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A LATE-GLACIAL AND HOLOCENE POLLEN DIAGRAM FROM CIENAGA DEL VISITADOR (DEPT. BOYACA, COLOMBIA)

BY

T. VAN DER HAMMEN & E. GONZALEZ

SUMMARY

In a C 14 dated pollen diagram from "Cienaga del Visitador" (ca 6°8'N; 72°47' W) in the Colombian Eastern Cordillera the zones Ib + Ic + II (including the Allerød and Bølling interstadials) form one fluctuation in the diagram, as the short cold zone Ic is not reflected. An earlier Late-glacial interstadial is recognized and is called Susacá-interstadial. It probably lasted from about 13900 to 13100 B.P., was colder than the Bølling-interstadial, and is probably reflected in pollen diagrams from other parts of the world. The Holocene part of the diagram shows very high Gramineae-percentages, apparently due to a considerable lowering of the "tree-line". This must have been caused by the fact that the Holocene local climate has been much drier than the Late-glacial, even dominating the effect of the increase of temperature on the tree-line. The pollen zonation is nevertheless rather clear, and directly comparable with that from the Sierra Nevada del Cocuy and other areas. The contemporaneity of the Colombian and European pollen zones, strongly suggested or proved by earlier partly-dated diagrams, seems to be fully confirmed by the present one.

INTRODUCTION

In August of 1958 a section of more than 4 m was collected for pollen analysis, with the Dachnovsky sonde, in the "Cienaga del Visitador", a large mountain mire in the Paramo del Desaguadero, Paramo de Guantiva (Susacá, Department of Boyacá, fig. 1 and 3). It is situated at an altitude of 3300 m in an old and wide glacial valley-system in the Eastern Cordillera. The plateau-like part of the Cordillera where these valleys are found is surrounded by higher mountains, up to about 4000 meters (Alto de los Bobos). The outer slopes of these mountains, which fall down towards lower and warmer valleys, are covered with cloud-forests, a Quercetum, growing up to the forest-limit, as high as 3400—3600 meters (fig. 4). The inner slopes and also the "plateau" with its flat valleys, are devoid of higher forest (see fig. 2 and 3). Only locally in wind-protected valleys and on very marshy sites, is a "dwarf-forest" found, consisting of Polylepietum or Escalonietum, respectively. There has certainly been some human influence on the vegetation, but this seems principally to have been a change of floristic composition of the low open Paramo vegetation in the drier flat parts, due to grazing, which has also led to a decrease of "dwarf-forest". Open grass-land, Espeletion and bog-vegetation now prevails on the inner slopes of the surrounding mountains, the plateau and its flat valleys. Further details on the vegetation-types from this region are given in van der Hammen & Gonzalez (1960a) p. 275—278.

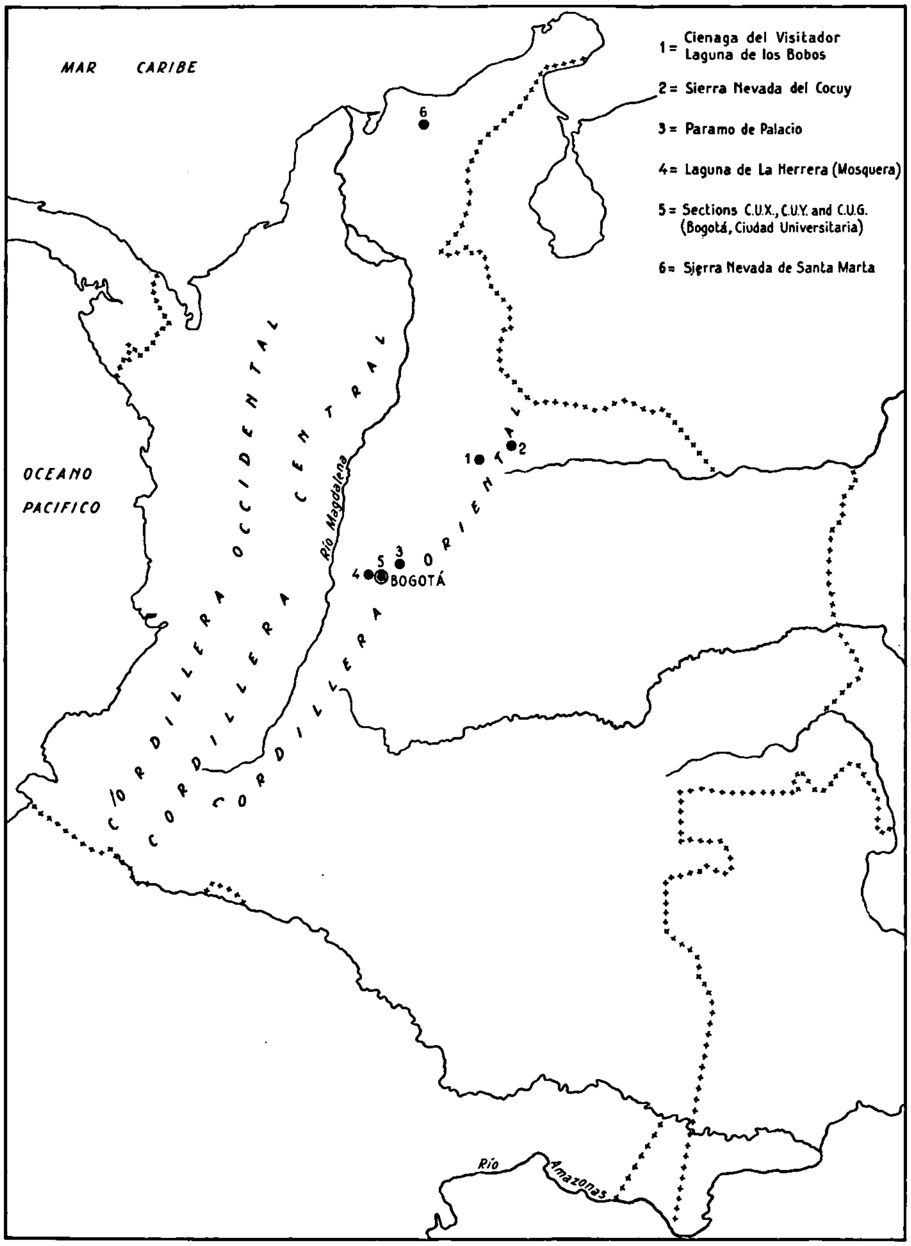

Fig. 1. Map of Colombia, showing approximate position of Cienaga del Visitador.

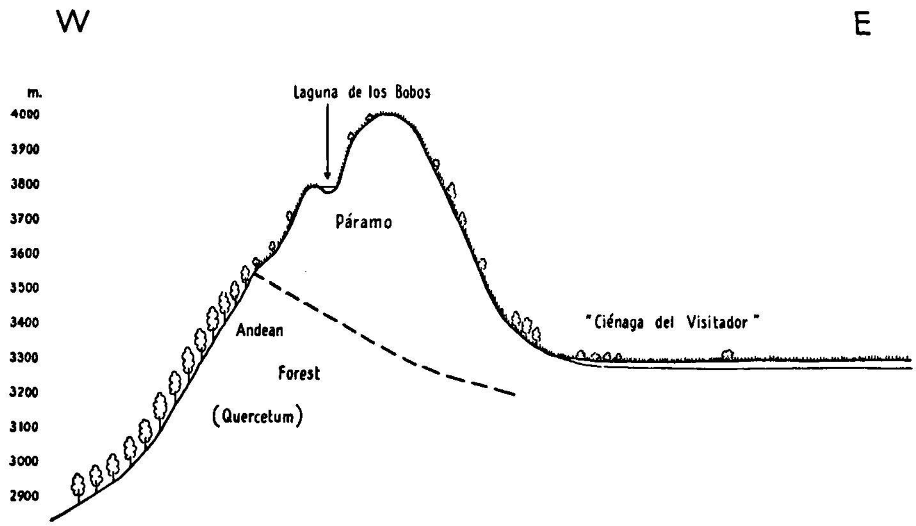

Fig. 2. Generalized profile through the area of Cienaga del Visitador and Laguna de los Bobos, showing the principal vegetation belts.

Fig. 3. Cienaga del Visitador. The boring was made on the place where the two men are standing. Altitude ca 3300 m. Slopes almost completely devoid of forest.

Fig. 4. Western outer slopes of mountains West of Cienaga del Visitador. Oak-forests cover the slopes, up to elevations of 3500 m and more. The foto was taken from an elevation of 3900 m on Alto de Laguna de los Bobos.

"LAGUNA DE LOS BOBOS"

The results of the pollen analysis of a C 14 dated section of lake deposits from the lake "Laguna de los Bobos", were published earlier (van der Hammen, 1962). This lake is situated on the humid outer slopes of the Alto de los Bobos, at an altitude of 3800 m (see fig. 2). The diagram represents the Colombian pollen zones VII and VIII (corresponding to the European Subboreal and Subatlantic zones). The percentage of forest-elements to a total of forest-elements and Gramineae fluctuates between about 25 and 50 % (uppermost spectra about 40—50 % forest-elements and 50—60 % Gramineae, reflecting actual conditions of approximately 300 m above the local "tree-line"). The relation of *Quercus* to the total forest elements less *Alnus* and *Podocarpus* ("*Quercus*-ratio"; see van der Hammen & Gonzalez, 1960a, p. 302) is about 50 % in the uppermost samples, corresponding to a local "tree-line" of approximately 3550 m.

On the outer slope of the mountains the history of vegetation and climate of the last 5000 years is rather clearly reflected in the pollen diagram (fluctuations of *Quercus*-ratio and of tree-limit; influence of man). We will see that the Upper Holocene history of climate is much less clearly reflected in the upper part of the diagram of Cienaga del Visitador. This is apparently due to the fact that during the entire Holocene the local tree-line was at a lower altitude than the plateau, so almost no tree pollen was produced locally, and it could not reach the area by air-lift from lower altitudes, as in the case of Laguna de los Bobos.

The Late-glacial history, on the other hand, is very clearly reflected in the present diagram.

HISTORY OF VEGETATION AND CLIMATE

The principal diagram (fig. 6) is composed in the same way as those published earlier from Colombia (van der Hammen & Gonzalez, 1960a, b, and 1962). It shows a rather curious picture of the vegetation history. One more important fluctuation of the tree-line is reflected in the lower part of the diagram. Almost all the forest elements participated in this fluctuation of the tree-line. The *Quercus*-ratio is approximately 50 % and according to recent tree-line and *Quercus*-ratio correlations in the nearby Laguna de los Bobos, this ratio corresponds, under the present temperature conditions, to a tree-line of about 3550 m. The humidity-conditions at that time seem to have corresponded therefore to those prevailing at present on the outside slopes of the surrounding mountains of the plateau. From sample 28 to 26 a lowering of tree-line is reflected, the *Quercus*-ratio is a little lower, and the sedimentation changed from organogene to minerogene.

In sample 25 conditions had changed again, but in a different way. The sedimentation became organogene again, *Quercus* increased at one moment, as if the humidity was going to rise again, but immediately after that, conditions seem to have become drier. This is also indicated by the way the *Isoetes*-curve falls almost to zero, demonstrating a partial drying-up of the lake. The curves of Compositae, *Hypericum*, *Lycopodium* (fov.) and Cyperaceae show a marked and sudden decrease. The Gramineae-percentages remain almost constant until high in the diagram so that the plateau must have been almost treeless. A comparison with the pollen diagrams from Sierra Nevada del Cocuy (Gonzalez, van der Hammen & Flint, 1965) and even with those from Paramo de Palacio (van der Hammen & Gonzalez, 1960b), show many similarities in the course of the different curves. These similarities make it possible to recognize most of the Late-glacial and Holocene Colombian pollen zones. Two C 14 dates from the lower part of the section were also most helpful for correlation with the above-mentioned regions. They were analysed by Dr. J. C. Vogel of the Groningen C 14 laboratory, and paid by the Netherlands Foundation for Pure Scientific Research Z.W.O.

GRN 3053 — Sample Col 24 — Dark lake sediment. Depth 370—390 cm. "Cienaga del Visitador", Paramo de Guantiva, Dept. Boyacá (Colombia). 12770 ± 130 yr

GRN 2477 — Sample Col 32 — Dark lake sediment. Depth 270—300 cm. "Cienaga del Visitador", Paramo de Guantiva, Dept. Boyacá (Colombia). 9830 ± 140 yr

The two dates enable us to calculate the average rate of sedimentation in the lower and upper part of the section. Between 285 and 380 cm depth, this rate was 32 cm per 1000 year. Between 0 and 285 cm depth this rate was 29 cm per 1000 year. The two values are, apart from the very small difference, so similar that it seems justified to use them to calculate the age of the zone-borders, as an additional verification of the correlation with other regions and of the age of these zones.

In fig. 5 we show most of the relevant features of the diagram, in relation to depth and calculated age. The zonal limits are indicated as lines, connecting its place on the depth-scale with the corresponding calculated age. In those cases where the precise position of a boundary was not quite certain, two lines were drawn, enclosing the (hatched) area within which this boundary must at any rate be located. A doubtful position of a boundary is indicated by an interrupted line. The European units are added, the boundary being placed at the corresponding time (according to European Radio-carbon dates), to show the close correspondence of the Colombian Cordilleran zones, and the European. A few additional remarks follow below.

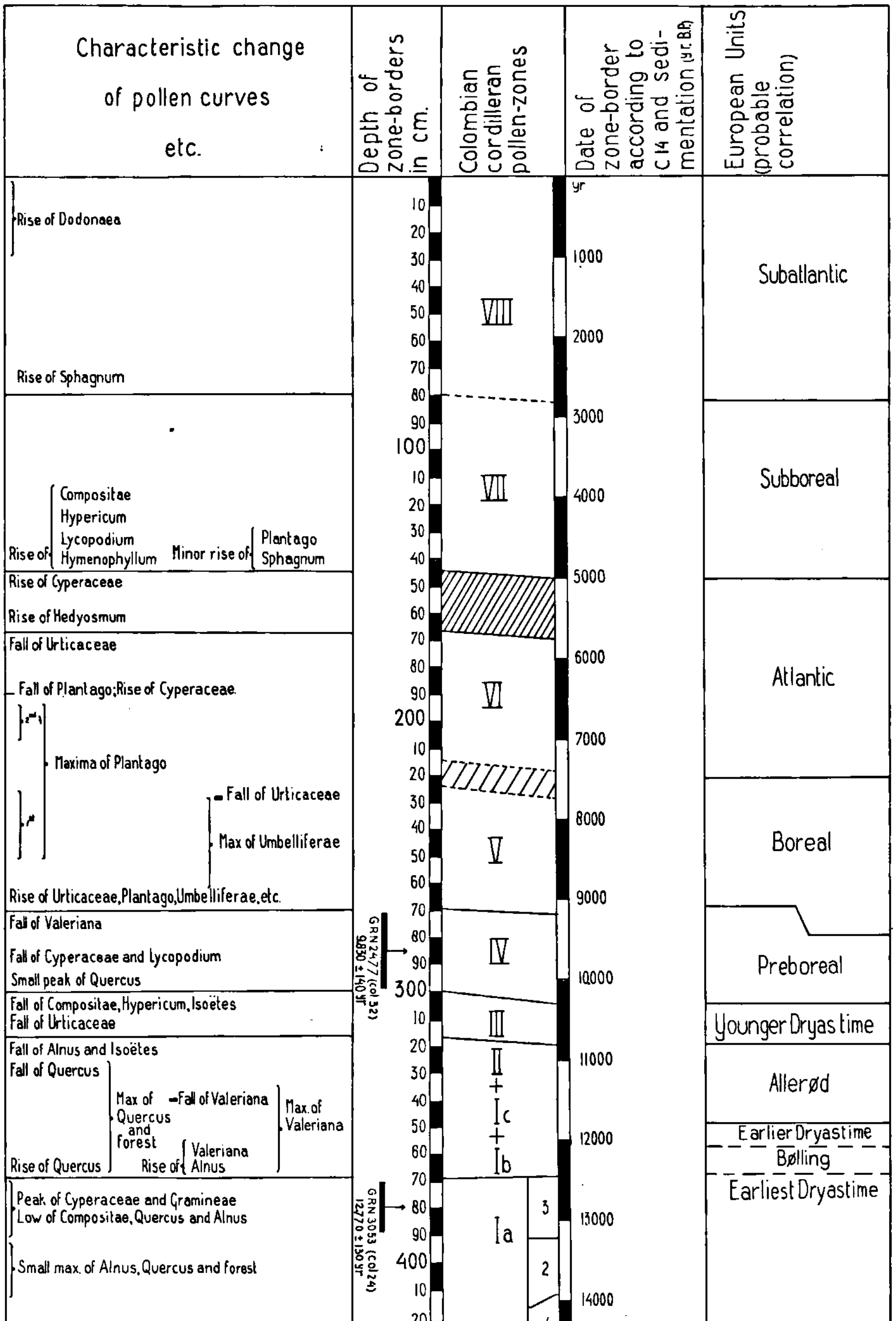

Fig. 5. Principal changes, zonation and dating of the pollen diagram of Cienaga del Visitador.

In zone Ia the diagram shows a temporary rise of tree pollen, followed by a maximum of Gramineae (and Cyperaceae). On this basis, the zone might be subdivided in three: Ia 1, Ia 2 and Ia 3 (see fig. 5). The cold Ia 3 was directly dated by C 14 analysis GRN 3053 as 12.770 ± 130 yr, while the calculated age (duration) of Ia 2 is between about 13.900—13.100 yr. If we compare these values with those of a pre-Bølling fluctuation in a diagram of Laguna de Los Sanguijuelas in Spain (Menendez Amor & Florschütz, 1961), we see a striking correspondence: the cold phase between this "fluctuation" and the Bølling is dated as GRN 702—12.830 ± 280 yr and the base of the "fluctuation" itself as GRN 705—13.700 ± 300 yr.

A comparison with the pollen diagram of Kaisungor, Mt. Kenya, equatorial Africa, at an altitude of 2900 m (van Zinderen Bakker, 1964), is equally interesting. Zone III is clearly represented as a high peak of the Gramineae; the calculated age corresponds exactly with the European Younger Dryas Time. Below it is zone II, and below that there is a Gramineae-peak again, dated as GRN 3048—12.650 ± 100 yr. Then follows a zone with somewhat lower Gramineae and higher Ericaceae percentages (about 300—330 cm), with a calculated age (duration) of between ca 14.300—13.000 yr. Below 330 cm follows a very rapid rise of the Gramineae. It is clear, that this diagram shows many similarities with ours, both in the fact that zones Ib + Ic + II (Bølling, Earlier Dryas and Allerød) appear as one fluctuation, as in that there is a pre-Bølling s.s. fluctuation. The first fact might be partly due to the relatively wide sample-distance, but it seems, just as the appearance of a pre-Bølling interstadial, that it may be due to the comparatively low altitude of the sites. We call this interstadial the Susacá-interstadial, and its duration may be provisionally established as about 13.900—13.100 yr. This interstadial can apparently not be recognized in Northern Europe, but in Central Europe there are indications of its existence in some pollen diagrams, and in Southern Europe it may be clearly reflected. We will soon publish more about this interstadial and its importance for the subdivision of the Late-glacial.

Zones Ib + Ic + II are inseparable, as the Gramineae-maximum of Ic is lacking (for the subdivision of zone I in Colombia, see also Gonzalez, van der Hammen & Flint, 1965).

The relatively wide sample-distance may be the reason for this difficulty, but a similar succession is shown by other diagrams (van Zinderen Bakker, 1964), and it seems that on more favourable sites (lower altitude or latitude) the climatic deterioration during the short time represented by zone Ic might have had little effect on the vegetation.

Zone III — In the stratigraphical sequence this zone corresponds to an intercalation of minerogene sediment. The same was the case with zone III in the diagram of Paramo de Palacio (van der Hammen & Gonzalez, 1960b), from an altitude of 3500 m.

Zone V and VI — As in the diagrams from Sierra Nevada del Cocuy (Gonzalez, van der Hammen & Flint, 1965) it is not possible to indicate a clear boundary between these zones. The fluctuations of the *Plantago*-curve are comparable with those in the Cocuy area. There are two marked maxima in our diagram, but it is not yet clear what they mean. *Plantago* grows to-day in the Paramo on dry moraine debris or rock.

Zone VII and VIII — The boundary between zones VI and VII is indicated by a great number of changes in the different curves. This phenomenon is spread over a 20 cm interval, and it is therefore that the limit cannot be defined more accurately than indicated. The limit between zones VII and VIII seems to be reasonably located at the first higher *Sphagnum* maximum, but the normal rise of the Gramineae-percentage is not visible because of the special geographic-climatological conditions mentioned in the introduction.

CONCLUSIONS

The curious general picture of the diagram, with high Gramineae-percentages for the Holocene, and lower ones for the Late-glacial, may be explained accepting a wetter local climate on the plateau during this last-mentioned period.

Conditions of humidity may have been comparable to those on the outer slopes of the surrounding mountains, where the tree-line may occur up to elevations of about 3600 m (the *Quercus*-ratio seems to confirm this view). Under these conditions, the colder (but much more humid) Late-glacial could have had a higher local tree-line than the warmer (and drier) Holocene. This picture may have been accentuated by a greater local Gramineae-production in the Holocene in the surrounding mire.

The zonation and the more important changes in pollen-composition are represented in fig. 5. The comparison of the calculated ages of the zone-boundaries with those from the European ones, demonstrated once more their comtemporaneity.

The zones Ib + Ic + II (including the Bølling and Allerød-interstadials) form one fluctuation in the diagram, as the short cold zone Ic is not reflected. This may be due to the relatively wide sample-distance and/or to the comparatively low altitude. A pre-Bølling interstadial is recognized, called Susacá-interstadial, that lasted approximately from about 13.900—13.100 yr B.P. This interstadial seems also to be reflected in diagrams from central Africa and Spain.

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