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Breaks in the sedimentary and environmental equilibrium in the Congo Basin and incidences on the Oceanic sedimentation during Quaternary

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Abstract - Four climatic successions in the Congo region were observed for about 70 000 years B.P.: the first half of the Würmian or Wisconsinian (Maluekian, the most arid hypothermal phase), middle of Würmian (Njilien, wetter hyperthermal), Late Würmian (Leopoldvillian, dryer hypothermal) and Holocene (Kibangian, wetter hyperthermal). The strongest podzolisations were located turing Njilian and Kibangian episodes. Clayey and impermeable slopes were eroded mostly during seasonal contrast phases, sandy slopes were incised during more regularly humid climate where the water table was near the surface. Stone-line accumulations correspond to loss balance during climatic changes. The transition from a slightly arid period toward a most humid one is correlated with an increase of precipitation on slopes tending to stay with savannah environments; the oceanic signal corresponds in the speeding-up of rates of sedimentation (x6 to x10) and in the flushing of quartzose sands. Iron content in marine deposits is higher during hyperthermal episodes.

Résumé - Pendant les 70 derniers millénaires, on distingue la succession de quatre épisodes climatiques dans la région congolaise : première moitié du Würm (Maluékien, hypothermal plus aride), milieu Würm (Njilien, hyperthermal humide), fin du Würm (Léopoldvillien, hypothermal plus aride) et Holocène (Kibangien, hyperthermal humide). Les podzolisations les plus intenses se situent au Njilien et au Kibangien. L'érosion des versants argileux imperméables interviendrait surtout lors des phases à saisons les plus contrastées, celle sur versant sableux serait le fait des phases les plus pluvieuses où la saturation en eau se manifeste. Les renversements climatiques constituent des ruptures d'équilibre favorables à la mise en place de stone-lines. La transition d'une phase à tendance aride vers une phase plus humide se traduit par une intensification des précipitations sur des versants encore savanicoles, le signal océanique est donné par une accélération du rythme du dépôt (x6 à x10) et par le flux de sables quartzeux. Le fer est plus abondant dans l'océan lors des périodes hyperthermales.

INTRODUCTION

From 18 000 yrs B.P. up to the Present, major climatic changes combined with eustatic irregular sea level rise controlled important variations in sedimentary conditions on the Congolese and Gabonese margins between 6°S and 2°S. Geographic distributions and genetic to historic problems have been studied by many authors (Caratini and Giresse, 1979; Giresse and Odin, 1973; Giresse, 1980; Giresse *et al.*, 1981; Giresse, 1985; Moguedet *et al.*, 1986).

Other sources of environmental data were available from the continent (De Ploey, 1963; Giresse and Lanfranchi, 1984; Kinga-Mouzeo, 1986; Lanfranchi and Schwartz, 1988; Schwartz, 1985; Schwartz *et al.*, 1986), but unfortunately, the lack of similar and extensive data prevented a thorough review.

This paper has the following objectives: (1) to describe the main pedogenetic processes within the last 70 thousand yrs in the Brazzaville and Pointe-Noire regions, (2) to characterize the erosional evolution of some sandy and argillaceous valleys (Niari, Mayombe slopes and Brazzaville region); emphasis will be laid on some aspects of the phenomenon of stone-line formations, (3) to suggest palaeoclimatic and palaeophysiographic controls of these continental environments on deep sea-fan sedimentation of the Congo River and particularly on the succession of iron deliveries.

PRESENT ENVIRONMENTAL CONDITIONS

The important guide lines on paleoclimatic changes of physical parameters in the South-eastern Atlantic were proposed by Van Zinderen Bakker (1968 and 1975). He defines: (1) hypothermal phases (e.g. Glacial) of shift of Antarctic waters close to the southern limits of the African Continent, of extension of the Benguela Current close to the equator and of northern development of the Namibian desert; (2) hyperthermal phases (e.g. Interglacial) where the oceanic circulation was quite similar to that of present-day conditions. A hypothermal phase implies a northern position for the south Atlantic anticyclone and an important reduction in the extension of the Monsoon. Inversely, an hyperthermal phase implies a considerable development of this Monsoon (Fig. 1). This view point which is essentially based on the uneven geographic density of pollens and spores, is verified by recent palaeoclimatic reconstitutions (Maley, 1987).

A climatic index relevant to the Holocene and Upper Pleistocene paleo-environments signifies the occurrence of significant changes within the relatively continuous tropical environment. These changes occurred in continental as well as oceanic environment. The savanisation of the Congolese landscape during the hypothermal phases was almost general and each reappearance of equatorial precipitation constituted a rupture of the environmental equilibrium. The pedogenetic geochemical and sedimentological consequences of such ruptures will be examined.

The latitude of the continental studied area is close to the present day limits of the Guinea-Congolese and Angola forest zones which are of the Sudanese type. The oceanic area is also close to the present-day limits of circulation of dense and cold waters (e.g. Benguela Current) which stay at the surface during the southern dry season (Fig. 2).

Consequently, the climate and oceanic oscillations which are related to the large Quaternary glacial cycles will be particularly sensitive in this *transitional* sector.

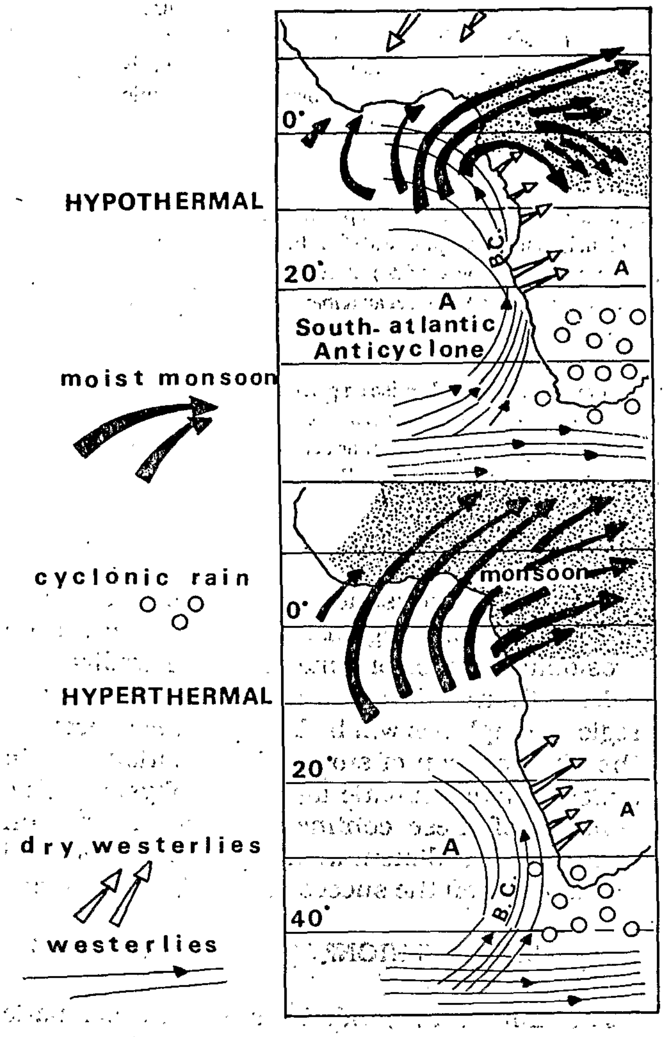

Fig. 1. Schematic interpretation of some trends of Atlantic Central African climatology during southern winters of hypothermal (glacial) periods and hyperthermal (interglacial) periods (after van Zinderen Bakker, 1968). B.C.: Benguela Current; dotted areas: high intensity of precipitation.

Fig. 1. Schéma de quelques mécanismes climatiques pendant les hivers austraux des périodes hypothermales et hyperthermales (d'après van Zinderen Bakker, 1968). B.C. : Courant de Benguela; les surfaces en pointillés correspondent aux zones de forte précipitation.

PEDOGENETIC VIEWPOINT

In the Kinshasa region (Fig. 3) De Ploey (1963) identified four climatic episodes for the period since about 70 000 yrs B.P.: the first half of the Würmian which is the most arid hypothermal phase (Maluekian), middle of Würmian which is a wetter hyperthermal (Njilien), Late Würmian which is a drier hypothermal (Leopoldvillian) and Holocene wetter hyperthermal (Kibangian). These four successions have profoundly affected the morphology of the soils and also influenced the pedogenetic processes of various areas of the Congo Basin.

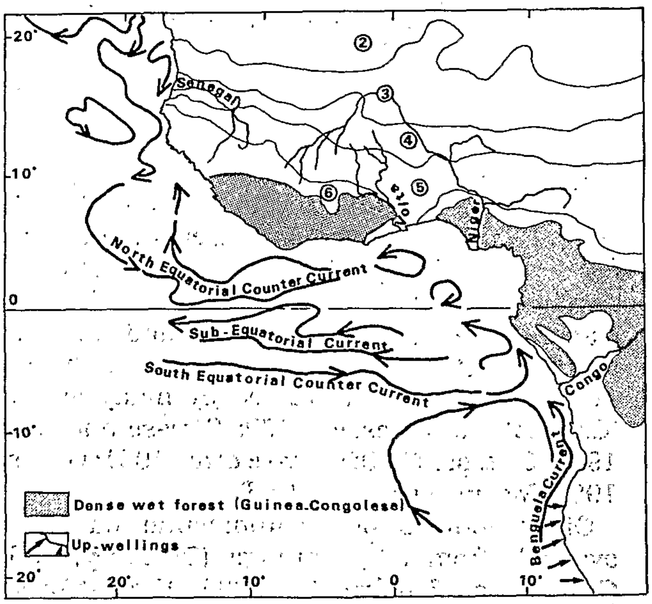

Fig. 2. Vegetation zones and oceanic circulation. 2: desert or Saharian 8teppe; 3: Sahelian savannah; 4: Soudanian savannah; 5: Soudanian-Guinean wooded savannah; 6: transition zone.

Fig. 2. Ceintures végétales et circulation océanique. 2: Désert ou steppe saharienne. 3: Savane sahélienne. 4: Savane soudanienne. 5: Savane arbustive soudano-guinéenne. 6: Zone de transition.

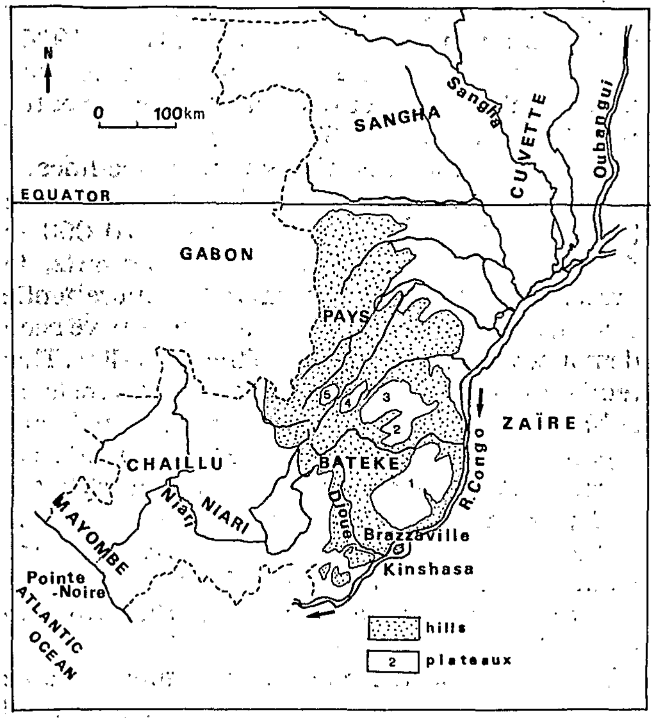

Fig. 3. Location of the studied areas in Congo P.R. Bateke Plateaux: 1- Mbé, 2- Ngo, 3- Nsa, 4- Djambala, 5- Koukouya.
Fig. 3. Localisation des zones d'observation en R.P. Congo. Plateaux Bateke: 1- Mbé, 2- Ngo, 3- Nsa, 4- Djambala, 5- Koukouya.

The soils preserved valuable records which facilitate the reconstruction of their history in relation with the paleoclimatic variations. It is the case of the coastal plains and the Bateke region where the sandy deposits were covered during various periods by tropical podzols (Schwartz, 1985).

In the Brazzaville region, the podzolisation was particularly intense during the Njilian humid period. The podzols were formed in the lower forest zone which was subjected to the action of fluctuating groundwater (Schwartz, 1986). Other less important phases of podzolisation have also been identified during the Kibangian. Podzols are mostly well drained and are situated in a terrace position; the vegetation is fairly uniform and is made up mostly of grasses dominated by *Loudetia simplex*.

In the sands around Pointe-Noire, on-going research by one of us (D.S.) has identified an important phase of podzolisation during the Kibangian in a similar forest environment that is flooded periodically. This podzolisation seems to be considerably slowed down by the dryness of the climate known around 3000-4000 yrs B.P. (Giresse and Lanfranchi, 1984).

In both cases, this pedologic evolution occurs within the more humid climatic periods. The permanence of a dry season is confirmed by the rather intensive fluctuation of the saturation-level which is a necessary condition for podzolisation.

Climate influence may be indirect but controls the presence of forested vegetation and the underground water. The mostly organic hardpans are characterized by *the virtually completed elimination of iron.*

In another topic, it is advisable to note that today the ferralitic soils of Northern Congo (Sangha) have a red tint whereas those of the southern part of this country have a yellow tone. This particular situation means that these yellow soils corresponded to a significant less contrasted climate than the red ones (Segalen, 1964). These features are contrary to the present climatic stage and may be probably due to an old rupture of equilibrium: a climatic inversion developed on both sides of the Equator.

EROSION VIEWPOINT

It is convenient to distinguish the evolution of basins that are predominantly argillaceous and of those that are predominantly sandy. In the argillaceous soils of the Niari valley (Fig. 3) the erosional forms are many and varied. They include the following: lavaka-type, sheet-type, terrace-type etc. There is every reason to believe that erosion is still presently very active. During the flood seasons the discharge can attain 51,8 mg/l as against 17,9 mg/l during the low season (Kinga-Mouzeo, 1986). Isotope analyses ($^{13}C/^{12}C$) of the organic component of the suspended load indicate a high contribution of savannah soil with graminea cover (analysis by Mariotti, in preparation).

The savannah isolated within the Mayombe forested block (Fig. 3) is equally subject to intensive forms of erosion. ^{13}C and ^{14}C analyses on paleosols super-imposed on the bottom of the valleys indicate that they are 1500 yrs old; during this period, there was a succession of several probably discontinuous phases of erosion (Schwartz and Lanfranchi, in press). This type of wooded savannah or sparsely wooded forest appears palaeoclimatic just as the slightly depreciated climate that was known around 3-4000 B.P. (Giresse and Lanfranchi, 1984) but it could also be comparable to more ancient relics of the last hypothermal savannah (Leopoldvillian) which the advancing Holocene forest (Kibangian) did not have time to erase. It was probably broken up by the first farming population so-called Bantu population (last millenary).

Over the sandy slopes, the modalities seem to be different. If De Ploey (1963) estimated that the driest climatic periods (with contrasted seasons) were the most favourable to erosion, then the results of our analyses carried out seems to be contrary. In reality, all the ^{14}C datations on reworked soils fall within the Kibangian and particularly within the Kibangian A which is more humid (12 000 to 3-4000 B.P.) (Lanfranchi and Schwartz, in press). Sauter (1970), in his study of erosional cycles, already proposed this hypothesis without being able to prove it then. This reworking is directly related to the sandy nature of the materials. During the wet climatic periods, these soils within which water infiltration is extremely rapid remain saturated. This situation was long enough to permit the intervention of the minimum force which could initiate erosion.

The stream along the sandy slopes (Djoué, Djili) (Fig. 4) near Brazzaville, presently has a low solid charge rate (4.6-7.1 mg/l) and its organic material shows $^{13}C/^{12}C$ ratio that typifies contribution from forest galleries along river banks (Kinga-Mouzeo, 1986). Depending on the dominance of infiltrating rain water, the savannah organic material from the slopes may not intervene whilst that form the river banks of the basin dominates.

Thus erosion of the sandy material appears to be recorded within the most rainy climatic periods. Whereas on the argillaceous materials the abrasion will rather be more during the hypothermal phases when the most contrasted seasons will be consequential.

STONE-LINE FORMATIONS

Stone-lines are decimetric or metric pebble layers which are interbedded in soil formations. These layers roughly parallel to the topographic surface are compound of ferruginous cuirasse remains, parent rock or neighbour rock fragments and sometimes of prehistoric tools.

This complex phenomenon has been differently explained by several authors. In the Congo and neighbouring regions, most authors attribute them to lateral reworking (Riquier, 1969; Gras, 1970). This lateral reworking is sometimes combined with termite action in order to explain the origin of the stone-lines (Stoops, 1967).

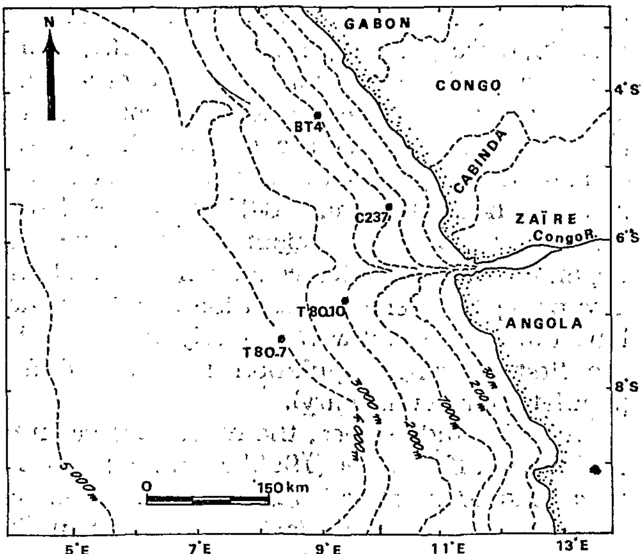

Fig. 4. Locations of the cores mentionned in the text.
Fig. 4. Situation des carottes citées dans le texte.

In the Mayombe and the Sangha stone-lines, a major prehistoric industry of middle stone-age (Sangoen facies) is dated at around 70 000 to 40 000 yrs B.P. (Lanfranchi and Schwartz, in press). In the Sangha sector along the more gentle slopes, undisturbed areas of habitation have been demonstrated at the surface of the stone-line. This tends to support the hypothesis of erosional cobblestones without transport. Different arguments (absence of most recent prehistoric tool assemblages, no-reworked deposits, overlying of various stone-line with the same prehistoric tools...) suggested that the formation of cover horizons resulting from the mobilisation of materials brought up by termites, promptly succeeded the formation of the stone-line.

The totality of this phenomenon appears to be situated within the last but one hypothermal (Maluekian, 70 000-40 000 B.P.) and particularly during the climatic reversal of 40 000 yrs just before Njilian. Such a phase of rupture of equilibrium is more favourable to this type of event: the climate was sufficiently humid to permit transportation along the slopes but the vegetation cover was not yet sufficient to stop erosion.

EVIDENCE OF SEDIMENTARY AND GEOCHEMICAL ACCUMULATION IN THE OCEAN

The accumulation of detritic deposits in the deep sea-fan of the Congo River shows that in the abyssal plain environment, a higher rate of deposition of planktonic carbonates with slight dissolutions occurred during the warm biozones Z, X, ... (Jansen *et al.*, 1984). On the contrary, the non-carbonate sedimentation (siliclastic and opal) accentuated during the cold water biozones (Y, W,...).This therefore conforms the importance of carbonate peaks.

On the continental slopes, one observes a carbonate peak around 14 000 B.P. inside of a rapid phase of carbonate accumulation extending from 27 000 to 12 500 yrs B.P. In fact, this peak is the consequence of a diminution in the rate of deposition of non-carbonate clastics. During hypothermal phases, opal can account for 50-65 % of the total sediment but only for 35-45 % during hyperthermal phases (Jansen *et al.*, 1984 and Van der Gast and Jansen, 1984). These fluctuations take into consideration the rate of non-carbonate deposition which is 3,6-5,3 times higher during glacial phases than during interglacial phases.

One can also infer a rate terrigenous siliclastic material accumulation which is twice as high during glacial phases where the vegetation cover and the rain falls are more irregular.

Cores from the slopes and near the mouth of the Congo River (237 and BT 4) permit to control the rupture in sedimentation that occur during the transitions between hypothermal and hyperthermal phases. The rate of sedimentation for the last 25 000 yrs was estimated with precision on slightly compacted sediments for which several ^{14}C dates were available (Fig. 5).

The rate of sedimentation at -1000 m off the mouth of Congo River before the Holocene was in the order of 40-60 cm/10^3 yrs but increased abruptly to 160 cm/10^3yrs between 11 000 and 10 000 B.P. (Fig. 5). This increase is interpreted to be a function of renewed precipitations on the slopes where the savannah was not yet invaded by "ombrophile" forest (Caratini and Giresse, 1979). This increased rate of sedimentation is more intense on the Niger delta where around -1000 m, it rises to 650 cm/10^3 yrs (Pastouret *et al.*, 1978). It is explained by the denudation of the flanks of the river basin which was more intense than that of the Congo and therefore suggests intensive erosion. About 300 km north away from the mouth of the Congo River, the average deposition rate diminishes strongly and therefore this pre-Holocene accelerated sedimentation is not recorded.

At 2000 m water depth (Core T 80-10) off the mouth of the Congo, the rate of accumulation is more moderate but the accelerated rate of sedimentation (114 cm/10^3 yrs) was still recorded around 11 000 yrs B.P.

On the other hand, at -4000 m the depositional rhythm is slow and relatively constant (in the order of 3 to 7 cm/10^3 yrs). It does not allow the observations of the rupture at 11 000 yrs B.P. where the amplitude, if it exists, can only be identified at this scale of measurement.

The alluvial increased influence of the Congo River from 11 000 yrs to the present is characterized by the supply to the oceanic basin of grains of quartz larger than 50 µm, rare but significant. The counting of grains shows a sudden change from Y to Z at -1000 m (C237). It is more moderate at -2000 m (T 80-10) where however the passage from W to X is similarly recorded. At -1000 m and 300 km from the mouth (BT 4), these grains are rare and their distribution is of less importance, if not for their rarity in the isotopic 2 stage. The contents could be seen as constant enough at -4000 m (Fig. 6).

The iron, despite its probable link with different components of alluvial organic matter, shows no positive correlation with organic carbon. In fact, organic carbon has partial oceanic origin which is obvious especially during cold biozones (Y, W) with strong primary productivity (Fig. 7). In a drainage basin in which the sandy or gritty terrain constitutes about 75 % of the surface area, the podzolisation represent a significant phenomenon of pedogenesis which spread during

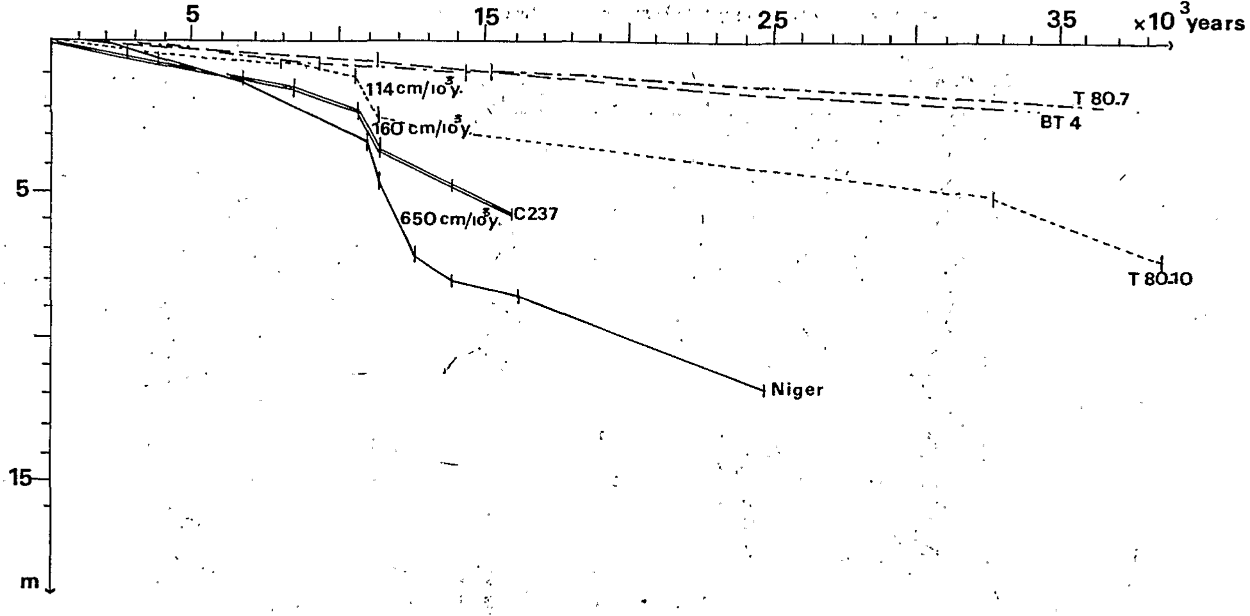

Fig. 5. Comparison of the sedimentation rates of the Niger river mouth (depth: ca 1000 m) and Congo river mouth (depth: C 237 ca 1000 m, T 80-10 ca 2000 m, T 80-7 ca 4000 m); core BT 4 (depth: ca 1000 m) is located at some 300 km northern Congo river mouth.

Fig. 5. Comparaison des vitesses de sédimentation au large des embouchures du Niger (profondeur vers 1000 m) et du Congo (C 237: profondeur vers -1000 m, T 80-10: profondeur vers 2000 m et T 80-7: profondeur vers 4000 m); la carotte BT 4 (vers -1000 m) est située vers 300 km au Nord de l'embouchure du Congo

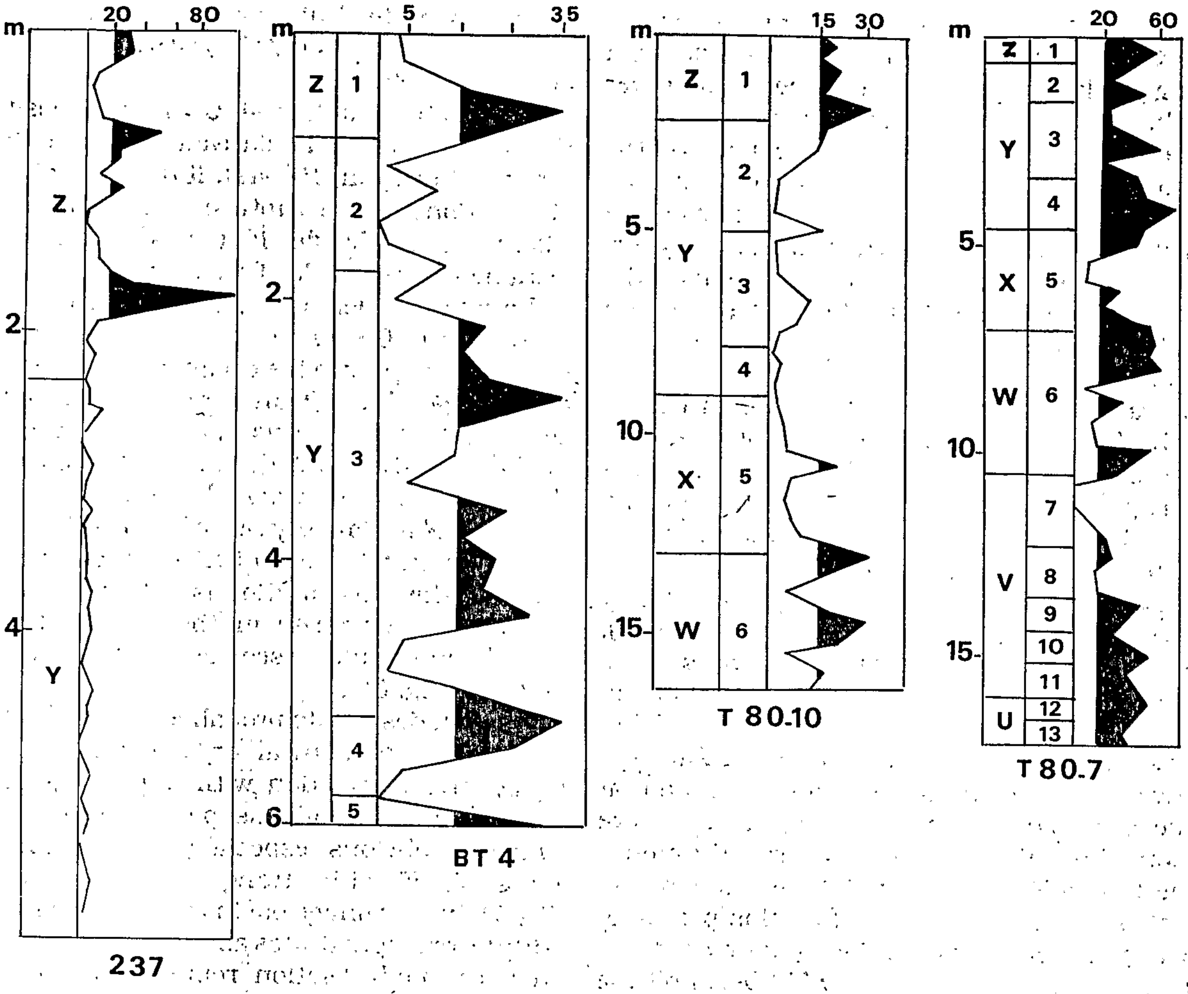

Fig. 6. Quartz distribution from C 237, BT 4, T 80-10 and T 80-7 cores. Age scale derived from ^{14}C data and oxygen isotopi curves from *Globigerinoides ruber*.

Fig. 6. Teneurs en grains de quartz dans la carotte C 237, BT 4, T 80-10 et T 80-7. La chronostratigraphie est basée sur les datations au ^{14}C sur les courbes isotopiques de l'oxygène à partir de *Globigerinoides ruber*.

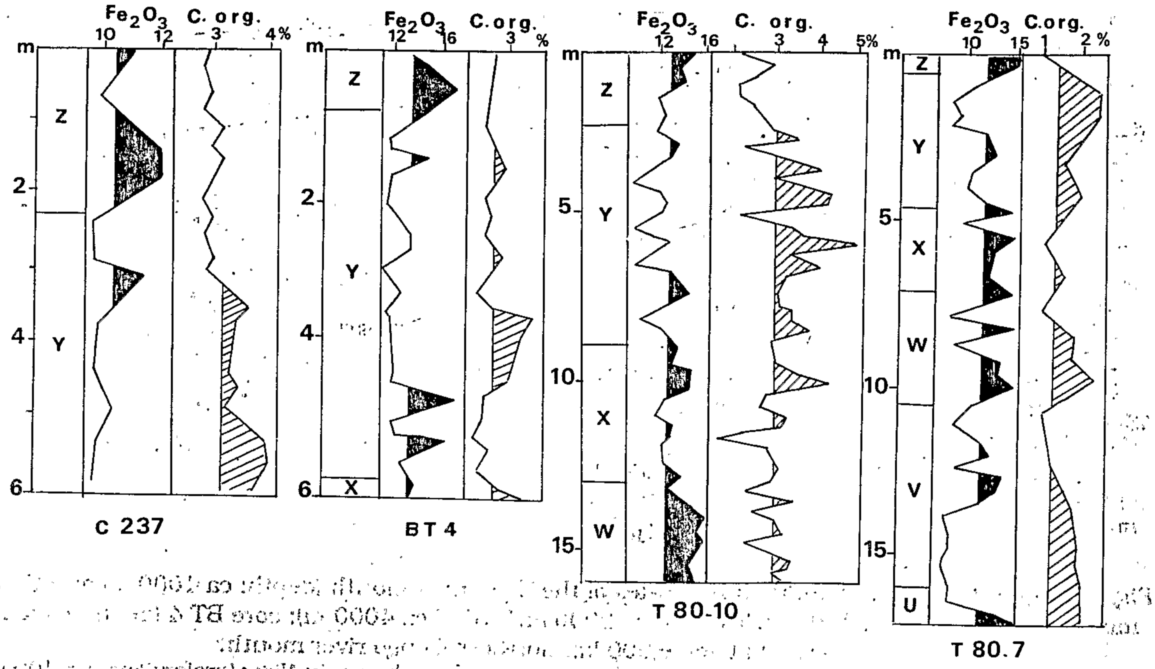

Fig. 7. Iron and organic carbon distribution from C 237, BT 4, T 80-10 and T 80-7 cores.

Fig. 7. Distribution du fer et du carbone organique d'après les carottes C 237, BT 4, T 80-10 et T 80-7.

the most humid periods. These periods are related with an extension of some swamps and with some forest environment periodically flooded.

The components of these podzols show a virtual absence of iron (Schwartz, 1985) whose transfer to microcolloidal state has attained the maximum levels during hyperthermal periods. The curves of Fe_2O_3 (Fig. 7) shows us the relative concentration of iron from Y towards Z at -1000 m (C 237 and BT 4) and at 2000 m. In the levels X and W from 2000 m and W, V and U from 4000 m, the diagenetic iron mobility appears to have interfered with the initial accumulation, but even at 4000 m, the difference between Y and Z is still appreciable. It should be emphasized that all the contents of iron are elevated (10 to 15%) regardless of the bathymetry, but they are higher (up to 22%) in the deposits of the shelf off the mouth where they allow the abundant and localised development of glauconitisation. In view to record the changes of the intensity of podzolisation, the shelf forms a site probably more suitable to establish a succession of the state of iron delivery, but we unfortunately only have the last evidence subsequent to 20-25 000 yrs before the present.

REFERENCES

Caratini, C. and Giresse, P. 1979. Contribution à la connaissance des environnements continentaux et marins du Congo à la fin du Quaternaire. *C.R. Acad. Sc. Paris*, **288**, D, 379-382.

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

Giresse, P. 1980. Carte sédimentologique du plateau continental du Congo. *ORSTOM*, Paris, Notice explicative, **85**, 24 p.

Giresse, P. 1985. Le fer et les glauconies au large de l'embouchure du Congo. *Sci. Géol. Bull. Strasbourg*, **38(4)**, 293-322.

Giresse, P. and Odin, G. S. 1973. Nature minéralogique et origine des glauconies du plateau continental du Gabon et du Congo. *Sedimentology*, **20**, 457-488.

Giresse, P, Jansen, J. H. F., Kouyoumontzákis, G. and Moguedet, G. 1981. Les fonds du plateau continental congolais et le delta sous-marin du fleuve Congo. Bilan de huit années de recherches sédimentologiques, paléontologiques, géochimiques et géophysiques. In: *Milieu marin et Ressources halieutiques de la République du Congo*. **138**, 13-45. *Trav. et Doc. ORSTOM*, Paris, France.

Giresse, P. and Lanfranchi, R. 1984. Les climats et les océans de la région congolaise pendant l'Holocène. Bilans selon les échelles et les méthodes de l'observation. *Palaeoecology of Africa*, **6**, 77-88.

Gras, F. 1970. Surfaces d'aplanissement et remaniement des sols sur la bordure orientale du Mayombe. *Cah. ORSTOM*, Sér. Pédol., **VIII(3)**, 274-294.

Jansen, J. H. F., Van Weering, T. C. E., Gieles, R. and Van Iperen, J. 1984. Middle and Late Quaternary oceanography and climatology of the Zaire Congo fan and the adjacent eastern Angola Basin. *Netherlands J. of Sea Research*, Texel, **17(2-4)**, 201-249.

Kinga-Mouzeo 1986. Transport particulaire actuel du fleuve Congo et de quelques affluents; enregistrement quaternaire dans l'éventail détritique profond (sédimentologie, minéralogie et géochimie). Thèse Doc. Univ. Perpignan, mention Géologie, 252 p.

Lanfranchi, R. and Schwartz, D. 1989. L'évolution du Mayombe congolais à la fin du Quaternaire. Nouvelles données géomorphologiques, pédologiques et préhistoriques. Catena (in press).

Maley, J. 1987. Fragmentation de la forêt dense humide africaine et extension des biotopes montagnards au Quaternaire récent: nouvelles données polliniques et chronologiques. Implications paléoclimatiques et biogéographiques. *Palaeoecology of Africa*, **18**, 307-334.

Moguedet, G., Bongo-Passi, G., Giresse, P. and Schwartz, D. 1986. Corrélations entre sédiments quaternaires continentaux et marins au Congo. *Rev. Géol. dynam. Géogr. phys.*, **27**, 2, 131-140.

Pastouret, L., Chamley, H., Delibrias G., Duplessy, J. C. and Thiede, J. 1978.

Late Quaternary climatic changes in Western Tropical Africa deduced from deep-sea sedimentation of the Niger delta. *Oceanologica Acta*, **1(2)**, 217-231.

Riquier, J. 1969. Contribution à l'étude des "stone-lines" en régions tropicale et équatoriale. *Cahiers ORSTOM*, sér. Pédol., **VII(1)**, 70-110.

Sauter, G. 1970. Essai sur les formes d'érosion en «cirques» dans la région de Brazzaville. *Mém. Doc. CNRS*, **9**, 170 p, Paris.

Schwartz, D. 1985. Histoire d'un paysage: le Lousseke. Paléoenvironnements quaternaires et podzolisation sur sables Batéké (quarante derniers millenaires, région de Brazzaville, R.P. Congo). Thèse Doct. Etat, Univ. Nancy I, 215 p.

Schwartz, D., Mariotti, A., Lanfranchi, R. and Guillet, B. 1986. $^{13}C/^{12}C$ ratios of soil organic matter as indicators of vegetation change in the Congo. *Geoderma*, **39(1)**, 97-103.

Schwartz D. and Lanfranchi R. (in press). Les remaniements de sols dans la région de Brazzaville. *Mém. ORSTOM*, Paris.

Segalen P. 1964. Le fer dans les sols. I.D.T. n°4, ORSTOM, Paris, 150 p.

Stoops, G. 1967. Le profil d'altération au bas-Congo (Kinshasa), sa description et sa genèse. *Pédologie*, **XVII(1)**, 60-105.

Van der Gast, S. J. and Jansen, J. H. F. 1984. Mineralogy, opal and manganese of Middle and Late Quaternary sediments of the Zaire (Congo) deep-sea fan: origin and climatic evolution. *Netherlands J. of Sea Research*, **7(2-4)**, 313-341.

Van Zinderen Bakker, E. M. 1967. Upper Pleistocene and Holocene stratigraphy and ecology on the basis of vegetation changes in sub-Saharan Africa. In: *Background to Evolution in Africa* (W. W. Bishop and Desmond Clark Eas), 125-147. Univ. Chicago press. U.S.A.

Van Zinderen Bakker, E. M. 1975. The origin and paleoenvironment of the Namib Desert biome. *J. Biogeogr.*, **2**, 65-73.