

CHANGES IN VEGETATION AND CLIMATE IN THE AMAZON BASIN AND SURROUNDING AREAS DURING THE PLEISTOCENE

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The nature and the effect of climatic changes in the Amazon Basin during the Quaternary and their possible effect on the local vegetation, have been much debated in the last decade. Especially biogeographers have repeatedly pointed out that the recent pattern of distribution of species and of subspecies in the Amazonian rain forest can only be satisfactorily explained in terms of an erstwhile temporary isolation, and they have postulated the former occurrence of large stretches of savanna throughout the extensive area of the Basin concomitant with the restriction of the areas under rain forest to a number of isolated refugia (see, e.g. Haffer, 1969). Indications of a former drier climate have also been noted by geomorphologists.

Recently Simpson-Vuilleumier (1971) gave a most useful compilation of data relating to important climatic changes in South America during the Pleistocene as the cause of the recent speciation patterns. She quite rightly remarked that at the time of her writing no palaeobotanic or palynologic evidence was available to substantiate the supposed vegetational changes in the Amazon Basin.

This note is to report on very recently gained palynological information undeniably indicating important changes in the vegetation cover of the area under discussion, supplemented by only partly published data from the immediately adjacent areas to the N. and to the W. of it.

DATA FROM THE SURROUNDING AREAS

Palynological studies and ¹⁴C datings of sediments from the Colombian Eastern Cordillera have shown that glacial-interglacial cycles during the Pleistocene in the northern High Andes are manifest, at tropical latitudes, as marked changes in the elevation of altitudinal vegetation belts. For a summary of the published data and a complete bibliography, see van der Hammen (1968). Since the publication of this summary additional and still unpublished evidence has been assembled. During the glacial periods the tree line became lowered by at least 1200 to 1500 m, which corresponds with a maximum decrease of the mean annual temperature of about 8 (perhaps up to 10) centigrades. The climate was wet during the first part of the last glacial period, but it has now been established that the interval between ca. 21 000 and ca. 13 000 B.P. was considerably drier than during the periods just before or after that interval.

It is uncertain to what level the temperature decreased at sea level at that time, but even allowing for the possibility of a "compression" of the temperature gradient one may assume that it has been appreciable. In this connection the lowering of the temperature of the surface ocean water in the Caribbean by about 4.5 centigrades, as deduced from oxygen-isotopic analysis obtained from deep sea cores by Emiliani (e.g., 1964), appears to be significant. If one takes these data and earlier calculations of sea water temperatures into account (a difference of $4^{\circ}\text{C} \pm 1$ was reported by, e.g., Wilhelmy,

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1957), a temporary decrease of the mean annual temperature by 4°-5°C in the tropical lowlands of Northern South America may be accepted. However, as Wilhelmy remarks, the drop may have been greater, if the climatic conditions associated with the degree of moisture were fundamentally different at that time, but it could, in his opinion, not exceed 7 centigrades. Judging by the floral composition of the lower tropical forest belt of the Northern Andes (elevation 0-700 m), most tropical species of the lowlands would withstand such a temperature decrease; and that is why in such regions, and also in the extensive lowland forests of the interior, such a decrease in the average annual temperature would hardly show up in pollen diagrams from that area as a conspicuous change in the floral composition, although quantitative changes in the vegetation cover associated with altered climatic factors (such as humidity) may have been very pronounced.

Palynological evidence and ¹⁴C datings indicate that during the last period of glaciation, a grass savanna must have been the predominant vegetation type in the area which is now the coastal plain of Gujana (v a n d e r H a m m e n, 1963). The sea level was considerably lower at that time and the savannas must have extended across a much dissected plain of older interglacial sediments mainly consisting of clays. This is suggestive of the prevalence of a much drier climate, which would tally with a lower average temperature. A more precise interpretation of the climatic conditions obtaining at that time appears to be difficult, however, owing to the appreciable influence of even paramount importance, of edaphic factors on such a relatively high-lying and deeply dissected plain of clayey sediments. Later studies by W i j m s t r a (1969, 1971), based on pollen diagrams obtained from deep sections from coastal Surinam, revealed that phases of savanna and of savanna woodland (with *Byrsonima*) are of frequent occurrence in the Plio-Pleistocene deposits, alternating with phases of mangrove- and swamp forest, which is highly suggestive of the prevalence of savanna vegetation during those stages in which the sea levels were low as the result of large-scale glaciations.

Farther to the south, in the Rupununi savannas of Guyana, close to the Brazilian border, data were assembled from a palynological study of lake sedi-

ments dating back from the recent to well into the last glacial (W i j m s t r a & v a n d e r H a m m e n, 1966). The pollen diagram shows that at least during the larger part of the Holocene (*viz.*, approximately during the last 7 000 years) the lake was surrounded by open savanna vegetation, with smaller or larger patches of *Byrsonima*. Before that time, during the earlier Holocene and the later stages of the last glacial, there was considerably more extensive *Byrsonima* savanna woodland, which interval was interrupted by some short but conspicuous periods during which an open savanna type of vegetation became much more wide-spread.

From the Colombian savannas of the Llanos Orientales we have so far only diagrams of Holocene deposits (W i j m s t r a & v a n d e r H a m m e n, 1966). The longest sequence (from the Laguna de Agua Sucia) represents approximately the last 6 000 years and shows several clear changes from savanna woodland to open savanna vegetation, and *vice versa*.

DATA FROM THE AMAZON BASIN

Recently a small series of borehole samples from the Katira Creek in northern Rondonia (Brasil), about 120 km SE of Porto Velho (approximately 9°S. and 63°W.L.) was received by courtesy of the Billiton Company. This part of the Amazon Basin is nowadays almost completely covered with a dense tropical rain forest. The nearest patches of more open vegetation types are found at least 150-200 km to the south on higher sandstone table-lands.

The series of unconsolidated, chiefly clayey, sediments from which the samples were taken is about 25 m thick and overlies a hard lateritic sediment. The Creek flows through a small valley which it has cut into the uppermost sediments. At about 13 m below the bottom level of that valley a black clay with an abundance of plant remains was found. The pollen flora of this layer of clay is very rich and represents the pollen rain of a dense, tropical marsh forest with, e.g., *Mauritia* and several other palms, *Ilex*, *Symphonia*, Bombacaceae, Myrtaceae, Melastomataceae, etc. Smaller numbers of grains of *Hedyosmum*, *Podocarpus*, *Sagittaria*, Compositae and *Eichhornia* were encountered and also some larger gramineous grains (> 40 μ). Only about 10% of the pollen is of

herbaceous taxa, the remaining 90% being tree pollen. The association of species is clearly indicative of a very young Cenozoic age (Uppermost Pliocene to Quaternary) and it is most probably Quaternary. Overlying the dark clay, and forming the deposit 6-12 m below the surface, is a grey layer of clay which contains in its pollen total only less than 5% of arboreal or of presumably arboreal pollen grains and over 95% of herbaceous pollen mainly consisting of smaller ($< 40 \mu$) pollen types of Gramineae, with an admixture of Cyperaceae, Compositae and *Cuphea*. In one sample studied the percentage of *Cuphea* was even as high as 6%. Representatives of this lythraecous genus are very common in, e.g., the Colombian savannas, and in that area pollen of *Cuphea* has repeatedly been recorded from lake sediments in percentages which sometimes approximate their representation in the grey clay of Katira Creek. There can be very little doubt that the dominant *in situ* vegetation type during the time of deposition of this clay was a very open grass savanna.

Overlying the grey clay deposit and forming the sediment series 2 m to 6 m below the valley bottom is a tough red clay, possibly representing colluviated soil material. Above this sediment the deposit consists of partly eroded, yellowish grey clay which proved to contain more than 90% of herbaceous pollen grains and up to nearly 10% of *Mauritia* pollen. Gramineous types again provided the bulk of the non-arboreal pollen and the vegetation cover must at that time have corresponded with an open grass savanna.

It is hoped that we soon will have the disposal of more complete and better samples of these sediments, but the rather scanty preliminary data already suffice to permit the conclusion that in this part of the Amazon Basin the tropical rain forest was temporarily replaced by open savanna vegetation, presumably during a part of the Pleistocene.

The above-mentioned indications of the prevalence in areas immediately to the N. and W. of the Basin of a dry or drier climate during periods of maximum glaciation, and the presence in northern Rondonia of rain forest under the present "interglacial" climatic conditions strongly suggest that the replacement of rain forest by a "dry" vegetation type took place during one or more of the glacial periods of the Pleistocene.

CONCLUSIONS

Palynological evidence recently obtained from the Amazon Basin, in conjunction with corroborative data from adjacent areas, are strongly suggestive of the occurrence in that region of marked changes of climate and vegetation concomitant with the late Cenozoic (and, more particularly, Pleistocene) glacial-interglacial climatic cycles. During periods of maximum glaciation the mean annual temperature may have been at least 4 to 5 centigrades lower than it is to-day, and simultaneously the climate would have been considerably drier. The direct effect of the drop in the temperature on the tropical lowland vegetation may have been slight, but the decrease in rainfall must have had a far-reaching effect leading to an extension and encroachment of open grass savannas in areas nowadays covered by an almost continuous tropical rain forest.

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