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A POLLEN DIAGRAM FROM THE UPPER HOLOCENE OF THE LOWER MAGDALENA VALLEY

BY

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ABSTRACT

In this article the results of a pollen analytical investigation of a section in the tropical lowland of Colombia are discussed. The section has been taken from a lake in the lower course of the River Magdalena (fig. 1). This lake, called "Cienaga de Morrocayal", is situated about 20 metres above sea-level; the section represents the greater part of the Subatlantic, and in the course of this period there was a succession of humid and drier periods. These fluctuations seem to represent a cyclic phenomenon. Two C14 analyses of charcoal-samples from the peatlayers, found in this section, showed that these layers were formed at about 1470 A.D. and about 1230 A.D.

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INTRODUCTION

The Magdalena River, which has its source in that part of Colombia where the Cordillera Central and the Cordillera Oriental meet, flows in its lower course through a wide riverplain.
One of the morphological elements of which this plain is composed are the cienagas and the old levees.
These cienagas (fig. 1) are a kind of lakes, which are formed by old river-courses and other depressions in the river-landscape. The material, deposited in the cienagas, is brought by the water of the Magdalena River, which deposits clay in these extensive, relatively shallow lakes.
In one of these lakes, the so-called Cienaga de Morrocayal, a series of samples was taken by Dr. T. van der Hammen during an expedition to the lower course of the Magdalena River in April 1956. These samples were taken for pollen analytical examination, with the Dachnovsky sonde.
This article presents the results of the examination of these samples.

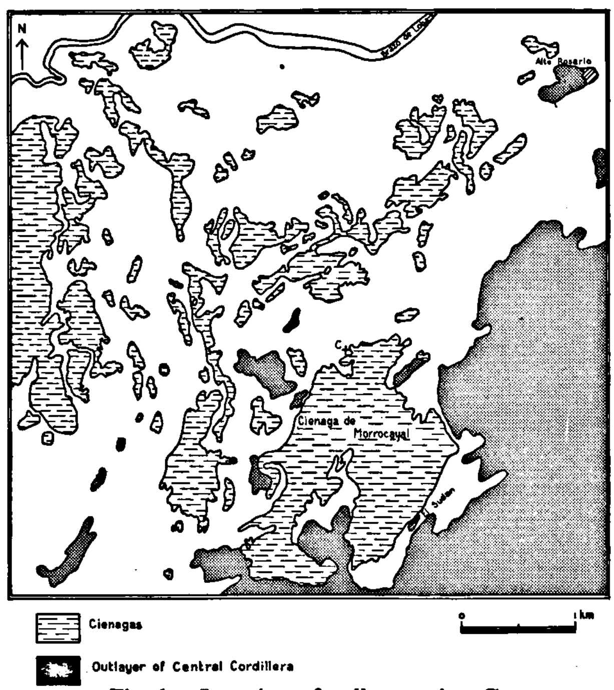

Fig. 1. Location of pollen section C.

VEGETATION

The following outline of the flora in the lower course of the Magdalena River has been taken from an article of José Cuatrecasas (1958), completed with field observations (expedition-report by Dr. van der Hammen).
In the riverplain of the Magdalena the following vegetation types may be distinguished.

a. An open vegetation, consisting of grassy plains with scattered groups of trees.
b. A dense vegetation along the riversides (gallery forest).

Fig. 2. Vegetation bordering the river-branches. Behind the narrow Gramineae-belt stands of *Cecropia* and *Heliconia*.

c. The vegetation-belts around the cienagas.

On these types of vegetation the following remarks can be made.

The open vegetation

This type can be subdivided into a) open grassy plains in which are found scattered groups of trees, and b) a more dense vegetation which may be compared with the "savanna woodland".
The grassy plains consist of associations of *Andropogon bicornis*, *Paspalum millegranum*, *Panicum vulgaris*, etc.
Among the trees, found in the open grassy plains, we may mention *Mauritia minor*, *Hirtella elongata*, *Bowdichia*, *Byrsonima crassifolia*, *Curatella americana*, *Palicourea rigida* and *Cecropia*.
In the denser forest type of the savanna woodland we find, besides the trees mentioned before, also *Croton glabellum* and *Ficus elliptica*.
This type of vegetation arises under rather extreme climatic conditions, such as rainfall concentrated in a few months every year, whereas in the rest of the year the climate is dry; it may also arise when great changes of ground-water-table occur, etc.

The dense vegetation along the riversides

Along the river-levees there is a tree- and brush-vegetation (fig. 2) in which sometimes one species is dominating. These dominating species may be: *Inga calliandra*, *Albizzia* sp., *Heliocarpus* sp., *Salix* sp., *Cecropia* sp., or *Celtis* sp.
Where the strip of wood along the riversides is getting broader, a vegetation arises which is composed of different kinds of trees. The most important belong to the Bombacaceae, Anacardiaceae, Polygalaceae, *Hediosmum*, *Miconia*, and various kinds of Palmae. In places where the forest is often inundated by the river, we find Cyperaceae and Gramineae.

The vegetation-belts around the Cienagas

In areas with deeper water, there may be found *Nymphaea*, *Limnanthemum*, *Trapa* and *Cabomba*.
Going landward from the open water, we find at first a vegetation-belt which partly is inundated continuously, partly inundated temporary (fig. 3). As the most important representatives of this vegetation may be mentioned *Eichhornia crassipens* and *Pistia stratiotes* (fig. 4).

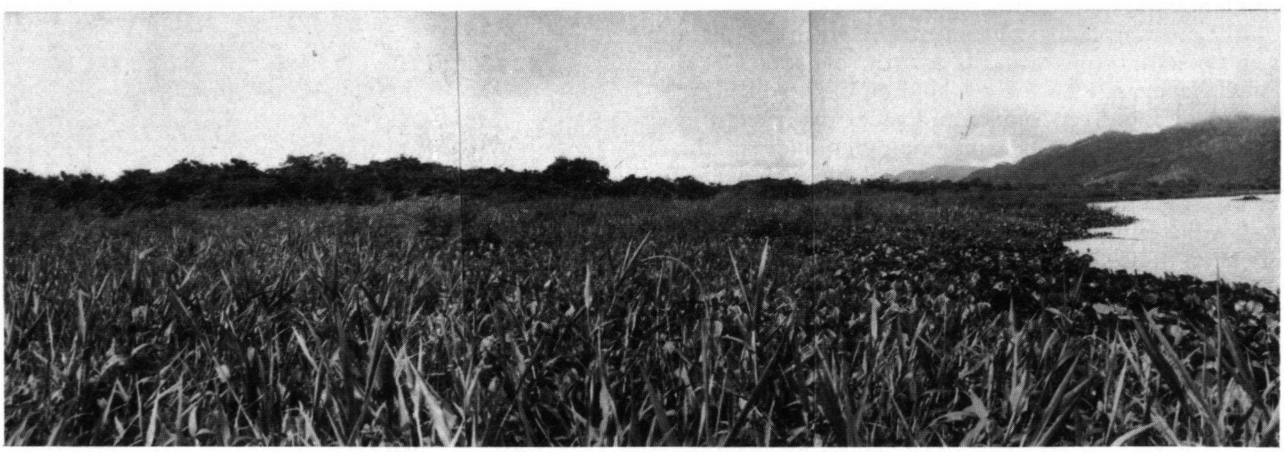

Fig. 3. Vegetation-belts bordering the Cienaga de Morrocayal. From right to left *Eichhornia*-belt, Gramineae-belt and low forest.

Fig. 4. Partly floating vegetation near the shore of a Cienaga: *Eichhornia* and *Pistia*.

In these associations are also found species of *Salvinia*, *Marsillia*, *Jussiaea* and *Polygonum*.
Going more inland from this above-mentioned belt, we find at first a vegetation (that is inundated during a greater part of the year) with grasses and sedges (fig. 5), which is getting drier gradually; the next belt consists of brush- and tree-vegetation.
A further investigation of the grasses in these belts shows that they may consist of one or more species. If there is one species dominating in the grasses, this is often the genus *Paspalum*. If there is no dominance of one single species, then this association is often composed of the grasses *Eriochloa*, *Panicum*, *Leptochloa*, *Eragrostis*, *Echinochloa*, and of the Cyperaceae *Cyperus*, *Ligularis* and *Imperata contracta*.
When the soil is more consolidated and the mineral- and water-management improved, other grasses appear, like *Hymenache*, *Gynerium sagittatum* and *Tessaria integrifolia*.
In the intermediate zone between the Graminetum and the associations richer in bushes and trees, we often find a reed-vegetation formed by *Gynerium sagittatum*.
Finally there is a zone with an association in which the trees dominate. This zone appears where the ground-water-level is at its lowest. As prominent representatives we may mention *Cecropia*, *Ficus*, *Celtis*, *Psychotria*. In this zone we also find *Zygia*, *Inga* and other Mimosaceae.
For the interpretation of the diagram it is important that only in the upper course of the Magdalena River and its tributaries, species occur like *Salix humboldtium*, *Alnus* and *Myrica*. These plants grow all between about 2000 and 3500 metres in the Andes.

WORKING-METHOD AND DIAGRAM-CONSTRUCTION

The samples have all been prepared using the normal palynologic technics. In each sample 500 pollen grains were counted. In order to find the most suitable way of representation of events in the area under discussion, several kinds of general diagrams (Plate I) were constructed, each one based on a different pollen sum. For one diagram a pollen sum was used in which all trees and herbs were included; in the other one only the trees were taken into account. In both pollen sums the spores were excluded (except *Ceratopteris*). Also a diagram was made which only comprises the herbs (Plate I).
As to the construction of the general diagrams the following remarks can be made. The second diagram includes various species of herbs; in this one are plotted from left to right Gramineae, Cyperaceae, Compositae, and a group composed of *Ceratopteris*, *Polygonum*, Amaranthaceae, Chenopodiaceae, *Sagittaria* and *Eichhornia*. A third diagram includes only the tree pollen. In this diagram the following groups are plotted from left to right.

1. *Cecropia*, *Ficus* and Ulmaceae.
2. *Byrsonima*, *Curatella* and *Ouratea*.
3. *Hediosmum*, *Virola*, Malpighiaceae, Anacardiaceae, Palmae, Rubiaceae, Mimosaceae, Bombacaceae, Polygalaceae, Myrtaceae, Melastomataceae (wet forest elements).
4. *Alnus*, Ericaceae, *Myrica*, *Juglans* and *Podocarpus*. This group was separated from the other elements because these trees don't belong to the tropical lowland vegetation.

Fig. 5. Gramineae-belt and forest bordering the Cienaga de Morrocayal. Site of boring in the foreground.

To the right of these general diagrams, separate curves of all pollen types have been drawn.

THE IDENTIFIED SPECIES

The species, plotted in the diagram, are mentioned below. The trees are *Cecropia*, *Ficus*, Ulmaceae, *Alnus*, *Hediosmum*, *Ilex*, Ericaceae, Rubiaceae, Myrtaceae, Malpighiaceae, Melastomataceae, *Juglans*, *Podocarpus*, *Myrica*, Anacardiaceae, Palmae, Mimosaceae, Bombacaceae, and Polygalaceae.
The herbs are Gramineae, Cyperaceae, Compositae, Chenopodiaceae, *Polygonum persicaria* type, Amaranthaceae-*Alternanthera* type, *Ceratopteris*, *Sagittaria* and *Eichhornia*.
These pollen types are discussed and illustrated in van der Hammen & Gonzalez (1960), van der Hammen (1963), van der Hammen & Wijmstra (1964), Tsukada (1964), Wijmstra & van der Hammen (1966). The determination of the pollen types mentioned here was made with the aid of the collection of the recent flora from South America in the Palynological Laboratory in Leiden.

RADIOCARBON ANALYSIS

In the Laboratory for C14 determinations of the Groningen University, the age of two samples was determined. The place of these samples in the stratigraphical column is shown in the diagram.
The ages appeared to be
GRN 2425-Col. 18a—480 $\pm$ 60 yrs (A.D. 1470)
GRN 2427-Col. 18b—720 $\pm$ 80 yrs (A.D. 1230)
This determination of age was made possible by a grant of the Netherlands Foundation for Pure Scientific Research.

INTERPRETATION OF THE DIAGRAM

In the first diagram (Plate I) (sum = tree pollen + herb pollen) the tree pollen is plotted against grasses, sedges and herbs. From this diagram it appears that there are intervals, in which the herbs, grasses and sedges are dominating in the pollen sum, alternating with intervals in which the tree pollen shows higher percentages.
In order to get a better insight into the meaning of this phenomenon, two general diagrams (Plate I) were constructed and will be discussed now. It will also be shown that the intervals with higher herb-percentages may correspond to drier periods.
In the herb-diagram, from left to right the following groups are plotted: Gramineae, Cyperaceae, Compositae, and a group consisting of Chenopodiaceae, Amaranthaceae, *Polygonum persicaria* type, *Sagittaria*, *Eichhornia* and *Ceratopteris*. This last group includes representatives which are found in the wet zones around and in the cienaga and so they will be represented in greater numbers when the lake-level is falling. In this diagram it can be noticed that when the percentage of pollen from the elements growing in the wet zones around the cienaga is high, the percentage of grass pollen is low. Thus it appears that the grasses belong to the relatively dry part of the vegetation, and a high percentage of grass pollen may be considered as an indication of a relatively dry period.
The two preceding diagrams give us only a partial insight into the change of vegetation in our area. It is possible only to say that they show an alternation of drier and wetter periods in our area.
The tree pollen diagram, on the other hand, gives us a much better insight into the change of vegetation in the area.
It may be remarked, however, that the subdivision which will be introduced in the tree pollen diagram, also gives a logical subdivision for the preceding ones.
Concerning the tree pollen diagram the following may be remarked. On oecological grounds the following groups of species were assembled in this diagram. From left to right.

1. *Cecropia*, *Ficus* and Ulmaceae (which grow in bushes in the dry border zones of the cienagas).
2. *Byrsonima*, *Curatella* and *Ouratea* (are found together in the savanna).
3. Palmae, Bombacaceae, Myrtaceae, *Hediosmum*, *Virola*, Malpighiaceae (except *Byrsonima*), Anacardiaceae, Rubiaceae, Mimosaceae, Polygalaceae, Melastomataceae (these families and genera belong predominantly to the wet forest along the rivers).
4. The group comprising *Alnus*, *Myrica*, *Juglans*, *Podocarpus* and Ericaceae (does not grow in the lower course of the River Magdalena). This group of tree pollen was apparently supplied by the river from the mountain areas, especially during periods with a higher precipitation and transportation.

It is striking that there is an alternation in the diagram of zones in which trees from groups 1 and 2 are dominating, with zones in which the groups 3 and 4 strongly increase. Thus it is possible to subdivide the diagram into zones in the following way: A, B, C, D, E, F, G and H. The limits of these zones (1—8; see diagram) are drawn at the maxima of *Ficus*, *Cecropia*, and Ulmaceae (group 1).
On this grouping the following may be remarked. The two tops of the *Cecropia*-etc. curve at boundary 6, were considered as one single top for the subdivision. This was done on account of the fact that here a disturbing effect appears, as there was 95 % *Sagittaria* in the intermediate sample (*Sagittaria* belongs to a pioneer vegetation).
With these composed curves we consequently arrive now at pollen associations which alternate mutually. They represent a dry vegetation type or dry conditions with as representants group 1 and 2 (see above), and a humid vegetation type or humid conditions (higher percentage of pollen grains transported by the river) with the groups 3 and 4. As *Cecropia* is a tree which grows in open places that receive more light, the appearance of *Cecropia* in this dry vegetation most probably is not a result of greater dryness, but it is due to the fact that this type of vegetation is much more open, because *Cecropia* likes plenty of light. We see now a relatively dry vegetation, succeeded by a relatively humid one, which grows in the areas which are under

the influence of the river water and where consequently the water-table is much higher. In this humid vegetation, an under-growth of Gramineae and Cyperaceae (*Calyptrocarya*) is found in places which are often inundated.

The bottom-sample of the section (Plate I) shows a low percentage of dry-forest-elements and a rather high percentage of humid-forest-elements and *Calyptrocarya.* In the course of this zone we see a gradual decrease of the humid forest and an increase of the dry-forest-elements, till we attain the first maximum of the *Cecropia*-etc. curve. After this maximum we find in zone B again an increase of the humid forest. A difference with the former zone is the fact that here a higher percentage of Palmae is found. At the end of zone B we see again an increase of the dry-forest-elements. Zone C does not show any differences with the picture already sketched.

In the second half of zone D, a peaty clay was formed. At the same time we recognize a strong increase of the *Cecropia*-etc. curve and a maximum in the *Byrsonima-*, *Curatella-*, *Ouratea-* curve. This upper part consequently must have been formed in a rather dry period with a low lake-level. In zone E we find at first a short period in which occurs an increase of the humid-forest-elements, after which follows a strong increase of dry ones in the second half. There also is a deposition of peaty clay in the second half of zone E. The climate also must have been drier here, as shown by the pollen curves. In zone F we see again a strong increase of the humid forest. The percentage of *Byrsonima*-etc. is very low, and just like in zone B, we find a maximum of Palmae here. At the end of zone F we see again a rather strong increase of the *Cecropia*-etc. curve, attended by a maximum of the dry-forest-elements. Near the limit F-G the lake-level must have been much lower for a short time (vide the high percentage of *Sagittaria*). Thus zone F apparently also ends with a drier climate. Some peat has been formed here too. The zones G and H show the same succession.

Recapitulating, we may say the following. In this diagram a succession of relatively humid and relatively dry periods may be distinguished. Now the question arises whether this is a local phenomenon, or if there are indications that similar and contemporaneous climatic fluctuations are reflected in other places in Colombia and elsewhere in the world. With the C14 dates it is possible to give a more or less accurate dating for two of the periods in which we find a rather dry climate in the Magdalena area. These drier periods were also periods with a lower water-table (see discussion on zones D and E and the meaning of the *Cecropia*-etc. and *Byrsonima*-etc. curves above). In order to check if there are also found climatic fluctuations elsewhere in this period, the table below was composed.

It is striking, that not only elsewhere in Colombia (Laguna de La Herrera) a period of drier climate, connected with lower water-level was found, but that apparently also in other places of the world a change of climate took place at nearly the same time. This change is reflected in the following way: drier climate, enlargement of glaciers, period of lower water-levels of rivers, lower sea-levels, and periods of winters with less ice around Iceland.

In the discussion on the meaning of the zonation (see above) it appeared that a succession of drier and wetter periods could be observed in our diagram. In order to examine if the same periodicity could be noticed

Place	Time	Phenomena
Laguna de La Herrera (in Colombia, alt. 2550 m)	A.D. 1370±60 A.D. 1250±65	Period of low water-level in the lake (after van der Hammen & Gonzalez, 1965).
Grindelwald and Aletsch Glacier (Swiss Alps)	A.D. 1150—1250 A.D. 1250—1600	Enlargement of glaciers (after Mayr, 1964).
Geiki Inlet Glacier Bay	A.D. 1600—1850	Enlargement of glaciers (after Heusser, 1961).
Petsamo area	A.D. 1600—1850	Disturbance of vegetation, caused by greater drought (after Aario, 1943).
Brooks River sites in Alaska	A.D. 1500 A.D. 1250	Ash-layers in dry and cold periods (after Heusser, 1963).
Tregaron Bog (Engl.)	A.D. 1190±70 A.D. 1182±90	Recurrence horizon (after Godwin & Willis, 1960).
Fenn's Moss site (Engl.)	A.D. 1214±90	Recurrence horizon (after Godwin & Willis, 1960).
Fløgeln (Sweden)	A.D. 1160±40	Recurrence horizon (after Vogel & Waterbolk, 1963).
Ice conditions around Iceland and Greenland	A.D. 750—1050 A.D. 450— 550	Little ice along the coast of Iceland and Greenland (after Schell, 1963).
Turnagain arm in Alaska	A.D. 1250±250 A.D. 1850	Low sea-level and enlargement of glaciers (after Karlstrom, 1961).
Nile	A.D. 1150 A.D. 1450	Low water-levels (after Brooks, 1949).
Snöromsmossen (Sweden)	A.D. 1500	Dry period (after Karlstrom, 1961).

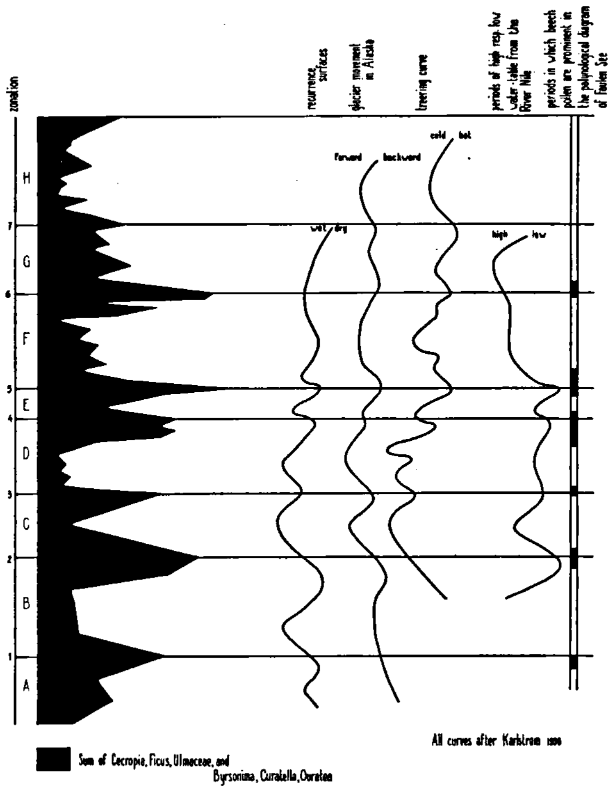

Fig. 6. Relation between *Cecropia*-etc. curve and climatological phenomena.

elsewhere, fig. 6 was constructed. This was done as follows: with the help of the C14 dates we could calculate the average rate of sedimentation for parts of our section. In this way the lapse of time between two tops of the *Cecropia*-etc. curve could be calculated; this appeared to be about 240 years; herewith it was possible to calculate the lapse of time during which the sedimentation took place in our lake; it appeared to be about 750 years.
For the representation of the relatively dry and humid periods in this figure (no. 6), the curve of *Cecropia*-etc. was taken. When we compare the curve of *Cecropia*-etc. to some curves taken from literature, as done in fig. 6 (see Karlstrom, 1961, Brooks, 1949, Schove, 1955, von Post, 1946), we find that generally there is a similarity between these curves. So it is certainly possible indeed that the fluctuations, found in the lake-level of the lake of Cienaga de Morrocayal, give a reasonable insight into the succession of climatic changes in the upper part of the Subatlantic in that part of the world.

CONCLUSIONS

The diagram discussed can be explained, assuming a variation in the water-level of the Magdalena River. Several sections in this area prove that the sediments rest on an old soil surface. This soil has apparently been inundated by higher water-levels after the birth of Christ. The soil itself may have been formed during the time in which the recurrence horizon of Weber came into existence. In the period between 1100 and 1500 in our diagram, climatic fluctuations are found, which have already been found in many other places in the world.

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