SCHWARTZ

PALAEO GEOGRAPHY CLIMATOLOGY ECOLOGY

ELSEVIER Palaeogeography, Palaeoclimatology, Palaeoecology 109 (1994) 345–356

Pollen evidence of late Quaternary vegetation and inferred climate changes in Congo

H. Elenga [a,b], D. Schwartz [b], A. Vincens [a]

[a] *Géologie du Quaternaire CNRS, Faculté de Sciences de Luminy, Case 907, 13288 Marseille Cedex 9, France*
[b] *Dynamique Historique des Ecosystèmes Intertropicaux, ORSTOM, B.P. 1286, Pointe Noire, Congo*

(Received May 6, 1993; revised and accepted September 1, 1993)

Abstract

A detailed palynological analysis of two cores recovered from a swamp in the Southern Batéké Plateaux (Congo), provides information on the botanical history of this region during the last 24,000 yr B.P. Rich and well-diversified pollen counts exhibit changes in the vegetational communities related to hydrological and climatic fluctuations. Around 24,000 yr B.P., the occurrence of hydromorphous forest elements gives evidence of a humid phase. Between 24,000 and around 13,000 yr B.P., swampy herbaceous communities expanded, indicating slightly drier climatic conditions. From approximately 13,000 yr B.P. onward, the beginning of a humid episode is reflected by the development of mesophilous forests. The decrease of these forests is documented since 3000 yr B.P. Grasslands are found to extend locally whereas *Elaies guineensis* (oil palm) spreads out, indicating both climatic change but also anthropogenic activities.

1. Introduction

In West Equatorial Africa, from a large forested area included in the Guineo-Congolian region (White, 1983), very few pollen data are reported concerning the history of its vegetation and the climatic fluctuations during the Quaternary. The only continental pollen sequences studied in this region have been recovered from Cameroun: Lake Barombi Mbo (4°40′N, 9°24′E; Brenac, 1988; Maley et al., 1990a) and Mboandong (Richards, 1986).

From Congo, in the absence of pollen data, the reconstruction of Quaternary vegetational environments has been primarily based on indirect arguments inferred from geomorphological, pedological and archaeological studies and on remains of macroflora (De Ploey, 1963, 1965; De Ploey and Van Morsel, 1963; Lanfranchi, 1979; Giresse et al., 1981; Delibrias et al., 1983; Schwartz, 1988; Dechamps et al., 1988a,b). The major climatic and vegetation changes of the last 40,000 yr based on these works are summarized as follow:

—40,000–30,000 yr B.P.: humid period characterized by forest development;
—30,000–12,000 yr B.P.: arid period with an extension of wooded savanna;
—12,000–3000 yr B.P.: humid period with a new forest development;
—ca. 3000 yr B.P.: the climate and vegetation reach their present characteristics.

Palynological data obtained in the Batéké region and on coastal swamps give new information for the dynamics of vegetational and floristical environments in Congo (Elenga, 1992). The occurrence of montane species on the Batéké plateaux

SSDI 0031-0182(93)E0182-S

ca. 11,000 yr B.P. was interpreted as an effect of temperature drop (Elenga et al., 1991). Such migrations to the tropical West African lowlands of cold elements were recorded in other sites (Van Zinderen Bakker and Clark, 1962; Maley and Livingstone, 1983; Maley, 1987). Pollen data from the littoral suggest that a dry episode occurred ca. 3000 yr B.P., approximately synchronous with human impact (Elenga et al., 1992).

This paper presents new palynological results from two cores collected in the Ngamakala Pond on the Batéké plateaux. The records give informations on vegetation and hydrological changes at local and regional scale, since 24,000 yr B.P.

2. The Batéké Plateaux

The Batéké Plateaux (1–4°S, 14–16°E) cover an area of 12,000 km² at an altitude between 600 and 886 m and are surrounded by a hilly area of 70,000 km² which ranges in altitude between 350 and 800 m (Fig. 1).

The modern climatic conditions prevailing in this region are of the equatorial type. They are characterized, according to latitudinal and altitudinal location, by a mean annual rainfall comprised between 1300 mm (Brazzaville meteorological station) and 1900 mm (Djambala meteorological station), with a dry season reaching 3–4 months. The mean annual temperature ranges between 22 and 25°C with a mean annual thermal amplitude of 6°C (A. Sec. N.A., 1964).

The Batéké region is located within the mosaic of Guineo-Congolian lowland rain forest and secondary grassland (White, 1983). It is covered for 90% of its area by more or less wooded savannas. Locally, the occurrence of hygrophytic associations is related to local humid edaphic conditions (Duvigneaud, 1949; Descoings, 1969; Makany, 1976). The clumps of forest, sometimes well developed, are either of anthropogenic origin and characterized by the abundance of cultivated plants such as *Elaeis guineensis* (oil palm) and *Mangifera indica* (Mango), or forested galleries with *Pentaclethra eetveldeana* and *Parinari excelsa*. The occurrence of typical rainforest species such as *Pycnanthus angolensis*, *Dacryodes edulis*, etc., in the less damaged zones could indicate that of these galleries might be the relics of a former more expanded forest environment. The hygrophytic associations are either grasslands with *Sphagnum*, *Xyris*, *Stipularia africana* and other aquatic herbs, or swamp forests with *Syzygium guineensis*, *Alstonia boonei*, *Xylopia rubescens*, etc.

3. Material and methods

The Ngamakala Pond (4°4′30″S, 15°23′E, 400 m) is located within the hill area defined above. It is a swampy depression 750 m long and 200 m wide, largely covered by *Sphagnum*. The canopy cover is dominated by *Alstonia boonei* (Fig. 2).

3.1. Core sampling and laboratory analysis

The cores Gama 4 and Gama 1 have been collected, using a Russian corer (Fig. 2; Belokupitov and Beresnevich, 1955). On each core, samples for pollen study were taken every 3 cm. Therefore, a total of 70 distinct levels have been counted in the two cores. The sediments were processed using the standard method described by Faegri and Iversen (1975), working with successive chemical attacks of HF, HCl and KOH. Pollen and spores were identified by comparison with the reference pollen collection of the Laboratoire de Géologie du Quaternaire (Marseille, France: 7500 African tropical specimen). Each pollen spectrum includes at least twenty taxa and a total pollen sum averaging 400 grains. Such total counts are significant to characterize the vegetational associations found in the study of modern pollen rain of equatorial forests from Gabon (Jolly, 1987). The relative frequencies of pollen types or pollen groups are calculated on the total pollen sum excluding the unidentifiable grains.

3.2. Lithology and chronology of the deposits

The sediments of both cores Gama 1 and Gama 4 mainly consist of fibrous peat with silty or clayey layers. The bottom of the core Gama 4 is dominated by compact silty clay abruptly replaced by

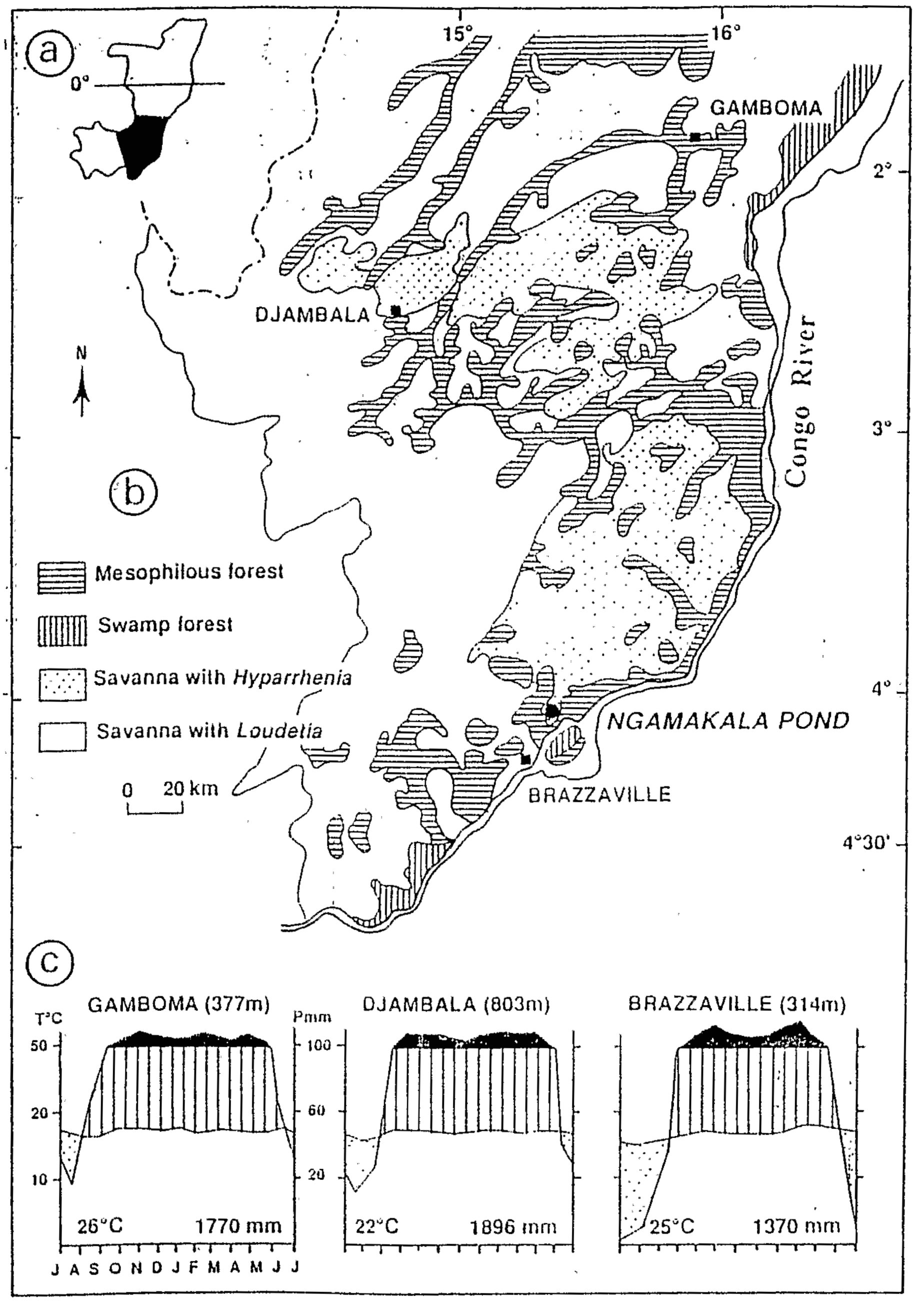

Fig. 1. (a) Location of the study area in Congo. (b) Major vegetation types of the Batéké region and location of the Ngamakala Pond. (c) Climatic diagrams of the three meteorological stations of the studied area (Atlas du Congo, 1969).

a humid silty peat (Fig. 3). Around 250 cm, a more clayey peat occurs which is contemporaneous with the bottom deposits of the core Gama 1 (Fig. 4). The upper part of the two cores consist of a fibrous peat containing abundant roots in the process of decomposition. In the cores Gama 1 (between 40 and 0 cm) and Gama 4 (between 140 and 0 cm) the deposits composed of plant remains were saturated of water. Therefore, it has been impossible to collect these levels.

Eight standard radiocarbon datings made on total organic matter content have been performed on the cores Gama 4 and Gama 1 (Laboratoire de Géologie du Quaternaire, Marseille). The dates obtained are presented in Table 1. These indicate that the sequence found in Gama 4 covers the period ca. 24,000 to ca. 3500 yr B.P., but the ^{14}C dates suggest a possible gap between 10,880 ± 160 and 3940 ± 130 yr B.P. The Gama 1 core registers the period ca. 3300 to ca. 900 yr B.P.

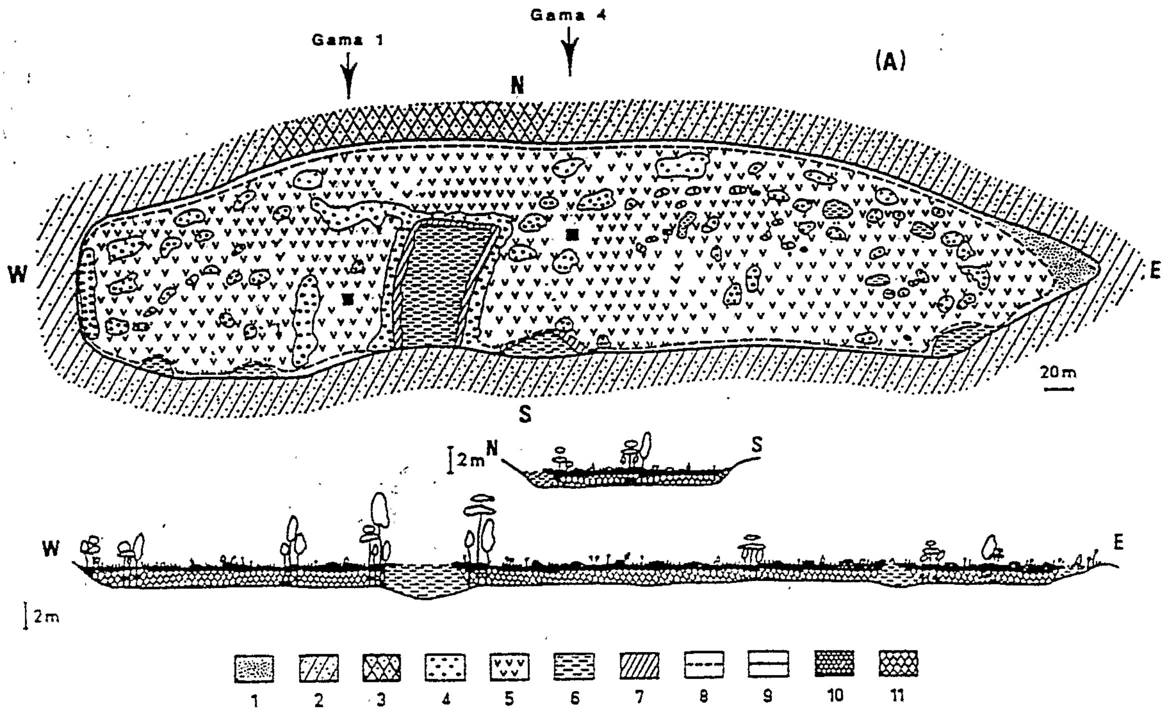

Fig. 2. The Ngamakala Pond (Makany, 1976) and location of the core sites Gama 1 and Gama 4. *1*=fluctuating limit of water level; *2*=*Loudetia demeusei* savanna; *3*=new growth with *Pentaclethra eetveldeana*; *4*=clumps of *Alstonia boonei*; *5*=*Sphagnum* peat; *6*=pond; *7*=*Stipularia africana* zone; *8*=peatbog extension; *9*=pond extension; *10*=floating upper part of the peat; *11*= lower part of the peat largely saturated in water.

Table 1
List of ^{14}C ages performed on total organic matter in cores Gama 4 and Gama 1, Ngamakala Pond (LGQ, Marseille)

Core	Material	Depth (cm)	^{14}C ages (yr B.P.)	Laboratory (no.)
Gama 4				
	Organic matter	140–150	3650±180	LGQ 244
	Organic matter	165–175	3950±130	LGQ 446
	Organic matter	180–190	10,880±160	LGQ 553
	Organic matter	190–200	13,260±220	LGQ 447
	Organic matter	210–221	14,090±230	LGQ 405
	Organic matter	258–270	24,000±580	LGQ 501
	Organic matter	290–300	24,200±480	LGQ 242
Gama 1				
	Organic matter	10–20	930±140	LGQ 564
	Organic matter	100–110	3300±130	LGQ 495

4. Palynological results

The pollen diagrams presented in Figs. 3 and 4 include only the main taxa which are abundant and consistently occurring, and therefore are considered as the most important for the palaeoenvironmental interpretation. Four main pollen zones (G4 to G1) have been differentiated on the frequency fluctuations. They are described from the bottom to the top of the cores.

4.1. Pollen zone G4

This zone is represented only at the bottom of the core Gama 4, between 300 and 285 cm. Dated around 24,000 yr B.P., it is characterized by the

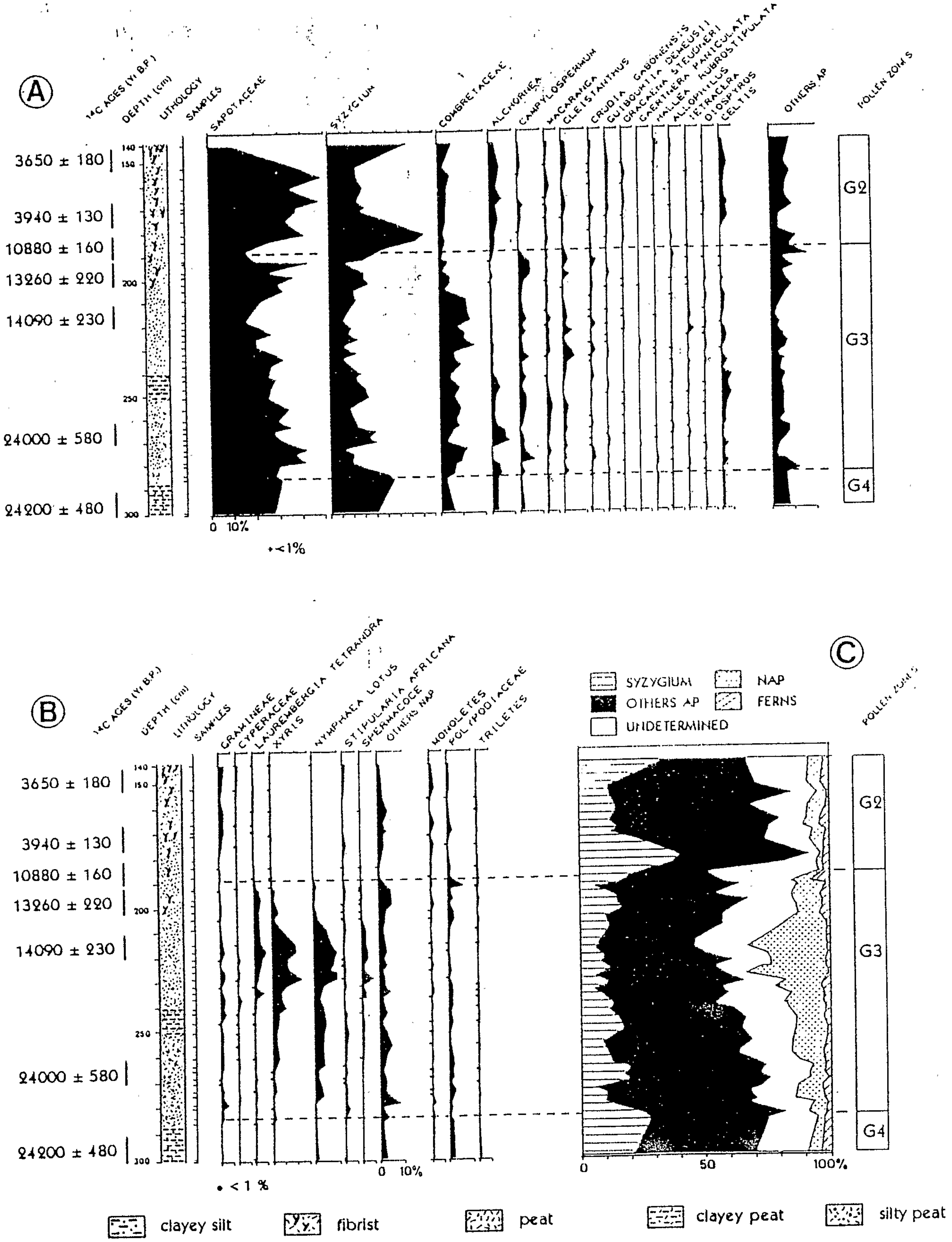

Fig. 3. Pollen diagram from core Gama 4, Ngamakala Pond (values are relative percentages of total pollen and spores, unidentifiables grains excluded). (A) Main arboreal and climber taxa. (B) Main herbaceous taxa and spores. (C) Synthetic diagram.

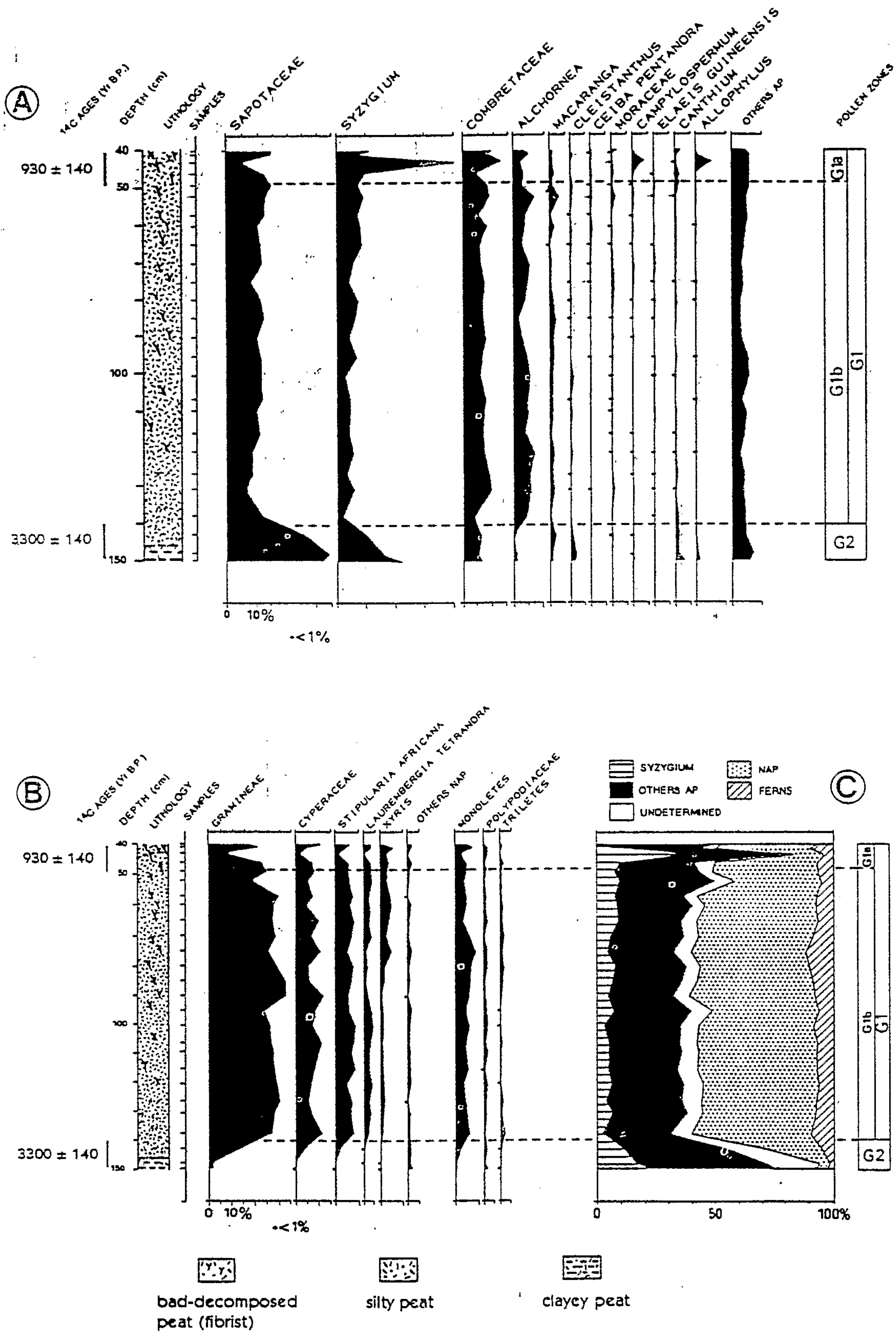

Fig. 4. Pollen diagram from core Gama 1, Ngamakala Pond (values are relative percentages of total pollen and spores, unidentifiables grains excluded). (A) Main arboreal and climber taxa. (B) Main herbaceous taxa and spores. (C) Synthetic diagram.

dominance of arboreal taxa which represent more than 70% of the total pollen count. The most abundant ones are the Sapotaceae (35%), *Syzygium* (20%) associated with some *Alchornea* (5%), *Macaranga*, *Crudia* type and *Celtis* (1–2%). The Combretaceae (10%), probably belonging to the genus *Combretum* as shown by the numerous botanical studies undertaken on this site (Makany, 1976), and *Tetracera* (less than 1%) represent the main climber components in the pollen spectra. Herbaceous taxa are very scarce. Pteridophyta represent mean percentages of about 3%.

4.2. Pollen zone G3

This zone, such as the previously described, is present only in the core Gama 4, between 285 and 190 cm. It is dated between ca. 24,000 and ca. 13,000 yr B.P. The vegetation shows a significant change. The Sapotaceae (20%) and *Syzygium* (10%) decrease. During the same time, arboreal taxa such as *Cleistanthus* (5%) and *Celtis* (5%) develop. The climbers are more abundant with always Combretaceae (15%) and *Tetracera* (1–2%) dominant. The herbaceous taxa increase, particularly the aquatic and swampy components such as *Xyris* (10%), *Nymphaea lotus* type (10%) and *Laurembergia tetrandra*. Gramineae and *Spermacoce* are present, but in low percentages (2%).

4.3. Pollen zone G2

This zone is present in the core Gama 4 between 190 and 140 cm, and only its upper part in the core Gama 1, between 150 and 140 cm. It corresponds to the period from ca. 11,000 to ca. 3000 yr B.P. and is characterized by a large representation of arboreal taxa, particularly of the Sapotaceae (45%) and *Syzygium* (35%) associated with some *Alchornea* and *Celtis*. The climbers (Combretaceae (5%) and *Tetracera* (less than 1%)) greatly decrease such as the herbaceous taxa (less than 5%).

4.4. Pollen zone G1

It is represented only in the core Gama 1, between 140 and 40 cm and covers the episode from ca. 3000 yr B.P. to the sub-actual period. It has been divided into two sub-zones:

Sub-zone G1a

It is characterized by an abrupt increase in the frequencies of herbaceous taxa with a mean value of about 60% of the total count. The most abundant components are the Gramineae (30%), the Cyperaceae (10%), *Stipularia africana* (10%), *Laurembergia tetrandra* and *Xyris* (2–5%). Pteridophyta are also well represented. The arboreal taxa significantly decrease with only 35%. *Elaeis guineensis* (oil palm) appears at the bottom of this sub-zone.

Sub-zone G1b

In this sub-zone, an increase of arboreal taxa such as *Syzygium* associated with *Allophylus* and *Camplylospermum* is registered.

5. Major environmental changes and paleoclimatic implications

Pollen analysis of the deposits recovered in the Ngamakala swamp, Batéké region, clearly show that the dynamics of the vegetation occurring on this site during the late Quaternary was characterized by extension and retreat of the local forested environment.

At approximately 24,000 yr B.P. an hydromorphous forest occupies a large area in the Ngamakala depression. The low representation of herbaceous elements, particularly of Gramineae which have a great local pollen production as demonstrated in modern pollen rain studies in Congo (Elenga, 1992), suggests that grassland was missing at the site. Such a palaeobotanical environment would indicate a humid climatic episode with precipitation certainly higher than today. Although these data have been obtained on a single site, it can be supposed that ca. 24,000 yr B.P. most of the Batéké depressions were occupied by hydromorphous forests.

Between ca. 24,000 and 13,000 yr B.P., pollen data show a retreat of the arboreal strata on the Ngamakala site giving way to hygrophytic grasslands rich in *Xyris*, *Nymphaea lotus* and some other herbaceous components which were particularly well developed before ca. 14,000 yr B.P. During this period, the vegetation could be interpreted as a mosaic of swampy grasslands with free and open water indicated by local patches of forests, suggesting drier climatic conditions than before. Such a reconstruction is consistent with the modern distribution of the aquatic plants identified in the fossil spectra. Indeed, *Nymphaea lotus* can develop in temporary pools flooded only during four months a year. So, it is possible that between 24,000 and 13,000 yr B.P., a rainfall decrease coincided with a more contrasting seasonal distribution of precipitation. During the long dry season, the drop of the surface water level could have permitted the development of *Xyris* on the emerged sandy banks of the site, whereas *Laurembergia tetrandra* and *Stipularia africana* occupied more boggy soils. At the same time, the forest, rather open as confirmed by the presence of numerous climbers, could have remained in the lowest zones of the depression where water would have been present. Such occurrence of water in the Batéké depressions during a period interpreted as dry can be explained by the fact that these low zones would have taken advantage of the flow of underground water of which the circulation was favoured by the sandy nature of the substratum.

After 13,000 yr B.P., pollen data give evidence of an expansion of the hydromorphous forests in the depression. The floristic composition is close to the one registered ca. 24,000 yr B.P. This new extension of forests corresponds to the onset of the Holocene climatic optimum now well known all over Africa and characterized by the establishment of higher precipitations than before. The succession of the dates $10,880 \pm 160$ and 3940 ± 130 yr B.P. indicates that early and middle Holocene deposits are not represented in core Gama 4, such as in the first record of the Kashiru swamp (Bonnefille and Riollet, 1988).

From ca. 3000 yr B.P. onwards, a new retreat of the hydromorphous forests is registered but it is less important than during the period ca. 24,000 to ca. 13,000 yr B.P. The pollen spectra indicate at the same time a re-expansion of the hygrophytic grasslands. This period is marked by an increase of the Gramineae which has no equivalent in older deposits. This phenomenom, which could [be] related to human activities as shown also by th[e] occurrence of *Elaeis guineensis* at the same time, will be discussed later.

A new expansion of the forested area seems to take place ca. 900 yr B.P. This trend is today still observed in many Congolese regions, but it is largely slowed down by human pressure.

6. Discussion

The humid episode dated at ca. 24,000 yr B.P. and characterized by an extension of forests in the swampy depressions of the Batéké region, is for the first time demonstrated in Congo. It would correspond to a humid phase within the Leopoldvillian arid period dated between ca. 30,000 and ca. 12,000 yr B.P. as recognized in West Central Africa (Lanfranchi and Schwartz, 1990). This wet phase was recently described in a pollen sequence from lake Barombi Mbo, Cameroun (Maley and Brenac, 1987), where ca. 24,000 yr B.P. high frequencies of arboreal taxa (more than 60%) indicate the forested nature of the vegetation. In East Tropical Africa, palynological data supply evidence of a similar humid climatic phase between 25,000 and 20,000 yr B.P. (Bonnefille and Riollet, 1988; Vincens, 1986, 1991a,b). Also other approaches led to the recognition of this event. Limnological studies indicate that in this period many tropical African lakes have registered a high or intermediate water level (Street and Grove, 1979; Gasse et al., 1989). In the interior Zaire basin, Preuss (1990) describes phenomena of podsolization on alluvial deposits between 26,000 and 23,000 yr B.P. related to higher precipitation. Many data obtained in Tropical Africa seem to confirm the occurrence ca. 24,000 yr B.P. of a humid climatic fluctuation within the dry period described between 30,000 and 12,000 yr B.P. and contemporaneous to the last glacial period in the northern hemisphere.

Ca. 11,000 B.P., contrary to pollen results previously obtained in the Bois de Bilanko depression located 30 km northward (Elenga et al., 1991), no montane element such as *Podocarpus latifolius*, *Olea capensis* or *Ilex mitis* is present in the vicinity of the Ngamakala Pond. Therefore, it can be supposed that the lowest limit for their development was situated between the altitude of Bois de Bilanko (700 m) and of Ngamakala (400 m). Such a downward migration to their modern altitudinal range has been interpreted as a drop of the mean annual temperature of about 4–5°C compared to modern values when applying a mean temperature gradient of 0.6°C/100 m displacement of the vegetation (Elenga et al., 1991). Considering the very short distance between the two sites and their morphological location, it seems possible that any other factor such as an important cloudiness has influenced this distribution, although this factor has been used to explain the modern occurrence of *Podocarpus latifolius* in one residual settlement in the Chaillu Massif (Congo) at 700 m in altitude (Maley et al., 1990b).

A climatic optimum is reached ca. 10,000–9000 yr B.P. It is marked by the expansion of the humid rain forests on the Bosumtwi (Ghana) and Barombi Mbo (Cameroon) sites (Maley and Livingstone, 1983; Maley and Brenac, 1987; Maley, 1991) and, on the East African mountains, by the spread to high elevation up to 2500 m of the forest belt (Hamilton, 1982; Bonnefille et al., 1991; Jolly and Bonnefille, 1991). In marine sediments, the $\delta^{18}O$ curve obtained on a core off the Congolese coast clearly registers an increase in precipitation (Giresse et al., 1982).

In the Batéké region, this warm and humid period is though not well documented.

At appoximately 3000 yr B.P. a new establishment of dry climatic conditions is registered. This change has been previously assessed in Congo (Caratini and Giresse, 1979; Dechamps et al., 1988a,b; Schwartz et al., 1990a,b,c; Elenga et al., 1992; Schwartz, 1992) and in Cameroon (Richards, 1986; Brenac, 1988; Maley, 1991, 1992) at the same time. It was also detected in other African regions between ca. 4000 and ca. 2500 yr B.P. (Kendall, 1969; Vincens, 1987, 1989, 1993; Bonnefille and Riollet, 1988; Taylor, 1990; Jolly and Bonnefille, 1991; Mworia, 1991; Ssemmanda and Vincens, 1993; Jolly, 1993). In West Equatorial Africa, this dry phase ca. 3000 yr B.P., more abrupt and more important than the one previously recognized, may have led to local fragmentation of the African forest. The modern evidences of such a fragmentation would be found in the isolated enclosed savannas in some forested areas of Congo (De Foresta, 1990; Schwartz et al., 1990c). This opening of the forest would have contributed to migration of the Bantu populations originating from the Cameroon Grassfields towards the South of the African continent (Schwartz, 1992).

Moreover, the results obtained from the pollen sequences of the Ngamakala site indicate that the environment at ca. 3000 yr B.P. had no equivalent in the past 24,000 yr. Even during the glacial period interpreted as been the driest one, Gramineae were never as abundant as during the period 3000–950 yr B.P. It seems that the savannas found in the Batéké Plateaux today are not to be compared to the vegetation occurring there between 24,000 and 13,000 yr B.P., which was probably of a more wooded type. Such a conclusion has been previously proposed on the Congolese littoral (Elenga et al., 1992).

7. The environment from 3000 yr B.P. onwards: human interference on the landscape

The fact that the modern savannas have no equivalent during the former late Quaternary dry climatic phases and the early occurrence of *Elaeis guineensis* (oil palm), an anthropic species probably originating from the Gulf of Guinea (Ghana–Nigeria) where its pollen grains have been identified in older sediments than those presented here (Sowunmi, 1981) raise the problem of the effect of human impact on the physionomy and the distribution of modern vegetation.

Firstly, it is noticeable that in the Ngamakala pollen diagrams the appearance of oil palm pollen is not exactly synchronous with the increase of grains from grassland savanna, but closely follows it. Similar results have previously been obtained from the Congolese littoral (Elenga, 1992). The comparison between investigations on macroflora remains in situ (Dechamps et al., 1988a) and on pollen from peat deposits (Elenga et al., 1992) allows to place the beginning of the dry late Holocene phase at ca. 3100–3000 yr B.P. In return, the oil palm only appears in this region between 2850 and 2700 yr B.P., maybe at the same time as ceramics, though for the moment there are some divergences on their dating (Denbow, 1990; Schwartz, 1992). It seems that on the Congolese littoral, as in the Batéké region, the establishment of proto-agricultural populations, assimilated to Bantu-speaking groups, follows the start of the dry climatic event. Similar conclusions have been found in Rwanda by Van Grunderbeek et al. (1984). Two other arguments are in favor of a climatic origin of the detected environmental change at ca. 3000 yr B.P. The first one is the synchronism of this event in as different regions as the Congolese littoral, the Batéké plateaux and the Lake Barombi Mbo in Cameroon (Schwartz, 1992; Maley, 1992). The second one is that this change has also been observed on hydromorphous podzols, chemically corresponding to very poor soils influenced by a fluctuating water table, conditions which are not favourable for agricultural activities (Schwartz, 1988; Schwartz et al., 1989). So, the hypothesis of an abrupt climatic change towards drier conditions ca. 3000 yr B.P., leading to a partial fragmentation of the African rain forest of which the Iron Age populations would have taken advantage by their migrations, must be taken in serious consideration (Schwartz, 1992).

8. Conclusion

The pollen sequences presented in this paper provide new detailed information mainly concerning the evolution of the vegetation in the Batéké swampy depressions. They are in agreement with the patterns previously suggested by studies on macroflora remains (Delibrias et al., 1983; Schwartz, 1988; Dechamps et al., 1988b) and with pollen record from marine cores of the Congolese coast (Caratini and Giresse, 1979; Bengo and Maley, 1991). As new evidence, we must emphasize the occurrence of a humid phase ca. 24,000 yr B.P., the decrease of forest cover and the development of a swampy herbaceous vegetation between 24,000 and 13,000 yr B.P. indicating slightly drier conditions but not arid as suggested by geomorphological and pedological data. It is clear that during the Late Glacial Maximum, forested areas were present in the Batéké region at the southern limit of the Batéké Plateaux, near the Congo river. The pollen data confirm that the last 3000 yr B.P. were the driest ones of the Holocene.

Acknowledgements

The work presented here is part of Elenga's thesis defended at Marseille (1992), in the *Laboratoire de Géologie du Quaternaire* CNRS. The authors are indebted to R. Bonnefille for laboratory support, advice and encouragement during this research and revision of the manuscript; we acknowledge M. Servant, G. Caballé and C. de Namur for helpful comments and discussions. Radiocarbon dating was provided by R. Lafont (LGQ-Marseille). We thank G. Buchet, G. Riollet and M. Decobert for technical assistance; N. Buchet and R. Smadja for computer storage; J. Adams for the English translation. Financial support comes from CNRS and ORSTOM.

References

A.SEC.N.A. Aperçu sur le climat du Congo Brazzaville. Serv. Météorol. Brazzaville, 23 pp.

Atlas du Congo, 1969. Le climat du Congo. ORSTOM/Min. Coop., Paris.

Belokupitov, I.E. and Beresnevich, V.V., 1955. Giktorf's peat borers. Turf Prom., 8: 9–10.

Bengo, M.D. and Maley, J., 1991. Analyses des flux polliniques sur la marge sud du Golfe de Guinée depuis 135 000 ans. C. R. Acad. Sci. Paris, Ser. 2, 313: 843–849.

Bonnefille, R. and Riollet, G., 1988. The Kashiru pollen sequence (Burundi). Palaeoclimatic implications for the last 40,000 yrs B.P. in tropical Africa. Quat. Res., 30: 19–35.

Bonnefille, R., Riollet, G. and Buchet, G., 1991. Nouvelle séquence pollinique d'une tourbière de la crête Zaïre-Nil (Burundi). Rev. Palaeobot. Palynol., 67: 315–330.

Brenac, P., 1988. Evolution de la végétation et du climat dans l'Ouest Cameroun entre 25 000 et 11 000 ans B.P. Act. 10th Symp. APLF, Bordeaux, Trav. Sec. Sci. Tech. Inst. Fr. Pondichery, 25: 91–103.

Caratini, C. and Giresse, P., 1979. Contribution palynologique à la connaissance des environnements continentaux et marins du Congo à la fin du Quaternaire. C. R. Acad. Sci. Paris, Ser. D, 288: 379–382.

Dechamps, R., Guillet, B. and Schwartz, D., 1988a. Découverte d'une flore forestière mi-Holocène (5800–3100 B.P.) conservée in situ sur le littoral ponténégrin (R.P. du Congo). C. R. Acad. Sci. Paris, Ser. 2, 306: 615–618.

Dechamps, R., Lanfranchi, R., Le Cocq, A. and Schwartz, D., 1988b. Reconstitution d'environnements quaternaires par l'étude de macrorestes végétaux (Pays Bateke, R.P. du Congo). Palaeogeogr., Palaeoclimatol., Palaeoecol., 66: 33–44.

De Foresta, H., 1990. Origine et évolution des savanes intramayombiennes (R.P. du Congo). II. Apports de la botanique forestière. In: R. Lanfranchi and D. Schwartz (Editors), Paysages Quaternaires de l'Afrique Centrale Atlantique. ORSTOM, Paris, pp. 236–355.

Delibrias, G., Giresse, P., Lanfranchi, R. and Le Cocq, A., 1983. Datations des dépôts holorganiques quaternaires sur la bordure occidentale de la Cuvette Congolaise (R.P. du Congo); corrélations avec les sédiments marins voisins. C. R. Acad. Sci. Paris, Ser. 2, 296: 463–466.

Denbow, J., 1990. Congo to Kalahari: data and hypotheses about the political economy of the western stream of the Early Iron Age. Afr. Archaeol. Rev., 8: 139–175.

De Ploey, J., 1963. Quelques indices sur l'évolution morphologique et paléoclimatique des environs du Stanley-Pool (Congo). Stud. Univ. Lovanium, Univ. Kinshasa 17, 16 pp.

De Ploey, J., 1965. Position géomorphologique, genèse et chronologie de certains dépôts superficiels du Congo occidental. Quaternaria, 7: 131–154.

De Ploey, J. and Van Morsel, H., 1963. Contribution à la connaissance chronologique et paléogéographique des gisements préhistoriques des environs de Léopoldville (Congo). Stud. Univ. Lovanium, Mus. Préhist., 19 pp.

Descoings, B., 1969. Phytogéographie. Esquisse phytogéographique du Congo. In: Atlas du Congo, ORSTOM, Paris, 2 pp.

Duvigneaud, P., 1949. Les savanes du Bas-Congo. Essai de phytosociologie topographique. Lejeunia 10, 192 pp.

Elenga, H., 1992. Végétation et climat du Congo depuis 24 000 ans B.P. Analyse palynologique de séquences sédimentaires du Pays Bateke et du littoral. Thèse Doct. Univ. Aix-Marseille III, 237 pp.

Elenga, H., Vincens, A. and Schwartz, D., 1991. Présence d'éléments forestiers montagnards sur les Plateaux Batéké (Congo) au Pléistocène supérieur: nouvelles données palynologiques. Palaeoecol. Afr., 22: 239–252.

Elenga, H., Schwartz, D. and Vincens, A., 1992. Changements climatiques et action anthropique sur le littoral congolais au cours de l'Holocène. Bull. Soc. Géol. Fr., 163(1): 83–90.

Faegri, K. and Iversen, J., 1975. Textbook of Pollen Analysis. Blackwell, Oxford, 295 pp.

Gasse, F., Ledée, V., Massault, M. and Fontes, J.C., 1989. Lake Tanganyika in phase with the ocean during the last glaciation and deglaciation. Nature, 342: 57–59.

Giresse, P., Lanfranchi, R. and Peyrot, B., 1981. Les terrasses alluviales en République Populaire du Congo. Bull. ASSEQUA, 62/63 pp. 43–66.

Giresse, P., Bongo-Passi, G., Delibrias, G. and Duplessy, J.C., 1982. La lithostratigraphie des sédiments hémipélagiques du delta profond du fleuve Congo et ses indications sur les paléoclimats de la fin du Quaternaire. Bull. Soc. Géol. Fr., 24(4): 803–815.

Hamilton, A.C., 1982. Environmental History of East Africa. A Study of the Quaternary. Academic Press, London, 328 pp.

Jolly, D., 1987. Représentation pollinique des forêts sempervirentes du N.E. du Gabon. Mém. DEA, Univ. Montpellier, 85 pp. (unpubl.).

Jolly, D., 1993. Evolution et dynamique des écosystèmes du Burundi. Pollen et statistique. Thèse Doct. Univ. Aix-Marseille II, 143 pp.

Jolly, D. and Bonnefille, R., 1991. Diagramme pollinique d'un sondage holocène de la Kuruyange (Burundi, Afrique Centrale). Palaeoecol. Afr., 22: 265–274.

Kendall, R.L., 1969. An ecological history of the lake Victoria Basin. Ecol. Monogr., 39: 121–176.

Koechlin, J., 1961. La Végétation des Savanes dans le Sud de la République du Congo. ORSTOM, Paris, 310 pp.

Lanfranchi, R., 1979. Recherches préhistoriques dans la moyenne vallée du Niari (R.P. du Congo). Thèse 3ième cycle, Univ. Paris I, 2 Vol., 675 pp.

Lanfranchi, R. and Schwartz, D. (Editors), 1990. Paysages Quaternaires de l'Afrique Centrale Atlantique. In: Collect. Didactiques. ORSTOM, Paris, 535 pp.

Makany, L., 1976. Végétation des plateaux Téké. Trav. Univ. Brazzaville 1, 301 pp.

Maley, J., 1987. Fragmentation de la forêt dense humide africaine et extension de biotopes montagnards au Quaternaire récent: nouvelles données polliniques et chronologiques. Implications paléoclimatiques et biogéographiques. Palaeoecol. Afr., 18: 307–334.

Maley, J., 1991. The African rainforest vegetation and paleoenvironments during Late Quaternary. Climatic Changes, 19: 79–98.

Maley, J., 1992. Commentaires sur la note de D. Schwartz. Mise en évidence d'une péjoration climatique entre ca. 2500 et 2000 B.P. en Afrique tropicale humide. Bull. Soc. Géol. Fr., 16(3): 363–365.

Maley, J. and Brenac, P., 1987. Analyses polliniques préliminaires du Quaternaire récent de l'Ouest Cameroun: mise en évidence de refuges forestiers et discussion des problèmes paléoclimatiques. Mém. Trav. E.P.H.E., Inst. Montpellier, 17: 129–142.

Maley, J. and Livingstone, D.A., 1983. Extension d'un élément montagnard dans le Sud du Ghana (Afrique de l'Ouest) au Pléistocène supérieur et à l'Holocène inférieur: premières données polliniques. C. R. Acad. Sci. Paris, Ser. 2, 296: 1287–1292.

Maley, J., Livingstone, D.A., Giresse, P., Thouveny, N., Brenac, P., Kelts, K., Kling, G., Stager, C., Haag, M., Fournier, M., Bandet, Y., Williamson, D. and Zogning, A., 1990a. Lithostratigraphy, volcanism, paleomagnetism and palynology of Quaternary lacustrine deposits from Barombi Mbo (West Cameroon): preliminary results. J. Volcanol. Geotherm. Res., 42: 319–335.

Maley, J., Caballé, G. and Sita, P., 1990b. Etude d'un peuplement résiduel à basse altitude de Podocarpus latifolius sur le flanc congolais du massif du Chaillu. Implications paléoclimatiques et biogéographiques. Etude de la pluie pollinique actuelle. In: R. Lanfranchi and D. Schwhartz (Editors), Paysages Quaternaires de l'Afrique Centrale Atlantique. ORSTOM, Paris, pp. 336–352.

Mworia, M., 1991. Vegetation response to climatic change in Central Rift Valley, Kenya. Quat. Res., 35: 234–245.

Preuss, J., 1990. L'évolution des paysages du bassin intérieur du Zaïre pendant les quarante derniers millénaires. In: R. Lanfranchi and D. Schwartz (Editors), Paysages Quaternaires de l'Afrique Centrale Atlantique. ORSTOM, Paris, pp. 260–270.

Richards, K., 1986. Preliminary results of pollen analysis of a 6000 year core from Mboandong, a crater lake in Cameroon. Hull Univ. Geogr. Dep., Misc. Ser., 32: 14–28.

Schwartz, D., 1988. Some podzols on Bateke sands and their origins, People's Republic of Congo. Geoderma, 43(2/3): 229–247.

Schwartz, D., 1992. Assèchement climatique vers 3000 B.P. et expansion Bantu en Afrique centrale atlantique: quelques reflexions. Bull. Soc. Géol. Fr., 163(3): 353–361.

Schwartz, D., Dechamps, R. and Guillet, B., 1989. Une flore holocène (8000 B.P.) découverte à Ngidi (Congo). Nsi. 5: 9–14.

Schwartz, D., De Foresta, H., Dechamps, R. and Lanfranchi, R., 1990a. Découverte d'un premier site de l'âge du fer ancien (2110 B.P.) dans le Mayombe congolais. Implications paléobotaniques et pédologiques. C. R. Acad. Sci. Paris, Ser. 2, 310: 1293–1298.

Schwartz, D., Guillet, B. and Dechamps, R., 1990b. Etude de deux flores forestières mi-Holocène (6000–3000 B.P.) et subactuelle (500 B.P.) conservées in situ sur le littoral ponténégrin (Congo). In: R. Lanfranchi and D. Schwartz (Editors), Paysages Quaternaires de l'Afrique Centrale Atlantique. ORSTOM, Paris, pp. 283–297.

Schwartz, D., Lanfranchi, R. and Mariotti, A., 1990c. Origine et évolution des savanes intramayombiennes (R.P. du Congo). I. Apports de la pédologie et de la biogéochimie isotopique (^{14}C et ^{13}C). In: R. Lanfranchi and D. Schwartz (Editors), Paysages Quaternaires de l'Afrique Centrale Atlantique. ORSTOM, Paris, pp. 314–325.

Sowunmi, M.A., 1981. The late quaternary environmental changes in Nigeria. Pollen Spores, 23(1): 125–148.

Ssemmanda, I. and Vincens, A., 1993. Végétation et climat dans le bassin du lac Albert (Ouganda, Zaïre) depuis 13 000 ans B.P. Apport de la palynologie. C. R. Acad. Sci., Paris, Ser. 2, 316: 561–567.

Street, F.A. and Grove, A.T., 1979. Global maps of lake-level fluctuations since 30 000 yr B.P. Quat. Res., 12: 83–118.

Taylor, D.M., 1990. Late Quaternary pollen records from two Uganda mires: evidence for environmental change in the Rukiga Highlands of Southwest Uganda. Palaeogeogr., Palaeoclimatol., Palaeoecol., 80: 283–300.

Van Grunderbeek, M.C., Doutrelepont, H. and Roche, E., 1984. Influence humaine sur le milieu au Rwanda et au Burundi à l'âge du fer ancien (220–665 A.D.). Apports de la palynologie et de l'étude de charbons de bois. Rev. Paléobiol., Vol. Spéc., pp. 221–229.

Van Zinderen Bakker, E.M. and Clark, J.D., 1962. Pleistocene climates and cultures in North-Eastern Angola. Nature, 196: 639–642.

Vincens, A., 1986. Diagramme pollinique d'un sondage pléistocène supérieur–holocène du lac Bogoria (Kenya). Rev. Palaeobot. Palynol., 47: 169–192.

Vincens, A., 1987. La sédimentation pléistocène supérieur–holocène. Pollens et spores: indices de l'évolution climatique. In: J.J. Tiercelin and A. Vincens (Coordinators), Le Demi-graben de Baringo–Bogoria, Rift Gregory, Kenya. 30 000 Ans d'Histoire Hydrologique et Sédimentaire. Bull. Cent. Rech. Explor. Prod. Elf-Aquitaine, 11: 437–451.

Vincens, A., 1989. Paléoenvironnements du bassin Nord-Tanganyika (Zaïre, Burundi, Tanzanie) au cours des 13 derniers mille ans: apport de la palynologie. Rev. Palaeobot. Palynol., 61: 69–88.

Vincens, A., 1991a. Late Quaternary vegetation history of the South-Tanganyika basin. Climatic implications in South Central Africa. Palaeogeogr., Palaeoclimatol., Palaeoecol., 86: 207–226.

Vincens, A., 1991b. Végétation et climat dans le bassin Sud-Tanganyika entre 25 000 et 9000 ans B.P.: nouvelles données palynologiques. Palaeoecol. Afr., 22: 253–263.

Vincens, A., 1993. Nouvelle séquence pollinique du lac Tanganyika. 30 000 ans d'histoire botanique et climatique du Bassin Nord. Rev. Palaeobot. Palynol., 78: 381–394.

White, F., 1983. The Vegetation Map of Africa. UNESCO, Paris, 356 pp.