PALAEOECOLOGY OF AFRICA
AND THE SURROUNDING ISLANDS

VOLUME 18

Edited by
J.A.COETZEE (D.Sc.)
Department of Botany, University of Orange Free State, Bloemfontein

OFFPRINT

A.A.BALKEMA / ROTTERDAM / BROOKFIELD / 1987

PALAEOCLIMATIC EVIDENCE FROM EARLY TO MID-HOLOCENE PLAYAS IN THE GILF KEBIR (SOUTHWEST EGYPT)

S.KRÖPELIN
Institut für Physische Geographie, Freie Universität Berlin, F.R.Germany

SUMMARY

Investigations of the sediments of early to Mid-Holocene playas in valleys of the Gilf Kebir Plateau (c. 23°N/26°E) resulted in new data on the palaeoclimate in the centre of the largest hyperarid region of the earth. From detailed stratigraphic evidence, scanning electron microscopy, more than forty radiocarbon-dates and interpretations of prehistoric floral and faunal remains, the following climatic development was reconstructed: Up to about 9500 years BP an extremely arid climate, similar to the present, prevailed. The period between c. 9500 and 6000 BP had an arid climate with rare heavy rainfalls (approximately four events per 100 years), feeble soil formation and sparse plant growth in the surroundings of the temporary rainpools, and high wind activity. Between 6000 and 5000 BP conditions tended towards moderate aridity with an estimated maximum annual rainfall of 100 mm. This millennium seems to represent the main phase of Neolithic settlement. The playa deposits contain no evidence of the subsequent increase in aridity about 4800 BP. On the whole, there is growing evidence that in this part of the eastern Sahara – in contrary to more southerly regions of the Libyan Desert – the climate was arid during the entire Holocene, with only a slight, sporadic tendency towards semi-arid conditions.

RESUME

Des études au sujet du milieu de sédimentation des playas dans les vallées du plateau de Gilf Kébir (environ 23°N/26°E) ont apporté des données paléo-écologiques concernant le paléoclimat du centre de la région hyperaride la plus étendue de la terre pendant l'Holocène inférieur et moyen. D'après les résultats microstratigraphiques en rapport avec une quarantaine de datations à radiocarbone jusqu'ici disponible, des études en microscopie électronique ainsi que des interprétations des restes de la flore et de la faune préhistoriques, il en résulte le déroulement climatique suivant: Jusqu'à environ 9 500 BP régnait un climat extrêmement aride, comparable à celui de nos jours. La période entre environ 9 500 et 6 000 BP semble être caractérisée par un climat aride, accompagné des averses rares (environ quatre événements par 100 ans), avec une formation de sol faible et une végétation modeste dans les environs des playas et une activité éolienne importante. De 6 000 à 5 000 BP les conditions climatiques ont eu une tendance vers le sémiaride avec des précipitations annuelles éstimées à 100 mm maximum. C'est à cette époque que la colonisation Néolithique principale à apparemment eu lieu. L'aridification qui suivit après environ 4 800 BP n'est plus documentée dans les accumulations de playa. En résumé, il semble que cette région du Sahara oriental était caractérisée par une aridité persistante pendant tout l'Holocène, contrairement à la partie plus au sud du Désert Libyque.

ZUSAMMENFASSUNG

Untersuchungen zum Sedimentationsmilieu früh- bis mittelholozäner Playas in Tälern des Gilf-Kebir-Plateaus (ca. 23°N/26°E) erbrachten paläoklimatisch ausdeutbare Daten aus dem Zentrum des ausgedehntesten hyperariden Raumes der Erde. Aus den mikrostratigraphischen Befunden, rasterelektronen-mikroskopischen Ergebnissen, über 40 bisher vorliegenden ^{14}C-Altern sowie Interpretationen der prähistorischen Floren- und Faunenreste wird folgender Klimaablauf abgeleitet: Vor etwa 9 500 BP herrschte ein den rezenten Verhältnissen vergleichbares extrem arides Klima. Der Zeitraum von etwa 9 500 BP bis 6 000 BP scheint durch ein von seltenen Starkniederschlagsereignissen (ca. vier Ereignisse/100 Jahre) geprägtes arides Klima mit ansatzhafter Bodenbildung und spärlichem Pflanzenwachstum im Umfeld der Playas sowie hoher äolischer Aktivität gekennzeichnet gewesen zu sein. Von etwa 6 000 bis 5 000 BP tendierten die Verhältnisse zu einer abgeschwächten Aridität mit geschätzten Jahresniederschlägen von maximal 100 mm. In diesem Jahrtausend sind anscheinend auch die neolithischen Hauptbesiedlungsphasen anzusetzen. Die in der Folgezeit nach etwa 4 800 BP einsetzende zunehmende Trockenheit ist nicht mehr in den Playaakkumulationen dokumentiert. Insgesamt verdichtet sich somit der Eindruck eines Raumes in diesem Teil der östlichen Sahara, der – im Gegensatz zu den südlicher gelegenen Teilen der Libyschen Wüste – während des gesamten Holozäns von einem ariden und nur phasenhaft zum Semiariden hin tendierenden Klima geprägt war.

INTRODUCTION

The results presented here were obtained during several field seasons in SW Egypt and NW Sudan from 1980 onwards. The investigations formed part of the interdisciplinary research project 'Prehistoric Settlement of the Eastern

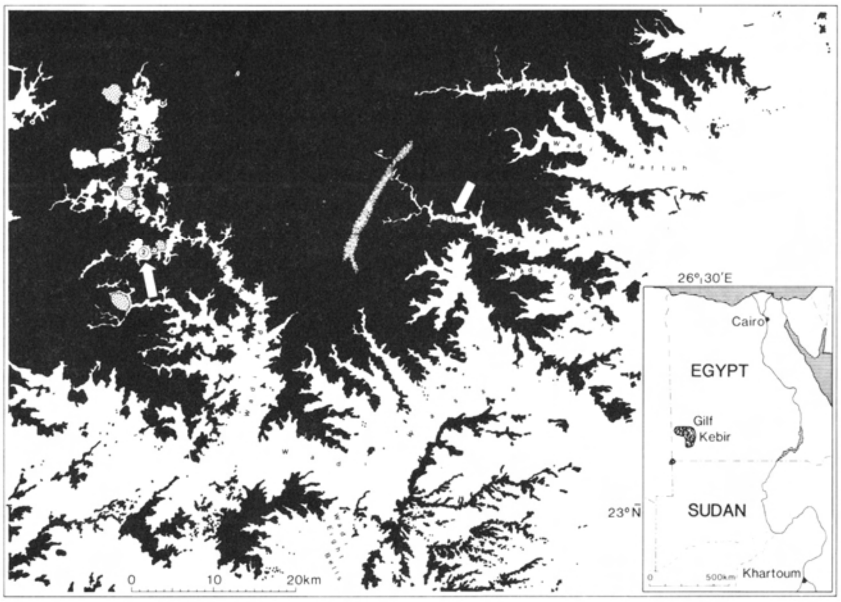

Figure 1. Southeastern part of the Gilf Kebir Plateau with localities. 1. Playa Wadi el Bakht; 2. Playa Wadi Ard el Akhdar; dotted areas: basaltic intrusions; shaded area: wind eroded depression along major fault. Source of data: Landsat and Apollo VII imagery.

Sahara' (BOS) with the title 'Cultural development, landform evolution and life styles in relation to climatic change in the eastern Sahara'. In this connection archaeological evidence has shown that during the early and middle Holocene the playas of the Gilf Kebir were favourite Neolithic settlement sites owing to their temporary water supply in this nowadays totally uninhabited part of Egypt's Western Desert. The objective of the present study was to investigate the sedimentary environments of the playa deposits and thus to clarify the boundary conditions for settlement at the time of deposition. Almost inevitably, this also yielded data contributing to the reconstruction of the palaeoclimate.

THE GILF KEBIR

The playas dealt with here are located in two valleys of the Gilf Kebir Plateau, which is situated at the Tropic of Cancer at about 26°E in the SW-Egyptian part of the Libyan Desert. The Gilf Kebir is a sandstone plateau c. 5800 km^2 in size, dissected by numerous valleys and with steep cuesta-like edges at approximately 1000 m a.s.l. (Fig. 1).

The plateau escarpment was first sighted from a great distance in 1909 (Harding-King 1912), but it was observed at close range and given its name only in 1926 (Gilf el Kebir = 'great scarp' in Arabic; Ball 1927, Kemal El Dine Hussein 1928). The actual pioneer exploration of the remote plateau during the thirties was motivated by geodetic, archaeological and military factors and is linked with the names of Almásy (1936), Bagnold (1939), Clayton (1933), Kádár (1937), Myers (1939), Peel (1939), Penderel (1934), Rhotert (1952), Shaw (1936) and Winkler (1939).

Not until the early seventies, after a thirty year break, field research was taken up again in the Gilf Kebir area (Expédition Belge, Geological Survey of Egypt, Combined Prehistoric Expedition, Technical and Free University of Berlin, BOS, Special Research Project Arid Areas; cf. Misonne 1969, Issawi 1978, Wendorf et al. 1976, Klitzsch 1978, Pachur & Gabriel 1980, El-Baz & Maxwell 1982, Kuper 1981, Klitzsch, Said & Schrank 1984; for a history of exploration see Meckelein 1975, McHugh 1981a).

The geological structure of the southern Gilf Kebir consists of horizontally bedded, Jurassic and Cretaceous sandstone, unconformably overlying the Pre-Cambrian or various Lower Palaeozoic formations (Klitzsch & List 1978). Basaltic hills and flows, apparently associated with the NW-SE, NE-SW and N-S striking fault system, point to intrusive and effusive volcanic activity on the plateau during the Tertiary (Klitzsch 1979).

Most likely the existing valley morphology with its box canyons and abrupt headcuts was controlled by the highly resistant quartzitic caprock of the southern plateau (Peel 1939). Haynes (1981) presumed that the initial fluvial dissection of the plateau cut into overlying, less resistant shales which were later completely stripped by aeolian erosion. Other processes such as subsurface drainage with undercutting of cliffs may have contributed to the formation of steep valley sides (Maxwell 1981), just as morphodynamic activity in mainly arid and semiarid conditions during Quaternary times remodelled the entire valley morphology (McCauley, Breed & Grolier 1981).

The region of the Gilf Kebir is situated in the centre of what is today the vastest hyperarid area of the world (based on the Budyko-Ratio; Henning & Flohn 1977). Half-way between the Mediterranean winter rainfall zone in the north and the summer rainfall zone of the wet-dry tropics an equatorial trade wind desert climate of strong continentality with an estimated mean precipitation of less than 5 mm/year prevails in this part of the eastern Sahara, the increased hyperaridity being due to the cross circulation of the easterly jet (Flohn 1964). Because of the almost complete absence of rainfall and the lack of any waterholes the Gilf Kebir is virtually inanimate except for a few isolated localities with sparse vegetation (Back 1981).

WADI EL BAKHT

Wadi el Bakht ('lucky valley' in Arabic; Bagnold et al. 1939) is one of the longest valleys cutting into the Gilf Kebir plateau. About 12.5 km below the valley head the psammitic-psephitic facies of characteristic wadi deposits is gradually succeeded by a pelitic facies. This is the location of the c. 66000 m^2 pluvial playa (Fig. 1, loc. 1). The importance of this locality was stressed by McHugh (1980: 65) when he wrote: 'This locale has outstanding potential for contributing to the study of the late prehistoric palaeoenvironments and cultural adaption in the area.'

The position of the playa and the thick valley fill up-stream are due to the previous complete blockage of the valley by a still partly preserved fossil dune, covered in part by a recent falling dune (Photo 1). The long profile is almost horizontal over 3 km above the dune barrier, which indicates that the local base level remained stable over a long period. We measured a gradient of only 4.15 m/950.5 m, i.e. 0.0044; Maxwell (1980: 79) gave a gradient of 0.0028 over about 1 775 m.

Mud crack polygons of different orders with diameters between 1 and 10 m cover the playa surface and document the final desiccation. The NE corner of the playa was lowered 3 m by increased deflation probably caused by turbulences at the foot of the falling dune. Here several yardangs about 1 m high are preserved at different levels and provide the best evidence of the presence of old roots, most likely mainly of reed (*Phragmites communis*). The central part of the fossil playa is covered by a 400 m^2 sized, 3 cm thick layer of curled clay flakes, the remains of recent playa deposits.

Similar deposits with a maximum thickness of 10 cm were found 11 km northward, in the 'Winkelwadi', the northern branch of Wadi el Maftuh, as well as in parts of Wadi Wassa (cf. Fig. 1). These pelitic deposits, known as 'Daq' in the Persian deserts, are evidence of secular rainstorms, which occur even during the present hyperarid climate. Field evidence suggests that water columns more than 2 m high can be attained in such short-lived rainpools (Kröpelin 1985). Cemented-in 1930s petrol cans in contemporary 'clay-flake-playas' in the western Wadi Wassa are proof of their recent age.

The prehistoric implements on the slopes of the fossil dune barrier are remarkably abundant (McHugh 1981b, Schön 1984, Wendorf & Schild 1980: 217-222). This dense layer of hundreds of thousands of stone tools and flakes seems to have preserved the fossil dune beyond the consolidated shore zone. However, it is likely that projection or slope processes contributed to the concentration of artifacts. Similar observations were also made at Wadi Howar in NW Sudan where Neolithic implements have stabilized early Holocene parabolic dunes which are surrounded by mobile barchan chains (Gabriel et al. 1985).

The minor channel incision of the upstream portion of the wadi floor also continues into the playa deposits. At its eastern edge it turns into a step-like gorge which descends 9 m down to the original valley floor over a horizontal distance of only 20 m (Photo 2). At this site the dune barrier was breached, thus terminating the former local base level.

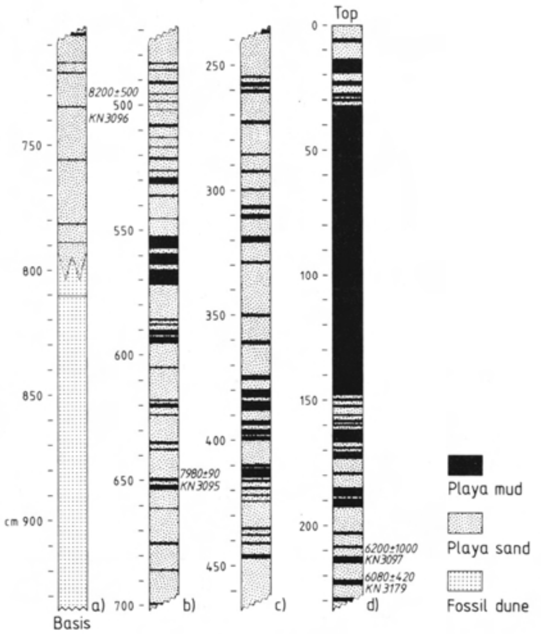

Figure 2. Wadi el Bakht, section 82/13.

Stratigraphy

The smoothened outcrop at the former playa-lake shore gives an excellent insight into the sequence of sedimentary processes (Photo 2). As already established by Peel (1939: 306), the deposits consist of thin alternating layers of mud and partially cemented red sand, overlain by a 6 ft (= 183 cm) thick mud cover (Peel mentions 6 inches = 15.24 cm; as this is obviously a slip of the pen, the correct value of 6 ft has been given here). Maxwell (1980) called for detailed stratigraphic investigations in order to clarify sedimentary conditions. These studies were carried out during our stay in January/February 1982. Figure 2 shows the micro-stratigraphic column of section 82/13. Both the scale and the few symbols demonstrate that it is a sequence of homogeneous clastic sediments with no indications of erosional disconformities.

The underlying bed is the former western slope of the fossil blocking dune and consists of cross-bedded medium sand with sharp grain-size differences between individual laminae and is undoubtedly aeolian in origin. The internal structure strikes 170° and dips 12°W on average. The fossil dune sands are orange (Munsell 5 YR 6/8 dry) and show numerous calcified root casts in their upper parts. Between 810 and 790 cm below the surface the underlying dune sands interfinger with the overlying psammites, which will be referred to here as 'playa sands' in the sense of sands that have been deposited in a playa area. This is the first occurrence here of the reddish yellow playa sands (Munsell 5 YR 6/6-8 dry). Due to a non-calcareous pelitic matrix, the medium to coarse grained sands are well consolidated.

At 788 cm the first clayey silty deposit occurs, a layer of 5 mm thick. Up to the top these deposits recur 89 times, with thicknesses up to a maximum of more than 1 m (Fig. 2). Pachur & Röper (1984: 254) quote a grain size distribution from the opposite wall of 54% silt, 45% clay and 1% sand, classifying the sediments as very clayey silts. 77% of these strata are less than 2 cm thick, 22% are 2-7 cm thick, and only the near-surface layer is 116 cm thick. Disregarding this top layer, the mean thickness is 1.43 cm with a standard deviation of 1.26 cm. On the whole, the pelites form 30% (242 cm) of the vertical thickness of the profile above the fossil dune sands.

An important argument in favour of the playa sands having been deposited in a wet environment is that load casts (Kuenen 1953) occur at almost all the basal sides of the sand layers. These pressure marks are evidence of plasticity of the still saturated pelitic layers during or shortly after sedimentation. Curled clay flakes, on the other hand, which would be evidence of complete surficial desiccation, were not found at all, although the clay content of the fossil pelites is somewhat lower than in the recent playa deposits mentioned above.

What is remarkable, however, is the total lack of signs of 'anthropoturbation'. If either humans or animals had walked over the wet, unconsolidated mud at or after playa deposition the thinly interbedded layers would have been disrupted to a greater extent. Possibly the reeds hindered entry to the swampy environment.

Of particular interest are several finds of pottery up to depths of approximately 5 m in the playa deposits. One sherd was found in the profile 82/13 at about 4 m below the surface. It is of the same type as that of a vessel found in the main profile 80/7-1 in bed D at Wadi Ard el Akhdar which was dated at about 8 000 BP (R.Kuper, pers. comm. 1982; cf. Fig. 3).

Scanning electron microscopy and energy-dispersive analysis of playa sediments

Analogous to what has been described by Walker (1979) the consolidation of parts of the fossil dune is attributed to mechanically infiltrated clay minerals (cf. Crone 1975) and extremely finely distributed iron oxides. The playa sands and pelites were analysed, taking into account results by El-Baz & Prestel (1981) who investigated the coatings of loose dune sand from Wadi el Bakht, and by Potter & Rossman (1979) who established the significance of clay minerals in the Mn-Fe-oxide deposition. Scanning electron microscopy and semi-quantitative energy-dispersive X-ray microanalysis (EDAX) of the

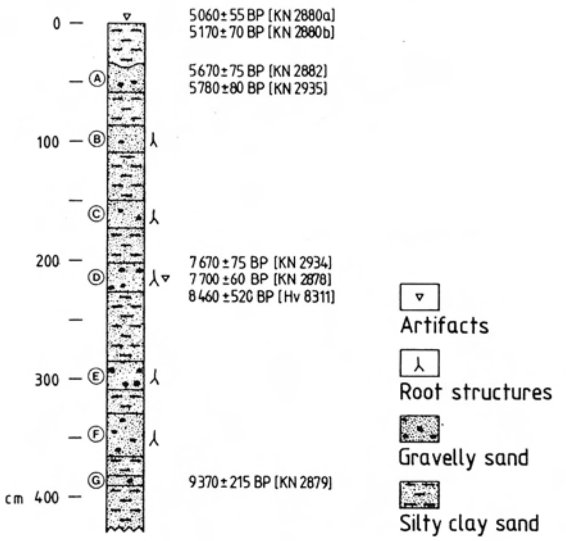

Figure 3. Wadi Ard el Akhdar, section 80/7-1 (modified after Kuper 1981).

playa sands and pelites yielded the following results:

a. Both the coatings and matrix of fossil dune and playa sands seem to consist of the same material.

b. Both coatings and matrix consist of detritic alumosilicates, mainly kaolinite, and hematite. The latter is evidence of oxidization during and after formation.

c. The water necessary for redistributing both clay minerals and iron oxides originated from the playa and not (as Walker (1979) proposes for similar features in Libya) directly from rainfall, as consolidation of fossil dune sands and playa sands only occurs in the intake area of the playa; fossil dune sands outside the shore zone of the former playa lake are still loose today. This may be a further variant in the formation of red beds, i.e. in the vicinity of playas.

d. The clay minerals and matrix of aeolianite and playa sands originated in the fluvially deposited pelites of the playa which in turn came from the cementing material of the surrounding 'Nubian' sandstone. Hence the material forming the matrix does not consist of aeolian dust, contrary to the findings of Walker (1979) in Libya.

e. Evidence of authigenic mineral formation (? Halloysite) within the porous playa sands is proof of distinctly higher humidity, as under the recent and subrecent hyperarid conditions such clay mineral formation would be impossible.

f. The micromorphological comparison between playa sands and aeolianite indicates that the playa sands were deposited in a humid environment thus confirming the conclusions drawn from the load casts mentioned above and related microstratigraphic features. The playa sands are therefore not to be interpreted as wind-blown sand deposited after total desiccation of the playa-lake.

g. The pelites have the typical structure of clastic silicate mud deposits with a high kaolinite content.

h. Furthermore the total absence of any micro- and nannofossils emphasizes that the environment within the playa was hostile to life.

WADI ARD EL AKHDAR

In the upper reaches of Wadi Ard el Akhdar ('wadi with the green floor'; Bagnold et al. 1939) the valley widens out in several places, as the satellite image interpregation map shows (Fig. 1). The playa is located in a depression which is 2 200 m long, 750-1 500 m wide, with a total area of aoout 3 km^2, and lies about 35 km upvalley from the junction with Wadi Wassa. In the eastern part the playa surface of about 160 000 m^2 is covered with a network of small channels. They run more or less radially from the edges into a 50-80 m wide main channel which cuts up to 8 m into the playa deposits. The narrow mouth of the depression is situated at the eastern end of the main channel, below a basaltic intrusion recently dated at 38 ± 2 Ma (Franz, Puchelt & Pasteels 1986; cf. Fig. 1, dotted signature E of loc. 2). This constriction is about 600 m long and only 50 m wide, and the valley floor is reduced to about 10 m width by a recent, N-S striking dune.

The complete blockage of this constriction in earlier times was due to a dune barrier formed in the lee of the basaltic hill, as the present situation suggests (McCauley, Breed & Grolier 1981, Pachur & Braun 1982). This blockage which seems to have been initiated by an apparently sudden fall of metre-size boulders from the southern slope (Kröpelin 1985) caused the depression to fill with thick, loose sediments over a considerable span of time.

Stratigraphy

The most significant section 80/7-1 is located 640 m upvalley from the fossil dune barrier on the north side of the main channel. Here, pottery sherds were found about 2 m below the surface. Associated charcoal was dated at 8 460 ± 520 BP (Hv 8311) so that the fragments are among the oldest pottery in the entire Sahara (Pachur & Gabriel 1980). Figure 3 shows seven alternations of pale and dark layers. The darker strata, marked A to G, mostly contain root structures and bioturbational features, and have distinctly more coarse sand and fine, angular gravels than the comparatively homogeneous paler layers (Kuper 1981: 232).

Detailed chemical analyses and grain-size distributions of this profile have been published by Pachur & Röper (1984: 253). They confirm the predominantly psammitic nature of all the layers which show a content of sand between 41.4 and 81.5% ($\overline{X}$ = 63.2%), silt between 3.4 and 31.6% ($\overline{X}$ = 19.1%) and clay between 6.7 and 25.3% ($\overline{X}$ = 13.5%) with poor sorting and, in part, bimodal distribution. Higher gravel contents of 20.8% and 8.4% were found only in the two samples from the top, the others have less than 3.3%. The organic carbon content varies between 0.03% and 0.09%. As the radiocarbon dates in Figure 3 show, section 80/7-1 reflects the course of sedimentation in part of the depression from about 9 400 to 5 000 BP; an erosion-induced unconformity is only perceptible above the A layer.

The material was probably washed by sheetfloods or rill erosion over a short distance only from the margins into the deeper, central part of the depression, a process which has been verified in other sections by corresponding sediments (basalt and quartzite particles; W.Schön 1984 in litt.). Both the poor sorting and the high degree of consolidation are typical of such fanglomerates. Better sorting occurs only in a position further downvalley, where there are few or no psephite components in the over-9-m-thick, fine sandy-silty deposits which represent the core of the playa and occupy c. 12 000 m^2. This means that at the time of deposition site 80/7-1 was situated at the periphery of the former playa lake. This interpretation, based on independent evidence, corresponds in the main to the conclusions drawn by Pachur & Röper (1984: 252) from this profile: that it is a sedimentary environment characterized by short and heavily loaded sediment transport, with no features of genuine limnic sedimentation.

In fact, the upper Wadi Ard el Akhdar contains almost no purely pelitic stillwater deposits, i.e. playa sediments in the narrow sense (with grain sizes $< 63\ \mu m$), comparable to the pelitic layers in Wadi el Bakht. This is the main facies difference to the accumulations there. Several sections and test pits confirmed the predominantly lateral-colluvial character of the Holocene deposits, which reveal a comparatively high energy level.

PREHISTORIC FAUNA AND FLORA

The faunal remains obtained from Wadi el Bakht and Wadi Ard el Akhdar suggest a meagre palaeofauna and, indirectly, as well a poor palaeoflora (Table 1). They were found mainly on or in surface layers at some distance from the playas and belong exclusively to non-aquatic organisms. Since it is by no means certain that the bone only tentatively identified as ?*Elephas* did in fact come from Wadi el Bakht or Gilf Kebir (see note to Table 1), the only significant palaeoecological evidence of wild fauna consists of two finds of giraffe bones (Pachur & Röper 1984; this chapter). Since giraffes subsist on the leaves, buds and twigs of trees, mainly acacias, these scanty relics are the only faunal indications of tree vegetation. The other wild mammals found here are desert animals accustomed to extreme aridity rather than typical

Table 1. Faunal remains from Wadi el Bakht and Wadi Ard el Akhdar, Gilf Kebir

Name	Specific name	Source
Wadi el Bakht		
? Elephant	? *Elephas* sp.	McHugh 1975*
Big bovide	*Bos* sp.	McHugh 1975*
Addax	*Addax* sp. *nasomaculatus*	McHugh 1975*
Damaliscus	*Damaliscus* sp.	McHugh 1975*
Gazelle	*Gazella* sp.	McHugh 1975*
? Goat	? *Capra* sp.	McHugh 1975*
Jackal, ? dog	*Canis* cf. *anthus*	McHugh 1975*
Ostrich	*Struthio camelus*	McHugh 1975*
Wild donkey	*Equus asinus*	McHugh 1975*
Ostrich	*Struthio camelus*	Gautier 1980
Big dog	*Canis lupus* f. *familiaris*	Gautier 1980
Dorcas gazelle	*Gazella dorcas*	Gautier 1980
Sheep or	*Ovis ammon* f. *arres* or	Gautier 1980
goat	*Capra aegragus* f. *hircus*	Gautier 1980
Domestic cattle	*Bos primigenius* f. *taurus*	Gautier 1981
Big bovides	*Bos* sp.	Gautier 1981
Giraffe	*Giraffa camelopardalis*	Pachur & Röper 1984 (det. Uerpmann, Tübingen)
Buffalo	*Bubalus* sp.	
Antelope	?	
Gazelle	?	
Giraffe	*Giraffa camelopardalis*	This chapter (det. Uerpmann, Tübingen; Kuper 1984 in litt.)
Cattle	*Bos* sp.	
Mice	?	
Wadi Ard el Akhdar		
?	? *Bos* sp.	Gautier 1981
Giraffe	*Giraffa camelopardalis*	This chapter (det. Uerpmann, Tübingen; Kuper 1984 in litt.)
Dorcas gazelle	*Gazella dorcas*	
Gazelle	*Gazella* sp.	
Kamma antelope	*Tragelaphus oryx*	
Rock rabbit	*Procavia capensis*	
Ostrich	*Struthio camelus*	
Bovide	*Bos* sp.	
Big buffalo	*Bubalus* sp.	
Capride	?	
See above	See above	McHugh 1975*

*These faunal remains were collected by O.H.Myers in 1938 (Myers 1939) and only preliminarily identified by D.M.A.Bate & J.Johnson, London. Their provenance from Wadi el Bakht or Wadi Ard el Akhdar or even from the Gilf Kebir is not ascertained though it is likely that some of them were associated with artifact assemblages recorded by Myers in the upstream portions of these valleys (Gautier 1981). Therefore parts of the material listed under Wadi el Bakht could possibly have come from Wadi Ard el Akhdar.

savanna species. Addax, Dorcas gazelle and Damaliscus live on grass and herbs only and can exist for months, years or even entirely without water other than the fluid intake from plants and dew (Haltenorth & Diller 1977). Furthermore, Almásy (1936: 45) mentions finding the fresh carcass of an *Addax nasomaculatus* on the western side of the Gilf Kebir as late as 1933.

Owing to the absence of pollen, diatoms and identifiable opal phytoliths, until recently the only direct palaeofloral evidence consisted of root structures (Fig. 3), a few root and stem fillings with diameters up to 10 cm, and the close-set stone casts of roots and stalks, which were identified as reeds (*Phragmites communis*) by their position, cross-sections, and diameters of about 1 cm. In addition, grass steppe fires were deduced from the widespread minuscule traces of charcoal found well away from hearth sites.

Recently, however, the results of extensive palaeoxylotomic studies of charcoal remains with the aid of scanning electron microscopy have been presented (Neumann, this volume, and 1986), the great majority of which have been dated by radiocarbon. They provide independent confirmation of conclusions on palaeoflora and early and mid-Holocene rainfall drawn from sediment facies, electric conductivity logging, the absence of micro- and nannofossils, geomorphological mapping and other evidence (Kröpelin 1985). Relicts of almost all the identified genera and species, mainly acacia (*Acacia tortilis* subsp. *raddiana* and *Acacia ehrenbergiana*), *Maerua crassifolia* and *Balanites aegyptica*, still occur in Gilf Kebir; *Tamarix articulata* is found in the neighbouring Jebel Uweinat. Only *Acacia albida* and *Ziziphus lotus* no longer occur here today, but are found in the mountains of the central Sahara (Neumann 1986).

DISCUSSION AND PALAEOCLIMATIC CONCLUSIONS

Playas which are not groundwater-fed represent valuable indicators of climate because their occurrence is due only to surficial run-off, contrary to lakes in the Sahara which are always dependent on specific conditions in which local, non-climatic factors may play a major part (Rognon 1980). The evidence presented above strongly suggests that the early to mid-Holocene playas in the Gilf Kebir were such 'dry playas' (Motts 1965), i.e. temporary pools containing water for days, weeks or months only.

Of course, local factors are also important to a certain degree in the formation of both fossil and recent playas in the Gilf Kebir. The necessary conditions for the origin of basins and thus for the accumulation of playa sediments are the result of a combination of W-E trending valleys with constant winds blowing roughly N-S (trade winds), and a source of sand in the north (Great Sand Sea). Additional factors were residual terraces ('Winkelwadi') or valley constrictions (Wadi Ard el Akhdar). On the other hand, such special local influences would not have had any great effect had they not been accompanied by climatic parameters considerably different from the present day.

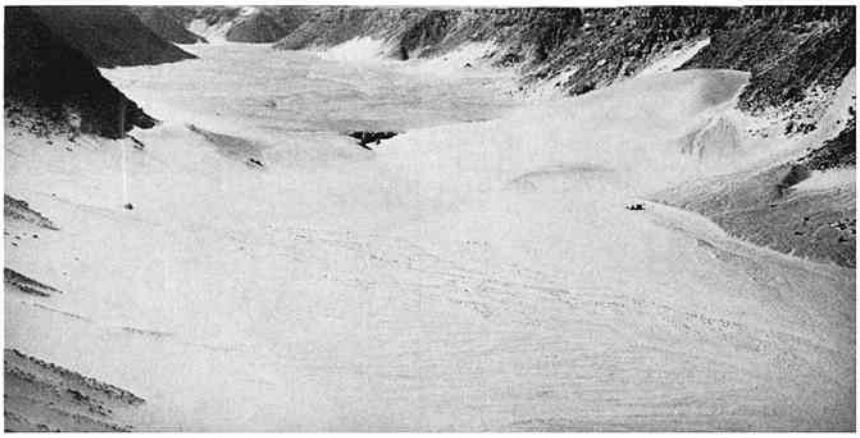

Photo 1. Wadi el Bakht. View WNW upvalley with residual fossil dune responsible for damming the valley and causing the accumulation of stillwater sediments between c. 9 000 and 5 000 BP. Valley width: 650 m, difference in elevation between plateau edge and playa surface: 110 m. Two Unimogs show scale of photo. (Photo by S.Kröpelin, 29/1/1982)

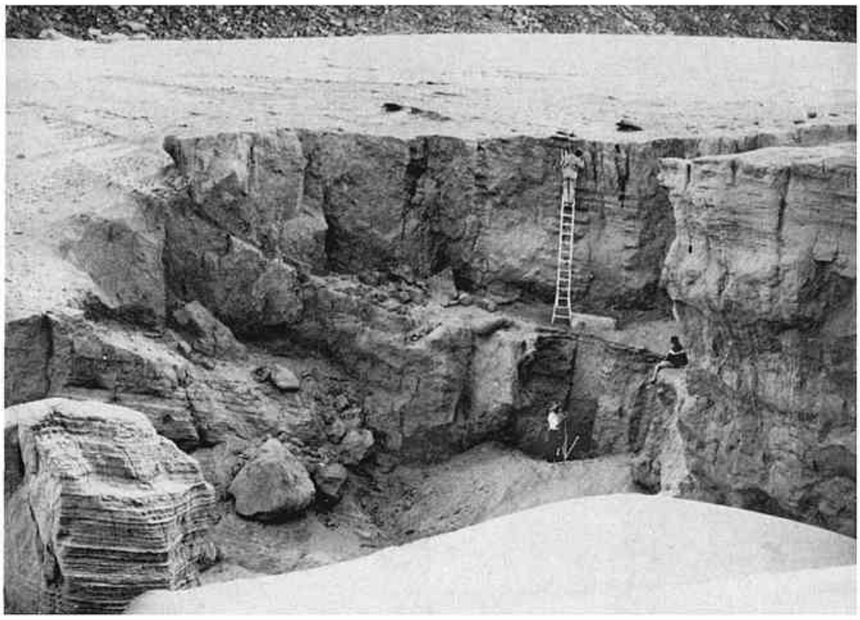

Photo 2. Wadi el Bakht, section 82/13. Natural outcrop in the gorge breaching the fossil dune barrier (see centre of Photo 1). Date of breach probably about 4 800 BP. The playa sediments dip W upvalley and are over 8 m thick at this site near the former playa lake shore. (Photo by S.Kröpelin, 3/2/1982)

The sections of Wadi el Bakht and Wadi Ard el Akhdar (82/13 and 80/7-1) show the following climatic development: Blockage of the valleys, which created the conditions necessary for playa accumulation must have occurred, or at least begun, before 9 370 ± 215 or 8 200 ± 500 BP (cf. Table 2); the latter seems to be the case in Wadi Ard el Akhdar. An age of about 9 400 BP is more likely to be correct since the date from Wadi el Bakht is from material overlying the earliest deposits in the playa centre. The climate seems to have been even more arid than today, since actual dunes are not able to cause total blockage of the valleys of Wadi el Bakht and Wadi Ard el Akhdar. However, different non-climatic boundary conditions may have prevailed, causing for example an increased supply of sand.

For the subsequent period up to about 6 200 BP the section 82/13 (Fig. 2) is more instructive because the playa in Wadi el Bakht had a larger catchment area and therefore, due to the amplifying effect, provides more information on the course of sedimentation than the Wadi Ard el Akhdar playa where lateral influences dominated. The number of pelitic strata documented in section 82/13 between 8 200 ± 500 BP and 6 080 ± 420 or 6 200 ± 1000 BP (cf. Fig. 2) could be explained by the fact that rainfall events were only twice as frequent (approximately 70 events/2 000 years) as in the present hyperarid climate (approximately 2 events/100 years = 40 events/2 000 years). Likewise the thicknesses of fossil deposits (less than 2 cm on average) roughly correspond to recent rates of sedimentation in the 'Winkelwadi' or in Wadi Wassa. Nevertheless, neither the spatial extent and volume of the deposits, nor the composition of the sediments are conceivable under the actual climatic regime. This suggests that there must have been both heavier or lengthier rainfall and, above all, different conditions for material supply. Particularly the texture of the pelites can only be explained by more intense weathering or soil formation in the source area. There are signs of pedogenesis at numerous outcrops especially in the surroundings of the playa in Wadi Ard el Akhdar where there are root structures, bioturbation features, still measurable organic carbon, higher proportions of clay, at least some of which probably formed in situ, and red beds in various stratigraphic positions.

Hence, the strata A to G in section 80/7-1 (Fig. 3) cannot be interpreted as representing pluvial phases of climate, since they probably resulted from single fanglomeratic depositions after exceptional rainfall. However, they contain pedogenetic features which provide palaeoecological evidence for the entire phase between two depositional events. At any rate, this period, roughly lasting from 9 000 to 6 000 BP, was characterised by uneven, discontinuous sedimentation, which points to an arid climate with single heavy showers of rain.

Only after 6 200 ± 1 000 or 6 080 ± 420 BP does the series of pelitic layers in section 82/13 become denser, and there is a more or less continuous deposition of the thick pelitic top, lasting up to about 5 000 BP (cf. Fig. 2). Some evidence of earlier human occupation exists; however, radiocarbon dates

Table 2. ^{14}C-dates from Wadi el Bakht and Wadi Ard el Akhdar, Gilf Kebir

No.	Age BP	Site/Stratigraphic level	Material	Source
Hv 11644	8 715 ± 920	10 m W of section 82/13, 310 cm below top	Charcoal	Pachur & Röper 1984
KN 3096	8 200 ± 500	Section 82/13, 720 cm below top	Charcoal	Kuper 1984
KN 3095	7 980 ± 90	Section 82/13, 640 cm below top	Charcoal	Kuper 1984
Hv 11648	7 585 ± 80	Fossil dune	Calc. rt.	Pachur & Röper 1984
SMU 273	6 980 ± 80	Northeastern part of playa surface	Ostr.	Haynes in litt. 1981
KN 3410	6 700 ± 300p	Site 82/21-2, artifact layer	Charcoal	Kuper 1984
KN 3097	6 200 ± 1 000	Section 82/13, 220 cm below top	Charcoal	Kuper 1984
KN 3328	6 150 ± 200	Site 82/22, ditch	Charcoal	Kuper 1984
KN 3179	6 080 ± 420	Section 82/13, 240 cm below top	Charcoal	Kuper 1984
KN 3079	5 180 ± 60	Site 82/15, artifact layer	Charcoal	Kuper 1984
KN 3149	5 070 ± 60	Site 82/15, hearth	Charcoal	Kuper 1984
KN 3182	4 880 ± 390	Site 82/18, hearth	Charcoal	Kuper 1984
KN 3096	4 820 ± 60	Site 82/16, hearth	Charcoal	Kuper 1984
KN 3184	4 770 ± 130	Site 82/19, hearth	Charcoal	Kuper 1984
Wadi Ard el Akhdar				
KN 2879	9 370 ± 215	Section 80/7-1, layer G	Charcoal	Kuper 1981
Hv 8312	8 695 ± 560	Root horizon	Calc. rt.	Pachur & Gabriel 1980
Hv 8311	8 460 ± 520	Section 80/7-1, layer D	Charcoal	Pachur & Gabriel 1980
KN 2878	7 700 ± 60	Section 80/7-1, layer D	Charcoal	Kuper 1981
KN 2934	7 670 ± 75	Section 80/7-1, layer D	Charcoal	Kuper 1981
KN 3191	6 510 ± 220	Site 80/32, hearth	Charcoal	Kuper 1984
KN 3176	5 940 ± 230	Site 81/8, surface artifact layer	Charcoal	Kuper 1984
KN 3358	5 800 ± 450	Section 81/4, layer III	Charcoal	Kuper 1984
KN 2935	5 780 ± 80	Section 80/7-1, layer A	Charcoal	Kuper 1981
KN 2882	5 670 ± 75	Section 80/7-1, layer A	Charcoal	Kuper 1981
KN 3016	5 670 ± 65	Section 81/4, layer II	Charcoal	Kuper 1984
KN 3381	5 650 ± 130	Section 81/4, layer II	Charcoal	Kuper 1984
KN 2936	5 610 ± 60	Site 80/7-2, artifact layer	Charcoal	Kuper 1984
KN 3187	5 500 ± 60	Site 81/4, hearth	Charcoal	Kuper 1984
KN 3106	5 440 ± 60	Section 81/2	Charcoal	Kuper 1984
KN 3103	5 430 ± 65	Site 81/8, hearth	Charcoal	Kuper 1984
KN 2881a	5 420 ± 65	Site 80/12-1, hearth	Charcoal	Kuper 1984
KN 2881b	5 360 ± 210	Site 80/12-1, hearth	Charcoal	Kuper 1984
KN 3104	5 250 ± 140	Site 80/15-2, hearth	Charcoal	Kuper 1984
KN 2880b	5 170 ± 70	Site 80/7-5, surface artifact layer	Charcoal	Kuper 1984
KN 2933	5 150 ± 125	Site 80/12-1, hearth	Charcoal	Kuper 1984
KN 2880a	5 060 ± 55	Site 80/7-5, surface artifact layer	Charcoal	Kuper 1984
Hv 8313	4 365 ± 95	?	Calc. rt.	Pachur & Gabriel 1980
KN 3085	4 200 ± 1 100	Site 80/14, hearth	Charcoal	Kuper 1984
KN 3173	4 150 ± 55	Site 80/14, southern annex	Ostr.	Kuper 1984
KN 2926	3 950 ± 55	Site 80/14, right concentration	Ostr.	Kuper 1984
KN 2925	3 860 ± 60	Site 80/14, left concentration	Ostr.	Kuper 1984
Hv 8242	3 830 ± 365	Hearth	Charcoal	Pachur & Gabriel 1980

calc. rt. = calcified root casts; ostr. = ostrich egg-shells; p = preliminary date show that the main settlement phases occurred between 6 000 and 5 000 BP, both in Wadi el Bakht and Wadi Ard el Akhdar (Cziesla 1986, Schön 1984; cf. Table 2). This could also be evidence of comparatively favourable climatic conditions.

Not long after c. 5 000 BP the deposition of playa sediments stopped in both valleys, as the two main sections 82/13 and 80/7-1 (Figs. 2 and 3) and numerous surface dates show, even if a certain amount of deflation is taken into account. This suggests that the dunes blocking Wadi el Bakht and Wadi Ard el Akhdar were breached during this period. There are two possible explanations: Either the breaches were due to an unprecedented, exceptionally high water pressure or level, pointing to a climatic optimum with comparatively high precipitation or a unique millennial rainfall event. Or the sediments had reached the same height as the dune barriers so that overflow and breaching were inevitable. The fact that the occurrence of thick pelitic deposits (section 82/13) coincides with the cessation of playa sedimentation 'shortly afterwards' and the roughly contemporary breaching of the blockages in both valleys makes the first explanation more likely.

We have now reached the open question of whether accumulation or erosion was the prevailing process during the Saharan pluvials (cf. Butzer 1963, Chavaillon 1964, Hagedorn 1980, and, with reference to Wadi el Bakht, Pachur & Röper 1984). However, it would be going too far here to equate playa formation in the Gilf Kebir with arid phases and fluvial erosion with humid conditions. A possible approach to solving this apparent contradiction may be to consider the distribution of rainfall rather than its annual mean, i.e. the rainfall regime, as Gabriel (1977) suggested in the case of the Tibesti mountains. Thus a west-wind-induced type of occasional winter rainfall with steady rains could have alternated with a regime of secular monsoonal-convective summer rainstorms triggered by exceptional northward surges of the surface inter-tropical convergence zone (cf. Pedgley 1974). The former is more likely in the case of the more or less continuous pelitic deposits at the top of section 82/13, and the latter in the case of the preceding and subsequent 'wet' phases. At any rate, after about 5 000 BP no more playa sediments were deposited and hence, there is no evidence of the renewed climatic deterioration which is underlined by the fact that the following fluvial erosion obviously had no significant effect on their degradation, at least in Wadi el Bakht. However, this interpretation of events implies that the main gully in the upper Wadi Ard el Akhdar already existed during the late settlement phase around 4 000 BP.

In attempting to estimate the approximate rainfall level we do not intend to repeat the above mentioned conclusions which were drawn from the sedimentary structure of the playa deposits, the absence of micro- and nannofossils, the faunal remains of non-aquatic organisms and palaeofloral evidence. Nevertheless, botanical results established by Walther (1979: 124) will be quoted which bear on the question of palaeoevegetation – and thus indirectly of the palaeofauna – in the valleys from the desert near Helwân with rainfall about 25 mm/year. Given that 40% of the rainfall flows down into the deepest parts of the relief which cover about 2% of the whole area there, the plants at these favourable sites would receive the same amount of water as those in the plain with a rainfall of 500 mm/year. Yet we do not have to go that far to explain the occurrence of reeds and resistant species of acacia in the Gilf Kebir valleys. The fact that the vegetation in the valleys was apparently not abundant, suggests that the plant cover on the surrounding plateau was very sparse.

It is true that Neolithic implements in this nowadays completely uninhabited area are surprisingly frequent. However, they are few compared with the abundance of archaeological remains found in the more elevated Tibesti mountains (Gabriel 1977) or in the Wadi Howar (Gabriel & Kröpelin 1986, Kuper 1981). Thus it seems unlikely that the area was permanently occupied even during the most favourable periods.

On the basis of the evidence described above and compared to the conditions under the present Sahel climate (cf. Ibrahim 1980, Mensching 1984, Rzóska 1961, Wickens 1976, and others), the amount of rainfall in the Gilf Kebir during the 'Neolithic' pluvials more likely lay within the lower range of 50-100 mm/year estimated by Butzer (1959: 77) and Hester & Hobler (1969: 164) on general considerations for the area. Here, the higher values should be restricted to the mid-Holocene period approximately between 6 000 and 4 500 BP, lasting from the onset of the top pelitic layer at Wadi el Bakht to the time after the barrier breaches.

McHugh (1974: 13) based his estimate of 200-800 mm/year rainfall mainly on the normal ecological requirements of the giraffe, ostrich, oryx and domestic cattle depicted by rock art (cf. Rhotert 1952, Winkler 1939). However, it is not necessary to postulate such a high maximum to account for Neolithic pastoralists migrating seasonally or sporadically at times of good grazing with their herds from the climatically more favourable Jebel Uweinat with its waterholes to the southern Gilf Kebir, 150 km away. At the beginning of this century cattle were still being driven 200 km from Kufra oasis to graze in the northwestern Gilf Kebir (now known as Abu Ras Plateau) after exceptional summer rainfall (Almásy 1939: 131 f.). Thus, the conclusions drawn here lie even somewhat below the palaeoclimatic inferences drawn by Pachur & Gabriel (1980) and Pachur & Röper (1984) from the 'montane variant of pelitic sediments' in the Libyan desert, according to which a semi-arid climate with high wind activity and rainfall around 200 mm/year prevailed at the Gilf Kebir between 8 000 and 4 000 BP.

On the whole, it becomes more evident that climatic conditions during the entire Holocene in this central part of the eastern Sahara were arid, with only a sporadic tendency towards semi-aridity (cf. Cour & Duzer 1976, Meckelein 1982, Wendorf & Hassan 1980). It seems possible that such wetter phases may be over-interpreted in some cases.

ACKNOWLEDGEMENTS

The BOS project is supported by the German Research Council ('Deutsche Forschungsgemeinschaft'). I am particularly grateful to Dr Rudolph Kuper, Cologne, and Dr Baldur Gabriel, Berlin, as well as to the other members of the BOS team for their friendly and constructive cooperation during the months of field seasons. Valuable information was provided by Professor Dr H.-J.Pachur, Berlin, on the occasion of a joint inspection of the Wadi Ard el Akhdar. Scanning electron microscopy was carried out at the Central SEM Unit of the Technical University Berlin (ZELMI). Furthermore I wish to thank Mrs Katharina Neumann, Frankfurt, for permission to include her latest palaeoxylotomic results, Dr H.-P.Uerpmann, Tübingen, for osteological identifications, and Mrs Anne Beck for translating the manuscript.

REFERENCES

Almásy, L.E. de 1936. Récentes explorations dans le désert Libyque (1932-1936). *Publ. Spéc. Soc. Roy. Géogr. Egypte,* Cairo, 100 pp.

Almásy, L.E. de 1939. *Unbekannte Sahara – Mit Flugzeug und Auto in der Libyschen Wüste.* Leipzig: Brockhaus, 214 pp.

Back, H.E. 1981. Beitrag zur Faunistik und Zoogeographie der Lepidopteren in der östlichen Sahara. *Nota lepid.* 4: 111-125.

Bagnold, R.A., O.H.Myers, R.F.Peel & H.A.Winkler 1939. An expedition to the Gilf el Kebir and Uweinat, 1938. *Geogr. J.* 93: 281-313.

Ball, J. 1927. Problems of the Libyan desert. *Geogr. J.* 70: 21-38, 108-128, 209-224.

Butzer, K.W. 1959. Environment and human ecology in Egypt during predynastic and early dynastic times. *Bull. Soc. Géogr. Egypte* 32: 43-88.

Butzer, K.W. 1963. Climatic-geomorphologic interpretation of Pleistocene sediments in the Eurafrica subtropics. In F.C.Howell & F.Bourlière (eds.), African ecology and human evolution. *Viking Fund Publ. Antropol.* 36: 1-27.

Chavaillon, J. 1964. Etude stratigraphique des formations quaternaires du Sahara nord-occidental (Colomb-Béchar à Reggane). *Publ. Centre Rech. Zones Arides, CNRS, Sér. Géol.* 5, 393 pp.

Clayton, P.A. 1933. The western side of the Gilf Kebir. *Geogr. J.* 81: 254-259.

Cour, P. & D.Duzer 1976. Persistance d'un climat hyperaride au Sahara central et méridional au cours de l'Holocène. *Rév. Géogr. phys. Géol. dynam.* 18(2): 175-198.

Crone, A.J. 1975. Laboratory and field studies of mechanically infiltrated matrix clay in arid fluvial sediments. Ph.D. thesis, Colorado Univ., 162 pp.

Cziesla, E. 1986. Der Fundplatz Wadi el Akhdar 80/14. *Forschungen zur Prähistorie Afrikas* 1 (in press).

El-Baz, F. et al. 1980. Journey to the Gilf Kebir and Uweinat, southwest Egypt, 1978. *Geogr. J.* 146: 51-93.

El-Baz, F. & T.A.Maxwell (eds.), 1982. *Desert landforms of southwest Egypt: A basis for comparison with Mars.* NASA Contr. Rep. 3611, 372 pp.

El-Baz, F. & D.Prestel 1981. Coatings on sand grains from southwestern Egypt. *Ann. Geol. Surv. Egypt* 11: 175-188.

Flohn, H. 1964. Investigations on the Tropical Easterly Jet. *Bonner Meteor. Abh.* 4, 83 pp.

Franz, G., H.Puchelt & P.Pasteels 1986. Petrology, geochemistry and age relations of Triassic and Tertiary volcanic rocks from SW-Egypt and NW-Sudan. *J. African Earth Sc.* 4 (in press).

Gabriel, B. 1977. Zum ökologischen Wandel im Neolithikum der östlichen Zentralsahara. *Berliner Geogr. Abh.* 27, 111 pp.
Gabriel, B. 1986. Die östliche Libysche Wüste im Jungquartär. *Berliner Geogr. Stud.* 19 (in press).
Gabriel, B. & S.Kröpelin 1984. Holocene lake deposits in northwest-Sudan. *Palaeoecol. of Africa* 16: 295-299.
Gabriel, B. & S.Kröpelin 1986. Habitats dunaires néolithiques au Soudan septentrional et implications paléoclimatiques. In *Proc. of INQUA-ASEQUA Symp. Intern. 'Changements globaux en Afrique durant le Quaternaire: passé – présent – futur', Dakar, Senegal,* Editions de l'ORSTOM, Coll. Travaux et Documents 197: 157-160.
Gabriel, B., S.Kröpelin, J.Richter & E.Cziesla 1985. Parabeldünen am Wadi Howar – Besiedlung und Klima in neolithischer Zeit im Nordsudan. *Geowissenschaften in unserer Zeit* 3: 105-112.
Gautier, A. 1980. Contribution to the archaeozoology of Egypt. In F.Wendorf & R.Schild (eds.), *Prehistory of the Eastern Sahara*: 317-344. New York: Academic Press.
Gautier, A. 1981. Neolithic faunal remains in the Gilf Kebir and the Abu Hussein dunefield. *Ann. Geol. Surv. Egypt* 11: 335-339.
Hagedorn, H. 1980. Fluvial processes in the Sahara. *Palaeoecol. of Africa* 12: 115-123.
Haltenorth, T. & H.Diller 1977. *Säugetiere Afrikas und Madagaskars.* Munich: BLV, 403 pp.
Harding-King, W.J. 1912. Travels in the Libyan desert. *Geogr. J.* 39: 133-137.
Haynes, C.V. 1981. The Darb El-Arba'in desert: a product of Quaternary climatic change. *Ann. Geol. Surv. Egypt* 11: 91-117.
Henning, D. & H.Flohn 1977. Climate Aridity Index Map. In *Proc. of UN Conf. 'Desertification', UNEP, Nairobi, Kenya,* UN Doc. A/CONF. 74/31.
Hester, J.J. & P.Hobler 1969. *Prehistoric settlement patterns in the Libyan desert.* Univ. Utah Pap. Anthropol. 92, 171 pp.
Ibrahim, F.N. 1980. Desertifikation in Nord-Darfur. *Hamburger Geogr. Schr.* 35, 175 pp.
Issawi, B. 1978. New findings in the Gilf-Uweinat area. *Ann. Geol. Surv. Egypt* 8: 275-293.
Kádár, L. 1937. La morfologia dell'altipiano del Gilf Kebir. *Boll. R. Soc. Geogr. Italiana* 7: 485-503.
Kemal El Dine Hussein 1928. L'exploration du désert Libyque. *La Géographie* 50: 171-183, 320-336.
Klitzsch, E. 1978. Geologische Bearbeitung Südwest-Agyptens. *Geol. Rdsch.* 67: 509-520.
Klitzsch, E. 1979. Zur Geologie des Gilf Kebir Gebietes in der Ostsahara. *Clausthaler Geol. Abh.* 30: 113-132.
Klitzsch, E. & F.K.List (eds.) 1978. Geological Interpretation Map Egypt/Sudan 1:500 000, Sheets 2523 Gilf Kebir, 2521 Gebel Uweinat. TFH Berlin.
Klitzsch, E., R.Said & E.Schrank (eds.) 1984. Research in Egypt and Sudan. Sonderforschungsbereich 69: Results of the Special Research Project Arid Areas, period 1981-1984. *Berliner geowiss. Abh. (A)* 50, 457 pp.
Kröpelin, S. 1985. Untersuchungen zum Sedimentationsmilieu von Playas im Gilf Kebir (SW-Agypten). M.A. thesis, Techn. Univ. Berlin, 194 pp.
Kuenen, P.H. 1953. Significant features of graded bedding. *Amer. Assoc. Petrol. Geol. Bull.* 37: 1044-1066.
Kuper, R. 1981. Untersuchungen zur Besiedlungsgeschichte der östlichen Sahara. *Allg. Vergl. Archäol. Beitr.* 3: 215-275.
Kuper, R. 1984. The eastern Sahara from north to south: data and dates from the BOS project. Symp. 'Late prehistory of the Nile basin and the eastern Sahara', Poznán (in press).
Maxwell, T.A. 1980. Geomorphology of the Gilf Kebir. *Geogr. J.* 146: 76-83.
Maxwell, T.A. 1981. Erosional patterns of the Gilf Kebir Plateau and implications for

the origin of Martian canyonlands. *Ann. Geol. Surv. Egypt* 11: 281-300.
McCauley, J.F., C.S.Breed & M.J.Grolier 1981. The interplay of fluvial, mass-wasting and eolican processes in the eastern Gilf Kebir region. *Ann. Geol. Surv. Egypt* 11: 207-239.
McHugh, W.P. 1971. Late prehistoric cultural adaption in the southeastern Libyan desert. Ph.D. dissertation, Univ. of Wisconsin, Dept. Anthropology, 434 pp.
McHugh, W.P. 1974. Late prehistoric cultural adaption in southwest Egypt and the problem of the Nilotic origins of Saharan cattle pastoralism. *J. American Res. Center Egypt* 11: 9-22.
McHugh, W.P. 1975. Some archaeological results of the Bagnold-Mond expedition to the Gilf Kebir and Gebel Üweinat, southern Libyan desert. *J. Near Eastern Stud.* 34: 31-62.
McHugh, W.P. 1980. Archaeological sites of the Gilf Kebir. *Geogr. J.* 146: 64-68.
McHugh, W.P. 1981a. A chronicle of research and exploration in the Gilf Kebir – Uweinat mountain region. *Ann. Geol. Surv. Egypt* 11: 21-26.
McHugh, W.P. 1981b. Archaeological investigations in the Gilf Kebir and the Abu Hussein dunefield. *Ann. Geol. Surv. Egypt* 11: 301-334.
Meckelein, W. 1975. Progress in the exploration and in the scientific research of the Libyan desert since Gerhard Rohlfs. *Ann. Geol. Surv. Egypt* 5: 47-60.
Meckelein, W. 1982. The question of permanent aridity in the Central Sahara since the Pliocene. *Bull. Assoc. Géogr. Franç.* 484: 39-42.
Mensching, H. (ed.) 1984. *Beiträge zur Morphodynamik im Relief des Jebel-Marra-Massivs und in seinem Vorland (Darfur/Republik Sudan).* Hamburg: 253 pp.
Misonne, X. 1969. Expédition scientifique Belge dans le désert de Libye. La faune. *Africa-Tervuren* 15: 117-119.
Motts, W.S. 1965. Hydrologic types of playas and closed valleys and some relations of hydrology to playa geology. In J.T.Neal (ed.), *Geology, mineralogy and hydrology of US playas.* AFCRL Environm. Res. Pap. 96: 73-104.
Myers, O.H. 1939. The Sir Robert Mond expedition of the Egypt Exploration Society, *Geogr. J.* 93: 287-291.
Neumann, K. 1986. Holzkohlen aus prähistorischen Fundstätten des Gilf Kebir (SW-Agypten). *Forschungen zur Prähistorie Afrikas* 1 (in press).
Pachur, H.-J. & G.Braun 1980. The palaeoclimate of the Central Sahara, Libya, and the Libyan desert. *Palaeoecol. of Africa* 2: 351-363.
Pachur, H.-J. & G.Braun 1982. Aspekte paläoklimatischer Befunde in der östlichen Zentralsahara. *Geomethodica* 7: 23-54.
Pachur, H.-J. & B.Gabriel 1980. Quartärklimatische Befunde aus der Libyschen Wüste (Agypten). Unpubl. ms., 24 pp.
Pachur, H.-J. & H.P.Röper 1984. The Libyan (western) desert and northern Sudan during the late Pleistocene and Holocene. *Berliner geowiss. Abh. (A)* 50: 249-284.
Pedgley, D.C. 1974. An exceptional desert rainstorm at Kufra, Libya. *Weather* 29: 64-71.
Peel, R.F. 1939. The Gilf Kebir. *Geogr. J.* 93: 295-307.
Penderel, H.W.G.J. 1934. The Gilf Kebir. *Geogr. J.* 83: 449-456.
Potter, R.M. & J.R.Rossman 1979. The manganese and iron oxide mineralogy of desert varnish. *Chem. Geol.* 25: 79-94.
Rhotert, H. 1952. *Libysche Felsbilder.* Darmstadt: Wittich, 146 pp.
Rognon, P. 1980. Pluvial and arid phases in the Sahara: The role of non-climatic factors. *Palaeoecol. of Africa* 12: 45-62.
Rzóska, J. 1961. Observations on tropical rainpools and general remarks on temporary waters. *Hydrobiologia* 17: 265-286.
Schön, W. 1984. New results from two playa sites in the Gilf Kebir. Symp. 'Late prehistory of the Nile basin and the eastern Sahara', Poznań (in press).
Shaw, W.B.K. 1936. An expedition in the southern Libyan desert. *Geogr. J.* 87: 193-221.
Vahrson, W.-G. 1986. Aspekte bodenphysikalischer Untersuchungen in der Libyschen Wüste – ein Beitrag zur Frage spätpleistozäner und Holozäner Grundwasserbildung. *Berliner Geogr. Abh.* 43 (in press).

Walker, T.R. 1979. Red color in dune sand. In E.D.McKee (ed.), *A study of global sand seas.* US Geol. Survey Prof. Pap. 1052: 61-81.
Walther, H. 1979. *Vegetation und Klimazonen.* Stuttgart: Ulmer, 342 pp.
Wendorf, F. & F.A.Hassan 1980. Holocene ecology and prehistory in the Egyptian Sahara. In M.A.Williams & H.Faure (eds.), *The Sahara and the Nile.* Rotterdam: Balkema, 407-419.
Wendorf, F. & R.Schild 1980. *Prehistory of the Eastern Sahara.* New York: Academic Press, 414 pp.
Wendorf, F., R.Schild, R.Said, C.V.Haynes, A.Gautier & M.Kobusiewicz 1976. The prehistory of the Egyptian Sahara. *Science* 193: 103-114.
Wickens, G.E. 1976. The flora of Jebel Marra (Sudan Republic) and its geographical affinities. *Roy. Bot. Gard. Kew Bull. Add. Ser.* 5, 368 pp.
Winkler, H.A. 1939. *Rock drawings of Southern Upper Egypt,* II. London: Oxford Univ. Press, 40 pp., 61 pl.

ISSN 0168-6208

Palaeoecology of Africa – *and the surrounding islands*
(E.M.van Zinderen Bakker & J.A.Coetzee, eds. (1966–1986) & K.Heine, ed. (1987–)
1966–, 22 cm, c.250 pp., Hfl.105/$55.00/£31.50 per volume
Annual publication. Comprehensive & up-to-date information on research in many different disciplines which give an overall insight into the environmental history of Africa. Volumes 1, 2, 3, 4 & 5 are out of print. Editors: Institute of Environmental Sciences, University of Bloemfontein.
Volume 6 – *Africa: 1969-71*. 75 reports on non-palynological information. 1972, 312 pp., 0 86961 034 1.
Volume 7 – *Africa: 1969-71*. A.C.Hamilton: Pollen diagrams from E Africa & 17 reports. 1972, 222 pp., 0 86961 035 X.
Volume 8 – *Proceedings of the Scientific Committee on Antarctic Research Conference on Quaternary Studies, Canberra, 9–12 August 1972*. 1973, 208 pp., 0 86961 032 5.
Volume 9 – *Africa: 1972–74*. 36 reports & 4 articles. 1976, 231 pp., 0 86961 082 1.
Volume 10 – *Africa: 1975–77*. 20 contributions on new research in S Africa. 1978, 200 pp., 90 6191 028 5.
Volume 11 – *Africa: 1975–77*. 23 contributions on northern & eastern Africa. 1979, 245 pp., 90 6191 037 4.
Volume 12 – *Sahara and surrounding seas: Sediments and climatic changes (Proceedings of an international symposium, Mainz, 1–4 April 1979)*, edited by M.Sarnthein, E.Seibold & P.Rognon. 32 contributions. Editors: University Kiel & University Paris. 1980, 416 pp., 90 6191 050 1.
Volume 13 – 19 contributions. 1981, 290 pp., 90 6191 203 2.
Volume 14 – 16 contributions on: Glacial sequence of Mt. Kenya; Temperature changes & biogeography of the Sahara; Lake level changes in Ethiopia; Discharge of Senegal River & drought in Sahel; etc. 1982, 186 pp., 90 6191 204 0.
Volume 15 – *Southern African Society for Quaternary Research, proceedings of the 6th biennial conference, Pretoria, 26–29 May 1981*, (J.C.Vogel, E.A.Voigt & T.C.Partridge, eds.). 25 papers: Caves & fossil sites; Palaeoclimates; Cenozoic stratigraphy; Namib. 1982, 235 pp., 90 6191 257 1.
Volume 16 – 30 contributions on oceans & ocean margins; Sahara & West Africa; Kenya; Malaŵi; Southern Africa. Basic information on the parameters that determine the present. 1984, 488 pp., 1 color map, 90 6191 510 4.
Volume 17 – *Southern African Society for Quaternary Research, Proceedings of the 7th biennial conference held at the University of Stellenbosch, 29 March–3 April 1985*. (E.M.van Zinderen Bakker, J.A.Coetzee & L.Scott, eds.). Geology, geomorphology, palynology, palaeontology & archaeology in the fynbos region, southern-most Africa; Pans; Historical biogeography. 1986, 272 pp., 90 6191 625 9.
Volume 18 – 32 contributions: Climatology; Oceanography; Palaeoenvironments of desert, East Africa, Central & West Africa, Southern Africa & the Islands; Anthropology; Archaeology. 1987, 460 pp., 90 6191 689 5.

All books available from your bookseller or from:

A.A.Balkema
P.O.Box 1675
Rotterdam
Netherlands
&
A.A.Balkema Publishers
Old Post Road
Brookfield, VT 05036
USA