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Climatic changes in the arid zones of Africa during early to mid-Holocene times

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Summary

The arid zones of Africa, while always subject to comparatively dry climate during more recent geological times, have nonetheless experienced a succession of moister or drier oscillations during the Pleistocene and Holocene. The various classes of palaeoclimatic evidence (archaeological, geological, pedological, palynological, palaeontological) are reviewed briefly. Despite considerable advances during the last decade, the present status of information is still highly unsatisfactory, due in part to the limited numbers of workers in the field, and in part to the difficulties of exact dating and reliable correlation. In the case of the Sahara the available evidence suggests that a hyper-arid oscillation *c.* 2350-870 b.c. was preceded by a moister sub-pluvial period *c.* 5500-2350 b.c., possibly interrupted by one or more dry spells. There is some further evidence in favour of moister conditions during the 7th millennium while conditions may have been hyper-arid a millennium earlier. None of these changes in precipitation or effective moisture can be quantitatively defined, and there is no evidence concerning temperature conditions. A palaeoclimatic outline is not yet possible for the remaining arid zones of Africa, no matter how tentative.

1. Introduction

The Sahara and the Kalahari-Namib deserts of Africa have experienced comparatively dry climates throughout most of geological history. In the case of the Sahara, a discussion of Palaeozoic, Mesozoic and Tertiary strata and their facies by Schwarzbach (1953) leaves no doubt that arid and semi-arid conditions have been the rule rather than the exception. Similarly, dry climates appear to have prevailed in the Kalahari-Namib throughout most of the Mesozoic and Tertiary (King 1961). This is not surprising since, with modern continental distributions and axial positions of the planet, the Sahara and Kalahari-Namib are climatic deserts. However, the degree of aridity experienced and the boundaries that demarcate the moister peripheral regions of both of these desert complexes (Fig. 1) have changed in the course of time. Geomorphic, geological, pedological and biological evidence attests to recurrent moister climates, often of some duration and magnitude, sometimes localized, more often of regional prevalence. At no time do the desert lowlands appear to have experienced truly humid conditions, however. Climatic variation has been a matter of degree rather than of kind, and moister palaeoclimates may have been sub-arid or semi-arid or sub-humid, rather than arid or hyper-arid, as they commonly are today. Similarly there have been times of greater aridity, when arid conditions prevailed in what are, today, semi-arid climates.

Considerable effort has been expended on the study of geological and biological information concerning the Pleistocene and post-Pleistocene of the areas in question. Palynology was first successfully applied about a decade ago, thanks primarily to the efforts of P. Quézel and M. Van Campo in the Sahara, and to van Zinderen Bakker and his associates in southern Africa. Interdisciplinary studies have been carried out in different parts of the Sahara, providing well-documented local sequences. Yet despite the gratifying acceleration of studies devoted indirectly or directly to Quaternary palaeoclimates, our understanding remains fragmentary and unsatisfactory. There are abundant qualitative data to be sure, but commonly they are difficult to interpret with precision and seldom can they be dated accurately. Radiocarbon dates are available from several areas but they are still pitifully few when seen within the vast realms of barely-explored desert.

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The following paper will attempt to review the current state of information concerning palaeoclimates between about 8000 B.C. and the beginning of our era. Emphasis will be on the Sahara, reflecting both on the field experience of the writer in the Nile Valley and on the paucity of data from the Kalahari-Namib. In order to provide a basic framework rather than a mass of facts, the nature and character of the evidence will be discussed, followed by an outline of a few better-understood sequences.

2. The nature of the evidence

Before embarking on a discussion of some of the local evidence, it would seem useful to summarize briefly the more important classes of evidence available.

(a). *Archaeological.* The widespread distribution of human artifacts over uninhabitable deserts, often many miles from existing waterholes, has commonly been cited in favour of greater precipitation or a higher ground-water table, or both. In the case of the Saharan and South African post-Pleistocene the rock drawings of big game (Mauny 1956; Clark 1959) are well known. Two amazing archaeological complexes have been recognized through most of the Saharan uplands, an Epi-Palaeolithic hunting culture, and an early Neolithic food-producing culture with cattle, sheep and local cultivation of cereals (Lhote 1964; Mori 1965). The younger group of pastoralists has now been approximately dated through radiocarbon with determinations ranging from about 5500 to 2500 B.C. The hunting culture has not yet been dated accurately. Certain palaeoclimatic conclusions concerning the distribution of elephant, rhinoceros and giraffe representations can be made (see Butzer 1958), but indirect data of this kind must be used with caution, particularly when their chronological position is not properly understood. With these reservations in mind, it has been suggested that the northern and southern semi-desert peripheries of the Sahara had shifted towards the desert interior by 100-200 kilometres, with the interior highlands emerging as moister islands, enjoying an annual precipitation of 50-200 mm compared with 5-75 mm today.

(b). *Geological.* A variety of fluvial and aeolian deposits as well as erosional features can be attributed to geomorphic activity in post-Pleistocene times. Where these phenomena differ from contemporary processes or distributions, palaeoclimatic inferences may be possible (see Butzer 1963). However, data of this kind are qualitative at best and major changes have been uncommon in the recent geological past, so that Holocene deposits are seldom distinctive. Above all, exact dating is essential but usually difficult or impossible to obtain.

(c). *Pedological.* Buried or relict soils, no longer forming today, imply soil-forming conditions at variance with contemporary climate or vegetation. Such palaeosols, if accurately dated and interpreted, may provide interesting information on the intensity of chemical weathering and the stability of the soil mantle versus erosion. Two kinds of palaeosols are frequently reported on from the Sahara, red zones of weathering and black, organic horizons. The former commonly record oxidation and clay mineral formation. The latter may represent floodplain soils or organic alluvium and, without accurate description, their meaning remains dubious.

(d). *Palynological.* Pollen analysis has proved a most useful innovation in all climatic regions, and the arid zones are no exception. However, pollen preservation in Saharan deposits is inevitably poor and sample preparation necessarily involves concentration of such pollen grains as there are by various techniques. With concentration of selectively preserved pollen, the statistical and ecological value of a pollen spectrum rapidly diminishes and long-distance transport or local derivation from older sediments becomes a serious problem. Many pollen counts from the Sahara have been made from as many as 50 preparations, often with only one pollen grain per slide (see Beucher 1963). Consequently, a few dozen grains, as are frequently reported on in the current literature, are of somewhat dubious value (see review in Butzer 1964). Only a few spectra thus far published are based on pollen counts exceeding 100 grains. Determination of plant megafossils is seldom possible.

(e). *Palaeontological.* Whereas rock drawings of big game are many, actual fossils of post-Pleistocene age are rare in the arid zones of Africa. In part this reflects on the current state of investigation. However, conditions for fossilization are generally poor with little or no sedimentation and limited possibilities for mineralization. Despite a number of molluscan and mammalian collections, the actual palaeontological evidence remains fragmentary.

3. Lower Nubia and Egypt

The Nubian Monuments Campaign of the past few years has not only stimulated archaeological salvage in southern Egypt and the northern Sudan, but has also provided opportunity for geological work devoted to Quaternary problems. Palynological studies are incomplete thus far, but do not seem promising for post-Pleistocene sediments in the Nile Valley. However, fascinating interrelationships can be observed between nilotic deposits, derived from Ethiopia via the summer flood régime, and local wadi deposits, related to winter rains within Egypt or the northern Sudan.

A terminal Nile aggradation to 13-16 m above modern floodplain began approximately 11,100 years ago (9140 ± 200 B.C.) suggesting higher and slightly more vigorous Nile floods (Butzer and Hansen 1966; de Heinzelin, 1966). Two millennia later (7440 ± 180 B.C., Wendorf *et al.*, 1965) degradation was well under way and a period of severe deflation can be recognized on the Kom Ombo Plain at approximately the same time or a little later. During the subsequent millennia, floodplain level fluctuated between that of today and a level of about 6-7 m higher. A last aggradation to 126 m (+ 5 m) occurred during the middle A-Group period in Nubia (see Säve-Söderbergh 1964), i.e., shortly after 3000 B.C. The exact age and meaning of these Nile pulsations is not yet completely understood.

Local rainfall conditions in southern Egypt are recorded by a number of alluvial deposits in the local wadis (Butzer and Hansen, 1966). An older fill with a terminal radiocarbon date of 6940 ± 160 B.C., forms a + 2 to 5 m terrace in many wadis. Fairly homogeneous, fine-grained deposits suggest a vegetative mat along the wadi floors and a period of fairly frequent rains of moderate intensity. Profusions of terrestrial snails, now extinct in Egypt, further suggest a moister climate. A subsequent cycle of stream incision was interrupted by a period of geomorphic stability, during which a 30-50 cm deep, reddish soil profile developed. A certain amount of decalcification was accompanied by oxidation and the formation of kaolinitic clays. This suggests biochemical weathering, some form of vegetative mat and more frequent, gentle rains. The age of this ubiquitous reddish paleosol in southern Egypt may be about 7000 years.

After another period of wadi cutting, coarse wash deposits were laid down by violent sheetfloods, suggesting a period of frequent torrential rains. This wash locally grades into a wadi fill with abundant root impressions of xerophytic shrubs. Dating from this last phase of wadi alluviation is the + 2·5 m fill of Khor Adindan, which is interdigitated with Nile silts at 5·5 m above floodplain. The latter belong to the final prehistoric aggradation *c.* 3000 B.C. The interfingering Nile and wadi deposits at this locality are of considerable interest. Intact laminae of the wadi sands penetrate into the nilotic silt complex, while lenses of redeposited silts occur within the wadi sands. The two facies are contemporary but out of phase seasonally. During the summer, nilotic alluviation was uninterrupted by any wadi activity. In winter, however, wadi aggradation took place in a ponded area near the wadi mouth, with very localized fill and scour of nilotic silts on the floodplain periphery. These exposures emphasize the dualism of exotic summer floods and local rains during the last significant period of Nile and wadi aggradation.

The end of this last significant moist interval can be documented by indirect archaeological evidence. The extinction of elephant, rhinoceros, giraffe and gerenuk gazelle in

Egypt can be dated between the 1st and 4th Dynasties (Butzer 1959), i.e. between about 2900 and 2600 B.C. Yet a number of 5th Dynasty (*c.* 2500-2350 B.C.) reliefs show wild animals in the open, on undulating desert sands studded with tree-size sycomores and acacias as well as desert shrubs. The case for a desert grass-savanna in the desert wadis and other edaphically favoured localities outside of the riverine zone is supported by sycomore, acacia and tamarisk roots, contemporary with late prehistoric occupation sites found along the desert margins. At a later date all hunting scenes of desert game are depicted within artificial enclosures, while vegetation is no longer indicated on such desert surfaces as are drawn. Similarly, gazelles become the most significant desert game, displacing antelope, addax and ibex. On these grounds, the mid-Holocene moist interval appears to have terminated completely about 2350 B.C., after a first climatic crisis had been sustained five or six centuries earlier.

Direct evidence for a subsequent arid spell is provided by eolian deposition in former habitation shelters near Seiyala in Nubia, beginning a little after 3000 B.C. and terminating somewhat before A.D. 300 (Butzer 1966). Similar conditions are indicated by the alternating dune and alluvial beds found on the western margins of the Nile Valley in Middle Egypt (Butzer 1959). During or after the close of the 6th Dynasty (*c.* 2350-2180 B.C.), the Nile floods no longer inundated the peripheries of the floodplain, and blowing sands from the Libyan Desert covered much of the former alluvium. Although not a result of local climatic change, the implications can be seen from various famines recorded between *c.* 2100-1950 B.C. and attributed to failure of the annual floods. On the basis of direct and indirect archeological evidence in Middle Egypt,these sand dunes were buried by higher and more vigorous Nile floods well prior to the 4th century B.C. Other historical records suggest that the annual floods had regained their normal level at least several centuries earlier and may have been comparatively higher than today between 870 B.C. and A.D. 100. There is, however, no reliable evidence to support the notion of a local increase of precipitation within Egypt during classical, i.e., Graeco-Roman times.

Over all, the Nubian and Egyptian evidence indicates a complex moist interval beginning before *c.* 7000 B.C., interrupted by some drier spells and terminating in stages between 2900 and 2350 B.C. During at least the last millennium or two of its duration, this sub-pluvial, as it may be called, was contemporary in Egypt and Ethiopia, since high Nile floods coincided with accelerated wadi activity – at different seasons of the year. This sub-pluvial coincided fairly closely with the Boreal and Atlantic phases in Europe and may have been marked by three rainfall maxima *c.* 7000 B.C., *c.* 5000 B.C. and *c.* 3000 B.C. The subsequent palaeoclimatic unit is fairly well defined and lasted from about 2350 to 870 B.C. At this time Egyptian climate was hyper-arid, with accelerated aeolian activity, while Nile floods were exceptionally low, suggesting a weakening of the summer monsoonal rains in the Blue Nile Basin. This dry interval corresponds temporally with the sub-Boreal.

4. Central Sudan

Little information is available from the Khartum area of the central Sudan, despite a valuable faunal collection from two prehistoric sites. The Neolithic station of Shaheinab (Arkell 1953) includes the large land snail *Limicolaria flammata* as well as *Celtis* seeds. On the basis of contemporary distributions of these species in the Sudan, Arkell (1953) suggests a local rainfall of over 500 mm, obviously sufficient to transport the wadi gravels in which the archeological finds were made. Two C^{14} dates were obtained and they average at 3250 $\pm$ 415 B.C. The slightly earlier Khartum Mesolithic inventory includes remains of several swamp-loving mammals, including the Nile lechwe, white-eared cob, water mongoose and an extinct reed rat. Unfortunately the riverine setting near the Nile precludes any specific deductions on local climate, although *Limicolaria* may again have been present. Arkell (1949; 1953) shows that Nile flood levels were at least 4 m higher than today, possibly as much as 10 m.

General as the evidence at Khartum is, it appears to be similar in nature to that of Lower Nubia.

5. The Fezzan

Although little conclusive significant evidence of early to mid-Holocene climatic change has been uncovered in Tripolitania (see Hey 1962) or Cyrenaica (Hey 1962; McBurney and Hey 1955), archaeological evidence has long suggested a moist interval of Neolithic age in the Fezzan and the Libyan Desert. The well-known rock drawings, originally discovered by Frobenius and Graziosi, are of considerable ecological interest for a mid-Holocene moist interval. Earliest in the record is the naturalistic art of an Epi-Palaeolithic hunting culture, recording numbers of such moisture-demanding species as elephant, rhinoceros and an extinct buffalo at sites ranging from south-western Egypt across the northern Tibesti to the Algerian border (see Butzer 1958 with references). Giraffes, various antelopes, barbary sheep, gazelle, ostrich and lion are also extremely common on these same representations. Occasional drawings of crocodile and fallow deer (*Dama* sp.) may also be present. Although usually localized in wadis, the sites of these rock engravings and paintings could not support such a fauna today and movements across the intervening desert plains demand an explanation.

A particularly promising study area is located in the Acacus hills (1,373 m), some 30 km east of Ghat in the south-western Fezzan. The shelter of Uan Muhuggiag has been excavated by Mori (1965) and his associates. Beginning with the base, the following strata are recognized :

(*a*). *Reddish brown clayey sand.* 5-10 cm thick. Sterile.

(*b*). *Lower Hearth Complex.* 50-60 cm thick. Cultural remains, intermingled with sandy lenses and occasional rocks, including bones of domesticated cattle and sheep as well as ostrich, varanus and tortoise. Pollen studies by Durante indicate that *Typha*, a north African swamp plant, accounts for over 50 per cent of the samples of four horizons, with the desert shrubs *Aristida* and *Artemisia herba-alba* accounting for about 10 per cent each. Macrobotanical remains include abundant *Typha* together with *Acacia albida*, *Balanites aegyptiaca* and some desert shrubs. Extrapolation of two radiocarbon dates (5590 $\pm$ 220 and 4000 $\pm$ 120 B.C.) suggests a time range of 5600 to 3800 B.C. for this moister phase with its record of permanent local swamps and livestock-raising in a now desert environment.

The lower Hearth Complex was terminated by sterile deposits of aeolian (?) sand.

(*c*). *Middle Hearth Complex.* 50-60 cm. Similar archaeological materials with over 50 per cent *Artemisa herba-alba* in most strata, 25 per cent *Aristida* and up to 10 per cent *Artemisia campestris*. *Chenopodiaceae*, *Typha* and *Cyperaceae* show up in some spectra. Although some swampy ground was present much of the time, the vegetation was semi-arid in character. By extrapolation the radiocarbon dates (3450 $\pm$ 180 and 2780 $\pm$ 310 B.C.) suggest a time interval of 3500 to 2500 B.C. Drier conditions with little or no occupation appear to have preceded as well as followed the Middle Hearth Complex.

(*d*). *Aeolian sands.* Sterile.

(*e*). *Upper Hearth Complex.* No data other than pollen given. Chenopods dominate with *Artemisia campestris* and *Aristida*. Aquatic plants are absent and near-desert conditions seem to have prevailed.

(*f*). *Aeolian sands.* Sterile.

The Uan Muhuggiag section and the associated pastoral cultures of the central Sahara suggest moister conditions *c.* 5600-3800 B.C., and again 3500-2500 B.C., broadly contemporary with the sub-pluvial discussed for Egypt. However, there is evidence in the Fezzan, for an older hunting population, whose favourite game was giraffe and elephant. A potential radiocarbon date for this earlier culture may be provided by charcoal in the lower horizon at Fozzigiaren (6120 $\pm$ 100 B.C.). Presumably there was another, earlier moist interval corresponding to the time of the naturalistic rock drawings (during the 7th millennium B.C. ?). It should be emphasized, however, that publication of Mori's results leaves much to be desired and no numerical pollen counts are given. But at least the information seems promising.

6. Hoggar and Tassili Uplands

The late prehistoric rock-drawings of the western Saharan highlands are justly famous for their fine artistry (see Lhote 1964, for a recent classification), and point towards a sub-pluvial of mid-Holocene age. These implications of greater moisture are also borne out by a variety of black organic sediments and other geological and archaeological evidence in the western Sahara (see Monod 1963, for a review of the earlier literature), almost invariably poorly dated. So, for example, the terrace sequence of the Saoura Valley, draining the Saharan Atlas, includes a 'Neolithic' fill (Chavaillon 1964) with a date of 4210 ± 1700 B.C. Pollen was studied from an exposure of gray sands intercalated with organic horizons and capped by a travertine layer. The limited pollen of the organic zones includes pine (*halepensis ?*) and acacia (*raddiana ?*), but few grasses (Beucher 1963). The travertine, however, is dominated by pollen of xerophytic species (*Ephedra*, chenopods), with some dubious traces of birch, alder, hornbeam and pine.

Other pollen evidence is available from a number of 'Neolithic' sites. The rock shelter at Meniet in the Hoggar contains strata from which 87 pollen grains were identified by Quézel and Martinez (1958). Of these pollen 56 per cent belong to arboreal species. In order of numerical importance they include cypress, Aleppo pine, evergreen oak, wild olive, hackberry (*Celtis australis*), the thorn bush *Ziziphus*, juniper, and tamarisk. Macro-remains of *Ziziphus*, lotus and hackberry help substantiate the pollen record, which further includes cereal, grass, sedge and *Artemisia*. The uppermost stratum at Meniet has a C^{14} date of 3450 ± 300 B.C. (Délibrias *et al.* 1959) and contains bones of an extinct buffalo. Similar results were obtained from a sample of hyrax dung from Taessa in the Hoggar, at some 2,200 m elevation. Pollen (3,000 grains) included similar genera as at Meniet together with pistachio and walnut. A C^{14} date of 2730 ± 300 B.C. was obtained for the dung. Limited numbers of pollen grains were also studied from sediments with cattle bones found below rock-drawings in the Tassili (Quézel and Martinez 1962). These grains included Aleppo pine, evergreen oak and cypress. In general, the evidence seems to speak for an open, subtropical woodland or parkland at edaphically favoured localities in the Saharan highlands. Possibly the younger moist interval of the Fezzan is documented at Meniet and Taessa. But the dating is still vague.

7. The Tibesti Highlands and the Ténéré

As many other parts of the Sahara, the Tibesti area has a wealth of naturalistic rock drawings pertaining to prehistoric hunting groups. A list of these sites has been compiled by Huard (1962). Giraffe, elephant and, to a lesser extent, rhinoceros are fairly common among these drawings, both in the highlands and in the Borkou foothills. Although geological evidence is not yet available, elephant fossils have been reported, and palynological data are available from Neolithic cave sediments at Mosséi (Quézel and Martinez 1958). The pollen count here was 60 per cent non-arboreal, and included 35 per cent *Acacia flava*. However, over 80 per cent of the macro-remains pertained to pine and juniper. An ecological picture of a savanna-type vegetation in the highlands and along the desert wadis appears to emerge for this period.

Near the Djado Oasis, south-west of Tibesti, several lacustrine deposits with sub-fossil mollusca have been studied by Llabador (1962). All appear to have been laid down during the moister interval in 'Neolithic' times. The Neolithic lacustrine beds of Adrar Bous, north-east of the Air Massiv, have yielded valuable palaeo-ecological information concerning the local mid-Holocene environment. The fauna includes equids, cattle, antelope, wart hog, hippopotamus, tortoise, and crocodile. Two genera of fish, ostrich, and three species of gastropods complete the preliminary faunal inventory (Llabador 1962). Macro-botanical remains include the common reed and live oak. Two distinct palynological horizons are defined by Quézel and Martinez (1962). The lower consists of diatomite, attaining 3 m in thickness, with 66 per cent of 251 identified pollen grains from non-arboreal species. The upper horizon is a blackish swamp sediment of 10-30 cm thickness, with 82 per cent of 192 grains in the non-arboreal class, almost exclusively chenopods. The arboreal species present in the diatomite include 13 per cent juniper, 12 per cent cypress, 5 per cent an extinct pine, 4 per cent myrtle, and 2 per cent pistachio. The limited arboreal species of the upper, swampy beds, dated 3180 ± 300 B.C. (Délibrias and Hugot 1962), contain 12 per cent myrtle, 3 per cent cypress and 2 per cent juniper. A severe degradation of the open mediterranean-type vegetation is postulated at the close of a mid-Holocene moist interval.

Faure (1965) has studied the lacustrine deposits of the intradunal depressions of the Ténéré, phenomena having a wider distribution along the southern margins of the Sahara. Diatomites were laid down in freshwater lakes, some 40-45 m in depth, somewhat earlier than a radiocarbon-dated sample 19,400 ± 350 B.C. After some fluctuations these lakes still existed in 7290 ± 130 B.C., reached a maximum depth a little later (6630 ± 110 B.C.) and began to dry out after about 5000 B.C. Hippopotamus is still verified as late as 1400 B.C. ± 200 and the terminal sediments consist of silts and clays, suggesting swampy conditions. Aeolian deposition has been dominant since.

8. Lake Chad

During the late Pleistocene or early Holocene, Lake Chad expanded so as to occupy an area of 400,000 sq. km, attaining a relative level of + 52 m and overflowing to the Atlantic Ocean via the Benue River (Pias 1962; Grove and Pullan 1963). Subsequently, this lake was reduced to its present dimensions, while a series of longitudinal dunes were built up east and southwest of the modern lake, corresponding with modern effective wind directions. Parts of the Hausaland sand fields of northern Nigeria appear to have been deposited at that time (Grove 1958; Grove and Pullman 1963). Dune activity in this part of Nigeria would imply 150 mm instead of the modern 750 mm annual precipitation.

Increased discharge and alluviation of the Logone and Shari accompanied a renewed advance of the lake to + 13 m or so in Nigeria, with clays transgressing over the preceding dunes (Grove and Pullan 1963). This may be equivalent to alluvial terraces in the Bahr el-Ghazal ('major terrace' of Barbeau 1961) and Wadai ('alluvium III' of Franz 1958).

Unfortunately, radiocarbon dates are not yet available from the Chad sequence. The 52 m shoreline of Lake Chad may be contemporary with the maximum level of the Ténéré lakes (7th millennium B.C.) or it may be considerably earlier. The later wet and dry oscillations must be dated accordingly. A last positive oscillation of Lake Chad is recorded from about the 10th century A.D.

9. Conclusions concerning the Sahara

The preceding conspectus of outstanding palaeoclimatic sequences in the Sahara is far from satisfactory. Most of the evidence is difficult to date with any precision, so that large-scale correlation is next to impossible. All that can be said with confidence is that a part of the mid-Holocene was comparatively moist in most parts of the Sahara, corresponding to occupation by pastoral and fishing cultures of Neolithic type.

As a working hypothesis, several very tentative suggestions can be offered, however :

(a). The period *c.* 2350-870 B.C. was hyper-arid in Egypt and comparatively dry in Ethiopia, and a similar dry spell seems to be recorded in the Fezzan and possibly in the Tassili and Hoggar. Chronologically this is the approximate time range of the sub-Boreal.

(b). The period c. 5500 to 2350 B.C. was comparatively moist in all of the areas under consideration, corresponding to the Saharan Neolithic occupance. Savanna woodlands may have been present on some of the better-watered highlands, and good pastures were probably available seasonally on the remaining uplands and in most of the wadi systems. Moisture was most abundant and vegetation more luxuriant during the first half of this 'sub-pluvial.' In the case of southern Egypt, rainfall was seasonally out of phase with the Nile floods, indicating a persistance of the present winter rainfall régime. This period coincides approximately with the Atlantic.

(c). Between about 8000 and 5500 B.C. the evidence from the different parts of the Sahara is extremely fragmentary. Conditions were somewhat moister than today in the Ténéré, in Egypt and in Ethiopia, at least for a part of this time, and the same may apply to the Fezzan. Possibly there was a sub-pluvial corresponding temporally to the Boreal period of Europe. But the evident is still inconclusive.

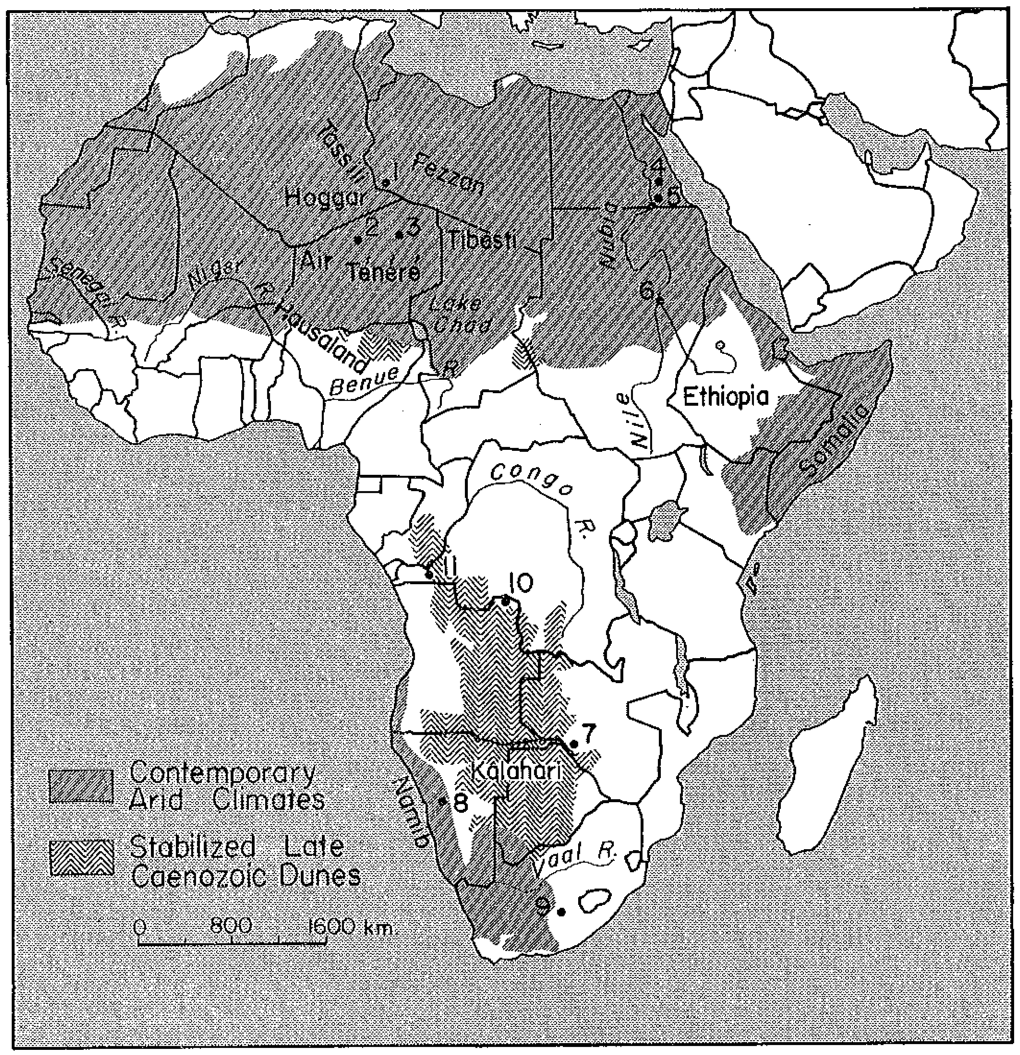

Figure 1. The contemporary arid zones of Africa (as defined by Thornthwaite, after Carter 1954). Fossilized or otherwise inactive dunes or aeolian sands of Pliocene to Holocene age are only shown outside of the modern arid zone. 1: Acacus, 2: Adrar Bous, 3: Djado, 4: Kom Ombo Plain, 5: Adindan, 6: Khartum, 7: Victoria Falls, 8: Phillip's Cave, 9: Aliwal North, 10: Dundo, 11: Léopoldville.

None of these changes in precipitation or effective moisture can be quantitatively defined and there is no evidence concerning possible changes of temperature.

A major unresolved problem is presented by the belt of fossil or otherwise stabilized dune fields that lie athwart the southern periphery of the Sahara, between the lower Senegal and the central Sudan (Grove 1958; Monod 1963). Although, with notable exception of the Hausaland Erg, most of these inactive dunes lie within Thornthwaite's 'arid' moisture region today (Fig. 1), there can be little doubt that they bear witness to times of more arid climate. In fact, these aeolian sands lie 400 to 600 km beyond the active dune fields of the contemporary Sahara. The available evidence indicates that many of these sand sheets are rather complex in origin, and that some of the primary sand accumulations may be of late Tertiary or early Pleistocene age. However, in the case of the Hausaland Erg, aeolian activity was responsible for modelling or remodelling dunal forms in the terminal Pleistocene or during one or more phases of the Holocene. It would be rather important to know the age of these last aeolian phases, but relevant radiocarbon dates are not yet available.

10. Evidence from Somalia

The only true arid climates of East Africa are found in Somalia. The existing evidence on Quaternary palaeoclimates has been published by Clark (1954). Two minor moist periods in Holocene times are suggested by a variety of geological phenomena, at least some which are difficult to interpret with confidence. These moister intervals are broadly correlated with local stone industries but no firm chronological information is available.

11. Evidence from the arid zone of Southern Africa

General indications in SW. Africa, Bechuanaland and adjacent areas have long pointed towards a terminal Pleistocene or early Holocene dry phase, followed by a mid-Holocene moist interval. So, for example, aeolian sands of Kalahari type were deposited in the Victoria Falls area during a period of drier climate (375 mm precipitation compared with 625 mm today) at about the time of the Magosian culture (Bond and Clark 1954). Similar aeolian sands of Magosian age are also known from Bechuanaland and possibly from the Vaal River valley. In SW. Africa the Kalahari dunes were probably modelled to their present morphology during the same general time interval (Korn and Martin 1957).

A return to more favourable conditions with a similar or slightly higher rainfall than today in mid-Holocene times is possibly suggested by black 'soils' with calcrete nodules in Bechuanaland (Bond 1963), by a sandy calcareous alluvium with Wilton implements in the Victoria Falls area (Bond and Clark 1954) and by widespread settlement of desert areas in SW. Africa by people with an early variant of the Smithfield culture (Korn and Martin 1957). A single radiocarbon date of 1415 $\pm$ 200 B.C. has been determined for the local Smithfield culture at Phillip's Cave.

In the absence of detailed local studies, other than at the Victoria Falls, and with an almost total lack of isotopic dating, palaeoclimatic deductions seem premature at the moment. Pollen samples have been collected at the Cape by A. V. Hall and at Aliwal North by J. A. Coetzee, but have either not been studied or published (van Zinderen Bakker 1964).

As in the case of the southern Sahara, there are extensive stabilized aeolian deposits on the equatorward margins of the Kalahari-Namib arid zone. These are part of the upper member of the Kalahari Sands, generally thought to be of Pliocene age. However, the surficial sands have been frequently reworked by aeolian activity during the Pleistocene and even during Holocene times. As indicated above, terminal Pleistocene or early Holocene sands of this type are known in stratigraphic context at Victoria Falls and in eastern Bechuanaland, and possibly in the Vaal Valley. More surprising is the fact that deflation and aeolian redeposition played a prominent role in the Leopoldville area, Congo, during the terminal Pleistocene, perhaps even after 8000 B.C. (De Ploey 1965).

A certain amount of geological and palynological detail from the Dundo area of north-eastern Angola places these intensive dry spells into a more certain stratigraphic setting (van Zinderen Bakker and Clark 1962). One dry period, characterized by deposition of 2·5 m of redistributed Kalahari sands, can be dated a little after 9240 $\pm$ 490 B.C., a date obtained from wood resting on a gravel surface and directly overlain by these sands. In mid-Holocene times climate was slightly warmer and moister than today as indicated by deposition of peaty clay and a pollen spectrum suggesting *Brachystegia* woodland on the upland surfaces. Well outside of the contemporary arid or semi-arid climatic zone today, these evidences of major vegetation change and repeated aeolian activity in the western part of the Congo Basin raise problems of considerable palaeoclimatic interest. However, here again more work will be necessary before any firm conclusions may be drawn.

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Discussion

Dr. C. J. Heusser : In view of the poor recovery of pollen grains in the terrestrial sediments you have dealt with, I should think that it would be palynologically far more remunerative to investigate sea cores from the Mediterranean, or cores from the Nile Delta. Do you know if these are available and if so, whether they are being studied ?

Dr. L. F. H. Merton : I should like to ask whether you have any evidence of change of former lake levels in the Qattara Depression ? I am thinking of the evidence from Iran, where a number of archaeological sites of varying age are known from the former margin of lakes now completely dried up.

Dr. D. J. Schove : I am interested to hear of the pollen investigations in Africa and I wonder whether the comparisons can yet be made with the results of Van der Hammen in South America. Also, from African radiocarbon dates published in *Radiocarbon*, *Asequa*, etcetera, I have tentatively selected certain centuries as sub-pluvial peaks : e.g., 7600-7200 B.C., *c.* 6600 B.C., 5300 B.C., *c.* 4900 B.C., *c.* 3550 B.C., *c.* 2150 B.C., and I wonder whether these peaks can be identified in the pollen profiles, or in other evidence ?

Dr. F. Oldfield : In view of the frequent references to the American south-west, it may be interesting to compare your tentative deductions regarding the course of post-glacial climatic change in the Sahara with those which are suggested by some of the recent pollen analytical and stratigraphic work in the semi-arid West Texas-New Mexico border area of the Llano Estacado. Here, too, the deductions are extremely tentative through lack of evidence and difficulty in interpreting the stratigraphic and palaeo-ecological record. The record, such as it is, seems amenable to provisional and qualitative interpretation in terms of variations in total effective moisture, which has probably been, to some extent, inversely related to the degree of dependance on inefficient summer rainfall. The pollen-analytical evidence points to a relatively moist phase soon after the opening of the post-glacial period in the area, perhaps sometime before *c.* 6000 B.C., which allowed a spread of piñon pine cover over parts of the present grassland area. A succeeding phase of grassland dominance, of minimum lake levels and hence, presumably, of low effective moisture (the ' altithermal ' in the area) indicated in both the pollen-analytical and stratigraphic record, is not closely dated and may occupy any part, or indeed, most of the time between *c.* 6000 and around 2000 B.P. After this there is a little evidence from the previously mentioned San Jon site and from a smaller in-filled basin close to Lubbock, for a more recent ponding interval in which pollen record and the evidence of somewhat higher lake levels, could point to a more recent increase in effective moisture. Associated pottery at Lubbock suggests a date within the last millennium. Certainly the record is badly in need of dating and of confirmation and elaboration from many more sites, but it is interesting to note that the indications so far suggest changes in almost exactly the opposite sense from those proposed by Dr. Butzer in the Sahara. I know of no reason why this should not be so. At the very least, it means that the evidence is fortunately very far from encouraging any facile detailed scheme of closely correlated variations in the two areas such as Dr. Schove purports to infer from the European evidence. Indeed, it is not really possible yet, to correlate the post-glacial evidence for climatic change from the Llano Estacado with that from other parts of the arid and semi-arid south-west of the United States.

Mr. P. C. Spink : Re Dr. Butzer's remarks on the anomaly of finding evidence of pollen grains belonging to various exotic trees and plants in mid-Sahara. Could these not have been blown from the Mediterranean coast by strong northerly winds ? There is evidence, I believe, for pollen grains being windborne for many hundreds of miles.

Dr. R. L. Raikes : Can Dr. Butzer say whether the possibility has been considered, for the desert highlands of the Sahara, that the very high variability of rainfall, overgrazing (whether by flocks or by wild animals) and the lack of a source of re-population by vegetational species, could account for the present denuded state of these highland areas ? I believe that we are concerned here with denudation rather than with simple rainfall deficiency.

The question of variability of rainfall is of great importance. To speak of mean rainfalls of the order of 25 mm (presumably that of the desert highlands is considerably more, being described as relatively high) is to speak of a fictional statistical concept. With 300 years of reliable records it could conceivably be possible to say that for those 300 years and for the point at which the measurements had been made, the mean rainfall of an area of appreciable size might have some meaning. Rainfall measurement stations in Saudi Arabia having an estimated mean rainfall of 350 mm (= about 14 inches) estimated on scanty records, vegetational indicators and geomorphological evidence, are known to have had many years with no rainfall at all. The recent case of Ma'an in Jordan, where many lives were lost and half the town destroyed, lends force to this argument. Ma'an, in the desert marginal belt of Jordan had, on that occasion, approximately its whole ' national ' mean annual rainfall in one storm of considerable intensity and short duration. A nearby rainfall station registered 60 mm of rainfall in 20 minutes – or 180 mm per hour (= rather more than 7 inches per hour).

It is my conviction that desert rainfall occurs mainly as sporadic convective storms of limited area and duration and of entirely unpredictable distribution in time and space.

(*Communicated later*) : The evidence shown by Dr. Butzer in various colour slides is entirely consistent with sporadic heavy localized rainfall of high intensity that is quite capable of producing the gravel outwash illustrated in one single storm episode. Some of the Nile alluvium illustrated is entirely consistent with re-erosion of earlier alluviation and its re-deposition elsewhere.

I would also like to add that evidence of fauna and of various phases of human hunting-collecting cultures in the western Sahara means nothing in terms of climate change unless the implications of McBurney's theory of an early prehistoric upper Niger that flowed northward into the Sahara – into the internal drainage basin of El Juf – are proved false. Gazelle are still found, to my certain knowledge, in the Libyan Desert (alongside oryx, ostrich, desert foxes, etcetera). Giraffe move right up into northern Darfur. Lion move into the desert fringe during the summer inter tropical-front rainfall period. The geomorphology and ecology of the desert and its fringes, whether north or south, can only be understood if the hydrological parameters of all kinds are properly understood. This does not mean merely allotting ' numbers,' for these have of necessity to be statistically derived : it means an understanding based on the whole complex of hydrological-ecological factors.

Dr. K. W. Butzer (*in reply*) : (To Dr. Heusser) : Pollen studies of marine-littoral sediments have been made from Pleistocene and younger sediments on the coast of Israel by Roussignol, and have been recently published in *Pollen et Spores*. So far, attempts to find pollen-bearing sediments from cores in the Nile Delta have proved unsuccessful.

(To Dr. Merton) : No evidence of prehistoric lakes is available from the Qattara depression, although lacustrine beds appear to exist at Bahariya while a well-known cultural succession has been established from spring tufas and associated beds at Kharga (Libyan Desert).

(To Mr. Spink) : At least some part of the very rare exotic pollen is a product of long-distance transport, although derivation from older sediments may also be involved.

(To Dr. Raikes) : Periodically the suggestion has been made that the Sahara is a man-made desert, whereas in fact all lines of physical evidence indicate that it is one of the driest deserts of the world and a natural phenomenon. On the other hand, natural vegetation undoubtedly would be *a little* more luxuriant in the wadi valleys or uplands, without any human interference. Certainly rainfall variability is high in arid lands but this does not alter the fact that the climate is arid. In reply to Dr. Raikes's written communication : The wadi gravels and nilotic silts discussed from Nubia can hardly be interpreted from a colour slide. On the basis of bedding properties and general stratigraphic relationships none of these deposits are the product of a single storm, while the calibration of the bed-load or the degree of rolling of pebbles commonly indicates greater stream competence or transport distances, as the case may be, in comparison with contemporary deposits at the same locality.