Paleo-Environmental Perspectives on the Sahel Drought of 1968–73

Butzer, K.W., Prof., Dept. of Geogr., The University of Chicago,
5828 S University Ave., Chicago, IL 60637, USA

Abstract: A review of stream, dune and lake phenomena in several well-studied sectors of the Sahel indicates an informative record of repeated environmental change. Blowing sand encroached far into the now semi-arid savanna between approximately 20,000 and 12,500 years ago, while lakes had substantially greater volumes and rivers higher discharges between 9000 and 5000 years ago. But rapid change and high-amplitude variability have always been the rule. During the last 2500 years conditions fluctuated about the modern median, with strong short and medium-term oscillations. The Sahel drought after 1968 falls within the norm of at least 6 earlier, dry anomalies verfied since 1400 AD. Whether or not the coincidence of cumulative overgrazing and population pressure with severe drought has triggered a geomorphologic response that is unique in the record, can only be decided after much more systematic work has been carried out.

One of the more catastrophic and well-documented recent famines was unleashed by the severe drought that affected the southern Saharan borderlands during 1968–73. Relatively little attention has been devoted to whether this drought was unique, as a consequence of recent changes of land use patterns and population growth, or whether it was but another example of severe and recurrent environmental stress in the area. This question can be addressed by a paleo-environmental review, to place the 1968–73 drought in an historical context.

In fact, no other region of Africa has as conspicuous a record of environmental change as the semiarid and subarid zone along the southern margins of the Sahara, between the Senegal and Nile Rivers. This record is best expressed in great expanses of active or immobilized sand dunes on the one hand, and dry lake beds on the other. Such evidence is not unique to this Sahel zone, a designation of Arabic origin for the associated vegetation of grass and thorn-tree savanna that spans the 100–500 mm rainfall belt centered around latitude 15°N. But nowhere else in Africa is the surface record of ancient climates so extensive and conspicuous.

Three basic categories of evidence can be examined: (1) stream deposits, exposed in well-studied river valleys and in the offshore sediment cones of the principal rivers; (2) fossil sands, in vegetated dune fields and as struck by cores beneath Lake Chad or in the deep sea; and (3) lake beds and related, abandoned shorelines found in the major tectonic depressions, as well as in the swales between fixed or active dunes.

This primary record is complemented by a number of paleosols, by fossil pollen, and by lake microorganisms such as diatoms. It has been reasonably well fixed in temporal terms by an unusually large number of radiocarbon dates. The emphasis of the discussion is on the amplitude and wavelength of environmental change, not on paleoclimatic reconstruction or interpretation.

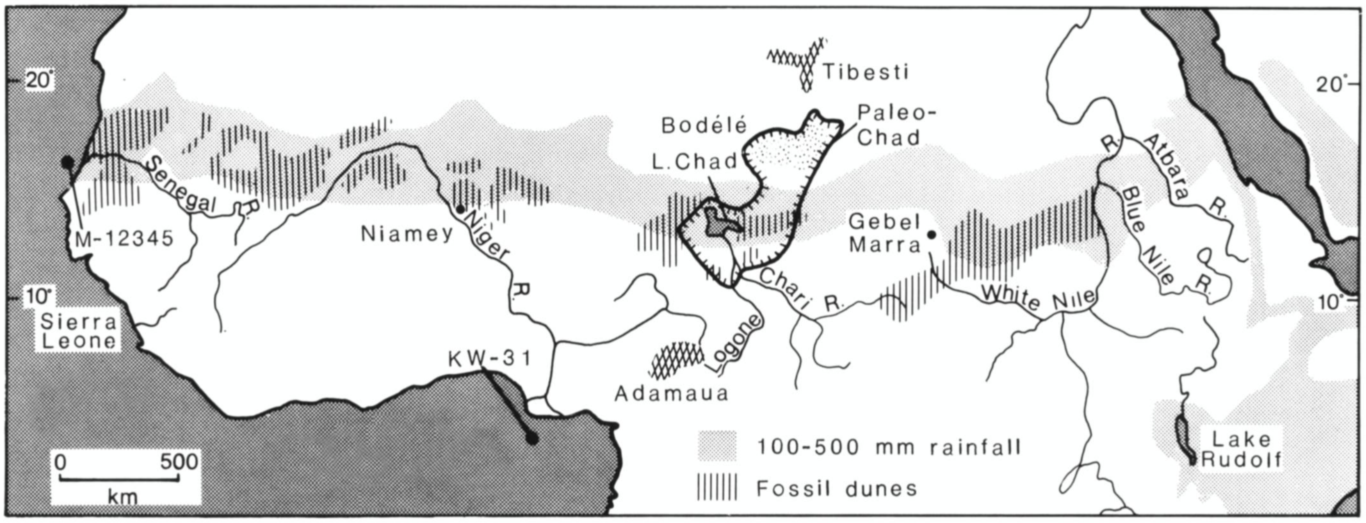

Fig 1 The Sahel Zone of Africa

The Fluvial Record

In the Senegal River valley the datum for Late Quaternary events is provided by gravelly alluvium, 2 m above modern floodplain, related to a relatively high world sea level before 31,000 years ago (Michel 1973, Beaudet et al. 1976). Subsequently, sea level fell and the river was able to remove much of this gravel infilling and cut down into its bedrock floor, suggesting periodically strong floods. But eventually the lower valley was drowned by dunes advancing southwestward out of the Saharan fringe, building up sand forms with a relief of 30 m and extending out onto the edge of the continental shelf; the Senegal River was unable to reach the coast at this time. Later, a deep red soil, indicative of a complete vegetative mat and intensive biochemical weathering, developed on these dunes while the Senegal and other rivers once again cut through the dune field to reach the sea. Between 5000 and 4000 years ago (BP) a rising sea level flooded into the new Senegal delta and the reduced river gradient favoured sandy alluviation as much as 250 km upstream. Sea level then dropped a little and, from 3000–1650 BP, was again slightly higher, resulting in development of a series of beach ridges along the delta, while the river had a regime similar to that of today.

This picture of alternating drier and wetter conditions is parallelled further south, in central Sierra Leone (8° latitude), where dating is somewhat more precise (Thomas and Thorp 1980). In this wetter environment, broad swampy valleys with poorly defined channels were flooded by high and protracted, monsoonal runoff from before 36,000 until about 20,500 BP. A subsequent absence of sediments and organic matter indicates drier conditions without forest. About 12,500 BP river discharge increased, first eroding bedrock, then depositing gravelly alluvium by 9000 BP, increasingly interbedded with swamp clays. About 6000 BP river activity had stabilized and soils began to develop on the uplands. Renewed, increasingly swampy deposition is indicated 3300–1750 BP and during the last 900 years or so.

This pattern is pinpointed in deep-sea core M-12345, off the Senegal delta, where windborne sands and dust with Saharan pollen were deposited between 16,300 and 12,500 BP after which river discharge contributed abundant sediment, with tropical pollen, particularly during several millennia after 8600 BP (Sarnthein et al. 1982). A similar pattern is indicated in core KW-31 off the Niger Delta, where discharge was very low about 20,000 to 15,000 BP; thereafter flow increased markedly and, with brief fluctuations, remained high until about 4000 BP (Pastouret et al. 1978).

At about the same latitude, the White Nile appears to have been deprived of Ugandan runoff between about 25,000 and 12,500 BP, so that a body of still, saline water was ponded up in the lower White Nile floodplain (Williams and Adamson 1980). Subsequently, massive White Nile floods built up silts to 4 m above modern floodplain, until 11,400 BP, when discharge again declined and dunes were able to move across the valley onto the east bank. Stronger floods resumend by 8400 BP, when local watercourses also became more active than today. Relatively high discharge is identified in the later record ca. 7000, 5500, 3000, 2700, and 2000–1500 BP. The Blue Nile record, and that of the combined Nile drainage below the Atbara confluence (Williams and Adamson 1980, Butzer 1980a), reflect mainly on trends in upland Ethiopia and are peripheral to the present discussion.

In terms of preliminary evaluation, the fluvial indicators reviewed speak for an exceptionally dry climate in the Sahel between about 20,000 and 12,500 BP, when the region evidently was an extension of the Sahara. Subsequently, conditions have been relatively moist, but subject to considerable variation. The details of this later variability are only poorly resolved in the fluvial record.

The Dune Record

The eolian sands of the Sahel interdigitate with the record of increasing and decreasing stream activity, to help date the expanse of immobile and vegetated dune fields or sand sheets so common through much of the Sahel (Grove and Warren 1968, Mainguet et al. 1980, Talbot 1980). In northern Nigeria such dunes are well developed in areas with as much as 750 mm of rainfall today, although few active sand fields can now be identified in areas with more than 150 mm. This argues for desert conditions an average of 3^{o} latitude further south than is the case today. But such extreme aridity has not been experienced during the last 12,500 years.

Dust of Saharan origin first became abundant off the Senegal coast during two protracted episodes between about 7.5 and 5.5 million years ago (Sarnthein et al. 1982). After 2.5 million years windborne dust fluctuated considerably, but generally remained quite prominent, suggesting an arid Sahara comparable to that of the present day. Deep cores under the Chad Basin record a dominance of clays, lake diatomites, and alluvial sands from the late Oligocene or early Miocene until the end of the Pliocene (Servant and Servant-Vildary 1980). Thereafter eolian sands are dominant, but repeatedly interbedded with lenses of lake deposits.

The dune sands and windborne dust consequently serve to document the development of the Sahara Desert at the onset of the Quaternary era, some 2 million years ago. As interfingered with marine, stream, and lake deposits they subsequently provide a fundamental indicator of relatively dry climate, as a deteriorating vegetative cover repeatedly allowed eolian processes to advance into what is now a savanna environment. The last major advance of dunes and sand fields, across a belt up to 500 km wide, predates 12,500 BP, and latitudinal shifts since about 7000 BP have been comparatively limited in extent.

The Lake Record

The distribution of dry lake beds in the Sahel and even in parts of the Sahara is quite remarkable, and provides the most detailed record of climatic fluctuations during the past 12 millennia. The best-studied record, serving as a key indicator of Sahelian climate, is that of the Chad Basin (Servant 1973, Servant-Vildary 1978, Servant and Servant-Vildary 1980, Maley 1981, 1982).

The surface of modern Lake Chad had a fluctuating area of 10,000 to 20,000 km^2, with a mean depth varying from 3 to 7 m during the last millennium. The lake is separated from the lowest point of the basin, the Bodélé-Djourab depression some 500 km to the northeast, by a low divide; shorelines at +4 m are at an elevation (286 m above sea level) that would permit water to overflow into this depression. The highest shorelines are however at +40m, corresponding to the Paleo-Chad maximum. This great inland water body of about 350,000 km^2 was almost comparable in size to the modern Caspian Sea. It was primarily supplied by the waters of the Chari and Logone rivers, draining what in historical times were forested watersheds at latitudes $6-10^{o}$, and also by rains falling in the Sahel zone. Despite a vast evaporating surface, the Paleo-Chad maintained various high levels between 7500 and about 5000 BP. It not only supported a substantially higher watertable throughout its basin, but probably also indirectly fed innumerable seepage lakes between the dune fields to the west and north.

The history of Chad lake episodes first acquires detail with intermediate to high levels about 30,000–20,000 BP. During the first lacustrine phase ca. 30,000–26,000 BP, the associated diatoms were of montane or high-latitude environments, but the pollen data indicate a desert vegetation, with very few tropical taxa. Later, about 25,000–20,000 BP, the "cool" diatoms persisted but in association with several tropical species; the pollen indicate a strong increase in tropical elements and a corresponding decline of desert taxa.

During the period of maximum aridity between 20,000 and 13,000 BP, the southern Chad tributaries were characterized by perennial discharge and, after 17,000 BP, by a major extension of swampy floodplains. North of the lake, lacustrine deposits, mainly of saline facies, reappear between 13,000 and 12,500 BP and probably reflect in part a positive movement of the watertable, fed from a southerly source. Between 12,500 and 9200 BP several modest lacustrine phases were interrupted by dry interludes ca. 12,400–12,000, 10,600–10,200, and 9600–9400 BP. A rapid rise of the lake to an intermediate level began about 9200 BP, lasting until about 8500 BP. From about 12,500 until 7000 BP the diatom fauna indicates cool waters and oligotrophic conditions. After a fall of the lake level to its modern position 7400–7000 BP, the Paleo-Chad maximum was achieved at +40 m, fluctuating below this high level until 5200–5000 BP. The associated diatoms indicate temperatures similar to those to today, with eutrophic waters. After a long and important regression, centered about 4000 BP, a last high lake level is dated between 3500 and 3000 BP. Subsequent levels fluctuated around those of the last millenium.

Palynological study of various lacustrine sedimentary sequences (Maley 1981) shows that Sahelian forms began to slowly replace desert shrub after 12,500 BP, gaining dominance by 10,000 BP. At this time the 12 Sahelian taxa verified include 5 tree species. Nonetheless, until 7000 BP, tree pollen account for only 7 % of the available spectra. Thereafter tree pollen increase rapidly and toward 5000 BP they exceeded non-arboreal types, clearly documenting a tree-savanna during mid-Holocene times. This matches the sedimentary record, which indicates maximum precipitation and Chari-Logone discharge during the same period.

The high lake stands ca. 7500–5200 BP potentially allow reconstruction of a hydrological budget, assuming similar radiation, temperature, and wind conditions of those of today. Kutzbach (1980) has proposed a rainfall averaging a little over 650 mm per year across the basin, compared with only about 350 mm today. But he adopted a non-empirical lake surface evaporation estimate of 1297 mm per year, whereas in reality this figure is over 2200 mm (J. Maley, pers. comm.). Perhaps more significant than this conservative modal value is the repeated evidence for sharp periodicities in lake level. Servant and Servant-Vildary (1980) suggest four scale-models for such variability: fluctuations of several tens of meters over time spans of several millennia, of 1 to 5 m over several centuries, of up to 3 m over several decades, and of about 50 cm between seasons. This scale of change is broadly replicated in other, smaller lakes of the Chad Basin fed by groundwater or by a combination of runoff and watertable. That it is characteristic of a broad climatic belt spanning the African continent from west to east can be seen by comparing the trace of Lake Rudolf (Turkana), which had a similar history to that of Lake Chad since 10,000 BP, with similar abrupt fluctuations (Butzer 1980b).

Comparison of measured stream discharge and lake level changes since 1900 (Faure and Gac 1981, Maley 1981) indeed shows that the history of Lake Chad is fully representative of hydrological changes across the Sahel. Basic data of the area west of Lake Chad are reviewed by Talbot (1980) and Maley (1981). Another, less precisely-dated, local sequence has been reported from the caldera of Gebel Marra (13° latitude), in the southern Sudan (Williams et al. 1980). Here a +25 m lake of considerable longevity shrank about 19,000 BP, but was reconstituted at +5 to +8 m about 19,000–16,000 BP. After another drop, the level regained +9 m ca. 14,000 BP, and then maintained an intermediate level until about 3000 BP; since then the level has fluctuated between –2 and +2.5 m. This record to some degree reflects special conditions, but it is interesting because it shows that the time between about 20,000 and 12,500 BP was not uniformly arid, confirming local lacustrine beds from the Tibesti mountains that indicate that climate at higher elevations and higher latitudes was predominantly wetter since as early as 16,000 BP (Jäkel 1979), even while the Saharan lowlands and the Sahel were desert.

Lake Chad history for the last 800 years has been reconstructed in detail by Maley (1981: Fig 2.1) on the basis of dune history, pollen and lake level fluctuations, as well as flood data for the Niger and Nile rivers, and population movements, to establish broadly synchronous climatic anomalies for the Sahel. The lake level dropped some 5 m within a few decades prior to 1450 AD, then recovered 3 m by 1500, only to fall again by 1550. A +5 m level was maintained throughout the 17th century. Subsequent levels have fluctuated in the 0 to +3 m range, with two lows during the 18th century, one ca. 1850, another after 1913 and again during the 1970s. This scale of variation is more rapid than that revealed by the older, generalized lake trace, but corresponds better with the major oscillations of the parallel pollen records that were frequently compressed within one to three centuries (Maley 1981). Even more detailed are the smoothened discharge data of the Sahel rivers, which indicate major dry anomalies every 30 years or so since the turn of the century (Faure and Gac 1981). In conjunction with the historical evidence and oral tradition (Nicholson 1979), this hydrologic information points up the significant differences in scale resolution picked up by different research modes:

(a) Short-term severe droughts such as those of 1968–73 are reversed within less than a decade, but appear to be too brief to show up in most sedimentological or biotic records.

(b) Intermediate-scale, dry anomalies lasting several decades are more likely to be revealed by detailed geological or biological studies but, even though their repercussions on productivity, biomass and carrying capacity may be severe, they most commonly represent no more than temporary oscillations in the highly variable climatic regime of monsoonal Africa (Butzer 1971).

(c) Long-term drying trends over several centuries or millennia are primarily responsible for the simplified trace of stream, dune and lake records reviewed here; they comprise many positive and negative, intermediate-scale oscillations that cumulatively effect fundamental changes in hydrology, biotic distributions, and regional geomorphologic thresholds. These are the magnitudes of change – in terms of amplitude and wavelength – reflected in the history of Lake Chad over the last 12 millennia.

The lake records discussed here are among the most detailed available for the Late Quaternary of Africa. They serve to show that much of the period 9000–5000 BP was substantially wetter than today, providing a counterpoint to the evidence for drier Sahelian climate in the period before 12,500 BP. They further place recent climatic oscillations into context: anomalies comparable to the drought after 1968 are verified on at least 6 occasions since 1400 AD, and may have a recurrence frequency of three times per century.

Concluding Discussion

In paleoclimatic terms, the Sahel drought of 1968–73 evidently falls well within the range of short and medium-term variability directly documented for the last few centuries and indirectly shown for the last 12 millennia or so. Kates (1981), in fact, argues that the human impact of a similar drought in 1913–14 was of similar or greater proportions, although both the criteria and data to make such an evaluation are unsatisfactory. Other authors, however, believe that colonial and post-colonial changes in land use and sustained population growth since the turn of the century have dramatically increased pressures on the ecosystem, rendering it unusually vulnerable to periodic stress (Glantz 1976, Dalby et al. 1977). Without addressing this underlying issue, of whether or not the rapid technological and social transformations defined as "development" serve to increase systemic fragility, it is pertinent here to explore the degree to which recent desertification has had tangible geomorphic impact.

It is reasonable to expect that overgrazing, devegetation, soil erosion, and even secondary meso-climatic change will follow in the wake of ecological disbalance, accentuated by years of extreme drought. Yet the "historical", i.e. geomorphological context for desertification remains hopelessly fragmentary. Only a few examples have been published thus far.

Near Niamey (Niger), Talbot and Williams (1979) studied the cycles of erosion and deposition that periodically account for small fans building up below gully systems that cut back into fixed dunes. The most recent such cycle switched from fan accumulation to geomorphic stability over 300 years ago, but stream incision is now active, with gullies cutting back into the partly-devegetated dunes. Two earlier cycles of cutting do not seem to have proceded at different rates, suggesting that ecological recovery is merely a matter of time.

On the Adamaua Plateau of north-central Cameroons, Hurault (1975), based on airphoto interpretation, ground controls, and local informants, was able to show that about 1900 AD intermediate-order streams were perennial, with low flood peaks, and deposited suspended sediment. As a result of overgrazing and degraded ground cover during the 20th century, channels have been incised, and are now lined with coarse bed load; they function intermittently, mainly during flash floods following rains. This set of processes is familiar from several other contemporary and historical settings, in the American Southwest, the Mediterranean Basin, and upland Ethiopia (Butzer 1981), and do not specifically reflect the 1968–73 drought.

In central Sierra Leone, Thomas and Thorp (1980) established several alluvial episodes that span the last 12,500 years. Although artifacts related to agricultural settlement are evident since 4000 BP and imply a measure of deforestation, there is no qualitative difference in the development of earlier and later alluvial sediment suites.

These examples do not do justice to the extent and severity of ecological degradation by rapid population growth in West Africa during the last 50 years. But they do caution that environmental trends since the advent of agriculture and pastoralism in the Sahel cannot automatically be attributed to human intervention, without verification by means of meticulous local studies. They also suggest that there is an urgent need for systematic geomorphologic examination of modern desertification processes in an historical context, in order to determine to what extent these are unique, or simply cyclical within the Holocene record.

Acknowledgement

Jean Maley (Montpellier) provided valuable criticisms and suggestions on an earlier version of the manuscript.

References

Beaudet, G., Michel, P., Nahon, D., Oliva, P., Riser, J., Ruellan, A.: Formes, formations superficielles, et variations climatiques récentes du Sahara occidentale. Revue de Géographie physique et Géologie dynamique 18, 157–74 (1976)

Butzer, K.W.: Recent History of an Ethiopian Delta. University of Chicago, Dept. of Geography Research Paper 136, 1–184 (1971)

Butzer, K.W.: Pleistocene history of the Nile Valley in Egypt and Lower Nubia. In: Williams, M.A.J., Faure, H. (eds.), The Sahara and the Nile. pp. 248–276. Balkema, Rotterdam 1980a.

Butzer, K.W.: The Holocene lake plain of North Rudolf, East Africa. Physical Geography 1, 44–58 (1980b)

Butzer, K.W.: Rise and fall of Axum, Ethiopia: a geo-archaeological perspective. American Antiquity 46, 471–495 (1981)

Dalby, D., Church, R.J.H., Bezzaz, F. (eds.): Drought in Africa, 2nd Ed. International African Institute, London 1977.

Faure, H., Gac, J.Y.: Will the Sahelian drought end in 1985? Nature 291, 475–78, and 293, 414 (1981)

Glantz, M.H. (ed.): The Politics of Natural Disasters: the Case of the Sahel Drought. Praeger, New York 1976.

Grove, A.T., Warren, A.: Quaternary landforms and climate on the south side of the Sahara. Geographical Journal 134, 194–208 (1968)

Hurault, J.: Surpâturage et transformation du milieu physique: formations végétales, hydrologie de surface, géomorphologie. L'exemple des Hauts Plateaux de l'Adamaoua (Cameroun). Etudes de Photo-Interpretation de l'Institut Géographique National (Paris) 7, 1–218 (1975)

Jäkel, D.: Run-off and fluvial formation processes in the Tibesti Mountains as indicators of climatic history in the Central Sahara during the late Pleistocene and Holocene. Palaeoecology of Africa 10–11, 13–44 (1979)

Kates, R.W.: Drought impact in the Sahelian-Sudanic zone of West Africa: a comparative analysis of 1910–15 and 1968–74. Center for Technology, Environment and Development, Clark University, Background Paper No. 2, 1–92 (1981)

Kutzbach, J.E.: Estimates of past climate at Paleolake Chad, North Africa, based on hydrological energy-balance model. Quaternary Research 4, 210–23 (1980)

Mainguet, M., Canon, L., Chemin, M.C.: Le Sahara: géomorphologie et paléogéomorphologie éoliennes. In: Williams, M.A.J., Faure, H. (eds.), The Sahara and the Nile. pp. 17–35. Balkema, Rotterdam 1980.

Maley, J.: Études palynologiques dans le Bassin du Tchad et paléoclimatologie de l'Afrique nord-tropicale de 30,000 ans à l'époque actuelle. Travaux et Documents de l'Office de la Recherche Scientifique et Technique Outre-Mer (Paris) 129, 1–586 (1981)

Maley, J.: Dust, clouds, rain types, and climatic variations in tropical North Africa. Quaternary Research 18, 1–16 (1982)

Michel, P.: Les bassins des fleuves Sénégal et Gambie: étude géomorphologique. Mémoire de l'Office de la Recherche Scientifique et Technique Outre-Mer (Paris) 63, 1–752 (1973)

Nicholson, S.E.: The methodology of historical climate reconstruction and its application to Africa. Journal of African History 20, 31–49 (1979)

Pastouret, L., Chamley, H., Delibrias, G., Duplessy, J.C., Tiede, J.: Late Quaternary climatic changes in western tropical Africa deduced from deep-sea sedimentation off the Niger Delta. Oceanologica Acta 1, 217–232 (1978)

Sarnthein, M., Thiede, J., Pflaumann, U., Erlenkeuser, H., Fütterer, D., Koopmann, B., Lange, H., Seibold, E.: Atmospheric and oceanic circulation patterns off Northwest Africa during the past 25 million years. In: von Rad, U., Hinz, K., Sarnthein, M., Seibold, E. (eds.), Geology of the Northwest African Continental Margin. pp. 454–694. Springer, Berlin 1982.

Servant, M.: Séquences continentales et variations climatiques: évolution du Bassin du Tchad au Cénozoique Supérieur. Thèse Université de Paris VI, 348 pp. 1973.

Servant, M., Servant-Vildary, S.: L'environment quaternaire du Tchad. In: Williams, M.A.J., Faure, H. (eds.), The Sahara and the Nile. pp. 133–62. Balkema, Rotterdam 1980.

Servant-Vildary, S.: Étude des diatomées et paléolimnologie du bassin tchadien au Cénozoique supérieur. Travaux et Documents de l'Office de la Recherche Scientifique et Technique Outre-Mer (Paris) 84, 2 vol. (1978)

Talbot, M.R.: Environmental responses to climatic change in the West African Sahel over the past 20,000 years. In: Williams, M.A.J., Faure, H. (eds.), The Sahara and the Nile. pp. 37–62. Balkema, Rotterdam 1980.

Thomas, M.F., Thorp, M.B.: Some aspects of the geomorphological interpretation of Quaternary alluvial sediments in Sierra Leone. Zeitschrift für Geomorphologie, Suppl. Vol. 36, 140–61 (1980)

Williams, M.A.J., Adamson, D.A.: Late Quaternary depositional history of the Blue and White Nile rivers in central Sudan. In: Williams, M.A.J., Faure, H. (eds.), The Sahara and the Nile. pp. 281–304. Balkema, Rotterdam 1980.

Williams, M.A.J., Adamson, D.A., Williams, F.M., Morton, W.H., Parry, D.E.: Jebel Marra volcano: a link between the Nile Valley, the Sahara and Central Africa. In: Williams, M.A.J., Faure, H. (eds.), The Sahara and the Nile. pp. 305–337. Balkema, Rotterdam 1980.