BOLETIN GEOLOGICO, VOL. VIII. Nos. 1 - 3 — PAGINAS 95 - 132. FIGURAS 36

LATE PALEOZOIC AND EARLY MESOZOIC PLANT FOSSILS FROM THE CORDILLERA ORIENTAL OF COLOMBIA AND CORRELATION OF THE GIRON FORMATION

(con 5 planchas)

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CONTENT:

PLANT FOSSIL ASSEMBLAGES:

ABSTRACT

Plant fossils from a few localities in the Girón Formation and associated rocks in Santander and Boyacá provide additional information regarding the age of the Girón Formation. Despite poor preservation preventing specific identification of many of the specimens, the plant assemblages provide a good indication of general age.

Mesocalamites from the Bocas formation indicates that the Girón Formation rests on Early Pennsylvanian rocks in the Lebrija Gorge. The assemblage of pecopterids, *Rhodea, Calamites,* etc., from the Middle Girón Formation in the Lebrija Gorge point to a Late Pennsylvanian age. No plant fossils were found in the Upper Girón Formation either at the Lebrija Gorge or at the Pujamanes section.

Fossils from Floridablanca (stratigraphically just below the Mesa de Ruitoque section) are not related to those from the Middle Girón Formation at Lebrija Gorge. Abundant specimens of *Ptilophyllum* seem to indicate a Jurassic age.

The plant assemblage from the middle shaly member of the Arcabuco section (previously considered Girón Formation by R. L. LANGENHEIM 1959) may be either Rhaetic or Jurassic. These plants are accompanied by estherids assigned by W. BOCK (1953) to the Rhaetic, although he thinks that they might be younger. The plant assemblage, including *Sagenopteris* cf. *nilssoniana, Elatocladus, Ptilophyllum* and *Podozamites,* generally tends to indicate a Jurassic rather than Rhaetic age. Thus, correlation of the middle member of the Arcabuco section and the middle member of the Lebrija Gorge Section is not feasible in terms of evidence from the plant fossil assemblages because the Lebrija assemblage is clearly Late Pennsylvanian and could not be younger than Permian. Therefore the beds on the Arcabuco Range, previously considered as the eastern facies of the Girón Formation, are now referred to the Montebel Formation.

RESUMEN

Las plantas fósiles de unas pocas localidades en la formación Girón y rocas asociadas en Santander y Boyacá, suministran información adicional con respecto a la edad de la formación Girón. A pesar de la mala conservación que impide una identificación específica de muchos de los especímenes, los conjuntos de plantas suministran una buena indicación de la edad general.

Los *Mesocalamites* de la formación Bocas indican que la formación Girón reposa sobre rocas del Pensilvaniano inferior en la garganta de Lebrija. El conjunto de *pecopteridios, Rhodea, Calamites,* etc, de la formación Girón medio en la garganta de Lebrija, sugieren una edad Pensilvaniana superior. No se encontraron plantas fósiles en la formación Girón superior, en la garganta de Lebrija ni en la sección de Pujamanes.

Los fósiles de Floridablanca (inmediatamente debajo, estratigráficamente, de la sección de la Mesa de Ruitoque) no están relacionados con los de la formación Girón medio en la garganta de Lebrija. La abundancia de especímenes de *Ptilophyllum* parece indicar edad jurásica.

El conjunto de plantas del miembro arcilloso medio de la sección de Arcabuco (anteriormente considerada formación Girón por R. L. LANGENHEIM 1959) puede ser Rhético o Jurásico. Estas plantas están acompañadas por estheridios asignados por W. BOCK (1953) al Rhaético, aunque cree que pueden ser más jóvenes. El conjunto de plantas, que incluye *Sagenopteris* cf. *nilssoniana, Elatocladus, Ptilophyllum* y *Podozamites,* tiende en general a indicar edad jurásica más bien que rhaética. Entonces, la correlación del miembro medio de la sección de Arcabuco y el miembro medio de la sección de la garganta de Lebrija, no es factible en términos de la evidencia derivada de los conjuntos de plantas fósiles, porque el conjunto de Lebrija es claramente Pensilvaniano superior y no puede ser más joven que el Permiano. Por consiguiente las capas de la cordillera de Arcabuco que antes se consideraron como la facies oriental de la formación Girón, se asignan ahora a la formación Montebel.

INTRODUCTION

The Paleozoic and early Mesozoic roks which form the core of many ranges in the Cordillera Oriental, as well as other portions of the Andes in Colombia, Venezuela and Ecuador, generally have not been studied in detail. Prominent among these in Colombia and Venezuela are the widely distributed redbeds and continental sediments broadly referred to as the Girón Formation. This formation and some of the older rocks associated with it, are poorly fossiliferous, and few of the known plants, fish and non-marine invertebrates have yet been described. Thus the age of the Girón rocks has been a subject of prolonged controversy. Most of the interpretation of age has been based on very few collections from the Girón Formation itself and stratigraphic relationship to rocks of similar character in Colombia and Venezuela. Therefore, information from plant fossils obtained at a few localities in the Girón Formation and associated rocks in Santander and Boyacá is of considerable interest, even though the plants are not abundant and generally poorly preserved. In addition, so few plant fossils have been reported for northern South America that record of their occurrence in itself has significance.

This study was made under the auspices of the Instituto Geológico Nacional de Colombia during the summer of 1953. Dr. Enrique Hubach, Director at that time, brought the problem to our attention and guided the research. Field work for the paleobotanical investigation was carried out in connection with an overall project to adequately describe the Girón Formation and discover its age in the type region as well as to interpret the geologic history of the area. The field party consisted of the author and R. L. Langenheim, Jr., Alberto Ronderos, and William D. Meyers, geologists, and Daniel Valenzuela, assistant. In addition, Jaime González, civil engeneer, and several field assistants helped survey the Arcabuco Range traverse. Hervert F. Belding and James M. Doreen arranged for cooperation by International Petroleum Corporation, Colombia and took an active interest in the success of the project. Hypotypes of specimens are located in the Museo de Paleontología, Servicio Geológico Nacional, Bogotá; the remainder of the collection is in the Museum of Paleontology, University of California, Berkeley. Numbers in the following style, L57-53-10, refer to the hypotype specimens in the Museo de Paleontología, Bogotá; numbers preceded by PA, e. g. PA 29, refer to the locality catalogue of the Museum of Paleontology, Berkeley. Thanks are due to Owen Poe for all of the illustrations of the plant fossils and to Natalie Davis for the first two figures. I am also grateful to R. L. Langenheim, Jr., J. Wyatt Durhan, Wayne L. Fry, Wilson Stewart, and Theodore Develovoryas for advice in preparing, as well as criticism of the manuscript.

STRATIGRAPHIC SUMMARY

The following brief discussion of the stratigraphic context of the paleobotanical materials is summarized from and modified after an earlier paper by R. L. LANGENHEIM (1959). The major changes in interpretation since publication of this earlier paper are a consequence of more adequate understanding of the plant fossils, and modification of LANGENHEIM'S (1959) interpretation has been carried out in consultation with him.

Stratigraphic sections of the Girón Formation were measured at Jordán, Mesa de Ruitoque, Quebrada Pujamanes, and the Lebrija Gorge (Figs. 1 and 2). A traverse of the Montebel Formation (previously considered Girón by R. L. LANGENHEIM 1959) was made in the Arcabuco range between Duitama and Charalá.

The Lebrija Gorge section was selected as the type section by LANGENHEIM (1959) because both the top and the base of the formation are present and the traverse is located within the original outcrop area described by A. HETTNER (1892). HETTNER did not designate a type section and likewise failed to clearly define the stratigraphic limits of the Girón Formation. In the Lebrija Gorge the Girón is apparently conformable with the underlying Bocas Formation, considered Carboniferous by B. ALVARADO & A. DEL RÍO (1947) near Las Bocas, but truncates the Carboniferous upstream from Las Bocas. Elsewhere in the Bucaramanga area there is a basal conglomerate containing pebbles of Carboniferous limestone and fragments of reworked shale from the Bocas Formation. The Girón Formation is approximately 3500 m thick in the Lebrija Gorge and includes three members separated by gradational contacts. The lower sandstone member, approximately 750 m thick is composed of alternating medium to coarse, gray, quartzitic, arkosic or feldespathic sandstone and massive, thin-thick bedded gray, green or red mudstone. The middle shaly member, approximately 1250 m thick, is dominated by mudstone and siltstone with lesser amounts of arkosic and feldespathic sandstone. Most of the rock is gray or black but some of it is green or red. One bed of black shale contains abundant plant fossils of probable Late Pennsylvanian age. The uppermost sandstone member, approximately 1500 m thick, is composed almost entirely of gray arkose or feldspathic sandstone.

In the Lebrija Gorge a sequence of conglomerate, redbeds and sandstone lies between the restricted Girón Formation and the Lowest black shale and limestone in the Cretaceous. As R. L. LANGENHEIM (1959) indicates, these Early Cretaceous rocks have formerly been included in the formation (DICKEY 1941; TRUMPY 1943), correlated with the Cocuy quartzite (OPPENHEIM 1940) or described separately. LANGENHEIM considers them physically correlative with the cliff-forming sandstone of the Arcabuco area and therefore equivalent to the Arcabuco Sandstone in the restricted sense. Much confusion, however, has resulted in the name Arcabuco being applied to both the upper part of the restricted Girón Formation as well as to the restricted Arcabuco Sandstone. Therefore the name Tambor Formation (L. G. MORALES & AL. 1958) will be employed in this paper, although LANGENHEIM (1959) considers the Tambor Formation as a facies equivalent to the restricted Arcabuco Sandstone. The type section of the Tambor Formation is located in the Lebrija Gorge in geographic continuity with the type section of the Girón Formation.

The boulder conglomerate near the base of the type section of the Tambor Formation crops out in the Lebrija Gorge section, even though the top of the Girón Formation is poorly exposed. The conglomerate is bright red and boulders of quartzite from the Girón Formation are abundant. These rocks are succeeded by white, medium to fine quartzitic sandstone similar to the upper sandstone at Mesa de Ruitoque and Jordán. This sandstone is succeeded by dark marine shale and limestone containing Cretaceous fossils.

The section at Quebrada Pujamanes consists of 90 m of white, crossbedded medium to coarse arkose that appears to correlate with the upper member of the Girón at the Lebrija Gorge. Two red boulder conglomerates, separated by coarse arkose, occur at the base of the Tambor Formation. The remainder of the Tambor Formation consists of deep red, massive mudstone, green mudstone and fine gray sandstone. The contact with the black marine shale and limestone above is poorly exposed.

At Mesa de Ruitoque only 400 m of Girón are exposed below the Tambor. Medium to coarse red arkose is prominent, but is interbedded with an aproximately equal amount of brick-red mudstone and siltstone as well as many beds of arkosic conglomerate scattered troughout. There is no conglomerate at the base of the Tambor Formation and the contact is arbitrarily placed at the base of the first well-washed, buff sandstone. Layers of dark red, massive mudstone interbedded with white sandstone are succeeded by thick-bedded, white cliff-forming sandstone capping the mesa. Plant fossils of probable Jurassic age were discovered nearby at Floridablanca in a lens of micaceous shale approximately 50 m below the lowest beds measured in the Ruitoque section.

In the Jordán section 417 m of Girón are exposed. At the base of the section red arkose alternates with brick-red mudstone; higher in the section arkose beds are thinner and less abundant. All of the rock above the basal 100 m is composed of thick-red mudstone. Prominent white arkosic conglomerate 2-3 m thick occurs at the base of the Tambor Formation; the contact with the Girón mudstone is sharp. The conglomerate is succeeded by alternating buff sandstone and red sandy shale and siltstone; the sandstone is more abundant and forms a cliff.

The correlation of the red mudstones of the Mesa de Ruitoque and Jordán sections with the upper member of the Girón Formation from the Lebrija Gorge and Pujamanes sections was suggested by R. L. LANGENHEIM (1959) but is not entirely satisfactory even from a lithologic point of view. This correlation will be discussed further in terms of the age assignment indicated from plant fossils.

Rocks cropping out on the Arcabuco Range along the Duitama Charalá road were considered to be correlative with the Girón Formation by R. L. LANGENHEIM (1959). The lowest exposed portion of the sequence consists of interbedded steel-gray arkose and micaceous mudstone cropping out in Palermo Canyon. These rocks are similar to those in the Lebrija Gorge and were tentatively assigned to the lower sandstone member of the Girón formation. Rocks of the lower sandstone member are gradationally succeeded by dark gray black mudstone interbedded with fine sandstone and siltstone in the middle shaly member. Approximately 1000 m of this middle member were measured in the traverse. The mudstone and shale contain widely disseminated plant debris as well as estherids, ostracods and fresh-water mollusca probably of Rhaetic to Jurassic age.

The middle shaly member is succeeded by approximately 400 m of medium to coarse red arkose and arkosic conglomerate interbedded with micaceous red siltstone and mudstone.

The correlation by R. L. LANGENHEIM (1959) of the sequence in the Arcabuco range with the Girón Formation of the Lebrija Gorge, on the basis of general lithologic character and position in sequence, has now been abandoned (personal communication 1961) because of the great difference in age indicated by the fossils from the two areas. The name Montebel, previously applied by TRUMPY (1943) and others, is here employed for these rocks.

The Montebel Formation is succeeded by massive, white, feldspathic or arkosic, cliff-forming sandstone in the Tambor Formation on the northwest side of the range. Thin erosional remnants of the Tambor Formation cap some of the higher spurs on the southeast side of the range.

PLANT FOSSIL ASSEMBLAGES

Bocas Assemblage

Plants occur near the top of the Bocas Formation in a black shale and muddy siltstone cropping out from road level to ten meters above the road at the east end of the bridge across the Río Lebrija at Las Bocas. The Bocas Formation rests on rocks containing earliest Pennsylvanian or youngest Mississippian fossils (DICKEY 1941, TRUMPY 1943) and is unconformably succeeded by the Girón Formation.

Only a few specimens are identifiable from this collection. A carbonized impression of a parallel veined leaf, approximately 2 cm wide and 5 cm long, is determined as *Cordaites*. Other fragments of smaller leaves also are probably *Cordaites*.

A cast of a fragment of a calamitalean stem, approximately 12mm long and a little over 2 mm wide (Fig. 3), is the most significant fossil from this locality. Although poorly preserved, it appears to have 8 ribs and one node. The ribs seem to be superposed and converge to a common focal point at the node. These characters were the basis for R. KIDSTON & W. J. JONGMANS (1915-1917) separating *Mesocalamites* from *Calamites*. *Calamites* has alternating ribs. The specimen is not adequate for specific determination.

Cordaites occurs widely from Mississippian to Early Permian and may occur in the Triassic. *Mesocalamites*, however, appears to be restricted to beds of Pottsville or pre-Pottsville age. R. KIDSTON & W. J. JONGMANS (1915-1917) indicate that, with the exception of *M. roemeri* GOEPPERT, which is known to occur in the basal part of the European Lower Carboniferous, the species belonging to this group are charasteristic of the uppermost part of the Mississippian. In addition, C. A. ARNOLD (1953) cites North American occurrences from the Pottsville of Pennsylvania and West Virginia, the Canso Group (Lower Pennsylvanian) of Nova Scotia and the Namurian of Greenland. S. H. MAMAY & B. READ (1956) record *Mesocalamites hesperius* (ARNOLD) MAMAY & READ and *M. crookensis* MAMAY & READ from the Spotted Ridge Formation of Oregon. On the basis of *Mesocalamites,* they suggest, that an Early Pennsylvanian or even Late Mississippian age might be assumed for the Spotted Ridge Formation. Associated floral elements, however, render the precise position of the Spotted Ridge Formation uncertain within the Carboniferous.

Thus, the ranges of *Mesocalamites* and *Cordaites* permit a Namurian to Pottsville age for the Bocas Formation collection. The stratigraphic position of the Bocas Formation, however, tends to favor an Early Pennsylvanian age.

Lebrija Assemblage

Fossils were collected from the middle shaly member of the Girón Formation at Quebrada Honda (Quebrada Las Palmas, BRÜCKNER 1954). A reasonably extensive suite of specimens was obtained from the well indurated black, micaceous clay siltstone exposed in the bottom of Quebrada Honda approximately 1400 m upstream from the railway bridge. These fossils are primarily impressions although a few are casts. Even though they are essentially unweathered few details of structure are preserved. The six genera recognized from this locality are:

Pecopteris
Callipteridium
Asterotheca
Rhodea
Calamites
Carpolithus.

Fern-like foliage is the most abundant and best preserved. The majority of the pinnules are sterile, although some have evidence of synangia. There are no complete fronds, but the fragments of pinnae form layers covering the surface of the beds. Careful examination of these pinnae leads to recognition of four different types of sterile pinnules and two fertile ones. Table 1 gives comparative data for available characters. The sterile pinnules have characters similar to those of *Pecopteris, Alethopteris* or *Callipteridium.* Characters of these three genera intergrade sufficiently to make it difficult in some cases to distinguish among the genera. For example, pinnules of *Alethopteris* are generally linear, being longer than broad, and somewhat attenuated at the apex. The pinnules are generally decurrent (especially when immature) on the proximal edge and a

Species	Length of Pinnule	Width of Pinnule	Apex
Pecopteris sp. A	8-10 mm	3-4 mm	Slightly curved
Pecopteris sp. B	5-6 mm	3-4 mm	Bluntly rounded
Pecopteris sp. C	3-4 mm	2 mm	Broadly rounded
Gallipteridium sp.	10-12 mm	1-2 mm	Slightly tapering
Asterotheca sp. A	5-6 mm	3 mm	Bluntly rounded
Asterotheca sp. B	8-10 mm	2 mm	Slightly curved

Table I. Comparison of characters of broad groups of *Pecopteris*, *Gallipteridium* and *Asterotheca* from the Lebrija Assemblage.

prominent midrib extends to the apex. However, *Alethopteris* pinnules are not as regular as in *Pecopteris*. *Pecopteris* has pinnules which are mostly smaller than those of *Alethopteris* and have parallel or slightly curved margins attached to the rachis by the whole width of the base. The midvein is strong, straight, and forks just short of the apex. As ARNOLD (1947) indicates, the foliage of *Callipteridium* probably belongs to more than one genetic group. Some species are similar to *Alethopteris* but the pinnules differ in being more blunt and are not at all or only slightly decurrent. Other species resemble *Pecopteris*, but are distinguished from it in that the veins enter the pinnules directly from the rachis.

Three different groups of pinnae from Quebrada Honda have been recognized as *Pecopteris* because of the small size, oblong shape and the attachment of the pinnules to the rachis by the whole base. Because lateral venation is not preserved, the differences between the three groups are based mainly on the relative length and width of the pinnules (Table 1). In *Pecopteris* sp. A (Figs. 4, 6, 7) the pinnules are 8-10 mm long and 3-4 mm wide; in *Pecopteris* sp. B (Figs. 5, 8, 9) they are 5-6 mm long and 3-4 mm wide and in *Pecopteris* sp. C (Figs. 10 and 11) they are 3-4 mm long and 2 mm wide. *Pecopteris* sp. A has an apex which is somewhat attenuated and often slightly curved; the apex in *Pecopteris* sp. B and C is more broadly rounded. Because the characters of *Pecopteris* sp. B and C are essentially the same except for size, it is possible that the pinnae belong to the same frond with *Pecopteris* sp. C representing more ultimate pinnae. These three groups are described to display the variation in kinds of pinnae present in this collection. Inasmuch as the more definitive characters of lateral venation are not preserved, these fossils have not been given specific names. *Pecopteris* sp. A is abundant in the collection whereas there are only a few specimens of *Pecopteris* sp. B and C.

Another abundant type of pinnae at Quebrada Honda has been identified as *Callipteridium* (Figs. 12 and 13), although it has some characters of both *Alethopteris* and *Pecopteris*. In this form the pinnules are linear being 10-13 mm long and 1-2 mm wide, with a slight tapering toward the apex.

The pinnules are closely spaced with parallel borders. Most of the pinnules are attached perpendicularly to the rachis, although in a few specimens a slight decurrency is present. Again lateral venation is not preserved.

BRÜCKNER (1954) reports that R. Kräusel and W. J. Jongmans determined material from the Quebrada Las Palmas as belonging to the *Callipteridium* group. It seems possible that these may be similar fossils.

Several species of *Pecopteris* have been reported from South America. The only one previously described from Colombia is *P. colombiana* LIPPS from Barremian or Aptian beds near Salina de Chita in Boyacá (LIPPS 1938). This species, although possibly from rocks comparable to the Girón Formation, is not comparable either in size or shape to the pinnules of the material from the Lebrija Gorge.

Pecopteris fuchsi SCHIMPER, reported from the Atacama district of Chile (Rhaetic or Jurassic) by ZEILLER (1875) and SOLMS-LAUBACH (1899), likewise does not compare with the Lebrija specimens. The pinnules of *P. fuchsi* are significantly wider (4-7 mm) than the Lebrija pecopterids.

Pecopteris cambuhyensis, P. pedrasica and *P. paranaensis* were described from scanty materia from Late Paleozoic beds in the Parana and Santa Catarina Basins of Brasil by READ (1941). READ finds them similar to species reported from widely separated geographic areas. *Pecopteris cambuhyensis* appears to resemble both *P. unita* BRONGNIART from Europe and *P. arcuata* HALLE from eastern Asia. *Pecopteris pedrasica* also suggests *P. arcuata*. *Pecopteris paranensis* is similar to *P. arborescens* SCHLOTHEIM from Rhodesia. Thus, READ prefers not to refer the specimens from Brasil to these species from such diverse geographic areas because of the implied phylogenetic relationships. FRENGUELLI (1953) reports the occurrence of *P. cambuhyensis* and *P. pedrasica,* as well as unnamed species of *Pecopteris* from the Chubut, Argentina. On the basis of the presence of these pecopterids and other associated plants, FRENGUELLI considers the age of the beds in the Chubut to be Lower Permian.

There are some similarities in the size of the pinnules of *P. cambuhyensis* and *Pecopteris* sp. A from the Lebrija Gorge. Both are within the range of 8-10 mm long and 3-4 mm wide. Also the attachment of the pinnule to the rachis and the shape of the apex are similar. However, because lateral venation is not preserved, it is uncertain whether *Pecopteris* sp. A should be referred to *P. cambuhyensis.*

The fertile pinnules have been referred to the form genus *Asterotheca.* The synangia are not sufficiently well preserved to observe definitely the form, number and arrangement of the sporangia. However, the synangia appear sessile, there is slight indication that they could be five sporangiate, and they are arranged in two rows parallel to the midvein of the pinnule. Two different groups have been recognized, based primarily on the size of the pinnules. *Asterotheca* sp. A (Figs. 15 and 16) has pinnules 5-6 mm long and 3 mm wide whereas *Astherotheca* sp. B (Fig. 14) has pinnules 8-10 mm long and 2 mm wide. Except for fructifications, *Asterotheca* sp. B has the same characters as *Pecopteris* sp. A and thus may be pinnae from the same plant. As in the case of *Pecopteris*, because details of nervation are not preserved and because of poor preservation of the fructification, it does not seem desirable to describe these specimens as new species. However, these specimens correspond generally to the section of the genus *Asterotheca* with larger pinnules such as *A. miltoni* ARTIS, and *A. candolleanus* (BRONGNIART) HIRMER of the Carboniferous and Permian of Europe and North America. Also it is of some interest to compare these specimens with species of *Asterotheca* described by FRENGUELLI (1953) from the Permian of Chubut, Argentina. *Asterotheca* sp. B has many of the characters of *A. feruglioi* FRENGUELLI, in that the pinnules are almost perpendicular to the rachis, and are linear-oblong, tapering but rounded at the apex. They are somewhat larger than *Asterotheca* sp. B in that they are 8-12 mm long and 5 mm wide. In addition, the nervation is well preserved in *A. feruglioi* and considered to be one of the diagnostic characters.

Several specimens have been referred to *Rhodea* sp. (Figs. 18, 19, 20). Determination of this material is difficult because *Sphenopteris, Rhodea, Diplothmema* and *Mariopteris* are from genera of ferns or fern-like plants representing a large and diversified group of primitive frond types. Considerable confusion exists concerning criteria used to distinguish these genera. ARNOLD (1947) states that *Sphenopteris* is usually considered to have small pinnules, oval or oblong in outline, lobed or toothed or sometimes cut into acute or obtuse lobes. HIDSTON (1923-25) indicates that *Rhodea* is used for plants, previously in *Sphenopteris,* whose pinnules are segmented through dichotomous division into very narrow segments. A single vein enter each segment of the pinnule and is bordered by a narrow band of the lamina. The vein, however, most frecuently is not visible. Specimens with *Rhodea*-type pinnules, but which are fertile, are placed in genera based on caracters of the fructification, i. e. *Zeilleria, Urnatopteris* and *Telangium.* Other sterile specimens possessing the *Rhodea*-type pinnule have been placed in the genus *Diplothmema* because of frond structure. In *Diplothmema* the leaf stalk below the lowest pinnae is equally forked. ARNOLD (1947) further indicates that it is difficult to distinguish between *Diplothmema* and *Mariopteris* which both have this forking character. WALTON (1931) points out also that *Sphenopteridium, Aneminites, Adiatites, Palmopteris* and *Eremopteris* all have this type of frond structure. Therefore, confusion is displayed in descriptions and discussion of leaf types of this general group, which is further complicated by the tendency of the material to be fragmentary and often poorly preserved.

The few specimens found from the Lebrija Gorge occur as a carbonaceous film. Because the matrix of the rock is black, details of the fossils are often difficult to see. Although there were no complete specimens, considerable detail of the frond is preserved in several. These specimens have been assigned to *Rhodea* because the pinnules are dichotomized into very narrow segments, thus separating it from *Sphenopteris.* There is no evidence among the specimens that there is a fork in the frond that divides it into two main divisions, and hence they are not assigned to *Diplothmema, Mariopteris, Sphenopteridium,* etc.

Several specimens of this *Sphenopteris* complex have been reported from South America. *Rhodea* sp. is reported by DOLIANITI (1954) from Lower Carboniferous beds from Teresina, Piaui, Brazil. These specimens, however, are much smaller than those from Lebrija. Another member of this group of leaf types from Teresina is *Adiantites* of which DOLIANITI describes four species. The most abundant form, described previously as *Sphenopteris furcata* by OLIVEIRA (1935), is called *Adiantites gothanica* by DOLIANITI. *Sphenopteris furcata* is an Upper Carboniferous species which also has been refered to *Diplothmema* or *Palmopteris.*

SEWARD (1922) discusses specimens from the Carboniferous of the coast of Perú which he determined as *Sphenopteris.* He points out, however, that the deeply dissected form of the lamina suggests comparison with pinnules of species of *Rhodea* and *Sphenopteridium.*

READ (1941) identified a specimen from Paracas, Perú as *Aphlebia australis.* The description is based on a single specimen having neither basal nor ultimate divisions, but the size and type of dichotomies are those characteristic of the Lebrija material. Because of the fragmentary nature of the Peruvian *Aphlebia,* it still seams best to refer the Lebrija material to the *Rhodea* complex.

Several casts of *Calamites* were collected. They consist of fragments of stems with no nodes preserved and with eroded and partially obscured rib structure (Fig. 17). Several pieces range in width from 14-18 mm and appear to expose 13 ribs. Other fragments are approximately 7 mm in width and so weathered that the ribs can not be counted. Therefore, no specific designation has been given.

The age of the Lebrija assemblage is considered to be Late Pennsylvanian. This conclusion is drawn both from its stratigraphic position above the Bocas Formation and from the overlapping ranges of the fossils. The time range indicated by the fossils is not narrowly limited because determination has been made only to the generic level. Perhaps the genus with the most restricted age range is *Rhodea.* However, the previously discussed confusion of nomenclature is a serious handicap in utilizing it as an age indicator. Nevertheless, the species to which the Lebrija *Rhodea* specimens could be assigned are characteristic of Mississippian floras, although it occurs in the Late Pennsylvanian (SEWARD 1931). *Calamites* ranges from the Mississippian through the Late Permian, *Callipteridium,* on the other hand is most characteristic of the Early Permian although it occurs in the Late Pennsylvanian (Stephanian). *Asterotheca* ranges from Late Pennsylvanian (Westphalian) to Rhaetic. *Pecopteris* is generally considered to range from Westphalian to Triassic although specimens from the Rhaetic-Jurassic and Cretaceous of South America have been referred to *Pecopteris.*

Floridablanca Assemblage

Fragmentary plants were obtained from a lens of micaceous mudstone in the Girón Formation in a conglomerate ledge east of the highway bridge over Quebrada Mensuli, just south of Floridablanca. The fossil bed stratigraphically is 50 m below the lowest rocks measured in the Mesa de Ruitoque section (R. L. LANGENHEIM 1959). These rocks are much fractured and deeply weathered and thus the fossils, although abundant, are largely fragmentary and oxidized. Maceration techniques and preparation of balsam transfers did not yield cuticular material which would permit more accurate determinations. Attempts to recover spores were also unsuccessful. Several nearly complete fronds were salvaged (Figs. 22 and 23) and have been identified as *Ptilophyllum* sp. Fragments of *Elatocladus (Pagiophyllum)* occur sparingly. Fruit-like structures were abundant but insufficiently preserved to determine their nature.

Fronds of the character of *Ptilophyllum* were cosmopolitan in their distribution especially from the middle Triassic to the middle Jurassic.

BERRY (1924) notes that many students of Mesozoic floras (Schimper, Feistmantel, Schenk, Saporta, Nathorst, Seward and Halle) have attempted from differing points of view to bring order out of the confusion regarding ptillophylloid fronds. Unfortunately the confusion still exists. SEWARD (1917, 1931) points out that the use by some authors of the generic names *Ptilophyllum, Zamites* and *Otozamites* creates a false impression of the degree of difference between the numerous forms of the fronds. He further indicates that it is particularly difficult to make any distinction without microscopic preparation of superficial cell layers or the cuticle.

The genus *Ptilophyllum* was established by MORRIS (1840) for specimens from Cutch, India. He defined the genus as "Fronds pinnate; pinnae closely approximated, linear, lanceolate more or less elongate, imbricate at the base, attached obliquely; base semicircular or rounded; veins equal, slender, parallel". He distinguished *Ptilophyllum* from *Zamites* by the oblique insertion and the overlapping of the pinnae at the base. However, the genus *Otozamites,* as defined by FEISTMANTEL (1880), has a pinnate base which is asymmetrical and SEWARD (1917) states that several species of *Otozamites* are indistinguishable from *Ptilophyllum* MORRIS. HALLE (1913b) and ZEILLER (1875) differentiate *Ptilophyllum* from *Otozamites* by the decurrence of the pinnae by their lower edges, although HALLE also indicates that it is difficult in some instances to draw this distinction. SEWARD (1917) adds the additional distinguishing character that the attachment of the pinnae almost completely covers the upper face of the rachis. He also points out that the pinnae are linear and differ considerably in ratio of length to breadth and in the form of the form of the apex.

The specimens from Floridablanca have pinnate fronds. The pinnae are linear-lanceolate, more or less falcate and are attached by nearly the entire base, appearing to cover the upper face of the rachis were the attachment is visible. The venation is poorly preserved but obviously parallel.

The figured specimens (Figs. 22 and 23) do not show such characters as decurrence of pinnae, asymmetrical base of pinnae or covering of the rachis by the pinnae on the upper surface of the frond that distinguish *Ptilophyllum* from *Otozamites* and *Zamites*. The frond structure and the shape and size of the pinnae are merely outlined. However, small fragments of fronds display the above mentioned characters that lead to the determination as *Ptilophyllum*. Several specimens of *Ptilophyllum* were sent to T. M. HARRIS for analysis of possible cuticular material. No cuticle was recovered from either the graphitized pinnae or enclosing rock fragments. In consequence of the poor preservation and lack of cuticular material, it does not seem justifiable either to describe these specimens as new species or to attempt to relate them to existing ones.

Ptilophyllum is considered by most paleobotanists to be restricted to the Jurassic; *Elatocladus (Pagiophyllum)* ranges from the Rhaetic to the Cretaceous but reaches its optimun development in the Jurassic. This suggests that the beds lying just below the lower portion of the Mesa de Ruitoque section are Jurassic in age.

Montebel Assemblage

Two collections were obtained along the road that crosses the Arcabuco Range between the towns of Duitama and Charalá. Both localities are in the middle shaly member of the Montebel Formation. One is in a road cut ¼ km west of the village of Montebel. Here fossils occur as impressions in black shale which weathers buff to white and is associated with siltstone.

Eight taxa have been identified:

Sagenopteris cf. *S. nilssoniana*
Elatocladus sp
Elatocladus (Brachyphyllum) sp.
Zamites sp.
Ginkgophytes
Cladophlebis (Coniopteris) sp.
Cycadolepis
Sphenopteris.

The second collection is from the road metal quarry approximately 2½ km west of the village of Montebel and just east of Infiernito. Here the fossils are in black, silty, micaceous shale weathering buff to white, associated with siltstone and mudstone.

Nine taxa from this locality have been identified:

Sagenopteris cf. *S. nilssoniana*
Elatocladus sp.
Elatocladus (Brachyphyllum) sp.
Elatocladus (Pagiophyllum) sp.

Otozamites sp.
Zamites sp.
Podozamites sp.
Asterotheca sp.
Coniopterid.

It will be noted that *Sagenopteris, Elatocladus* and *E. (Brachyphyllum)* occur in both Arcabuco localities.

The identification of *Sagenopteris* cf. *nilssoniana* (BRONGNIART) WARD was made on the basis of the shape and venation of several fragmentary leaflets. No complete leaflet was preserved, but portions of three (Figs. 24, 25, 26) provide a composite. The specimen shown in Fig. 24 is essentially one side of a lamina with neither apex nor basal portion preserved. It is 40 mm long and 20 mm wide at its greatest width. The median nerve is large and some of the lateral nerves are well preserved. The secondaries dichotomize and anastomose to produce a network with a rhombic pattern. Another specimen (Fig. 25), with just the basal portion preserved, is 40 mm long and 25 mm wide at its maximum width. The outline is spatulate with an asymmetric tapering at the base. The median nerve is strong and several lateral veins are well preserved; the secondaries are not so well preserved as in the specimen in Fig. 24 but they have the same general character. Fig. 26 shows a specimen with a bluntly rounded apex; the venation is not so well preserved as in the other specimens but indicates the same pattern. Several other fragments were discovered, but are smaller than the figured specimens.

These specimens have measurements within the range of leaflets of *Sagenopteris nilssoniana* from Piedra Pintada, Argentina (FRENGUELLI 1941). They are wider than the normal specimens of *S. nilssoniana* cited from Scoresby Sound, Greenland (HARRIS 1932). Although venation patterns are not particularly clear in Frenguelli's photographs, the general character of the Montebel specimens appears similar to those of Piedra Pintada. The venation also resembles *S. Phillipsi* (BRONGNIART) MORR. of HARRIS 1940), but as SEWARD (1910) indicates, the distinction between *S. nilssoniana (S. rhoifolia* PRESL.) and *S. Phillipsi* is not well founded. HARRIS (1932) mentions, however, they are distinct. FRENGUELLI states that probably there is considerable variability in the form and structure of the pinnae of *S. nilssoniana,* and therefore prefers to synonimize several species of *Sagenopteris* with *S. nilssoniana*. HARRIS likewise attempted to obtain cuticular material from specimens from Montebel but was unsuccessful.

Numerous specimens of *Coniferales Incertae Sedis* were found at these localities. HARRIS (1935) prefers to refer all sterile conifer twigs with small needles to the form genus *Elatocladus* until the fossil conifers have been investigated more thoroughly. SEWARD (1919), however used *Elatocladus* in a narrower sense for shoots which are dimorphic bearing both distichous, linear leaves and crowded scale-like leaves. He refers sterile shoots exhibiting no dimorphism to *Brachyphyllum* and *Pagiophyllum* with *Brachyphyllum* bearing fleshy appressed leaves and *Pagiophyllum* with falcate leaves.

HARRIS' concept will be employed in this study with all of the material being referred to *Elatocladus* (Figs. 27, 30, 33, 35 and 36). However, those forms which appear to have appressed leaves are indicated as resembling *Brachyphyllum* (Fig. 36) and those with falcate leaves as resembling *Pagiophyllum* (Figs. 30 and 35).

A few small fern-like foliage types occur. Some appear to be apical segments of a sphenopterid type (Fig. 28) because of the lobed lamina, and contracted and wedge-shaped base with dichotomizing branched veins radiating from the base. Others were considered more coniopterid (Fig. 31). Although the pinnules of *Coniopteris* are considered intermediate between *Sphenopteris* and *Pecopteris* (SEWARD 1910), the rounded lobing was used as distinctive in this case. Also impressions of pinnules of the pecopterid type with fairly well preserved synangia were referred to *Asterotheca* (Fig. 29).

Several specimens apper to be ginkgoalean leaves. In all cases there are only fragments of leaves without petioles and with poorly preserved venation. No cuticle has been recovered. Even generic determination of *Ginkgo* can be only tentative on the basis of the characters present, and for this reason the specimens are determined only as ginkgophytes (Fig. 32). HARRIS (1935) has even found it unsatisfactory to identify his own specimens of ginkgoalean leaves with one another without the structure of cuticles and therefore useless to compare them with specimens where the cuticle is unknown.

A bract or bract-like structure, 12-15 mm long and 2-3 mm wide, has been referred to the form genus *Cycadolepis*. SEWARD (1917) indicates that Saporta used this name for linear lanceolate scales from Upper Jurassic rocks in France which he compared with bud scales of recent cycads. SEWARD feels that Saporta's term may be usefully employed in a more extended sense to compromise various scale or bract-like organs. HARRIS (1932), however, states that specimens which possess stomata are of the bennettitalean type and it is probable that most species belong to the Bennettitales. Again the Montebel material did not have cuticular material preserved so that this affinity could not be ascertained.

There are several fragmentary specimens of leaves identified as *Otozamites* sp. and *Zamites* sp. (KNOWLTON 1914) or *Pelourdea* sp. FERUGLIO 1933). Other fragments can questionably be considered *Podozamites*. None of this material is adequate for description but it substantiates the general age range assigned to the flora.

In addition to collections from the above two Montebel localities, additional specimens were studied. The precise locality is not available for these but is is along the Teorama road in northern Santander and presumably from the Montebel Formation as used in this paper. There are several impressions of *Ptilophyllum* (Fig. 34), as well as *Otozamites* and *Equisitites*.

In general, the plants from the Montebel Formation indicate an age range from Rhaetic to Jurassic. Probably the most significant constituent of the flora is *Sagenopteris* cf. *nilssoniana*. *Sagenopteris* has a wide geographic distribution with an age range from Rhaetic to Cretaceous (SEWARD 1931). *Sagenopteris,* however, had not been reported from South America until FRENGUELLI (1941) recorded *S. nilssoniana* from the Liassic of Piedra Pintada, Argentina. *Sagenopteris nilssoniana* has a more restricted range than the genus as a whole; it is known from Rhaetic to Liassic. *Elatocladus (Pagiophyllum)* and *E. (Brachyphyllum)* occur from the Rhaetic to Cretaceous but reach their optimum development in the Jurassic. *Podozamites* and *Cladophlebis (Coniopteris)* range from the Rhaetic through early Jurassic, again being more characteristic of the Jurassic. *Ptilophyllum,* as indicated previously, is primarily characteristic of the Jurassic. *Otozamites* has a more extensive range, occurring from the Lower Triassic to the Cretaceous. *Gingko* appears in the Lower Triassic and is still living. The only genus from the Arcabuco collections which is not reported from the Jurassic is *Asterotheca* which is generally reported to have become extinct in the Rhaetic. Thus, the assemblage as a whole is considered to indicate a possible age range of Rhaetic through Jurassic.

CONCLUSIONS

Despite poor preservation not permitting specific identification or even comparison with other material in some cases, the assemblages of plant fossils from Colombia provide a good indication of general age.

The few specimens from the Bocas Formation tend to confirm the opinion of B. ALVARADO & A. DEL RÍO (1947) that the Girón Formation rests on Carboniferous beds in the Lebrija Gorge with *Mesocalamites* suggesting an early Pennsylvanian age for the Bocas. Contrary to the view of B. ALVARADO & A. DEL RÍO (1947), who consider the Girón in the Lebrija Area to be Jurassic-Rhaetic because of its stratigraphic position, the assemblage of pecopterids, *Rhodea, Calamites,* etc., from the middle member points to a Late Pennsylvanian age. Unfortunately, fossils were not found in the upper member of the Girón either at the Lebrija Gorge or Pujamanes section, which is correlated lithologically with that at Lebrija.

The fossils from Floridablanca are not related to those from the middle Girón at Lebrija Gorge. The abundant *Ptilophyllum* seems to indicate a Jurassic age. The Ruitoque section does not correlate well lithologically with the Pujamanes or Lebrija sections. It is certain, however, that the beds containing the flora (at Floridablanca) in the Ruitoque area appear to be Jurassic, which would indicate that the upper Girón member of the Lebrija Gorge is Jurassic if the Ruitoque and Lebrija sections are correlative. Fossils were not found in the Jordán section which does correlate lithologically with the Ruitoque section.

R. L. LANGENHEIM (1959) considered the Arcabuco section correlative with the Lebrija Gorge section. The thick gray and buff beds of the Arcabuco-Lebrija areas were called the western facies of the Girón Formation and the thinner redbeds of the Bucaramanga —Los Santos area (Jordán and Ruitoque sections) the eastern facies. However, this correlation now appears dubious, because of markedly different ages indicated by the fossil plants.

The plant assemblage from the shaly member, near the middle of the Arcabuco section, may be either Rhaetic or Jurassic in age. These plants are accompanied by abundant estherids described by W. Bock (1953) a, b) as *Howellisaura columbianus*, and assigned a Rhaetic age. However, R. L. Langenheim (1959) states that Bock has indicated in personal correspondence that *H. columbianus* is not comparable to any Triassic estherid and that his age assignment was based on a type of ostracod which he considers abundant in the Triassic. Furthermore Bock is certain that the beds from which the fossils came are not older than late Triassic and he is inclined to assign them to a somewhat younger age. The plants more generally tend to indicate Jurassic rather than Rhaetic age. In either case, however, correlation of the middle member of the Arcabuco section with the middle member of the Girón Formation in the Lebrija section is not feasible. The Lebrija flora clearly is of Late Pennsylvanian age and could not be younger than Permian.

The Arcabuco assemblage, on the other hand, generally indicates a Late Triassic-Jurassic age and it would be difficult to envisage the Flora as old as Early Triassic.

Further progress in understanding the pre-Cretaceous rocks of Colombia requires sustained and systematic investigation. Although great effort has been expended in study of these rocks and although many papers have been published touching upon their geology, almost all of the work has been either a "by-product" of an investigation having another purpose or has been a short-range project conducted by a man who never returned to consideration of these rocks. As a result, the literature pertaining to the Colombian pre-Cretaceous is in large part contradictory, repetitious, or fragmentary.

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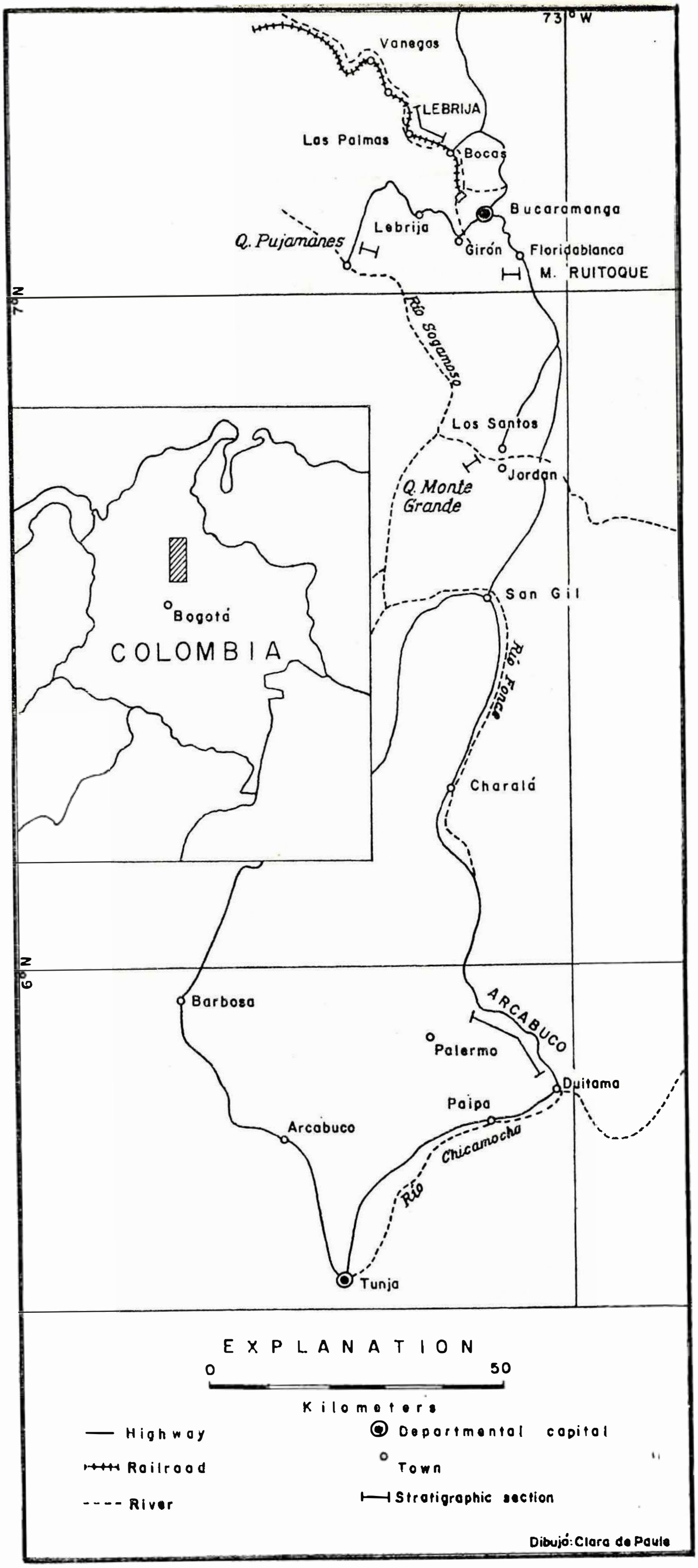


Figure 1. Location of measured sections of the Girón and Montebel Formations.

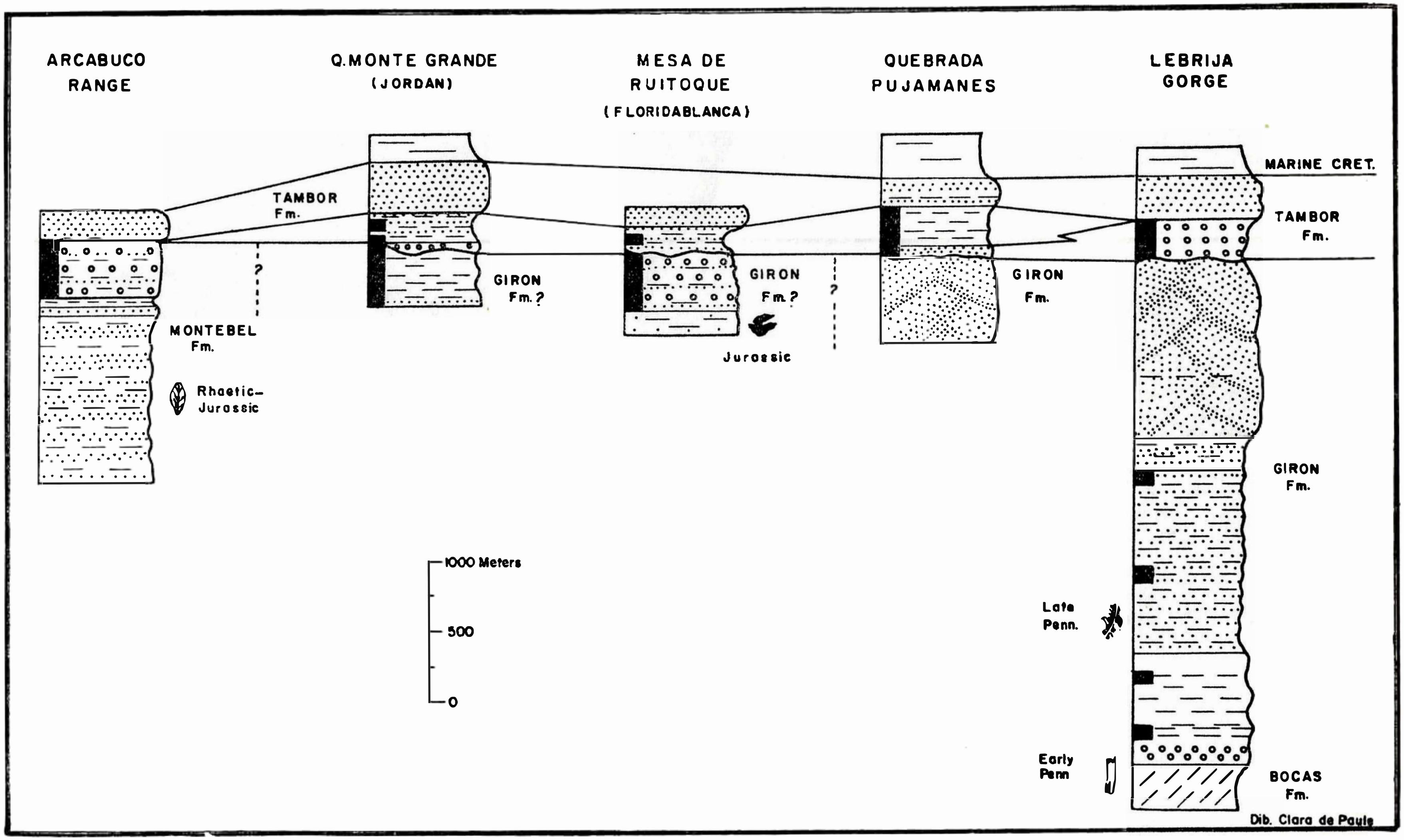


Figure 2. Columnar sections of the Girón and Montebel Formations. The Tambor Formation is shown diagramatically and does not conform to the indicated scale. The black band on the left side of the column indicates the presence of redbeds.

Figure adapted from that of R. L. LANGENHEIM 1959.

EXPLANATION OF FIGURES

Fig. 3. *Mesocalamites* sp. Portion of stem. x8
Las Bocas. (Hypotype L19-53/1) (Locality PA 27)

Fig. 4. *Pecopteris* sp. A. Portion of sterile pinna. x2
Quebrada Honda. (Hypotype L57-53/8) (Locality PA 28)

Fig. 5. *Pecopteris* sp. B. Portion of sterile pinna. x2
Quebrada Honda. (Hypotype L57-53/9) (Locality PA 28)

Fig. 6. *Pecopteris* sp. A. Portion of sterile pinna. x2
Quebrada Honda. (Hypotype L57-53/7) (Locality PA 28)

Fig. 7. *Pecopteris* sp. A. Portion of sterile pinna. x2
Quebrada Honda. (Hypotype L57-53/6) (Locality PA 28)

Fig. 8. *Pecopteris* sp. B. Portion of sterile pinna. x2
Quebrada Honda. (Hypotype L57-53/10) (Locality PA 28)

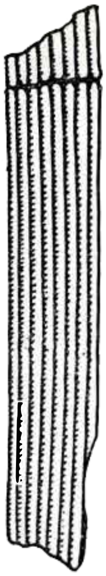
Fig. 9. *Pecopteris* sp. B. Portion of sterile pinna. x2
Quebrada Honda. (Hypotype L57-53/17) (Locality PA 28)

Fig. 10. *Pecopteris* sp. C. Portion of sterile pinna. x2
Quebrada Honda. (Hypotype L57-53/18) (Locality PA 28)

Fig. 11. *Pecopteris* sp. C. Portion of sterile pinna. x2
Quebrada Honda. (Hypotype L57-53/11) (Locality PA 28)

Fig. 12. *Callipteridium* sp. Portion of sterile pinna. x2
Quebrada Honda. (Hypotype L57-53/13) (Locality PA 28)

Fig. 13. *Callipteridium* sp. Portion of sterile pinna.
Quebrada Honda. (Hypotype L57-53/12) (Locality PA 28)



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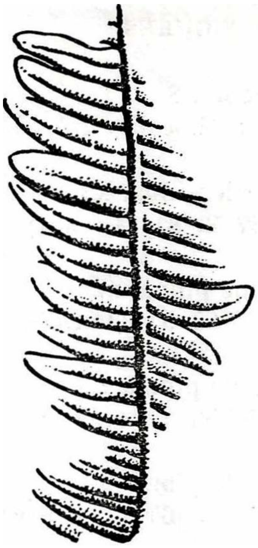

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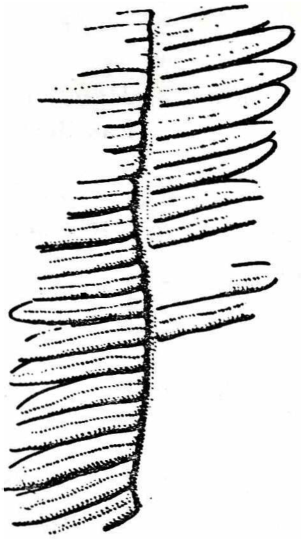

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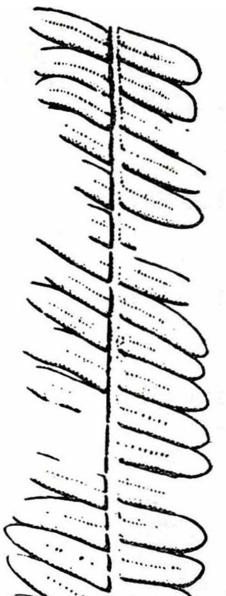

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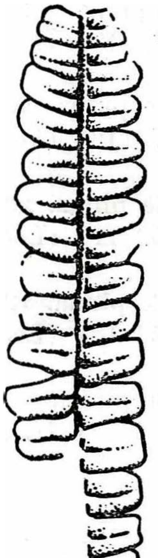

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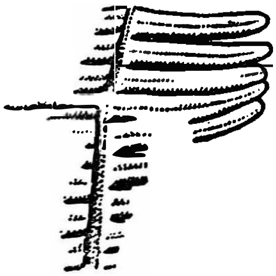

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EXPLANATION OF FIGURES

Fig. 14. *Asterotheca* sp. B. Portion of fertile pinna. x2
Quebrada Honda. (Hypotype L57-53/16) (Locality PA 28)

Fig. 15. *Asterotheca* sp. A. Portion of fertile pinna. x2
Quebrada Honda. (Hypotype L57-53/15) (Locality PA 28)

Fig. 16. *Asterotheca* sp. A. Portion of fertile pinna. x2
Quebrada Honda. (Hypotype L57-53/14) (Locality PA 28)

Fig. 17. *Calamites* sp. Portion of eroded stem. x1
Quebrada Honda. (Hypotype L57-53/1) (Locality PA 28)

Fig. 18. *Rhodea* sp. Fragment of main portion of frond with a lateral branch. x1
Quebrada Honda. (Hypotype L57-53/4) (Locality PA 28)

Fig. 19. *Rhodea* sp. Several fragments of fronds. x1
Quebrada Honda. (Hypotype L57-53/5) (Locality PA 28)

Fig. 20. *Rhodea* sp. Portion of main branch of frond? x½
Quebrada Honda. (Hypotype L57-53/3) (Locality PA 28)

Fig. 21. *Carpolithus* sp. Fructification x4
Quebrada Honda. (Hypotype L57-53/2) (Locality PA 28)

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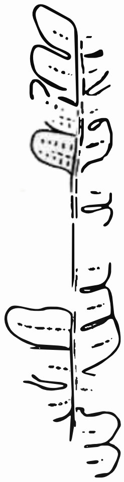

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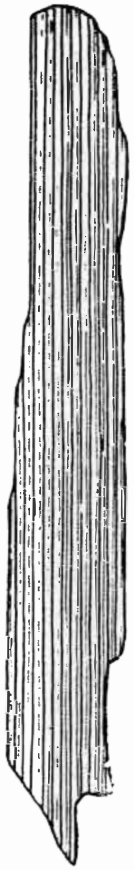

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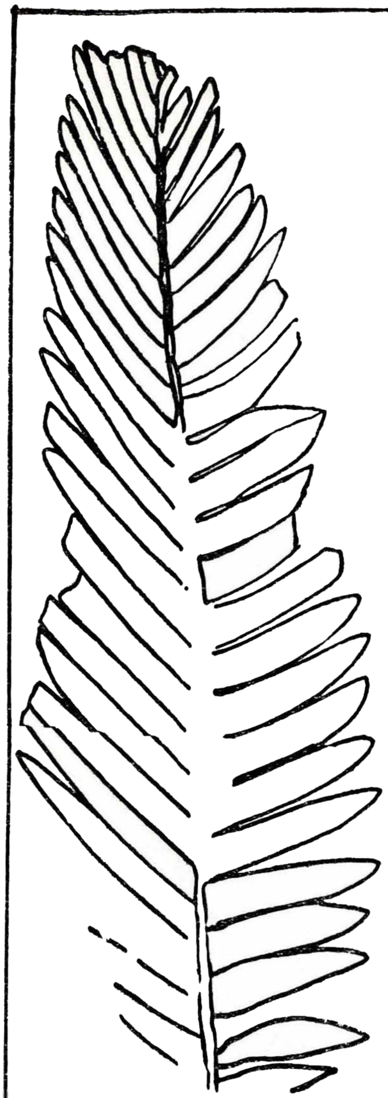
EXPLANATION OF FIGURES

Fig. 22. *Ptilophyllum* sp. Portion of frond.
Floridablanca. (Hypotype L58-53/2) (Locality PA 31)

Fig. 23. *Ptilophyllum* sp. Fragments of fronds. x1½
Floridablanca. (Hypotype L58-53/1) (Locality PA 31)

Fig. 24. *Sagenopteris cf. nilssoniana* (BRONGNIART) WARD. One side of lamina x4
Montebel. (Hypotype L61-54/2) (Locality PA 29)



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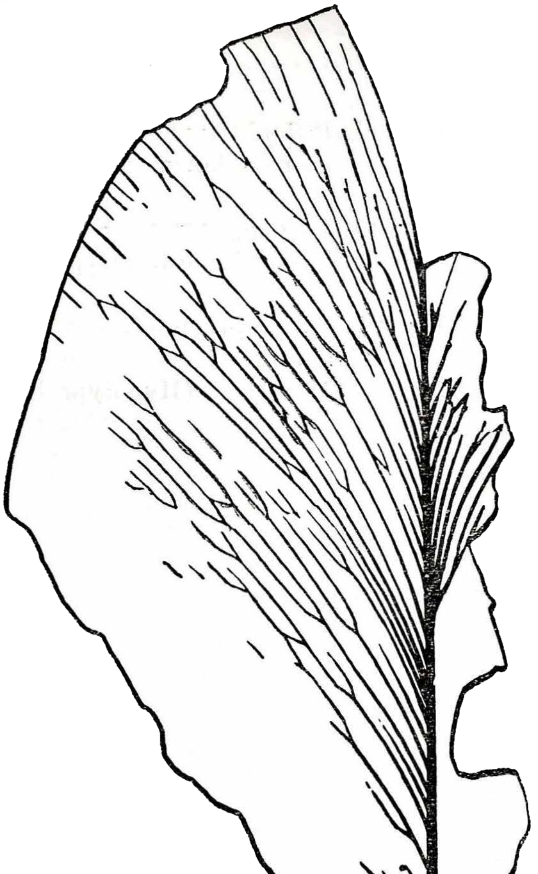

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EXPLANATION OF FIGURES

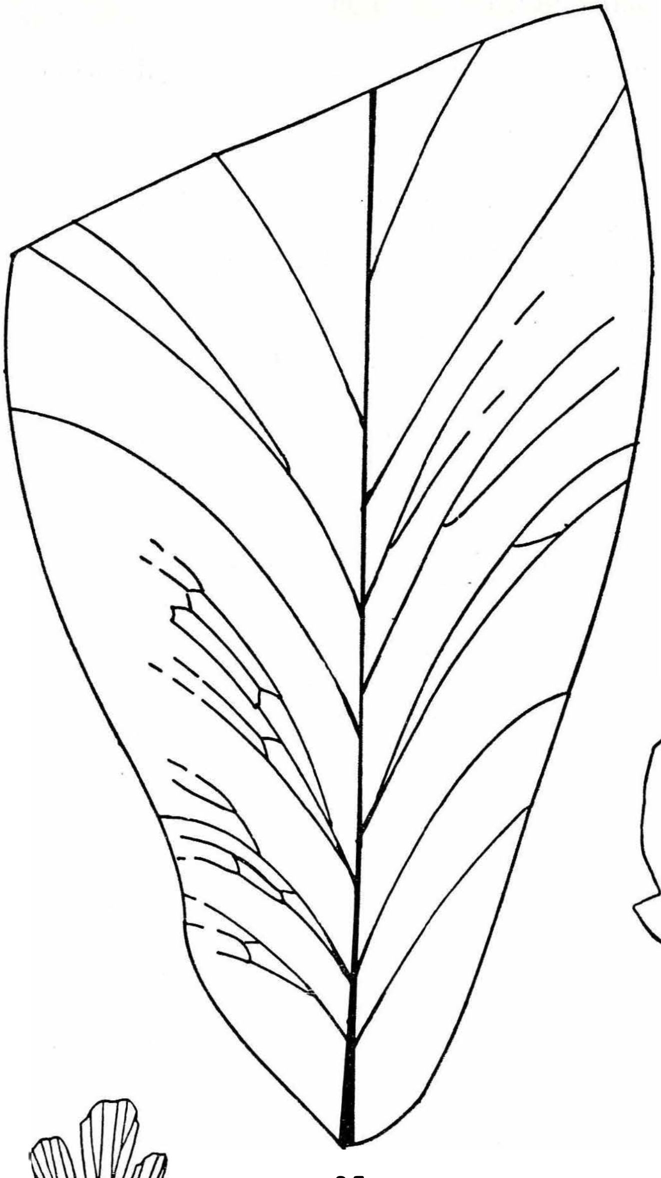
Fig. 25. *Sagenopteris* cf. *nilssoniana* (BRONGNIART) WARD. Basal portion of lamina x4
Montebel. (Hypotype L61-53/1) (Locality PA 29)

Fig. 26. *Sagenopteris* cf. *nilssoniana* (BRONGNIART) WARD. Fragment of lamina with apex intact. x4
Montebel. (Hypotype L61-53/3) (Locality PA 29)

Fig. 27. *Elatocladus* sp. Portion of leafy twig. x6
Montebel. (Hypotype L61-53/4) (Locality PA 29)

Fig. 28. Sphenopterid. Possible apical segment. x6
Montebel. (Hypotype L61-53/5) (Locality PA 29)

Fig. 29. *Asterotheca* sp. Fertile pinnule. x4
Montebel. (Hypotype L60-53/4) (Locality PA 29)



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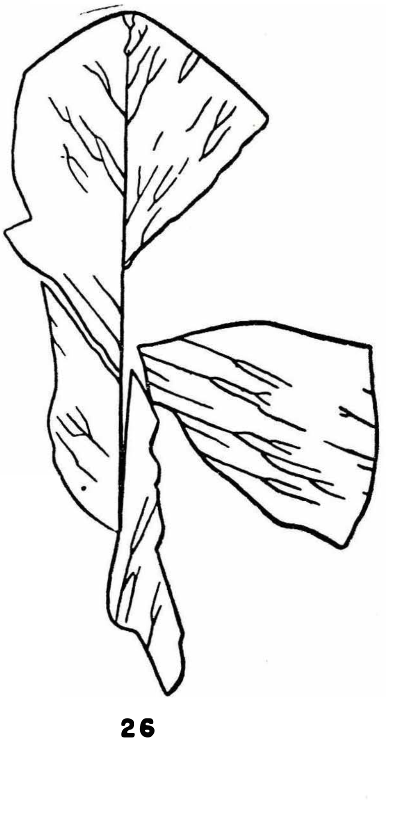

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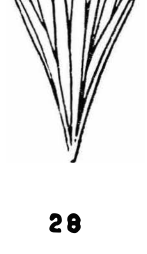

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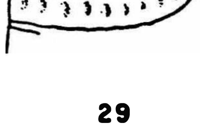


29

EXPLANATION OF FIGURES

Fig. 30. *Elatocladus (Pagiophyllum)* sp. Portion of leafy twig. x9
Montebel. (Hypotype L61-53/8) (Locality PA 29)

Fig. 31. Coniopterid. Segment of foliage. x12
Montebel. (Hypotype L61-53/6) (Locality PA 29)

Fig. 32. Gingkophyte. Portion of leaf. x4
Montebel. (Hypotype L61-53/6) (Locality PA 29)

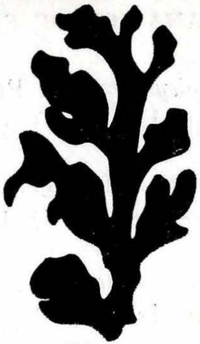
Fig. 33. *Elatocladus* sp. Portion of leafy twig. x4
Montebel. (Hypotype L61-53/3) (Locality PA 29)

Fig. 34. *Ptilophyllum* sp. Portion of frond. x1
Road Teobroma

Fig. 35. *Elatocladus (Pagiophyllum)* sp. Portion of leafy twig. x6
Montebel. (Hypotype L60-53/7) (Locality PA 30)

Fig. 36. *Elatocladus (Brachyphyllum)* sp. Portion of leafy twig. x6
Montebel (Hypotype L60-53/2) (Locality PA 30)

30



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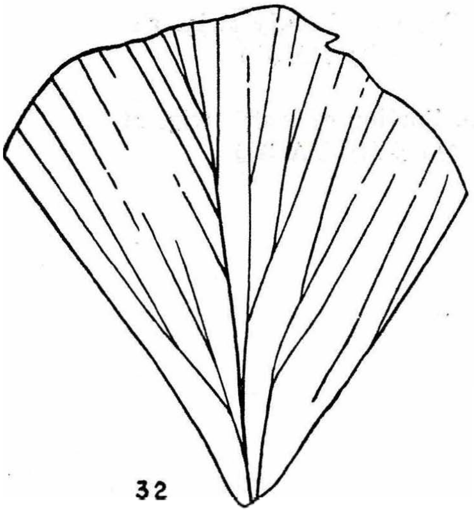

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