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VEGETATION AND CLIMATIC CHANGES IN THE MERIDA ANDES DURING THE LAST 13,000 YEARS

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This article presents a comparison of the paleoecological results from the Mérida Andes, in Venezuela, including different elevations and different mountain ranges. No attempt is done to correlate it with the results from other Andean mountains, although it certainly exists. The purpose here is to organize and compare the data from seven stratigraphic sections (Table I) at elevations above 3,000 m from the Mérida Andes in order to identify changes in vegetation and climate in the last 13,000 years.

Deglaciation started at 12,650 B.P. in elevations of 3,500-3,600 m and plants began to colonize the deglaciated soil (SALGADO-LABOURIAU et al., 1977). At about 8,300-7,530 B.P. the Mucubají glacial valley and the Páramo de La Culata were covered already by a rich páramo vegetation. At 3,900 m elevation (Páramo de Miranda) colonization occurred much later (ca. 9,400 B.P.) showing a delay according to elevation, as one might expect. The sequence of arrival of each pollen type was the same in Mucubají and in Miranda. Figure 1 depicts the arrival of the páramo elements at the superpáramo (elevations above 3,900 m). Colonization took place slowly after the glacial cirque of Miranda was deglaciated.

The almost continuous record for more than 11,470+170 radiocarbon years B.P. to present (SALGADO-LABOURIAU et al., 1988) show that the diversity of pollen and spores assemblages of páramo elements increased due to new arrivals until about 3,000 B.P. (Fig. 1). From there onwards these assemblages contained all the elements found in modern deposition inside the cirque. These results (SALGADO-LABOURIAU, 1988) illustrate how long it takes to form a superpáramo vegetation after its destruction.

The paleoecological results from the six sites were summarized on Table II. It represents a tentative interpretation of the climatic oscillations and vegetational changes during the last 13,000 years.

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Table I - Characteristics of the stratigraphic sections from the Mérida Andes.

Sites	Elevation (m)	Characteristics of the sites	References
Laguna Victoria	3,250	peat bog, core	SALGADO-LABOURIAU & SCHUBERT (1977)
Mucubají valley	3,600	peat & clay; fluvio-glacial terrace	SALGADO-LABOURIAU et al. (1977)
Lake Mucubají	3,540	lake sediment, two cores	SALGADO-LABOURIAU (unpublished)
La Culata	3,800	peat & clay; fluvio-glacial terrace	SALGADO-LABOURIAU & SCHUBERT (1976)
Páramo de Miranda	3,900	peat & clay; fluvio-glacial terrace	SALGADO-LABOURIAU et al. (1988)
Páramo de Piedras Blancas	4,080	peat bog, core	RULL et al. (1987)

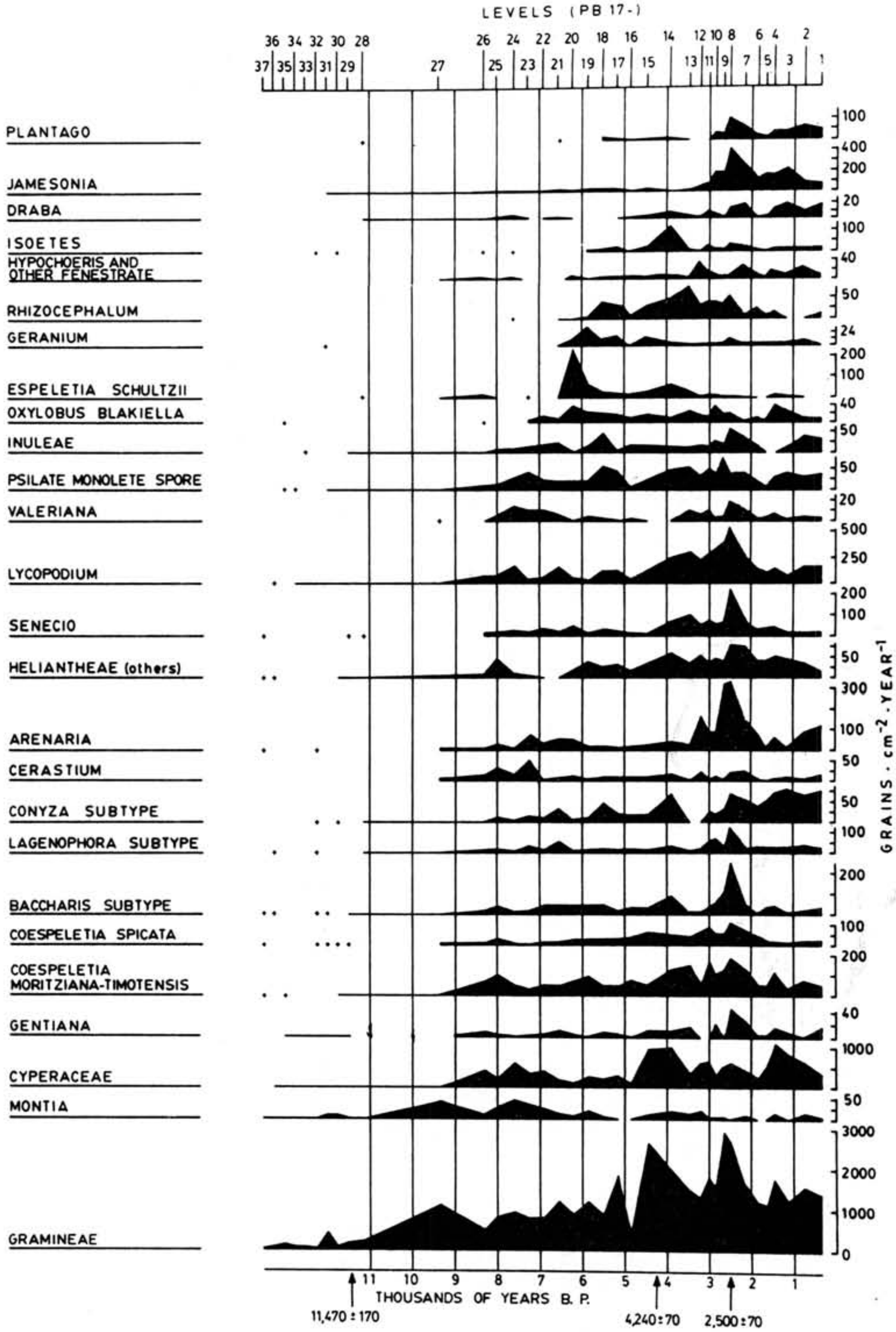

Figure 1 - Sequence of arrival of páramo pollen and spores at the Miranda glacial cirque after deglaciation. The asterisks at the left of the curves indicate a low frequence isolated occurrence; the first peak is considered to be the time when the taxon started to grow around the site (after SALGADO-LABOURIAU, 1988).

Table II - Late Quaternary climatic oscillations in the Mérida Andes.

Estimated Interval	Years Before Present (B.P.) Radiocarbon dates	Site	Vegetation and climate at elevations from 3,250 m to 4,080 m.
180 to 340	260±70	PB	Man's distubance of the montane ecosystems. Piedras Blancas Cold Phase (PB, LV).
380 to 700			Depression of treeline and páramo belts for more than 200 m elev. very scarce vegetation in superpáramo, probably a glacial desert. Temperature ca. 2 ° C below present average. Piedras Blancas Cold Phase. (PB, LV).
740 to 900			Vegetation and climate similar to present, but with less Compositae and more *Podocarpus*. High humidity. Subpáramo at 3,250 m, páramo at 3,400-3,800 m, superpáramo above 3,900 m elev. (PB, LV, LMu, Mi).
950 to 1,340	1,220±80	PB	Vegetational belts below modern position; páramo proper lowers to 3,250 m. elev. Climate cooler and more humid at lower elevation and drier at
4,000 m (PB, LV, Mi).			
1,350 to 2,235	1,550±245 2,235±380	LMu LMu	Vegetation and climate similar to present (less Compositae and more *Podocarpus*). Miranda site is flooded.
2,500 to 3,000	2,500±70 2,520±70	Mi LC	Abundant vegetation, more dense than at present at 3,550-3,900 m elev. Raise of vegetational belts above modern position. Humid climate, temperature probably above the present. (Mi, LC, LMu).
ca. 3,000			All superpáramo elements are present at 3,900 m elev. from here to present.
3,000 to 3,640			Vegetation and climate similar to present at páramo. Successive arrival of new elements at superpáramo.
3,700 to 4,900	4,240±70 4,745±275	Mi LMu	High pollen and spores input at 3,550 to 3,900 m elev. Raise of páramo and superpáramo belts. Increase in humidity (Mi, LC, LMu). Climate more humid and probably warmer than at present.
5,000 to 5,300	5,250±80 5,290±80	LC LC	Low pollen and spores input at 3,800 to 4,000 m elev. Climate drier and probably cooler.
5,300 to 6,100	6,075±290	LMu	Increase in humidity at Miranda and Mucubaji; cold and wet climate. *Coespeletia* and grasses dominate the superpáramo above 3,900 m

Table II - continuation.

6,100 to 6,250	6,070±80 6,130±80 6,250±140	LC LC LC	Pollen and spores input decrease; poor local and adjacent vegetation in páramo and superpáramo. Climate cooler and drier than at present. La Culata Cold and Dry Phase (LC, Mi, LMu).
6,250 to 9,360	6,240±90 6,350±90 7,530±80 8,300±225	LC LC LC LMu	Páramo vegetation similar to present but with less Compositae and more *Podocarpus* (3,550-3,800 m elev.). Superpáramo vegetation abundant but with less species than today; gradual arrival of new superpáramo elements during this interval at 3,900 m elev. Climate similar to present (LC, Mi, LMu).
ca. 9,360			Sharp increase of pollen and spores concentration at 3,900 m (Mi). Beginning of plant colonization at this elevation.
9,500 to 11,700	11,470±170	Mi	Low pollen and spores input at 3,550 to 3,900 m elev. Sparce vegetation at 3,600 m; glacial desert at 3,900 m elev. Climate colder than at present, and humid; average temperature ca. 2-3 °C below present. Deglaciation at 3,900 m elev. Miranda Cold and Humid Phase (Mi, Mu).
11,900 to 12,250	11,960±100 12,250±150	Mu Mu	Humid páramo vegetation at 3,550-3,600 m elev. Climate similar to present. Average temperature ca. 5.5 °C. Mucubaji Warm Phase (Mu).
12,300 to 12,700	12,390±250 12,570±130 12,650±130	Mu Mu Mu	Scarce superpáramo vegetation at 3,600 m elev. with less species than modern superpáramo. Climate colder and drier than at present; average temperature ca. 2.9 °C. Deglaciation at Mucubaji. Mucubaji Cold Phase (Mu).
Before 12,700			Mérida Glaciation

LC = La Culata (3,800 m)
LMu = Lake Mucubají (3,540 m)
LV = Laguna Victoria (3,250 m)

Mi = Miranda (3,290 m)
Mu = Mucubají valley (3,600m)
PB = Piedras Blancas (4,080m)

The comparison of the different sites showed that it was possible to ascertain the same oscillations of temperatures in the different sites because the events were marked in the pollen assemblages being thus, simultaneous. Five cold phases were detected, respectively at: ca. 700-100 B.P.; ca. 940-1,340 B.P.; ca. 5,300-6,250 B.P.; 9,500-11,700 B.P. and, ca. 12,300-12,700 B.P. In these phases the temperature was below the modern average. Two warm phases had temperature above the present (ca. 2,500 to 3,000; and probably at ca. 3,700-4,900 B.P.). The rest of the time was similar to the present temperature.

In contrast, the degree of humidity varied from site to site and only rarely its change was synchronous in two different elevations. The strongest difference between sites occurred at the time interval of 940-1,340 B.P. when the higher elevations were drier than at present, whereas Laguna Victoria at 3,250 m, today at the páramo-forest ecotone, was larger than at present and its waters covered the core site which at present is a peat bog close to it.

These results indicate that changes in humidity were local events whereas changes in temperature were simultaneous and involved the whole mountain system of Mérida. They also show that a decrease in temperature (below modern average) is not always connected with dryness. There were cold phases that were relatively dry and others that were relatively wet, such as, respectively, at 12,300-12,700 B.P. and at 9,500-11,700 B.P. (Table II).

The comparison among the pollen and spores diagrams from different sites in the Andes of Mérida has shown that the composition of vegetation was not the same during the Late Quaternary. It had less species after deglaciation and increased slowly in number of species, as described above. Furthermore, dominance of páramo elements and of arboreal pollen changed in the last centuries indicating disturbance of the natural environment.

Archeological data from the Venezuelan Andes have shown that there were no permanent settlements at elevations above 3,000 m before the arrival of the Europeans. The pre-colombian inhabitants lived below the páramos, and visited the highlands occasionally for short periods of time. They had no type of livestock, but agriculture was present up to 3,000 m elevation, and especially between 2,000 and 800 m (WAGNER, 1967, 1979). They probably never had a dense population in the Andes. Shortly after the Spanish arrival, in 1570 A.D. European cattle was introduced in the Andes (FEBRES, 1930) and it was raised up to 4,000 m elevation. Intense agriculture began at this time resulting in the almost destruction of the lower belt of montane forest that limits with the savannas of the Llanos. The cloud forest at 1,700 to 3,300 m elevation was deforested in the plateaux but the steep slopes still have primary forest. During the last hundred years, coffee has been cultivated in the lower slopes, and potato and wheat in the transition zone between páramo and montane forest. At present other plants were added and the terraces are intensely cultivated. Many exotic trees, such as *Pinus* and *Eucalyptus* were introduced above the present tree line and in the páramo-forest ecotone.

The disturbance of the natural montane ecosystems is marked in the pollen assemblages of the upper layers of sediments, a few centimeters from the top. This is clearly seen in three families, the Podocarpaceae, the Gramineae and the Compositae.

PODOCARPACEAE

Podocarpus is a genus of coniferous trees and shrubs of the southern hemisphere, western China and Japan. The Venezuelan species are trees of the montane rainforest that may reach 45 m height (VEILLON, 1962). The most common species in the Andean cloud forest is *Podocarpus rospighiosii* Pilger (*Decussocarpus rospighiosii* (Pilger) De Laubenfels). Many modern species of the genus *Podocarpus* l'Heritier ex Person have been recently grouped into two new genera by DE LAUBENFELS (1982) but for the purpose of this article we will use *Podocarpus sensu* l'Heritier including the three genera of De Laubenfels. The study of the pollen morphology of the South America species is greatly needed to allow their identification in sediments, at the species level.

Pollen of *Podocarpus* is transported by wind up to the regions above the tree line. The number of grains decreases gradually with elevation thus allowing a rough estimation of the distance between the deposition site and the elevation where the trees grow (SALGADO-LABOURIAU, 1979). The pollen analyses of sediments above the tree line from the Venezuelan Andes has shown that the frequency and concentration of *Podocarpus* pollen was much higher in the past. In all the stratigraphic levels where forest pollen is abundant its grains are the dominant or the co-dominant among the tree pollen. It is frequent at Piedras Blancas (levels 16 to 26), at Miranda (levels 7 to 26), at La Culata (all levels), at Lake Mucubají and the Mucubají terrace, and at Laguna Victoria (levels 9 to 18). Its maximum was reached around 900 B.P. Nevertheless, in the few centimeters below the surface, and in the modern deposition of pollen, its frequency is low suggesting that these trees were much more abundant in the past.

The deposition of pollen and spores from the cloud and the gallery forest elements diminished from about 700 B.P. onwards showing a retreat of the forest belt towards low elevations. This marks the beginning of the Little Ice Age in the Mérida Andes (RULL et al., 1987). Although *Podocarpus* pollen follow this decrease, it further reduces or disappears from 340 B.P. (17th century) onwards, loosing its dominance over the arboreal pollen and suggesting that the trees were cut down after the Spanish arrival at the Venezuelan Andes.

Podocarpus wood can be used for the same purposes of pine wood. Its trees were probably cut down for this purpose shortly after the beginning of the Spanish settlement in the Mérida Andes. Large trees are still abundant in steep slopes and in some forest reservations such as "La Carbonera". Sometimes single trees are found growing in pastures as a remnant of the former forest.

GRAMINEAE

Grass pollen is the dominant over all the pollen types in the old sediment pollen assemblages above 3,250 m elevation from 13,000 years B.P. onwards. Nevertheless, it is not dominant in the samples of modern deposition. Its decline at present is usually limited to the uppermost levels, a few centimeters from the soil suface, where it decreases to modern values for the site. An example of this decline is illustrated in the pollen diagram of Piedras Blancas (Fig. 2) and in the modern pollen deposition from Miranda (top of Fig. 3). Radiocarbon date of the Piedras Blancas section show that it occurred after 250$\pm$70 B.P., thus indicating that the decline took place in the last centuries. At present the soil is covered by grasses in the páramo grassland,in the shrub páramo and in the transition zone between páramo and forest. They are much more abundant than any herb. At the superpáramo the grass cover is scarce and the rocky soil is mostly bare. This field observation suggests that grass pollen is under-represented in modern assemblages of páramo.

Because no other element shows this change in representation, and grasses are high pollen producers, one may infer that a new factor came into play in the last two centuries. Archeological evidence indicates that the páramo never had a dense human population in Venezuela prior to the Spanish arrival. Llamas, vicuñas and other camelidians did not live in the Venezuelan mountains (WAGNER, 1967, 1979). Historical documents give 1,570 A.D. for the introduction of European cattle there and the beginning of agriculture (FEBRES, 1930).

Today husbandry is done up to almost 4,000 m elevation and is intense in many places. Based on the pollen analyses it can be assumed that after the 17th century cattle grazing was sufficiently intensive to prevent flowering of the grasses. Therefore, although they exist and constitute the dominant plants of the low stratum, their pollen production is low.

COMPOSITAE

At present Compositae plants are abundant up to the snow line (approx. 4,700 m elevation). The genus *Espeletia* is the most common from 2,800 to 3,800 m. *E. schultzii* forms pure stands in some páramo and covers the old moraines in places as the Mucubají valley. The tall rosette-forming plants of several species of the genus *Coespeletia* are mostly found above 3,800 m elevation. They grow side by side on rocky soil in large areas of the Páramo de Piedras Blancas at 3,900-4,400 m elevation.

Compositae pollen is the dominant or the co-dominant in the modern assemblages from surface soil indicating that it is well represented in the samples. Nevertheless, it is not frequent in the old pollen assemblages showing that the individual plants were not so abundant in the past.

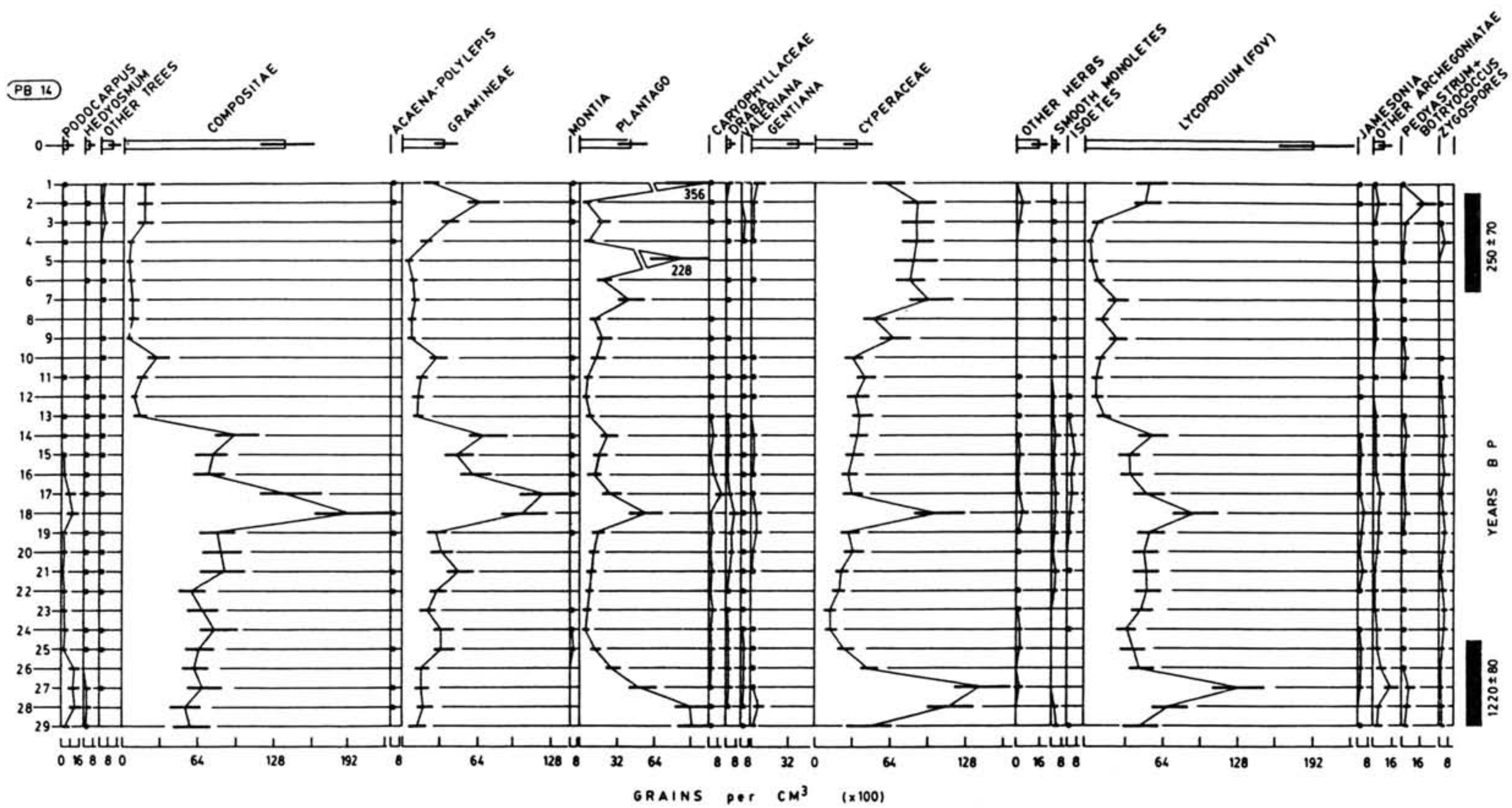

Figure 2 - Pollen and spore concentration diagram from the superpáramo at Piedras Blancas. PB14 - 1 to PB14 - 29 are the samples taken in stratigraphic order from a 2.90 m core at a peat bog. Sample PB14.0 is a surface sample close to the core site. At right are two radiocarbon dates (adapted from RULL et al., 1987).

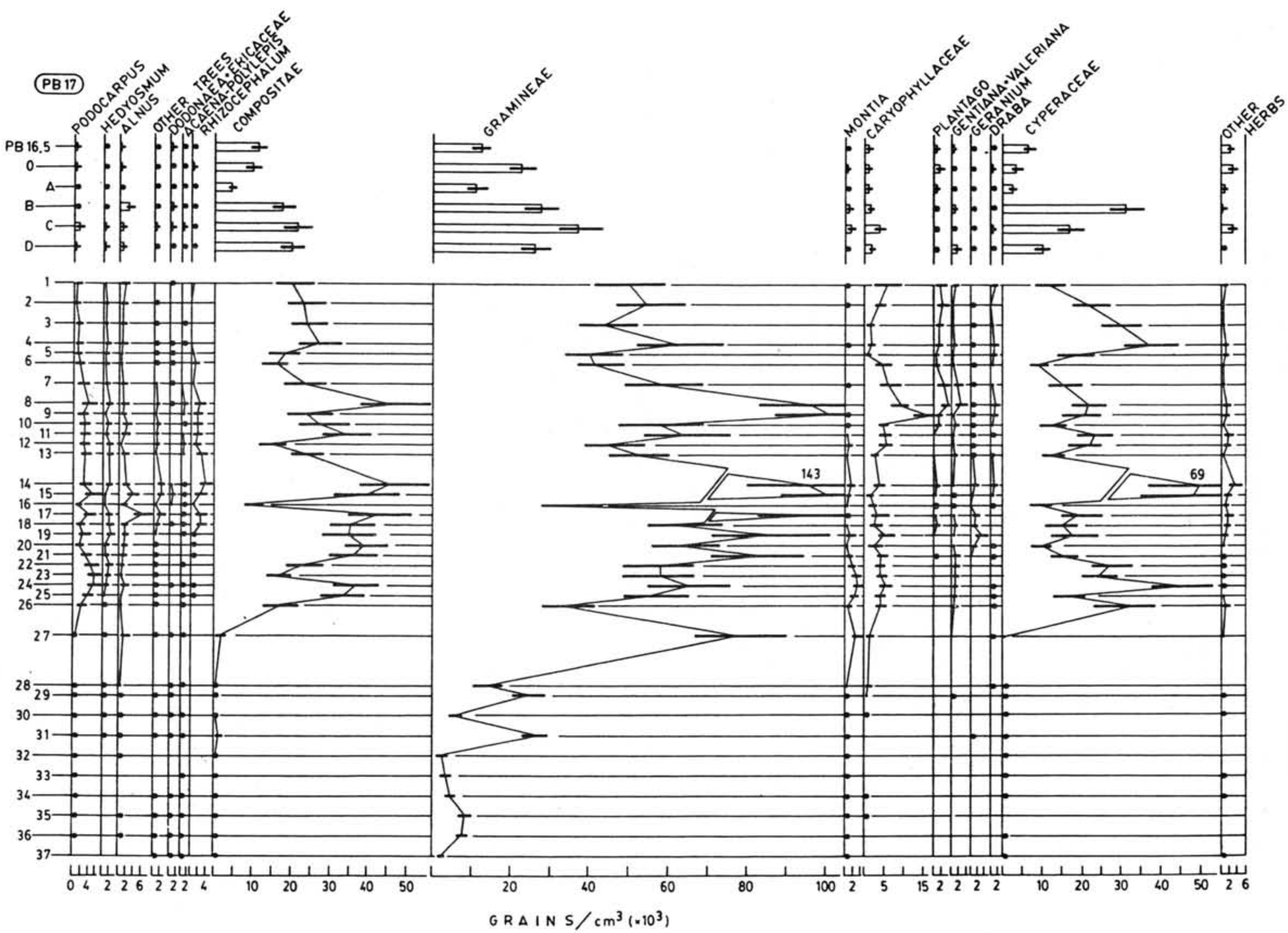

Figure 3 - Pollen concentration diagram from the Páramo de Miranda. Six surface samples inside the glacial cirque (peat bog) are at the top of the diagram (samples PB17, A, B, C, D and O). Samples PB17.1 to PB17.28 are taken in stratigraphic order from a 2.20 m fluvio-glacial terrace within the glacial cirque; samples PB17.29 to PB17.37 are from a 0.80 m core taken at the base of the terrace; below this is a sand layer that prevented further coring. Samples for radiocarbon dating were collected at three levels: PB17.28 = 11,470±170 B.P.; PB17.14 to 15 = 4,240±70 B.P.; PB17.8 to 7 = 2,500±70 B.P. (from SALGADO-LABOURIAU et al., 1988).

The increase of their pollen is at the same time as the grass pollen decline suggesting that it is related with the use of the land. Nevertheless, the role of man in the multiplication of Compositae plants is not clear. *Espeletia schultzii* is a invader of fallow lands at low elevations where forest was cut down for agriculture of pasture use (SALGADO-LABOURIAU, 1982). Nevertheless, its abundance in the páramo proper as well as the high frequency of three species of the genus *Coespeletia* in the superpáramo can not be explained by invasion of untilled land. Their recent expansion is still an open problem.

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