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Holocene vegetation of the Eastern Sahara: charcoal from prehistoric sites

Introduction

The Eastern Sahara, *i.e.* Egypt and Northern Sudan West of the Nile, is one of the most arid regions of the world. The larger part of the area is an absolute desert with almost no vegetation (Fig. 1) and one can easily travel for hundreds of kilometers without coming across a single plant. In contrast to this harshness, a great number of prehistoric settlement remains act as evidence to indicate rich environmental resources in the past. Many studies on quaternary sediments, on prehistory and on faunal remains have stated a more humid period for the Eastern Sahara during the Early and Middle Holocene coinciding with a savanna-like environment. Yet, direct evidence of such savanna was missing and the reconstruction of the vegetational changes were based almost entirely on data provided by other disciplines (Wickens 1975; 1982). The interdisciplinary project ''Settlement history of the Eastern Sahara'' (B.O.S.) of the University of Cologne, searches into the relations of Neolithic culture development and the changes of natural environment during the Early and Middle Holocene (Kuper 1981; 1988; see also the contributions of Cziesla, Hahn, Keding, Kröpelin, Kuper and Schuck, this volume), relying especially on botanical evidence. Funded by the German Research Foundation, 514 prehistoric sites along a north-south transect of 1300 km were registered and partly excavated in the years 1980 - 1985. During the field campaigns more than 1500 botanical samples were recovered, most of them consisting of charred wood.

In the past, most of the research concerning Holocene Saharan Vegetation history has been conducted in the Central Sahara. The first palynological studies interpreted the presence of mediterranean and temperate elements in the Late Pleistocene and Holocene pollen spectra as resulting from northern influence

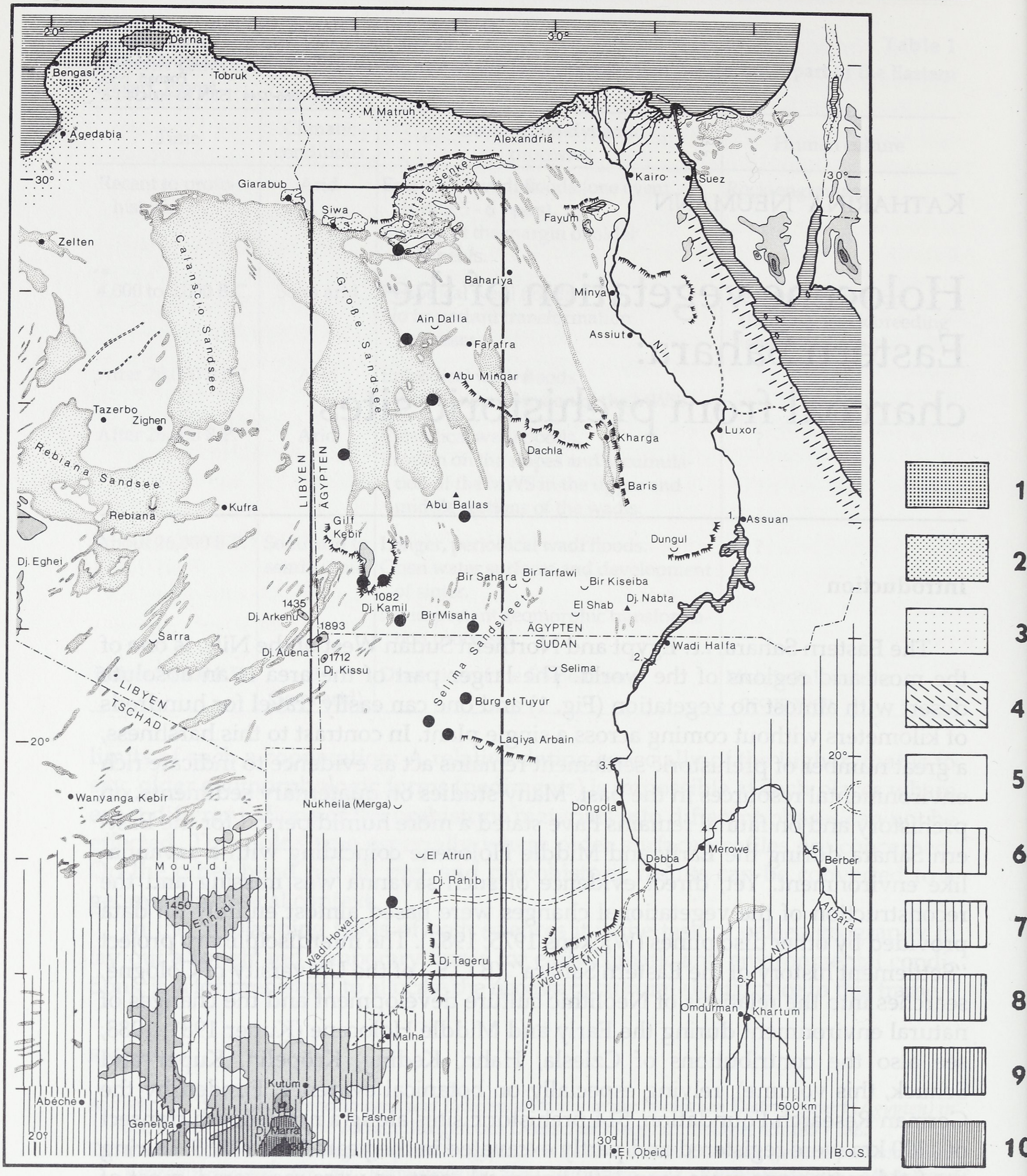

Fig. 1. The Eastern Sahara. Vegetation zones and areas where identifiable charcoal was found (after Kassas 1971; UNESCO/AETFAT/UNSO 1983; and Wickens 1982, modified).
Explanations for Figures 1 - 3;

1: mediterranean sclerophyllous forest; 2: sub-mediterranean anthropic vegetation; 3: contracted desert vegetation, northern type with dwarf shrubs, rainfall in winter; 4: coastal desert along the Red Sea; 5: absolute desert; 6: contracted desert vegetation, southern type with grasses and tropical trees and shrubs, rainfall in summer; 7: *Acacia* desert scrub; 8: thorn savanna; 9 : deciduous savanna; 10: montane vegetation of Jebel Marra.

(Quézel and Martinez 1958/59; van Campo *et al.* 1964). Later, when the recent pollen rain was investigated, it became clear that most of these "northern" pollen were due to long-distance transport. It was evident that additional methods were needed to ascertain a more distinct picture of the plant cover in the past. The identification of charcoal from prehistoric sites provides a good tool to reconstruct the woody vegetation at a particular place. In general, pieces of charred wood can be regarded as direct evidence that this species was growing on the site or close by. This method is complementary to palynology and can give precise information on the local woody flora, or at least on that part of it that was selected by man for firewood. Charcoal samples can be radiocarbon-dated after microscopic examination which furnishes the possibility of an exact temporal association of each sample.

In contrast to Europe with its elaborate archaeobotanical research, there are only a few scattered studies on botanical macro-remains from African sites. The first attempts on the identification of charcoal failed to result in any broader application because of difficulties with preparation. In the 1960's, Couvert (1970) embedded the charcoal pieces into synthetic resin to produce thin-cuts and also tried to reconstruct past climate and vegetation with the help of archaeobotanical data (Couvert 1976). The use of scanning electron microscopy (SEM) has opened new perspectives for the identification and documentation of botanical macro-remains. It allows to take well-focused photographs of the irregular charcoal surfaces without complicated preparations and also observation of even the finest anatomical details.

This paper refers only the general results of the archaeobotanical investigations. A detailed version will be published elsewhere (Neumann 1989). It includes C-14 dates, the complete results, figures of recent and reconstructed vegetation types and an atlas of the wood anatomy of 27 taxa.

Recent climate and vegetation

There are only a few meteorological stations in the Eastern Sahara – four in Egypt, none in the Sudan – and most of the data have to be extrapolated from adjacent stations. The area is affected by two climatic regimes: 1) In the north the mediterranean one with winter rains; 2) Approximately from 22°N southwards the tropical regime with higher temperatures and summer rains. Precipitations decrease from 50 - 100 mm at the northern and southern margins to almost zero in the centre (Walter and Lieth 1967). Mean annual temperatures rise from 10°C in the north (Siwa) to 28°C (Khartoum) in the south. In Egypt winter frosts are common (Alaily *et al.* 1987), which set distribution limits for thermophil tropical plant species.

The greater part of the research area is a rainless desert without periodical precipitations where perennial plant life is only found in cases depending completely on fossil groundwater (Fig. 1). Outside the oases an "accidental" vegetation may occur, consisting of potential perennials which can survive as long as there is some soil moisture derived from the incidental rains (Kassas 1971). However, the greatest part of the Eastern Sahara is completely bare of vegetation.

In the southwestern corner of Egypt there are two mountain areas which receive slightly higher rainfall supplying a comparatively richer vegetation than the surrounding plains. In some of the wadis which dissect the northwestern and the southeastern cliffs of the Gilf Kebir plateau, trees (*Acacia tortilis* subsp. *raddiana, Acacia ehrenbergiana, Maerua crassifolia* and *Balanites aegyptiaca*) and accidental shrubs can be found (Alaily *et al.* 1987). For Jebel Uweinat, Léonard (1969) even states that he collected more than 100 plant species during a three month field survey. Above 1250 m he found mediterranean elements whereas in the lower lying parts Saharo-Sindian and Sudano-Sahelian species prevail. Another mountain, Jebel Kissu, with a height of more than 1700 m, is situated 50 km southeast of Jebel Uweinat. It carries a very poor vegetation which is completely unknown up to now.

North of Laqiya Arba'in, three connected wadis stretch along the sandstone escarpments: Laqiya Valley, Wadi Shaw and Wadi Sahal. At the lower lying parts of the valleys there are groundwater-dependent shrubs of *Acacia ehrenbergiana, Capparis decidua* and hummocks of *Tamarix articulata,* which can reach a maximum height of 12 m. In smaller runnels coming down the escarpment, some acacias are growing which seem to be supported merely by precipitations, despite the fact that the mean annual rainfall probably does not exceed 5 - 10 mm. Further south, areas with accidental vegetation increase and solitary specimens of *Maerua crassifolia* and *Capparis decidua* are found on the plains where they can draw some water from the cleft sandstone.

Wadi Howar is a band of vegetation 2 - 5 km wide that stretches 640 km from the mountainous regions between Ennedi and Jebel Marra into the southern Libyan Desert. Its southwestern part is situated in the Sahelian *Acacia* desert scrub while in the greater part of the wadi desert conditions prevail. The vegetation between 25°E and 27°25'E (Jebel Rahib) is monotonous and comprises only four woody species: *Acacia ehrenbergiana, Acacia tortilis* subsp. *raddiana, Capparis decidua* and *Salvadora persica.* East of Jebel Rahib, the wadi is bare of plant growth. In the sandy areas south of Wadi Howar and west of Jebel Tageru, the perennial grass *Panicum turgidum* gains a diffuse distribution and in the depressions scattered trees are found. This "Saharan savanna", already described by Schulz (1988) for W-Africa, indicates that the southern border of the Sahara is reached.

Charcoal identification: material and methods

Flotation of the desiccated charcoal is not possible because the pieces disintegrate to dust during the procedure. On the site the charcoal was therefore separated from the sediment by dry sieving with 2 mm and 1 mm mesh width and packed carefully in sterile sand or it was taken home with parts of the coarser sediment and picked out by hand. 320 representative samples from different sites, covering the time span from 9,000 to 3,300 b.p., were chosen to examination, containing altogether more than 10,000 pieces. The smaller samples (< 200 - 300 pieces) were identified completely whereas 10 - 30% were taken as random samples from the larger ones after the method described by van der Veen and Fieller (1982).

The charcoal pieces with the size from 1 mm to 15 mm were fractured manually into the diagnostic relevant transverse, tangential and radial planes. For the SEM examination, the pieces were fixed on aluminium stubs with conductive carbon cement and coated with gold. Yet, for "everyday" determination most of the charcoal pieces had not to be treated in this way. Instead, after fracturing they were transferred into a small plastic box filled with fine sand which was mounted on a slide. The sand allows fixing the pieces in a proper position for the examination under an incident light microscope. Furthermore, these charcoal samples can be C-14 dated afterwards. As the diagnostic relevant features do not change significantly during the charring process, a slide collection of recent woody species can be used for checking the identity of the charcoal.

The interpretation is based on comparison of the species composition in the archaeological samples with that of recent plant communities. The ecological conditions under which the trees and shrubs grow today and information on environmental factors of the sites themselves furnish the main frame for the reconstruction of the former vegetation. No associations in terms of plant sociology can be reconstructed because of three reasons: 1) The herbal flora is not represented in the samples; 2) Plant sociological studies on the present vegetation of the Sahara and the Sahel are very limited; 3) Savanna and even desert vegetation have been altered by man to a very large extent which limits the use of present types as models for the past. Rather, I prefer using the "formations": these are plant communities defined by the presence of dominant plant species. There is a good chance that these dominants will appear also in the charcoal samples, especially when they make good firewood.

Results

Northern Egypt down to 25°N

From this region 48 samples were examined, coming from Sitra in the south of the Qattara depression and from the southwestern and eastern edges of the Great Sand Sea. They cover a time span from 9,000 b.p. to 6,150 b.p. with one exception from the western Sandsea which was dated around 5,400 b.p. The species combination is poor (*Tamarix sp., Acacia sp.* and *Chenopodiaceae*) and there are no differences between the Early Holocene and the Middle Holocene samples. It seems that the vegetation consisted of the same elements as today, but with a wider distribution. A contracted desert vegetation of trees and shrubs was growing along the escarpments, in wadis and depressions. The slightly higher precipitations, indicated by the occurrence of woody plants, supported also dwarf shrubs, grasses and herbs the remains of which unfortunately have not been preserved. Yet, pollen diagrams from Saudi-Arabia show Gramineae, Cyperaceae and a number of dwarf shrubs as evidence for a semi-desert similar to the north-eastern Sahara or the An Nafud/Saudi-Arabia (Schulz and Whitney 1986). Like the An Nafud today, the sandy areas of the Egyptian Sahara, especially the Great Sand Sea, were temporarily visited by nomads who found there a rich wildlife and pastures for their stock. Today this whole region is completely bare of plant life.

Abu Ballas / Mudpans

South of the Abu Ballas escarpment there is an area of deflation hollows filled with fine-clastic playa sediments dated between 10,000 and 6,400 b.p. which are interpreted as resulting from interacting eolian processes and flooding (Pachur and Braun 1980: 352).

The three sites, 83/39, 85/56 and 85/50, yielded very rich botanical material from which 99 samples were selected for examination. The results indicate a marked chance of vegetation and climate over a period of 1700 years. The species spectrum of 83/39 (dated by 8,200 b.p. with three C-14 dates) and of 85/56 (dated by 7,500 b.p. with eight C-14 dates) is quite poor. Like in the samples from the other parts of the Egyptian Sahara, acacias and tamarisks prevail, with additional presence of solitary pieces from *Maerua crassifolia, Leptadenia pyrotechnica* and Chenopodiaceae. This combination points to a contracted desert vegetation along runnels and in depressions as it has been described for the present Central Sahara by Schulz (1980: 40 - 43).

Around 7,000 b.p. climatic conditions changed, resulting in a richer species combination of the samples from site 85/50 (five C-14 dates between 7,000 and 6,500 b.p.). Besides *Acacia sp.* and *Tamarix sp.* still dominant in the samples, *Maerua crassifolia, Grewia tenax, Calotropis procera, Leptadenia pyrotechnica, Ziziphus sp.* and cf. *Cassia senna* appear. These are the northernmost outposts of the tropical savannas which were moving northwards and reached their maximum expansion during this period. Nevertheless, the vegetation at Mudpand was not a diffuse savanna as it is characteristic for the Sahel. Due to the cleft sandstone and the marked relief with high runoff, mudpans offered favorable conditions for Sahelian elements arranged in "contracted" patterns: this type of vegetation is characteristic for desert habitats which receive additional runoff water by means of which plant growth concentrates at the deeper-lying parts of the relief.

Some of the species found in the samples have edible fruits and propagation of these plant outside of their original distributions areas might have been supported by man. The occurrence of *Calotropis procera* points to a human disturbance of the natural vegetation; this species is regarded as an indicator for desertification (Batanouny 1983). A situation comparable to site 85/50 is found today in the Bayuda at the southern margins of the Libyan desert. Annual precipitations from 25 to 50 mm support an extrazonal Sahelian woody vegetation which is used by the nomads as pasture and for firewood and charcoal production (Pflaumbaum 1987: 24 - 25).

Gilf Kebir

The Gilf Kebir is a plateau of "Nubian" sandstone reaching 1000 m above sea level. Its southeastern cliffs are dissected by numerous wadis, in two of which, the Wadi el Akhdar (Arab. = *wadi* with the green floor) and the Wadi Bakht (Arab. = happy *wadi*) the main archaeological work was conducted. The lower parts of both wadis are filled with thick layers of playa sediments. The playas developed during the Early and Middle Holocene behind fossil dunes which blocked the wadi entrances (Kröpelin 1987; 1989). From the excavated charcoal samples, 46 were examined covering a time span from 7,700 b.p. to 4,300 b.p.

The most abundant taxon in the samples is *Tamarix sp*. This points to a more or less arid environment for the entire Early and Middle Holocene. The drier phases of this period witnessed a sparse tree cover whereas, during the moister phases, the vegetation may have consisted of dense stands of tamarisks *(Tamarix articulata?)* in the lower parts of the wadis. These "gallery forests" are known today from some wadis in the Hoggar and Tibesti (Quézel 1965: 179) and northern Egypt (Kassas 1952; Kassas and Iman 1954) under an average rainfall of 50 - 100 mm.

Although there is no evidence of a permanent groundwater table in Wadi el Akhdar and Wadi Bakht (Kröpelin 1989), the sandy layers of the playa sediments were capable of water storage and supplying the trees with sufficient moisture. Temporary pools, indicated by thick pelitic playa layers (Kröpelin 1987: 195 - 197) probably carried at their margins dense stands of sedges and other hygrophylous herbs mixed with *Tamarix*. Today we can find this plant community around shallow *guelti* in the wadis of the Central Saharan mountains (Quézel 1965: 203).

The second dominant taxon in the samples, though much less abundant, is *Ziziphus sp*. A clear identification of that wood up to the species level as it was formerly stated (Neumann 1987: 184) is not possible because of the quantitative changes which occur during the charring process. Probably the wood does not belong to the Irano-Turanian *Z. lotus* but rather to one of the Sahelian species *Z. mauritiana* or *Z. spina-christi*. Because of their edible fruits, both might have been introduced from the south by man. Today, *Z. mauritiana* is a common plant in the Ennedi where it sometimes forms impenetrable thickets (Carvalho and Gillet 1960: 73). *Z. spina-christi* occurs as a rare element of the desert woodland in some wadis of northern Egypt (Kassas and Iman 1954).

In contrast to other contemporary samples from the Eastern Sahara, the Gilf Kebir samples rarely contain *Acacia* wood. This might be due to the fine-grained nature of the playa sediments not suitable for the acacias which prefer coarser ground. In most of the samples where *Acacia* is present, it occurs in combination with one or more of the tropical species *Maerua crassifolia, Ziziphus sp.* and *Balanites aegyptiaca.* This assemblage is present around 6,600 b.p., 5,700 b.p. and 4,800 b.p. During these phases, climatic conditions were slightly more favorable and tropical plants were able to invade the Gilf Kebir whereas the drought-resistant tamarisks survived even under extreme conditions. The isolate presence of *Acacia albida* around 6,150 b.p. also points to a slightly moister period with precipitations between 50 and 100 mm which is the minimum under which the recent *Acacia albida* survives in the Central Sahara.

Generally speaking, the archaeological data fit with the results of the sedimentological (Kröpelin 1987; 1989) and the archaeozoological investigations (Peters 1988; van Neer and Uerpmann 1989). Both state arid to, at best, semiarid conditions for the Gilf Kebir throughout the Holocene. Kröpelin postulates a "semiarid" phase from 6,000 to 5,000 b.p., but according to the botanical results the more humid climate lasted only for a short period around 5,700 b.p. From 5,600 b.p. onwards, the environment must have been very dry because the samples from this period contain only *tamarix* wood. The assumption of Kröpelin (1987: 203) that there was either a climatic optimum or an unique millennial rainfall event not long after 5,000 b.p. is confirmed by the occurrence of *Ziziphus sp., Maerua crassifolia, Acacia sp.* and *Balanites aegyptiaca* between 5,100 and 4,800 b.p.

In spite of the arid climate the Gilf Kebir offered a favorable environment for prehistoric nomads because of the seasonal availability of surface water. A slight increase in precipitation created extensive stands of ephemeral grasses and herbs and thus furnished a basis for nomadic cattle keeping and gathering activities. The episodic visits of nomads to the Gilf Kebir continued up to the hyperarid 20th century (Almasy 1939: 131, 163) even though the surrounding lowlands then were a hostile and almost barren landscape.

Selima Sand Sheet

The Selima Sand Sheet covers an area of *ca.* 60,000 km^2 north and south of the recent frontier between Egypt and Sudan. Eolian sands form a featureless landscape of vast flat plains and gently undulated dunes without any vegetation. Plant remains were found in the excavations of Bir Misaha (one sample identified) and Burg et Tuyur (22 samples identified).

The Bir Misaha sample from around 6,300 b.p. consists only of *Acacia* wood while the samples from the Burg et Tuyur, dated between 6,000 and 5,700 b.p., yielded an assemblage of the following nine taxa: *Acacia sp., Acacia albida, Maerua crassifolia, Leptadenia pyrotechnica, Ziziphus sp., Bosica senegalensis, Balanites aegyptiaca,* cf. *Cassia senna* and *Chenopodiaceae.*

Comparison between the Burg et Tuyur samples and those from Mudpans 85/50 shows that the sites have five species in common. But taking into consideration that the ecological conditions of both sites are not the same, a different type of vegetation has to be reconstructed for Burg et Tuyur. As Walter (1979: 116) and Rognon (1980: 47) have shown, sandy soils in arid regions are capable of storing large amounts of water compared to clay soils and rock surfaces where runoff is high. On sands, precipitations infiltrate the soil quickly and evaporation is reduced. Under slightly higher rainfall, these areas are immediately colonized by grasses which take advantage of the moisture in the upper layers. In the beginning tree growth is very sparse and confined to depressions where some runoff water accumulates. With an increased moisture content of the deeper layers, flat-rooted woody plants will be found also on the upper parts of the dunes. This is what we call a savanna in the sense of Walter (1979: 92): a homogeneous tropical grassland with scattered trees and shrubs. The most important feature of a savanna is its diffuse distribution of plant growth whereas all desert formations are characterized by a contracted pattern.

The Sahelian savannas comprising the same species as those found in the Burg et Tuyur samples are called "Acacia desert scrub" (Smith 1949) in the Sudan. The situation at Burg et Tuyur around 5,700 b.p. is comparable with the recent *goz* in northern Darfur and northern Kordofan. However, the density of tree growth on the *goz* cannot serve as a model for the Middle Holocene Selima Sand Sheet because it has been severely altered by man during the last decades.

Gabriel and Kröpelin (1983) have proposed a low density of settlement remains on the Selima Sand Sheet which they think to be due to the penetrable sands and a deep groundwater table that was not easily accessible to Neolithic man. Yet, hundreds of prehistoric sites were discovered during the recent surveys of the B.O.S. project. The presence of *Acacia albida* in the charcoal samples points to a comparatively high groundwater table at Burg et Tuyur. In general, this species is regarded as a reliable indicator for the presence of groundwater (Carvalho and Gillet 1960: 56; Maydell 1983: 89), and the Zaghawa say: "When we find *(teli)* in a place, we dig wells and we are sure to find water" (Tubiana 1977: 35).

To sum up, the Sahelian savanna of Burg et Tuyur around 5,700 b.p. was suitable for cattle-keeping because of its groundwater reserves, its grass cover and the trees and shrubs most of which can be used for fodder (Maydell 1983: 50 - 52; Tubiana 1977: 95 - 98). A periodic settlement of the site seems likely and the famous rock picture of a cow might be for such find an explanation.

Wadi Shaw / Wadi Sahal

The tectonically induced wadi-like depressions, Wadi Shaw and Wadi Sahal cut about 30 - 60 m into the slightly undulating rocky plains of the southern Libyan Desert. In the depression, there are a number of playa-like deposits which always show a similar stratigraphic record of two limnic accumulation separated and accompanied by sandy layers (Gabriel and Kröpelin 1983; 1984). Most of the settlement remains and the charcoal samples were found in the deposits younger than 6,000 b.p., above the limnic accumulations. During the main phase of settlement, no permanent lakes existed any more and drinking water had to be obtained from wells. 71 charcoal samples were examined; from the results three phases can be distinguished.

Phase one starts around 5,700 b.p. and ends around 5,400 b.p. The samples contain *Acacia sp.* and *Tamarix sp.*, furthermore the Sahelian taxa *Maerua crassifolia, Balanites aegyptiaca, Ziziphus sp.*, cf. *Grewia tenax, Boscia* cf. *senegalensis, Acacia nilotica, Grewia* type *villosa/bicolor* and cf. *Rubiaceae*. The spectrum is similar to that from Burg et Tuyur and it seems that both areas were included in the same vegetation zone, the northern Sahelian Acacia desert scrub. No Sudanian influence is noticeable, except maybe the badly preserved wood of cf. Rubiaceae; no woody Rubiaceae are growing today in the Sahel and only a few relics survived in the Ennedi (Gillet 1968: 159).

Due to the pronounced relief and high runoff, the valleys probably carried a dense woody herbal vegetation as described by Murat (1937: 28) and Gillet (1968: 130) for the Ennedi. At the edge of temporary pools, larger specimens of *Acacia nilotica, Ziziphus sp.* and *Balanites aegyptiaca* were growing. On the slopes tree growth was sparser, including *Maerua crassifolia, Boscia senegalensis* and the two *Grewia* species. The grass cover was not as dense as in Burg et Tuyur because water supply on the cleft sandstone is more favorable for deep-rooted woody plants.

The wood of *Tamarix sp.* does not seem to fit well into the Sahelian assemblage. The recent distribution of tamarisks in the Eastern Sahara is limited to the area north of the transition zone Sahara/Sahel. In the Sahel tamarisks occur only around brackish pools (Aubréville 1950: 76; Carvalho and Gillet 1960: 33), and they are replaced by other species, especially *Acacia nilotica,* when freshwater conditions prevail. The presence of *Tamarix sp. Acacia nilotica* in the same samples might be explained by an arid period around 6,000 b.p. when tamarisks were only plants to survive. The humid phase that followed around 5,700 b.p. was of short duration, so that the Sahelian woody plants were not able to replace the tamarisks completely.

During phase two, from around 5,200 b.p. to 4,400 b.p., the environment was very dry and in the samples from this period only *Tamarix sp.* and *Acacia sp.* are present. In the samples from phase three (4,000 to 3,300 b.p.) *Tamarix sp., Acacia sp.* and *Capparis decidua* are the main constituents, with occasional admixture of *Salvadora persica,* cf. *Grewia tenax, Maerua crassifolia* and *Boscia* cf. *senegalensis.* The presence of the Sahelian taxa may be due to the great number of the identified samples and their excellent preservation which increases the probability of discovering rarer species. A desert-like environment, comparable with the recent Wadi Howar, did not offer very rich resources for man and his animals. However, the high groundwater table in the valleys created favorable conditions for tree growth and temporary settlements, even with cattle (Cziesla 1986), while on the surrounding plains the sparse vegetation gave way to an absolute desert.

Wadi Howar

Wadi Howar is an ancient river system that was connected with the Nile during the Early and Middle Holocene (Pachur and Kröpelin 1987). Excavations were conducted in the area east of Jebel Rabib, between 26°30′ and 27°30′. From the sedimentological, archaeological and zoological data it can be stated that local rainfall was markedly higher from 9,500 to 4,000 b.p. (Pachur *et al.* 1987: 359). This on the other hand led to a deterioration of the conditions for the preservation of plant material. 17 botanical samples from the sites dated between 4,600 and 4,000 b.p. were examined. The reconstruction of the vegetation for the earlier periods has to rely on archaeobotanical results from other sites.

There is evidence that Wadi Howar was included in the Sudanian or southern Sahelian savanna zone in Middle Holocene times. Comparison between palynological data from the Eastern (Ritchie *et al.* 1985) and the Central Sahara (Schulz 1987) suggests that a northward shift of the vegetation zones occurred simultaneously in both areas around 7,000 b.p. Therefore, it seems possible to transfer the archaeobotanical interpretation from Fachi-Dogonboulo/Niger (18°18′N) (Neumann 1988; Neumann and Schulz 1987) to the Wadi Howar (17°30′N).

At Fachi-Dogonboulo, in the heart of the hyperarid Erg de Ténéré, a charcoal layer resulting from a bush fire was found between limnic sediments. A sample from this layer contained the following 12 woody taxa: *Terminalia* cf. *macroptera, Anona senegalensis,* cf. *Rhus sp., Crateva adansonii, Celtis intergrifolia, Ximenia americana, Ficus sp., Boscia* cf. *salicifolia, Balanites aegyptiaca, Cadaba farinosa, Ziziphus sp.* and *Acacia albida.* All these species have their recent main distribution area in the Sudan Zone, 550 - 600 km further south (Aubréville 1950). They can be associated with 1) The alluvial habitats near the lake and along the drainage lines, and 2) The more xerophytic vegetation on the slopes of the escarpment. Typical Sahelian taxa, especially the acacias, are missing in the sample. It is probable that Fachi-Dogonboulo was not an extrazonal outpost of the Sudanian savannas but rather situated in the Sudan zone itself. The formation was either savanna or even woodland, with a rather dense cover of trees and shrubs. A similar vegetation can be assumed for the dunes of Wadi Howar around 7,000 b.p. The deeper-lying parts of the wadi were periodically inundated and apparently some of these lakes existed for decades (Pachur *et al.* 1987: 359). They were surrounded by a swampy environment with a dense grass cover and only scattered trees as it has been described for the Central Chad by Pias (1970: 29).

With increasing aridity from 5,300 b.p. onwards, the Sudanian vegetation in Wadi Howar was replaced by Sahelian types. In the charcoal samples *Acacia sp.* is dominant; minor constituents are *Acacia nilotica, Ziziphus sp.,* cf. *Grewia tenax* and Capparidaceae. This poor assemblage cannot be attributed to a particular formation. Most likely the environmental changes between 5,300 and 3,300 b.p. were more quantitative than qualitative in nature: the density of the savanna formations outside Wadi Howar decreased and woody plants became confined to the wadi-bed. The dry conditions resulted in a concentration of settlement in the wadi, in an intensified use of its plant resources and finally to a desertification, *i.e.* a man-made degradation of the plant cover (Neumann, in press).

In 11 of the archaeobotanical samples from Wadi Howar uncharred kernels of *Celtis integrifolia* were found. *Celtis integrifolia* is a species with mainly a

Sudanian distribution; in the southern Sahel it is confined to the edge of lakes and river courses. In the case of Wadi Howar, we cannot use this plant as an indicator for a Sudanian savanna in the fifth millennium b.p. because it occurs together with charred wood of northern Sahelian species in the samples. The tree bares edible fruits which are collected today by the people in the Sahel. Around 4,000 b.p., either the fruits were imported from the savanna regions of the upper Wadi Howar or the tree was planted and was able to survive because of human care and the extraordinary water supply in the wadi.

Palaeoclimatic interpretation

The poor species assemblage in all the Early Holocene samples from Egypt seems to be in contradiction with the sedimentological evidence which is supposed to correlate with increased precipitation during this period (Pachur and Braun 1980; Pachur *et al.* 1987; Wendorf and Hassan 1980; Wendorf and Schild 1980). This might be explained by another climatic factor that has not been taken into consideration so far: if the temperatures had been lower than today, a slight increase of the precipitation would have led to temporary lakes due to reduced evaporation and at the same time tropical elements were prevented from expanding further to the north. Under cooler conditions, a mean annual rainfall of 30 - 50 mm should be sufficient to support a quite dense desert vegetation. The lack of mediterranean plants in the samples points to a plant cover that consisted of the same elements as today but with a wider distribution.

Unfortunately there are no Early Holocene charcoal samples from sites in the Sudan. From the investigations of Ritchie and Haynes (1987) and Ritchie *et al.* (1985) we know that from 10,000 b.p. onwards, the lake levels of Selima and Oyo were rising and the tropical savannas started to expand northwards. Around 7,000 b.p. a climatic change, especially a rise of temperatures, took place and tropical elements immigrated into the Gilf Kebir and the area of Mudpans. Even if we admit that the richer flora of Mudpans was an outpost of the Sahelian savannas and was not included in the Sahel itself, we can assume a northward shift of the tropical vegetation zones of about 500 - 600 km. The vegetation was *Acacia* desert scrub on the Selima Sand Sheet, thorn savanna at Laqiya Arba'in and deciduous savanna in Wadi Howar (Fig. 2). Most likely the southern and the northern "wetting front" (Haynes 1987) touched each other somewhere in Central Egypt during this climatic optimum between 7,000 and 6,500 b.p., so did the vegetation zones and the absolute desert disappeared. Around 6,000 b.p., a dry phase followed the climatic optimum. Tamarisks replaced the tropical plants in Wadi Shaw and the lake of Oyo became shallower (Ritchie *et al.* 1985). Around 5,700 b.p., a second, minor shift occurred and the vegetation zones were situated 300 - 400 km north of their present range (Fig. 3). Nomadic cattle keeping was possible as far north as Burg et Tuyur. In Egypt, a very dry environment prevailed from 6,000 b.p. onwards and there are no charcoal samples from later sites, except from the Gilf Kebir where settlement activities

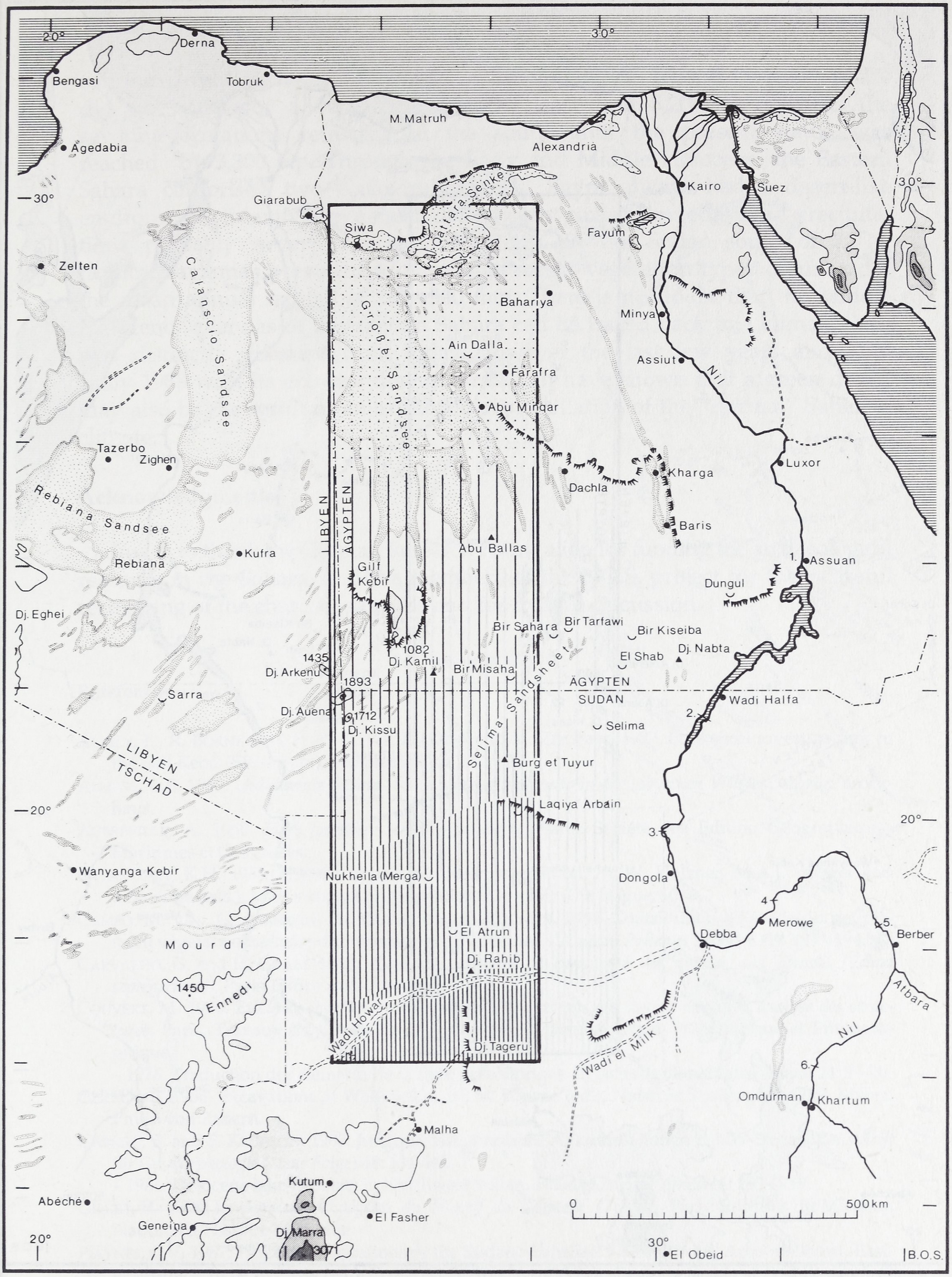

Fig. 2. Vegetation zones in the B.O.S. working area for the period 7,000 - 6,500 b.p.

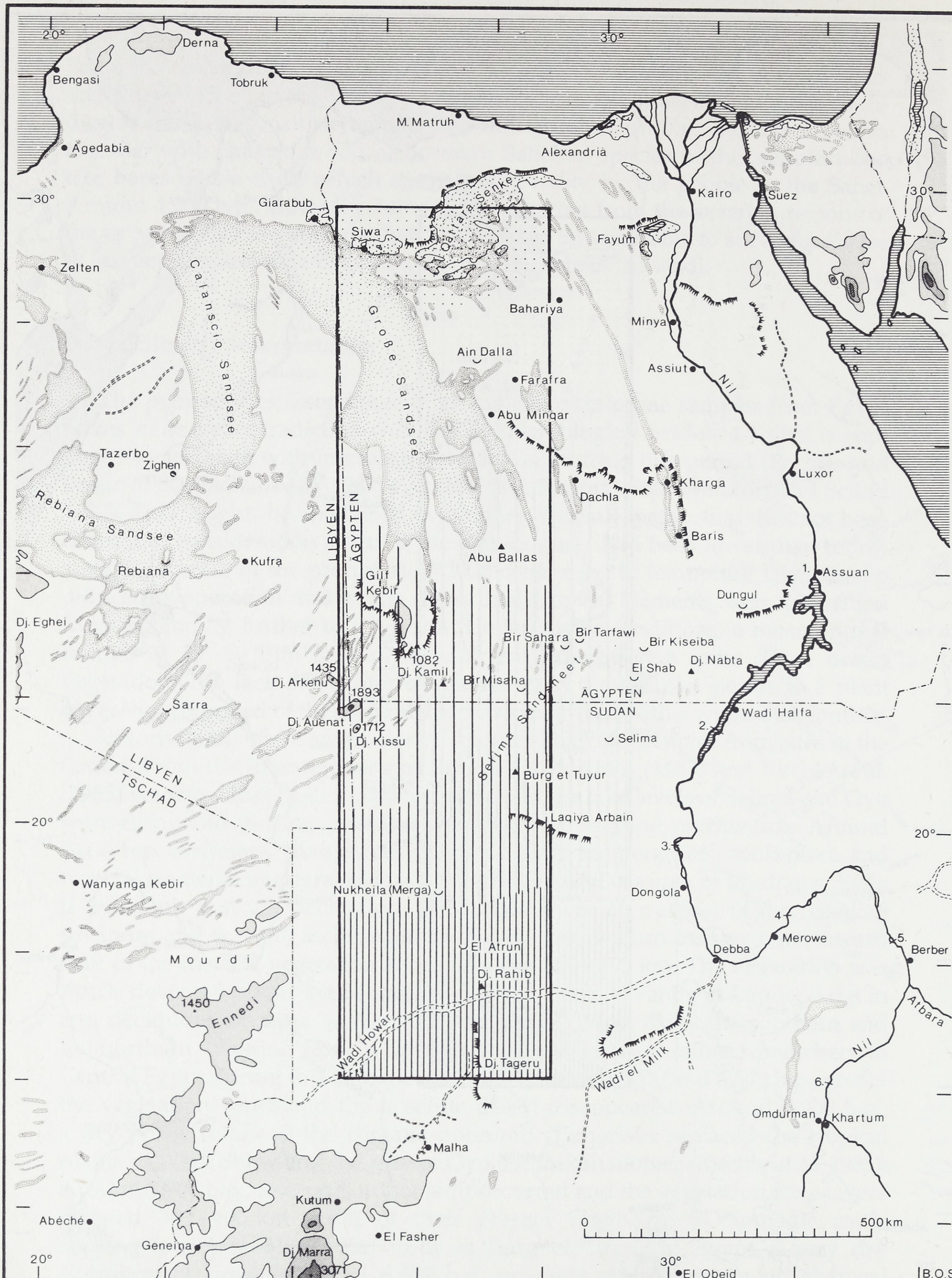

Fig. 3. Vegetation zones in the B.O.S. working area around 5,700 b.p.

continued until 4,300 b.p. But even in the Sudan, the second "wetter" phase did not last for a very long time. At least from 5,200 b.p. onwards the savanna formations retreated to the south until the present status was reached by 3,300 b.p. Through the Early and Middle Holocene, the Eastern Sahara comprised two ecological regions: Egypt always had a desert-like environment, though with a much denser plant cover than today, and precipitations probably never exceeded 50 - 100 mm. In the Sudan, south of 22°N, tropical savannas prevailed. Comparable recent vegetation types occur under the mean annual rainfall of 100 - 500 mm. There is no doubt that the Middle Holocene savannas of the Eastern Sahara can be traced back to a climate that was distinctly different from today. However, the last few years and especially 1988 with its extreme downpours again have shown that a green desert may also be the result of an extraordinary oscillation of the "normal" Sahelian climate.

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