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Reconstruction of Palaeoenvironments in Tropical Africa during the Würm Glacial Maximum: A Review

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ヴュルム氷期最寒期における熱帯アフリカの古環境復原——展望

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Introduction

It has been suggested by many writers that most of the landforms in humid tropical Africa are not monogenic ones being developed under the stable bioclimatic conditions, but are polygenic and multicyclic ones being developed under the influence of palaeoclimatic oscillations (*e. g.* Tricart, 1963; Fairbridge, 1964; Tricart et Cailleux, 1965; Thomas, 1974; Zonneveld, 1975). The author and his colleagues have also supported such idea on the basis of a field research in the forest and savanna areas of Cameroon (Kadomura, ed., 1977), and have a view of palaeoenvironments in the present-day rainforest zone during the Würm Glacial Maximum (Kadomura and Hori, 1978).

In the present paper, different views on the palaeoenvironments during the glacial maximum are compared in the form of diagram, and palaeoclimatic and palaeoenvironmental maps are compiled using recently published data, so as to review the questions inherent in the studies of late-Quaternary palaeoenvironments and geomorphology in tropical Africa. Because of limitations of space author's views will be given in the form of diagram and map, and the references are selected mainly from the collective articles, excepting for those dealing with landforms, superficial deposits and soils.

Palaeoenvironments at Around 18,000 B. P.

It was formerly believed that a glacial stage in the high latitudes equaled a pluvial stage in the low latitudes. Based on this theory, Büdel (1953, 1963) sug-

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gested that during the Würm while dry zone of the Sahara was reduced in size to a considerable extent, the savanna zone extended northwards into the present-day desert, with a slight northward extension of rainforest zone (Fig. 1). However, such view of palaeoenvironments on the basis of the theory of glacial-pluvial synchronism is not correct as criticized by Tricart (1963), Fairbridge (1964), Tricart et Cailleux (1965), and others. Although available data are still fragmental, much of recent studies have revealed widespread aridity over tropical Africa during the glacial maximum, not only over Sahelian to Sudanase Zones (*e.g.* Michel, 1971, 1977; Rognon, 1976; Talbot, 1978) but also over savanna and rainforest zones (*e.g.* Aubréville, 1962; Fairbridge, 1964, 1972; Zinderen Bakker, 1967, 1976 a; Zinderen Bakker and Coetzee, 1972; Hamilton, 1976; Nicholson, 1978).

Figure 1 shows a summary of the views on Würm Glacial Maximum palaeoenvironments proposed by various authors. A sketch map of palaeoclimates in Africa during the Würm Glacial Maximum has been compiled using data presented in Fairbridge (1964, 1972), Zinderen Bakker (1967, 1967 b), and Rognon (1976) (Fig. 2). Published data which are thought to be indicative of palaeoclimatic and palaeoenvironmental conditions during the Würm Glacial Maximum, culminating at around 18,000 B. P., have been plotted on Fig. 3. Considering the accuracy of datings and the length of the cold stage, those data cover the dates 18,000±3,000 B. P. have been used in compiling Fig. 3. According to these figures, Würm Glacial Maximum palaeoclimates and palaeoenvironments in Africa would be summarized as follows:

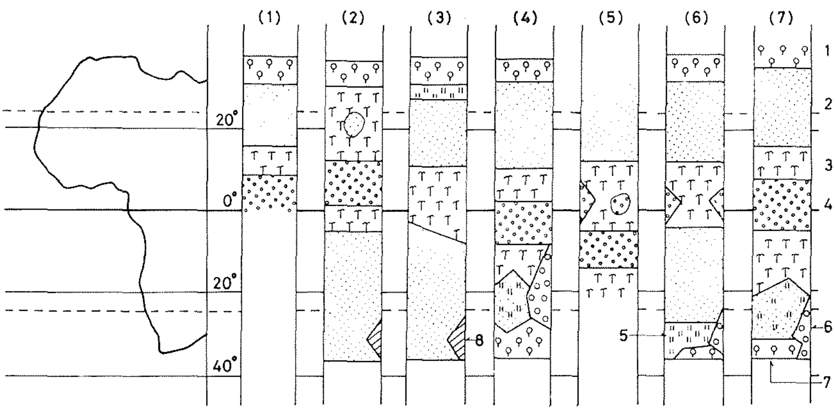

Fig. 1. Different views on Würm Glacial Maximum palaeoenvironments in Africa (Modified from Gellert, 1974)

Vegetation zones during Würm Glacial Maximum

(1): Büdel, 1953, (2): Büdel, 1963 (Northern Hemisphere only); Suzuki, 1975, (3): Kobayashi and Sakaguchi, 1977, (4): Gellert, 1974, (5): Aubréville, 1962, (6): Present paper.

Present vegetation zones

(7): Gellert, 1974.

1: Mediterranean hard leaf forest, 2: Desert and semi-desert, 3: Savanna and woodland, 4: Tropical rainforest, 5: Steppe, 6: Subtropical forest, 7: Cape hard leaf forest, 8: Tundra. Effective for 0°-30°E except for Büdel (1953).

(1) The development of inland ice sheet over North Europe and cooling of ocean water of high to middle latitudes in both hemispheres resulted in the increase in thermal gradient between the middle and low latitudes, strengthening meridional atmospheric circulation.

(2) This led to equatorward displacement of all climatic belts of both hemispheres. As a result, the northern margins of the Sahara and the southern margins of the Kalahari became wetter than the present conditions because the westeries bringing winter rains enchroached on those areas. Data on the palaeoclimatic conditions in the Kalahari are still in dispute (Heine, 1978, 1979 ; Cook, 1979).

(3) The southern Sahara and the Sahelian zone, over which the strongly

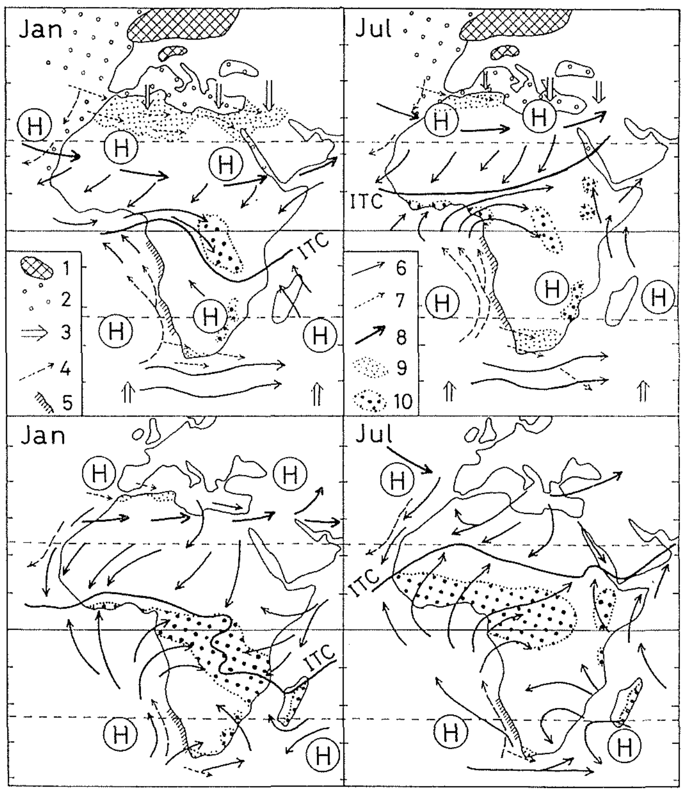

Fig. 2. Climates during Würm Glacial Maximum and present

Würm Glacial Maximum (Top : after Fairbridge, 1964, 1972 ; Rognon, 1976 ; Rognon and Williams, 1977 ; Zinderen Bakker, 1967, 1976 b)

1 : Ice sheet and cap, 2 : Oceanic cooling, 3 : Advection of polar air, 4 : Cold current, 5 : Up-welling, 6 : Prevailing wind, 7 : Path of temperate depressions, 8 : Position of jet stream, 9 : Temperate rainfall, 10 : Intertropical rainfall (Area of heavy rainfall).

Present (Bottom : after Tsuchiya, ed., 1972)

10 : Intertropical rainfall (Jan : Area of heavy rainfall of more than 750 mm during November-April ; Jul : Area of heavy rainfall of more than 750 mm during May-October).

ITC : Intertropical convergence, H : anticyclone.

Fig. 3. Reconstruction of palaeoenvironments in Africa during Würm Glacial Maximum at around 18,000 B. P.

Würm Glacial Maximum Palaeoenvironments

1: Ice cap, 2: Sand dune area, 3: Effective wind regime, 4: Tropical lowland forest, 5: Tropical montane forest, 6: Impoverished montane forest, 7: Woodland, savanna and steppe, 8: Subtropical forest, 9: Possible migration of tropical rainforest, 10: Possible migration of woodland and savanna, 11: High lake-level indicative of more humid climate than today, 12: Low lake-level or desiccation indicative of more arid climate than today, 13: Pollen evidence of drier conditions, 14: Superficial deposits like pediment gravels and stone-lines, or gully development indicative of drier conditions or reduced vegetation cover. Figures indicate thousand years B.P.

Present

15: Natural limit of tropical rainforest, 16: Limit of active dune area, 17: Main rivers, the courses of which were dried up and blocked everywhere by the development of sand dunes during glacial maximum.

Data based on 1–3: Sarnthein and Diester-Haass (1977), 4–7: Aubréville (1962); Hamilton (1976), Zinderen Bakker (1976 a, 1976 b), 8–10: Zinderen Bakker (1976 b), 11–12: Rognon (1976); Rognon and Williams (1977); Street and Grove (1976), 13: Zinderen Bakker and Coetzee (1972), 14: West Africa—Fölster (1969); Rohdenburg (1969), Bruke and Durotoye (1971); Michel (1971, 1978); Talbot (1978), Central Africa—Vogt (1962); De Ploey (1965); Fritsch (1969, 1970); Hervieu (1970); Hurault (1970); Kadomura, ed. (1977); Kadomura and Hori (1978), Southern Africa—Alexandre et Alexandre-Pyre (1970); Heine (1978), 15: Hamilton (1976).

reinforced subtropical anticyclones advanced from the north, experienced strong aridity. Such changes in the subtropical anticyclones seem related to change in the position and wave amplitude of the subtropical jet stream (Rognon, 1976; Rognon and Williams, 1977). Together with the intensification of trade winds, the Sahelian zone was replaced by active dune building field and the Saharan sands spread as far south as at least 500 km from the present limit.

(4) In the southern hemisphere dune building in the Kalahari was also strongly activated due both to the great aridity and the intensification of trade winds. This resulted in the greater extension of the Kalahari sands to the Congo Basin and the northern limit crossed the Congo (the Zair).

(5) Most of the main rivers of the continent such as the Zair, the Nile, the Niger and the Senegal were dried up and blocked here and there by the development of dunes.

(6) On the southwest coast of Africa, extreme aridity was also evidenced by the extension of the Namib desert, especially northward extension. The northward migration of South Atlantic anticyclone and the cold Benguela Current with near-shore up-wellings gave an aridifying effect on the adjacent coast, by condensing moist sea air and forming coastal fog banks (Zinderen Bakker, 1976 b; Tankard and Rogers, 1978).

(7) The lowering of sealevel at 100 m or more led to the increase of continentality, and also contributed to the desiccation of inland areas. The lowering of sealevel resulted in the lowering of ground water level, and this would also lead to aridity, drought and desert expansion (Mörner, 1978).

(8) The ITCZ retreated equatorward from both hemispheres, and the belt receiving monsoonal rains narrowed to a great extent. Lower sea surface temperature which reduced evaporation also contributed to the decrease of monsoonal rains.

(9) The combined effect of equatorward migration of drier belts from both hemispheres, the great decrease of rainfall and the intensification of rainfall seasonality over the equatorial belt, and increased continentality and lowered ground water level resulting from the lowering of sealevel would had brought drastic aridity throughout tropical Africa.

(10) Such desiccation inevitably led to vegetational changes and the distribution of lowland tropical rainforest would be extremely limited to the scattered "refuges" along the coast of the Gulf of Guinea and of eastern Zair.

(11) Such changes in the forest vegetation have also been supported by other biogeographical evidences on the distribution of birds, butterflies, etc. (Hamilton, 1976).

(12) Most of the equatorial belt, presently occupied by dense moist forest, would be replaced by woodland or savanna vegetation being invaded from adjacent areas.

Problems and Conclusions

As mentioned above, our knowledge on the basis of published data so far has revealed that tropical Africa during the Würm Glacial Maximum would had experienced widespread, drastic aridity. However, in the rainforest zone reliable data indicating the palaeoclimates or palaeoenvironments are still very sparse, and no radiometrically-dated data are available until now. All of the data in this zone have been derived from interpretation of superficial deposits like pediment gravels and stone-lines, and fossil gullying and other geomorphological evidences, the palaeoenvironmental implications of which call for careful interpretations. In addition, the picture of vegetational changes in the equatorial belt of West and Central Africa is based largely on speculations. Well-dated palaeoenvironmental studies are almost completely lacking in this belt, as evidenced in Fig. 3. To reconstruct a more detailed picture of palaoenvironmnts in tropical Africa requires intensive studies of the rainforest zone which are based on absolute datings as well as more dependable palaeoenvironmental indicators.

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References

Alexandre, J. et Alexandre-Pyre, S. (1970): Les surfaces d'aplanissement d'une région de savane (Haut Katanga). *Z. Geomorph.*, Suppl., **9**, 127–137.

Aubréville, A. (1962): Savanisation tropicale et glaciations quaternaires. *Adansonia, N. S.*, **2** (1), 16–84.

Burke, K. and Durotoye, A. B. (1971): Late Quaternary climatic variation in south-western Nigeria: evidence from pediments and pediment deposits. *Étude sur le Quaternaire dans le Monde*, **1**, VII Congrès INQUA, Paris 1969, 143–153.

Büdel, J. (1953): Die "Periglaziale"-morphologische Wirkungen des Eiszeitklima auf der ganzen Erde. *Erdkunde*, **7**, 249–265.

Büdel, J. (1963): Die jungpliozänen und quatären "Pluvialzeiten" der Sahara. *Eiszeitalter und Gegenwart*, **13**, 167–187.

Cook, H. J. (1979): K. Heine: Radiocarbon chronology of late-Quaternary lakes in the Kalahari, southern Africa: A discussion. *Catena*, **6**, 107.

De Ploey, J. (1965): Position géomorphologique, génèse et chronologie de certains dépôts superficiels au Congo Occidental. *Quaternaria*, **7**, 131–154.

Fairbridge, R. W. (1964): African ice age aridity. In A. E. M. Nairn, ed., *Problems of Palaeoclimatology*, Interscience Publication, New York, 356–360.

Fairbridge, R. W. (1972): Climatology of glacial cycle. *Quaternary Res.*, **2**, 283–302.

Fölster, H. (1969): Slope development in SW-Nigeria during late Pleistocene and Holocene. *Giessener Geogr. Schrift.*, **20**, 3–56.

Fritsch, P. (1969): Note preliminaire sur la morphologie du piémont Nord de l'Adamaoua, dans la région de Kontcha (Cameroun). *Ann. de Fac. Sci. du Cameroun*, **3**, 101–111.

Fritsch, P. (1970): Reconnaissance morphologique de la Plaine Tikar (Cameroun). *ibid.*, **4**, 35–51.

Gelleit, J. F. (1974): Pluviale und Interpluviale in Afrika—Geologische-paläokilmatische und paläogeographische Fakten und Probleme. *Petrm. Geogr. Mitt.*, **98**, 104–116.

Hamilton, A. (1976): The significance of patterns of distribution shown by tropical plants and animals in tropical Africa for the reconstruction of upper Pleistocene palaeoenvironments: A review. *Palaeoecol. Afr.*, **9**, 63–97.

Heine, K. (1978): Radiocarbon chronology of late-Quaternary lakes in the Kalahari, southern Africa. *Catena*, **5**, 145–149.

Heine, K. (1979): Reply to Cook's discussion of: K. Heine: Radiocarbon chronology of Late Qurternary Lakes in the Kalahari, southern Africa. *Catena* **6**, 259–266.

Hervieu, J. (1970): Influence des changements climat quaternaires sur le relief et les sols du Nord-Cameroun. *Ann. de Géogr.*, **433**, 386–398.

Hurault, J. (1970): Les lavaka de Banyo (Cameroun), témoins de paléoclimats. *Bull. Ass. Géogr. fr.*, **377/378**, 3–13.

Kadomura, H., ed. (1977): *Geomorphological Studies in the forest and savanna areas of Cameroon: An interim report of the Tropical African Geomorphology Research Project-1975/76.* Spec. Publ. No. 1, Lab. Fundament. Res., Div. Environ. Structure, Grad. Sch. Sci., Hokkaido Univ., 130 p.

Kadomura, H. and Hori, N. (1978): Some notes on landforms and superficial deposits in the forest and savanna zones of inland Cameroon. *Geogr. J.* (*Tokyo*), **87**, 349–467. (in Japanese with English summary)

Kobayashi, K. and Sakaguchi, Y. (1977): Reappraisal of ice age. *Kagaku*, **47**, 578–591. (in Japanese)

Michel, P. (1971): Chronologie du quaternaire des bassins des fleuves Sénégal et Gambie: essai de synthèse. *Étude sur le Quaternaire dans le Monde*, **1**, VII Congrès INQUA, Paris 1969, 49–61.

Michel, P. (1977): Recherches sur le Quaternaire en Afrique Occidentale. *Suppl. au Bull. AFEO*, 1977–1, **50**, 143–154.

Mörner, N.-A. (1978): Palaeogeoid changes and palaeoecological changes in Africa with respect to real and apparent palaeoclimatic changes. *Palaeoecol. Afr.*, **10**, 1–12.

Nicholson, S. E. (1978): Comparison of historical and recent African rainfall anomalies with late Pleistocene and early Holocene. *ibid.*, **10**, 99–123.

Rohdenburg, H. (1969): Hangpedimentation und klimawechsel als wichitigste Faktoren der Flächen-und Stufenbildung in der wechselfeuchten Tropen an Beispielen aus Westafrika, besonders aus dem Schichtstufenland Südost-Nigerias. *Giessener Geogr. Schrift.*, **20**, 57–152.

Rognon, P. (1976): Essai d'interprétation des variations climatiques du Sahara depuis 40,000 ans. *Rev. Géogr. phys. Géol. dyn.* (2), **18**, facs. 2–3, 251–282.

Rognon, P. and Williams, M. A. J. (1977): Late Quaternary climatic changes in Australia and North Africa: A preliminary interpretation. *Palaeogeogr. Plalaeoclimat. Palaeoecol.*, **21**, 285–327.

Sarnthein, M. and Diester-Haass, L. (1977): Eolian-sand turbiditites. *J. Sed. Pet.*, **47**, 868–890.

Street, F. A. and Grove, A. T. (1976): Environmental and climatic implications of late Quaternary lake-level changes in Africa. *Nature*, **261**, 385–390.

Suzuki, H. (1975): *Glacial age.* Kodansha, Tokyo, 189 p. (in Japanese)

Talbot, M. R. (1978): Environmental response to climatic changes in the west African Sahara over the past 20,000 years. In: M. A. J. Williams and H. Faure, eds., *The Sahara and the Nile*, A. A. Balkema, Rotherdam, 37–62.

Tankard, A. and Rogers, J. (1978): Late Cenozoic palaeoenvironments on the west coast of southern Africa. *J. Biogeogr.*, **5**, 319–337.

Thomas, M. F. (1974): *Tropical geomorphology: A study of weathering and landform development in warm climates.* Macmillan, London and Basingstoke, 332 p.

Tricart, J. (1963): Oscillations et modifications de caractère de la zone aride en Afrique et en Amérique latine lors des périodes glaciers des hautes latitudes. *Arid Zone Research* **XX**, Paris: UNESCO, 415–419.

Tricart, J. et Cailleux, A. (1965): *Introduction à la géomorphologie climatique.* SEDES, Paris, 306 p. English translation by C. J. Kiwiet Jong. Longman, 1972, 295 p.

Tsuchiya, I., ed. (1972): *Climates of Africa.* Kokonshoin, Tokyo, 637 p. (in Japanese)

Vogt, J. (1962): Note de géomorphologie gabonasie. *Rev. Géomorph. dyn.*, **13**, 161–169.

Zinderen Bakker, E. M. van (1967): Upper Pleistocene and Holocene stratigraphy and ecology on the basis of vegetation changes in Sub-Sahara Africa. In: W. W. Bishop and J. D. Clark, eds., *Background to evolution in Africa*, Univ. Chicago Press, 125–147.

Zinderen Bakker, E. M. van (1976 a): Frontispiece and its explanation. *Palaeoecol. Afr.*, **9**.

Zinderen Bakker, E. M. van (1976 b): The evolution of late-Quaternary palaeoclimates of southern Africa. *ibid.*, **9**, 160–202.

Zinderen Bakker, E. M. van and Coetzee, J. A. (1972): Re-appraisal of late-Quaternary climatic evidence from tropical Africa. *ibid.*, **7**, 151–181.

Zonneveld, J. I. S. (1975): Some problems of tropical geomorphology. *Z. Geomorph. N. F.*, **19**, 377–392.

Summary

Recent studies on the palaeoenvironments in tropical Africa during the Würm Glacial Maximum at about 18,000 B. P. are reviewed by compiling palaeoenvironmental maps using published data. It is suggested that drastic aridity would had prevailed throughout the equatorial belt of Africa, which is presently covered with dense moist forest. However, in the forest zone well-dated studies are lacking.