LOWER CRETACEOUS PALYNOSTRATIGRAPHY, ORGANIC SEDIMENTOLOGY AND EVOLUTION OF THE MARACAIBO BASIN, WESTERN VENEZUELA

by

Omar A. Colmenares

A thesis submitted in conformity with the requirements
for the Degree of Doctor of Philosophy,
Department of Geology, in the
University of Toronto

Para un gran amigo
Con los mejores deseos
Omar
Dic - 1994.

LOWER CRETACEOUS PALYNOSTRATIGRAPHY, ORGANIC SEDIMENTOLOGY AND EVOLUTION OF THE MARACAIBO BASIN, WESTERN VENEZUELA

by

Omar A. Colmenares

A thesis submitted in conformity with the requirements
for the Degree of Doctor of Philosophy,
Department of Geology, in the
University of Toronto

LOWER CRETACEOUS PALYNOSTRATIGRAPHY, ORGANIC SEDIMENTOLOGY AND EVOLUTION OF THE MARACAIBO BASIN, WESTERN VENEZUELA

Ph.D., 1994

Omar A. Colmenares

Department of Geology, University of Toronto

ABSTRACT

Palynological analyses of four outcrop and four subsurface sections of the Aptian–Albian siliciclastic-carbonate platform facies of the Aguardiente Formation and the Cogollo Group of the Maracaibo Basin yielded a total of 97 species of miospores 60 species of dinoflagellate cysts, freshwater protists and acritarchs, and numerous phytoclasts.

Corollina, Araucariacites and *Afropollis* are the most common elements, indicating close resemblance with coeval assemblages from Brazil and Africa. Quantitative comparison of the dinoflagellate cysts and the occurrence of *Xenascus plotei*, *Achomosphaera triangulata*, *Kiokansium unituberculatum* and some species of *Subtilisphaera* indicate similarities with low latitude areas. The occurrence of several species of *Subtilisphaera* in tropical and subtropical areas indicates initiation of provincialism of peridiniacean dinocysts during the Aptian–Albian.

Four biozones are defined using marine and terrestrial species of palynomorphs. Biozones I (Early Aptian) and II (Early to Middle Aptian) have rich terrestrial assemblages and lesser or absent marine components. Biozone III (Late Aptian) is characterized by the diversification of tricolpate angiosperm pollen in northern South America and increasingly diverse dinocysts. Biozone IV is defined by the first occurrence

of *Elaterosporites klaszi* and *Xenascus plotei*, determining the base to be Early Albian. The Aguardiente Formation is Aptian–Albian, the Apón Formation is restricted to the Aptian, the Lisure Formation is Late Aptian to Albian and the Maraca Formation is Albian. Regional palynostratigraphic correlation indicates major facies changes related to carbonate dominance northwards away from the siliciclastic influx from the south.

The palynofacies and palynological assemblages of the Aguardiente Formation are dominated by terrestrial organic matter. Size statistical variations of terrestrial phytoclasts and the compositional variation of the palynofacies are related to relative sea-level changes and to paleoenvironmental oxidation. Five sedimentary phases are defined indicating transgressive and regressive pulses, correlated to relative sea-level changes.

The miospore assemblages of this study are inferred to represent mainly coastal plant communities. Dinoflagellate cysts are dominated by a few generalist species. Seven new species of miospores are described and new taxonomic combinations and emendation are also proposed. Many species of rare miospores and dinocysts are described in open nomenclature and may be new.

ACKNOWLEDGEMENTS

My especial gratitude to Professor Geoffrey Norris, my Ph.D. supervisor, for his support and critical suggestions that considerably improved quality of this work. My especial thanks to the members of my Graduate Committee, Professors Andrew Miall and Peter von Bitter, who kindly provided critical discussions on the topics of this thesis. Professor Edward J. Spooner and Dr. Martin J. Head also contributed to the significant improvement of the final manuscript throughout their critical reading and wise suggestions. My especial thanks also go to Doctor Robert A. Fensome and Doctor Graham L. Williams, of the Geological Survey of Canada in Dartmouth, Nova Scotia. Rob conveyed his critical and invaluable judgment of this thesis. He and Dr. Graham L. Williams kindly gave a valuable part of their time and resources during the stages of the identification and systematic treatment of the taxa reviewed in this work. Their hospitality will always be remembered. Dr. Pierre A. Zippi took part of his time to review some of the sample maceration techniques that were used in this study. Mr. Florin Neuman was kind to give the opportune tip regarding the cumbersome world of computers.

This thesis and my studies in the Department of Geology at the University of Toronto would have been impossible without the scholarship program of INTEVEP, S.A., the Research and Development Center of Petróleos de Venezuela (PDVSA). My gratitude for this opportunity to broaden my professional horizons. Many friends and colleagues also provided their continuous support, that constantly made me feel close to home during these four years. First, my especial recognition to Dr. Argenis Rodríguez and Mrs. Andreina Isea, of the Geology Section, for always showing their trust and guidance. Mrs. Iraida Paredes de Ramos, for always giving her advise and experience. Mr. Armando Ruggiero and Mr. Julio Pérez also provided their discussion and points of view regarding geochemical data of the Lower Cretaceous of western Venezuela. Mr. Nelsón Martínez for his dedication during the field-trip in the Venezuelan Andes in 1992. My especial gratitude also goes to the personnel of Human Resources Division: Ms. Zulma Reyeszumeta, Mrs. Begoña Zotes and Mrs. Daysi Boscán, for their continuous and very professional support regarding the management of the administrative tasks of the scholarship program.

My acknowledgment also goes to MARAVEN, S.A., for providing part of the samples that are included this study. My especial thanks to Ms. Izaskun Azpiritxaga, Mr. Johny Casas, Mr. Fernando Chacartegui, and Mr. José Méndez of the Production Division; to Dr. Xiomara Márquez, Dr. María Antonieta Lorente, Dr. Bruno Murat, Mrs. Selena Mederos and Mr. Miguel Velásquez of the Exploration Division for letting me have access to the information available on the subject and the logistics for field trips in the Perijá Ranges. My gratitude also goes to Mr. Oscar Quintero and the personnel of the core-storage facility of MARAVEN, S.A. in La Concepción, for their great patience and their even greater hospitality.

Part of the expenses of this work were covered by a grant of the Natural Sciences and Engineering Research Council of Canada (NSERC) awarded to Prof. Geoffrey Norris.

DEDICATION

Esta tesis esta dedicada a quienes siempre han sido la parte mas importante de mi vida.

A mi madre, Alicia. Siempre has dado lo mejor de ti. Siempre supistes inculcarme ese deseo de ampliar horizontes y nunca cesar en el esfuerzo por cada dia ser mejor. Pero por sobre todas las cosas, siempre me has enseñado a ser útil.

A mi hermano Miguel. Tú abristes la senda y el camino a nuevos horizontes. Gracias por siempre darme tu estímulo y apoyo. Pero por sobre todo, gracias por tu ejemplo.

En memoria de mi padre. Tu recuerdo y sobre todo, tu ejemplo, siempre estarán presentes en mi vida.

NOMENCLATURAL DISCLAIMER

This thesis is not intended for effective publication as defined in the *International Code of Botanical Nomenclature* (ICBN, Greuter *et al.*, 1988). Therefore, taxonomic and nomenclatural proposals contained in this thesis are not considered as validly published (ICBN; Article 29).

TABLE OF CONTENTS

CHAPTER 4

CHAPTER 5

LIST OF FIGURES

LIST OF PLATES

1. INTRODUCTION AND OBJECTIVES.

This study involves the palynological analysis of samples from nine outcrop and subsurface sections of the Lower Cretaceous (Aptian-Albian) siliciclastic and carbonate facies of the Maracaibo Basin in western Venezuela (Figure 1). Specifically this study includes the description and biostratigraphic analyses of assemblages of dispersed organic-walled microfossils; miospores of land plants and dinoflagellate cysts. Miospores are considered in this study to include pollen, and pteridophyte and fern isospores whose size is less than 200 µm. Traverse (1988) observed that fossilized pollen is only the wall of microspores of seed plants, produced by meiosis in the sporagium of the parent plant. Dinoflagellates are eukaryotic, primarily single-celled organisms (Taylor, 1990), mainly marine but with fresh-water species (Batten, 1985; Batten and Lister, 1988; Zippi, 1992, for example). Evitt (1985) pointed out that the life cycles of some dinoflagellates may involve phases of vegetative and sexual reproduction, as well as periods of nonmotility. Motile dinoflagellates are characterized by the possession of a complex external amphiesma, enclosing the cell nucleus and organelles. The amphiesma contains vesicles which might contain cellulose, forming thecal plates of the armored dinoflagellates. Unarmored dinoflagellates, on the other hand, lack these thecal plates. The nonmotile state of the life cycle of some dinoflagellates is generally by means of production of functional cysts. Fensome et al. (1993) pointed out that cysts might be temporary (ecdysal cyst), vegetative, digestive and resting cyst. Below (1987) and Fensome et al. (1993) pointed out that the majority of fossil dinoflagellate cysts appears to be resting cysts.

The Early Cretaceous was a time when different miospore provinces existed and when the assemblages showed floral composition changes, related in part to the origin and evolution of the angiosperms and to climatic factors (Herngreen and Chlonova, 1981). Dinoflagellates were a flourishing group during the Early Cretaceous. Bujak and Williams (1979) pointed out that dinoflagellate species diversity (measured by the number of existing species at any moment) increased after the Jurassic and reached a peak during the Albian (a total of 279 species). These authors also reported a total of 170 species of dinoflagellates for the Aptian. These authors observed that most of the intervals showing increasing number of species of dinoflagellates coincided with major transgressive events. However, they also cautioned that a complex interaction of factors controls the diversity of dinoflagellate cysts. A significant number of publications deals with Lower Cretaceous palynological assemblages on a worldwide basis. Major

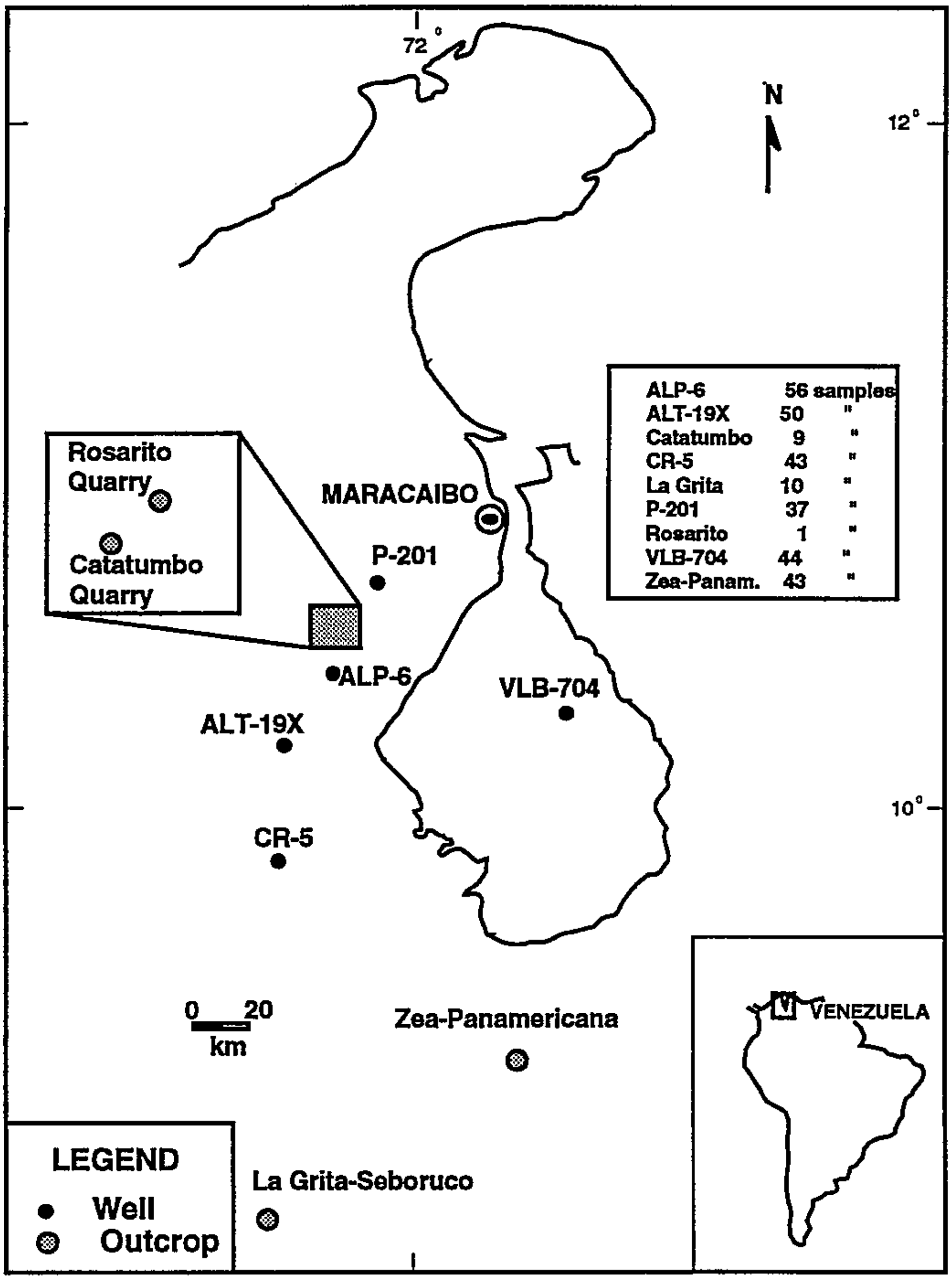

Figure 1. Geographical locations in the Maracaibo Basin of sampled outcrop and subsurface cored sections of the Cogollo Group in the Maracaibo Basin, with the number of samples that were studied per section.

publications dealing with the compilation of stratigraphic ranges and systematics of palynomorphs have been produced for dinoflagellate cysts and they include the index of fossil dinoflagellate genera and species (Lentin and Williams, 1993) as well as the compilation of known stratigraphic ranges (Foucher, 1981; Williams and Bujak, 1985; Helby et al., 1987; Costa and Davey, 1992; Williams et al., 1993). However, literature on the Lower Cretaceous miospores lacks such extensive compilations.

Because of the lack of detailed palynological studies on the Lower Cretaceous in northern South America, the first objective of this study is to describe and illustrate the assemblages of miospores and dinoflagellate cysts. Palynomorph species with potential biostratigraphic value will be identified. The detailed characterization of the assemblages will also be useful in the comparison of these assemblages with others reported worldwide. The Early Cretaceous was a time of significant changes in miospore and dinoflagellate assemblages at worldwide level. Occurrences of angiosperm pollen in the northern part of South America will be characterized and compared with patterns observed in Africa (Doyle et al., 1982) and in temperate areas (Penny, 1988, 1989 and 1992; Doyle, 1992). The preliminary assessment of dinoflagellates will also allow the determination of the distribution pattern of this group for the Lower Cretaceous of western Venezuela and the possibilities of establishing correlations with assemblages reported from the Aptian and Albian stratotypes of Europe.

This study focuses not only on the palynological analyses of the siliciclastic and carbonate facies of the Aptian–Albian of the Maracaibo Basin, but also on the particulate organic matter. The purpose of this characterization is to produce information concerning the types of organic matter and its distribution in the regional context. Little is known about the paleoecology of low latitude dinoflagellate cyst assemblages in shallow water environments. The reported distribution of this fossil group in the Lower Cretaceous of the Maracaibo Basin will allow assessment of species which might be restricted to particular types of paleoenvironments. The integration of the information coming from the palynological and palynofacies analyses will allow inferences regarding the evolution of the Maracaibo Basin during the Early Cretaceous.

1.1 Miospores: Lower Cretaceous palynofloristic provinces.

Brenner (1976) defined four palynofloristic provinces during the Barremian–Cenomanian based on miospore occurrences; the Northern Laurasian (above 60° N), the

Southern Laurasian (mid-latitudes of the Northern Hemisphere), Northern Gondwana (northern Africa and South America) and Southern Gondwana (southern regions of South America, Australia, New Zealand and India). Srivastava (1978) proposed three different phytogeographic provinces during the Neocomian and two for the Albian. As in Brenner (1976), distribution of the provinces roughly reflected latitudinal-climatic gradients. Srivastava (1978) used the abundance and occurrences of pollen of *Corollina* and *Dicheiropollis etruscus* to differentiate microfloral provinces during the Neocomian.

Herngreen and Chlonova (1981) defined three main microfloral provinces for the Lower Cretaceous:

- Boreal; characterized by the abundance of bryophyte spores and gymnosperm pollen in areas at high-intermediate latitudes in the northern hemisphere.

-West African-South American (WASA); characterized by dominance of some species of gymnosperm and the occurrences of early angiosperm pollen in northern South America and west Africa prior to the Albian.

- Gondwana; characterized by the abundance and predominance of gymnosperm pollen in the southern regions of South America, Africa and Australia.

These authors also noted that another province, the so-called African-South American (ASA) province existed during most of the Albian and Cenomanian, characterized by an increasingly diverse angiosperm pollen suite, decreasing dominance of gymnosperm pollen, occurrence of characteristic species bearing elaters and the diversification of different genera of polyplicate pollen related to the *Ephedra* complex.

Miospore assemblages are strikingly similar in eastern South America (Brazil) and western Africa during the Cretaceous (Jardiné et al., 1974a-b; Regali et al., 1974a-b; Herngreen, 1974; Herngreen and Chlonova, 1981; Lima and Boltenhagen, 1981). Specifically, palynological studies of Lower Cretaceous miospore assemblages from northern South America, especially from eastern and northeastern Brazil, have revealed almost parallel trends in evolution regarding the composition and abundance of the main taxa with coeval microfloral assemblages from Africa (Jardiné and Maglorie, 1965; Muller, 1966; Herngreen, 1972, 1973, 1974 and 1975a; Lawal and Moullade, 1986;

Lima, 1978a-b; Lima and Boltenhagen, 1981; Regali, 1980; Regali et al., 1974a-b; Arai et al., 1989, Salard-Cheboldaeff, 1991; Schrank, 1991; Aboul Ela and Mahrous, 1992).

Lower Cretaceous (pre-Aptian) assemblages are dominated by gymnosperm pollen such as *Dicheiropollis etruscus*, species of the genera *Araucariacites*, *Equistetosporites*, *Corollina*, *Cycadopites* and *Inaperturopollenites*. These microfloral assemblages are significantly different from the assemblages of Laurasia, characterized by the abundance of fern spores and bisaccate pollen grains. Herngreen and Chlonova (1981) pointed out that the abundance of gymnosperm pollen is the main element of the Albian assemblages of the ASA province.

Occurrences of angiosperm pollen during the Aptian and Albian in Africa and South America are limited. Doyle (1969) and Brenner (1976) discussed the occurrences of *Clavatipollenites* in Barremian beds in the northern and southern hemisphere. Brenner (1968) and Doyle et al. (1977 and 1982) have reported the occurrences of pollen of the genus *Afropollis*, a reticulate genus of likely angiosperm affinity, in Aptian sediments of Peru and Africa. More recently, Penny (1989) described pollen of this genus in Barremian sediments of Egypt and England. Doyle et al. (1977) and Penny (1988), Doyle et al. (1975) and Hickey and Doyle (1977) and Hughes et al. (1979) reported tricolpate angiosperm pollen in the Late Barremian of Africa, North America and England. Doyle (1992) reported that several species of monocolpate and tricolpate angiosperm pollen were present in the Barremian-Aptian of Gabon.

During the Late Aptian–Albian, a characteristic group of palynomorphs with elaters began to appear simultaneously in Africa and South America (Jardiné, 1967). These taxa, restricted to low latitudinal areas (mainly northern-eastern South America, Africa and the Middle East) became more diverse by the Late Albian-Cenomanian. Herngreen and Dueñas Jiménez (1990) have also reported occurrences of species of elater-bearing palynomorphs in China and Australia. Concurrently, angiosperm pollen also diversified, with reticulate-monocolpate, tricolpate and colporate species making their first occurrences in Africa and South America. Ibrahim (1992) reported microfloras with great similarities to that of the WASA province and a new species of *Afropollis* in the Aptian–Albian from Egypt. Herngreen and Chlonova (1981) also pointed out that fern spore assemblages are characterized by the irregular occurrence of world-wide distributed genera such as *Cicatricosisporites*, *Retitriletes Ischyosporites*, *Osmundacidites*, *Uvaesporites*, *Leptolepidites*, *Aequitriradites* and *Perotriletes* Brenner, for example.

The diversification of angiosperm pollen continued during the Cenomanian–Turonian in Africa and South America. The replacement of the gymnosperm floras was continuous during the early Late Cretaceous and led to the establishment of a microfloral province dominated mainly by angiosperm pollen, characteristically related to palms (the Palmae microfloral province of Herngreen and Chlonova, 1981) during the Senonian.

Hochuli (1981) and Hochuli and Kelts (1980) observed that the distribution of elements from the Southern Laurasian and North Gondwanan provinces of Brenner (1976) might have been related to climatic fluctuations. Hochuli's study in the southern Alps region showed that North Gondwanan elements were present in this area during the Aptian, and began to decline in abundance and importance throughout the Late Aptian–Cenomanian. Extensive descriptions of Lower Cretaceous microfloral assemblages from Europe and England have been reported by Delcourt and Sprumont (1955), Couper (1958), Döring (1965) and Norris (1969). Kemp (1970) and Batten (1979) have reported Aptian-Albian miospore assemblages from England.

Pocock (1962 and 1965), Singh (1964) and Norris (1967) have presented extensive descriptions of Lower Cretaceous miospore assemblages from Canada. Singh (1971) described Middle to Upper Albian microfloral assemblages from Alberta, Canada. These assemblages included angiosperm pollen (mainly mono- and tricolpates), fern spores and gymnosperm pollen, as well as polyplicate pollen of the genus *Equisetosporites* and pollen of the genus *Corollina.* Doyle (1969) and Doyle and Robbins (1977) reported monocolpate angiosperm pollen in low abundances in the Barremian–Aptian of the Atlantic Coastal Plain. Retallack and Dilcher (1986) considered the report of angiosperm pollen by Doyle (1969) as the earliest occurrence of angiosperm pollen in North America. Monosulcate and tricolpate angiosperm pollen has been found in the Albian of Louisiana, Oklahoma and Kansas (Hedlund and Norris, 1968; Paden Phillips and Felix, 1971b; Srivastava, 1977). Angiosperm pollen became widespread and common in North America by the Middle Albian and especially after the Cenomanian. Zavada and Dilcher (1988) reported that angiosperm pollen comprises less than 5% of pollen assemblages of the Albian of Kansas whereas it reaches 20% of the total assemblages of the Cenomanian Dakota Formation in Kansas, Nebraska and Minnesota. Norris et al. (1975) and Retallack and Dilcher (1986) mentioned that the replacement of gymnosperm by angiosperm floras is observed only at the local level in the Lower Cretaceous. Retallack and Dilcher (1981 and 1986) pointed out that the first angiosperm plants preferred disturbed open habitats where generalized methods of pollination and seed dispersal were likely to prevail.

In the southern Gondwana province (Herngreen and Chlonova, 1981) bi- and trisaccates, inaperturate and monosulcate gymnosperm pollen dominate the assemblages. Unlike the ASA and WASA provinces, pollen of *Corollina* and *Equisetosporites* are rare elements of these southern assemblages. The former is observed to dominate some assemblages of Argentina and South Africa, perhaps related to coastal facies. Archangelsky and Gamerro (1965 and 1967) described Barremian–Aptian assemblages of Argentina, reporting the occurrence of *Clavatipollenites hughesii*. These assemblages are dominated by gymnosperm pollen and endemic species of schizaealean spores (mainly of *Cicatricosisporites*). Lower Cretaceous assemblages of India and Australia are also dominated by gymnosperms and pteridophytes. Extensive information exists on the Australian Lower Cretaceous microfloras, for example Balme (1957), Cookson (1953 and 1954), Cookson and Dettmann (1958 and 1959a), Dettmann (1959 and 1963) and Dettmann and Playford (1969). Kemp (1970) noticed the limited similarities between the Aptian–Albian microfloras of Australia and England. The diversification of angiosperms has been reported to occur during the Cenomanian–Turonian, coinciding with the disappearance of some important groups of gymnosperm and pteridophytes, and the decrease in diversity of bisaccates (Herngreen and Chlonova, 1981). For the Senonian, the *Nothofagidites* microfloral province had become defined in Australia, New Zealand, Antarctica and southern South America (Herngreen and Chlonova, 1981).

There are very few studies of published palynological assemblages of the Lower Cretaceous in the northern part of South America. Paredes de Ramos and Fasola (in Moldovanyi and Pinto Ausó, 1987) reported 63 different species of pollen and spores in samples of well ALT-19X from western Venezuela. The overall composition of these assemblages suggests close resemblance with assemblages of Aptian–Albian age of South America and Africa (the ASA and WASA provinces defined by Herngreen and Chlonova, 1981). Aptian–Albian assemblages reported by Brenner (1968)—from Peru— and Belsky et al. (1975)—from Surinam—also show these similarities. Muller et al. (1987) proposed a palynological zonation for the northern part of South America, the product of years of exploratory work by palynologists for oil companies. However, none of the zones proposed by these authors for the Lower Cretaceous have been identified in the Maracaibo Basin in western Venezuela. Prössl and Vergara-Streinesberger (1993) presented preliminary characterization of palynological assemblages of a few samples from the Aptian of Colombia, mainly in paleoenvironments considered to be fluvial, with some indications of transgressive events during the Early Aptian.

1.2 Dinoflagellate cysts: Lower Cretaceous distribution.

Patterns of provincialism have been proposed for dinoflagellate cysts (Norris, 1975; Stancliffe and Sarjeant, 1988). However, Uwins and Batten (1988) pointed out that dinoflagellates are more cosmopolitan organisms and that they do not show patterns of provincialism as marked as those reported for miospores.

Stancliffe and Sarjeant (1988) proposed that dinoflagellate cysts distribution during the Oxfordian (early Late Jurassic) reflected the existence of at least three provinces; Boreal, Euro-Atlantic and Tethyan. Norris (1975) suggested that certain species of dinoflagellates showed restricted distribution during the Late Jurassic–Early Cretaceous related to the existence of Boreal, Tethyan, and Austral provinces. Williams and Bujak (1985) also pointed out the existence of different dinoflagellate assemblages for the Jurassic and Lower Cretaceous in the Arctic, Boreal, Tethyan and Australian regions.

Brideaux and McIntyre (1975), Doerenkamp et al. (1976) and Århus (1991) reported that Aptian–Albian dinoflagellate cyst assemblages of northern Canada and Greenland are similar but that they differ from others reported elsewhere in Europe and Australia, although several of the species reported from Aptian and Albian stratotypes are present in these arctic assemblages and allow a preliminary correlation.

Assemblages from the Aptian and Albian stratotype sections of France were described by Davey and Verdier (1971, 1973 and 1974), Verdier (1975) and Fauconnier (1979). Robaszynsky et al. (1980) reported Aptian through Santonian dinoflagellate assemblages from France and noticed the remarkable similarity with those of the stratotype sections. Batten (1979) and Duxbury (1983) also noticed similarities of Lower Cretaceous dinoflagellates of England and those of the European sections. Antonescu et al. (1977) described palynological assemblages, including dinoflagellate cysts from Romania which are similar to those reported from the uppermost Albian (Vraconian) of Europe and England.

Several of the taxa reported by these authors had worldwide occurrences during the Early Cretaceous. This fact has been well documented by the dinoflagellate studies of the Deep Sea Drilling Project. Similar taxa to those of the European sections have been reported in the northwestern part of the Atlantic (Davey, 1979a and Fauconnier, 1984 in the Bay of Biscay; Williams, 1978 and Below, 1984 in offshore northwestern Africa; Morgan, 1978 in the South Atlantic Angola Basin; McLachlan and Pieterse, 1978 and Davey, 1978 in offshore southwestern Africa and Hedlund and Beju, 1976 in the South Atlantic Falkland Plateau). Morgan (1978) noticed that Albian assemblages from the Angola Basin are similar to those of the European sections, but that also showed some southern (Australian) influence because of the occurrence of *Dioxya villosa*. McLachlan and Pieterse (1978) also mentioned that Lower Cretaceous phytoplankton assemblages are of cosmopolitan nature, containing species that have been reported in Europe and Australia. Hedlund and Beju (1976) described an Albian south Atlantic dinoflagellate assemblage which is essentially cosmopolitan and also reflects some degree of Australasian influence because of the occurrence of *Muderongia macwhaei*. Assemblages which have been reported from northern Africa also showed remarkable resemblance to those of the European sections (Below, 1981 and 1982 and Gubeli et al., 1984 in Morocco; Batten and Uwins, 1985 and Uwins and Batten, 1988 in northern Libya).

Williams (1975) and Williams et al. (1990) noted that dinoflagellate cysts from offshore eastern Canada show great similarities to those of the European sections but are different from those of the Canadian Arctic. Williams et al. (1990) noticed that the Lower Cretaceous dinoflagellate cyst assemblages from eastern Canada show major changes in the regional affinities, reflecting the development of the proto-Gulf Stream. Neocomian assemblages are considered to be north temperate and closely resemble those of eastern England (Duxbury, 1977; Davey, 1979b). A change was noted starting in the Barremian, reflected by the occurrence of north temperate and tropical elements, suggesting that the proto-Gulf Stream began to be a factor controlling the distribution of dinoflagellates. Bujak and Williams (1978) noted that Aptian and Albian dinoflagellate assemblages from eastern Canada show some differences with those reported from the European sections. Williams et al. (1990) noticed that dinoflagellate provincialism during the Aptian was more pronounced with the occurrence in eastern Canada of temperate elements similar to those reported by Davey (1979a) and Fauconier (1984) in the northern Bay of Biscay and by Duxbury (1983) in England. Assemblages from mid-latitudes, such as those of Habib (1977 and 1978) in the western North Atlantic (offshore the United States) and Below (1981, 1982 and 1984) in Morocco show both temperate and tropical elements, suggesting uniform climatic conditions or an "evolutionary burst" (Williams et al., 1990). Albian assemblages are the most diverse in the Cretaceous (reaching a total of 70 species) in eastern offshore Canada. About 36 species are common with those reported in Europe. As in the Aptian assemblages, several species are present in the European sections and absent in Canada, such as *Carpodinium granulatum*, *C. obliquiscostatum*, *Cauca parva*, *Litosphaeridium arundum* and *Litosphaeridium conispinum*. Also, some species are present in eastern Canada but absent in Europe; *Kiokansium williamsii* (Tasch), *Chichaouadinium* sp. cf. C. *vestitum*, as well as several species of the genus *Oligosphaeridium*.

Williams et al. (1990) noted that Albian assemblages could be grouped in four major assemblages; tropical-subtropical, north temperate, south temperate and boreal. Dinocyst assemblages from the Scotian Shelf show great similarities with those reported in mid-latitudes (tropical-subtropical) whereas assemblages from eastern Newfoundland show more similarities with those of Europe (north temperate). These differences in the assemblages seem to reflect warm ocean currents (proto-Gulf Stream) flowing northwards along the western margin of the north Atlantic. Differences of the assemblages can also be the result of facies differences between Europe and eastern Canada during the Aptian and Albian. Williams (1975) and Williams et al. (1990) noted that the Aptian-Albian was a period of deposition in non-marine and marginal marine environments in the Scotian Shelf whereas epicontinental seas covering extensive shelf areas were dominant in southern England and the Paris Basin area (Davey, 1979a). Albian assemblages of Alberta (Brideaux, 1971; Singh, 1971) have several species in common with coeval European assemblages. Williams (1975) noted similarities between the offshore Canadian assemblages and those reported in Alberta by Singh (1971).

Australian assemblages show differences from to those of the European sections. A review of the literature concerning Lower Cretaceous assemblages from Australia, reported by Cookson and Eisenack (1958, 1960 and 1970), Verdier (1970), Morgan (1979), Stevens and Helby (1987), Stevens (1987), Backhouse (1987) and Stover and Helby (1987a and 1987b), indicates a relatively high proportion of endemic species. Stratigraphic ranges and a palynological zonation based on the occurrences of both miospores and dinoflagellates was proposed by Helby et al. (1987) for the Mesozoic of Australia.

Scott and Kidson (1977) reported dinoflagellate assemblages from the Lower and lowermost Upper Cretaceous carbonate deposits in Texas, but did not provide details of these assemblages. Hedlund and Norris (1986) reported dinoflagellate assemblages from the Middle Albian of Texas, including species that are also present the European sections, northern Canada, and Morocco.

Few Aptian-Albian dinoflagellate assemblages have been described from the Caribbean area. Riley and Fenton (1984) reported a total of 14 species for the Aptian from the southeastern Gulf of Mexico. Most of these species are also present in the European sections. Habib (1972) reported five dinoflagellate species in Albian sediments north of Surinam (northern South America). These species were also described by Habib (1978 and 1979) in the Blake Bahamas Plateau area, as well as in the European sections. Paredes de Ramos and Fasola (in Moldovanyi and Pinto-Auso, 1987) described 27 species of dinoflagellates from well ALT-19X in the Maracaibo Basin, with several species that have also been found in the European sections. Prössl (1992) gave a preliminary report of poorly preserved phytoplankton assemblages from few samples of the Aptian-Turonian of Colombia, but did not discuss their biostratigraphic significance.

1.3 Palynofacies and distribution of particulate organic matter

A complex interaction of several factors has an effect on the distribution of palynomorphs at the regional level. Palynomorphs and phytoclasts behave like sedimentary particles; therefore, their distribution and abundance is affected by the nature of the sedimentary environments. Cross et al. (1966) noted that large concentrations of terrestrial palynomorphs are detected in silty clays at delta mouths whereas low concentrations along the shore are related to winnowing from coarse sediments. It is well established that the proportion of terrestrial palynomorphs and phytoclasts tends to decrease with the distance from the coast line (Muller, 1959 and Cross et al., 1966). Muller (1959) and Cross et al. (1966) noted that some species of pollen grains become less common with the distance from shore, whereas others, such as mangrove pollen, increase in relative frequency offshore. The use of the ratio of terrestrially derived spores and pollen to marine phytoplankton has been used as a method for approximating the distance from the coast. Cross et al. (1966) also noted that the proportion of phytoclasts (tracheids and cuticles) are more abundant closer to the shoreline and delta mouths.

In general the studies of palynofacies—the total associations of organic matter left after the palynological maceration of samples (Combaz, 1964)—has been widely used not only in source rock studies, but also for paleoenvironmental assessment. More recently, palynofacies studies have been used within the framework of sequence stratigraphy and relative sea-level changes (Gorin and Steffen, 1991; Habib and Miller, 1987; Tribovillard and Gorin, 1991). Most of these studies have been carried out mainly on fine-grained siliciclastic sediments or in deep water carbonate sediments (Steffen and Gorin, 1993a-b) where high rates of sedimentation and low level of energy of the paleoenvironments enhance the preservation of the organic matter. Few studies have been done on shallow carbonate platform deposits, because of the highly oxidizing conditions of these paleoenvironments.

2. REGIONAL GEOLOGY: INTRODUCTION.

The Maracaibo Basin is located in the northwestern part of Venezuela, limited to the north by the Oca Fault, to the west by the Perijá Ranges, to the south and south east by the Venezuelan Mérida Andes and to the east by the Trujillo Ranges and the lowlands of the Lara and Falcon states (González de Juana et al., 1980) (Figure 2).

The tectonic evolution of the Maracaibo Basin during the Mesozoic has been related to the break-up of Pangea and the subsequent formation of the Gulf of Mexico and the Caribbean Basin (Burke, 1988; Burke et al., 1988; Ross and Scotese, 1988). Maze (1984) pointed out the difficulty of classifying the Maracaibo Basin as an active or a passive margin because of its position on the northwest edge of Gondwana during the Mesozoic. Some authors (for example, Pindell and Dewey, 1982) have proposed that the northwest corner of South America may have been isolated from the convergent tectonic setting produced at the boundary between the Pacific and the Americas, whereas others have proposed that the northwest area was part of large subduction-arc complex at this plate margin (for example, Dickinson and Coney, 1980).

2.1 Structure of the Maracaibo Basin.

Within the basin, the most noticeable structural features show an approximately north-south trend (Figure 3), roughly parallel to the Perijá Ranges and perhaps related to incipient orogenesis during the Late Cretaceous–Paleocene (González de Juana et al., 1980; Kellog, 1984), resulting in the formation of small anticlines and north-northeast trending normal faults. A second period of deformation might have occurred during the Late Eocene–Oligocene, characterized by intensive compressional stress that resulted in the formation of important north-northeast structures (Urdaneta, Lama and Centro anticlines). On the other hand, Audemard et al. (1987) inferred two major discrete events that caused the development of several of the geologic structures in the basin, based on structural studies in the western area of the Maracaibo Basin. The oldest of these events is proposed to have occurred in the Late Eocene–Oligocene and consisted of a compressive event, which activated north-south trending faults. Lugo (1991) has recently proposed that major folding and thrusting in the Eocene caused the reactivation of Jurassic normal faults as convergent strike-slip and reverse faults. According to this author, the accretion of island arc terranes in the northeast area of the Maracaibo Basin led to the formation of

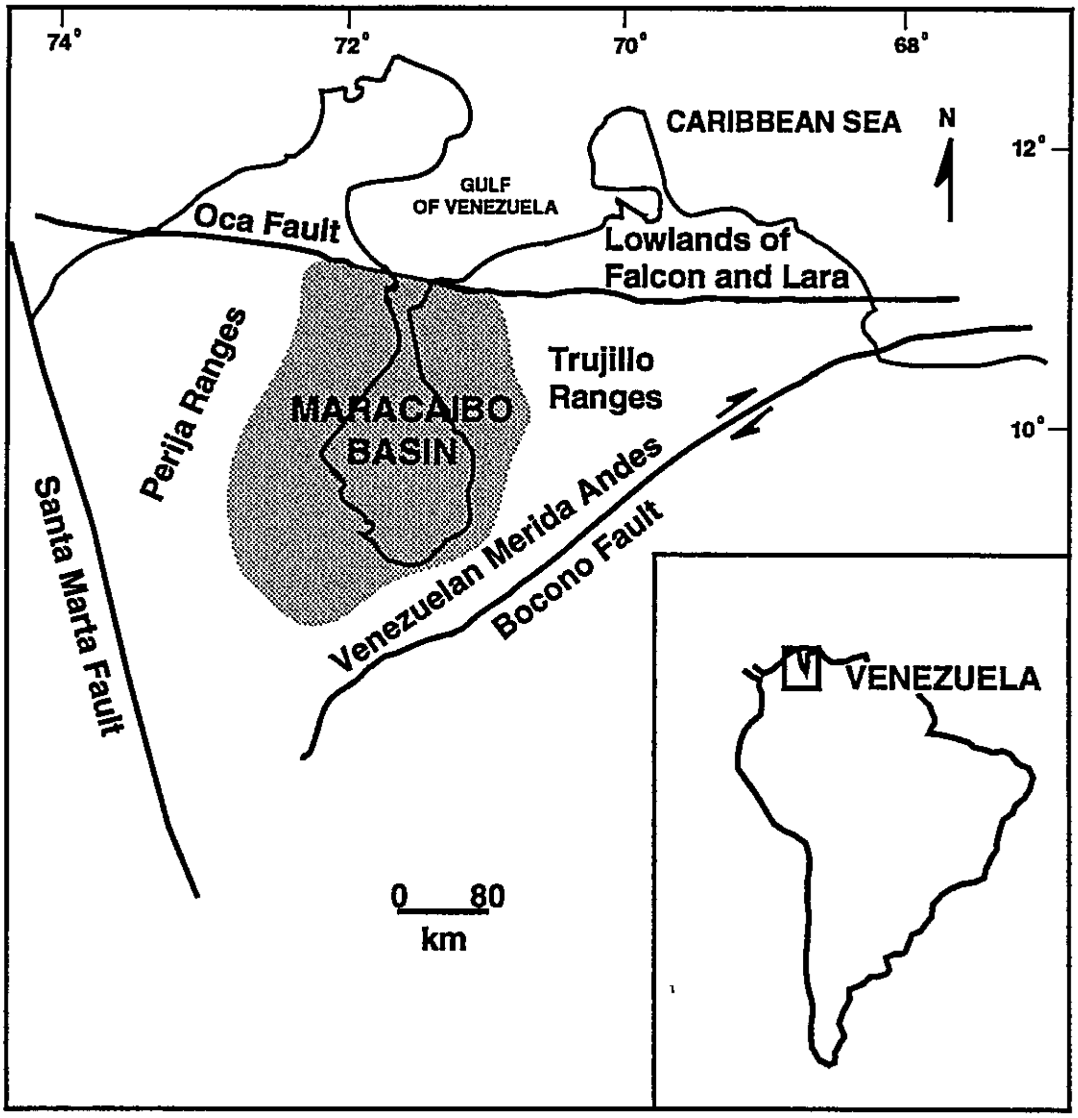

Figure 2. Geographical location of the Maracaibo Basin, western Venezuela, showing major faults.

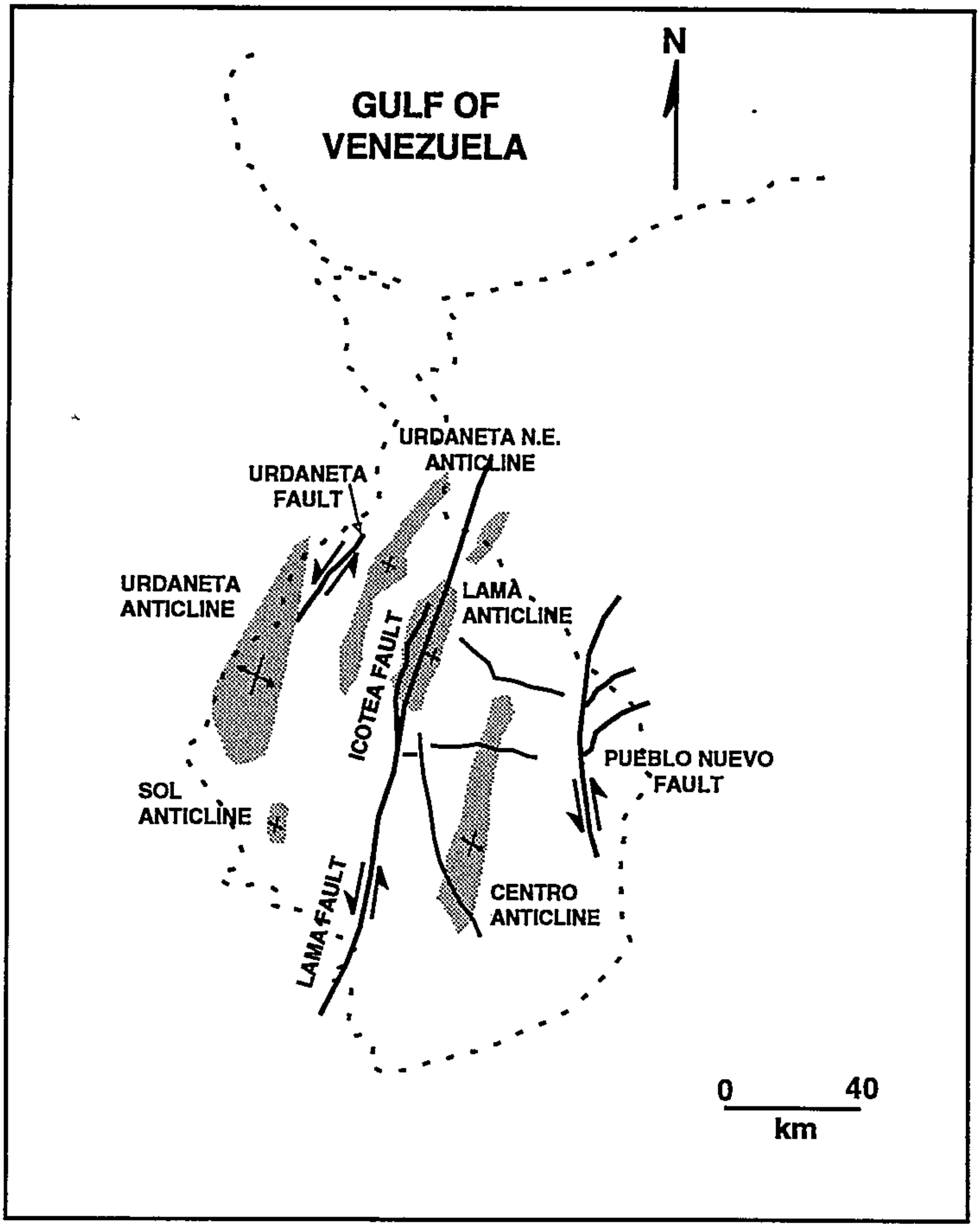

Figure 3. Main structural features of the Maracaibo Basin. Two major tectonic events have been proposed to have initiated these structural features of the Maracaibo Basin; Upper Cretaceous-Paleoecene (Icotea and Pueblo Nuevo faults and the Sol Anticline) and Upper Eocene-Oligocene (Urdaneta, Lama and Centro anticlines).

the so-called Maracaibo foredeep, that was filled by a thick clastic sequence that prograded from the northeast to the southwest. The youngest major tectonic event proposed by Audemard et al. (1987) began to unfold by the Miocene-Pliocene and led to the uplifts of the Perijá and the Mérida Andes ranges. This event finished shaping the major structural features of the basin. Lugo (1991) concluded that continued slow convergence between the Caribbean and the South American plates during the Paleogene–Neogene, reactivated Jurassic normal faults as reverse and left-lateral strike-slip faults, leading to the uplift of the peripheral mountain ranges and the deposition of more than 10 km of clastic sediments in the basin after the Miocene–Pliocene.

2.2 Mesozoic sedimentation in northern South America.

Sedimentation during the Jurassic and part of the Early Cretaceous was related to incipient rifting between North and South America (Pindell and Dewey, 1982; Pindell et al., 1988). The continental red beds and volcanics of the La Quinta Formation represent the typical sediments of the early rifting phase, deposited mainly in northeast-southwest subsiding grabens (Maze, 1984). Macellari (1988) recognized that sedimentation during the Cretaceous took place in a variety of tectonic settings, ranging from passive or stable platforms (associated with the Guayana and Brazilian massifs) in the east to back-arc settings in the west. He pointed out that in general, the deposition of Lower Cretaceous sediments in the northern South America took place on extensive platforms that covered regions of Venezuela, Colombia, Ecuador and Peru. This complex platform system was encroached upon repeatedly by a series of transgressive events that largely determined the sedimentary styles in these platforms.

Macellari (1988) proposed three depositional (regional unconformity-bounded) cycles for the Jurassic–Early Cretaceous in the northern part of South America (Venezuela and Colombia). The first took place during the Tithonian to Valanginian and was characterized by deposition largely controlled by rapidly subsiding grabens that were oriented northeast-northwest. This phase led to the deposition of thick sequences of the Jurassic La Quinta Formation. Within the Maracaibo Basin, some of the north-northwest rapidly subsiding grabens, principally the Machiques, Uribante and Barquisimeto troughs (Figure 4), were still active during part of the Early Cretaceous and largely controlled the deposition of the Rio Negro Formation. Thick deposits of quartz and feldspathic arenites and microconglomerates of this formation were deposited in these troughs during the first of Macellari's cycles (González de Juana et al., 1980; Macellari, 1988).

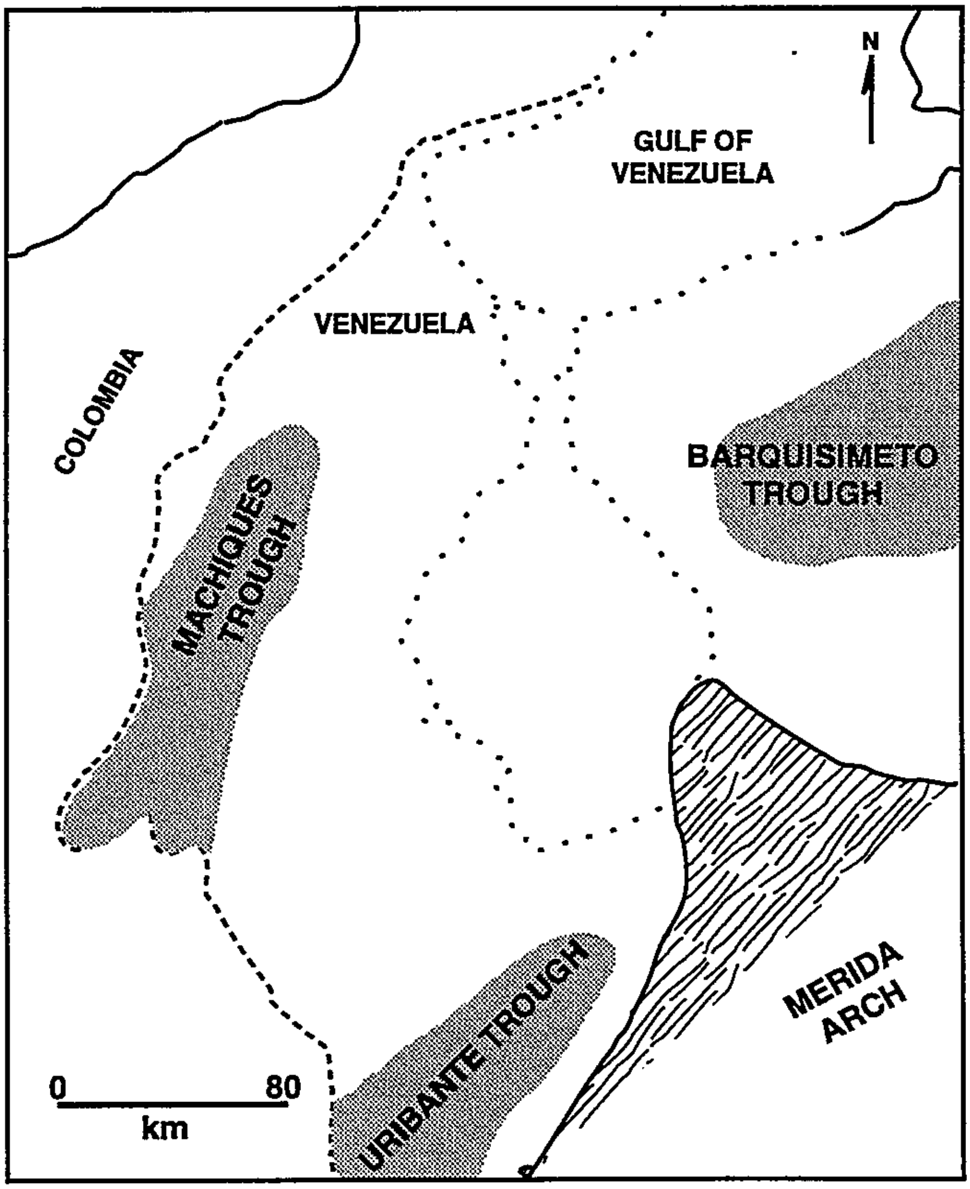

Figure 4. Lower Cretaceous structural features of the Maracaibo Basin (after Zambrano et al., 1971). The Barquisimeto, Machiques and Uribante troughs were rapidly subsiding grabens, where Jurassic and pre-Aptian sedimentation (La Quinta and Rio Negro formations) took place.

The second of Macellari's cycles is characterized by a transition from locally centered subsidence in the grabens to widespread and thermally-driven subsidence that occurred the Valanginian to Late Aptian. Toward the end of the Barremian–Early Aptian and continuing for the rest of the Cretaceous, sedimentation was largely controlled by the successive encroachment of transgressive events onto the platform in the Maracaibo Basin area. Tectonic events were localized (mainly in the depositional troughs) and the deposition of the upper part of the Rio Negro Formation and the Apón Formation took place mainly on a stable shallow-water platform.

A third phase of deposition took place at a time of widespread subsidence controlled by thermal cooling, that combined with rising sea level, resulted in the flooding of several of the paleohigh areas during the Albian to Turonian. According to Macellari (1988), the deposition of the Aguardiente Formation in the south-southwest of the Maracaibo Basin is associated with this transgressive event and it is capped by the shaly facies of the La Grita Member of the Capacho Formation (during the Late Albian–Cenomanian). Basinwards, carbonate deposition took place, resulting in the deposition of the calcareous facies of the Aguardiente Formation (in the southern part of the basin), the Piché Member (of the Apón Formation) and the Lisure, Maraca and La Luna formations.

2.3 Aptian-Albian stratigraphy of the Maracaibo Basin.

Pre-Aptian sedimentation in the Maracaibo Basin is characterized by deposition of continental clastic sediments in localized grabens, the Uribante, Machiques and Barquisimeto troughs (Zambrano et al., 1971), followed by widespread carbonate deposition on a relatively stable platform, with transgressive phases occurring in the Aptian–Albian (González de Juana et al., 1980). Figures 5 and 6 show the stratigraphic nomenclature and correlation for the Lower and lowermost Upper Cretaceous lithological units of the Maracaibo Basin. The palynological study here described is centered on the Lower Cretaceous carbonate and siliciclastic stratigraphic units of the Cogollo Group and the Aguardiente Formation in the surface and subsurface of the Maracaibo Basin.

2.3.1 Cogollo Group.

Garner (1926) used the term Cogollo for the first time, as a formational unit

<table>
<tr><th colspan="9">STRATIGRAPHIC NOMENCLATURE OF THE LOWER CRETACEOUS IN THE MARACAIBO BASIN, WESTERN VENEZUELA</th></tr>
<tr><th>STAGE</th><th colspan="3">MARACAIBO PLATFORM (I)</th><th colspan="3">MACHIQUES TROUGH (II)</th><th colspan="2">SOUTHWEST ANDES (III)</th></tr>
<tr><td>SANTONIAN</td><td colspan="3" rowspan="4">LA LUNA FM.</td><td colspan="3" rowspan="4">LA LUNA FM.</td><td colspan="2" rowspan="2">LA LUNA FM.</td></tr>
<tr><td>CONIACIAN</td></tr>
<tr><td>TURONIAN</td><td colspan="2" rowspan="2">CAPACHO FM.</td></tr>
<tr><td>CENOMANIAN</td></tr>
<tr><td rowspan="2">ALBIAN</td><td rowspan="5">COGOLLO GR.</td><td colspan="2">MARACA FM.</td><td rowspan="5">COGOLLO GR.</td><td colspan="2">MARACA FM.</td><td colspan="2">MARACA FM.</td></tr>
<tr><td colspan="2">LISURE FM.</td><td colspan="2">LISURE FM.</td><td colspan="2" rowspan="2">AGUARDIENTE FM.</td></tr>
<tr><td rowspan="3">APTIAN</td><td rowspan="3">APON FM.</td><td>PICHE MB.</td><td rowspan="3">APON FM.</td><td>PICHE MB.</td></tr>
<tr><td>GUAIMAROS MB.</td><td>MACHIQUES MB.</td><td rowspan="2">APON FM.</td><td>GUAIMAROS MB.</td></tr>
<tr><td>TIBU MB.</td><td>TIBU MB.</td><td>TIBU MB.</td></tr>
<tr><td>PRE-APTIAN</td><td colspan="3">RIO NEGRO FM.</td><td colspan="3">RIO NEGRO FM.</td><td colspan="2">RIO NEGRO FM.</td></tr>
</table>

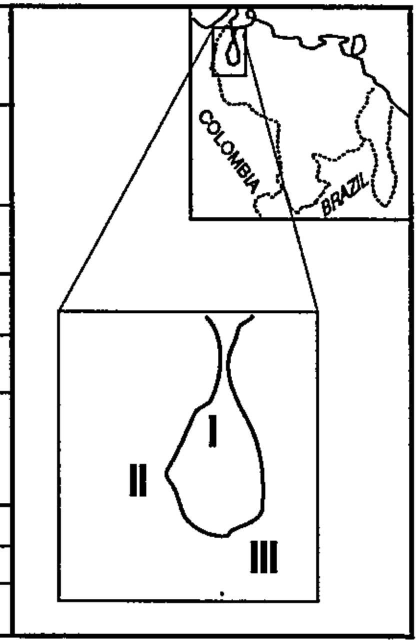

Figure 5. Stratigraphic nomenclature for the Lower Cretaceous of the three principal areas of the Maracaibo Basin, western Venezuela. From the *Léxico Estratigráfico de Venezuela* (1970) and González de Juana *et al.* (1980).

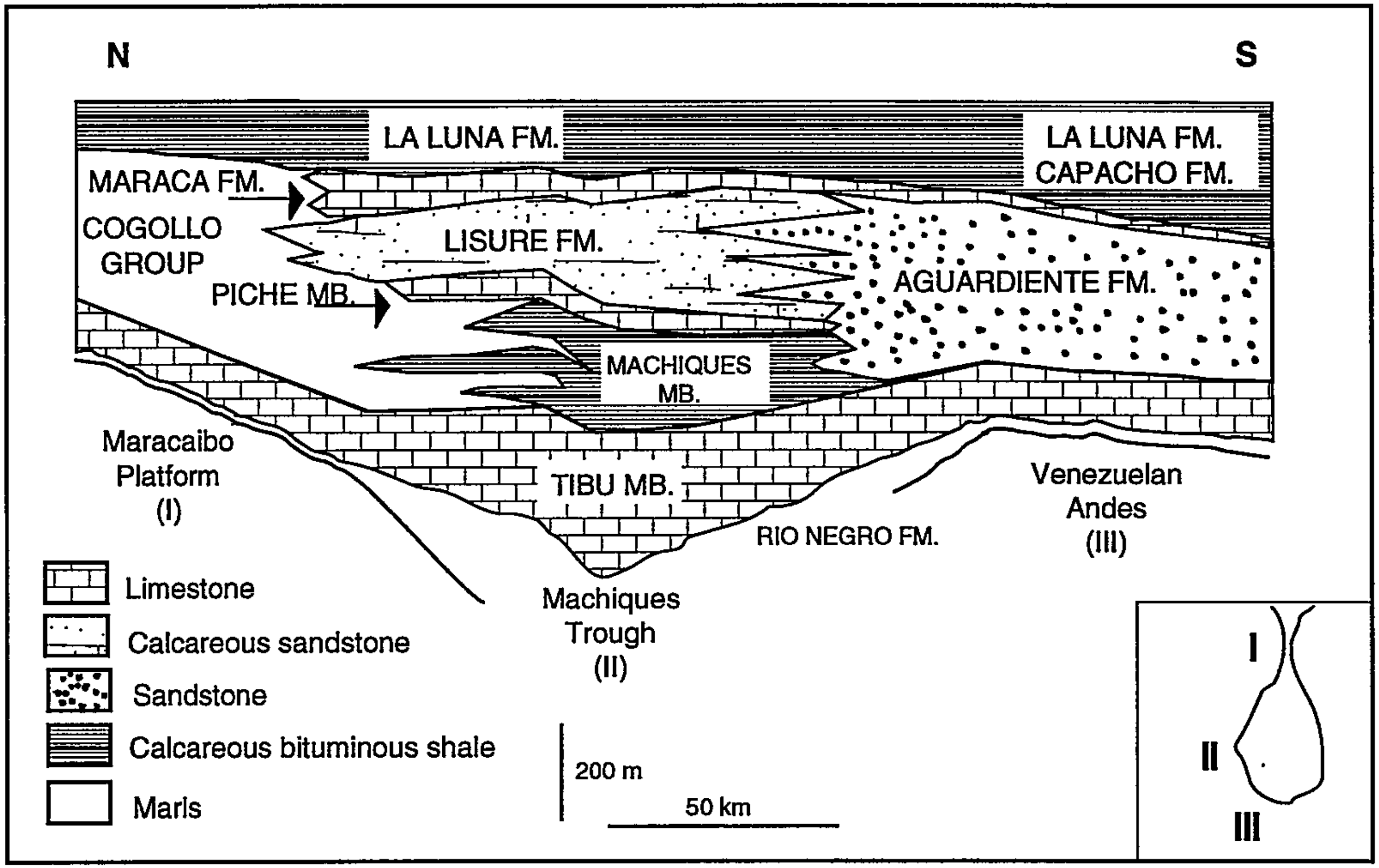

Figure 6. Correlation and distribution of lithostratigraphic units along the western flank of the Maracaibo Basin (modified after Renz, 1982).

comprising the crystalline limestone underlying the La Luna Formation in western Venezuela. As more studies were conducted in the oil-prolific Maracaibo Basin, it became recognized that several limestone units underlying the La Luna Formation could be discriminated. Sutton (1946) attempted to redefine the Cogollo, this time as group, including the limestone sediments of the Apón Formation, the sandstones and clastics of the Aguardiente Formation and the shales of the Capacho Formation outcropping in the Venezuelan Andes.

As more geological studies were completed in the Perijá Ranges, the Cogollo Group was redefined to encompass mainly calcareous units outcropping in this area. Rod and Maync (1954) proposed that the limestones of the Apón, Lisure and Maraca formations should be included in the newly defined Cogollo Group. This modification was accepted and incorporated into the *Léxico Estratigráfico de Venezuela* (1970). González de Juana et al. (1980) confirmed that this division is useful in the subsurface of the Maracaibo Basin and in areas of the Venezuelan Perijá Ranges.

2.3.1.1 Apón Formation.

The term Apón was initially used by Sutton (1946) to refer to the lowermost carbonate unit of the Cogollo Group. In general the lithology consists of relatively massive, crystalline, bluish-grayish wackestones and packstones with interstratified shales. The contact with the underlying calcareous microconglomerates and sandstones of the Rio Negro Formation is considered transitional and diachronous.

Rod and Maync (1954) further subdivided the Apón Formation into three lithologically distinct members but failed to formally name them. Renz (1959) introduced the names Tibú, Machiques and Piché for these members in the Machiques area, indicating that the topmost member, the Piché, graded to the south into the more clastic facies of the Aguardiente Formation. A fourth member, the Guaimaros, present in other areas of the Maracaibo Basin was also described by Renz (1959).

- Tibú Member.

The name Tibú Member was originally used by Notestein et al. (1944) to refer to the lowermost massive Cretaceous carbonate unit outcropping in the periphery of the

Maracaibo Basin. Later, Renz (1959) formally defined it and included it within the Apón Formation.

In general, the lithology grades from wackestones, grainstones, calcareous sandstones and shales, at the base, into crystalline biostromic limestones, intercalated with dark colored marls. Maync (in Rod and Maync, 1954) reported the occurrence of foraminifers such as *Chofatella decipiens*, a key fossil of this unit indicative of the Aptian. Renz (1959) reported the occurrences of ammonites such as *Heminautilus etheringtoni* and a species of the genus *Roboloceras*, which has been reported in the Lower Aptian of England.

The *Léxico Estratigráfico de Venezuela* (1970) and González de Juana et al. (1980) have described the contact of the Tibú member with the underlying conglomeratic sandstones of the Rio Negro Formation as transitional and diachronous, as a result of the onlapping transgression onto the platform. The top of the Tibú Member is marked by the first occurrence of the shales of the Machiques or the Guaimaros members.

- Machiques Member.

The Machiques Member comprises interstratified bituminous dark-gray to black shales and limestones. This member was initially defined in the Machiques area by Renz (1959) and is characterized by the presence of abundant large-sized ellipsoidal calcareous concretions, which usually yield abundant fossil remains. Sutton (1946) and Maync (in Rod and Maync, 1954) reported ammonites such as *Deshayesites colombianus, Parahoplites* sp. cf. *P. inconstan* and *Deshayesites* sp. cf. *D. sutzeri* and of the genus *Colombiceras*, a faunal assemblage which is considered to be indicative of the Upper Aptian. Renz (1959 and 1982) reported ammonites of the genera *Deshayesites* and *Dufrenoyia*, indicative of the Aptian in Europe (see Hancock, 1991). However, Renz (1982) cautioned that the occurrences of species of *Dufrenoyia* must be considered with special care, arguing that this genus is facies controlled. Renz (1982) also reported ammonite species of *Parengonoceras* sp. cf. *P. hachourii* and *Prolyelliceras flandrini* in the upper part of the Machiques Member.

The thickness of the Machiques Member reaches a maximum of 205 m in the Machiques area, decreasing towards the north and the south, and disappearing in the subsurface of Lake Maracaibo.

- Guaimaros Member.

Renz (1959) observed a continuous shaly unit extended in other areas of the Maracaibo Basin, overlying the Tibú Member, and named it as the "Formación Lutitas de Guaimaros". However, Trump and Salvador (1964) considered it as a member of the Cogollo Group. The typical lithologies encompass grayish to dark gray dolomitic shales, with thin calcareous beds towards the top of the unit. Its thickness ranges from 20 to 30 m in the areas south of the Basin.

In general, few fossils have been reported from this unit, except for unidentified plant remains (mainly of *Weichselia* sp.) and isolated specimens of *Choffatella* sp. (Sutton, 1946; González de Juana et al., 1980 and Renz, 1982).

- Piché Member.

Overlying the Machiques Member in the Machiques Trough area, and the Guaimaros Member in the Maracaibo Lake area, Renz (1959) observed and defined the Piché Member, a highly fossiliferous-biostromic limestone unit that grades to the south into the more clastic deposits of the Aguardiente Formation.

Sutton (1946) reported the occurrences of echinoids such as *Phymosomas* cf. *texanum*, *Hulectypus* sp. and *Hardovinia* sp. and abundant specimens of bivalves of *Exogyra* sp. in the top part of the Apón Formation. Maync (in Rod and Maync, 1954) discussed the biostratigraphic value of the benthic foraminifer *Orbitolina texana*. This species has been used a marker of the Upper Aptian–Albian in the Maracaibo Basin (Azpiritxaga, 1991). Maync (in Rod and Maync, 1954) reported the occurrence of Albian ammonites of *Douvilliceiras* aff. *D. nonile* in the Upper Aptian of the Apón Formation. Renz (1982) reported the occurrences of several specimens of the bivalve *Trigonia* sp., which he considered as indicative of the Lower Albian for the top part of this member.

The *Léxico Estratigráfico de Venezuela* (1970) and González de Juana et al. (1980) have described the contact of the Piché Member with the overlying Lisure Formation as transitional and placed it at the top of the massive limestones.

2.3.1.2 Lisure Formation.

Rod and Maync (1954) formally described the Lisure Formation as the intermediate member of the Cogollo Group. The unit comprises mainly glauconitic-calcareous quartzitic sandstones and grainstones, interstratified with sandy shales and fossiliferous limestones layers. The lower conformable contact with the Apón Formation is transitional, as it is at the top with the Maraca Formation (González de Juana et al., 1980). It tends to become undifferentiated from other calcareous units of the Cogollo Group, because of increasing content of carbonate in the sediments towards the north of the Maracaibo Basin. To the south, it grades into the sandy deposits of the Aguardiente Formation.

González de Juana et al. (1980) reported the occurrence of the ammonite *Haplostiche texana,* indicative of Middle to Upper Albian for the Lisure Formation. Renz (1982) reported the occurrences of ammonites such as *Kremiceras* aff. *flexiloculosum* at the base of the Lisure Formation, a species which might be indicative of the Lower Albian. He also reported the occurrence of a single specimen of *Mortoniceras* sp. the upper part of the Lisure Formation. González de Juana et al. (1980) also reported the occurrence of an *Orbitolina* horizon, which is widespread in the Basin and extends into the south in the Aguardiente Formation.

2.3.1.3 Maraca Formation.

Rod and Maync (1954) introduced the name Maraca to include a characteristically fossiliferous limestone unit located in the topmost part of the Cogollo Group which is well represented all over the Maracaibo Basin and adjacent areas to the south and southeast. The unit mainly comprises sandy crystalline, fossiliferous limestones (with abundant *Ostrea* and other molluscs such as *Exogyra*) interstratified with marls and shales. Its lower contact with the Lisure Formation is transitional and conformable, whereas its contact with the overlying La Luna Formation (in the Maracaibo Basin area) and Capacho Formation (in the Venezuelan Andes to the south) is abrupt (González de Juana et al.,1980). Its thickness ranges from 120 m in the north of the Maracaibo Basin, thinning towards the south and the east, to 10-20 m in the subsurface of the Lake Maracaibo and the Venezuelan Mérida Andes.

The age of the formation has been inferred from its stratigraphical position, above the Middle Albian Lisure Formation. Renz (1982) observed several specimens of the ammonite genus *Oxitropidoceras*, which might be indicative of the Middle to Upper Albian in the Maraca Formation outcropping in the Venezuelan Andes .

2.3.2 Aguardiente Formation.

Notestein et al. (1944) introduced the term Aguardiente to refer to an arenaceous member of the Uribante Formation in Colombia. Sutton (1946) proposed it as a member within the Cogollo Group. Rod and Maync (1954) suggested that this unit was a lateral equivalent of the top of the Apón and the Lisure formations in the south-southeast area of the Maracaibo Basin. Renz (1959) proposed the Peñas Blancas Formation to include this arenaceous facies. However, Salvador (1961) defined it as a separate formation with the name of Aguardiente.

The unit comprises calcareous, light-gray to green sandstones with interstratified carbonaceous shales. Sandstones are locally more glauconitic in some areas of Táchira State (south of the Maracaibo Basin) and become more calcareous in the north and northwest this state (Trump and Salvador, 1964). In general the unit is characterized by quartzitic sandstones, massive and free of matrix, with alternations of gray to dark gray shales and thin limestone beds. Its contact with the underlying Apón Formation seems to be transitional and conformable. However, the *Léxico Estratigráfico de Venezuela* (1970) described the contact of this formation with the Jurassic La Quinta Formation as unconformable.

The occurrence of *Orbitolina texana* at the base of this unit indicates a Late Aptian–Early Albian age for the lowermost part of the Aguardiente Formation (González de Juana et al., 1980).

2.4 Sedimentology of the Cogollo Group and Aguardiente Formation.

The deposition of the Cogollo Group carbonates took place in shallow water environments of what could have been a ramp (as defined by Ahr, 1973) or a platform (as defined by Wilson, 1975). Bartok et al. (1981) described four major sedimentary environments for the Cogollo Group in the Maracaibo Basin:

- A deltaic-transitional marine environment, characterized by the dominance of siliciclastics of the Aguardiente Formation in the south and southeastern part of the basin. Prolonged erosion of the cratonic areas in the south and southeast caused the peneplanation of the area, involving a series of rivers which drained into a basin with major tidal influence.

- An internal platform, consisting of the supratidal/intertidal and the restricted marine environments. Carbonate facies are predominantly mud-supported (mudstones-wackestones) in the supratidal environments and sapropelic lagoonal mudstone-wackestones, pelecypod packstones and algal-oncolite packstone/wackestone in the restricted marine domain.

- An external shallow marine platform, with high to moderate energy. Ooid grainstones/packstones bars (associated with high energy), foraminifera-bryozoan-pelecypod and wackestone/mudstones (moderate energy) are the characteristic carbonate facies of this general sedimentary environment.

- Deep marine low energy environments. Wackestones and packstones, with large proportion of shales (deep marine low energy) are the characteristic lithofacies.

Ford and Houbolt (1963) described three types of microfacies in the Apón Formation, relating all of them to shallow water environments, specifically in the lower zone of wave action and below it. These authors, as well as Méndez (1989), also observed intervals of dolomitized shales, related to deposits of tidal flats, at the base of the Tibú Member of the Apón Formation. Moldovanyi and Pinto Ausó (1987) reported that intervals at the base of the Apón Formation in well ALT-19X (Figure 1) are characterized by microfacies of bioclastic wackestones, with up to 60% of micritic matrix. These microfacies have been related by these authors to low energy paleoenvironments. The top of the Apón Formation in this well is characterized by mollusc wackestones (with 50% of molluscs), associated with shales. These authors proposed that this microfacies is indicative of transitional environments with molluscs being transported. The most common microfacies reported by these authors for the Cogollo Group in this well is the packstone of molluscs, containing either *Ostrea* (Apón Formation) or thin bivalves (observed only in the Apón Formation). The authors concluded that these microfacies are related to relatively deep water paleoenvironments with low energy. Algal grainstones (dominated by green algae fragments at the top of the Apón Formation and the base of the Maraca Formation) are considered to be related to shallow-water paleoenvironments with high energy conditions. Azpiritxaga (1991) determined that the deposition of the Cogollo Group (Apón Formation) in the central area of Lake Maracaibo during the Aptian, took place during a relative sea-level fall (Figure 7) that caused repeated thin fining-upward cycles, that are in general capped with fine-grained low energy deposits in very shallow paleoenvironments (2-5 m depth). As a result of this inferred sea-level fall, she proposed that more land was exposed and there was the possibility of large inflows of siliciclastics into the basin.

Martínez and Hernández (1992) have proposed that Macellari's second depositional cycle ended with the incipient drowning of the carbonate platform in the Maracaibo Basin, representing a maximum flooding event, that is associated with the deposition of the bituminous shales of the Machiques Member in the Machiques Trough, and the shales of the Guaimaros Member elsewhere in the basin and in the Andes region. Martínez and Hernández (1992) positioned this flooding event at the boundary of the Aptian–Albian without providing any evidence for the dating. More recently, Pérez Infante and Farrimond (1993) have informally divided the Machiques Member into three units, based on geochemical and lithological information. Evidence provided by these authors indicates large, but variable, total organic content (TOC) up to 10% in thin interbedded shales and marls at the base of the Machiques Member. The middle unit, on the other hand, is characterized by thicker carbonate layers and lower TOC values (less than 3%) whereas the third or top unit, shows fluctuating values of TOC (up to 7%) in shale beds. They also found that the TOC varied strongly with the carbonate content of the sediments. According to their preliminary interpretation, these changes of organic content and lithology seem to be related to variations of the sedimentological and physical-chemical conditions of the paleoenvironments, with conditions of anoxia at the base of the unit and a clear trend to shallower and more oxidizing paleoenvironments towards the top of the unit.

Moldovanyi and Pinto-Auso (1987) reported relatively high-energy microfacies of intraclast (micrite and glauconite) and bioclast (dominated by bivalves with minor amounts of algae, quartz, bryozoans and corals) and green algae grainstones in the Lisure Formation. These authors also reported that sandy, silty and shaly facies are observed mainly in the Lisure Formation and to a lesser degree, in the Apón Formation. Kummerow and Pérez de Mejía (1989) reported that the Lisure Formation is

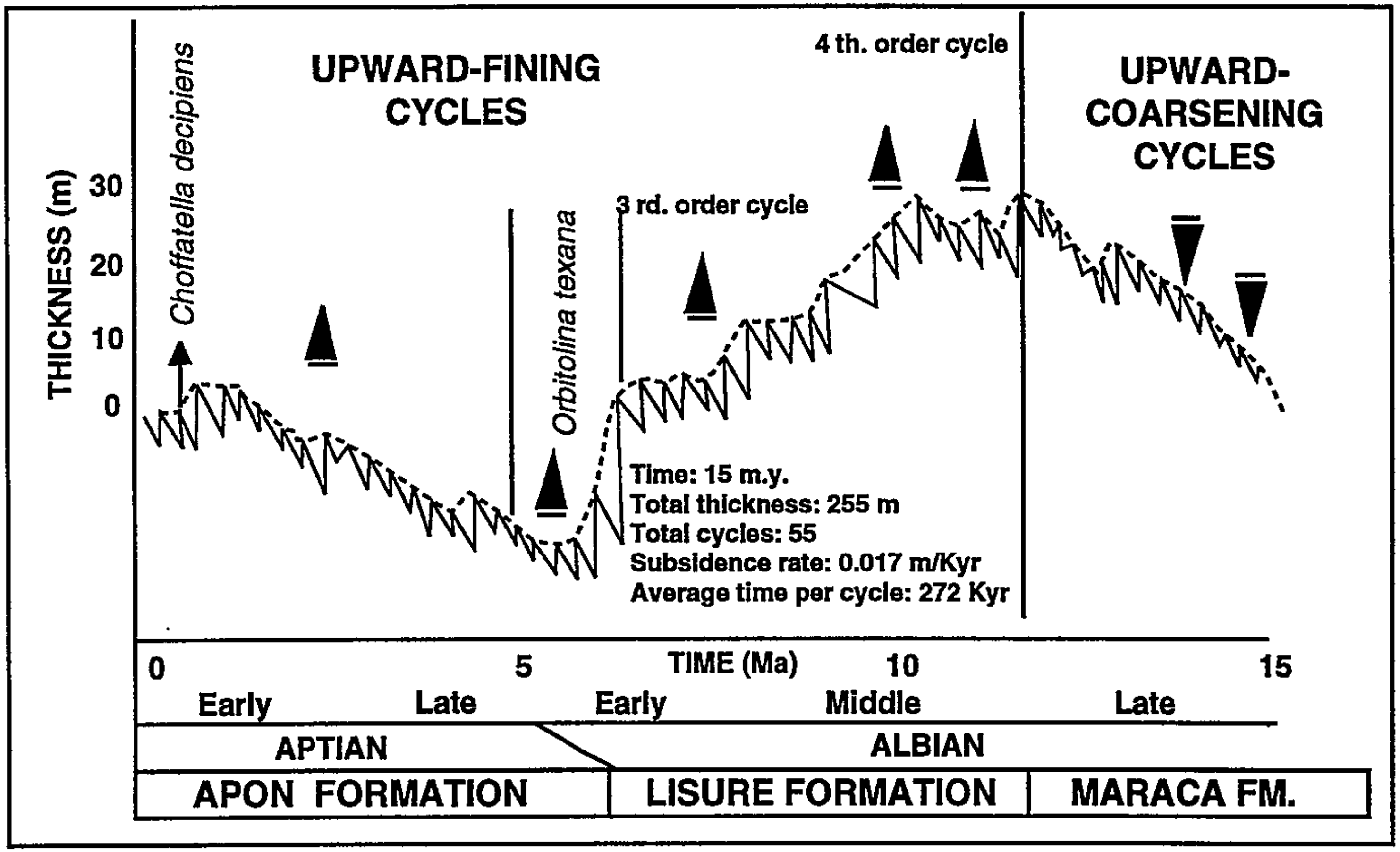

Figure 7. Fisher plot for the Cogollo Group (after Azpiritxaga, 1991). Sedimentary styles of the Cogollo Group in the central Lake Maracaibo area were characterized by upward-fining cycles during the Aptian (relative sea-level fall) and Early to Middle Albian (relative sea-level rise), and upward coarsening cycles during the Late Albian (during a period of relative sea-level fall).

characterized by the high content of glauconite and clastic intervals of calcareous sands and siltstones. These authors also reported a distinctive and widespread shale bed, that can be correlated all over the basin. Méndez (1989) reported that the predominant microfacies of the Lisure Formation are packstone-grainstone textures with predominance of oolites at the top and in the northern area of the basin (La Paz Field) and predominantly terrigeneous shales in the Machiques Trough. Méndez (1989) also pointed out that these pro-deltaic shales were deposited in two events, separated by the deposition of shallow water carbonates. Azpiritxaga (1991) described the alternation of fining-upward cycles in the Lisure Formation deposited during a relative sea-level rise beginning the Early Albian (Figure 7), in relatively deep paleoenvironments (5-15 m). These Albian fining-upward cycles developed during a relative sea-level rise and the evidence of hardground surfaces seems to indicate the relative deepening of the paleoenvironments. However, the deepening was not enough to remove the carbonate-producing organisms from the photic zone and they were able to build-up carbonate after this minor deepening phase. This setting has been defined by Tucker and Wright (1990) as an incipient drowned platform.

Moldovanyi and Pinto Ausó (1987) reported that the Maraca Formation lacks siliciclastic material in the southern Alturitas Field and that algal and oncolite-packstone/grainstones are the predominant microfacies. These authors concluded that the deposition of this unit took place in moderate energy conditions, with a definite and significant trend to low energy conditions at the top, perhaps related to more open oceanic environments. Méndez (1989) and Kummerow and Pérez de Mejía (1989) reported that the Maraca Formation generally shows uniform lithofacies and thicknesses all over the basin, with microfacies consisting mainly of mollusc packstones. Azpiritxaga (1991), on the other hand, reported that the sediments of the Maraca Formation in the central Lake area are characterized by coarsening-upward cycles (Figure 7) related to a high-energy shoal complex and concluded that they represent a shallowing-upward trend, from subtidal skeletal wackestone to intertidal ooid and skeletal grainstone/packstone.

Bartok et al. (1981) noteded that deposition in the south-southeast margin of the basin was characterized by the predominance of the clastic deposits of the Aguardiente Formation. González de Juana et al. (1980) summarized the facies of the Aguardiente Formation as an alternation of fluvial-coastal sandstone-shale facies and nearshore-marine limestones In general the sandstone facies are predominantly quartzitic, locally glauconitic, intercalated with sandy to lignitic shales. Bioclastic limestones are observed at the base of this unit, whereas, oolitic and fossiliferous limestones are present towards the top. Mederos (1992) reported that the cored section of the Aguardiente Formation in well CR-5 (see Figure 1 for location), in the southwest area of the Maracaibo Basin is characterized at the base by dolomitic sandstone, that is capped by calcareous sands with fragments of rudists, bivalves and occasional meliolids. Towards the top of the studied sequence, a more clastic section, with characteristic fining upward cycles, was observed.

2.5 Biostratigraphy and paleoprovincial considerations of the Lower Cretaceous in Venezuela.

As it has been reported by Sutton (1946), the *Léxico Estratigráfico de Venezuela* (1970) and Renz (1982), the biostratigraphic framework of Lower Cretaceous sediments in the Maracaibo Basin is mainly based on the occurrences of fossil ammonites and foraminifers. However, as Renz (1982) pointed out, the shallow water moderate energy paleoenvironments present at the time of the Cogollo Group deposition were not the most suitable for ammonites, and most of the fossils that have been identified in these platformal deposits have been non-diagnostic molluscs, echinoids, rudists and with some exceptions, benthic foraminifers (see Stratigraphic Nomenclature section for details of faunal assemblages found in the Cogollo Group). Renz (1982) also pointed out that most of the age-diagnostic ammonites have been collected only in outcrops in the Andes and Paerijá ranges and in localized lithologies such as the large ellipsoidal concretions of the Machiques Member (Apón Formation) and in facies of the Maraca and La Luna formations. He also pointed out that because of the poorly preserved micro- and macrofauna in the Albian, it has been impossible to precisely determine the Aptian–Albian boundary in this area. In the subsurface, Rod and Maync (1954) reported the occurrences of *Chofatella decipiens*, a key regional marker for the Aptian. These authors, as well as Sutton (1946), also reported the occurrence of *Orbitolina texana*, which has been used as a marker of the Upper Aptian–Albian in the Maracaibo Basin. The widespread *Orbitolina* horizon of the Lisure and Aguardiente formations, as well as the contact between the Maraca and La Luna formations have also been used as regional correlation datums (Azpiritxaga, 1991). The latter is most likely to be a diachronous contact, possibly younger in the south-southeast, where Renz (1982) discussed a Late Albian–Cenomanian age based on fossil ammonites for the top of the Maraca Formation. The diachronous nature of the Maraca-La Luna contact is probably related to progressive encroachment of the sea on the cratonic areas to the south-southeast as the sea-level rose during the Late Albian and Cenomanian (Haq et al., 1987).

There is also information concerning provincialism for other major fossil groups in Venezuela and the Caribbean area. Maync (in Rod and Maync, 1954) compared the stratigraphic occurrences of several benthic foraminifer species, such as *Ammobaculites subcretaceous*, *Cristellaria gautina*, *Neobulimina minima*, *Spiroplectamina goodlandana*, *Textularia rioensis*, and *Verneuilinoides schizea* which were reported in the Aptian of Venezuela and from the Lower to Middle Albian of Texas. He also pointed out the occurrence of certain ammonites, e.g. *Douvilliceiras* aff. *D. nonile*, characteristic of the Albian of Texas, in the Upper Aptian of the Apón Formation. He concluded that the Caribbean province in the western Tethys sea may have been the center of several species. Kauffman (1973), based on the distribution of bivalves, proposed the existence of a Tethyan Province, extending the northern areas of Africa and South America and the southern regions of North America and Laurasia. Renz (1982) reported significant Tethyan affinity for the Lower Cretaceous ammonite faunas collected in the Maracaibo Basin and other areas of Venezuela. Ammonite faunas of the Middle-Upper Jurassic of the Gulf of Mexico show marked Tethyan affinities (Scott, 1984). Alencaster (1984) also reported strong Tethyan affinities for the Jurassic-Lower Cretaceous mollusc faunas of the Gulf of Mexico. Masse and Rossi (1988) have proposed a new province; "the Southern Caribbean Province", related to the occurrence of endemic species of rudists in the eastern Coastal Ranges of Venezuela. However, it is necessary to point out that these authors reported similarities of the calcareous algae and benthic foraminifera found in Venezuela with those of north and northwest Africa. Scott (1990) pointed out that bivalves, gastropods, ammonites, corals and calcareous algae characterized the Caribbean province during the Early Cretaceous and shared some affinities with coeval assemblages of the Mediterranean Tethyan.

From the palynological point of view, limited palynological studies have been published on the Lower Cretaceous of Venezuela. Paredes de Ramos and Fasola (in Moldovanyi and Pinto Ausó, 1987) studied the calcareous nannoplankton and palynological assemblages of core samples of well ALT-19X. Dinoflagellate cyst species such as *Oligosphaeridium complex*, *Odontochitina costata*, *Exochospheridium bifidum*, *Aptea polymorpha*, *Coronifera oceanica*, *Florentinia mantelli*, *Dinopterygium tuberculatum* have been described from Lower Cretaceous sections of Europe. Miospores reported by these authors showed similarities to assemblages reported by Herngreen and Chlonova (1981) from the ASA province (Africa and South America). Pollen of *Afropollis*, *Elaterosporites*, *Galacornea*, *Sofrepites* and *Equisetosporites* have been extensively illustrated to be common in these areas during the Aptian–Albian. The palynological zonation proposed by Muller et al. (1987) will be discussed in detail in the chapter on biostratigraphy.

3. SYSTEMATIC PALYNOLOGY.

This chapter presents the taxonomy of miospores, dinoflagellates acritarchs and other protists that were observed in this study. One group of microfossils, foraminiferal linings are not treated in detail.

3.1 Taxonomic approach.

The fossil miospores, dinoflagellate and algae recovered in this study have been classified using several approaches. First, in the case of miospores, the suprageneric classification based on morphological features proposed by Potonié and Kremp (1954), Potonié (1956) and Dettmann (1963) is not used since it results in palynomorphs of very closely related plants being split into different artificial taxa (Davies, 1986; Fensome, 1987). Therefore, the grouping of miospore genera into groups based on botanical affinity is preferred in this study. The suprageneric classification is based on those of Cronquist (1960), Cronquist et al. (1966) and Taylor and Taylor (1993).

With regard to dinoflagellates, the suprageneric classification of living and fossil dinoflagellates recently published by Fensome et al. (1993) has been adopted. These authors have proposed that, at the level of subdivision and class, the characteristics of the nucleus (conventional eukaryotic nucleus or dinokaryon nucleus with condensed chromosomes present during the complete mitotic cycle) is of prime value. At the level of order and suborders, the pattern of tabulation or the structure of the amphiesma is the primary defining characters.

Tappan (1980) presented a compilation of suprageneric categories that has been proposed for the classification of acritarchs. These organisms are considered polyphyletic and their classification must be regarded as artificial. Downie et al. (1963) proposed several categories based on the morphology of the vesicle. However, as in the case of miospores, this grouping might prove confusing from the systematic point of view. Therefore, acritarch genera will be listed alphabetically within the Group Acritarca Evitt, as suggested by Turner (1984). Prasinophyte algae are also found in this study. Tappan (1980) included these organisms within the Division Prasinophyta Round. Mendelson (1993) pointed out that prasinophytes are a group of green algae whose systematic position has been extensively discussed, without major agreement on their systematics. In some cases (as Tappan, 1980) prasinophyte algae have been placed in the Division

Prasinophyta with four orders (Pedinomonadales, Pyramimonadales, Prasinocladales and Pterospermatales). However, Mendelson (1993) pointed out that there exists evidence for placing it within the Division Chlorophyta and the Class Prasinophaceae (with the four orders mentioned of the Division Cholorophyta by Tappan, 1980). This latter approach has been adopted in this study.

Nomenclature of taxa has followed the principles outlined in the International Code of Botanical Nomenclature (Greuter et al., 1988). The type and slide collection of this study will be stored in the Pedro Joaquín Bermúdez Micropaleontologic Systematic Collection at INTEVEP, S.A., in the city of Los Teques, Venezuela.

3.2 Procedure.

The procedure used for the maceration of samples and the isolation of palynological residues combines the tecniques of Barss and Williams (1973) and Phipps and Playford (1984). The methodology is schematically represented in Figure 8 and essentially consists of the removal of carbonates (using diluted hydrochloric acid—HCl 10%); silica and aluminosilicates (using concentrated hydrofluoric acid—HF 42-44%); fluoride byproducts (using hot concentrated hydrochloric acid—HCl 30%); and fine particulate organic matter by sieving through 10 μm mesh nylon cloth (using the technique described by Zippi, 1986). The double-layer microscope slides were prepared using Cellosize and Elvacite as mounting medium and sealing agent respectively. Transmitted light microscope observations were made using Interference Contrast (IC) optics under 40 and 100X objectives. Morphological terminology followed in this study is that of Kremp (1965) for miospores and Williams et al. (1978) for phytoplankton (dinoflagellates and acritarchs).

Observations in the Scanning Electronic Microscope (SEM) were made in some samples that showed good preservation and the occurrence of diagnostic species. In general the procedure was similar to that reported by Zippi (1991) for the preparation of SEM and light microscope slides. The mounted coverslips and residue were then gold coated (approximate thickness of the gold coat: 35-40 Å) in a sputter coater (SEM Coating Unit PS3 Bio Rad). Observations and black and white photographs were obtained in a JEOL JSM-840 SEM.

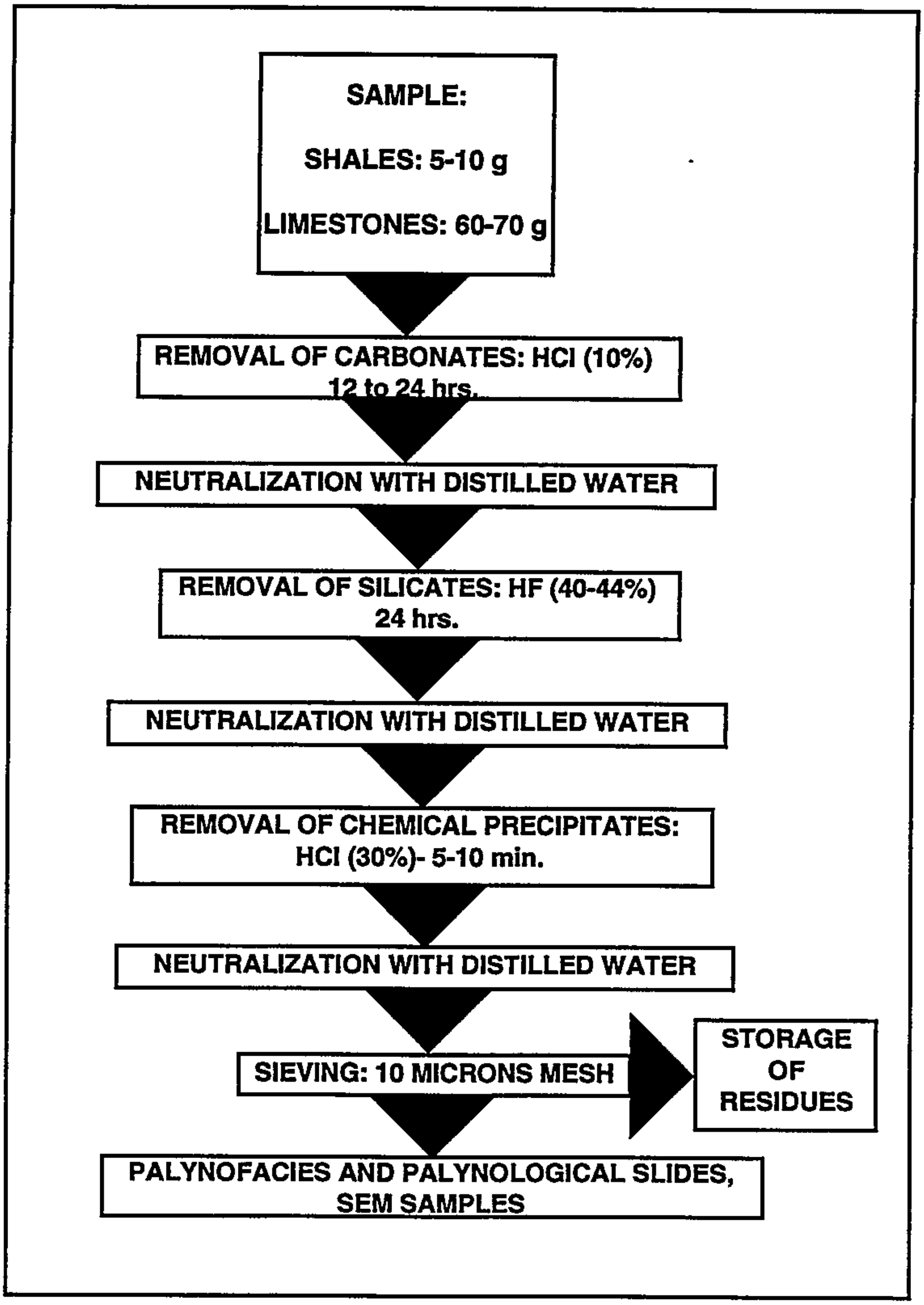

Figure 8. Sample preparation procedure.

3.3 Miospores.

DIVISION BRYOPHYTA BRAUN 1864

HEPATICACEAN SPORES

Genus *Aequitriradites* Delcourt & Sprumont 1955 emend. Cookson & Dettmann 1961

1955 *Aequitriradites* Delcourt & Sprumont, p. 44.
1961 *Selaginellidites* Krasnova in Samoilovitch & Mtchedlishvili, p. 38.
1961 *Aequitriradites* Delcourt & Sprumont emend. Cookson & Dettmann, p. 426.
1966 *Aequitriradites* Nakoman, p. 80 [Nomenclatural junior synonym of *Aequitriradites*, having the same type species]

Type Species. *Aequitriradites dubius* Delcourt & Sprumont 1955 (p. 45; plate 3, figure 7). Lower Cretaceous, Belgium.

Aequitriradites verrucosus (Cookson & Dettmann 1958) Cookson & Dettmann 1961
Plate 1, figure 1

1958 *Cirratriradites verrucosus* Cookson & Dettman, p. 112. Plate 18, figures 2-6.
1961 *Selaginellidites verrucatus* (Cookson & Dettmann) Krasnova in Samoilovitch & Mtchedlishvili, p. 40.
1961 *Aequitriradites verrucosus* (Delcourt & Sprumont) Cookson & Dettmann, p. 427.

Description. See Cookson and Dettmann (1958 and 1961).

Dimensions. Diameter: 50 (53) 56 μm (2 specimens).

Note. This species differs from *Aequitriradites dubius* Delcourt & Sprumont by the finer verrucate sculpture on the distal face.

Occurrences. This species is observed in the Aptian in the Zea-Panamericana outcrop section (samples 13-04-27 and 13-04-29).

This species has been reported in the Upper Tithonian to the Albian of Australia (Dettmann, 1963; Backhouse, 1988), Barremian of Brazil (Depeche et al., 1986), Valanginian to Upper Albian of western Canada (Burden and Hills, 1989), Aptian to Lower Albian of eastern Canada (Davies et al., 1984), Berriasian to Valanginian offshore west Africa (Williams and Bujak, 1980) and in the Neocomian to Senonian of western Siberia (Dettmann, 1963).

Genus *Triporoletes* Mtchedlishvili in Mtchedlishvili & Samoilovitch 1960 emend. Playford 1971

1960 *Triporoletes* Mtchedlishvili in Mtchedlishvili & Samoilovitch, p. 127
1961 *Seductisporites* Khlonova, p. 56
1961 *Zlivisporis* Pacltová, p. 40, 86-87.
1962 *Rouseisporites* Pocock, p. 52-53.
1963 *Rouseisporites* Pocock emend. Dettmann, p. 96.
1968 *Ricciaesporites* Nagy, p. 126.
1971 *Triporoletes* Mtchedlishvili emend. Playford, p. 551.

Type Species. *Triporoletes singularis* Mtchedlishvili in Mtchedlishvili & Samoilovitch 1960 (p. 168; figure 13). Upper Cretaceous (Cenomanian), Siberia.

Triporoletes sp. A
Plate 1, figure 2

Description. Only four incomplete specimens are observed in this study. Thin spore wall, less than 1.0 μm thick, finely granulate-psilate, with thickened anastomosing muroid ridges, 2 to 2.5 μm thick.

Dimensions. Diameter: 27 (36) 41 μm (4 specimens).

Note. Because only fragmented specimens are observed, it is impossible to compare them to described species of this genus.

Occurrences. The four specimens are observed in Upper Aptian samples of La Grita outcrop section (samples 09-04-04 and 09-04-05).

DIVISION LYCOPHYTA BOIVIN 1956

LYCOPODIALEAN SPORES

Genus *Apiculatisporis* Potonié & Kremp 1956

1956 *Apiculatisporis* Potonié & Kremp, p. 94.

Type Species. *Apiculatisporis aculeatus* (Ibrahim 1933; p. 23, plate 1, figure 57) Potonié 1956. Paleozoic (Westphalian B-C), Germany.

Apiculatisporis rotundus sp. nov.
Plate 1, figure 3

Diagnosis. A species of *Apiculatisporis* characterized by small overall size, circular amb, a relatively narrow cingulum and the possession of very short echinae, distributed in low density on the proximal and distal faces.

Etymology. Latin *rotundus*, circular, sometimes spherical. With reference to the characteristic circular amb of this species.

Description. Echinate-baculate cingulate trilete spore. Circular to rounded triangular amb, with convex sides. Exine, 1.3 μm thick with echinae. Cingulum, 2.5 μm thick, smooth. Echinae, short (less than 1.0 μm long), distributed in low density on both distal and proximal faces. Trilete mark straight, with thin lips, laesurae reaching up to 3/5 to 4/5 of the spore radius.

Holotype. Plate 1, figure 3. Diameter, 22 μm. Echinae, less than 1.0 μm long. Exine, 2.5 μm thick. La Grita outcrop section. Sample; 09-04-06. Slide 2. Coordinates; 13.0 x 99.6. Aguardiente Formation. 3 km NW of the town La Grita, Táchira State, western Venezuela. Upper Aptian.

Dimensions. Diameter: 20 (25) 31 μm (14 specimens).

Note. This species resembles *Apiculatisporis wonthaggiensis* Cookson & Dettmann 1958 (Neocomian to Aptian of Australia) in the circular amb, exine and length of the echinae.

However, the specimens observed in this study show ornamentation with less densely distributed echinae, a relatively wider cingulum and the observed size is smaller than that reported by Cookson and Dettmann (1958) for *Apiculatisporis wonthaggiensis.*

Occurrences. This species is rare in samples of the Aptian–Albian of La Grita, Zea-Panamericana and Catatumbo outcrop sections and in wells ALT-19X and ALP-6.

Genus *Camarozonosporites* Pant 1954 *ex* Potonié 1956 emend. Klaus 1960

1954 *Camarozonosporites* Pant, p. 20 [nomen nudum]
1956 *Camarozonosporites* Pant *ex* Potonié, p. 65.
1960 *Camarozonosporites* Pant *ex* Potonié emend. Klaus, p. 135.

Type Species. *Camarozonosporites cretaceus* (Weyland & Krieger 1953; p. 12; plate 3, figure 27) Potonié 1956. Lower Campanian, Germany.

Camarozonosporites sp. cf. *C. insignis* Norris 1967
Plate 1, figure 5

[cf.] 1967 *Camarozonosporites insignis* Norris, p. 96-97. Plate 13, figures 12-16.

Description. Distally rugulate, ?cingulate trilete spore. Rounded triangular amb. Exine, about 4.0 to 5.0 µm thick, distally rugulate, proximally psilate. Distal rugulae branching, 3.8 µm wide. Trilete mark, straight, with thick membranous lips, almost reaching the equator.

Dimensions. Diameter: 52 µm (1 specimen).

Note. Because only one poorly observed specimen is observed in this study, it is compared with rather than attributed to *Camarozonosporites insignis*. In the observed specimen, there is a faint indication of a cingulum, but because of the poor preservation it is difficult to ascertain its precise character.

Occurrences. Only one specimen is observed in the Albian of well CR-5 (sample CR-5 14210').

The compared species has been reported only in the Cretaceous; Albian of Oklahoma (Hedlund and Norris, 1968; Srivastava, 1977), Albian to Campanian of offshore east United States (Bebout, 1981), Albian to Cenomanian of Alberta (Norris, 1967), Upper Aptian to Upper Albian of northwest Canada (Burden and Hills, 1989), Upper Albian to Santonian offshore eastern Canada (Williams and Brideaux, 1975) and Upper Albian to Cenomanian (Zippi and Bajc, 1990) and Barremian to Albian of Israel (Brenner, 1974) and Aptian–Albian of England (Kemp, 1970).

Genus *Echinatisporis* Krutzsch 1959a

1959a *Echinatisporis* Krutzsch, p. 132.

Type Species. *Echinatisporis longechinus* Krutzsch 1959a (p. 133; plate 20, figure 217). Middle Eocene, Hungary.

Echinatisporis varispinosus (Pocock 1962) Srivastava 1977
Plate 1, figure 4a-b and 6

1962 *Acanthotriletes varispinosus* Pocock, p. 36. Plate 1, figures 18-20.
1972 *Ceratosporites pocockii* Srivastava, p. 8. Plate 4, figure 7.
1977 *Echinatisporis varispinosus* (Pocock) Srivastava, p. 39-40.

Description. See Pocock (1962).

Dimensions. Polar diameter: 21 (25) 32 µm (12 specimens).

Note. This species is characterized by the variable shape of the echinae, straight to slightly curved at the tips or in cases truncated (see Plate 1, figure 6). Echinae are completely absent from the proximal area, where the exine is psilate to finely granulate (Plate 1, figures 4a and 6).

Occurrences. This species is rarely observed in very low abundances in samples of the Aptian–Albian of La Grita and the Zea-Panamericana outcrop sections.

This species has been reported from Jurassic to Paleocene sediments and is common in the Lower Cretaceous; Aptian of Colombia (Pons, 1988; Prössl and Vergara

Streinsberger, 1993), Albian of Texas (Srivastava, 1977), Albian of Utah (Tschudy et al., 1984) and Berriasian to Maastrichtian of Maryland and offshore east of the United States (Bebout, 1981; Doyle, 1983), Berriasian to Upper Albian of western Canada (Burden and Hills, 1989), Middle to Upper Albian of Alberta, Canada (Norris, 1967; Singh, 1971), Upper Albian to Cenomanian of Ontario, Canada (Zippi and Bajc, 1990), Berriasian–Valanginian to Barremian–Albian of Israel (Brenner, 1974), Lower Albian of Spain (Arias and Doubinger, 1980), Berriasian to Lower Aptian of Germany (Dörhöfer and Norris, 1977; Batten and Li Wenben, 1987) and Tithonian to Berriasian of England (Norris, 1969).

Genus *Leptolepidites* Couper 1953 emend. Norris 1968

1953 *Leptolepidites* Couper, p. 28
1963 *Leptolepidisporites* Danzé & Laveine, p. 92.
1964a *Matthesisporites* Döring, p. 37.
1966 *Leptolepidites* Couper emend. Potonié, p. 30.
1967 *Leptolepidites* Couper emend. Schulz, p. 558.
1968 *Leptolepidites* Couper emend. Norris, p. 316.

Type Species. *Leptolepidites verrucatus* Couper 1953 (p. 28; plate 2, figure 14). Jurassic, New Zealand.

Remarks. Potonié (1966) emended the diagnosis of this genus including those species with circular amb. Schulz (1967) modified this diagnosis by including only species with reduced proximal ornamentation and uniform sculptural elements. Norris (1968) restricted this genus to those species with verrucae of variable size and shape, with occasional rugulae and reduced ornamentation on the proximal face. Fensome (1983) considered that the genus *Matthesisporites* is equal or closely similar to *Leptolepidites*.

Leptolepidites zeaensis sp. nov.
Plate 1, figure 9

Diagnosis. A species of *Leptolepidites* characterized by small overall size, circular to ellipsoidal amb and the very dense verrucate ornamentation on both the distal and proximal faces. Verrucae of irregular shape, somewhat higher than wide.

Etymology. With reference to the town of Zea, Mérida State, western Venezuela.

Description. Coarsely verrucate trilete spores. Circular amb with convex distal face. Very thick sexine, verrucate. Verrucae, very coarse, dome-shaped and relatively higher than wide, 3.0 to 5.0 µm wide and 4.0 to 6.0 µm high, becoming somewhat larger torwards the equatorial area and absent in the contact area, where the exine becomes granulate. Trilete mark, simple, straight, extending to the equator and almost obscured by the coarse ornamentation.

Holotype. Plate 1, figure 9. Diameter, 30 µm. Verrucae, 3.0 to 4.0 µm wide and 4.0 to 5.0 µm high. The Zea-Panamericana outcrop section. Sample; 13-04-02. Slide 1. Coordinates; 33.1 x 96.1. Aguardiente Formation. 4 km north of the town of Zea, Mérida State, western Venezuela. Lower Aptian.

Dimensions. Diameter: 27 (29) 31 µm (18 specimens).

Note. This species differs from *Leptolepidites psarosus* Norris 1969 by the smaller size and from *Leptolepidites* sp. A by the distribution, density and shape of the verrucae on the proximal and distal faces. It differs from *Leptolepidites crassibalteus* Filatoff 1975 by the lack of equatorial thickening related to fusion of verrucae in this area. *Leptolepidites pudens* (Balme 1957) Backhouse 1988 shows a rugulate ornamentation on the distal face. *Leptolepidites* sp. A of Backhouse (1988), from the Upper Jurassic to Berriasian of Australia, is characterized by the possession of large verrucae that resemble those of *Leptolepidites zeaensis* sp. nov. *Leptolepidites plurituberosus* (Döring 1964) Norris & Dörhöfer 1977 posseses larger verrucae.

Occurrences. This species is observed in the Aptian and Albian of the Zea-Panamericana and Catatumbo outcrop sections, as well as in wells ALT-19X, ALP-6 and P-201.

Leptolepidites sp. cf. *L. psarosus* Norris 1969
Plate 1, figure 7

[cf.] 1969 *Leptolepidites psarosus* Norris, p. 586. Plate 103, figures 4-5.

Description. Coarsely verrucate trilete spores. Circular to ellipsoidal amb. Exine, 1.3 µm thick, coarsely verrucate sexine. Verrucae, dome shaped and of variable size, 6 µm wide, closely packed on the distal face and with a general trend to larger verrucae towards the equator. Proximal face, finely granulate. Trilete mark, not observed.

Dimensions. Diameter: 45 (46) 48 μm (6 specimens).

Note. This species differs from *Leptolepidites psarosus* by the lack of rugulate sculpture, that Norris (1969) related to the densely packed verrucae on the distal face. The specimens observed in this study are larger than those reported by Norris (1969) for *Leptolepidites psarosus*.

Occurrences. This species is rarely observed in samples of the Aptian and Albian of the Zea-Panamericana outcrop section and in wells CR-5 and ALP-6.

Leptolepidites psarosus have been reported from the Berriasian of England (Norris, 1969).

Leptolepidites sp. A
Plate 1, figure 8

Description. Coarsely verrucate trilete spore. Irregular circular amb. Exine thickness obscured by the coarse verrucate ornamentation. Verrucae, densely distributed, relatively flat or with low relief in the polar area of the distal face, 3.0 μm wide, becoming coarser and coalescing in the equatorial area, 10 μm wide, and reduced in the proximal face. Trilete mark, simple, straight and reaching the equator.

Dimensions. Diameter: 25 (27) 30 μm (7 specimens).

Note. This species resembles *Leptolepidites proxigranulatus* (Brenner 1963) Dörhöfer 1979in the distribution and the variability of the verrucae on the proximal and distal faces. However, the ornamentation of the specimens observed in this study is more dense that has been reported for *Leptolepidites proxigranulatus*, in which the verrucae rarely have more than one point of contact.

Occurrences. This species is observed in the Aptian and Albian of Zea-Panamericana outcrop section and wells ALT-19X, ALP-6 and P-201.

Leptolepidites sp. B

Plate 1, figure 10a-b

Description. Coarsely verrucate trilete spore. Rounded triangular to circular amb with convex sides. Exine, 3.0 to 5.0 μm thick, verrucate. Verrucae of variable size and shape, up to 10 μm wide, becoming larger at the equatorial area, where they appear baculae/gemmae-like. Psilate-granulate in the proximal face. Trilete mark, simple, straight, reaching the equatorial area.

Dimensions. Diameter: 31 (34) 37 μm (4 specimens).

Note. This species differs from others observed in this study by the shape of the verrucae in the equatorial area.

Occurrences. This species is rarely observed in the Upper Aptian and Albian of Zea-Panamericana outcrop section and in well ALT-19X.

Genus *Neoraistrickia* Potonié 1956

1956 *Neoraistrickia* Potonié, p. 34.
1964 *Neoraistrickisporites* Levet-Carette, p. 99.
1972 *Neoraistrickia* Potonie emend. Bharadwaj & Kumar, p. 214.

Type Species. *Neoraistrickia truncata* (Cookson 1953; p. 471, plate 2, figure 36) Potonié 1956. "Pre-Tertiary", South Australia.

Remarks. Bharadwaj and Kumar (1972) proposed restricting the genus to those species without proximal ornamentation. However, species of *Neoraistrickia* have been reported with proximal ornamentation and correspond to the diagnosis of the genus proposed by Potonié (1956). Therefore, the emendation proposed by Bharadway and Kumar (1972) is not followed here.

Neoraistrickia sp. A

Plate 2, figure 1

Description. Echinate trilete spore. Circular to rounded triangular amb with convex sides. Exine 2.5 µm thick with echinate-baculate sexine. Coarse baculae-echinae 5 to 6 µm long, separated 4 to 5 µm from each other, with rounded tips, absent in the contact area where the exine is granulate. Trilete mark straight, thickened (1.5 to 2 µm), short, extending for less than 1/2 of the equatorial radius.

Dimensions. Polar diameter: 21 (25) 28 µm (2 specimens).

Note. This species differs from *Neoraistrickia truncata* (Cookson 1953) Potonié 1956 in the coarseness of the baculae and the terminations of the baculae, that are not truncated. Ornamentation of *Neoraistrickia truncata* is also more densely distributed than in the specimens observed in this study.

Occurrences. This species is only observed in the Aptian of La Grita (sample 09-04-07) and the Zea-Panamericana outcrop sections (sample 13-04-07).

Genus *Uvaesporites* Döring 1965

1965 *Uvaesporites* Döring, p. 39.

Type Species. *Uvaesporites glomeratus* Döring 1965 (p. 39; plate 9, figures 1-4). Berriasian–Valanginian, Germany.

Uvaesporites inferus sp. nov.

Plate 2, figure 2

Diagnosis. A species of *Uvaesporites* characterized by the circular amb, verrucate ornamentation forming a rugulate pattern on the distal face, partially fused in the equatorial area and virtually absent from the proximal face. Simple trilete laesurae with thin lips.

Etymology. Latin *inferus*, lower. With reference to peak of abundance of this species in the Lower Aptian interval of the Zea-Panamericana outcrop section.

Description: Verrucate trilete spores. Circular amb. Exine, 3.0 to 4.0 μm thick with verrucate sexine. Verrucae, 2.5 to 3.0 μm high, up to 3.8 μm diameter, of irregular shape, forming a rugulate pattern at high focus and becoming fused at the equatorial area, reduced in the contact area. Trilete mark raised by membranous lips, straight, reaching 4/5 of the spore radius.

Holotype. Plate 2, figure 2. Diameter, 30 μm. Verrucae, 3 μm wide and 4 μm high. La Grita outcrop section. Sample; 09-04-05. Slide 1. Coordinates; 32.3 x 95.1. Aguardiente Formation. 3 km NW of the town of La Grita, Táchira State, western Venezuela. Upper Aptian.

Dimensions. Diameter: 32 (33) 50 μm (12 specimens).

Note. The specimens observed in this study show coarse verrucate ornamentation, with a tendency for the verrucae to become fused at the equatorial area, a characteristic of the genus *Uvaesporites* described by Döring (1965). The poor preservation of the specimens precluded further morphological characterization.

Uvaesporites glomeratus was described as having thickened laesurae and triangular amb, with very dense verrucae ornamentation on the proximal and distal faces. The observed specimens in this study show a consistent circular outline, with relatively simple laesurae. They differ from *Uvaesporites pseudocingulatus* Döring 1965 in lacking the completely fused verrucae in the equator.

Occurrences. This species is observed in samples of the Aptian–Albian of La Grita and the Zea-Panamericana outcrop sections, and wells CR-5 and ALP-6. It is observed in high relative frequencies in few samples of the Zea-Panamericana outcrop section and is relatively rare in the other sections.

DIVISION PTERIDOPHYTA DE CANDOLLE 1813

LYGODIACEAN SPORES

Genus *Concavissimisporites* Delcourt & Sprumont 1955 emend. Delcourt et al. 1963, emend. Pocock 1965, emend. Fensome 1987

1955 *Concavissimisporites* Delcourt & Sprumont, p. 25.
1956 *Dennstaedtiites* Bolkhovitina, p. 50.
1961 *Lygodium* subgen. *Tuberculata* Ivanova in Samoilovitch & Mtchedlishvili, p. 95.
1963 *Concavissimisporites* Delcourt & Sprumont, emend. Delcourt et al., p. 284.
1964b *Tuberositriletes* Döring, p. 1103.
1965 *Concavissismisporites* Delcourt & Sprumont emend. Pocock, p. 181.
1969 *Impardecispora* Venkatachala et al., p. 124.
1987 *Concavissimisporites* Delcourt & Sprumont emend. Delcourt et al. emend. Pocock emend. Fensome, p. 18-19.

Type Species. *Concavissismisporites verrucosus* Delcourt and Sprumont 1955(p. 25; plate 2, figure 19). Lower Cretaceous, Belgium.

Remarks. Delcourt and Sprumont (1955) described the genus *Concavissimisporites* as including species with a characteristically concave amb, whereas Delcourt et al. (1963) emended the description to accept spores with straight sides. Pocock (1965) emended the description of the genus to allow for species with convex sides. Fensome (1987) discussed the extensive overlap between different genera such as *Concavissimisporites*, *Converrucosisporites* Potonié & Kremp 1954, *Maculatisporites* Döring 1964 and *Impardecispora* concluding that amb outline, distribution and density of the verrucae in species of these genera did not allow for a clearcut division.

The emendations proposed by Delcourt et al. (1963) and Pocock (1965), allowing species with amb outlines different from concave, and that of Fensome (1987), allowing species with coarser verrucae in the apices, to be included within the genus *Concavissimisporites*, are accepted in this study.

Concavissimisporites exquisitus (Singh 1971) Fensome 1987
Plate 2, figure 3a-b

1971 *Converrucosisporites exquisitus* Singh, p. 116. Plate 16, figures 4-5.
1987 *Concavissimisporites exquisitus* (Singh) Fensome, p. 21.

Description. See Singh (1971).

Dimensions. Diameter: 25 (32) 38 µm (25 specimens).

Occurrences. This species is observed in low numbers in samples of the Aptian and Albian of La Grita and Zea-Panamericana outcrop sections, as in wells CR-5, ALT-19X, ALP-6 and P-201.

This species has been reported in the Middle to Upper Albian of Alberta (Singh, 1971) and Berriasian to Middle Albian of western Canada (Burden and Hill, 1989) and in the Lower Cretaceous of the Vigo Seamount, offshore west of Spain (Habib, 1979). Its occurrence in the Jurassic of northwest Canada (Fensome, 1987) suggests a long stratigraphic range.

Concavissimisporites miniverrucatus sp. nov.
Plate 2, figure 4

Diagnosis. A species of *Concavissimisporites* characterized by its rounded-triangular amb, dense verrucate ornamentation, with small size verrucae on both distal and proximal faces.

Etymology. Latin *minutus*, small. With reference to small size of the verrucae that make up the ornamentation of this species.

Description. Verrucate trilete spores. Rounded triangular amb with relatively straight to slightly concave sides and rounded apices, convex distal face. Exine, relatively thin, about 1.3 µm or less, verrucate. Verrucae small, less than 1.3 µm high and wide, circular outline in cross section, closely packed on both the distal and proximal faces. Trilete mark slightly sinuous at the edges extending to about 3/4 of the equatorial radius.

Holotype. Plate 2, figure 4. Diameter, 35 µm. Verrucae, 1.0 to 1.5 µm wide and less than 1.0 µm high. La Grita outcrop section. Sample; 09-04-04. Slide 1. Coordinates; 45.0 x 94.8. Aguardiente Formation. 3 km NW of the town of La Grita, Táchira State, western Venezuela. Upper Aptian.

Dimensions. Diameter: 23 (30) 40 µm (55 specimens).

Note. This species differs from *Concavissimisporites exquisitus* by the smaller size of the verrucae and the overall spore diameter. It differs from *Rotverrusporites verrucatus* (Couper 1953) Döring 1965 by the absence of larger verrucae in the equator and overall shape. It also differs from *Concavissimisporites verrucosus* Delcourt & Sprumont 1955 by the triangular amb with straight sides rather than the concave amb of the latter. *Concavissimisporites irroratus* Paden-Phillips & Felix 1971a emend. Fensome 1987 has more loosely packed verrucae.

Occurrences. This species is observed in moderate numbers in Aptian–Albian samples of La Grita and Zea-Panamericana outcrop sections, as in wells CR-5, ALT-19X.

Concavissimisporites sp. A

Plate 2, figure 5

Description. Verrucate trilete spores. Rounded triangular amb with straight to slightly convex sides. Exine, 1.3 µm thick, verrucate. Verrucae, wider than high, 2.5 µm across and up to 1.3 µm high, dome-shaped and equally distributed on the proximal and distal faces, with individual elements separated from each other (less than 1.0 µm apart). Trilete mark straight, simple and reaching the equatorial area.

Dimensions. Diameter: 28 (32) 37 µm (10 specimens).

Note. This species resembles *Concavissimisporites montuosus* (Döring 1964) Fensome 1987 in the triangular outline and the spacing of the verrucae. However it differs by smaller overall diameter and size of the ornamentation.

Occurrences. This species is rarely observed in Aptian and Albian samples of La Grita and Zea-Panamericana outcrop sections, as in wells CR-5 and ALT-19X.

Concavissimisporites sp. B
Plate 2, figure 6

Description. Verrucate trilete spores. Triangular amb with rounded, broad apices and straight to slightly concave sides. Exine, less than 1.3 μm thick, verrucate. Verrucae of irregular shape, forming a rugulate pattern at mid-focus view, of small size and height, less than 1.3 μm, closely packed on the distal and proximal faces. Laesurae simple and difficult to observe, 1/2 of the spore radius.

Dimensions. Diameter: 25 (28) 31 μm (6 specimens).

Note. This species differs from others of the genus observed in this study by the irregular and small verrucae. It resembles *Concavissimisporites robustus* Dörhöfer 1977 in the triangular amb and the concave sides. However, it differs from *Concavissimisporites robustus* by thinner exine, lack of interradial thickening and smaller overall size.

Occurrences. This species is rarely observed in samples of the Upper Aptian–Albian of the Zea-Panamericana and La Grita outcrop sections.

Concavissimisporites sp. C
Plate 2, figure 8

Description. Verrucate trilete spore. Triangular amb with concave sides and rounded apices. Exine, 1.3 μm thick, verrucate on the distal face and finely granulate in the proximal face. Distally verrucae lack relief, are circular in cross section and are 1 to 2.5 μm wide. Trilete mark simple, reaching 4/5 of the spore radius.

Dimensions. Diameter: 33 μm (1 specimen)

Note. This species resembles *Concavissimisporites irroratus* in possesing finer circular verrucae. However, it differs from the latter in the absence of proximal verrucae and the closer packing of the distal verrucae. However, the single specimen recorded in this study precludes any attempt to ascertain the variability of the species.

Occurrences. A single specimen is observed in the Upper Aptian of La Grita outcrop section (sample 09-04-04).

Concavissimisporites sp. D

Plate 2, figure 10

Description. Large verrucate trilete spores. Triangular amb with concave sides and broad and rounded apices. Exine, 2.5 μm thick, verrucate. Verrucae, relatively flat or with little relief, circular in cross section, uniformly distributed on the distal face and almost absent near the laesurae, less than 1.3 μm high and 1.3 to 2.5 μm wide. Trilete mark straight and relatively short, about 1/2 to 2/3 of the spore radius.

Dimensions. Diameter: 43 (45) 46 μm (2 specimens).

Note. This species differs from *Concavissimisporites apiverrucatus* (Couper 1958) Döring 1965 emend. Fensome 1987 by possessing less densely distributed verrucae on the distal face. The specimens observed in this study show more closely-packed verrucae than reported for *Concavissimisporites variverrucatus* (Couper 1958) Brenner 1963 emend. Fensome 1968.

Occurrences. Two specimens are observed in this study in the Upper Aptian of La Grita (sample 09-04-04) and the Lower Aptian of the Zea-Panamericana (sample 13-04-06) outcrop sections.

Concavissimisporites sp. E

Plate 2, figure 9

Description. Large trilete verrucate spore. Triangular amb with slightly concave sides and broad, rounded apices. Exine, 1.3 μm thick, finely verrucate on both the distal and proximal faces. Verrucae very small and of irregular shape, forming a a fine vermiculate-rugulate pattern. Trilete mark simple, straight and relatively short, at about 1/2 of the spore radius.

Dimensions. Diameter: 60 μm (1 specimen)

Note. This species resembles *Concavissimisporites punctatus* (Delcourt & Sprumont 1955) Brenner 1963 in the microrugulate to granulate pattern of ornamentation. However, Brenner (1963) reported variablity in the size of the ornament elements, a feature that is not observed in the present specimen.

Occurrences. Only one specimen is observed in the Albian of La Grita outcrop section (sample 09-04-13).

Concavissimisporites sp. F
Plate 2, figure 7

Description. Small verrucate trilete spores. Circular to rounded triangular amb. Exine less than 1.3 μm thick, verrucate. Verrucae, taller than wider, up to 3 μm high, about 1.3 to 1.5 μm wide, dome-shaped to bacula-like, separated from each other on the distal face and reduced in the contact area near the laesurae. Trilete mark straight, raised by 1.0 μm lips and short, 1/2 of the spore radius.

Dimensions. Diameter: 20 (22) 26 μm (10 specimens).

Note. This species differs from others of this genus observed in this study by its relatively taller than wider verrucae and in its small spore diameter. It differs from *Concavissimisporites platyverrucosus* (Brenner 1963) Fensome 1987 in having spaced verrucae in the distal and proximal faces. *Concavissimisporites platyverrucosus* is also characterized by flat-topped verrucae, that differs from the baculate to dome-shaped verrucae observed in specimens in this study.

Occurrences. This species is rare in samples of the Aptian and Albian of the Zea-Panamericana and La Grita outcrop sections.

Concavissimisporites sp. G
Plate 2, figure 11

Description. Large verrucate trilete spores. Triangular amb, with concave sides, rounded lobes or apices and convex distal face. Exine 2.5 μm thick interradially, 3-4 μm thick and verrucate radially. Verrucae of low relief and irregular shape, almost fused in areas other than radially. Coarsely verrucate, forming muri of a reticulum at the apices. Trilete mark raised by lips, 1.0 to 2.0 μm across, straight and reaching 4/5 of the spore radius.

Dimensions. Diameter: 50 µm (2 specimens)

Occurrences. Only two fragmented specimens are observed in samples of the Lower Aptian of the Zea-Panamericana outcrop section (samples 13-04-01 and 13-04-02).

MATONIACEAN SPORES.

Genus *Matonisporites* Couper 1958

1958 *Matonisporites* Couper, p. 139.
1963 *Matonisporites* Couper emend. Dettmann, p. 58.
1964b *Toroisporis* subgen. *Crassiangularis* Döring, p. 1102.

Remarks. Dettmann (1963) emended the description of *Matonisporites* to include "exinal thickening (valva) in the three radial regions at the equator". As Fensome (1983) discussed, the thickening of the exine in *Matonisporites* is restricted to the equatorial area and does not constitute a valva. Therefore, the emendation proposed by Dettmann (1963) is not accepted in this study.

Type Species. *Matonisporites phlebopteroides* Couper 1958 (p. 140; plate 20, figure 15). Liassic–Aptian, England.

Matonisporites sp. A
Plate 2, figure 12

Description. Psilate trilete spore. Triangular amb with slightly concave sides and rounded apices. Exine, less than 1.3 µm in the interradial areas, thickening over the equatorial areas in the apices up to 2.0 to 5.0 µm thick, psilate to finely granulate. Trilete mark straight, simple and reaching the equatorial area.

Dimensions. Diameter: 35 µm (1 specimen).

Occurrences. This species observed in the Albian of La Grita outcrop section (sample 09-04-11).

Matonisporites sp. B
Plate 3, figure 1

Description. Psilate small trilete spore. Triangular amb with slightly concave-straight sides and rounded apices. Exine 1.3 µm in the interradial areas, thickening over the lobes up to 2 to 3 µm thick, psilate. Trilete mark straight, raised by thin lips and reaching 3/4 of the spore radius.

Dimensions. Diameter: 21 (25) 28 µm (8 specimens).

Note. This species differs from *Matonisporites cooksonii* Dettmann 1963 by lacking proximal punctae. It also differs from *Matonisporites phlebopteroides* Couper 1958 and *Matonisporites crassiangulatus* (Balme 1957) Dettmann 1963 by its small size.

Occurrences. This species is rarely observed in the Upper Aptian–Albian samples of La Grita outcrop section and in wells CR-5 and ALT-19X.

OSMUNDACEAN SPORES.

Genus *Baculatisporites* Pflug & Thomson in Thomson & Pflug 1953

1950 *Osmundasporites* Thiergart, p. 84 [nomen nudum].
1953 *Baculatisporites* Pflug & Thomson in Thomson & Pflug, p. 56.
1967 *Baculatisporites* Pflug & Thomson emend. Krutzsch, p. 6-7.

Type Species. *Baculatisporites* (al. *Sporites*) *primarius* (Wolf 1934; p. 66; plate 5, figure 8) Pflug & Thomson in Thomson & Pflug 1953. Pliocene, Germany.

Baculatisporites sp. cf. *B. comaumensis* (Cookson 1953) Potonié 1956
Plate 3, figure 2

[cf.] 1953 *Baculatisporites* (al. *Trilites*) *comaumensis* (Cookson) Potonié. In: Cookson, p. 470-471. Plate 2, figures 27-28.

Description. Baculate trilete spores. Circular to rounded triangular amb with convex sides. Exine 1.3 µm thick with baculate-granulate sexine. Baculae short (less than 1 µm long), evenly dispersed on both distal and proximal faces. Trilete mark straight, raised by thin lips, reaching up to 3/4 of the spore radius.

Dimensions. Diameter: 23 (27) 30 μm (5 specimens).

Note. Because of the poorly preserved specimens, they are compared with rather than attributed to *Baculatisporites comaumensis*.

Occurrences. This species is rarely observed in two samples of the Upper Aptian of La Grita outcrop section (samples 09-04-04 and 09-04-05).

Baculatisporites comaumensis has been reported from the Permian to the Eocene; Kimmeridgian to Aptian of Australia (Backhouse, 1988), Upper Albian to Cenomanian of Colombia (Pons, 1988), Albian of Oklahoma (Hedlund and Norris, 1968) and Albian of Utah, (Tschudy et al., 1984), United States, Berriasian to Upper Albian of western Canada (Burden and Hills, 1989), Albian to Cenomanian of Alberta (Norris, 1967; Singh, 1971) and Upper Albian to Cenomanian of Ontario (Zippi and Bajc, 1990), Canada and Lower Valanginian to Lower Aptian of Germany (Batten and Li, 1987).

Genus *Osmundacidites* Couper 1953

1953 *Osmundacidites* Couper, p. 50.
1958 *Bracteolinasporites* Nilsson, p. 48.
1960 *Conosmundasporites* Klaus, p. 127.
1963 *Osmundacidisporites* Danzé-Corsin & Laveine, p. 75.

Type Species. *Osmundacidites wellmanii* Couper 1953 (p. 20; plate 1, figure 5). Jurassic to Lower Cretaceous, New Zealand.

Osmundacidites wellmanii Couper, 1953
Plate 3, figure 3

1953 *Osmundacidites wellmanii* Couper, p. 20. Plate 1, figure 5.
1959a *Baculatisporites wellmanii* (Couper) Krutzsch, p. 142.
1964 *Osmundacidisporites wellmanii* (Couper) Level-Carette, p. 98.

Description. See Couper (1953), Dettmann (1963, p. 32 and 34) and Norris (1968, p. 315).

Dimensions. Diameter: 25 to 31 μm (27 μm average) (4 specimens)

Occurrences. This species is rarely observed in Aptian samples of the Zea-Panamericana outcrop section.

This species has been reported from Neocomian to Albian of Australia (Dettmann, 1963), Upper Albian to Lower Cenomanian of Colombia (Pons, 1988), Albian of Oklahoma, United States (Srivastava, 1977), Berriasian to Lower Albian of western Canada (Burden and Hills, 1989), Barremian to Upper Albian of Alberta (Singh, 1964 and 1971; Norris, 1967), Upper Albian to Cenomanian of Ontario, Canada (Zippi and Bajc, 1990), Aptian to Maastrichtian offshore South Africa (McLachlan and Pieterse, 1978), Lower Albian of Spain (Arias and Doubinger, 1980), Albian of France (Fauconnier, 1979), Lower Valanginian to Lower Aptian (Batten and Li, 1987), Upper Jurassic to Berriasian of England (Couper, 1958; Norris, 1969)

Osmundacidites sp. A
Plate 3, figure 4

Description. Trilete spore. Circular amb. Exine 1.3 μm thick, very finely granulate. Trilete mark straight, raised by thin lips (less than 1.0 μm thick), reaching the equatorial area.

Dimensions. Diameter: 33 μm (2 specimens)

Note. This species differs from *Osmundacidites wellmanii* in the more finer and looser distribution of the granulation and the thinner laesurae lips.

Occurrences. Only two specimens are observed in the Aptian of the Zea-Panamericana outcrop section (samples 13-04-07 and 13-04-29).

Genus *Todisporites* Couper 1958

1958 *Todisporites* Couper, p. 134.
1958 *Cyclinasporites* Nilsson, p. 42.
1963 *Todisporites* Levet-Carette, p. 103 [obligatory junior synonym of *Todisporites*].
1967 *Todisporites* Couper emend. Hiltmann, p. 153.

Type Species. *Todisporites major* Couper 1958 (p. 134-135; plate 16, figure 60). Liassic–Jurassic, Britain.

Remarks. Hiltmann (1967) proposed that secondary folding of specimens attributed to *Todisporites* Couper was a diagnostic character at the genus level. However, it seems to be that folding is related to the way the specimens have been compressed in the sediments. Therefore, the emendation proposed by Hiltmann (1967) is rejected in this study.

Todisporites sp. A
Plate 3, figure 5

Description. Psilate, large trilete spore. Circular amb. Exine, 1.3 µm thick, psilate to finely granulate (?preservational effects). Trilete mark, straight, raised by thin lips, reaching less than 2/3 of the equatorial radius.

Dimensions. Diameter: 60 (68) 75 µm (2 specimens).

Note. This species differs from *Todisporites major* only by the observed granulation of the exine. However, because of the poor preservation and the limited number of specimens observed in this study, it is not possible to ascertain if the granulation is a preservational factor

Occurrences. Only two specimens are observed in this study in the Aptian–Barremian of the Zea-Panamericana outcrop section (samples 13-04-02 and 13-04-05).

SCHIZAEACEAN SPORES.

Genus *Cicatricosisporites* Potonié & Gelletich 1933 emend. Potonie & Kremp 1954

1933 *Cicatricosisporites* Potonie & Gelletich, p. 522.
1949 *Trilaterina* Malyavkina, p. 30.
1951 *Mohrioidites* Thiegart, p. 84 [nomen nudum].
1951 *Mohrioidites* Potonié, p. 14.
1954 *Cicatricosisporites* Potonié & Gelletich emend. Potonié & Kremp, p. 142.
1955 *Liratosporites* Vishnu Mittre, p. 119 [nomen nudum].
1956 *Anagramites* Bolkhovitina, p. 61.
1966 *Cicatricosisporites* Potonié & Gelletich emend. Potonie, p. 58.

Type Species. *Cicatricosisporites dorogensis* Potonié and Gelletich 1933 (p. 522; plate 1, figure 1, lectotype, designated by Potonié, 1956, p. 47). Eocene, Hungary.

Cicatricosisporites abacus Burger 1966 emend. Fensome 1987
Plate 3, figure 6a-b

1966 *Cicatricosisporites abacus* Burger, p. 242. Plate 7, figure 3.
1969 *Plicatella abaca* (Burger) Norris, p. 591-592.
1987 *Cicatricosisporites abacus* Burger emend. Fensome, p. 14-15.

For a more extensive synonymy, refer to Fensome (1987).

Description. See Burger (1966) and Fensome (1987).

Dimensions. Diameter: 40 (47) 57 μm (4 specimens).

Occurrences. This species is observed only in samples of the Upper Aptian and Albian of La Grita outcrop sections.

This species has been reported from Berriasian of Maryland (Doyle, 1983), Albian of Egypt (Sultan, 1978), Valanginian of Israel (Brenner, 1974), Berriasian to Valanginian of Germany (Dörhöfer, 1977), Jurassic to Lower Cretaceous of Netherlands (Burger, 1966;

Herngreen and Chlonova, 1981), Jurassic to Valanginian of England (Hughes and Moody-Stuart, 1969; Norris, 1969).

Cicatricosisporites australiensis (Cookson 1953) Potonié 1956
Plate 3, figure 7a-b

1953 *Mohrioisporites australiensis* Cookson, p. 470. Plate 2, figures 31-34.
1956 *Cicatricosisporites australiensis* (Cookson) Potonié, p. 48.

For a more extensive synonymy, refer to Fensome (1987).

Description. See Dettmann (1963, p. 53).

Dimensions. Diameter: 31 (43) 62 μm (45 specimens).

Note. This species differs from *Cicatricosisporites abacus* in the relatively narrower costae and canals that form the sculpture. The number of costae per set in the distal face is also larger than that of *Cicatricosisporites abacus.*

Occurrences: This species is commonly observed throughtout this study, in the Aptian–Albian samples of Zea-Panamericana and La Grita outcrop sections, where they are found in low abundance. Its occurrence in samples of the Aptian–Albian are more sporadic in samples of the wells CR-5, ALT-19X and ALP-6.

This species has been reported in the Jurassic to Albian of Australia (Balme, 1957; Dettmann, 1963; Burger, 1980; Helby et al., 1987), Hauterivian to Aptian of Argentina (Archangelsky and Gamerro, 1966; Pramparo, 1989), Albian of Perú (Brenner, 1968), Aptian of Colombia (Pons, 1988), Berriasian of Maryland, United States (Doyle, 1983), Jurassic to Middle Albian of western Canada (Norris, 1967; Burden and Hills, 1989), Upper Albian of Ontario, Canada (Zippi and Bajc, 1990), Berriasian to Barremian offshore of the United States (Bebout, 1981), Aptian to Maastrichtian offshore South Africa (McLachlan and Pieterse, 1978), Albian of Egypt (Sultan, 1978), Berriasian to Aptian of Germany (Dörhöfer, 1977; Batten and Li, 1987) and Upper Jurassic to Berriasian of England (Norris, 1969).

Cicatricosisporites hallei Delcourt & Sprumont 1955
Plate 3, figure 13

1955 *Cicatricosisporites hallei* Delcourt & Sprumont, p. 17-19. Plate 1, figures 1-2.

Description. See Delcourt and Sprumont (1955, p. 17).

Dimensions. Diameter: 22 (28) 32 μm (15 specimens).

Note. The observed specimens in this study are characterized by the possession of two sets of costae, oblique to each other, on the distal face. Delcourt et al. (1963) reillustrated the holotype of this species and clearly showed the two sets of costae on the distal face. Delcourt and Sprumont (1955) reported that the observed diameter ranged from 35 to 57 μm. However, Brenner (1963) included smaller specimens (24 to 49 μm diameter). I do not consider that overall size is a diagnostic feature and therefore the specimens observed in this study are included within *Cicatricosisporites hallei*.

Cicatricosisporites hallei has been reported from the Aptian of Colombia (Pons, 1988), Albian to Cenomanian of Brazil (Herngreen, 1973), Albian of Oklahoma (Hedlund and Norris, 1968; Srivastava, 1977), Barremian to Santonian offshore eastern United States (Bebout, 1981)Berriasian to Upper Albian of western Canada (Burden and Hills, 1989), Middle to Upper Albian of Alberta (Norris, 1967; Singh, 1971), Aptian–Albian offshore South Africa (McLachlan and Pieterse, 1978), Barremian to Lower Albian of Spain (Arias and Doubinger, 1980; Doubinger and Mas, 1981), Neocomian of Belgium (Delcourt and Sprumont, 1955) and Barremian to Middle Albian of England (Kemp, 1970).

Occurrence. This species is found in low numbers in the Aptian–Albian of La Grita and Zea-Panamericana outcrop sections, and wells CR-5 and ALT-19X.

Cicatricosisporites sp. cf. *C. proxiradiatus* Kemp 1970
Plate 3, figure 8

[cf.] 1970 *Cicatricosisporites proxiradiatus* Kemp, p. 91. Plate 13, Figures 1-6. Text-figure 10 a-b.

Description. Canaliculate, small trilete spore. Spherical with clearly circular amb. Total exine thickness less than 1.3 µm. Costae, 1.0 to 1.3 µm wide and high, separated by relatively deep canals, up to 1.3 µm deep and wide. Costae seem to be arranged in two sets of 6-7, oblique to each other in the distal face and almost dissappering in the contact area. Trilete mark raised by thickened lips, up to 1.3 µm high, extending almost 4/5 of the equatorial radius.

Dimensions. Diameter: 25 µm (1 specimen).

Notes. The amb, rounded ribs (in profile) and the distribution of the costae in the distal face are similar to those reported by Kemp (1970) for *Cicatricosisporites proxiradiatus*. However, because of the single specimen observed in this study, it is compared with rather than directly attributed to *Cicatricosisporites proxiradiatus*.

Occurrences. Only one specimen is observed in one sample of the Upper Aptian of La Grita outcrop section (sample 09-04-05).

Kemp (1970) described *Cicatricosisporites proxiradiatus* from the Aptian–Albian of England.

Cicatricosisporites sp. A
Plate 3, figure 9

Description. Small canaliculate trilete spores. Spherical with circular amb. Total exine thickness, 1.3 µm. Costae not well differentiated, formed by fused verrucae. Their distribution apparently discontinuous and is difficult to determine. Verrucae 2 to 2.5 µm long. Trilete mark slightly thickened, reaching the equatorial area.

Dimensions. Diameter: 25 (29) 36 µm (8 specimens).

Note. This species resembles *Cicatricosisporites minor* (Bolkhovitina 1959) Pocock 1965 in the thickened laesurae and the low costae. However, it differs from the latter by size and discontinuous costae.

Occurrences. Most of the specimens are fragments that are present in low abundance in samples of the Aptian–Albian of the Zea-Panamericana and La Grita outcrop sections. In the sections of wells CR-5 and ALT-19X, it occurred very sporadically.

Cicatricosisporites sp. B
Plate 3, figure 10

Description. Cicatricate small trilete spore. Spherical with ellipsoidal equatorial view?. Total exine thickness, 1.3 µm. Costae less than 1.3 µm wide, relatively sinuous, separated by canals up to 3.0 to 3.8 µm wide. Trilete mark raised by lips, up to 1.3 µm high and seem to reach the equatorial area.

Dimensions. Diameter: 22 µm (1 specimen).

Note. The poor preservation and the unknown orientation of the observed specimen precludes detailed comparison with other species of this genus.

Occurrences. It is observed in the Upper Aptian of La Grita outcrop section (sample 09-04-06).

Cicatricosisporites sp. C
Plate 3, figure 11

Description. Cicatricate trilete spore. Ovoidal with circular amb. Distal face convex. Total exine thickness about 1.3 µm thick. Costae about the same height and width, 1.3 µm, separated by canals up to 4.0 µm wide. Arrangement of ribs unclear due to poor preservation and orientation, but ribs seem to coalesce at least at one of the apices. Ribs tend to be thinner or disappear on the contact area. Trilete mark seems to be short and simple.

Dimensions. Diameter: 43 (44) 45 µm (2 specimens).

Note. As discussed in the case of *Cicatricosisporites* sp. A, the poor preservation and the unknown orientation of the observed specimens precludes meaningful comparison.

Occurrences. It is observed in the Upper Aptian of La Grita outcrop section (sample 09-04-06) and the Aptian of Zea-Panamericana (sample 13-04-17).

Cicatricosisporites sp. D
Plate 3, figure 12

Description. Cicatricate trilete spore. Subtriangular amb?. Total exine thickness less than 1.3 μm. Costae 1.0 to 1.3 μm wide, separated by canals up to 2.5 μm wide. Costae arranged in three sets of 4 to 6, parallel to the sides of the spore in the distal face and reduced in the proximal face, especially in the contact area. Canals becoming somewhat wider torwards the lobes or the apices. Trilete mark obscured.

Dimensions. Diameter: 37 μm (1 specimen).

Note. The characteristics of the costae might indicate some resemblance to *Cicatricosisporites purbeckensis* Norris 1969. However, because of the orientation and the poor preservation of the specimen, it is impossible to fully compare these two species.

Occurrence. It is observed in the Lower Aptian of the Zea-Panamericana outcrop section (sample 13-04-02).

Cicatricosisporites sp. E
Plate 4, figure 1

Description. Canaliculate, large-sized trilete spore. Spherical with ellipsoidal amb and convex distal face. Total exine thickness, 2.0 to 2.5 μm. Costae, smooth and continuous, 10-12 μm wide, separated by canals 2.5 μm wide. Costae arranged in one set of 6-7 relatively parallel to one side of the spore in the distal face. No trilete mark is observed.

Dimensions. Diameter: 120 μm (1 specimen).

Note. *Cicatricosisporites crassistriatus* Burger 1966 and *Cicatricosisporites major* (Döring 1965) Fensome 1987 are characterized by having very coarse costae. The latter species has a larger reported size range. However, the specimen observed in this study differs from *Cicatricosisporites crassistriatus* and *Cicatricosisporites major* in the presence of one set of costae, parallel to one of the sides of the spore, in the distal face.

The latter are characterized by possessing three sets of costae, parallel to the sides of the spore on the distal face. The species observed in this study also differs from *Cicatricosisporites brevilaesuratus* Couper 1958 emend. Kremp 1970 by having a more triangular amb than the latter. However, because only one specimen is observed in this study, further studies are necessary to ascertain the variability of *Cicatricosisporites* sp. E.

Cicatricosisporites subrotundus Brenner also posseses coarser costae, but the arrangement of the costae on the distal face includes at least two sets, rather than one like the pattern observed in the species observed in this study. *Cicatricosisporites* sp. 1 of Reyre (1973) also shows wide or coarse costae, but the size reported by Reyre (1973) is smaller than that observed in this study.

Occurrences. A single specimen is observed in the Aptian of the Zea-Panamericana outcrop section (sample 13-04-01).

Cicatricosisporites sp. F
Plate 4, figure 2

Description. Cicatricate, trilete spore. Triangular amb. Total exine thickness 3 to 6 μm. Costae 2 to 4 μm wide, relatively sinuous, separated by shallow and wide canals, up to 6 μm wide. Costae arranged in three sets of 3-4, parallel to the sides of the spore in the distal face and all coalescing torwards the equatorial apices. Trilete mark obscured.

Dimensions. Diameter: 62 μm (1 specimen).

Note. The size, amb and general arrangement of the species observed in this study resemble those of *Cicatricosisporites ticoensis* Archangelsky & Gamerro 1966. However, since the observed specimen in this study is broken, it is impossible to discern if the costae anastomose like those of *Cicatricosisporites ticoensis* by Archangelsky and Gamerro (1966).

Occurrences. A single specimen is observed in one sample of the Lower Aptian of the Zea-Panamericana outcrop section (sample 13-04-02).

Cicatricosisporites sp. G
Plate 4, figure 3

Description. Cicatricate trilete spore. Spherical with rounded triangular amb with convex distal face. Total exine thickness about 1.3 μm. Costae less than 1.3 μm wide, separated by canals of about 1.3 μm width. Ribs arranged in two sets of 6-8, oblique to each other in the distal face and reduced in the proximal face and coalescing at one appex with adjacent ribs of their own series. Contact area granulate. Trilete mark straight and simple, reaching about 3/4 of the spore radius.

Dimensions. Diameter: 37 μm (1 specimen).

Note. The orientation of the specimen did not allow to determine the definite arrangement of costae. However, the narrow costae and the two sets determined in the specimen observed in this study show some resemblance to *Cicatricosisporites hallei*. *Cicatricosisporites potomacensis* Brenner 1963 also has narrow muri, but they are arranged in three sets of subparallel costae on the distal face.

Occurrences. A single specimen is observed in the Upper Aptian of the Zea-Panamericana outcrop section (sample 13-04-45).

Cicatricosisporites sp. H
Plate 4, figure 4a-b

Description. Cicatricate trilete spore. Triangular amb with convex distal face, with straight sides. Total exine thickness, 2.0 to 2.5 μm. Costae relatively narrow and sinuous, 1.0 to 1.3 μm wide, separated by wider canals (2.5 to 3.0 μm wide). Costae arranged in three sets of 3 to 5, relatively parallel to the sides of the spore in the dital face, coalescing torwards the apices with ribs of adajacent series, almost absent in the proximal face. Trilete mark straight, simple and reaching the equatorial area.

Dimensions. Diameter: 32 μm (1 specimen).

Note. This species resembles *Cicatricosisporites purbeckensis* by the sinuous and spaced costae in the distal face. However, Norris (1969) described the costae of *Cicatricosisporites purbeckensis* as uneven and with "swollen nodes", features that are not observed in the species reported here in this study. The costae of *Cicatricosisporites purbeckensis* do not coalesce at the apices, as they do in *Cicatricosisporites* sp. I.

Occurrences. A single specimen is observed in the Upper Aptian of the Zea-Panamericana outcrop section (sample 13-04-47).

Cicatricosisporites sp. I
Plate 4, figure 5a-b

Description. Cicatricate trilete spore. Spherical rounded triangular amb with convex sides. Total exine thickness, about 1.0 to 1.5 µm. Costae less than 1.3 µm wide, separated by canals of abouth 1.0 to 1.5 µm width. Costae perhaps arranged in two sets of 3 to 4, oblique to each other in the distal face and almost absent in the proximal face. Contact area smooth or finely granulate. Trilete mark thickened and reaching the equatorial area.

Dimensions. Diameter: 27 µm (1 specimen).

Occurrences. A single specimen is observed in the Aptian of well CR-5 (sample CR-5 14549').

Genus *Contignisporites* Dettmann 1963

1963 *Contignisporites* Dettmann, p. 73.

Type Species. *Contignisporites glebulentus* Dettmann 1963 (p. 74; plate 15, figures 1-2). Aptian–Albian, Australia.

Contignisporites sp. cf. *C. cooksonae* (Balme 1957) Dettmann 1963
Plate 4, figure 7

[cf.] 1963 *Contignisporites cooksonae* (Balme) Dettmann, p. 75. Plate XV, figures 11-16.

Description. Canaliculate cingulate trilete spore. Spherical with clearly circular amb. Total exine thickness, 2 to 2.5 µm. Cingulum, 4 µm thick. Very wide costae, 2.5 to 4 µm wide and separated by narrow canals, less than 1 µm. Costae arranged in one set of 4-6 ribs in the distal face and absent in a circular area in the proximal face. Contact area psilate-granulate, defined by a circular area limited by thickening of the wall. Laesurae sinuous and short, 1/2 to 2/3 of the equatorial radius.

Dimensions. Diameter: 37.5 μm (1 specimen).

Note. Because the single and poorly preserved specimen observed in this study, it is compared with rather than directly attributed to *Contignisporites cooksonae.*

Occurrences. It is observed in one sample of the Aptian of well CR-5 (sample CR-5 14460').

Contignisporites cooksonae has been reported from the Jurassic to Albian of Australia (Balme, 1957, Dettmann, 1963, Burger, 1980, Helby et al., 1987; Backhouse, 1988), Aptian of Colombia (Prössl and Vergara Streinesberger, 1993), Berriasian to Albian of offshore eastern United States (Bebout, 1981), Berriasian to Albian of Canada (Singh, 1971; Burden and Hills, 1989), Aptian–Albian of offshore South Africa (McLachlan and Pieterse, 1978), Lower Albian of Spain (Arias and Doubinger, 1980) and Barremian to Aptian of the former U.S.S.R. (Bolkhovitina, 1961).

Genus *Costatoperforosporites* Deák 1962

1962 *Costatoperforosporites* Deák, p. 230.

Type Species. *Costatoperforosporites foveolatus* Deak 1962 (p. 231, 234; plate 27, figure 4-6). Aptian, Hungary.

Costatoperforosporites sp. A
Plate 4, figure 8

Description. Canaliculate trilete spore. Ellipsoidal equatorial view, with convex distal face and pyramidal proximal face. Total exine thickness, 2.0 to 4.0 μm. Costae, 4.0 to 6.0 μm wide, straight with rows of circular perforations, 1.3 μm diameter. Costae separated by relatively narrow canals less than 1.3 μm wide.

Dimensions. Equatorial diameter: 62 μm (1 specimen).

Note. Because of the orientation and the fact that one specimen is observed, it is difficult to compare this species to others.

Occurrences. A single specimen is observed in the Albian of La Grita outcrop scetion (sample 09-04-13).

Genus Crassitudisporites Hiltmann 1967 emend. Fensome 1987

1967 *Crassitudisporites* Hiltmann, p. 171.
1977 *Asseretospora* Schuurman, p. 197.
1987 *Crassitudisporites* Hiltmann emend. Fensome, p. 11-12.

Type species. *Crassitudisporites problematicus* (Couper 1958; p. 146-147; plate 24, figure 11) Hiltmann 1967 emend. Fensome 1987. Middle Jurassic–Lower Cretaceous, England.

Crassitudisporites problematicus (Couper 1958) Hiltmann 1967 emend. Fensome 1987
Plate 4, figure 6a-b

1958 *Cingulatisporites problematicus* Couper, p. 146-147. Plate 24, figures 11-13.
1965 *Duplexisporites problematicus* (Couper) Playford & Dettmann, p. 140.
1965 *Duplexisporites gyratus* Playford & Dettmann, p. 141.
1965 *Contignisporites problematicus* (Couper) Döring, p. 51.
1967 *Crassitudisporites problematicus* (Couper) Hiltmann, p. 171.
1987 *Crassitudisporites problematicus* (Couper) Hiltmann emend. Fensome, p. 12-13.

Description. See Fensome (1987).

Dimensions. 37 (40) 43 μm (2 specimens).

Occurrences. This species is observed only in the Aptian of the Zea-Panamericana (sample 13-04-01) and Upper Aptian of La Grita (sample 09-04-04) outcrop sections.

According to Fensome (1987) this species has been reported mainly from the Jurassic, but has also been reported in the Valanginian to Barremian of Israel (Brenner, 1974) and as a possible reworked material in the Valanginian of northwest Canada (Fensome, 1987).

Genus *Distaltriangulisporites* Singh 1971

1971 *Distaltriangulisporites* Singh, p. 88.

Type Species. *Distaltriangulisporites perplexus* (Singh 1964; p. 55; plate 5, figures 6-9) Singh 1971. Middle to Upper Albian, Alberta, Canada.

Distaltriangulisporites sp. A
Plate 4, figure 9

Description. Cingulate trilete spore. Ovoidal with rounded sub-triangular amb with convex sides. Total cingulum thickness, 5.0 to 6.0 µm; smooth. Costae forming distal triangular shield, 3.0 to 4.0 µm wide, relatively sinuous with short blunt thickenings at the apices. Exine, 1.0 to 2.0 µm thick, psilate to finely granulate in the proximal face. Trilete laesurae straight and short, 1/2 of the equatorial radius of the spore.

Dimensions. Diameter: 41.3 µm (1 specimen).

Note. This species differs from *Distaltriangulisporites perplexus* in that the observed distal triangular shield did not show perforations or spaces reported by Singh (1971) for this species. *Distaltriangulisporites irregularis* Singh 1971 is characterized by a single costa running across the distal triangular shield, feature that is not observed in the species observed in this study.

Occurrences. This species is observed in the Upper Aptian of La Grita outcrop section (sample 09-04-05).

Genus *Ischyosporites* Balme 1957 emend. Fensome 1987

1957 *Ischyosporites* Balme, p. 23.
1958 *Klukisporites* Couper, p. 137.
1963 *Ischiosporites* Levet-Carette, p. 111.
1965 *Klukisporites* Couper emend. Pocock [pars], p. 193.
1970 *Ramanujamiaspora* Kar and Sah, p. 105.
1987 *Ischyosporites* Balme emend. Fensome, p. 17.

Type Species. *Ischyosporites crateris* Balme 1957 (p. 23-24; plate 3, figure 45). Cretaceous (?Neocomian–Aptian), Western Australia.

Ischyosporites pseudoreticulatus (Couper 1958) Döring 1965
Plate 5, figure 2

1958 *Klukisporites pseudoreticulatus* Couper, p. 138. Plate 19, Figures 8-10.
1962 *Dictyotriletes* (al. *Klukisporites*) *pseudoreticulatus* (Couper) Pocock, p. 41.
1965 *Ischyosporites pseudoreticulatus* (Couper) Döring, p. 42-43.

Description. See Couper (1958).

Dimensions. Diameter: 43.8 µm (1 specimen)

Occurrences. A single specimen is observed in the Albian of well ALT-19X (sample ALT-19X 17461').

This species has been reported in the Triassic to Cretaceous; Aptian of Colombia (Prössl and Vergara Streinesberger, 1993), Barremian to Albian of Maryland, (Brenner, 1963; Doyle, 1983) and Barremian? to Lower Albian of Colorado, United States (Tschudy et al., 1984), Barremian to Cenomanian? of Alberta (Singh, 1964 and 1971; Norris, 1967), Berriasian to Upper Albian of northwest Canada (Burden and Hills, 1989), Valanginian to Hauterivian of Israel (Brenner, 1974), Neocomian of Germany (Dörhöfer, 1977; Dörhöfer and Norris, 1977), Jurassic to Middle Albian of England (Norris, 1969; Kemp, 1970)

Ischyosporites variegatus (Couper 1958) Schulz 1967
Plate 5, figure 1a-b

1958 *Klukisporites variegatus* Couper, p. 137. Plate 19, figures 6-7.
1967 *Ischyosporites variegatus* (Couper) Schulz, p. 569.

Description. See Couper (1958).

Dimensions. Diameter: 37 (41) 50 µm (16 specimens).

Occurrences. This species is observed in low frequencies in samples of the Aptian and Albian of the Zea-Panamericana and La Grita outcrop sections, and in lesser numbers in wells CR-5 and ALP-6.

The species has been reported in sediments of Triassic to Tertiary in age; from the Kimmeridgian to Aptian of Australia (Backhouse, 1988), Lower to Middle Albian of Venezuela (Sinanoglu, 1984), Aptian of Colombia (Prössl and Vergara Streinesberger, 1993), Aptian to Cenomanian of Brazil (Regali et al., 1974a), Albian of Maryland (Brenner, 1963) and Oklahoma (Srivastava, 1977) United States, Barremian to Lower Aptian of France (de Reneville and Raynaud, 1981) and Aptian of Hungary (Deák, 1964).

Genus *Plicatella* Malyavkina 1949

1949 *Plicatella* Malyavkina, p. 60.
1953 *Appendicisporites* Weyland & Krieger, p. 12.
1989 *Plicatella* Mayavkina emend. Burden & Hills, p. 60.

Type Species. *Plicatella trichacantha* Maljavkina 1949 (p. 61; plate 11, figure 7). Aptian, former U.S.S.R.

Remarks. Davies (1986) considered *Appendicisporites* to be a junior synonym of *Plicatella*. This approach is followed in this study.

Plicatella potomacensis (Brenner 1963) Davies 1986
Plate 5, figure 3

1963 *Appendicisporites potomacensis* Brenner, p. 46. Plate 6, figures 4-5.
1986 *Plicatella potomacensis* (Brenner) Davies, p. A49.

Description. See Brenner (1963).

Dimensions. Diameter: 25 µm (1 specimen).

Note. This species resembles *Plicatella tricornitata* (Weyland & Greifeld 1953) Potonié 1960, but differs by the smaller size of the specimen observed in this study. *Plicatella problematica* Burger 1966 has three sets of 3 to 5 costae in the distal face.

Occurrences. Only one specimen is observed in the Albian of well ALT-19X (sample ALT-19X 17439').

Plicatella potomacensis has been reported from the Albian of Oklahoma (Srivastava, 1977), Barremian to Lower Cenomanian of Maryland, eastern USA (Brenner, 1963), Berriasian to Maastrichtian of offshore eastern USA (Bebout, 1981), Berriasian to Upper Albian of western Canada (Burden and Hills, 1989), Middle Albian to Cenomanian of Alberta, western Canada (Norris, 1967; Singh, 1971 and 1983), Upper Albian offshore eastern Canada (Williams and Brideaux, 1975), Barremian of Spain (Doubinger and Mas, 1981), Berriasian to Valanginian of Germany (Dörhöfer and Norris, 1977) and Berriasian of England (Norris, 1969).

PTERIDOPHYTE SPORES OF UNCERTAIN AFFINITY.

Genus *Rotverrusporites* Döring 1964b

1964b *Rotverrusporites* Döring, p. 1106.

Type Species. *Rotverrusporites obscurilaesuratus* (Pocock 1962; p. 72; plate 8, figure 127) Döring 1964b. Barremian, Canada.

Rotverrusporites convexus sp. nov.
Plate 5, figure 4

Diagnosis. A species of *Rotverrusporites* characterized by a triangular amb with convex sides, verrucate ornamentation, verrucae very dispersed on the proximal face and occurring more densely on the distal face.

Etymology. Latin *convexus*, convex. With reference to convex sides of the amb of this species.

Description. Verrucate trilete spore. Triangular to circular amb, with convex sides. Exine, 1.3 µm thick, verrucate sexine. Verrucae with circular cross-sections, dome-shaped, 1.3 to 2.5 µm wide, somewhat reduced in the contact area and densely distributed on the distal face, with their bases touching each other. Trilete mark straight, raised by lips (1.0 to 1.3 µm high) extending to the equator.

Holotype. Plate 5, figure 4. Diameter, 35 µm. Verrucae, 1.5 to 2.0 µm wide and less than 1.0 to 1.5 µm high. The Zea-Panamericana outcrop section. Sample; 13-04-05. Slide 1. Coordinates; 40.7 x 95.1. Aguardiente Formation. 4 km north of the town of Zea, Mérida State, western Venezuela. Lower Aptian.

Dimensions. Diameter: 35 (39) 50 µm (55 specimens).

Note. This species differs from *Rotverrusporites tenuis* Döring 1964b and *Rotverrusporites verrucatus* (Couper 1958) Döring 1964b by the possession of smaller verrucae that are not closely packed. *Rotverrusporites bossus* Döring 1964b has higher verrucae. This species resembles *Rotverrusporites* sp. 1, reported from the Bathonian–Kimmeridigian of the Sahara by Reyre (1973), but the specimens observed in this study are smaller. It is differentiated by small size from *Verrucosisporites* sp. A of Bharadwaj and Singh (1964) from the Upper Triassic of Austria. *Verrucosisporites morulae* Klaus 1960has closely-packed verrucae on both distal and proximal faces.

Occurrences. This species is commonly observed in the Lower Aptian of the Zea-Panamericana outcrop section and more rarely in the Aptian–Albian of La Grita outcrop section and in wells CR-5 and ALT-19X.

Rotverrusporites sp. A
Plate 5, figure 5a-b

Description. Verrucate trilete spore. Circular amb. Exine, 1.3 µm thick, verrucate. Verrucae, densely distributed on the distal face, less than 1.3 µm thick wide, of irregular shape, almost absent in the contact area. Trilete straight and raised by thin lips, reaching up to 3/4 to 4/5 of the spore radius.

Dimensions. Diameter: 31 (32) 33 µm (3 specimens).

Note. This species resembles *Rotverrusporites rupunumiensis* van der Hammen & Burger 1965 in the thickened laesurae, but differs from the latter by the smaller size of the verrucae and overall diameter. *Rotverrusporites obscurilaesuratus* (Pocock 1962) Döring 1964b has similar distribtion and shape of verrucae, but the laesurae is not well defined. *Rotverrusporites bossus* has higher verrucae. *Rotverrusporites* fsp. A of Döring (1964b) has polygonal verrucae.

Occurrences. This species is rarely found in samples of the Upper Aptian and Albian of La Grita and Zea-Panamericana outcrop sections and wells CR-5 and ALT-19X.

SPORES OF UNCERTAIN AFFINITY

Genus *Biretisporites* Delcourt & Sprumont 1955 Delcourt et al. 1963

1955 *Biretisporites* Delcourt & Sprumont, p. 40.
1957 *Hymenophyllumsporites* Rouse, p. 363.
1963 *Biretisporites* Delcourt & Sprumont 1955 emend. Delcourt et al. 1963, p. 283.

Type Species. *Biretisporites potoniaei* Delcourt & Sprumont 1955 emend. Delcourt et al. 1963. Cretaceous (Neocomian), Belgium.

Biretisporites potoniaei Delcourt & Sprumont 1955 (p. 40-41; text-figure 10) emend.
Delcourt et al. 1963
Plate 5, figures 6 and 7

1955 *Biretisporites potoniaei* Delcourt & Sprumont, p. 40-41. Text-figure 10.
1955 *Punctatisporites pileoulus* Delcourt & Sprumont, p. 30-31. Plate 2, figure 5.
1963 *Biretisporites potoniaei* Delcourt & Sprumont emend. Delcourt et al., p. 248.

Description. See Delcourt et al. (1963).

Note. This species is distinguished by the thickened laesurae, 1.0 to 2.0 µm high and wide (Plate 7, figure 7) and the microgranulate ornamentation.

Dimensions. Diameter: 26 (29) 36 µm (32 specimens).

Occurrences. This species is observed in moderate abundances in samples of the Aptian–Albian of La Grita, Zea-Panamericana and Catatumbo outcrop sections, as in wells ALT19-X and CR-5.

This species has been reported in the Jurassic–Cretaceous; Aptian to Upper Albian of Colombia (Pons, 1988), Albian of Oklahoma, United States (Hedlund and Norris, 1968), Berriasian to Upper Albian of western Canada (Pocock, 1962; Norris, 1967; Burden and Hills, 1989), Barremian and Lower Albian of Spain (Arias and Doubinger, 1981; Doubinger and Mas, 1981) and Neocomian of Belgium (Delcourt and Sprumont, 1955).

Genus *Cibotiumspora* Chang 1965

1965 *Cibotiumspora* Chang, p. 164.

Type species. *Cibotiumspora sinuata* (Couper 1953; p. 31; plate 3, figures 24-25) comb. nov. Middle Jurassic, New Zealand.

Cibotiumspora sinuata (Couper 1953) comb. nov.
Plate 5, figures 8 and 9a-b

1953 *Trilites sinuatus* Couper, p. 31. Plate 3, figures 24-25.
1957 *Concavisporites jurienensis* Balme, p. 20-21. Plate 2, figures 30-31.
1975 *Cibotiumspora jurienensis* (Balme) Filatoff, p. 61.

Description. See Filatoff (1975).

Dimensions. Diameter: 27 (37) 45 µm (6 specimens).

Note. Fensome (1983) pointed out that the main morphological variation of *Cibotiumspora sinuata* is the presence or absence of a proximal kyrtome. As he and Filatoff (1975) illustrated, the proximal kyrtome of this species might be observed as simple lips raising the laesurae to a thickened kyrtome close to the amb of the spore. It is my interpretation that this variation is shown in the specimens observed in this study; for example from a specimen with a relatively well developed kyrtome located near the laesurae (Plate 5, figure 8) to one specimen with a well developed kyrtome close the amb of the spore (Plate 5, figure 9a-b). The differences in wall thickness and ornamentation, from granulate to psilate, might be related to different developmental stages and to preservational artifacts.

Occurrences. This species is rarely observed in samples of the Albian of the Zea-La Grita and Catatumbo outcrop sections, as in well ALT-19X and ALP-6.

Cibotiumspora sinuata. has been reported from the Lower Jurassic to Aptian of Australia (Balme, 1957; Backhouse, 1988), Aptian of Colombia (Pons, 1988), Berriasian of Maryland, eastern USA (Doyle, 1983), Lower Cretaceous of western Canada (Burden and Hills, 1989), Valanginian to Barremian of Israel (Brenner, 1974), Berriasian of England (Norris, 1969). Other occurrences has been mainly reported from the Jurassic on an almost worldwide basis.

Genus *Concavisporites* Pflug in Thomson & Pflug 1953 emend. Delcourt & Sprumont 1955 emend Krutzsch 1959a

1953 *Concavisporites* Pflug in Thomson & Pflug [pars], p. 49.

1953 *Concavisporites* sektion *Hyalinoidae* Pflug in Thomson & Pflug, p. 49 [redundant name for typical section]

1953 *Concavisporites* sektion *Exiguidae* Pflug in Thomson & Pflug, p. 50.

1955 *Concavisporites* Pflug emend. Delcourt & Sprumont, p. 22.

1959a *Concavisporites* Pflug emend. Krutzsch, p. 116-117.

1959a *Toroisporis* Krutzsch [pars], p. 90.

1959a *Toroisporis* (*Toroisporis*) Krutzsch, p. 98.

1959a *Toroisporis* (*Exiguidae*) Krutzsch, p. 123

1960 *Paraconcanvisporites* Klaus, p. 121.

1964 *Vinculisporites* Deák, p. 97.

1966 *Concavisporites* Pflug emend. Potonié, p. 18.

1966 *Toroisporites* Nakoman [pars], p. 74 [Nomenclatural junior synonym of *Toroisporis*, having the same type species]

Type Species. *Concavisporites rugulatus* Pflug in Thomson & Pflug 1953 (p. 49; plate 1, figures 19-23). Paleocene–Lower Eocene, central Europe.

Concavisporites mesozoicus (Döring 1965) comb. nov.
Plate 6, figure 1a-b

1956 cf. *Clathropetris* sp. (Typ 6) Góczán, p. 145. Plate 5, figures 8, 11.
1965 *Toroisporis (Toroisporis) mesozoicus* Döring, p. 25. Plate 7, figures 1-3.

Description. See Döring (1965).

Dimensions. Diameter: 33 (42) 51 μm (26 specimens).

Note. The observed specimens in this study are quite similar to the characteristics reported by Döring (1965) for the species *mesozoicus*, except for the observed size range, that is smaller than that reported by Döring (1965) (50 to 74 μm). However, this character is not considered of taxonomic relevance.

Occurrences. This species is observed in low numbers in samples of the Aptian and Albian of La Grita, Zea-Panamericana and Catatumbo outcrop sections and in lesser numbers in wells CR-5, ALT-19X, ALP-6 and P-201.

This species was described by Döring (1965) in the Wealden of Germany and has also been reported by Góczán (1956) in the Jurassic of Hungary and in the type section of the Maastrichtian in the Netherlands (Kedves and Herngreen, 1980).

Concavisporites sp. cf. *C. toralis* (Leschik 1955) Nilsson 1958
Plate 6, figure 2

[cf.] 1958 *Concavisporites toralis* (Leschik) Nilsson, p. 34. Plate 1, figures 12-13.

Description. See Nilsson (1958) and Fensome (1983, p. 417-418).

Dimensions. Diameter: 25 (29) 36 μm (28 specimens).

Note. *Concavisporites toralis* (Leschik 1955) Nilsson 1958 differs from others of this genus in the small size range and general outline. Because of the poor preservation of most of the specimens, they are compared with rather than attributed it to *Concavisporites toralis*. Fensome (1983) proposed that forms with slightly concave and convex, as well as straight sides to be attributed to this species. This species differs from *Concavisporites mesozoicus* by the small overall size.

Occurrences. This species is observed in low numbers in samples of the Aptian–Albian of La Grita and the Zea-Panamericana outcrop sections.

Concavisporites toralis has been reported only in sediments of the Triassic and Jurassic, on an almost worldwide basis.

Genus *Deltoidospora* Miner 1935 *ex* Potonié 1956

1935 *Deltoidospora* Miner, p. 168.
1939 *Leiotriletes* Naumova, p. 355 [nomen nudum].
1947 *Alsophilidites* Cookson, p. 136 [nomen nudum].
1953 *Cyathidites* Couper, p. 27.
1954 *Leiotriletes* Naumova *ex* Ischenko emend. Potonié & Kremp, p. 120.
1956 *Deltoidospora* Miner *ex* Potonié, p. 13 [designation of type species].
1956 *Alsophilidites* Cookson *ex* Potonié, p. 14.
1961 *Lygodium* subgen. *Laevigatigranulata* [sic] Ivanova in Samoilovitch & Mtchedlishvili, p. 91.
1963 *Deltoidospora* Danzé-Corsin and Laveine, p. 64 [Nomenclatural junior synonym with the same type species].
1970 *Harrisispora* Pocock, p. 38.

Type Species. *Deltoidospora hallii* Miner 1935 (p. 618; plate 24, figure 7). Jurassic–Cretaceous boundary beds, Kootenay Formation, Montana, United States.

Remarks. As Dörhöfer (1977) and Fensome (1983) have suggested, the affinities and discrimination of smooth and simple trilete spores are poorly understood. For the purposes of this study, the approach taken by Fensome (1983) of considering the genera *Leiotriletes*, *Cyathidites* and *Harrisispora* as junior synonyms of *Deltoidospora* Miner *ex* Potonié is accepted.

Deltoidospora australis (Couper 1953) Pocock 1970
Plate 6, figure 3

1949 *Sporites adrienis* f. *mesozoicus* Thiergart, p. 11. Plate IV, figure 9.
1953 *Cyathidites australis* Couper, p. 27. Plate 2, figures 11-12.
1953 *Cyathidites minor* Couper, p. 28. Plate 2, figure 13.
1956 *Cyathidites mesozoicus* (Thiergart) Potonié, p. 14.
1957 *Cyathidites australis* forma *rimalis* Balme, p. 21-22. Plate 2, figures 34-35.
1970 *Deltoidospora australis* var. *rimalis* (Balme) Pocock, p. 28-29.
1970 *Deltoidospora minor* (Couper) Pocock, p. 28.
1977 *Deltoidospora mesozoica* (Thiergart) Schuurman, p. 182.

Description. See Couper (1953) and Pocock (1970).

Dimensions. Diameter: 25 (52) 69 μm (345 specimens).

Occurrences. This species is the most abundantly observed in samples of the Aptian–Albian in almost all the section under study.

In general, the species here included in *Deltoidospora australis* have been widely reported in Lower Cretaceous sediments on a worldwide basis and have a long stratigraphic range; Jurassic to Middle Albian of Australia (Burger, 1980), Jurassic to Albian of Argentina (Volkheimer and Quattrocchio, 1981), Albian of Oklahoma (Hedlund and Norris, 1968), Upper Albian of Utah (Tschudy et al., 1984), United States, Berriasian to Upper Albian of northwest Canada (Burden and Hills, 1989), Middle to Upper Albian of Alberta (Norris, 1967) and Upper Albian to Lower Cenomanian of Ontario (Zippi and Bajc, 1990), Canada, Albian to Lower Cenomanian of Egypt (Sultan, 1987), Barremian of Spain (Doubinger and Mas, 1981), Lower Albian to Cenomanian of France (Fauconnier, 1979), Upper Valanginian to Lower Aptian of Germany (Batten and Li, 1987), Barremian to Albian of England (Kemp, 1970)

Deltoidospora punctata (Delcourt & Sprumont 1955) Delcourt et al. 1963 comb. nov.
Plate 6, figure 6

1955 *Concavisporites punctatus* Delcourt & Sprumont, p. 25. Plate 1, figure 8.
1963 *Cyathidites punctatus* (Delcourt & Sprumont) Delcourt et al., p. 283.

1964b *Maculatisporites granulatus* (Ivanova) Döring, p. 1100-1101.

Description. See Delcourt and Sprumont (1955) and Fensome (1983, p. 432-433).

Dimensions. Diameter: 32 (44) 48 μm (28 specimens).

Note. Fensome (1983) proposed that *Deltoidospora punctata* can be differentiated from *Deltoidospora australis* by its thicker exine and larger overall size. However, the specimens of the *Deltoidospora punctata* observed in this study are characterized by the infrapunctate exine, small overall size and length of the laesurae (shorter in the case of *Deltoidospora punctata*, 2/3 of the equatorial radius). Thickness of the exine of both species are the same overall (about 1.3 μm thick).

Occurrences. This species is observed in low abundance in Aptian–Albian samples of all the sections considered in this study.

This species has been reported from the Neocomian to Middle Albian of Australia (Burger, 1980), Aptian of Colombia (Pons, 1988), Albian of Louisiana (Paden-Phillips and Felix, 1971a), Oklahoma (Srivastava, 1977) and Utah (Tschudy et al., 1984), Berriasian to Turonian of Maryland (Bebout, 1981), United States , Berriasian to Upper Albian of northwestern Canada (Burden & Hills, 1989) and Upper Albian to Cenomanian of Ontario, Canada (Zippi and Bajc, 1990), Albian of Egypt (Sultan, 1987), Barremian to Lower Albian of Spain (Arias and Doubinger, 1980; Doubinger and Mas, 1981), Wealden of Belgium (Delcourt and Sprumont, 1955) and Wealden to Aptian of England (Couper, 1958).

Genus *Dictyophyllidites* Couper 1958 emend. Dettmann 1963

1958 *Dictyophyllidites* Couper, p. 140.
1963 *Dictyophyllidites* Couper 1953, emend Dettmann, p. 27.

Type Species. *Dictyophyllidites harrisii* Couper 1958 (p. 140; plate 21, figure 6). Jurassic, Britain.

Remarks. Fensome (1983) pointed out that Couper (1958), in his original diagnosis of the genus, stated that the "commisures [were] clearly raised, bordered by a distinct margo". As Fensome (1983) discussed, the thickening of the exine can be incipient to prominent and located away from the laesurae (as noticed by Bharadwaj and Singh, 1964). Dettmann (1963) referred to the thickening of the exine, that she placed at "about the laesurate margin". For the purposes of this study species of *Dictyophyllidites* will be characterized by the occurrence of a distinct margo or by the presence of incipient to prominent thickening near or around the laesurae as described by Couper (1958) and Dettmann (1963).

Dictyophyllidites harrisii Couper 1958
Plate 6, figure 4

1958 *Dictyophyllidites harrisii* Couper, p. 140. Plate 21, figures 5-6.

Description. See Couper (1958).

Dimensions. Diameter: 28 (37) 52 µm (125 specimens).

Note. This species is characterized by the presence of an incipient arcuate thickening of the exine surrounding the laesurae in the interradial areas. The proposal of Fensome (1983), stating that the thickening of the exine of *Dictyophyllidites harrisii* is not a margo is accepted in this study.

Occurrences. This species is observed to be abundant in samples of the Aptian–Albian of La Grita, Zea-Panamericana Rosarito and Catatumbo outcrop sections, as well as in well CR-5. It is observed in less numbers in wells ALT-19X, ALP-6 and P-201.

This species has been reported from the Triassic to the Cretaceous; Albian of Oklahoma, United States (Hedlund and Norris, 1968; Srivastava, 1977), Berriasian to Upper Albian of western Canada (Burden and Hills, 1989) and Upper Albian to Cenomanian of Ontario, Canada (Zippi and Bajc, 1990), Albian to Cenomanian of Egypt (Sultan, 1987; Aboul Ela and Mahrous, 1992) and Tithonian to Berriasian of England (Norris, 1969).

Dictyophyllidites grandis sp. nov.
Plate 6, figure 5

1973 Azonotriletes lisse 3 Reyre, p. 111. Plate 4, figure 1.

Diagnosis. A species of *Dictyophyllidites* characterized by large overall size, triangular amb with straight sides, psilate wall and thick and well differentiated margo associated with the trilete laesurae.

Etymology. Latin *grandis*, great, large. With reference to the relatively large overall size of the specimens included in this species.

Description. Psilate-granulate, large trilete spore. Triangular amb with straight to slightly concave sides. Exine, 1.3 to 2.5 μm thick, psilate to finely granulate. Trilete mark straight, simple, reaching the equatorial area with well differentiated margo, 3.0 to 4.0 μm wide and 1.0 to 2.0 μm thick.

Holotype. Plate 6, figure 5. Diameter, 62 μm. Exine, 1.5 μm thick. The Zea-Panamericana outcrop section. Sample; 13-04-06. Slide 1. Coordinates; 11.4 x 94.1. Aguardiente Formation. 4 km north of the town of Zea, Mérida State, western Venezuela. Lower Aptian.

Dimensions. Diameter: 48 (54) 62 μm (14 specimens).

Note. This species differs from *Dictyophyllidites harrisii* by the larger overall size, granulate exine and the presence of well defined margo surrounding the laesurae.

Occurrences. This species is observed in low numbers in samples of the Aptian of the Zea-Panamericana outcrop section and more rarely in samples of the Upper Aptian of La Grita and Albian of wells CR-5, ALT-19X and ALP-6.

Genus *Foveosporites* Balme 1957

1957 *Foveosporites* Balme, p. 17.

Type Species. *Foveosporites canalis* Balme 1957 (p. 17; plate 1, figures 15-17). Lower Cretaceous (?Neocomian), Western Australia.

Foveosporites sp. cf. *F. subtriangularis* (Brenner 1963) Kemp 1970
Plate 7, figure 2a-b

[cf.] 1970 *Foveosporites subtriangularis* (Brenner) Kemp, p. 88. Plate 11, figures 12-13.

Description. Foveolate trilete spore. Circular to subtriangular amb. Exine, 2.5 µm thick, foveolate. Fovea of irregular shape, about 0.5 µm diameter, muri 2.5 µm. Trilete mark straight and simple almost reaching the equator.

Dimensions. Diameter: 35 µm (1 specimen).

Note. This species resembles *Foveosporites subtriangularis* in the overall amb and foveolate ornamentation. However, the diameter of fovea of *Foveosporites subtriangularis* was reported by Brenner (1963) between 1.0 to 1.5 µm, larger than the diameter observed for the specimen observed in this study.

Occurrences. A single specimen is observed in the Albian of well ALT-19X (sample ALT-19X 17439').

Foveosporites subtriangularis has been reported from the Upper Jurassic to Aptian of Australia (Backhouse, 1988), Cenomanian of Mississippi (Panden-Phillips and Felix, 1971a), Barremian to Albian of Maryland (Brenner, 1963), Berriasian to Turonian offshore eastern United States (Bebout, 1981), Berriasian to Upper Albian of western Canada (Burden and Hills, 1989), Middle to Upper Albian of Alberta (Singh, 1971), Aptian offshore South Africa (McLachlan and Pieterse, 1978), Albian of Egypt (Sultan, 1987), Barremian to Cenomanian of France (de Renéville and Raynaud, 1981; Fauconnier, 1979), Berriasian to Valanginian of Germany (Döring, 1965; Dörhöfer and Norris, 1977) and Barremian to Lower Albian of England (Kemp, 1970).

Genus *Foveotriletes* van der Hammen 1954 *ex* Potonié 1956

1954 *Foveotriletes* van der Hammen, p. 14.
1956 *Foveotriletes* van der Hammen *ex* Potonié 1956, p. 43.

Type Species. *Foveotriletes scrobiculatus* (Ross 1949) Potonié 1956. Cretaceous, Sweden.

Foveotriletes sp. A
Plate 6, figure 7

Description. Foveolate trilete spores. Triangular amb with slightly convex to straight sides. Exine, 1.0 to 1.3 µm thick, foveolate. Foveolae, circular, less than 1.3 µm diameter, uniform all over the distal and proximal faces. Trilete mark, straight, simple, reaching 4/5 of the spore radius.

Dimensions. Diameter: 32 (41) 50 µm (4 specimens).

Note. The few poorly preserved specimens that are observed in this study did not allow proper characterization of this species. It differs from *Foveosporites subtriangularis* by the more triangular amb. *Foveosporites subtriangularis* is characterized by variation in the diameter of the fovea, being larger in the distal face. *Foveosporites canalis* tends to show fused fovea. *Vadazisporites urkutius* (Deák 1964) Deák & Combaz 1968 has a similar triangular outline; however, this species is reticulate, with polygonal lumina.

Occurrences. The species is rarely observed in samples of the Upper Aptian and Albian of the Zea-Panamericana outcrop section and wells CR-5, ALT-19X and ALP-6.

Genus *Retitriletes* van der Hammen *ex* Pierce 1961 emend. Döring et al. in Krutzsch 1963

1956 *Retitriletes* van der Hammen, p. 76 [nomen nudum].
1961 *Retitriletes* Pierce, p. 21.
1963 *Retitriletes* van der Hammen *ex* Pierce emend Döring et al. in Krutzsch, p. 8.

Type Species. *Retitriletes pseudoreticulatus* Couper 1953 (p. 32; plate 3, figure 30). Jurassic, New Zealand.

Retitriletes sp. A
Plate 6, figure 8a-b

Description. Reticulate trilete spore. Rounded triangular amb. Exine 1.3 µm thick, finely reticulate. Reticulum with muri, 1.3 µm wide, polygonal lumina, about 1.3 to 1.5 µm diameter, with sinuous muri. Trilete mark straight, raised by thin lips, reaching the equatorial area.

Dimensions. Diameter: 30 µm (1 specimen).

Note. This species resembles *Vadazisporites urkutius* in the general outline and the reticulate ornamentation. However, it differs from the latter by the smaller overall size of the spore, the smaller diameter of the lumina and the thickened laesurae.

Occurrences. This species is observed in the Albian of the Zea-Panamericana outcrop section (sample 13-04-49).

Retitriletes sp. B
Plate 7, figure 1

Description. Reticulate trilete spore. Triangular amb with straight sides. Exine 2.5 µm thick, reticulate. Reticulum with baculate-muri, 1.3 µm across, polygonal to circular lumina of about 1.3 to 2.5 µm diameter, with smaller lumina size on the proximal face (less than 1.3 µm wide). Trilete mark straight, raised by thin lips, reaching 1/2 to 3/5 of the spore radius.

Dimensions. Diameter: 46 µm (1 specimen).

Note. This species differs from *Retitriletes* sp. A in the wider lumina and its variation of size on the proximal and distal faces. The distal reticulum of this species resembles that of *Retitriletes circolumenus* (Cookson & Dettmann 1958) Bachouse 1978, distal reticulum with anastomosing muri. However, diameter of the lumina and width of the muri are larger in the latter species. *Retritriletes circolumenus* also has verrucae on the proximal face.

Occurrences. A broken specimen is observed in the Albian of well ALT-19X (sample ALT-19X 17291').

Genus *Undulatisporites* Pflug in Thomson & Pflug 1953

1953 *Undulatisporites* Pflug in Thomson and Pflug, p.52.

Type Species. Undulatisporites microcutis Pflug in Thomson and Pflug 1953 (p. 52; plate 1, figure 18). Tertiary (Paleocene–Lower Eocene), Germany.

Undulatisporites undulapolus Brenner 1963
Plate 7, figure 4

1963 *Undulatisporites undulapolus* Brenner, p. 72. Plate 24, figure 1.

Description. See Brenner (1963).

Dimensions. Diameter: 27 (34) 43 µm (4 specimens).

Note. This species is characterized by the well defined and thickened (1 to 2 µm wide and high) sinuous laesurae.

Occurrences. This species is rarely observed in samples of the Aptian and Albian of the Zea-Panamericana and La Grita outcrop sections and in wells ALT-19X and ALP-6

This species has been reported from the Albian of Oklahoma (Hedlund and Norris, 1968), Barremian to Aptian of Maryland (Brenner, 1963), United States, Berriasian to Upper Albian of western Canada (Burden and Hills, 1989), Middle to Upper Albian of Alberta, Canada (Singh, 1971) and Lower Aptian of Germany (Batten and Li, 1987).

Undulatisporites sp. A
Plate 7, figure 3a-b

Description: Psilate, trilete spore. Rounded triangular amb with convex sides. Exine, less than 1.3 µm thick, finely perforate-psilate. Trilete mark, slightly undulose, somewhat thickened, about 1.0 µm or less wide, reaching the equatorial area.

Dimensions. Diameter: 31 μm (1 specimen).

Note. This species differs from *Undulatisporites undulapolus* in the thin laesurae lips and thinner exine. *Undulatisporites sinuousus* Groot & Groot 1962 has also a thicker laesurae and scabrate exine. *Undulatisporites pflugii* Pocock 1970 also shows thickened laesurae.

Occurrences. A single specimen is observed in the Lower Aptian of the Zea-Panamericana outcrop section (sample 13-04-06).

Reworked? spore A
Plate 7, figure 5a-b

Description. Zonate? microspore. Spherical with circular to ellipsoidal amb. Zona membranous, granulate and relatively thin, finely perforate and closely attached to the spore wall. Spore wall thick, 2.5 μm, with echinate projections, extending into the zonae, up to 5.0 μm long. Sinuous ridges on the surface form a reticulate network that entirely surrounds the spore. Either the distal side shows evidence of hymen (thining of the wall and the zone with irregular margins) or proximal face is absent (there is no evidence of a trilete mark).

Dimensions. 56 x 43 μm (1 specimen).

Note. The only specimen observed in this study shows a darker coloration than the rest of palynomorphs recovered in that sample. The morphology, overall outline and the echinate projections suggest some similarity to spores that have been attributed to the genus *Cirratriradites*, characteristic of the Devonian.

Occurrences. Only one specimen is observed in the Albian of the Zea-Panamericana section (sample 13-04-47).

DIVISION CONIFEROPHYTA CRONQUIST 1960

ARAUCARIACEAN POLLEN

Genus *Araucariacites* Cookson 1947 *ex* Couper 1958

1947 *Granulonapites* (*Araucariacites*) Cookson, p. 130 [nomen nudum].
1953 *Araucariacites* Cookson *ex* Couper, p. 39.
1958 *Granulonapites* Cookson *ex* Nilsson, p. 70.

Type Species. *Araucariacites australis* Cookson 1947 (p. 130; plate 13, figures 1-2, 3) *ex* Couper 1953 emend. Couper 1958. ?Lower Tertiary, Kerguelen Archipelago, Indian Ocean.

Araucariacites australis Cookson 1947 *ex* Couper 1953 emend. Couper 1958
Plate 7, figure 6

1947 *Granulonapites* (*Araucariacites*) *australis* Cookson, p. 130. Plate 13, figures 1-3 [nomen nudum]
1953 *Araucariacites australis* Cookson *ex* Couper, p. 39 [designation as type species].
1958 *Araucariacites australis* Cookson *ex* Couper emend. Couper, p. 151.

Description. See Couper (1958).

Dimensions. Diameter: 42 (58) 77 µm (200 specimens).

Note. Fensome (1983) observed that the thickness of this species ranged from 0.5 to 2.0 µm, in contrast to the range proposed by Couper (1958), 0.5 to 0.8 µm. Specimens observed in this study have exine less than 1.3 µm thick.

Occurences. This species is quite persistent and abundant in the Aptian–Albian of La Grita and the Zea-Panamericana outcrop sections, as in wells CR-5, ALT-19X and ALP-6, and is observed in lesser numbers in the other studied sections.

This species has been reported in sediments from the Middle Jurassic to the Tertiary and has a widespread occurrence in the Lower Cretaceous on worldwide basis; Kimmeridgian to Lower Albian of Australia (Burger, 1980; Backhouse, 1988), Upper Albian to Cenomanian of Perú (Brenner, 1968), Lower Cretaceous to Maastrichtian of Brazil (Herngreen, 1973; Regali et al., 1974a), Berriasian to Maastrichtian offshore eastern United States (Bebout, 1981), Berriasian to Middle Albian of western Canada (Burden and Hills, 1989), Aptian to Maastrichtian offshore South Africa (McLachlan and Pieterse, 1978), Neocomian to Middle Cenomanian of Senegal and Ivory Coast (Jardiné and Magloire, 1965), Upper Albian to Cenomanian of Sudan (Schrank, 1990), Jurassic to Lower Albian of Libya (Thusu and van der Eem, 1985; Thusu et al., 1988; Unwins and Batten, 1988), Neocomian of Egypt (Sultan, 1978 and 1987), Berriasian to Albian of Israel (Brenner, 1974), Barremian to Lower Albian of Spain (Arias and Doubinger, 1980; Doubinger and Mas, 1981), Lower Barremian to Lower Aptian of France (de Renéville and Rynaud, 1981) and Jurassic to Lower Albian of England (Couper, 1958; Norris, 1969; Kemp, 1970).

Genus *Callialasporites* Dev 1961

1961 *Callialasporites* Dev, p. 48.
1962 *Applanopsis* Döring, p. 112.
1962 *Triangulopsis* Döring, p. 113.
1962 *Pflugipollenites* Pocock, p. 72.
1964 *Applanopsipollenites* Levet-Carette, p. 107.
1965 *Applanopsis* Döring emend. Goubin et al., p. 227.
1969 *Applanopsis* Döring emend. Venkatachala & Kar, p. 34.
1969 *Triangulopsis* Döring emend. Jain, p. 43.
1970 *Singhiapollis* Kar & Sah, p. 107.
1972 *Callialasporites* Dev emend. Bharadwaj & Kumar, p. 219.
1974 *Callialasporites* Dev emend. Maheshwari, p. 43-36.

Type Species. *Callialasporites trilobatus* (Balme 1957; p. 33; plate 8, figure 91) Dev 1961. Jurassic (Oxfordian), Australia.

Remarks. The emendations proposed by Bharadwaj and Kumar (1972) and Masheswari (1974) are rejected since these authors considered the species of *Callialasporites* to be saccate or prosaccate

Callialasporites dampieri (Balme 1957) Dev 1961
Plate 7, figure 7

1957 *Zonalapollenites dampieri* Balme, p. 32. Plate 8, figures 88-90.
1957 *Zonalapollenites segmentatus* Balme, p. 33. Plate 9, figures 93-94.
1961 *Callialasporites* (al. *Zonalapollenites*) *dampieri* (Balme) Dev, p. 48.
1962 *Applanopsis dampieri* Döring, p. 113.
1962 *Applanopsis lenticularis* Döring, p. 113.
1963 *Tsugaepollenites dampieri* (Balme) Dettmann, p. 100.
1963 *Tsugaepollenites lenticularis* (Döring) Dettmann, p. 99.
1963 *Tsugaepollenites segmentatus* (Balme) Dettmann, p. 99.
1963 *Callialasporites segmentatus* (Balme) Srivastava, p. 1323.
1964 *Applanopsipollenites dampieri* (Balme) Levet-Carette, p. 107-108.

Description. See Balme (1957) and Filatoff (1975, p. 84).

Dimensions. Diameter: 36 to 62 µm (48 µm average) (30 specimens).

Note. Filatoff (1975) distinguished *Callialasporites dampieri* and "*Callialasporites segmentatus*" based on the ratio of the inner body to the total diameter of the palynomorph (larger than 1/2 and smaller than 3/4 for *Callialasporites dampieri*) and the type of the exoexinal folding (only convolute for *Callialasporites segmentatus*). Fensome (1983) proposed to consider *Callialasporites segmentatus* as a junior synonym of *Callialasporites dampieri*, since the forms are clearly gradational and it is impossible to separate them in a reliable way. This proposal is confirmed in this study. The specimens that are observed in this study show the sort of gradational trend that Fensome (1983) noticed for the ratio of inner body to total diameter and type of exoexinal folding. Therefore for the purposes of this study, both species are combined.

Occurrences. This species is observed in low abundance and sporadically in samples of the Aptian and Albian of La Grita, Zea-Panamericana and Catatumbo outcrop sections, and in lesser numbers in wells CR-5, ALT-19X, ALP-6 and P-201.

This species has been reported from the Jurassic to the Tertiary; Kimmeridgian to Middle Albian of Australia (Balme, 1957; Dettmann, 1963; Burger, 1980; Backhouse, 1988), Lower Cretaceous of Argentina (Gamerro, 1965), ?Upper Albian to Cenomanian of Perú