See MATSUOKA (1983: 134-135 )

Remarks: Cysts proximo-chorate, body ellipsoidal, with strong sutures and short gonial and intergonial processes with second order furcations. Archeopyle precingular.

Dimensions: Ø central body= 50-52 x 40-45 µm, Length of processes= 7-10 µm (n= 15)

Stratigraphic range:

Lower Miocene-?Upper Pliocene, offshore South West Britain (Powell, 1988)  
Upper Miocene-Lower Pliocene, Bering Sea (Bujak, 1984)  
Upper Miocene, Japan (Matsuoka, 1983)

***Spiniferites pseudofurcatus*** (KLUMPP 1953) SARJEANT 1970 emend. SARJEANT 1981  
(Pl. 5/Fig. 1)

- 1953: *Hystrichosphaera furcata*. - KLUMPP 1953: 387: Pl. 16/11.  
 1953: *Hystrichokibotium pseudofurcatum* n. sp. - KLUMPP 1953: p. 388, pl. 16/12-14  
 1969: *Hystrichosphaera pseudofurcata* comb. nov. - GOCHT 1969: p. 32-33, Pl. 4/12-13  
 1970: *Spiniferites pseudofurcatus* comb. nov. - SARJEANT 1970: 76.  
 1972: *Hystrichosphaera pseudofurcata*. - BENEDEK 1972: 24: Pl. 7/7.  
 1976: *Spiniferites pseudofurcatus*. - EATON 1976: 283: pl. 14/12-13.  
 1981: *Spiniferites pseudofurcatus* emend. - SARJEANT 1981: 108-109.  
 1984: *Spiniferites pseudofurcatus*. - HELENES 1984: pl. 5/10.  
 1993: *Spiniferites pseudofurcatus*. - STOVER & HARDENBOL 1993: Pl. 6/34a-c.  
 1997: *Spiniferites pseudofurcatus*. - PROSS 1997: 97: pl. 6/1 and 14/4.

Description: See Gocht (1969: 32-33)

Dimensions: Ø central body= 45-60 µm, Length of processes= 34-37 µm (n= 4)

Stratigraphic range:

Middle Eocene, Mexico (Helenes, 1984)

Lower-Upper Eocene, South England (Bujak et al., 1980)

Middle Eocene-Pliocene/Pleistocene, offshore North West Africa (Williams, 1978)

Lower-Upper Eocene, England (Eaton, 1976)

Middle-Upper Oligocene, Germany (Benedek, 1972)

Lower Eocene, England (Davey & Williams, 1966a)

Lower Eocene, Belgium-Germany (Morgenroth, 1966a)

***Spiniferites ramosus*** (EHRENBERG 1838) SARJEANT 1970 emend. DAVEY & WILLIAMS in DAVEY  
et al. 1966  
(Pl. 5/Fig. 2)

- 1838: *Xanthidium ramosum* n. sp. - EHRENBERG 1838: 109-136: Pl. 1/15.  
 1854: *Xanthidium ramosum* EHRENBERG 1838 comb. nov. - MANTELL 1854: 239.  
 1933: *Hystrichosphaera ramosa* comb. nov. - O. WETZEL 1933b: 35-39: Pl. 5/7-8;10-12;18-19.  
 1966: *Hystrichosphaera ramosa* emend. var. *ramosa* var. nov. - DAVEY & WILLIAMS in DAVEY et al. 1966: 32-34: Pl. 1/1-6.  
 1966: *Hystrichosphaera ramosa* emend. var. *gracilis* var. nov. - DAVEY & WILLIAMS in DAVEY et al. 1966: 34-35: Pl. 1/5; 5/6.  
 1969: *Hystrichosphaera ramosa*. - GOCHT 1969: 30-31: Pl. 4/10-11.  
 1969: *Hystrichosphaera ramosa* var. *gracilis*. - GOCHT 1969: 31-32: Pl. 4/9.  
 1970: *Spiniferites ramosus* comb. nov. - SARJEANT 1970: 75.  
 1972: *Hystrichosphaera ramosa* var. *ramosa*. - BENEDEK 1972: 23: Pl. 7/5,8.  
 1972: *Hystrichosphaera ramosa* var. *gracilis*. - BENEDEK 1972: 23: Pl. 4/2.  
 1984: *Spiniferites ramosus*. - HELENES 1984: Pl. 2/1-2.  
 1984: *Spiniferites ramosus*. - JAN DU CHÊNE & ADEDIRAN: 24: Pl. 18/5,13.  
 1984: *Spiniferites ramosus*. - BUJAK et al. 1984: Pl. 4/1-2.  
 1993: *Spiniferites ramosus*. - STOVER & HARDENBOL 1993: Pl. 6/35a-b.  
 1997: *Spiniferites ramosus*. - PROSS 1997: 98: Pl. 5/8,12; 14/3.

Description: See DAVEY & WILLIAMS (1966: 32-34)

Dimensions: LxB central body= 40-44 x 50-55 µm, Length processes= 18-20 µm (n= 8)

Stratigraphic range:

Lower Eocene, South West Nigeria (Oloto, 1992)

Eocene, North India (Sarkar & Singh, 1988)

Danian, Senegal (Jan du Chêne, 1988)

Upper Paleocene/Lower Eocene, Nigeria (Jan du Chêne & Adediran, 1985)

Albian, Mexico. (Helenes, 1984)

Middle-Upper Oligocene, West Germany (Benedek, 1972)

Maastrichtian-Pleistocene, offshore East. Canada (Williams & Bujak, 1977a)

Barremian-Lower Eocene, England (Davey & Williams, 1966c)

***Spiniferites* sp. A**  
(Pl. 5/Fig. 3)

Description: Cysts with elongated ovoidal and large, skolochorate body. Periphragm separated from endophragm at bases of processes and long sutural septa; surface of periphragm irregularly granulate. Antepex marked by 2 very large processes with wide bases connected at their bases along crests of sutural lines. The processes are bifurcate or trifurcate to second order; terminal branches of processes long and filamentous, not connected. Archeopyle precingular, Type P.

Dimensions: LxB central body= 50-52 x 40-44 µm, Length processes basal= 18-20 µm (n= 8)

Subfamily UncertainGenus: *Amphorosphaeridium* DAVEY 1969c

1969c: *Amphorosphaeridium* n. gen.- DAVEY 1969c: 30.  
 1978: *Amphorosphaeridium*.- STOVER & EVITT, 1978:140-141.

Type species: *Amphorosphaeridium fenestratum* DAVEY 1969c

***Amphorosphaeridium cf. major*** (LEJEUNE-CARPENTIER 1940) Emend. LEJEUNE-CARPENTIER & SARJEANT 1981  
 (Pl. 5/Fig. 4)

1940: *Hystriosphaeeridium major* n. sp.- LEJEUNE-CARPENTIER 1940:313 : Pl. B220-B221/13  
 1964: *Hystriosphaeeridium major*.- DOWNIE & SARJEANT 1964: 121.  
 1969: ?*Polysphaeridium major*.- DAVEY & WILLIAMS 1969: 6.  
 1981: *Amphorosphaeridium major*.- LEJEUNE-CARPENTIER & SARJEANT 1981: 12-13: Pl. 2/6-7

Description: See LEJEUNE-CARPENTIER & SARJEANT (1981: 12-13)

Dimensions: LxB central body= 70-78 x 58-56  $\mu\text{m}$ , Length processes= 18-22  $\mu\text{m}$  (n= 4)

Discussion: Skolochorate, with numerous large solid, fibrous processes with distal termination gradually tapering into small multiple furcate flared tips. Archeopyle probably precingular.

Stratigraphic range:

Senonian, Belgium (Lejeune-Carpentier, 1940)  
 Paleocene, Assam India (Mehrotra, 1983)

Genus *Sentusidinium* SARJEANT & STOVER 1978 emend. COURTINAT 1989

1978: *Sentusidinium* n. gen.- SARJEANT & STOVER 1978: 49-50.  
 1989: *Sentusidinium* emend.- COURTINAT 1989:192.

Type species *Sentusidinium rioultii* SARJEANT, 1968

***Sentusidinium sp. A***  
 (Pl. 5/Fig. 5)

Description: Proximate cysts, body subspherical with very delicate short possibly solid nontabular processes with termination furcate or more flared tips. Autophragm very thin. Archeopyle apical with detached operculum.

There is some similarity with the form described by Sarkar & Singh (1988: 52: Pl.3/13-15) as *Sentusidinium rioultii*.

Dimensions:  $\emptyset$  central body= 18-24  $\mu\text{m}$ , Length of processes= 1-3  $\mu\text{m}$  (n= 5)

Genus *Xenocodium* KLEMENT 1960

1960: *Xenocodium* n. gen.- KLEMENT 1960: 53-54.

***Xenocodium conispinosum* STOVER & HARDENBOL 1993**  
 (Pl. 8/Fig. 9)

1993: *Xenocodium conispinosum* n. sp.- STOVER & HARDENBOL 1993: 40: Pl. 7/42a-b; 43a-b.  
 1997: *Xenocodium conispinosum*.- PROSS 1997: 100: Pl. 6/11.

Description: See STOVER & HARDENBOL (1993: 40)

Dimensions: LxB central body= 32-34  $\mu\text{m}$ , Length of processes= 2-3  $\mu\text{m}$  (n= 5)

Stratigraphic range:

Lower Oligocene, Belgium (Stover & Hardenbol, 1993)  
 Lower Oligocene, South West Germany (Pross, 1997)

Family **Areoligeraceae** EVITT 1963

Genus ***Adnatosphaeridium* WILLIAMS & DOWNIE 1966c emend.  
STANCLIFFE & SARJEANT 1990**

1966: *Adnatosphaeridium* n. gen.- WILLIAMS & DOWNIE 1966c: 215.  
1990: *Adnatosphaeridium* WILLIAMS & DOWNIE 1966c emend. STANCLIFFE & SARJEANT 1990: 199-200.

Type species *Adnatosphaeridium vittatum*.- WILLIAMS & DOWNIE 1966c

***Adnatosphaeridium vittatum* WILLIAMS & DOWNIE 1966c  
(Pl. 5/ Fig. 6)**

1966: *Adnatosphaeridium vittatum* n. sp.- WILLIAMS & DOWNIE 1966c: 215:Pl. 24/3,7.  
1973: *Adnatosphaeridium vittatum*.- CARO 1973: 344: Pl. 1/11.  
1976: *Adnatosphaeridium vittatum*.- EATON 1976: 238: Pl. 2/1.  
1980: *Adnatosphaeridium vittatum*.- CHÂTEAUNEUF 1980: Pl. 19/5.  
1988: *Adnatosphaeridium vittatum*.- SARKAR & SINGH 1988: 38: Pl. 1/18-19.  
1990: *Adnatosphaeridium vittatum*.- KÖTHE 1990: Pl. 13/1; 15/15.

Description: See WILLIAMS & DOWNIE (1966c: 215)

Dimensions: LxB central body= 34-36 x 45-49 µm, Length of processes= 20-23 µm (n= 5)

Stratigraphic range:

Lower Eocene, South West Nigeria (Oloto, 1992)  
Lower-Upper Eocene, North West Germany (Köthe, 1990)  
Eocene, North India (Sarkar & Singh, 1988)  
Oligocene, North East India (Saxena, Rao & Singh, 1987)  
Lower-Upper Eocene, South England (Bujak et al., 1980)  
Upper Eocene-Lower Oligocene, North France (Châteauneuf, 1980)  
Middle Eocene, India (Jain & Tandon, 1981)  
Lower-Upper Eocene, England (Eaton, 1976)  
Lower Eocene, England (Williams & Downie, 1966c)

***Adnatosphaeridium multispinosum* WILLIAMS AND DOWNIE 1966c  
(Pl. 5/ Fig. 7)**

1966: *Adnatosphaeridium multispinosum* n. sp.- WILLIAMS & DOWNIE 1966c: 216: Pl. 24/5.  
1976: *Adnatosphaeridium multispinosum*.- EATON 1976: 239: Pl. 2/2.  
1980: *Adnatosphaeridium multispinosum*.- BUJAK et al. 1980: 3/10-11.  
1985: *Adnatosphaeridium multispinosum*.- JAN DU CHÊNE & ADEDIRAN 1985: 10: Pl. 24/1-6; 25/1-12.  
1988: *Adnatosphaeridium multispinosum*.- SARKAR & SINGH 1988: 38: Pl. 1/5-6.

Description: See WILLIAMS & DOWNIE (1966c: 216)

Remarks: Cysts skolochorate, body subspherical, with numerous solid narrow, slender processes connected distally by trabeculae. Autophragm with scabrate surface. Trabeculae of similar width as processes but tending to be wider at the junctions with the processes. Archeopyle apical.

Dimensions: LxB central body= 35-40 x 25-30 µm, Length of processes= 12-15 µm (n= 6)

Stratigraphic range:

Lower Eocene, North India (Sarkar, 1991)  
Lower Eocene-Lower Oligocene, North West Germany (Köthe, 1990)  
Eocene, North India (Sarkar & Singh, 1988)  
Paleocene-Middle Eocene, Pakistan (Köthe, Khan & Ashraf, 1988)  
Upper Paleocene/Lower Eocene, South West Nigeria (Jan du Chêne & Adediran, 1985)  
Lower-Upper Eocene, South England (Bujak et al., 1980)  
Lower-Upper Eocene, England (Eaton, 1976)  
Lower Eocene, England (Williams & Downie, 1966c)

Genus ***Areoligera* LEJEUNE-CARPENTIER 1938 emend. WILLIAMS & DOWNIE 1966c**

1938: *Areoligera* n. gen.- LEJEUNE-CARPENTIER 1938: 164.  
1966: *Areoligera* LEJEUNE-CARPENTIER 1938 emend.- WILLIAMS & DOWNIE 1966c: 227-228.

Type species *Areoligera senonensis* LEJEUNE-CARPENTIER 1938



***Areoligera senonensis* LEJEUNE-CARPENTIER 1938**  
(Pl. 5/ Fig. 8,9)

- 1938: *Areoligera senonensis* n. sp.- LEJEUNE-CARPENTIER 1938: 164-166: Figs. 1-3.  
 1966: *Areoligera cf. senonensis*- WILLIAMS & DOWNIE 1966: 230: Pl. 25/6.  
 1969: *Areoligera senonensis*- GOCHT 1969: 56-58: Pl. 8/4-9.  
 1976: *Areoligera cf. senonensis*- EATON 1976: 244: Pl. 3/1.  
 1976: *Areoligera senonensis*- EATON 1976: 244: Pl. 3/4-5.  
 1984: *Areoligera senonensis*- HELENES 1984: Pl. 4/11-12.  
 1988: *Areoligera cf. senonensis*- JAN DU CHÊNE 1988: 153: Pl. 9/6-9.  
 1990: *Areoligera senonensis*- KÖTHE 1990: Pl. 5/12; 8/2; 11/9.

Description: See GOCHT (1969: 56-58)

Dimensions: LxB central body= 50-54 x 55-60 µm, Length of processes= 20 µm (n= 5)

Stratigraphic range:

- Lower Eocene, North India (Sarkar, 1991)  
 Upper Paleocene-basal Upper Eocene, North West Germany (Köthe, 1990)  
 Danian, Senegal cf. (Jan du Chêne, 1988)  
 Campanian-Middle Eocene, General (Williams & Bujak, 1985)  
 Lower Paleocene, Mexico (Helenes, 1984)  
 Lower-basal Middle Miocene, Central Japan (Matsuoka, 1983)  
 Lower Eocene, South England (Bujak et al., 1980)  
 Upper Campanian-Lower Paleocene, offshore South East Canada (Bujak & Williams, 1978)  
 Maastrichtian-Upper Paleocene, offshore South East Canada (Williams & Bujak, 1977a)  
 Lower Eocene & Lower-Middle Eocene cf., England (Eaton, 1976)  
 Paleocene, Germany (Gocht, 1969)  
 Lower Eocene, England cf. (Williams & Downie, 1966c)

Genus *Chiropteridium* GOCHT 1960

- 1960: *Chiropteridium* n. gen.- GOCHT 1960: 221.

Type species *Chiropteridium lobospinosum*-GOCHT 1960

***Chiropteridium galea* (MAIER 1959) SARJEANT 1983 emend. SARJEANT 1983**  
(Pl. 5/ Fig. 10,11, 12)

- 1959: *Galea mespilana*- MAIER 1959: 306-307: Pl. 29/5-6.  
 1959: *Galea galea*- MAIER 1959: 306: Pl. 29/4.  
 1960: *Chiropteridium dispersum*- GOCHT 1960: 227: Pl. 18/1-16.  
 1983: *Chiropteridium galea* MAIER 1959 emend. SARJEANT 1983: 108.  
 1988: *Chiropteridium partispinatum*- BIFFI & MANUM 1988: Pl. 6/3.  
 1989: *Chiropteridium mespilanum*- HEILMANN-CLAUSEN & COSTA 1989: Pl. 20/5-6.  
 1990: *Chiropteridium mespilanum*- KÖTHE 1990: Pl. 24/1.

Description: See SARJEANT (1983: 108)

Dimensions: LxB central body= 50-55 x 60-68 µm, Length processes= 20-25 µm (n= 6)

Stratigraphic range:

- Lower Oligocene., North West Germany (Köthe, 1990)  
 Lower-Middle Eocene, North West Germany (Heilmann-Clausen & Costa, 1989)  
 Oligocene- Miocene, Central Italy (Biffi & Manum, 1988)  
 Oligocene-Miocene, offshore South West Alaska (Bujak, 1984)  
 Middle-Upper Oligocene, West Germany (Benedek, 1972)  
 Oligocene, offshore North West Africa (Williams, 1978)  
 Lower-Upper Oligocene, offshore South East Canada (Williams, 1975)  
 ?Upper Eocene-Oligocene, offshore East Canada (Williams & Brideaux, 1975)  
 Middle-Upper Oligocene, North West Germany (Gerlach, 1961)  
 Middle Oligocene, North West Germany (Gocht, 1960)

Genus *Glaphyrocysta* STOVER & EVITT 1978

- 1978: *Glaphyrocysta* n. gen.- STOVER & EVITT 1978: 49-50.

Type species *Glaphyrocysta retiintexta*- (COOKSON 1965a) STOVER AND EVITT 1978

***Glaphyrocysta texta*** (BUJAK 1976) STOVER & EVITT 1978  
(Pl. 6/Fig. 1)

1976: *Cyclonephelium textum* n. sp.- BUJAK 1976: 110: Pl. 3/6-11.  
1978: *Glaphyrocysta texta* BUJAK 1978 comb. nov.- STOVER & EVITT 1978: 50.  
1980: *Cyclonephelium textum*.- BUJAK et al. 1980: 14/10.  
1988: *Glaphyrocysta texta*.- WILSON 1988: 21: Pl. 9/3-4.

Description: See BUJAK (1976:110-112)

Dimensions: LxB central body= 38-40 x 42- 45 µm, Length processes= 18-20 µm (n= 2)

Stratigraphic range:

Lower Eocene, New Zealand (Wilson, 1988)

Upper Eocene, Egypt (El-Beialy, 1988b)

Middle-Upper Eocene, General (Williams & Bujak, 1985)

Upper Eocene, South England (Bujak et al., 1980)

Upper Eocene-Lower Oligocene, offshore East Canada (Williams & Bujak, 1977a)

Upper Eocene, England (Bujak, 1976)

Family **Goniodomineae** FENSOME et al.1993 (subordo nov.)  
Subfamily **Goniodomoideae** FENSOME et al. 1993 (AUTONYM)

Genus ***Heteraulacacysta*** DRUGG & LOEBLICH 1967 emend. BUJAK in BUJAK et al. 1980

1967: *Heteraulacacysta* n. gen.- DRUGG & LOEBLICH 1967: 183.  
1980: *Heteraulacacysta* DRUGG & LOEBLICH 1967 emend.- BUJAK IN BUJAK et al. 1980: 58.

Type species *Heteraulacacysta campanula*

***Heteraulacacysta campanula*** DRUGG & LOEBLICH 1967  
(Pl. 6/Fig. 2)

1967: *Heteraulacacysta campanula* n. sp.- DRUGG & LOEBLICH 1967: 183-184: pl. 1/6-8c.  
1975: *Heteraulacacysta campanula*.- DRUGG & STOVER 1975: Pl. 3/8.  
1988: *Heteraulacacysta campanula*.- RAUSCHER & SCHULER 1988: 2/3-4.

Description: See DRUGG & LOEBLICH (1967: 183-184)

Dimensions: Ø overall= 68-70 µm (n= 4)

Stratigraphic range:

Lower Oligocene-?Upper Miocene, Norwegian Sea (Manum et al, 1989)

Lower Oligocene, North East France (Rauscher & Schuler, 1988)

Lower Oligocene-Lower Miocene, General (Williams & Bujak, 1985)

Lower Oligocene, offshore East Canada (Williams & Bujak, 1977a)

Upper Middle Eocene-Lower Oligocene, General (Drugg & Stover, 1975)

Middle Eocene (Drugg & Loeblich, 1967)

Subfamily **Pyrodinioideae** LINDEMANN 1928  
Unterfamily **Pyrodinioideae** FENSONME et al. 1993

Genus ***Homotryblium*** DAVEY & WILLIAMS 1966b

1966: *Homotryblium* n. gen.- DAVEY & WILLIAMS 1966b: 100.

Type species *Homotryblium tenuispinosum* DAVEY & WILLIAMS 1966b

***Homotryblium floripes*** (DEFLANDRE & COOKSON 1955) STOVER 1975  
(Pl. 6/Fig. 3)

1955: *Hystrichosphaeridium floripes* n. sp.- DEFLANDRE & COOKSON 1955: 276:7/1, 2, 7.  
1963: *Cordosphaeridium floripes* (DEFLANDRE & COOKSON) EISENACK 1963b: 262.  
1972: *Cordosphaeridium floripes*.- BENEDEK 1972: 27, Pl.7/12.  
1975: *Homotryblium floripes* DEFLANDRE & COOKSON.- STOVER 1975: 36.

1975: *Homotryblium floripes*.- DRUGG & STOVER 1975: Pl. 3/10-11.  
 1988: *Homotryblium floripes*.- BIFFI & MANUM 1988: Pl. 15/7.  
 1988: *Homotryblium floripes*.- SARKAR & SINGH 1988: Pl. 2/17.  
 1997: *Homotryblium floripes*.- PROSS 1997: 105.

Description: See EISENACK & KJELLSTRÖM (1972: 257)

Dimensions: Ø central body= 45-47 µm, Length of processes= 18 µm (n= 12)

Stratigraphic range:

Upper Oligocene-Lower Miocene, Central Italy (Biffi & Manum, 1988)  
 Upper Eocene-Lower Oligocene, Egypt (El-Bassiouni et al., 1988a)  
 Eocene, North India (Sarkar & Singh, 1988)  
 Oligocene-Lower Miocene, North East India (Saxena, Rao & Singh, 1987)  
 Middle Eocene-Lower Miocene, General (Williams & Bujak, 1985)  
 Upper Eocene, South England (Bujak et al., 1980)  
 Upper Eocene-Upper Oligocene (Williams & Bujak, 1977a)  
 Middle Eocene-Middle Miocene, General (Drugg & Stover, 1975)  
 Middle-Upper Oligocene, West Germany (Benedek, 1972)  
 Lower Tertiary, Australia (Deflandre & Cookson, 1955)

***Homotryblium pallidum* DAVEY & WILLIAMS 1966b**  
 (Pl. 6/Fig. 4)

1966: *Homotryblium pallidum* n. sp.- DAVEY & WILLIAMS 1966b:102-103: Pl. 12/4, 6.  
 1975: *Homotryblium pallidum*.- WILLIAMS & BRIDEAUX 1975: Pl. 29/3; 32/2.  
 1980: *Homotryblium pallidum*.- BUJAK et al. 1980: Pl. 1/1-3.  
 1981: *Homotryblium pallidum*.- JAIN & TANDON 1981: Pl. 1/20.  
 1988: *Homotryblium pallidum*.- SARKAR & SINGH 1988: 45: Pl. 2/7-8.  
 1990: *Homotryblium pallidum*.- KÖTHE 1990: Pl. 16/4; 23/15.

Description: See DAVEY & WILLIAMS (1966b: 102-103)

Dimensions: Ø central body= 38-42 µm, Length of processes= 16-21 µm (n= 10)

Stratigraphic range:

Lower Eocene-Upper Oligocene, North West Germany (Köthe, 1990)  
 Eocene, North India (Sarkar & Singh, 1988)  
 Lower Eocene-Lower Oligocene, General (Williams & Bujak, 1985)  
 Middle Eocene, India (Jain & Tandon, 1981)  
 Lower-Upper Eocene, South England (Bujak et al., 1980)  
 Lower-Upper Eocene, offshore South East Canada (Williams, 1975)  
 Lower-Upper Eocene, offshore East Canada (Williams & Brideaux, 1975)  
 Lower Eocene, England (Davey & Williams, 1966b)

***Homotryblium plectilum* DRUGG & LOEBLICH Jr. 1967**  
 (Pl. 6/Fig. 5)

1967: *Homotryblium plectilum* n. sp.- DRUGG & LOEBLICH Jr. 1967:184-186:Pl.2/1-9.  
 1975: *Homotryblium plectilum*.- DRUGG & STOVER 1975: Pl. 3/12.  
 1981: *Homotryblium plectilum*.- JAIN & TANDON 1981: Pl. 4/51-54.  
 1986: *Homotryblium plectilum*.- EDWARDS 1986: Pl. 1/8.  
 1990: *Homotryblium plectilum*.- KÖTHE 1990.- Pl. 21/4-5; 26/4.

Description: See DRUGG & LOEBLICH Jr. (1967:184-186)

Dimensions: Ø central body= 50-54 µm, Length of processes=22-26 µm (n= 10)

Stratigraphic range:

Lower-Upper Oligocene, North West Germany (Köthe, 1990)  
 Upper Oligocene-Lower Miocene, South Carolina (Edwards, 1986)  
 Middle Eocene, West India (Kar, 1985)  
 Middle Eocene, India (Jain & Tandon, 1981)  
 Lower-Upper Oligocene, offshore East US (Stover, 1977)  
 Upper Middle Eocene-Lower Oligocene, General (Drugg & Stover, 1975)  
 Upper Middle Eocene-Middle Miocene, offshore South East Canada (Williams, 1975)  
 Oligocene, Gulf Coast US (Drugg & Loeblich, 1967)

***Homotryblium tasmaniense* COOKSON & EISENACK 1967**  
(Pl. 6/Fig. 6)

1967: *Homotryblium tasmaniense* n. sp.- COOKSON & EISENACK 1967a: 133:Pl. 20/1-11.  
1975: *Homotryblium tasmaniense*.- DRUGG & STOVER 1975: Pl. 4/4-5.  
1988: *Homotryblium tasmaniense*.- WILSON 1988: 21: Pl. 10/4.  
1990: *Homotryblium tasmaniense*.- EL-BEIALY 1990: Pl. 1/6-7.

Description: See EISENACK & KJELLSTRÖM (1972: 479)

Dimensions: Ø central body= 40-45 µm, Length of processes= 12-14 µm (n= 4)

Stratigraphic range:

Middle Eocene, North Egypt (El-Beialy, 1990)  
Lower Eocene, New Zealand (Wilson, 1988)  
Lower Eocene, Virginia-Maryland (Edwards, Goodman & Witmer, 1984)  
Lower Eocene, General (Drugg & Stover, 1975)  
Paleocene, West Tasmania (Cookson & Eisenack, 1967)

***Homotryblium tenuispinosum* DAVEY & WILLIAMS 1966b**  
(Pl. 6/Fig. 7)

1966: *Homotryblium tenuispinosum* n. sp.- DAVEY & WILLIAMS 1966b:101-102: Pl. 4/11; 12/1, 5, 7.  
1975: *Homotryblium tenuispinosum*.- DRUGG & STOVER 1975: Pl. 4/6.  
1976: *Homotryblium tenuispinosum*.- EATON 1976: 267: Pl. 10/1.  
1980: *Homotryblium tenuispinosum*.- BUJAK et al. 1980: Pl. 1/4-6.  
1988: *Homotryblium tenuispinosum*.- KÖTHE, KHAN & ASHRAF 1988: Pl. 17/8,13.  
1988: *Homotryblium tenuispinosum*.- SARKAR & SINGH 1988: 45: Pl. 2/4-6.  
1990: *Homotryblium tenuispinosum*.- KÖTHE 1990: Pl. 11/1; Pl. 19/1.  
1993: *Homotryblium tenuispinosum*.- STOVER & HARDENBOL 1993: Pl. 13/86a-b.  
1997: *Homotryblium tenuispinosum*.- PROSS 1997: 105: Pl. 8/7-8.

Description: See DAVEY & WILLIAMS (1966b:101-102)

Dimensions: Ø central body= 36-40 µm, Length of processes= 18-20 µm (n= 10)

Stratigraphic range:

Upper Paleocene-Upper Eocene, North West Germany (Köthe, 1990)  
Lower-Middle Eocene, Virginia (Edwards, 1989)  
Lower Oligocene, Central Italy (Biffi & Manum, 1988)  
Lower-Middle Eocene, Pakistan (Köthe, Khan & Ashraf, 1988)  
Eocene, North India (Sarkar & Singh, 1988)  
Upper Eocene, Egypt (El-Beialy, 1988b)  
Basal Middle Eocene, General (Williams & Bujak, 1985)  
Lower-Upper Eocene, South England (Bujak et al., 1980)  
Lower-Upper Eocene, offshore East Canada (Williams & Bujak, 1977a)  
Lower-Upper Eocene, England (Eaton, 1976)  
Lower-Middle Eocene, General (Drugg & Stover, 1975)  
Lower Eocene, England (Davey & Williams, 1966b)

***Homotryblium vallum* STOVER 1977**  
(Pl. 6/Fig. 8)

1977: *Homotryblium vallum* n. sp.- STOVER 1977: 79-80: Pl. 3/45-53.  
1986: *Homotryblium vallum*.- WRENN & KOKINOS 1986: Pl. 20/5.  
1986: *Homotryblium vallum*.- EDWARDS 1986: Pl. 1/9.  
1989: *Homotryblium vallum*.- EDWARDS 1989: Pl. 1/6.  
1990: *Homotryblium vallum*.- KÖTHE 1990: Pl. 22/13.

Description: See STOVER (1977: 79-80)

Dimensions: Ø central body= 44-48 µm, Length processes= 12-15 µm (n= 6)

Stratigraphic range:

Lower Oligocene, NW Germany (Köthe, 1990)  
Lower-Upper Miocene, Norwegian Sea (Manum et al., 1989)  
Miocene, Virginia (Edwards, 1989)  
Middle/Upper Miocene-Lower/Upper Pliocene, Gulf of Mexico (Wrenn & Kokinos, 1986)  
Upper Oligocene-Lower Miocene, South Carolina (Edwards, 1986)  
Lower Upper Oligocene, offshore East US (Stover, 1977)

**Genus *Hystrichosphaeridium* DEFLANDRE 1937b emend. DAVEY & WILLIAMS 1966b**

1937: *Hystrichosphaeridium* n. sp.- DEFLANDRE 1937b: 68.

1966: *Hystrichosphaeridium* DEFLANDRE 1937b emend.- DAVEY & WILLIAMS 1966b: 55-56.

Type species *Hystrichosphaeridium tubiferum* (EHRENBERG 1838) DEFLANDRE 1937b emend. DAVEY & WILLIAMS 1966b

***Hystrichosphaeridium* sp. A**

(Pl. 6/Fig. 9)

Remarks: Cysts subspherical, skolochorate, with hollow slender intratabular processes with funnel-shape termination, with horizontal to recurved margins. Autophragm. Archeopyle apical.

Dimensions: Ø central body= 40-45 µm, Length of processes= 10-15 µm (n= 8)

**Genus *Polysphaeridium* DAVEY & WILLIAMS 1966b emend. BUJAK et al. 1980**

1966: *Polysphaeridium* n. gen.- DAVEY & WILLIAMS 1966b: p. 91-92.

1980: *Polysphaeridium* comb. nov.- BUJAK et al. 1980: p. 32-34.

Type species: *Polysphaeridium subtile* DAVEY & WILLIAMS 1966b

***Polysphaeridium congregatum* (STOVER 1977) emend. BUJAK et al. 1980**

(Pl. 6/Fig. 10,11)

1977: *Hemicystodinium congregatum* n. sp.- STOVER 1977: 79: Pl. 3/39-44.

1980: *Polysphaeridium congregatum* comb. nov.- BUJAK et al. 1980: 34: Pl. 20/1-3.

1985: *Polysphaeridium congregatum*.- WILLIAMS & BUJAK 1985: Pl. 36/1.

Description: See STOVER (1977: 79)

Dimensions: LxB central body= 40-50 x 38-40 µm, Length of processes= 8-11 µm (n= 6)

Remarks: Processes arranged in groups (3-5), shorter and more slender than in *Polysphaeridium subtile*.

Stratigraphic range:

Upper Eocene-Upper Oligocene, General (Williams & Bujak, 1985)

Upper Eocene, South England (Bujak et al., 1980)

Upper Oligocene, Blake Plateau, Atlantic Ocean (Stover, 1977)

***Polysphaeridium subtile* DAVEY & WILLIAMS 1966b emend. BUJAK et al. 1980**

(Pl. 7/Fig. 1)

1966: *Polysphaeridium subtile* n. sp.- DAVEY & WILLIAMS 1966b: 92: Pl. 11/1.

1977: *Polysphaeridium subtile*.- WILLIAMS 1978: Pl. 1/5.

1976: *Polysphaeridium subtile*.- EATON 1976: Pl. 14/1-2.

1980: *Polysphaeridium subtile* comb. nov.- BUJAK et al. 1980: Pl. 9/12.

1980: *Polysphaeridium subtile*.- CHANTEAUNEUF 1980: Pl. 24/2-3.

1984: *Polysphaeridium subtile*.- JAN DU CHENE & ADEDIRAN 1984: Pl. 13/3

Description: See DAVEY & WILLIAMS (1966b: 92) & BUJAK et al. (1980: 34)

Dimensions: Ø central body=, 34-40 µm, Length of processes= 12-14 µm (n= 8)

Stratigraphic range:

Upper Paleocene-Middle Eocene, Pakistan (Köthe, Khan & Ashraf, 1988)

Eocene, North India (Sarkar & Singh, 1988)

Oligocene, North East India (Saxena, Rao & Singh, 1987)

Upper Oligocene-Pleistocene, South Carolina (Edwards, 1986)

Lower-Middle Eocene, General (Williams & Bujak, 1985)

Upper Paleocene-Lower Eocene, South West Nigeria (Jan du Chêne & Adediran, 1984)

Lower-Upper Eocene, England (Eaton, 1976)

Middle Oligocene-Lower Miocene, offshore East US (Stover, 1977)

Lower Eocene-Pleistocene, offshore West Africa (Williams, 1978)

Lower Eocene, England (Davey & Williams, 1966b)

***Polysphaeridium zoharyi* (ROSSIGNOL 1962) emend. BUJAK et al. 1980**  
(Pl. 7/ Fig. 2,3)

- 1962: *Hystrichosphaeridium zoharyi* n. sp.- ROSSIGNOL 1962: 132: Pl 2/10.  
 1966: *Hystrichosphaeridium breviatum*.- MORGENROTH 1966b: 29: Pl. 7/11-12.  
 1967: *Hemicystodinium zoharyi*.- WILLIAMS & BRIDEAUX, 1975: Pl. 29/8-9; 32/5; 37/2.  
 1980: *Polysphaeridium zoharyi* ROSSIGNOL 1962 emend.- BUJAK et al. 1980: 32-34.  
 1983: *Polysphaeridium subtile ktana*.- ISLAM 1983b:343: Pl 4/7.  
 1988: *Polysphaeridium subtile ktana*.- KÖTHE, KHAN & ASHRAF, 1988: Pl. 17/7,16.  
 1989: *Polysphaeridium zoharyi*.- EDWARDS 1989: Pl. 5/1.

Description: See EISENACK & KJELLSTRÖM (1972: 431)

Remarks: Cysts skolochorate, subspherical, with hollow processes, termination flared tips. Wall microreticulate. Archeopyle epicystal.

Dimensions: LxB central body= 40-45 x 30-34 µm, Length of processes= 9-12 µm (n= 5)

Stratigraphic range:

Middle Eocene, Pakistan (Köthe, Khan & Ashraf, 1988)

Middle Eocene, South England (Islam, 1983b)

Lower Eocene-Oligocene, offshore East Canada (Williams & Brideaux, 1975)

Lower Eocene, West Germany (Morgenroth, 1966a)

Pleistocene, Israel (Rossignol, 1964)

Family **Uncertain** FENSOME et al. 1993  
Subfamily **Uncertain** FENSOME et al. 1993

**Genus *Cleistosphaeridium* (DAVEY et al. 1966) emend. EATON et al. 2001**

- 1966: *Cleistosphaeridium* n. gen.- DAVEY et. al 1966: 166.  
 1993: *Systematophora*.- ISLAM 1993: 88.  
 2001: *Cleistosphaeridium* (DAVEY et al 1966) emend.- EATON et al 2001: 176-177.

Type species: *Cleistosphaeridium diversispinosum* DAVEY et. al 1966.

***Cleistosphaeridium ancyrea* (COOKSON & EISENACK 1965a)**  
(Pl. 7/ Fig. 4)

- 1965: *Systematophora ancyrea* n. sp.- COOKSON & EISENACK 1965a: 126: Pl. 14/1-3.  
 1970: *Systematophora ancyrea*.- WEYNS 1970: Pl. 4/49.  
 1975: *Systematophora ancyrea*.- WILLIAMS & BRIDEAUX 1975: Pl. 23/8; 25/1.  
 1976: *Systematophora ancyrea*.- MANUM 1976: Pl. 3/23.  
 1988: *Systematophora ancyrea*.- BIFFI & MANUM 1988: Pl. 7/8.  
 1988: *Systematophora ancyrea*.- POWELL 1988: Pl. 6/15,19.  
 1994: *Systematophora ancyrea*.- KURITA & MATSUOKA 1994: Pl. 2/22.  
 1996: *Systematophora ancyrea*.- GEDL 1996: Pl. 7/a-b, i.  
 2001: *Cleistosphaeridium ancyrea* comb. nov.- EATON et al. 2001: 191-194.

Description: See EISENACK & KJELLSTRÖM (1975b: 998a) and EATON et al. (2001: 191-194)

Remarks: Cysts skolochorate, body subspherical, with numerous long processes with hollow bases and solid shafts with bifurcate to branched to Y shaped termination, penitabulate. Surface scabrate to subgranular. Archeopyle apical.

Dimensions: LxB central body= 38-40 x 48-50 µm, Length of processes= 16-20 µm (n= 6)

Stratigraphic range:

Early Eocene-Miocene (Eaton et. al, 2001)

Early Oligocene, North Japan (Kurita & Matsouka, 1995)

Upper Oligocene-Lower Miocene, Marche Region, Italy (Biffi & Manum, 1988)

Lower Miocene, offshore SW Britain (Powell, 1988)

Upper Eocene Tongrien, Belgium (Weyns, 1970)

Upper Eocene., Victoria, Australia (Cookson & Eisenack, 1965)

***Cleistosphaeridium diversispinosum*** (DAVEY et al. 1966) emend. EATON et al 2001  
(Pl. 7/Fig. 5,6,7)

- 1966: *Cleistosphaeridium diversispinosum* sp. nov.- DAVEY et al 1966: 167: Pl. 10/7.  
1993: *Systematophora diversispinosa* - (DAVEY et al. 1966) ISLAM 1993: 88-89: Pl. 1/1-10.  
1993: *Cleistosphaeridium diversispinosum*.- STOVER & HARDENBOL 1993: Pl. 1/6a-b.  
2001: *Cleistosphaeridium diversispinosum* (DAVEY et al. 1966) emend.- EATON et al. 2001: 177-189: Fig. 1-9.

Description: See EATON et al. (2001: 177-189)

Dimensions: LxB central body= 34-36 x 54-60 µm, Length of processes= 16-18 µm (n= 12)

Stratigraphic range:

Lower Eocene to Lower Oligocene (Eaton et al., 2001)

Lower Eocene, England (Davey et al., 1966)

***Cleistosphaeridium placacanthum*** (DEFLANDRE & COOKSON 1955)  
(Pl. 7/Fig. 8,9)

- 1955: *Hystriospheraeridium placacanthum* n. sp.- DEFLANDRE & COOKSON 1955: 276-277: Pl. 9/1-3.  
1965: *Baltisphaeridium placacanthum* comb. nov.- DOWNIE & SARJEANT 1965: 94.  
1969: *Systematophora placacantha* comb. nov.- DAVEY et al. 1969: 17.  
1972: *Impletosphaerium placacanthum*.- BENEDEK 1972: 31: Pl. 10/3a-c.  
1975: *Systematophora placacantha*.- DRUGG & STOVER 1975: Pl. 7/1-2.  
1986: *systematophora placacantha*.- EDWARDS 1986: Pl. 3/10.  
1988: *Systematophora placacantha*.- BIFFI & MANUM 1988: Pl. 7/4.  
1988: *Systematophora placacantha*.- POWELL 1988: Pl. 6/14,18.  
1992: *Systematophora placacantha*.- FECHNER 1992: Pl. 3/1.  
1992: *Systematophora placacantha*.- GRADSTEIN et al. 1992: Pl. 3/1-2.  
1993: *Systematophora placacantha*: STOVER & HARDENBOL 1993: Pl. 3/20a-c.  
1997: *Systematophora placacantha*.- PROSS 1997: 85: Pl. 1/1-4.  
2001: *Cleistosphaeridium placacanthum* comb. nov.- EATON et al. 2001: 190-191.

Description: See BENEDEK (1972:31) und EATON et al. (2001: 190-191)

Remarks: *Cleistosphaeridium placacanthum* differs from the species *C. diversispinosum* and *C. ancyrea*, in that the majority, or all, of its processes are arranged in clearly defined penitabular process complexes (Eaton et al 2001, p. 190). These are emphasized by the extensive development of basal ridges.

Dimensions: Ø central body= 34-38 µm, Length of processes= 20-25 µm (n= 4)

Stratigraphic range:

Mid.Eocene-Late Miocene based on illustrated records (Eaton et al., 2001)

Early Oligocene, Mainzer Beckens South West, Germany (Pross, 1997)

Mid. Eocene-Late Miocene, Northern Hemisphere (Williams, Stover & Kidson, 1993)

Oligocene-Early Miocene, Marche Region, Italy (Biffi & Manum, 1988)

Late Eocene, Victoria, Australia, General (Drugg & Stover, 1975)

Mid-Late Oligocene, Tonisberg, Germany (Benedek, 1972)

***Cleistosphaeridium ? sp. A***  
(Pl. 7/Fig. 10,11)

Remarks: Cysts skolochorate, subspherical body, with numerous rather uniform closed acuminate processes. Surface scabrate. Archeopyle apical with operculum. This species can be compared with a species described by Kar 1985 (p. 198: Pl. 45/3-4) as *Cleistosphaeridium heteracanthum*, but his specimens disagree with the original description of this species.

Dimensions: LxB central body= 38-40 x 36-38 µm, Length processes= 10-11 µm (n= 6)

Genus ***Distatodinium*** EATON 1976

1976: *Distatodinium* n. gen.- EATON 1976: 262-263.

Type species *Distatodinium craterum* EATON 1976

***Distatodinium ellipticum*** (COOKSON 1965a) EATON 1976  
(Pl. 8/Fig. 1)

- 1965: *Hystriospheraeridium ellipticum* n. sp.- COOKSON 1965a: 87: Pl. 11/1-3a.  
1966: *Tanyosphaeridium ellipticum* comb. nov.- DAVEY & WILLIAMS in DAVEY et al 1966: 100.

1972: *Tanyosphaeridium ellipticum*.- BENEDEK 1972: 35: Pl. 9/13-14; 10/2.  
 1976: *Distatodinium ellipticum* comb. nov.- EATON 1976: 264-265: Pl. 9/7-9.  
 1980: *Distatodinium ellipticum*.- CHÂTEAUNEUF 1980: 136: Pl. 21/13.  
 1988: *Distatodinium ellipticum*.- SAKAR & SINGH 1988: 42: Pl. 1/21-22.  
 1997: *Distatodinium ellipticum*.- PROSS 1997: 109: Pl. 9/4.

Description: See BENEDEK (1972: 35)

Dimensions: LxB central body= 65-72 x 40-45 µm, Length of processes= 17-25 µm (n= 6)

Stratigraphic range:

Eocene, North India (Sarkar & Singh, 1988)

Oligocene-Pliocene, Egypt (El Beialy, 1988c)

Middle-Upper Eocene, General (Williams & Bujak, 1985)

Middle Eocene, South England (Islam, 1983)

Lower Oligocene, North France (Châteauneuf, 1980)

Upper Middle Eocene-Lower Oligocene, offshore East Canada (Williams & Bujak, 1977a)

Upper Eocene, England (Eaton, 1976)

Upper Middle Eocene-Lower Oligocene, General (Drugg & Stover, 1975)

Middle-Upper Oligocene, Germany (Benedek, 1972)

Upper Eocene, Victoria, Australia (Cookson, 1965)

***Distatodinium cf. tenerum* (BENEDEK 1972) EATON 1976**  
 (Pl. 8/Fig. 2,3)

1972: *Tanyosphaeridium tenerum*.-BENEDEK 1972: 35: Pl. 10/13-14.  
 1976: *Distatodinium tenerum*.- EATON 1976: 263.  
 1980: *Distatodinium tenerum*.- CHÂTEAUNEUF 1980: 137: Pl. 22/4-5.  
 1981: *Distatodinium tenerum* emend. BENEDEK & SARJEANT 1981: 347-348; Pl. 1/5.  
 1997: *Distatodinium tenerum*.- PROSS: 110: Pl. 9/7.

Description: See BENEDEK (1972:35)

Dimensions: LxB central body= 55-57 x 36-40 µm, Length of processes= 10-12 µm (n= 3)

Discussion: Cyst body ovoidal, proximo-chorate, outer surface scabrate, the bases of the processes suggest the presence of a pericoel. The numerous processes are short, hollow, flattened, furcate and distally flared, non tabular, arranged in linear groups which may indicate sutural features. Archeopyle apical.

Stratigraphic range:

Upper Eocene, North France (Châteauneuf, 1980)

Middle-Upper Oligocene, West Germany (Benedek, 1972)

Ordnung **Peridinales** HAECKEL 1984  
 Family **Congruentidiaceae** SCHILLER 1935  
 Subfamily **Congruentidioideae** FENSOME et al. 1993 (AUTONYM)

**Genus *Lejeunecysta* ARTZNER & DÖRHÖFER 1978 emend. BUJAK in BUJAK et al. 1980**

1978: *Lejeunecysta* n. gen.- ARTZNER & DÖRHÖFER 1978: 1381.  
 1980: *Lejeunecysta* ARTZNER & DÖRHÖFER 1978 emend.- BUJAK in BUJAK et al. 1980: 68.

Type species *Lejeunecysta hyalina* (GERLACH 1961) ARTZNER & DÖRHÖFER 1978 emend. KJELLSTRÖM 1972 emend. SARJEANT 1984b

***Lejeunecysta fallax* (MORGENROTH 1966b) ARTZNER & DÖRHÖFER emend.**  
**BIFFI & GRIGNANI 1983**  
 (Pl. 8/Fig. 4)

1966: *Lejeunia fallax* n. sp.- MORGENROTH 1966b: 2: Pl. 1/6-7.  
 1972: *Lejeunia fallax*.- BENEDEK 1972: 39-40: Pl. 6/14.  
 1978: *Lejeunecysta fallax* comb. nov.- ARTZNER & DÖRHÖFER 1978: 1381.  
 1983: *Lejeunecysta fallax* emend.- BIFFI & GRIGNANI 1983: 132.  
 1986: *Lejeunecysta fallax*.- BUJAK & MATSUOKA 1986b: Pl. 3/7.  
 1990: *Lejeunecysta fallax*.- KÖTHE 1990: Pl. 25/2.  
 1997: *Lejeunecysta fallax*.- PROSS 1997: 122: Pl. 12/4.



Description: See BENEDEK (1972: 39-40)

Dimensions: LxB central body= 36x 38 x 54-56 µm (n= 5)

Stratigraphic range:

Lower-Upper Oligocene, North West Germany (Köthe, 1990)  
 Upper Oligocene-Lower Miocene, Central Italy (Biffi & Manum, 1988)  
 Lower-basal Middle Miocene, West North Pacific (Bujak & Matsuoka, 1986)  
 Oligocene, Nigeria (Biffi & Grignani, 1983)  
 Middle Eocene-Oligocene, Africa (Williams, 1978)  
 Middle Oligocene-Middle Miocene, offshore SE Canada (Williams, 1975)  
 Middle Oligocene, West Germany (Benedek, 1972)  
 Middle Oligocene, West Germany (Morgenroth, 1966b)

***Lejeunecysta hyalina*** (GERLACH 1961) ARTZNER & DÖRHÖFER 1978 emend. KJELLSTRÖM 1972  
 emend. SARJEANT 1984b  
 (Pl. 8/Fig. 5,6)

1961: *Lejeunia hyalina* n. sp.- GERLACH 1961:169: Pl. 26/10-11.  
 1969: *Lejeunecysta hyalina*.- GOCHT 1969: 27-28.  
 1972: *Lejeunecysta hyalina*.- BENEDEK 1972: 40: Pl. 5/9.  
 1976: *Lejeunecysta hyalina*.- EATON 1976: 293, Pl. 17/5.  
 1978: *Lejeunecysta hyalina*.comb. nov. - ARTZNER & DÖRHÖFER 1978:1381.  
 1980: *Lejeunecysta hyalina*.- BUJAK et al 1980: Pl. 18/5-6.  
 1984: *Lejeunecysta hyalina* (GERLACH) ARTZNER & DÖRHÖFER emend.- SARJEANT 1984b: 89-90.  
 1988: *Lejeunecysta hyalina*.- BIFFI & MANUM 1988: Pl. 9/4.  
 1988: *Lejeunecysta hyalina*.- BRINKHUIS & ZACHARIASSE 1988: Pl. 7/1.  
 1997: *Lejeunecysta hyalina*.- PROSS 1997: 123: Pl. 12/3.

Description: See GERLACH (1961: 169-171)

Dimensions: LxB central body= 58-65 x 62-65 µm (n=10)

Stratigraphic range:

Maastrichtian-Danian, North West Tunisia (Brinkhuis & Zachariasse, 1988)  
 Upper Oligocene, Central Italy (Biffi & Manum, 1988)  
 Lower Oligocene, Egypt (El-Bassiouni et al., 1988)  
 Oligocene-Upper Miocene, Egypt (El-Beialy, 1988a)  
 Paleocene.-Lower Eocene, New Zealand (Wilson, 1988)  
 Lower Eocene-Lower Miocene, General (Williams & Bujak, 1985)  
 Lower-Middle Eocene, South England (Islam, 1983a, 1983b, 1983c)  
 Lower-Upper Eoc, South England (Bujak et al., 1980)  
 Middle Oligocene, North Germany (Benedek, 1972)  
 Lower Eocene, North Germany (Gocht, 1969)  
 Upper Oligocene, North Germany (Gerlach, 1961)

Genus ***Selenopemphix*** BENEDEK 1972 emend. BUJAK in BUJAK et al. 1980 emend. HEAD 1993

1970: *Selenopemphix* n. gen.- BENEDEK 1972: 47.  
 1980: *Selenopemphix* BENEDEK 1972 emend.- BUJAK in BUJAK et al. 1980: 82-83.  
 1993: *Selenopemphix* BENEDEK 1972 emend. BUJAK et al. 1980 emend.- HEAD 1993b: 32-34.

Type species *Selenopemphix nephroides*.- BENEDEK 1972 emend. BUJAK in BUJAK et al. 1980 emend. BENEDEK & SARJEANT 1981

***Selenopemphix nephroides*** BENEDEK 1972 emend. BUJAK in BUJAK et al. 1980 emend. BENEDEK  
 & SARJEANT 1981  
 (Pl. 8/Fig. 7,8)

1972: *Selenopemphix nephroides* n. sp.- BENEDEK 1972: 47-48: Pl. 11/13.  
 1972: *Selenopemphix psilodora* n. sp.- BENEDEK 1972: 42: Pl. 6/5.  
 1980: *Selenopemphix nephroides* emend.-Bujak, in Bujak et al. 1980: 84: Pl. 21/6.  
 1983: *Selenopemphix nephroides*.- BIFFI & GRIGNANI 1983: 143: Pl. 7/1-3.  
 1986: *Selenopemphix nephroides*.- BUJAK & MATSUOKA 1986b: Pl. 3/10.  
 1988: *Selenopemphix nephroides*.- BIFFI & MANUM 1988: Pl. 9/12.  
 1990: *Selenopemphix nephroides* emend.- BENEDEK & SARJEANT 1981: 333-336: Pl. 8/3-6.  
 1990: *Selenopemphix nephroides*.- KÖTHE 1990: 51: Pl. 24/6; 25/11.  
 1997: *Selenopemphix nephroides*.- PROSS 1997: 125: Pl. 12/6-8, 14.

Description: See BENEDEK & SARJEANT (1981: 333-336)

Dimensions: LxBoverall= 50-55 x 60-63  $\mu\text{m}$  (n= 10)

Stratigraphic range:

Lower Oligocene, North West Germany (Köthe, 1990)

Upper Oligocene-Lower Miocene, Central Italy (Biffi & Manum, 1988)

Oligocene-Pliocene, Egypt (El-Beialy, 1988a)

Lower Oligocene, Egypt (El-Bassiouni et al., 1988)

Lower Miocene-Upper Pleistocene, West North Pacific (Bujak & Matsuoka, 1986)

Middle Miocene-Pleistocene, Gulf of Mexico (Wrenn & Kokinos, 1986)

Upper Eocene-Lower Oligocene, Netherlands (de Coninck, 1986b)

Middle Eocene-Upper Miocene, General (Williams & Bujak, 1985)

Oligocene, Nigeria (Biffi & Grignani, 1983)

Oligocene, North West Germany (Benedek, 1972)

## 6.2 Taxonomy of acritarchs, prasinophyte algae and others

Group ***Acritarca*** EVITT, 1963

Genus ***Chomotriletes*** NAUMOVA 1939 ex 1953

1939: *Chomotriletes* n. gen.- NAUMOVA 1939: 355.

Type species *Chomotriletes vedugensis*.- NAUMOVA 1953: 58: Pl. 7/21-22.

***Chomotriletes minor*** (KEDVES 1961) POCOCK 1970  
(Pl. 9/Fig. 1)

1961: *Schizaeoisporites minor* n. sp.- KEDVES 1961: 129: Pl. 6/11-16.

1970: *Chomotriletes minor*.- POCOCK 1970: 61: Pl. 11/14.

2001: *Chomotriletes minor*.- JARAMILLO 2001: 97: Pl. 1/10.

Diagnosis: See JARAMILLO (2001: 97)

Remarks: This species probably is a flattened freshwater algal cyst of uncertain affinity (Schrank, 1994) rather than miospores. In agreement with Jaramillo (2001), it is here placed in the acritarchs (see also Fensome et al., 1990).

Dimensions: Ø overall= 40-42 µm (n= 4)

Stratigraphic range:

Jurassic to Lower Eocene (Fensome et al., 1993)

***Chomotriletes sp. A***  
(Pl. 9/Fig. 2)

Remarks: Cyst transparent, form circular, with concentric radial ridges and fine membrane.

Dimensions: LxB overall= 58-60 x 45-50 µm (n= 3)

Genus ***Cyclopsiella*** DRUGG & LOEBLICH 1967 emend. JAIN & DUTTA in DUTTA & JAIN 1980  
emend. HEAD et al. 1989c

1967: *Cyclopsiella* n. gen.- DRUG & LOEBLICH 1967: 188-190.

1980: *Cyclopsiella* DRUGG & LOEBLICH 1967 emend.- JAIN & DUTTA in DUTTA & JAIN 1980: 71.

1989: *Cyclopsiella* DRUGG & LOEBLICH 1967 emend.- HEAD et al. 1989c: 496.

Type species *Cyclopsiella elliptica* DRUG & LOEBLICH 1967

***Cyclopsiella sp. A***  
(Pl. 9/Fig. 3)

Remarks: Ellipsoidal cyst, with a small circular aperture. Wall double-layered. The endophragm is smooth to faintly granulate.

Dimensions: LxB overall= 30-34 x 24-26 µm, Ø aperture= 3-6 µm (n= 5)

Division **Chlorophyta** PACHER 1914  
Class **Prasinophyceae** CHRISTENSEN 1962

Order **Pyramimonadales**  
Family **Leiosphaeridiaceae**

Genus ***Leiosphaeridia*** EISENACK 1958a emend. DOWNIE & SARJENT 1963 emend. TURNER 1984

1958: *Leiosphaeridia* n. gen.- EISENACK 1958a: 2-5.

1963: *Leiosphaeridia* emend.- DOWNIE & SARJENT 1963: 94-95.

1984: *Leiosphaeridia* emend.- TURNER 1984: 116.

Type species *Leiosphaeridia baltica* EISENACK 1958a: 8: Pl. 2/5.

***Leiosphaeridia* sp. A**

(Pl. 9/Fig. 8)

Remarks: Spherical cyst with slightly microgranulate, relatively thin wall; compressed specimens with tapering and pointed folds.

Dimensions: LxB overall= 34-36 x 30-32  $\mu\text{m}$  (n= 8)

Order **Pterospermatales** SCHILLER 1925

Family **Cymatiosphaeraceae** MÄDLER 1963

**Genus *Cymatiosphaera* O. WETZEL 1933b ex DEFLANDRE 1954**

1933: *Cymatiosphaera*.- O. WETZEL 1933b: 27.

1954: *Cymatiosphaera* O.WETZEL 1933b.- DEFLANDRE 1954: 257-258.

Type species *Cymatiosphaera radiata* O. WETZEL 1933b emend. SARJEANT 1985.

***Cymatiosphaera radiata* O. WETZEL 1933b emend. SARJEANT 1985**

(Pl. 9/Fig. 4)

1933: *Cymatiosphaera radiata* n. sp.- O. WETZEL 1933b: 27: Pl. 4/8.

1972: *Cymatiosphaera cf. radiata*.- BENEDEK 1972: 51: Pl. 11/4.

1980: *Cymatiosphaera radiata*.- CHÂTEAUNEUF 1980: 151: Pl. 30/2.

1985: *Cymatiosphaera* emend.- SARJEANT 1985: 161-162.

1990: *Cymatiosphaera cf. radiata*.- KÖTHE 1990: Pl. 26/5.

1997: *Cymatiosphaera radiata*.- PROSS 1997: 130.

Diagnosis: See SARJEANT (1985: 161-162)

Dimensions:  $\emptyset$  overall= 25-30  $\mu\text{m}$  (n= 6)

Stratigraphic range:

Upper Eocene-Lower Oligocene, North France (Châteauneuf, 1980)

Upper Eocene-Lower Oligocene, Italy (Gruas-Cavagnetto & Barbin, 1988)

Upper Oligocene, North West Germany (Köthe, 1990)

***Cymatiosphaera* sp. A**

(Pl. 9/Fig. 5)

Remarks: Vesicle spherical with laevigate surface and somewhat thickened wall. The membrane is transparent, thin and produced triangular, square to rectangular polygonal outlines with striations along the membrane.

Dimensions:  $\emptyset$  overall= 60-64  $\mu\text{m}$ ,  $\emptyset$  central body= 32-34  $\mu\text{m}$  (n= 4)

**Family *Pterospermellaceae* EISENACK 1972****Genus *Pterospermella* EISENACK 1972**

1972: *Pterospermella* n. gen.- EISENACK 1972: 597.

Type species *Pterospermella aureolata*.- COOKSON & EISENACK 1958

***Pterospermella barbarae* (GORKA 1963) EISENACK et al. 1973**

(Pl. 9/Fig. 10)

1963: *Pteropermosis barbarae* n. sp.- GORKA 1963: 74: Pl. 11/3.

1969: *Pteropermosis barbarae*.- GOCHT 1969: 68: Pl. 10/19.

1972: *Pteropermosis barbarae*.- BENEDEK 1972: 52: Pl. 5/4-5.

1973: *Pterospermella barbarae* comb. nov.- EISENACK et al. 1973: 961.

1997: *Pterospermella barbarae*.- PROSS 1997: 130.

Diagnosis: See BENEDEK (1972: 52)

Remarks: This species is very small in size as compared to those of Benedek (1972) and Pross (1997).

Dimensions: LxB overall= 32-36 x 28-30  $\mu\text{m}$  (n= 3)

Stratigraphic range:

Maastrichtian-Danian, California (Drugg, 1966)

Eocene-Middle Oligocene, Germany (Gocht, 1969)

***Pterospermella aff. harti* SARJEANT 1960**

(Pl. 9/Fig. 6)

1960: *Pterospermopsis harti* n. sp.- SARJEANT 1960: 402: Pl. 14/16.

1968: *Pterospermella harti*- de CONINCK 1968.

1977: *Pteropermella aff. harti* .- de CONINCK 1977: 46: Pl. 7/32.

1986: *Pteropermella harti*.- de CONINCK 1986: Pl 3/1-2.

Diagnosis: See SARJEANT (1960: 402)

Remarks: Vesicle commonly spherical to oval, transparent and thin, of equal thickness as the equatorial membrane. The surface laevigate in appearance, with folds radiating from the vesicle.

Dimensions: Ø overall= 30-32 µm (n=4)

Stratigraphic range:

Lower Eocene., Belgium (de Coninck 1977)

***Pterospermella sp. A***

(Pl. 9/Fig. 9)

Remarks: Vesicle spherical, wall rather thick, with reticulate sculpture. The vesicle is enveloped by a thin membrane which is attached to it at the equator.

Dimensions: LxB overall= 135-140 x 115-120 µm, Ø central body= 28-32 µm (n= 6)

Class **Chlorophyceae** KÜTZING 1843

Order **Chlorococcales** MARCHAND 1895

Family **Hydrodictyaceae** (DUMORTIER 1829)

Genus ***Pediastrum*** MEYEN 1929

***Pediastrum cf. wilsonii* SINGH & KHANNA, 1978**

(Pl. 9/Fig. 7)

1978: *Pediastrum wilsonii*.- SINGH & KHANNA 1978: 468: Pl. 1/6-7.

1988: *Pediatrum wilsonii*.- SARKAR & SINGH 1988: 58: Pl. 5/10.

Diagnosis: See SARKAR & SINGH (1988: 58)

Remarks: Colonies di- or tricyclic; unicameral, with fringes of short pyramidal cells surmounted by long appendiform terminations with rounded tip. The central coenocysts are tetragonal or pentagonal.

Dimensions: LxB total colony= 45-47 x 40- 43 µm (n=10)

Stratigraphic range:

Eocene, North India (Sarkar & Singh, 1988)

Class **Rhizopodea** VON SIEBOLD 1845

Order **Foraminiferida** EICHWALD 1830

**Microforaminiferal linings**

(Pl. 9/Fig. 12, 13)

Many of the studied assemblages of marine palynomorphs contain resistant inner linings of trochospiral, biserial and planispiral microforaminiferal tests.

**Scolecodonts**  
(Pl. 9/Fig. 11, 14)

The morphology of the scolecodonts is variable. Most of them are elongated, double walled plates and denticulate along one margin (Szaniawki 1996). These forms are common in the studied material and their general shape corresponds to the morphogenera *Staurocephalites* HINDE 1849 and *Goniada* KINBERG 1866. Generally, scolecodonts occur in marine sediments, but are most abundant in shallow water and associated with spores and acritarchs (Szaniawki 1996).

### 6.3 Taxonomy of fungal spores, mycelia and fructifications

Class FUNGI IMPERFECTI  
Order SPORAE DISPERSAE

#### MONOCELLATE FUNGAL SPORES

Genus *Exesisporites* ELSIK 1969

1969: *Exesisporites* n. gen.- ELSIK 1969: 516.

Type species *Exesisporites neogenicus* ELSIK 1969

*Exesisporites annulatus* KALGUTKAR 1993  
(Pl.10/Fig. 1)

1993: *Exesisporites annulatus* n. sp.- KALGUTKAR 1993: 80:Pl. 4.2/22.

Diagnosis: See KALGUTKAR (1993: 80)

Dimensions: Ø overall= 30-34 µm (n= 3)

Stratigraphic range:

Upper Paleocene-Lower Eocene, Canada (Kalgutkar, 1993)

Genus *Inapertisporites* VAN DER HAMMEN 1954 ex ROUSE, emend.  
SHEFFY & DILCHER 1971

1954: *Inapertisporites* n. gen.- VAN DER HAMMEN 1954: 312.

1971: *Inapertisporites*- SHEFFY & DILCHER 1971: 37.

1986: *Inapertisporites*- SAXENA & BHATTACHARYYA 1986: 192.

2000: *Inapertisporites*- KALGUTKAR & JANSONIUS 2000: 146.

Type species *Inapertisporites variabilis* VAN DER HAMMEN 1954

*Inapertisporites cf. nodulus* SHEFFY & DILCHER 1971  
(Pl.10/Fig. 2)

1971: *Inapertisporites nodulus* n. sp.- SHEFFY & DILCHER 1971: 39: Pl. 13/11; 15/11.

2000: *Inapertisporites nodulus* comb. nov.- KALGUTKAR & JANSONIUS & 2000: Pl. 1/22.

Diagnosis: See SHEFFY & DILCHER (1971: 39)

Remarks: Spore inaperturate, circular, unicellate, smooth, brown, with two walls. The outer wall is 0.7 µm thick and the inner wall 1.5 µm. The cell presents a circular-curved 4-6 µm long projection. This species presents some similarity with *I. nodulus*, but the latter is smaller in size and the projection is spherical.

Dimensions: Ø overall= 70-74 µm (n=4)

Stratigraphic range:

Middle Eocene, Tennessee USA (Sheffy & Dilcher, 1971)

Genus *Monoporisporites* VAN DE HAMMEN 1954 emend.  
KALGUTKAR & JANSONIUS 2000

1954: *Monoporisporites* n. gen.- VAN DER HAMMEN 1954: 83, 103.

2000: *Monoporisporites* emend.- KALGUTKAR & JANSONIUS 2000: 175.

Type species *Monoporisporites minutus* VAN DER HAMMEN 1954

*Monoporisporites cf. traversii* EDIGER & ALISAN 1989  
(Pl. 10/Fig. 3)

1969: *Monoporisporites* sp. A.- HOPKINS, Jr. 1969: 1126: Pl. 11/166.

1989: *Monoporisporites traversii* n. sp.- EDIGER & ALISAN 1989: 154: Pl. 2/6.

2000: *Monoporisporites traversii* comb. nov.- KALGUTKAR & JANSONIUS 2000: 182-183: Pl. 3/7.

Diagnosis: See KALGUTKAR & JANSONIUS (2000: 178)

Remarks: The spore outline is somewhat teardrop-shaped, monoporate, pore not more than 3 µm in diameter, unicellular, smooth and brown in color. Hopkins (1969: 1126: Pl. 11/166) illustrates a spore with similar dimensions and shape.

Dimensions: Ø overall= 32-34µm (n=3)

Stratigraphic range:

Middle?-Upper Eocene to Upper Oligocene, Miocene-Pliocene (Kalgutkar & Jansonius, 2000)  
Middle Eocene, Southwest British Columbia (Hopkins, 1969)

***Monoporisporites lagenarius* SONG & LUO 1989**  
(Pl. 10/Fig. 4)

1989: *Monoporisporites lagenarius* n. sp.- SONG & LUO 1989: 38: Pl. 2/15.

2000: *Monoporisporites lagenarius*.- KALGUTKAR & JANSONIUS 2000: 178-179: Pl. 3/33.

Diagnosis: See KALGUTKAR & JANSONIUS (2000:178-179)

Dimesions: LxB overall= 40 x 36 µm (n= 4)

Stratigraphic range:

Lower -Middle Oligocene, China (Song & Luo, 1989)

**Genus *Striadiporites* VARMA & RAWAT 1963**

1963: *Striadiporites* n. gen.- VARMA & RAWAT 1963: 137.

1974: *Striadiporites* emend.- ELSIK & JANSONIUS 1974: 954.

Type species *Striadiporites reticulatus* VARMA & RAWAT 1963

***Striadiporites crucistriatus* sp. nov.**  
(Pl. 10/Fig. 7)

Holotype: Slide No. PP-8B; England Finder reference (38K4); Jarillal Formation, Pike-1X well; Depth 286,5-292,6 m.

Etymology: Named for cross-shaped striation as ornament.

Description: Monocellular.. Diporate, pores 8 µm in diameter. Ellipsoidal, shape of outline is laterally slightly convex. Outer layer (1.5- 2 µm) thicker than the inner one (0.5 µm). Exine with two muri, cross shaped, a single murus (width 3 µm) well-developed along principal spore axis and other murus not present; ridges of the surface parallel to equatorial axis (8 µm with). The spore is divided into four triangular lumina (10 µm with x 24 µm high), approximately similar in size. The exine is perforated by small pointed pores.

Dimensions: LxB overall= 72-74 x 34-36 µm (n= 15)

Comparison: The present specie differs from *S. dolium* (Ke & Shi, 1978) in its smaller size and the single striation along the major axis and in the size than is more smaller.

***Striadiporites cf. irregularis* KALGUTKAR 1993**  
(Pl. 10/Fig. 8)

1993: *Striadiporites irregularis* n. sp.- KALGUTKAR 1993: 88: Pl. 4.4/12.

2000: *Striadiporites irregularis*.- KALGUTKAR & JANSONIUS 2000: 289: Pl. 5/17.

Diagnosis: See KALGUTKAR & JANSONIUS (2000: 289)

Remarks: Unicellular, fusiform fungal spore, diporate, pores 5 µm in diameter, well developed, exine reticulate with tendency of muri (2 µm wide) and lumina that are perforated by diminute pores.

Dimensions: LxB overall= 66-68 x 40-44 µm (n= 4)

Stratigraphic range:

Upper Paleocene-Lower Eocene, Northwest Territories, Canada (Kalgutkar, 1993)

***Striadiporites reticulatus* VARMA & RAWAT 1963**  
(Pl. 10/Fig. 6)

1963: *Diporisporites reticulatus* n. sp.- VARMA & RAWAT 1963: 137.

1968: *Striadiporites reticulatus* nom. nud.- ELSIK 1968.

2000. *Striadiporites reticulatus*.- KALGUTKAR & JANSONIUS 2000: 290: Pl. 5/14.



Diagnosis: See KALGUTKAR & JANSONIUS (2000: 290)

Remarks: Ellipsoidal in shape, dark brown, diporate fungal spore, 12 luminae. Pores 6-8 µm in diameter.

Dimensions: LxB overall= 46-50 x 32-34 µm (n= 4)

Stratigraphic range:

Upper Oligocene-Lower Miocene, India (Varma & Rawat, 1963)

## DICELLATE FUNGAL SPORES

### Genus *Didymoporisporonites* SHEFFY & DILCHER 1971, emend. KALGUTKAR & JANSONIUS 2000

1971: *Didymoporisporonites* n. gen.- SHEFFY & DILCHER 1971: 42.

2000: *Didymoporisporonites* emend.- KALGUTKAR & JANSONIUS 2000: 76.

Type species *Didymoporisporonites psilatus* SHEFFY & DILCHER 1971

#### *Didymoporisporonites poratus* sp. nov. (Pl. 10/Fig. 5)

Holotype: Slide No. PP-35A; England Finder reference (58E); Jarillal Formation, Pike-1X well; Depth 1066.7 m.

Etymology: Named for the compound pore in the terminal cell.

Description: Spore two cells, monoporate, dicellate. Teardrop shape. The proximal cell is smooth, hyaline and contains a compound pore of 12 µm in diameter, other cell is opaque and wall is perforated by diminutive small pores which are not uniformly distributed on the surface of the cell. Wall 1.5-2 µm thick.

Dimensions: LxB overall= 68 x 46 µm (n= 10)

Comparison: The compound pore present in the proximal cell and the size distinguishes *Didymoporisporonites poratus* from the others species of genus.

### Genus *Fusiformisporites* ROUSE 1962 emend. ELSIK 1968

1962: *Fusiformisporites* n. gen.- ROUSE 1962: 210.

1968: *Fusiformisporites* emend.- ELSIK 1968: 269.

Type species *Fusiformisporites crabbii* ROUSE 1962

#### *Fusiformisporites crabbii* ROUSE 1962 (Pl. 10/Fig. 11)

1962: *Fusiformisporites crabbii* n. sp.- ROUSE 1962: 210: Pl. 4/27-29.

1993: *Fusiformisporites* sp.- KALGUTKAR 1993: Pl. 4.2/24.

1997: *Fusiformisporites crabbii*.- ROUSE & NORRIS 1997: Pl. 30/2; 31/15.

1999: *Fusiformisporites crabbii*.- PARSONS & NORRIS : 122: Pl. 4/17-18.

Diagnosis: Parsons & Norris (1999: 122)

Dimensions: LxB overall= 54-56 x 30-32 µm (n= 4)

Stratigraphic range:

Middle Eocene, British Columbia Canada (Rouse, 1962)

Lower Eocene, Yukon Territory Canada (Kalgutkar, 1993; Parsons & Norris, 1999)

#### *Fusiformisporites rugosus* SHEFFY & DILCHER 1971 (Pl. 10/Fig. 9)

1971: *Fusiformisporites rugosus* n. sp.- SHEFFY & DILCHER 1971: 48: Pl. 16/73.

1989: *Fusiformisporites rugosus*.- EDIGER & ALISAN 1989: Pl. III/9.

Diagnosis: See SHEFFY & DILCHER (1971: 48)

Dimensions: LxB overall= 40-42 x 16-18µm (n=4)

Stratigraphic range :

Upper Eocene-Lower Oligocene, Turkey (Ediger & Alisan, 1989)

Middle Eocene, Tenese USA (Sheffy & Dilcher, 1971)

***Fusiformisporites septatus* sp. nov.**  
(Pl. 10/Fig. 10)

Holotype: Slide No. PP-35A; England Finder reference (43C); Jarillal Formation, Pike-1X well; Depth 1066.7 m.

Etymology: Named for broad septum.

Description: Spore dicellate, inaperturate, with sides generally convex, rhomboidal in shape. The cells are all similar in shape and size and the acuminate apices are subrounded, 3.5- 4  $\mu\text{m}$  thick. Septum 5-5.3  $\mu\text{m}$ . Fungal spores with striate spore wall approximately 0.30  $\mu\text{m}$  thick.

Dimensions: LxB= 45-46 x 32.5-33  $\mu\text{m}$  (n= 12)

Comparison: In *Fusiformisporites foedus* (Salujha, Kindra & Rehman, 1974) the septum is smaller (2-2.5 wide) and oval in shape. *F. keralensis* (Ramanujam & Rao, 1978) differs from *F. septatus* sp.nov. by its numerous striae and the truncate terminations.

**MULTICELLATE FUNGAL SPORES**

**Genus *Brachysporisporites* LANGE & SMITH 1971**

1971: *Brachysporisporites* n. gen.- LANGE & SMITH 1971: 677.

1981: *Brachysporites* emend.- EDIGER 1981a: 93.

Type species *Brachysporisporites pyriformis* LANGE & SMITH 1971.

***Brachysporisporites jarillalensis* sp. nov.**  
(Pl. 11/Fig. 1)

Holotype: Slide No. PP-1A; England Finder reference (47R4); Jarillal Formation, Pica-1X well; Depth 304 ft.

Etymology: Named for the Jarillal Formation.

Description: Fungal spore, smooth, opaque. Tetracellate, typical pyriform shape and aperturate. The distal cells are separated by a thick septum, 7.8-8  $\mu\text{m}$  wide. Small apical cell is rectangular and hyaline, 7-7.5 wide and 1-1.5  $\mu\text{m}$  high.

Dimensions: LxB= 60-62 x 40-42  $\mu\text{m}$  (n= 10)

Comparison: *Brachysporisporites atratus* (Kalgutkar, 1993) has an ellipsoidal shape; in *B. cotalis* (Elsik & Jansonius) Norris 1986 the septum is indistinctly perforate; *B. pyriformis* (Lange & Smith 1971) differs from *B. jarillalensis* in being 50 % larger.

**Genus *Dictyosporites* FELIX 1894, emend. KALGUTKAR & JANSONIUS 2000**

1894: *Dictyosporites* n. gen.- FELIX 1894: 277.

1971: *Pleosporonites*.- LANGE & SMITH 1971.

2000: *Dictyosporites* emend.- KALGUTKAR & JANSONIUS 2000: 72.

Type species *Dictyosporites loculatus* FELIX 1894

***Dictyosporites odremanensis* sp. nov.**  
(Pl. 11/Fig. 2)

Holotype: Slide No. PP-1A; England Finder reference (47R3); Jarillal Formation, Pike-1X well; Depth 30.4 m.

Etymology: Named in honor of Prof. Oscar Odreman.

Description: Fungal spore, inaperturate, smooth, slightly opaque, oval shape, multicellate (16-18 cells), with internal septation 3.5-4  $\mu\text{m}$  wide, dark colored. Right side slightly larger than left one. The cells in the middle part of the spore are small and of approximately uniform size and aligned along the major axis. Lateral cells are rectangular in shape and similar in size. Exine is psilate, light colored.

Dimensions: LxB= 70-72 x 53-54  $\mu\text{m}$  (n= 10)

Comparison: *Dictyosporites odremanensis* differs from all other older and younger species of *Dictyosporites* by its distinct morphology.

***Dictyosporites morularis* SALARD-CHEBOLDAEFF & LOCQUIN 1980**  
(Pl. 11/Fig. 4)

1980: *Pleosporonites morularis* n. sp.- SALARD-CHEBOLDAEFF & LOCQUIN 1980: 190: Pl. 3/22.  
2000: *Dictyosporites morularis*.- KALGUTKAR & JANSONIUS 2000: 74: Pl. 15/32.

Diagnosis: See KALGUTKAR & JANSONIUS (2000: 74)

Dimensions: LxB overall= 60-62 x 44-46  $\mu\text{m}$  (n= 4)

Stratigraphic range:

Oligocene, Equatorial Africa (Salard-Cheboldaeff & Locquin, 1980)

***Dictyosporites cf. moruloides* SALARD-CHEBOLDAEFF & LOCQUIN 1980**  
(Pl. 11/Fig. 3)

1980: *Pleosporonites moruloides* n. sp.- SALARD-CHEBOLDAEFF & LOCQUIN 1980: 190: Pl. 3/3.  
2000: *Dictyosporites moruloides* comb. nov.- KALGUTKAR & JANSONIUS 2000: 74: Pl. 15/25.

Diagnosis: See KALGUTKAR & JANSONIUS (2000: 74)

Dimensions: LxB overall= 46-48 x 46-48  $\mu\text{m}$  (n= 5)

Stratigraphic range:

Lower Miocene, Equatorial Africa (Salard-Cheboldaeff & Locquin, 1980)

**Genus *Diporipollis?* DUTTA & SAH 1970 emend. KALGUTKAR & JANSONIUS 2000**

1970: *Diporipollis* n. gen.- DUTTA & SAH 1970: 45.  
2000: *Diporipollis* emend.- KALGUTKAR & JANSONIUS 2000: 90.

Type species *Diporipollis assamicus* DUTTA & SAH 1970: 45.

***Diporipollis? cf. melanii* (ELSIK) comb. nov.**  
(Pl. 11/Fig. 5)

1968: *Pluricellaesporites melanii* n. sp.- ELSIK 1968: 276: Pl. 3/4.  
1974: *Granatisporites melanii* (ELSIK).- ELSIK & JANSONIUS 1974.  
2000: *Diporipollis? Melanii*.- KALGUTKAR & JANSONIUS 2000: 90: Pl. 7/26.

Diagnosis: See KALGUTKAR & JANSONIUS (2000: 90)

Remarks: Tetracellate spore, with subspherical basal chamber 64  $\mu\text{m}$  in diameter, distal cell tapering, small and porate. This species is larger in size than *D. melanii*.

Dimensions: LxB overall= 88-90 x 64-66  $\mu\text{m}$  (n= 4)

Stratigraphic range:

Paleocene, Texas, USA (Elsik, 1968)

**Genus *Involutisporonites* CLARKE 1965**

1965: *Involutisporites* n. gen.- CLARKE 1965: 90.

Type species *Involutisporonites foraminus* CLARKE 1965: 90.

***Involutisporonites foraminus* CLARKE 1965**  
(Pl. 11/Fig. 7)

1965: *Involutisporonites foraminus* n. sp.- CLARKE 1965: 90: Pl. 1/11.

Diagnosis: See KALGUTKAR & JANSONIUS (2000: 156)

Remarks: Coiled aggregates of five cells, planispiral, multiseptate, psilate, individual cells lobate, absence of a pore in each septum.

Dimensions: LxB overall= 56 x 48  $\mu\text{m}$  (n= 3)

Stratigraphic range:

Upper Cretaceous, Colorado USA (Clarke, 1965)

***Involutisporonites cf. foraminus* CLARKE 1965**  
(Pl. 11/Fig. 6)

1965: *Involutisporonites foraminus* n. sp.- CLARKE 1965: 90:Pl. 1/11.

Diagnosis: See KALGUTKAR & JANSONIUS (2000: 156)

Remarks: Fungal spore of 10 rectangular cells of different size decreasing towards apical chamber, spiral, psilate, septate.

Dimensions: LxB overall= 42-44 x 39-40  $\mu\text{m}$  (n= 4)

Stratigraphic range:

Upper Cretaceous, Colorado USA (Clarke, 1965)

***Involutisporonites trapezoides* KALGUTKAR 1993**  
(Pl. 11/Fig. 8)

1993: *Involutisporonites trapezoides* n. sp.- KALGUTKAR 1993: 82: Pl. 4.2/25.

Diagnosis: See KALGUTKAR & JANSONIUS (2000: 156)

Remarks: Spore planispiral, individual cells rectangular and unequal in size. Septa always perforated and slightly thicker than wall.

Dimensions: LxB overall= 46-48 x 38-40  $\mu\text{m}$  (n= 4)

Stratigraphic range:

Upper Paleocene-Lower Eocene, Canada (Kalgutkar 1993)

**Genus *Marthurisporites* MARTHUR & MARTHUR 1969 emend. KALGUTKAR & JANSONIUS 2000**

1969: *Pluricellaesporites*.- MARTHUR & MARTHUR 1969: 3.

2000: *Marthurisporites* nov. gen.- KALGUTKAR & JANSONIUS 2000: 166.

Type species *Marthurisporites ellipticus* comb. nov.- MARTHUR & MARTHUR 1969

***Marthurisporites glomeratus* SRIVASTAVA 1968**  
(Pl. 11/Fig. 13)

1968: *Pluricellaesporites glomeratus* n. sp.- SRIVASTAVA 1968: 1116: Pl. 1/8.

2000: *Marthurisporites glomeratus* comb. nov.- KALGUTKAR & JANSONIUS 2000: 167: Pl. 12/43.

Diagnosis: See Kalgutkar & Jansonius (2000: 166-167)

Remarks: Fungal spore, composed of 6 cells, apical cell hyaline and triangular (6 x 10  $\mu\text{m}$ ) in shape, distal cell hyaline rectangular and porate (4  $\mu\text{m}$  in diameter).

Dimensions: LxB overall= 64-68 x 30  $\mu\text{m}$  (n=4)

Stratigraphic range:

Maastrichtian, Alberta, Canada (Srivastava, 1968)

**Genus *Multicellites* KALGUTKAR & JANSONIUS 2000**

2000: *Multicellites* n. gen.- KALGUTKAR & JANSONIUS 2000: 188-189.

Type species *Multicellites tener* KE & SHI 1978:39

***Multicellites cingulatus* KE & SHI 1978**  
(Pl. 11/Fig. 11)

1978: *Multicellaesporites cingulatus* n. sp.- KE & SHI 1978: 35: Pl. 2/14.

2000: *Multicellites cingulatus* comb. nov.- KALGUTKAR & JANSONIUS 2000: 189: Pl. 11/20.

Diagnosis: See Kalgutkar & Jansonius (2000: 189)

Dimensions: LxB overall= 64-65 x 20-22  $\mu\text{m}$  (n=8)

Stratigraphic range:

Eocene-Oligocene (Kalgutkar & Jansonius, 2000)

***Multicellites grandiusculus* SHEFFY & DILCHER 1971**  
(Pl. 11/Fig. 10)

1971: *Multicellaesporites grandiusculus* n. sp.- SHEFFY & DILCHER 1971: 45: Pl. 16/51.  
2000: *Multicellites grandiusculus* comb. nov.- KALGUTKAR & JANSONIUS 2000: 191: Pl. 11/22.

Diagnosis: See Kalgutkar & Jansonius (2000: 191)

Dimensions: LxB overall 50-52 x 19-20  $\mu\text{m}$  (n=3)

Stratigraphic range:

Middle Eocene, Tennessee, USA (Sheffy & Dilcher, 1971)

***Multicellites cf. ovatus* SHEFFY & DILCHER 1971**  
(Pl. 11/Fig. 9)

1971: *Multicellaesporites ovatus* n. sp.- SHEFFY & DILCHER 1971: 44: 16/44.  
2000: *Multicellites ovatus* comb. nov.- KALGUTKAR & JANSONIUS: 193: Pl. 11/14.

Diagnosis: See Kalgutkar & Jansonius (2000: 193)

Remarks: Tetracellate spore, uniserial, inaperturate, with three septa, dark with two septal folds, the septal thickness decreases towards the proximal cell that is smaller than the other cells. Size is bigger than in *M. ovatus*.

Dimensions: LxB overall 46-48 x 32-34  $\mu\text{m}$  (n=4)

Stratigraphic range:

Middle Eocene, Tennessee USA (Sheffy & Dilcher, 1971)

***Multicellites sp. A***  
(Pl. 11/Fig. 12)

Remarks: Multicellate, uniserial, inaperturate fungal spore, consists of five cells, outline elliptical. Spore slightly constricted at septa. Septa hyaline, 1.5  $\mu\text{m}$  wide and perforate. Cells at each end subcircular in shape.

Dimensions: LxB overall= 74-76 x 26-30  $\mu\text{m}$  (n=4)

**Genus *Octosporites* SALARD-CHEBOLDAEFF & LOCQUIN 1980**

1980: *Octosporinities* nom. nud.- SALARD-CHEBOLDAEFF & LOCQUIN 1980: 190.  
2000: *Octosporites*.- KALGUTKAR & JANSONIUS 2000: 198.

Type species *Octosporites saturoides* SALARD-CHEBOLDAEFF & LOCQUIN 1980

***Octosporites? cf. saturoides* SALARD-CHEBOLDAEFF & LOCQUIN 1980**  
(Pl. 12/Fig. 1)

1980: *Octosporites saturoides* n. sp.- SALARD-CHEBOLDAEFF & LOCQUIN 1980: 190: Pl. 3/20.  
2000: *Octosporites saturoides*.- KALGUTKAR & JANSONIUS 2000: 198: Pl. 19/8.

Diagnosis: See Kalgutkar & Jansonius (2000: 198)

Dimensions:  $\emptyset$  overall= 30-32  $\mu\text{m}$ ; LxB cross 24 x 4  $\mu\text{m}$  (n=4)

Stratigraphic range:

Lower Miocene, Equatorial Africa (Salard-Cheboldaeff & Locquin, 1980)

**Genus *Papulosporinities* SCHMIEDEKNECHT & SCHWAB 1964**

1964: *Papulosporonites* n. gen.- SCHMIEDEKNECHT & SCHWAB 1964: 686.

Type specie *Papulosporinities sphaeromorphus* SCHMIEDEKNECHT & SCHWAB 1964

***Papulosporinities mohgaoensis* CHITALEY & YAWALE 1978**  
(Pl. 12/Fig. 2)

1978: *Sorosporium mohgaoenses* n. sp.- CHITALEY & YAWALE 1978: 190: Pl. 1/1.  
2000: *Papulosporinities mohgaoensis* comb. nov.- KALGUTKAR & JANSONIUS 2000: 217: Pl. 18/6.

Remarks: See Kalgutkar & Jansonius (2000: 217)  
Dimensions: Ø overall= 42-43 µm (n=4)  
Stratigraphic range:  
 Upper Cretaceous, India (Chitale & Yawale, 1978)

Genus ***Paragranatisporites* ZHANG ZHONGYING 1980**

1980: *Paragranatisporites* n. gen.- ZHANG ZHONGYING 1980: 298.

Type species *Paragranatisporites lunpolaensis* ZHANG ZHONGYING 1980

***Paragranatisporites vermiculus* EDIGER 1981**  
 (Pl. 12/Fig. 5)

1981: *Pluricellaesporites vermiculus* n. sp.- EDIGER 1981a: 92: Pl. 2/7.

2000: *Paragranatisporites vermiculus* comb. nov.- KALGUTKAR & JANSONIUS: 219: Pl. 13/21.

Diagnosis: See Ediger (1981: 92)

Dimensions: LxB overall= 48-50 x 24-28 µm (n=4)

Stratigraphic range:

Upper Eocene-Oligocene, Miocene-Pliocene, Turkey (Ediger, 1981a)  
 Eocene-Oligocene, Indian Ocean (Kemp, 1978)

Genus ***Pluricellaesporites* VAN DER HAMMEN 1954 emend. ELSIK & JANSONIUS 1974**

1954: *Plucellaesporites* n. gen.- VAN DER HAMMEN 1954: 83.

1974: *Pluricellaesporites* emend.- ELSIK & JANSONIUS 1974: 955.

Type species *Plucellaesporites typicus* VAN DER HAMMEN 1954

***Pluricellaesporites trichocladites* KALGUTKAR 1997**  
 (Pl. 12/Fig. 4)

1997: *Plucellaesporites trichocladites* n. sp.- KALGUTKAR 1997: 221: Pl. 4/9.

2000: *Plucellaesporites trichocladites*.- KALGUTKAR & JANSONIUS 2000: 247-248: Pl. 12/15.

Diagnosis: See Kalgutkar & Jansonius (2000: 247-248)

Remarks: Fungal spore with four cells, opaque, asymmetrical along its axis, with a single aperture 4 µm in diameter. Septa inaperturate, brown and approximately of equal thickness (6 µm) and surface psilate.

Dimensions: LxB overall= 58-60 x 32-34 µm (n=3)

Stratigraphy range:

Upper Paleocene-Lower Eocene, Northwest Territories, Canada.

Genus ***Polyadosporites* VAN DER HAMMEN 1954 emend. KALGUTKAR & JANSONIUS 2000**

1954: *Polyadosporites* n. gen.- VAN DER HAMMEN 1954: 83.

2000: *Polyadosporites* emend.- KALGUTKAR & JANSONIUS 2000: 248.

Type species *Polyadosporites suescae* VAN DER HAMMEN 1954

***Polyadosporites suescae* VAN DER HAMMEN 1954**  
 (Pl. 12/Fig. 3)

1954: *Polyadosporites suescae* n. sp.- VAN DER HAMMEN 1954: 105: Pl. 21.

Diagnosis: See Kalgutkar & Jansonius (2000: 249)

Remarks: Spore composed of several united cells. Individual cells are spherical 12-14 µm in diameter, psilate. The aggregated upper cells are darker than the rest of the spore.

Dimensions: Ø clustered= 82-86 µm (n= 5)

Stratigraphic range:

Maastrichtian, Colombia (Van der Hammen, 1954)

**Genus *Staphlosporonites* SHEFFY & DILCHER 1971 emend. KALGUTKAR & JANSONIUS 2000**

1971: *Staphlosporonites* nov. gen.- SHEFFY & DILCHER 1971: 48.  
2000: *Staphlosporonites* emend.- KALGUTKAR & JANSONIUS 2000: 284.

Type species *Staphlosporonites conoideus* SHEFFY & DILCHER 1971

***Staphlosporonites* cf. *felixii* LANGE & SMITH 1971**  
(Pl. 12/Fig. 6, 10)

1971: *Dictyosporites felixii* nov. sp.- LANGE & SMITH 1971: 672:Pl. 6/A.  
2000: *Staphlosporonites felixii* comb. nov.- KALGUTKAR & JANSONIUS 2000: 285: Pl. 15/14.

Diagnosis: See Kalgutkar & Jansonius (2000: 285)  
Dimensions: LxB overall= 32 x 28  $\mu\text{m}$  (n=4)  
Stratigraphic range:  
Lower-Middle Eocene, South Australia (Lange & Smith, 1971)

**FUNGAL FRUITING BODIES**

**Genus *Appendicisporonites* SAXENA & KHARE 1992**

1992: *Appendicisporonites* n. gen.- SAXENA & KHARE 1992: 40.

Type specie *Appendicisporonites typicus* SAXENA & KHARE 1992

***Appendicisporonites typicus* SAXENA & KHARE 1992**  
(Pl. 12/Fig. 13)

1992: *Appendicisporonites typicus* n. sp.- SAXENA & KHARE 1992: 40: Pl. 1/1.  
2000: *Appendicisporonites typicus*.- KALGUTKAR & JANSONIUS 2000: 27: Pl. 19/1.

Diagnosis: See Kalgutkar & Jansonius (2000: 27)  
Dimensions:  $\emptyset$  body= 18-24  $\mu\text{m}$ ; Long processes= 18-20  $\mu\text{m}$  (n= 4)  
Stratigraphic range:  
Tertiary (Kalgutkar & Jansonius, 2000)

**Genus *Callimothallus* DILCHER 1965**

1965: *Callimothallus* n. gen.- DILCHER 1965: 13.  
1983: *Siwalikiathyrites*.- SAXENA & SINGH 1983.

Type species *Callimothallus pertusus* DILCHER 1965

***Callimothallus assamicus* KAR, SINGH & SAH 172**  
(Pl. 12/Fig. 9)

1970: *Callimothallus assamicus*,n. sp.- KAR, SINGH & SAH 1970: 151:Pl. 2/19-20.  
1978: *Callimothallus assamicus*.- KEMP 1978: 75: Pl. 1/7.  
1988: *Callimothallus assamicus*.- SARKAR & SINGH 1988: Pl. 6/22.  
2000: *Callimothallus assamicus*.- KALGUTKAR & JANSONIUS 2000: 46: Pl. 23/11.

Diagnosis: See Kalgutkar & Jansonius (2000: 46)  
Dimensions: LxB overall= 58-60 x 48-50  $\mu\text{m}$  (n=8)  
Stratigraphic range:  
Tertiary, Indian (Kar, Singh & Sah, 1970)  
Tertiary, Indian Ocean (Kemp, 1978)  
Eocene, India (Sarkar & Singh, 1988)

***Callimothallus pertusus* DILCHER 1965**  
(Pl. 12/Fig. 7, 8)

1965: *Callimothallus pertusus* n. sp.- DILCHER 1965: 13:Pl. 6/45.  
1985: *Callimothallus pertusus*.- DILCHER & KALGUTKAR 1985: 262: Pl. 31.1/1-4.  
1986: *Callimothallus pertusus*.- DILCHER & NORRIS 1986: 30: Pl. 6/4,6-9.  
1997: *Callimothallus pertusus*.- DILCHER & NORRIS 1997: Pl. 4/12.  
1999: *Callimothallus pertusus*.- PARSONS & NORRIS: 147:Pl. 13/1.

Diagnosis: See Dilcher (1965: 13)

Dimensions: Ø overall= 58-66 µm (n=8)

Stratigraphic range:

Lower to Middle Eocene, Northern Canada (Parsons & Norris, 1999)  
Upper Paleocene to Middle Eocene, Yukon Territory Canada (Kalgutkar, 1985)  
Eocene, Tennessee USA (Dilcher, 1965)

Genus ***Desmidiospora* THAXTER 1891**

1891: *Desmidiospora* nov. gen.- THAXTER 1891.

Type species *Desmidiospora myrmecophila* THAXTER 1891.

***Desmidiospora marginiconvoluta* KALGUTKAR 1997**  
(Pl. 12/Fig. 14)

1997: *Desmidiospora marginiconvoluta* nov. sp.- KALGUTKAR 1997: 209: Pl. 2/1.  
2000: *Desmidiospora marginiconvoluta*.- KALGUTKAR & JANSONIUS 2000: 62-63: Pl. 2/23.

Diagnosis: See Kalgutkar & Jansonius (2000: 62-63)

Dimensions: Ø overall= 18-20 µm (n= 4)

Stratigraphic range:

Upper Paleocene-Lower Eocene, Northwest Territories, Canada (Kalgutkar, 1997)

***Desmidiospora willoughbyi* (BRADLEY) ETHRIDGE GLASS, BROWN & ELSIK 1986**  
(Pl. 12/Fig. 15)

1967: *Entophlyctis willoughbyi* nov. sp.- BRADLEY 1967: 579: Fig. 6.  
1986: *Desmidiospora willoughbyi*.- Ethridge et al. 1986: 581.  
2000: *Desmidiospora willoughbyi*.- KALGUTKAR & JANSONIUS 2000: 63: Pl. 2/22.

Diagnosis: See Kalgutkar & Jansonius (2000: 63)

Dimensions: Ø overall= 24-26 µm (n=5)

Stratigraphic range:

Upper Eocene, Texas USA (Ethridge et al., 1986)  
Eocene, Colorado USA (Bradley, 1967)

Genus ***Kutchiathyrites* KAR 1979 emend. KALGUTKAR & JANSONIUS 2000**

1979: *Kutchiathyrites* n. gen.- KAR 1979: 32.  
2000: *Kutchiathyrites*.- KALGUTKAR & JANSONIUS 2000: 157.

Type species *Kutchiathyrites eccentricus* KAR 1979

***Kutchiathyrites palmatus* KE & SHI 1978**  
(Pl. 12/Fig. 11, 12)

1978: *Microthyracites palmatus* nov. sp.- KE & SHI 1978: 52: Pl. 5/14.  
2000: *Kutchiathyrites palmatus*.- KALGUTKAR & JANSONIUS 2000: 158: Pl. 18/2.

Diagnosis: See Kalgutkar & Jansonius (2000: 158)

Dimensions: LxB overall= 28-32 x 40-42 µm (n=3)

Stratigraphic range:

Eocene-Oligocene, China (Ke & Shi, 1978)



Genus ***Parmathyrites*** JAIN & GUPTA 1970

1970: *Parmathyrites* n. gen.- JAIN & GUPTA 1970: 177.

Type species *Parmathyrites indicus* JAIN & GUPTA 1970

***Parmathyrites cf. indicus*** JAIN & GUPTA 1970  
(Pl. 13/Fig. 6)

1970: *Parmathyrites indicus* n. sp.- JAIN & GUPTA 1970: 178: Pl. 1/1.

2000: *Paramathyrites indicus*.- KALGUTKAR & JANSONIUS 2000: 200: Pl. 25/4.

Diagnosis: See JAIN & GUPTA (1970: 178)

Dimensions: Long spines= 36-40  $\mu\text{m}$  (n=1)

Stratigraphic range:

Miocene, South India (Jain & Gupta, 1970)

Genus ***Plochmopeltinites*** COOKSON 1947a

1947: *Plochmopeltinites* n. gen.- COOKSON 1947a: 212: Pl. 13/14.

Type specie *Plochmopeltinites masonii* COOKSON 1947a

***Plochmopeltinites masonii*** COOKSON 1947  
(Pl. 13/Fig. 7)

1947: *Plochmopeltinites masonii* n. sp.- COOKSON 1947a: 212: Pl. 13/14,15.

1975: *Plochmopeltinites masonii*.- SELKIRK 1975: 84-85: Pl. 11/7-8; 12/1-4.

1986: *Plochmopeltinites masonii*.- NORRIS 1986: 28:Pl. 5/1-3.

1990: *Plochmopeltinites masonii*.- KALGUTKAR & MCINTYRE 1990: Pl. 1/21.

1999: *Plochmopeltinites masonii*.- PARSONS & NORRIS 1999: 150: Pl. 14/5-7.

Diagnosis: See Kalgutkar & Jansonius (2000: 237)

Dimensions:  $\emptyset$  overall= 140-160  $\mu\text{m}$  (n=6)

Stratigraphic range:

Oligocene-Miocene, Southern Australia (Cookson, 1947)

Middle Eocene–Miocene, Canada (Norris, 1986)

Lower Eocene, Northwest Territories, Canada (Kalgutkar & McIntyre, 1990)

**MYCELIAL HYPHAE**

**Hyphae Type A**  
(Pl. 13/Fig. 2)

Remarks: Branching and septate hyphae, cells 58  $\mu\text{m}$  long, 8  $\mu\text{m}$  wide, with branched conidiophore and conidium up to 18  $\mu\text{m}$  in diameter. Hyphal wall slightly thicker than septal wall.

Similar species have been found in Tertiary sediments on the Ninetyeast Ridge, Indian Ocean (Kemp, 1978).

**Hyphae Type B**  
(Pl. 13/Fig. 3)

Remarks: Overall length 160  $\mu\text{m}$ , septate and non-branching hyphae. Septa widely spaced, very slight constriction at the points of septal insertion.

**Hyphae Type C**  
(Pl. 13/Fig. 4)

Remarks: Filaments tubular, cylindrical, unbranched, septate. Length of septate cells 74-78  $\mu\text{m}$ . The septa are always perforate. Cell wall 2  $\mu\text{m}$  thick.

**Hyphae Type D**  
(Pl. 13/Fig. 8)

Remarks: Hyphae septate, smooth, distal termination tapering (1.5  $\mu\text{m}$  wide) and proximal termination rounded (10  $\mu\text{m}$  wide), hyphal wall 1.5  $\mu\text{m}$  thick.

**Hyphae Type E**  
(Pl. 13/Fig. 1)

Remarks: Hyphae septate, 150  $\mu\text{m}$  long, smooth, melanin color. Septa are closely spaced and not perforated.

In this section the most important conclusions are briefly presented. They are given following the sequence in which the different subjects have been treated in this study.

The assemblage consists of a total of 60 species of dinoflagellate cysts, 42 species of fungal remains and green algae and acritarchs. All these species are described and illustrated. A total of five new species of fungal remains are described: *Brachysporisporites jarillalensis*, *Dictyosporites odremanensis* sp., *Didymoporisporonites poratus* sp., *Fusiformisporites septatus* sp., *Striadiporites crosstriatus* sp.

Dinoflagellate cysts and Fungal remains are present in useful amounts in nearly all cores, cuttings and outcrop samples of the Middle to Late Eocene strata of Eastern Zulia sections studied. While pollen and spores are limited biostratigraphic value.

I consider the upper part of the Jarillal Formation to be Late Eocene, based on dinoflagellate cysts. This agrees with previous age determinations based on other microfossils.

Dinoflagellate cysts can be used throughout for zonation and correlation; however, key species for existing zonations are generally scarce or lacking. A local scheme was established based on the from the Pica-1X, VL-37X wells and Quebrada Bijugal, Quebrada Palma and Quebrada Bijugal outcrop sections. Still, sufficient age diagnostic species are present that allow identification of epochs. The dinocysts thus become particularly important in the Eocene sections where other biostratigraphic indicators are missing.

Dinoflagellate assemblages include several species that have been reported from the Middle to Late Eocene of Europe, North America and Asia. Quantitative comparison of the assemblages from other localities show high percentages of similarity, mainly with the assemblages from London Basin. The differences are considered to be related not only to climatic-latitude factors, but also to differences of the associated paleoenvironments of deposition.

Analysis of the relative distribution of the major categories of palynomorphs in the samples and of the most important dinocysts and fungi indicates that the Jarillal, Pauji formations were deposited in lower energy water relatively far from the coastline and Caus Formation was deposited in a marginal marine environment, under increasingly shallowing conditions.

Species diversity in dinoflagellate cysts shows a relationship with increase in foraminiferal test linings.

On the basis of fungal remains, I interpret the Eastern Zulia area during Middle to Late Eocene as representing a warm, tropical-subtropical and shallow, inner neritic to outer neritic environment.

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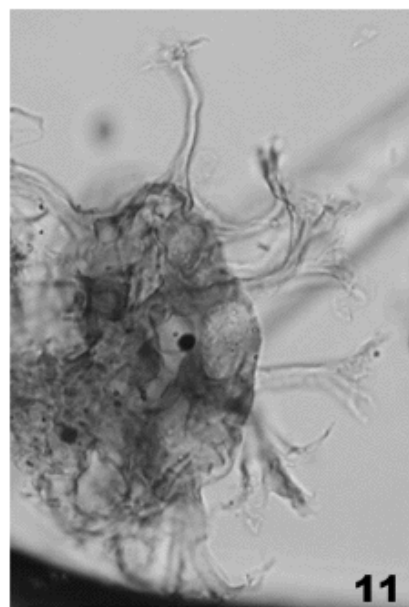
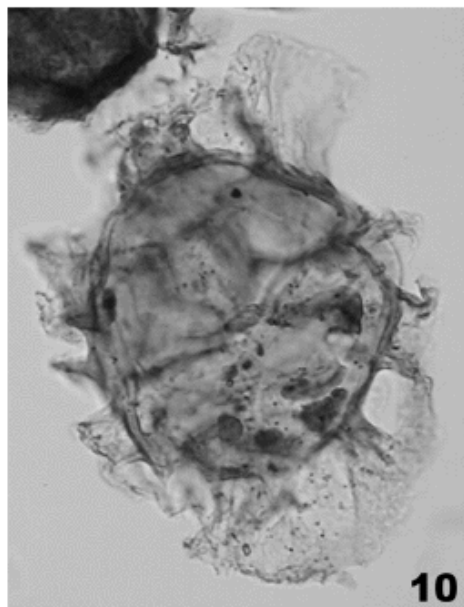
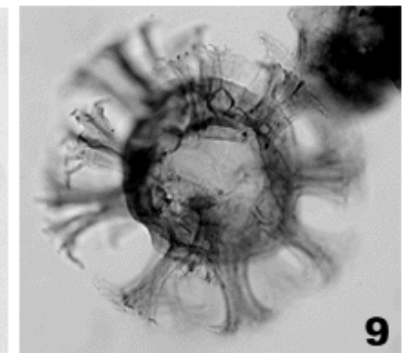
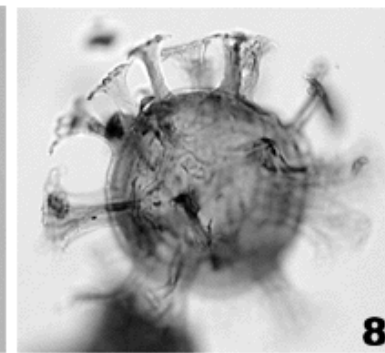
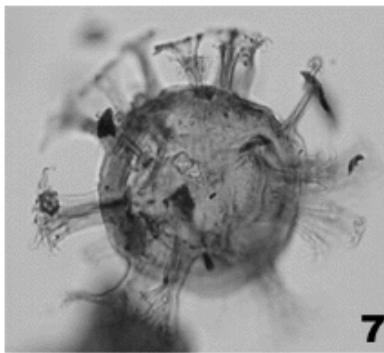
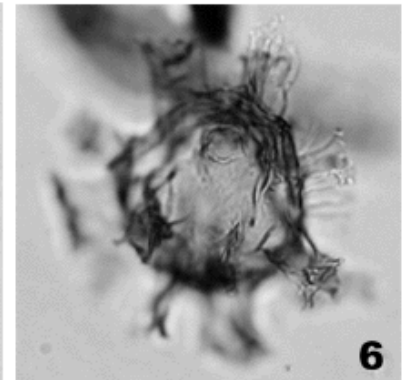
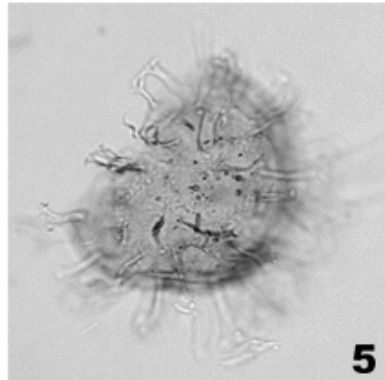
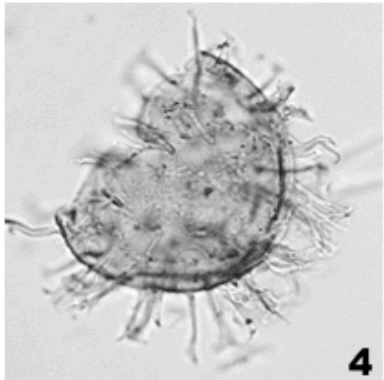
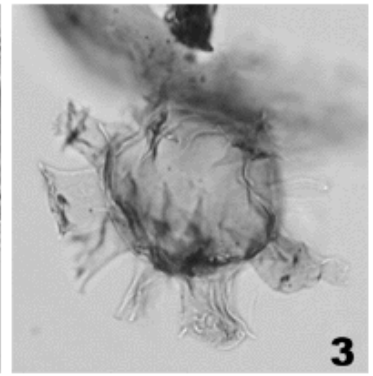
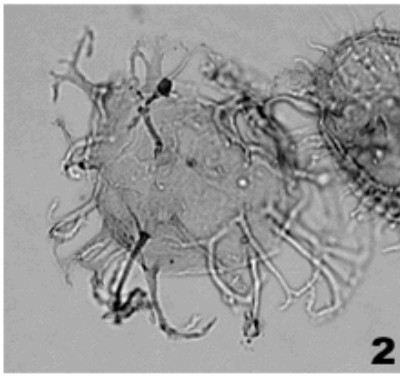
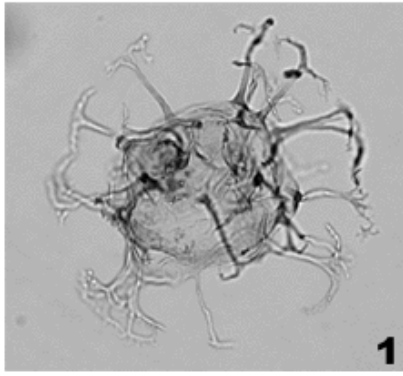
## **PLATES 1-13**

## PLATE 1

All figures 640x.

Fig.		Page
1	<b><i>Enneadocysta arcuatum</i></b> EATON 1971 Lateral views; surface of the body and shape of the processes. <i>Slide No. PP- 20A (40M2) [Pica-1X / 2357 ft]</i>	42
2	<b><i>Enneadocysta pectiniformis</i></b> (GERLACH 1961) STOVER & WILLIAMS 1995 Lateral views; surface of cyst and shape of the processes. <i>Slide No. PP-4A (36G3) [Pica-1X / 460 ft]</i>	42
11	<b><i>Cordosphaeridium cf. gracile</i></b> (EISENACK 1954) DAVEY & WILLIAMS 1966b Optical section; focused on the processes. <i>Slide No. PP-37A (35T1) [Pica-1X / 3610 ft]</i>	45
4, 5	<b><i>Systematosphora ? varibilis</i></b> (COOKSON & EISENACK 1967a) STOVER & EVITT 1978 4.- Ventral view; focused on the processes. Note the joined processes at the top of the picture. 5.- Ventral view; focused on the ventral surface. Arrow indicates the sulcal notch. <i>Slide No. PP-12A (32K2) [Pica-1X / 1432 ft]</i>	43
3, 6	<b><i>Achilleodinium biformoides</i></b> (EISENACK 1954b) EATON 1976 3.- Lateral view; focused on the archeopyle (arrow) and processes. 6.- Lateral view; focuse on the surface. <i>Slide No. PP-13A (53G4) [Pica-1X / 1554 ft]</i>	43
10	<b><i>Arenosphaera consociata</i></b> JAIN & TANDON 1976 Dorsal view; cingular zone devoid of processes and joined processes in the antapical region. <i>Slide No. PP-12A (43P) [Pica-1X / 1432 ft]</i>	44
7, 8, 9	<b><i>Cordosphaeridium cantharellum</i></b> (BROSIUS 1963) GOCHT 1969 7.- Antapical view; shape of the fibrous processes. 8.- Antapical view; focused on the surface. Same specimen as 7. 9.- Apical view; focused on the precingular archeopyle. <i>Slide No. PP-48A (45O) [Pica-1X / 4157 ft]</i>	44

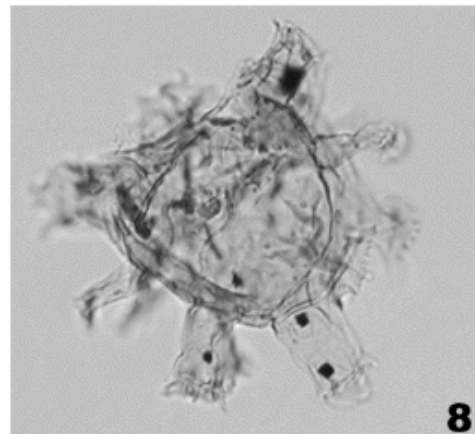
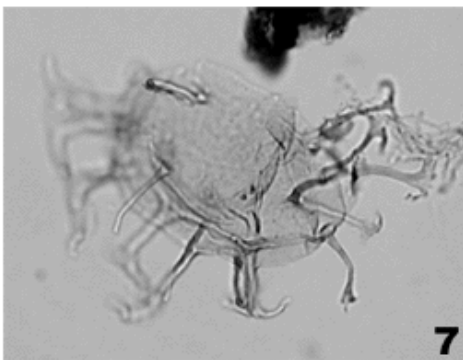
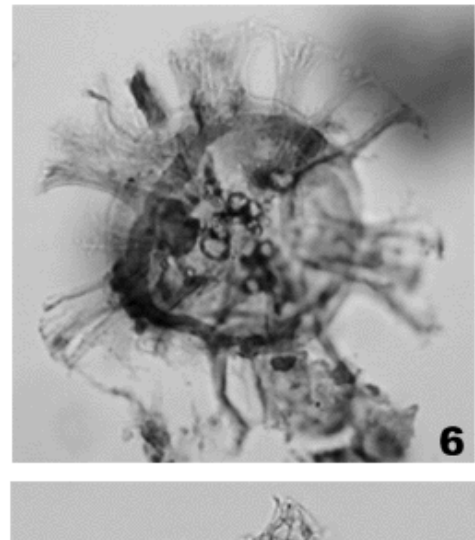
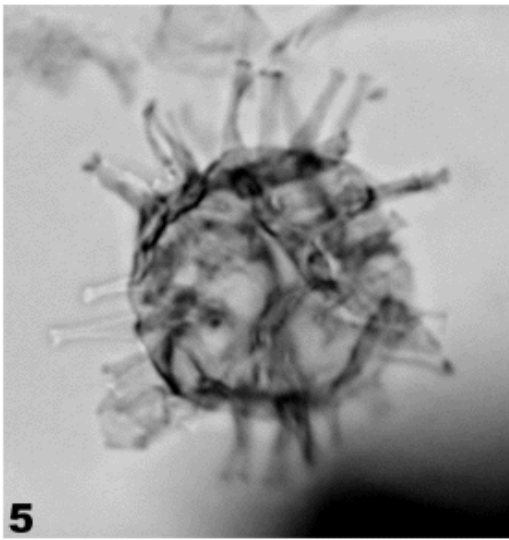
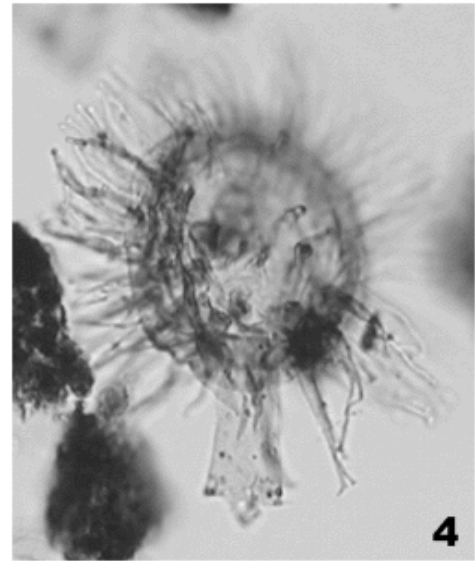
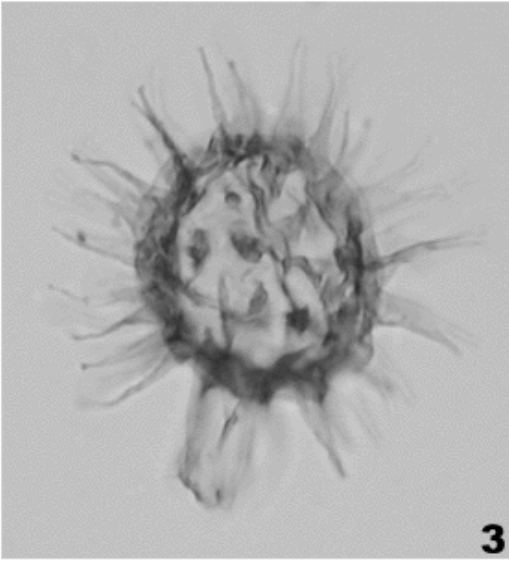
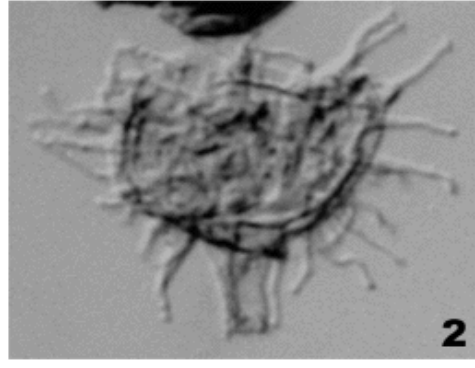
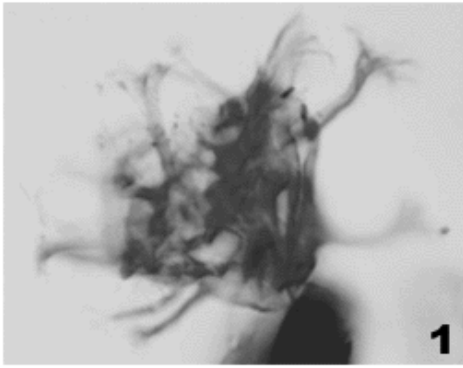




## PLATE 2

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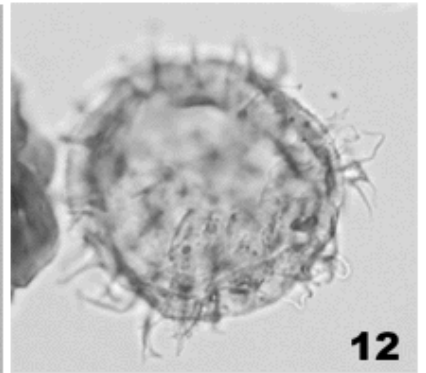
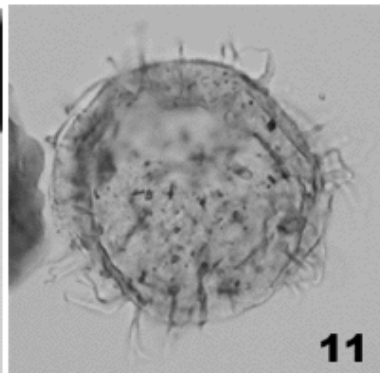
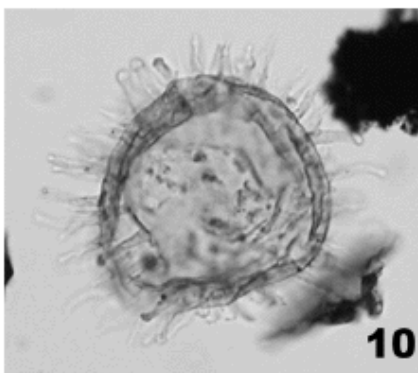
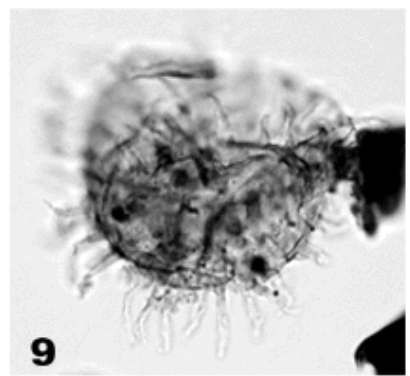
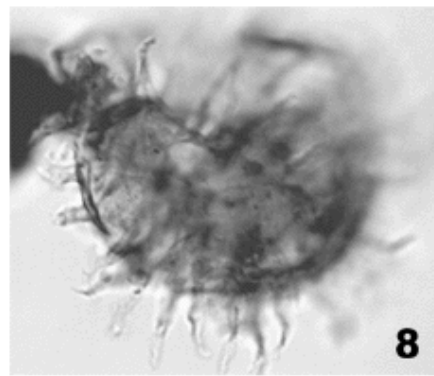
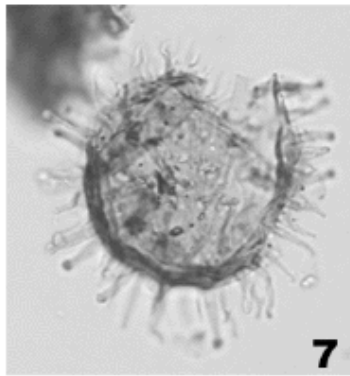
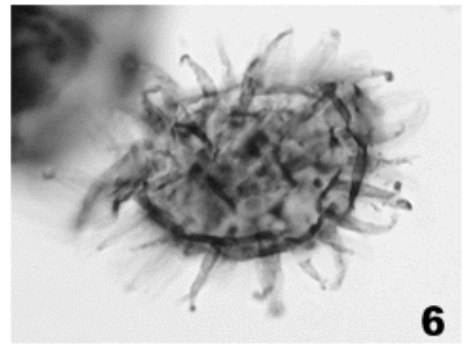
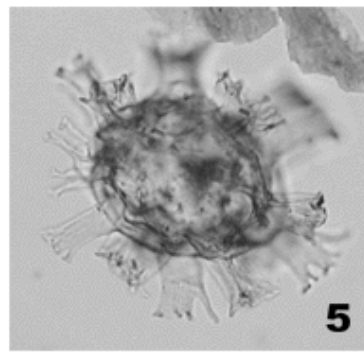
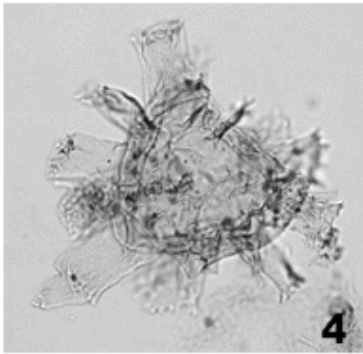
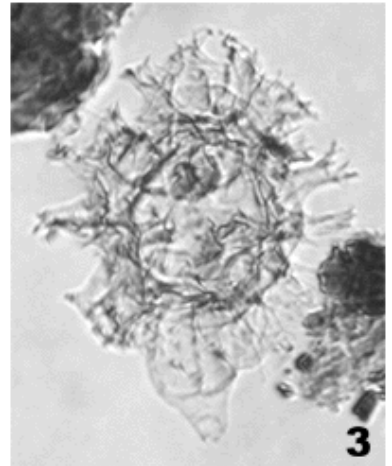
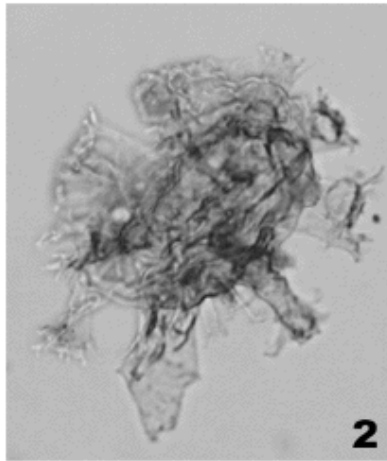
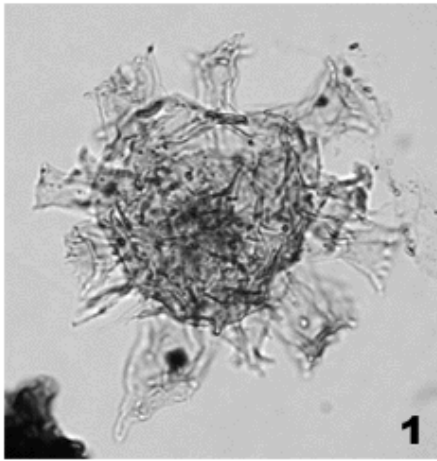
Fig.		Page
1	<p><b><i>Oligosphaeridium complex</i></b> (WHITE 1842) DAVEY &amp; WILLIAMS 1966b emend.            DAVEY &amp; WILLIAMS 1966b            Optical section; buccinate shape of the processes.  <i>Slide No. PP-</i> (21U2) [Pica-1X]            Magnification 500x</p>	43
2	<p><b><i>Diphyes cf. appendiculare</i></b> (COOKSON &amp; EISENACK 1970)            Ventral view; surface and shape of the processes.  <i>Slide No. PP-10A</i> (51D) [Pica-1X / 1170 ft]            Magnification 500X</p>	46
3, 4	<p><b><i>Diphyes spinulum</i></b> (DRUGG 1970b) STOVER &amp; EVITT 1978            3.- Ventral view; with attached operculum.            4.- Dorsal view; slender antapical process.  <i>Slide No. QB-1Ab</i> (39W1) [Quebrada Bijugal / 158,0 m]  <i>Slide No. QB-1Aa</i> (38W) [Quebrada Bijugal / 158,0 m]</p>	46
5	<p><b><i>Diphyes colligerum</i></b> (DEFLANDRE &amp; COOKSON 1955) COOKSON 1965 emend.            GOODMAN &amp; WITMER 1985            Optical section; broad antapical process.  <i>Slide No. PP-5A</i> (44V2) [Pica-1X / 580 ft]</p>	46
6	<p><b><i>Cordosphaeridium inodes</i></b> (KLUMPP 1953) EISENACK 1963b emend.            MORGENROTH 1968 emend. SARJEANT 1981            Antapical view; showing in detail the fibrous processes.  <i>Slide No. PP-41A</i> (24L3) [Pica-1X / 3818 ft]</p>	45
7	<p><b><i>Enneadocysta arcuatum</i></b> EATON 1971            Right lateral views; shape of the processes.  <i>Slide No. PP-20B</i> (44H1) [Pica-1X / 2357 ft]</p>	42
8	<p><b><i>Hystrichokolpoma cf. denticulata</i></b> MATSUOKA 1974            Ventral section, sulcal region.  <i>Slide No. PP-2A</i> (36Q) [Pica-1X / 220 ft]</p>	47



### PLATE 3

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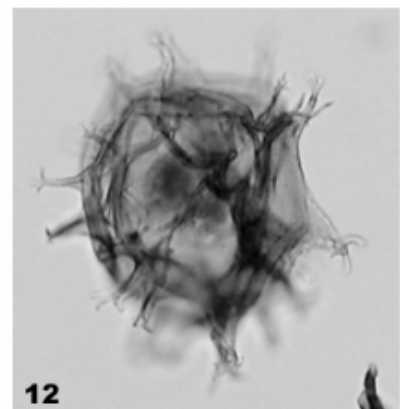
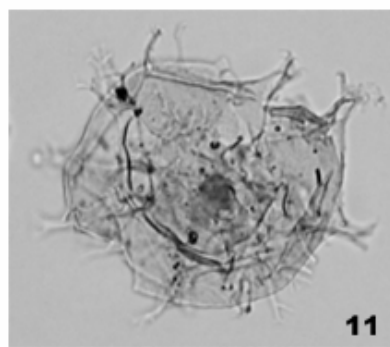
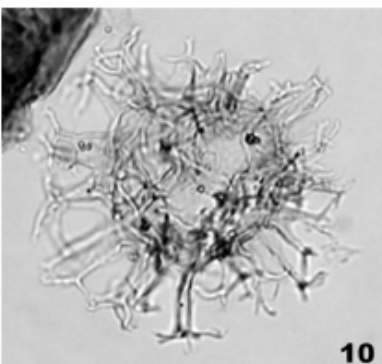
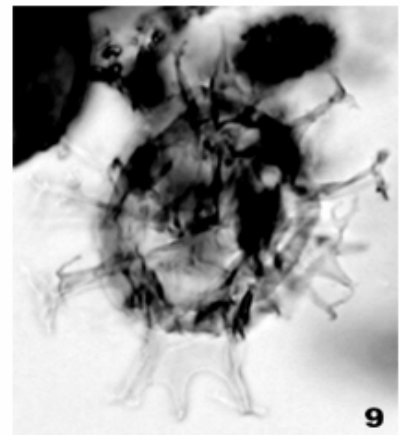
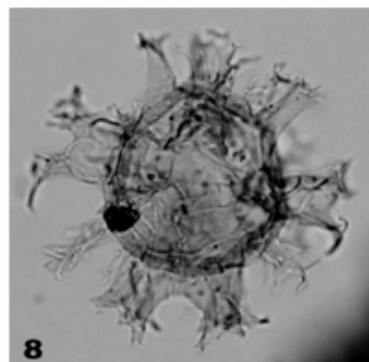
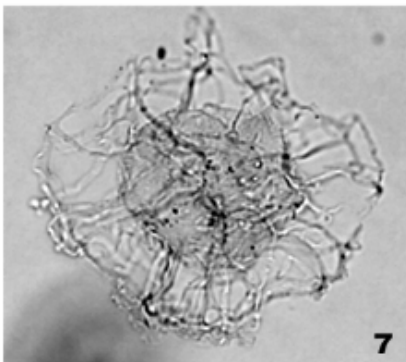
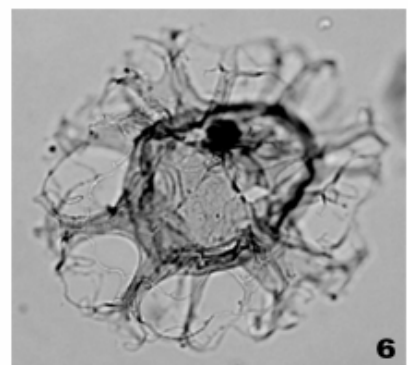
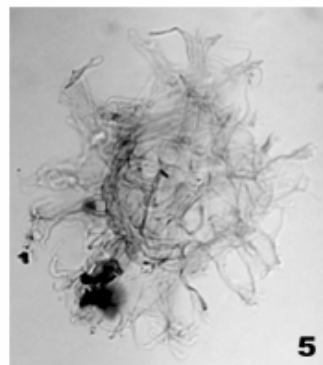
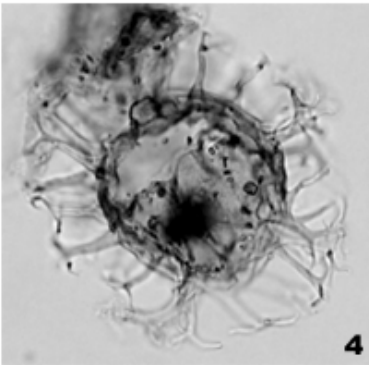
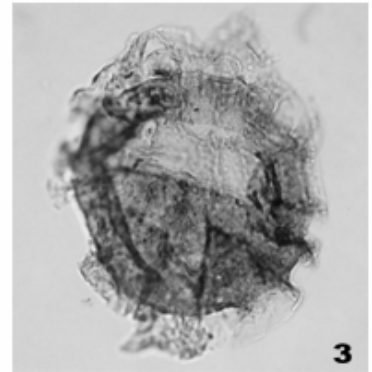
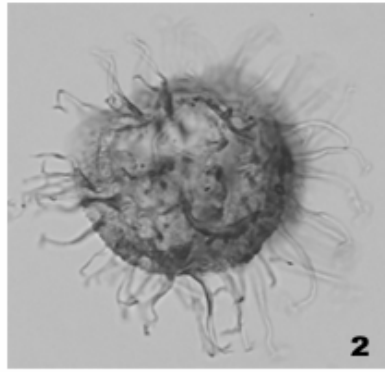
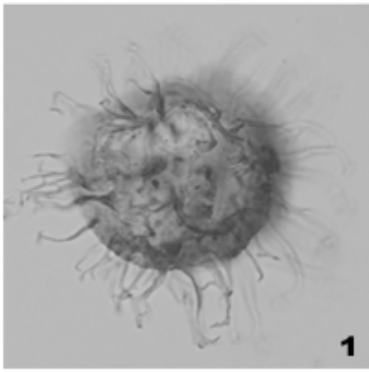
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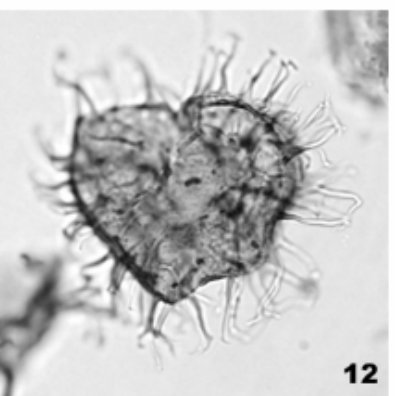
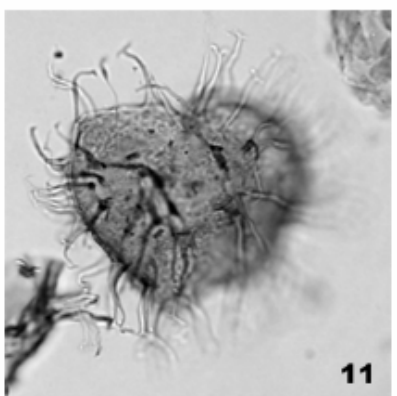
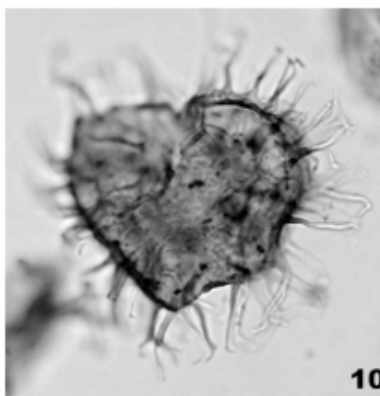
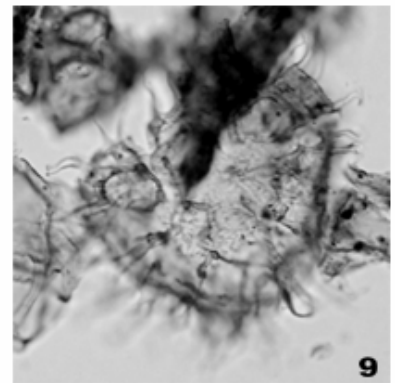
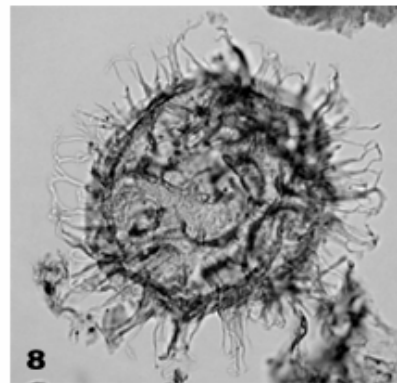
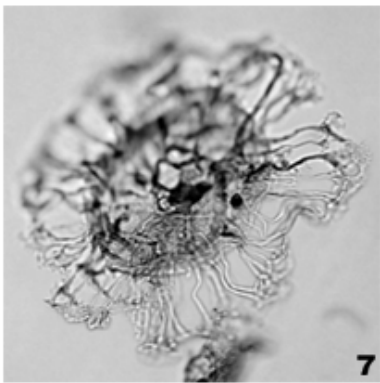
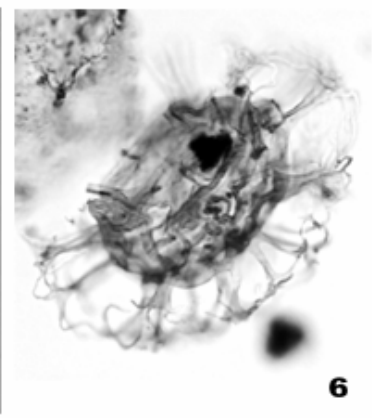
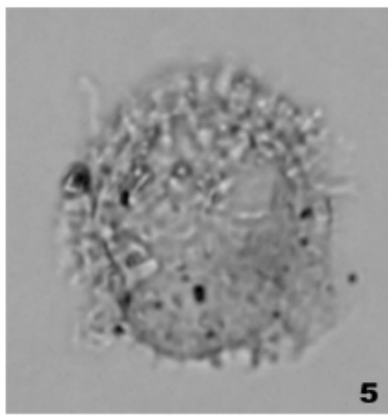
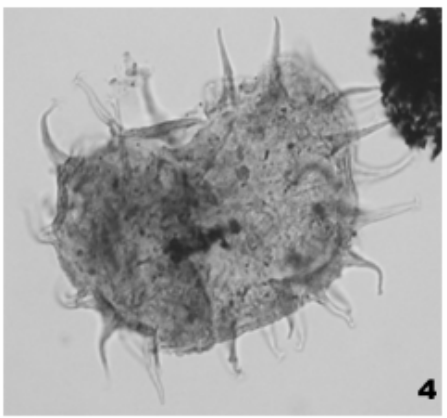
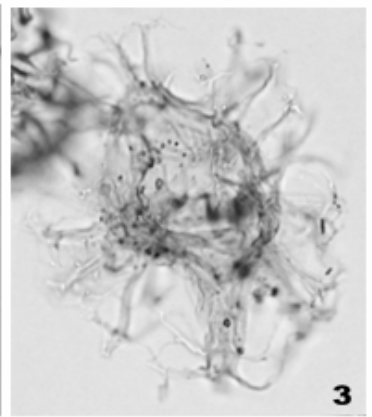
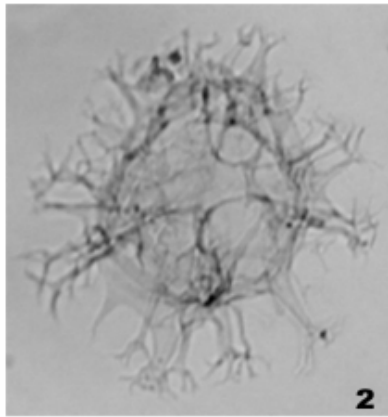
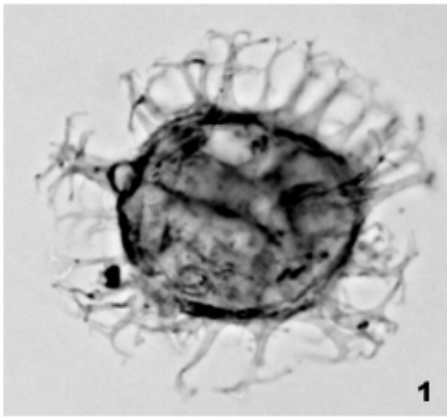


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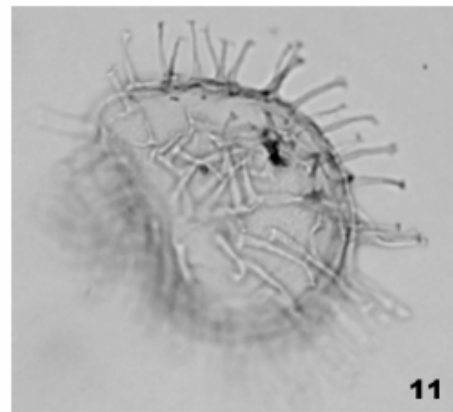
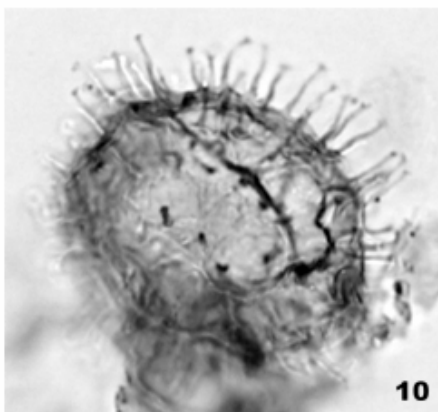
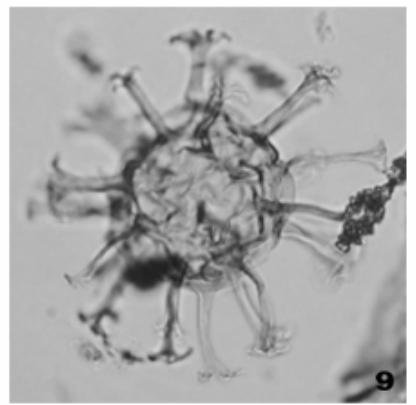
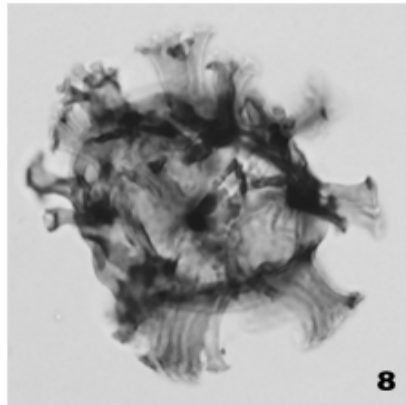
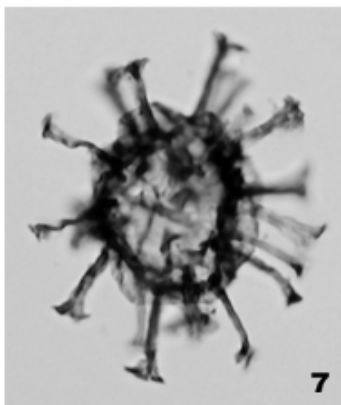
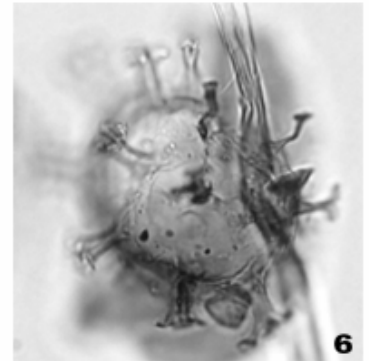
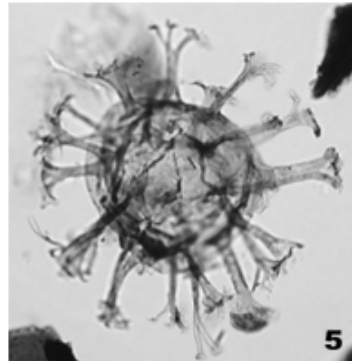
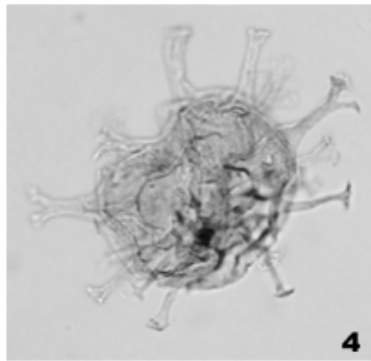
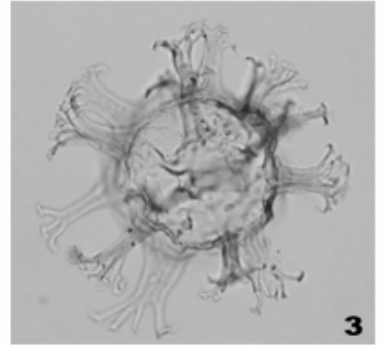
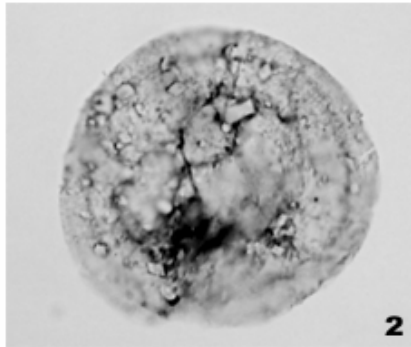
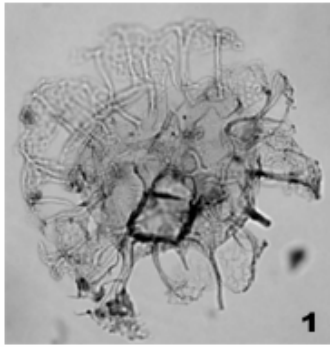




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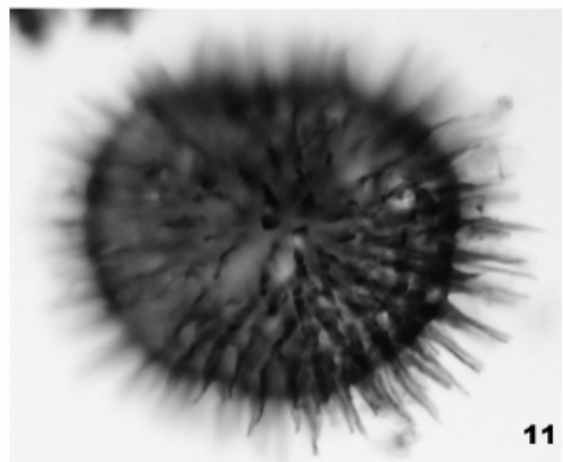
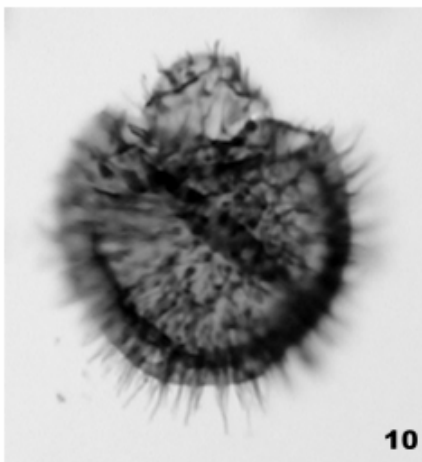
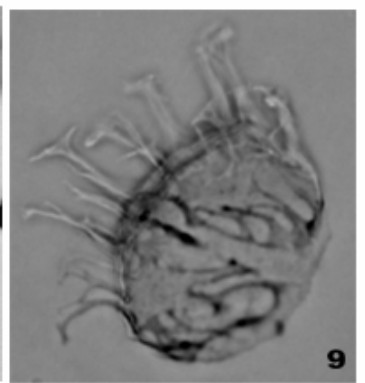
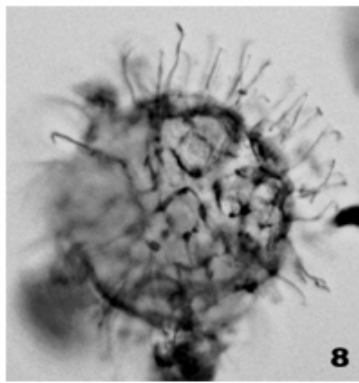
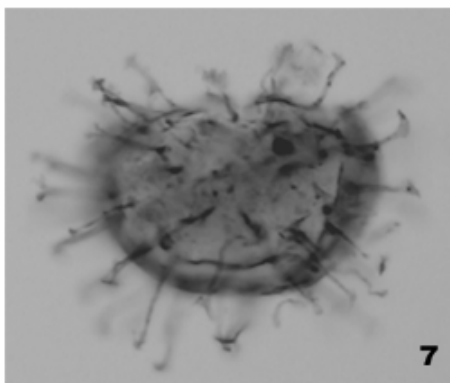
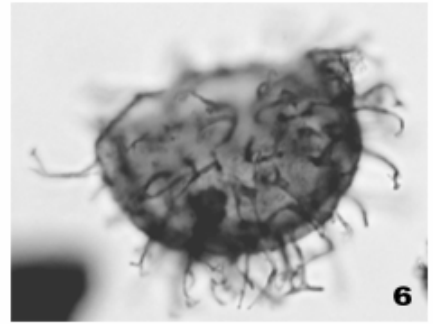
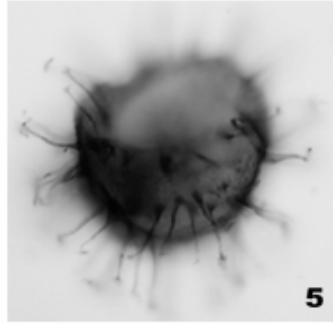
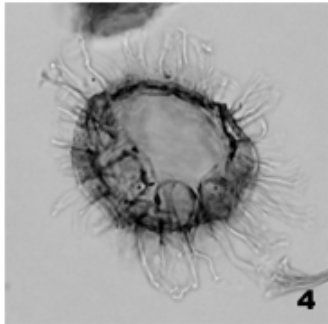
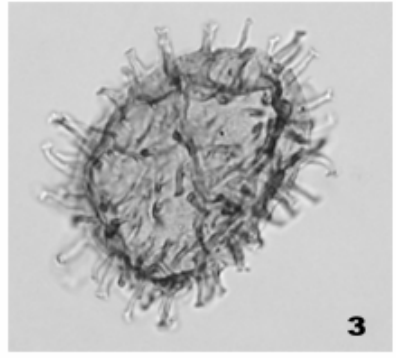
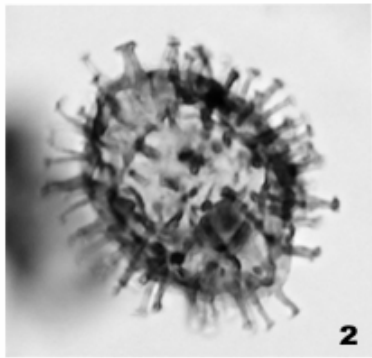
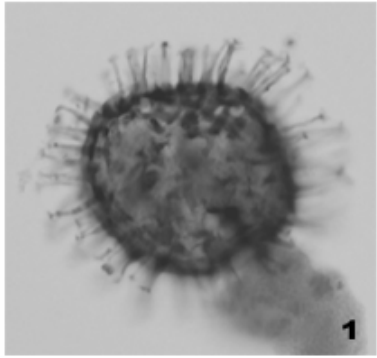
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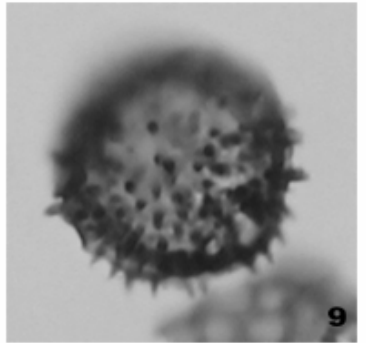
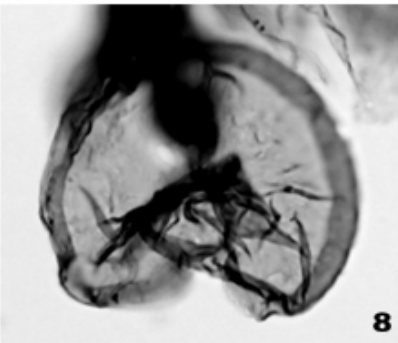
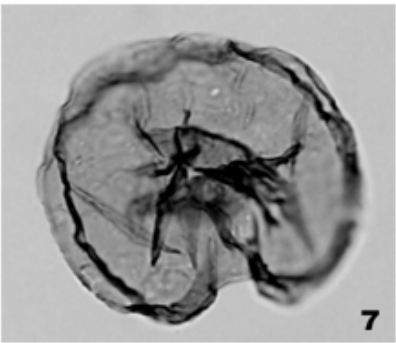
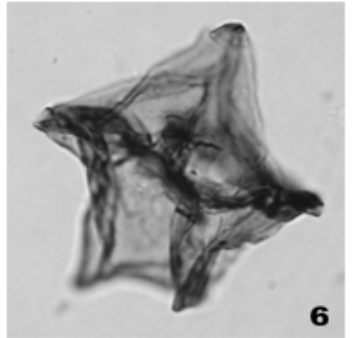
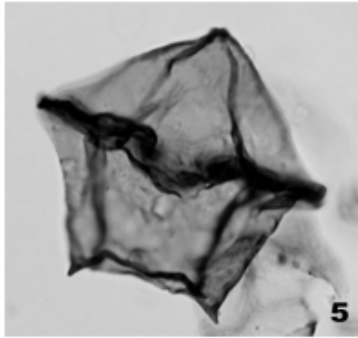
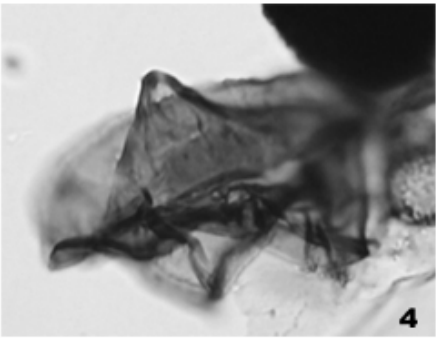
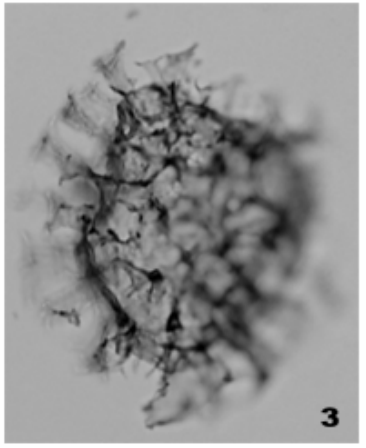
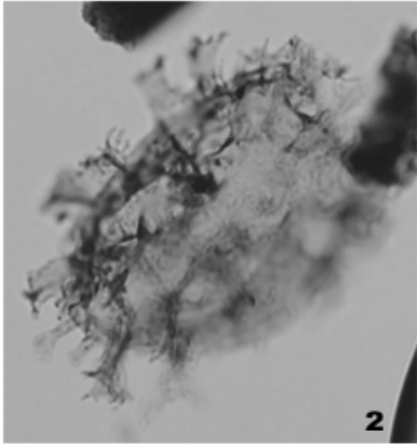
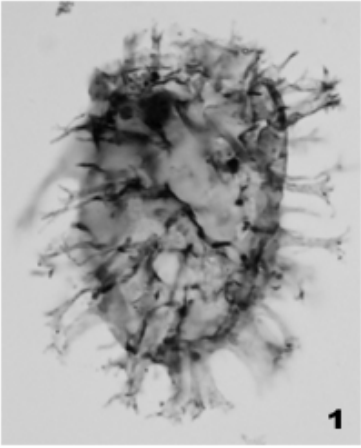
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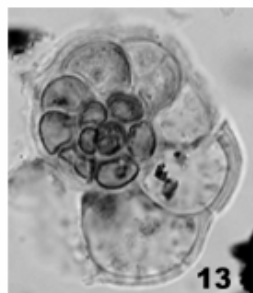
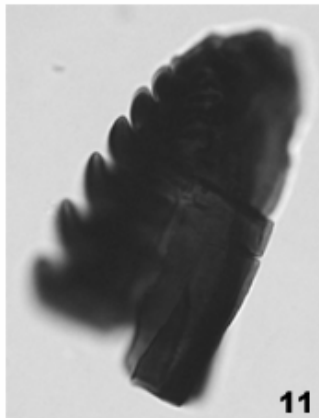
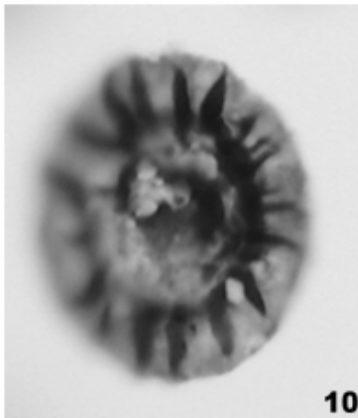
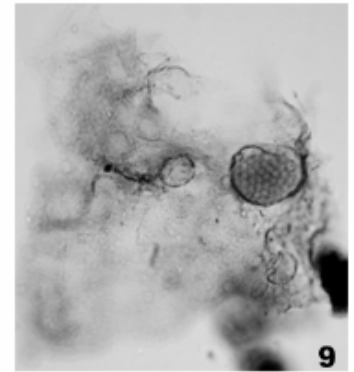
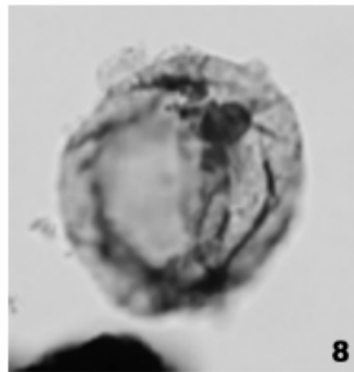
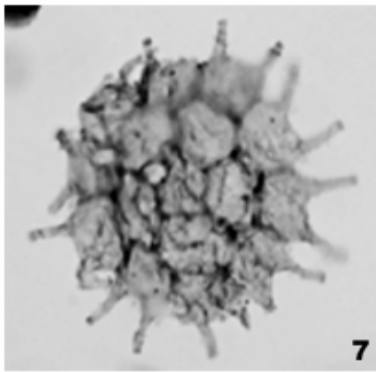
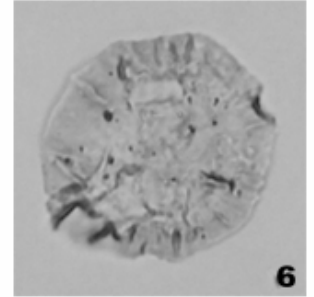
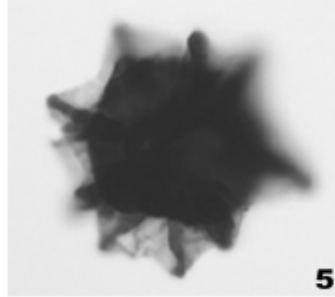
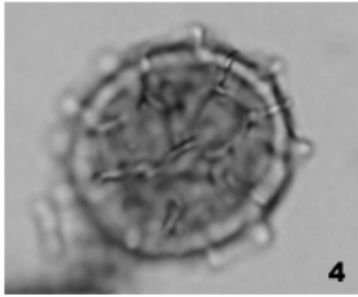
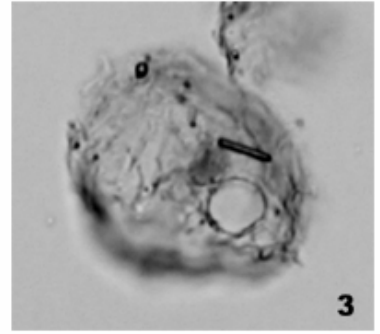
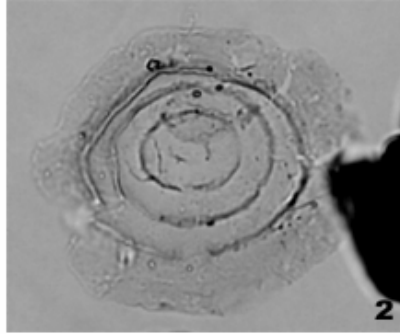
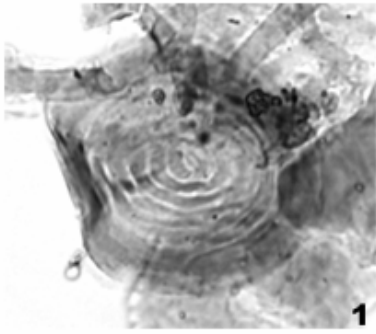


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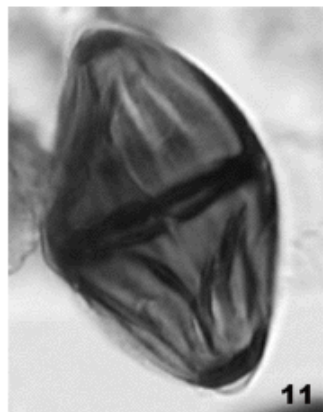
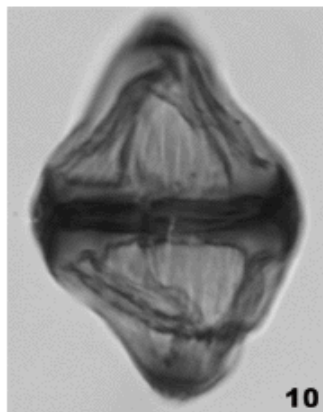
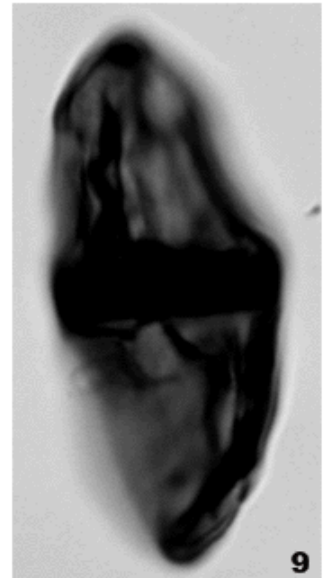
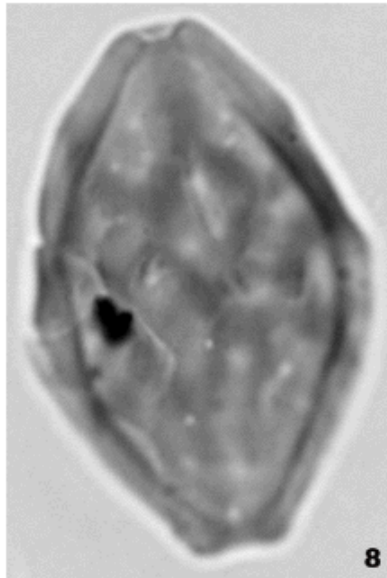
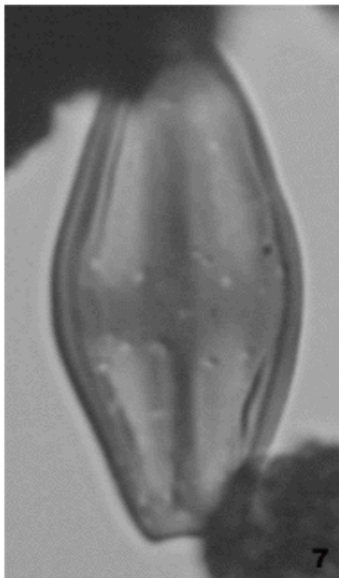
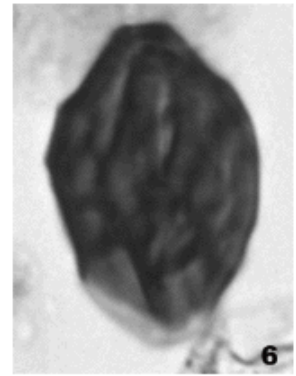
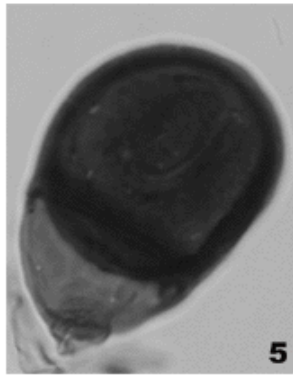
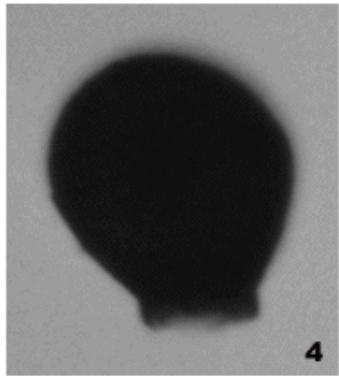
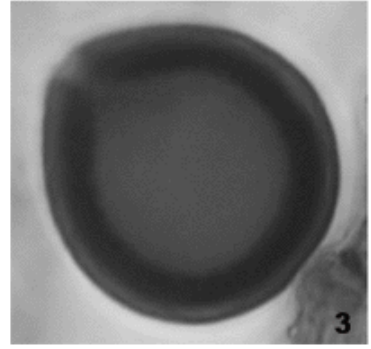
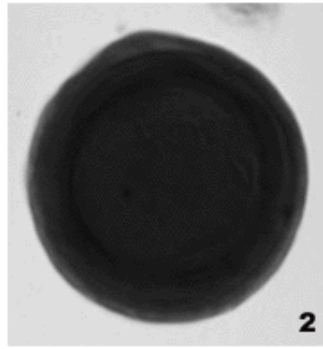
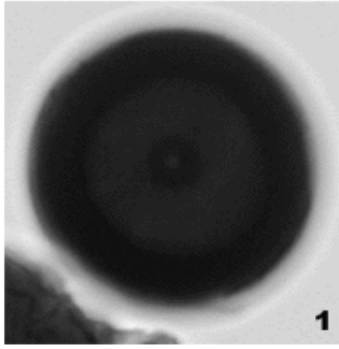




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All figures 500x, except Fig. 9 1250x

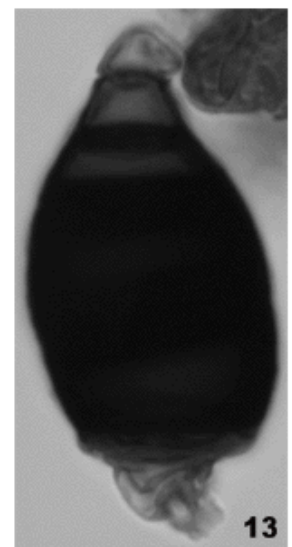
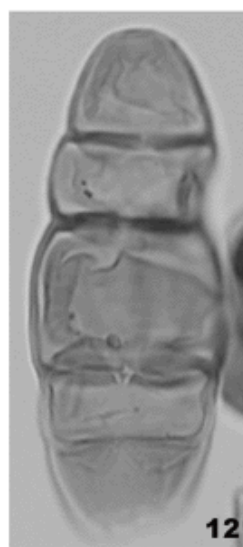
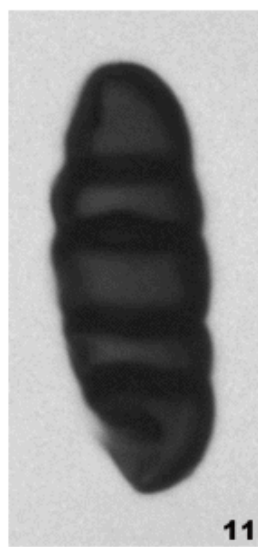
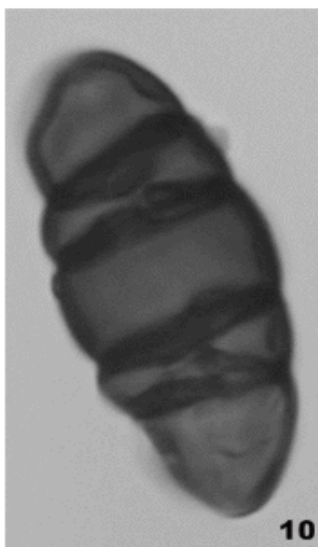
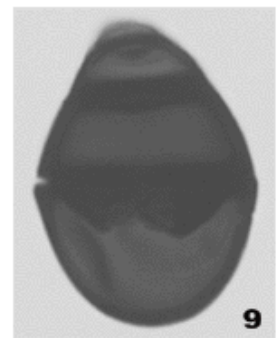
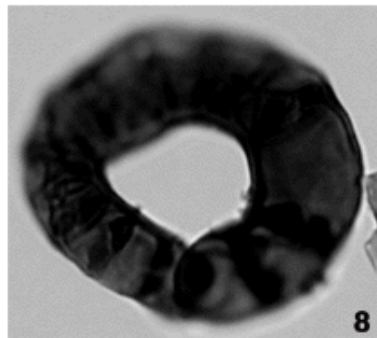
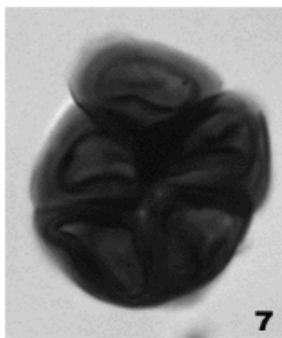
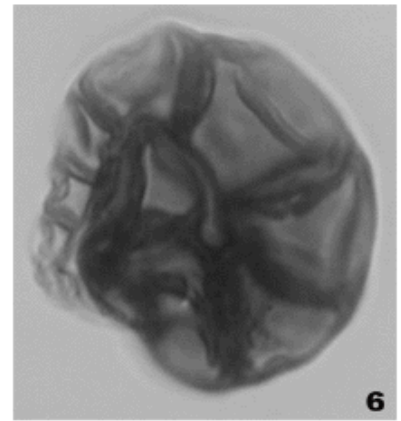
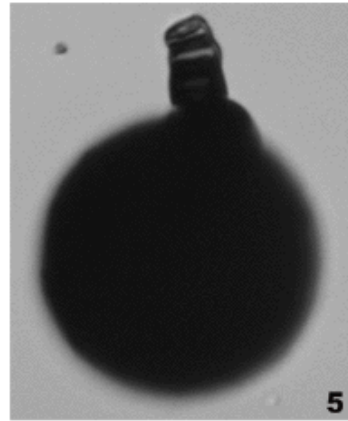
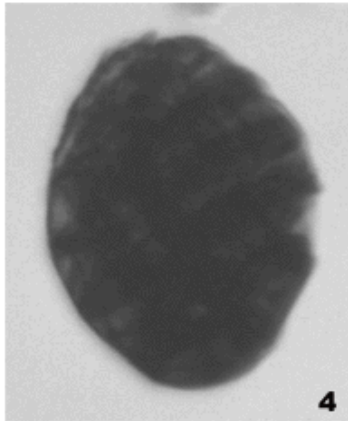
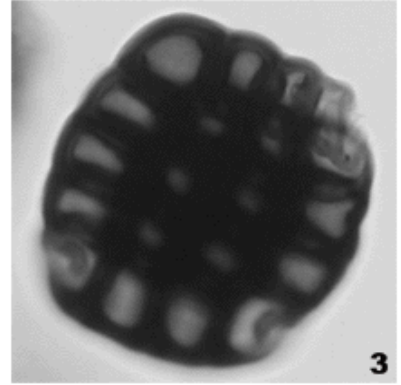
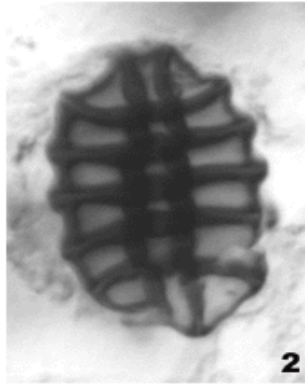
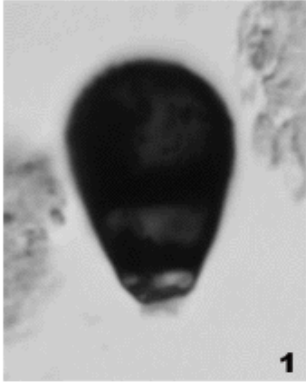
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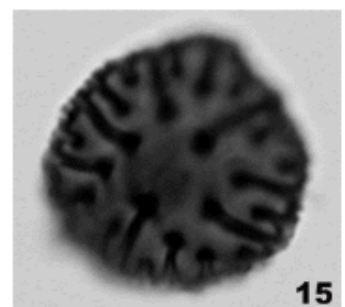
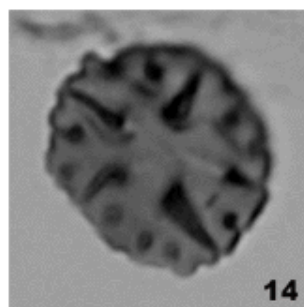
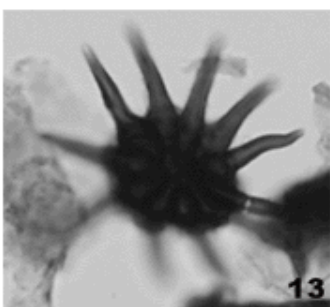
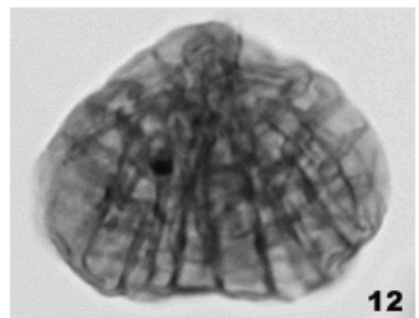
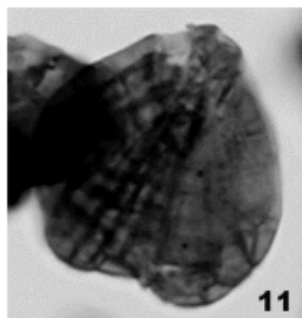
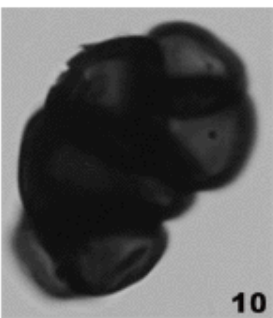
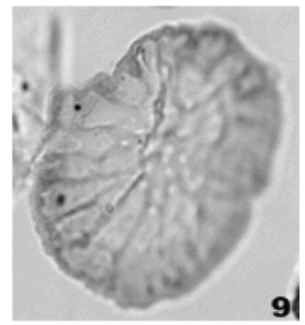
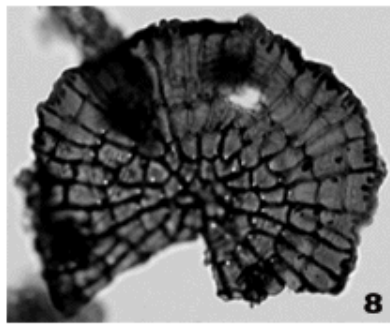
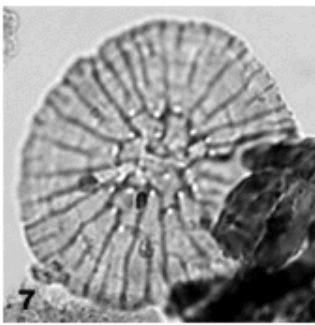
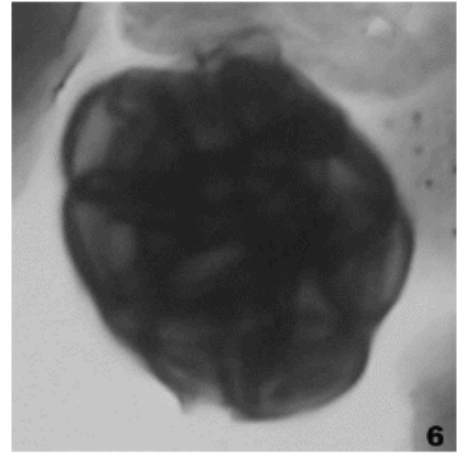
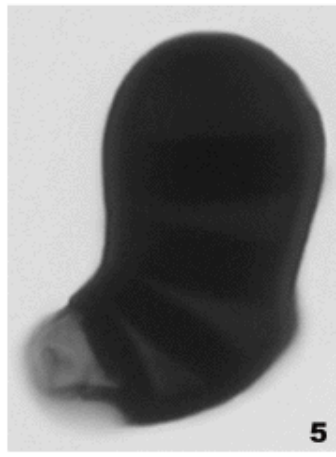
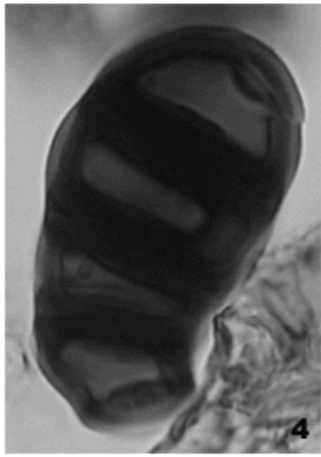
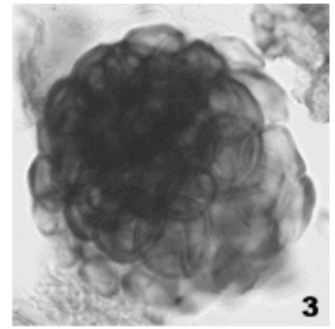
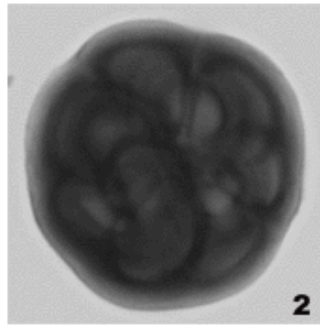
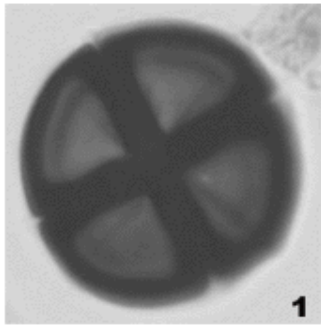
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6, 10	<b><i>Staphlosporinites cf. felixii</i></b> LANGE & SMITH 1971 <i>Slide No. PP-33A (51C; 34M4) [Pica-1X / 3390 ft]</i>	79
13	<b><i>Appendicisporonites typicus</i></b> SAXENA & KHARE 1992 <i>Slide No. PP-4A (47X) [Pica-1X / 460 ft]</i>	79
9	<b><i>Callimothallus assamicus</i></b> KAR, SINGH & SAH 1972 <i>Slide No. PP-4A (34K2) [Pica-1X / 460 ft]</i>	79
7, 8	<b><i>Callimothallus pertusus</i></b> DILCHER 1965 <i>Slide No. PP-1A (35T3; 51S1) [Pica-1X / 100 ft]</i>	80
14	<b><i>Desmidiospora marginiconvoluta</i></b> KALGUTKAR 1997 <i>Slide No. PP-14A (43T) [Pica-1X / 1642 ft]</i>	80
15	<b><i>Desmidiospora willoughbyi</i></b> (BRADLEY) ETHRIDGE GLASS, BROWN & ELSIK 1986 <i>Slide No. PP-1A (43S3) [Pica-1X / 100 ft]</i>	80
11, 12	<b><i>Kutchiathyrites palmatus</i></b> KE & SHI 1978 <i>Slide No. PP-3A (44H) [Pica-1X / 340 ft]</i>	80

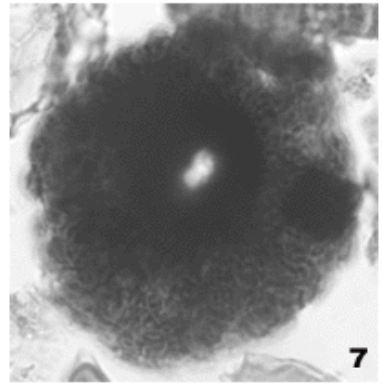
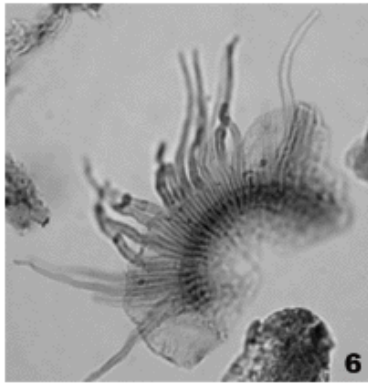
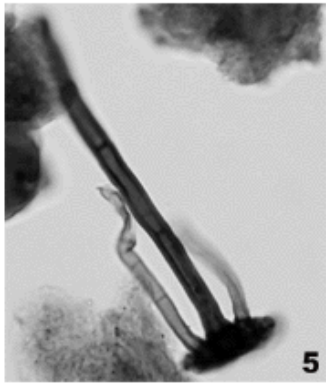
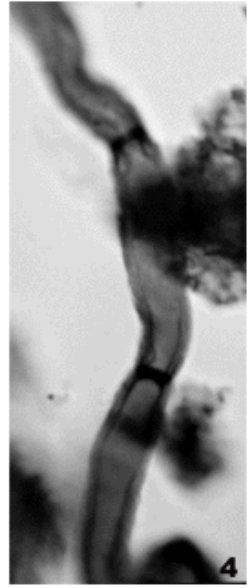
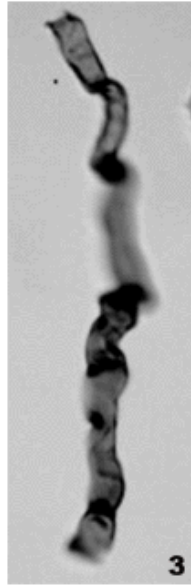
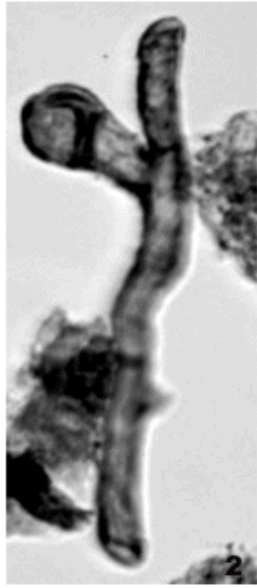
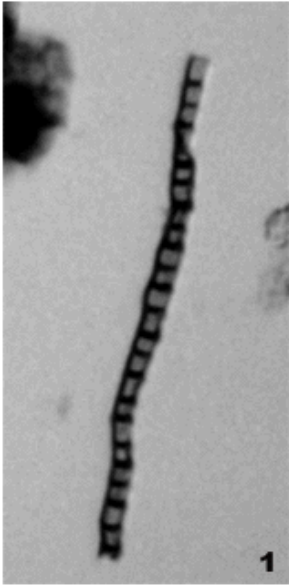


## PLATE 13

All figures 500x .

Fig.		Page
6	<b><i>Parmathyrites cf. indicus</i></b> JAIN & GUPTA 1970 <i>Slide No. PP-14A (48T1) [Pica-1X / 1642 ft]</i>	81
7	<b><i>Plochmopeltinites masonii</i></b> COOKSON 1947 <i>Slide No. PP-7A (36D) [Pica-1X / 820 ft]</i>	81
2	<b>Hyphae Type A</b> <i>Slide No. PP-3A (39C1) [Pica-1X / 340 ft]</i>	81
3	<b>Hyphae Type B</b> <i>Slide No. PP-3A (45D) [Pica-1X / 340 ft]</i>	81
4	<b>Hyphae Type C</b> <i>Slide No. PP-3A (36T1) [Pica-1X / 340 ft]</i>	82
8	<b>Hyphae Type D</b> <i>Slide No. PP-3A (52H3) [Pica-1X / 340 ft]</i>	82
1	<b>Hyphae Type E</b> <i>Slide No. PP-3B (45M1) [Pica-1X / 340 ft]</i>	82





## APPENDIX A: List of Identified Palynomorphs

### Dinoflagellate cysts

- Achilleodinium biformoides* (EISENACK 1954b) EATON 1976  
*Achomosphaera cf. multifurcata* JAIN & TANDON 1981  
*Adnatosphaeridium vittatum* WILLIAMS & DOWNIE 1966c  
*Adnatosphaeridium cf. multispinosum* WILLIAMS AND DOWNIE 1966c  
*Amphorosphaeridium cf. major* (LEJUENE-CARPENTIER, M. 1940) Emend. LEJUENE-CARPENTIER, M & SARJENT, W.A.S. 1981  
*Araneosphaera consociata* JAIN & TANDON 1981  
*Areoligera senonensis* LEJEUNE-CARPENTIER 1938  
*Chiropteridium galea* (MAIER 1959) SARJENT 1983 emend. SARJENT 1983  
*Cordosphaeridium cantharellum* (BROSIUS 1963) GOCHT 1969  
*Cordosphaeridium gracile* (EISENACK 1954) DAVEY & WILLIAMS 1966b  
*Cordosphaeridium inodes* (KLUMPP 1953) EISENACK 1963b emend. MORGENROTH 1968 emend. SARJEANT 1981  
*Cleistosphaeridium ancyrea* (COOKSON & EISENACK 1965a)  
*Cleistosphaeridium diversispinosum* (DAVEY et al. 1966) emend. EATON et al 2001  
*Cleistosphaeridium placacantha* (DEFLANDRE & COOKSON 1955)  
*Cleistosphaeridium? sp. A*  
*Diphyes cf. appendiculare* (COOKSON & EISENACK 1970a)  
*Diphyes colligerum* (DEFLANDRE & COOKSON 1955) COOKSON 1965a emend. GOODMAN & WITMER 1985  
*Diphyes spinulum* (DRUGG 1970b) STOVER & EVITT 1978  
*Distatodinium ellipticum* (COOKSON 1965a) EATON 1976  
*Distatodinium cf. tenerum* (BENEDEK 1972) EATON 1976  
*Enneadocysta arcuatum* (EATON 1971)  
*Enneadocysta pectiniformis* (GERLACH 1961) STOVER & WILLIAMS 1995  
*Glaphyrocysta texta* (BUJAK 1976) STOVER & EVITT 1978  
*Heteraulacacysta campanula* DRUGG & LOEBLICH 1967  
*Homotryblium floripes* (DEFLANDRE & COOKSON 1955) STOVER 1975  
*Homotryblium pallidum* DAVEY & WILLIAMS 1966b  
*Homotryblium plectilum* DRUGG & LOEBLICH Jr. 1967  
*Homotryblium tasmaniense* COOKSON & EISENACK 1967a  
*Homotryblium tenuispinosum* DAVEY & WILLIAMS 1966b  
*Homotryblium vallum* STOVER 1977  
*Hystrichokolpoma cf. denticulata* MATSOUKA 1974  
*Hystrichokolpoma elliptica* MATSOUKA 1974  
*Hystrichokolpoma cf. unispinum* WILLIAMS & DOWNIE 1966a  
*Hystrichokolpoma rigaudae* DEFLANDRE & COOKSON 1955  
*Hystrichokolpoma salacium* EATON 1976  
*Hystrichokolpoma sp. A*  
*Hystrichosphaeridium sp. A*  
*Hystrichostrogylon membraniphorum* AGEOPOULOS 1964 emend. STOVER & EVITT 1978

*Lejeunecysta fallax* (MORGENROTH 1966b) ARTZNER & DÖRHÖFER emend. BIFFI & GRIGNANI 1983  
*Lejeunecysta hyalina* (GERLACH 1961) ARTZNER & DÖRHÖFER 1978 emend. KJELLSTRÖM 1972 emend. SARJENT 1984b  
*Lingulodinium polyedrum* (DEFLANDRE & COOKSON 1955) WALL 1967  
*Lingulodinium pycnospinosum* (BENEDEK 1972) STOVER & EVITT 1978 emend. BENEDEK & SARJENT 1981  
*Nematosphaeropsis balcombiana* DEFLANDRE & COOKSON 1955  
*Nematosphaeropsis reticulensis* (PASTIELS 1948) SARJENT 1986 emend. SARJENT 1986  
*Oligosphaeridium complex* (WHITE 1842) DAVEY & WILLIAMS 1966b emend. DAVEY & WILLIAMS 1966b  
*Operculodinium centrocarpum* (DEFLANDRE & COOKSON 1955) WALL 1967  
*Operculodinium microtriainun* (KLUMPP 1953) ISLAM 1983a  
*Polysphaeridium congregatum* (STOVER 1977) emend. BUJAK et al. 1980  
*Polysphaeridium subtile* DAVEY & WILLIAMS 1966b Emend. BUJAK et al. 1980  
*Polysphaeridium zoharyi* (ROSSIGNOL 1962) emend. BUJAK et al. 1980  
*Turbiosphaera filosa* (WILSON 1967a) ARCHANGELSKY 1969a  
*Selenopemphix nephroides* BENEDEK 1972 emend. BUJAK in BUJAK et al. 1980 emend. BENEDEK & SARJENT 1981  
*Sentusidinium sp. A*  
*Spiniferites bulloideus* (DEFLANDRE & COOKSON 1955) SARJENT 1970  
*Spiniferites mirabilis* (ROSSIGNOL) SARJEANT 1970  
*Spiniferites cf. multibrevis* (DAVEY & WILLIAMS 1966 in DAVEY et al. 1966)  
*Spiniferites cf. ovatus* MATSUOKA 1983b  
*Spiniferites pseudofurcatus* (KLUMPP 1953) SARJENT 1970 emend. SARJENT 1981  
*Spiniferites ramosus* (EHRENBERG 1838) SARJENT 1970 emend. DAVEY & WILLIAMS in DAVEY et al. 1966  
*Spiniferites sp. A*

## Fungal Spores

*Appendicisporonites typicus* SAXENA & KHARE 1992  
*Brachysporisporites jarillalensis* sp. nov.  
*Callimothallus assamicus* KAR, SINGH & SAH 172  
*Callimothallus pertusus* DILCHER 1965  
*Desmidiospora marginiconvoluta* KALGUTKAR 1997  
*Desmidiospora willoughbyi* (BRADLEY) ETHRIDGE GLASS, BROWN & ELSIK 1986  
*Dictyosporites odremanensis* sp. nov.  
*Dictyosporites morularis* SALARD-CHEBOLDAEFF & LOCQUIN 1980  
*Dictyosporites cf. moruloides* SALARD-CHEBOLDAEFF & LOCQUIN 1980  
*Didymoporisporonites poratus* sp. nov.  
*Diporipollis? cf. melanii* (ELSIK) comb. nov.  
*Exisisporites annulatus* KALGUTKAR 1993  
*Fusiformisporites crabbii* ROUSE 1962  
*Fusiformisporites rugosus* SHEFFY & DILCHER 1971  
*Fusiformisporites septatus* sp. nov.  
 Hyphae Type A  
 Hyphae Type B  
 Hyphae Type C  
 Hyphae Type D  
 Hyphae Type E  
*Inapertisporites cf. nodulus* SHEFFY & DILCHER 1971  
*Involutisporonites foraminus* CLARKE 1965  
*Involutisporonites cf. foraminus* CLARKE 1965  
*Monoporisporites cf. traversii* EDIGER & ALISAN 1989  
*Involutisporonites trapezoides* KALGUTKAR 1993  
*Kutchiathyrites Palmatus* KE & SHI 1978  
*Marthurisporites glomeratus* SRIVASTAVA 1968  
*Monoporisporites lagenarius* SONG & LUO 1989  
*Multicellites cingulatus* KE & SHI 1978  
*Multicellites grandiusculus* SHEFFY & DILCHER 1971

*Multicellites* cf. *ovatus* SHEFFY & DILCHER 1971  
*Multicellites* sp. A  
*Octosporites?* cf. *saturoides* SALARD-CHEBOLDAEFF & LOCQUIN 1980  
*Papulosporinites mohgaoensis* CHITALEY & YAWALE 1978  
*Paragranatisporites vermiculus* EDIGER 1981  
*Parmathyrites* cf. *indicus* JAIN & GUPTA 1970  
*Plochmopeltinites masonii* COOKSON 1947  
*Pluricellaesporites trichocladites* KALGUTKAR 1997  
*Polyadosporites suescae* VAN DER HAMMEN 1954  
*Staphlosporinites* cf. *felixii* LANGE & SMITH 1971  
*Striadiporites crosstriatus* sp. nov.  
*Striadiporites* cf. *irregularis* KALGUTKAR 1993  
*Striadiporites reticulatus* VARMA & RAWAT 1963

**APPENDIX B:  
Chart of Distribution**

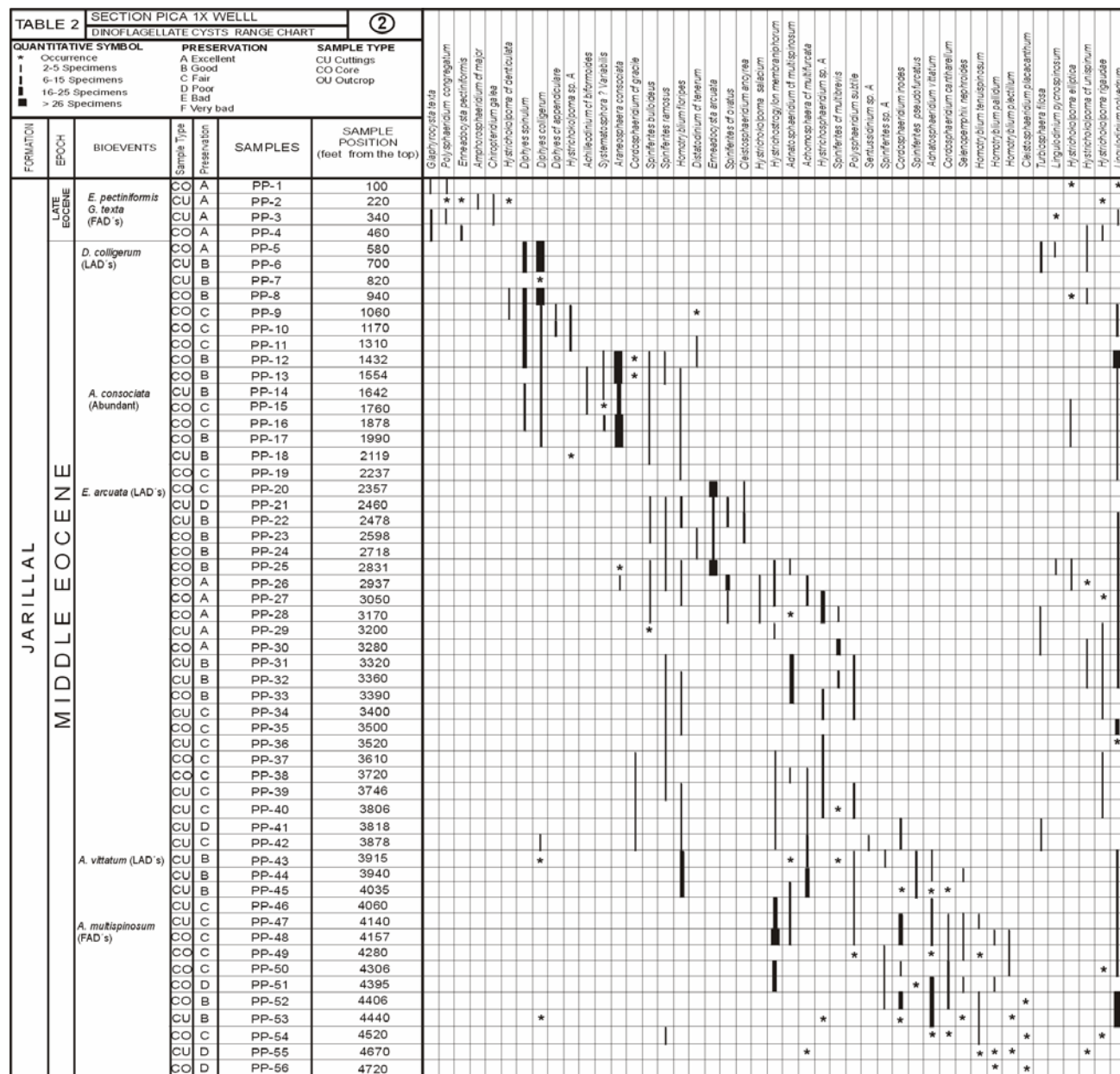


TABLE 2.- Dinoflagellate cysts distribution in samples from the Pica-1X section. Abundances are based on the total of specimens counted in a single slide.

TABLE 3		SECTION PICA 1X WELL		FUNGAL SPORES RANGE CHART		③	
FORMATION	EPOCH	BIOEVENTS	PRESERVATION		SAMPLES	SAMPLE POSITION (feet from the top)	Fungal Species
			Sample Type	Preservation			
JARILLAL	LATE EOCENE	F. rugosus P. vermiculus (FAD's)	CO A	A	PP-1	100	Desmidiospora wiloughbyi Octosporites cf. saturatus Inapertisporites cf. nodulus Striadporites reticulatus Polysporites straeae Brachysporites jirillensis Appendisporites typicus Multicellites cingulatus Fusiformisporites rugosus Callinolithus assamicus Callinolithus pertusus Dicyosporites odremanensis Paragratisporites vermiculus Dityosporites morulius Monosporites legenanus Exisisporites annulatus Marthuporites glomeratus Kutchiathyrites palmatus Multicellites cf. ovatus Fusiformisporites crabbii Plochmopeltites massonii Multicellites sp. A Dityosporites cf. moruloides Involutisporites foraminus Papuolobosporites mohagensis Striadporites cf. irregularis Diporipolis cf. meliani Involutisporites cf. foraminus Striadporites crosstriedus Monosporites cf. traversii Involutisporites trapezoides Multicellites grandiusculus Parnathyrites cf. indicus Desmidiospora marginiconvoluta Staphlosporites cf. felix Fusiformisporites septatus Didymosporites poratus Plucellaesporites trichoclactes
			CO A	A	PP-2	220	
			CO A	A	PP-3	340	
		D. monularis (FAD's)	CO A	A	PP-4	460	
			CO A	A	PP-5	580	
			CU B	B	PP-6	700	
		F. crabbii P. massonii (LAD's)	CU B	B	PP-7	820	
			CO B	B	PP-8	940	
			CO C	C	PP-9	1060	
		M. grandiusculus (LAD's)	CO C	C	PP-10	1170	
			CO C	C	PP-11	1310	
			CO B	B	PP-12	1432	
			CO B	B	PP-13	1554	
			CU B	B	PP-14	1642	
			CO C	C	PP-15	1760	
			CO C	C	PP-16	1878	
			CO B	B	PP-17	1990	
			CU B	B	PP-18	2119	
			CO C	C	PP-19	2237	
		S. cf. irregularis (FAD's)	CO C	C	PP-20	2357	
			CU D	D	PP-21	2460	
			CU B	B	PP-22	2478	
			CO B	B	PP-23	2598	
			CO B	B	PP-24	2718	
			CO B	B	PP-25	2831	
			CO A	A	PP-26	2937	
			CO A	A	PP-27	3050	
			CO A	A	PP-28	3170	
			CU A	A	PP-29	3200	
			CO A	A	PP-30	3280	
			CU B	B	PP-31	3320	
			CU B	B	PP-32	3360	
			CO B	B	PP-33	3390	
			CU C	C	PP-34	3400	
	CO C		C	PP-35	3500		
	CU C		C	PP-36	3520		
	CO C		C	PP-37	3610		
	CO C	C	PP-38	3720			
	CU C	C	PP-39	3746			
	CU C	C	PP-40	3806			
	CU D	D	PP-41	3818			
	CU C	C	PP-42	3878			
	CU B	B	PP-43	3915			
	CU B	B	PP-44	3940			
	CU B	B	PP-45	4035			
	CU C	C	PP-46	4060			
	CU C	C	PP-47	4140			
	CO C	C	PP-48	4157			
	CO C	C	PP-49	4280			
	CO C	C	PP-50	4306			
	CO D	D	PP-51	4395			
	CO B	B	PP-52	4406			
	CU B	B	PP-53	4440			
	CO C	C	PP-54	4520			
	CU D	D	PP-55	4670			
	CO D	D	PP-56	4720			

TABLE 3.- Fungal remains distribution in samples from the Pica-1X section. Abundances are based on the total of specimens counted in a single slide.



TABLE 6		SECTION QUEBRADA PALMA		6																													
		DINOFLAGELLATE CYSTS RANGE CHART																															
QUANTITATIVE SYMBOL			PRESERVATION		SAMPLE TYPE																												
* Occurrence			A Excellent		CU Cuttings																												
2-5 Specimens			B Good		CO Core																												
6-15 Specimens			C Fair		OU Outcrop																												
16-25 Specimens			D Poor																														
■ > 26 Specimens			E Bad																														
			F Very bad																														
FORMATION	EPOCH	BIOEVENTS	Sample Type	Preservation	SAMPLES	SAMPLE POSITION (m from the base)	Homotryblum tasmaniense	Spiniferites ramosus	Diphyes colligerum	Achomospaera cf multifurcata	Lejeunecysta hyalina	Cleistosphaeridium ancyrea	Hystriocholopoma elliptica	Lejeunecysta fallax	Spiniferites mirabilis	Spiniferites cf multibrevis	Selenopemphix nephroides	Homotryblum pallidum	Spiniferites bulloideus	Areoligera senonensis	Heteraulacysta campanula	Polysphaeridium subtile	Adnatosphaeridium vitatum	Nematosphaeropsis balcombiana	Homotryblum plectillum	Polysphaeridium zoharyi	Hystriocholopoma sp. A	Xenicodinium conispinosum	Lingulodinium polyedrum	Operculodinium microtriatinum			
CAUS	MIDDLE EOCENE	<i>H. tasmaniense</i> (LAD's)	OU	C	QP-1	115,0						*			*	*		*					*										
			OU	F	QP-2	110,5		*											*		*												
		<i>A. senonensis</i> (Abundant)	OU	C	QP-3	107,5		*																				*					
			OU	C	QP-4	104,5		*	*														*					*					
			OU	C	QP-5	100,5		*		*							*						*			*		*		*			
			OU	C	QP-6	92,0		*	*	*				*		*										*		*	*	*	*		
		?	OU	F	QP-7	52,0								*	*				*	*		*											
			OU	F	QP-8	3,5													*	*		*											

TABLE 6.- Dinoflagellate cysts distribution within samples from the Quebrada Palma section. Abundances are based on the total of specimens counted in a single slide.

TABLE 7		SECTION QUEBRADA HONDA		7																														
		DINOFLAGELLATE CYSTS RANGE CHART																																
QUANTITATIVE SYMBOL			PRESERVATION		SAMPLE TYPE																													
* Occurrence			A Excellent		CU Cuttings																													
2-5 Specimens			B Good		CO Core																													
6-15 Specimens			C Fair		OU Outcrop																													
16-25 Specimens			D Poor																															
■ > 26 Specimens			E Bad																															
			F Very bad																															
FORMATION	EPOCH	BIOEVENTS	Sample Type	Preservation	SAMPLES	SAMPLE POSITION (m from the base)	Homotryblum tasmaniense	Spiniferites ramosus	Diphyes colligerum	Turbosphaera filosa	Lejeunecysta hyalina	Cleistosphaeridium ancyrea	Lejeunecysta fallax	Spiniferites mirabilis	Spiniferites cf multibrevis	Selenopemphix nephroides	Homotryblum pallidum	Spiniferites bulloideus	Areoligera senonensis	Polysphaeridium subtile	Nematosphaeropsis balcombiana	Polysphaeridium zoharyi	Cleistosphaeridium sp. A	Hystriocholopoma cantharellum	Cordosphaeridium polyedrum	Lingulodinium microtriatinum	Operculodinium tenuispinosum							
CAUS	MIDDLE EOCENE	<i>P. subtile</i> <i>H. tenuispinosum</i> (LAD's)	OU	B	QH-1	56,0	*	*	*												*	*	*											
			OU	D	QH-2	53,5																												
		<i>P. zoharyi</i> (FAD's)	OU	B	QH-3	44,0		*	*	*													*											
			OU	B	QH-4	42,0																												
			OU	D	QH-5	40,0		*	*																									
			OU	C	QH-6	37,5																			*									
			OU	C	QH-7	35,0		*	*															*		*			*					
			OU	C	QH-8	33,5																*												
		<i>H. tasmaniense</i> (LAD's)	OU	C	QH-9	32,0																*												
			OU	C	QH-10	26,0																*												
			OU	B	QH-11	23,5																												
			OU	B	QH-12	20,5												*										*						
			<i>A. senonensis</i> (Abundant)	OU	B	QH-13	17,5										*							*				*						
				OU	B	QH-14	14,5										*			*														

TABLE 7.- Dinoflagellate cysts distribution within samples from the Quebrada Honda section. Abundances are based on the total of specimens counted in a single slide.



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