Hydrobiologia **214**: 359–365, 1991.
J. P. Smith, P. G. Appleby, R. W. Battarbee, J. A. Dearing, R. Flower, E. Y. Haworth, F. Oldfield & P. E. O'Sullivan (eds), 359
Environmental History and Palaeolimnology.

Holocene environments in the central Sahara

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Key words: central Sahara, Holocene, palynology, Palaeolakes, palaeoenvironment, palaeoclimate

Abstract

Palynological investigations of corings in the sebkhas of Taoudenni (N-Mali) and Segedim (N-Niger), archaeological excavations in the Acacus Mts. (SW-Libya) and charcoal records in the central Ténéré (Niger) give evidence for a northward shift of the desert-savanna boundary to 22°–20° N during the middle Holocene. Between Niger and S-Libya there was a ecological gradient from the sudanian, sahelian and saharan savannas to a denser saharan desert vegetation. After a transition phase between 6000 and 4000 BP the saharan desert vegetation was finally established in the Taoudenni and Segedim region and this degraded from ca. 2000 BP to its present condition.

During the middle Holocene the central Sahara had a monsoonal summer rain climate with an effective rainfall of 250–300 mm per year near the desert-savanna boundary (ca. 22° N). Interaction between the monsoon and the atlantic cyclones also allowed rainfall in other periods of the year.

Introduction

The steadily growing demand for water in desert areas and the need to mine water as a non renewable resource (Thorweihe, 1988) is the main background for the investigations of palaeoclimates and of former recharge estimates of groundwater in these areas. For the central and southern Sahara a great deal of information derives from the presence and history of palaeolakes (Baumhauer, 1986; Gasse, 1988; Kutzbach, 1980; Petit Maire & Riser, 1983). These palaeolakes provide information about regional environments e.g. vegetation, catchment area as well as local environments e.g. water chemistry, algal content and different lake levels. Discrimination between local and regional scales of information is important for the reconstruction of former climates and for estimations of non-renewable resources like fossil groundwater.

This paper deals with the reconstruction of the Holocene vegetation, its regional differences and its development during the Holocene. Based on the former vegetation some palaeoclimatological inferences are made. Cores from a variety of palaeolakes in the central Sahara provided samples rich enough in pollen and macrofossils to establish a vegetation history for the middle and late Holocene. These cores were taken in Taoudenni (N-Mali) (Petit-Maire, 1986; Fabre & Petit-Maire, 1987; Petit-Maire, 1988) and Segedim (Baumhauer & Schulz, 1984; Schulz, 1987). Additional information comes from archaeological sites in Dj. Acacus (SW-Libya) (Barich, 1987) and from charcoal findings from Fachi (Ténéré) (Neumann, 1988).

Methods

The Taoudenni sequence was sampled from an open pit in the upper part and cored with a

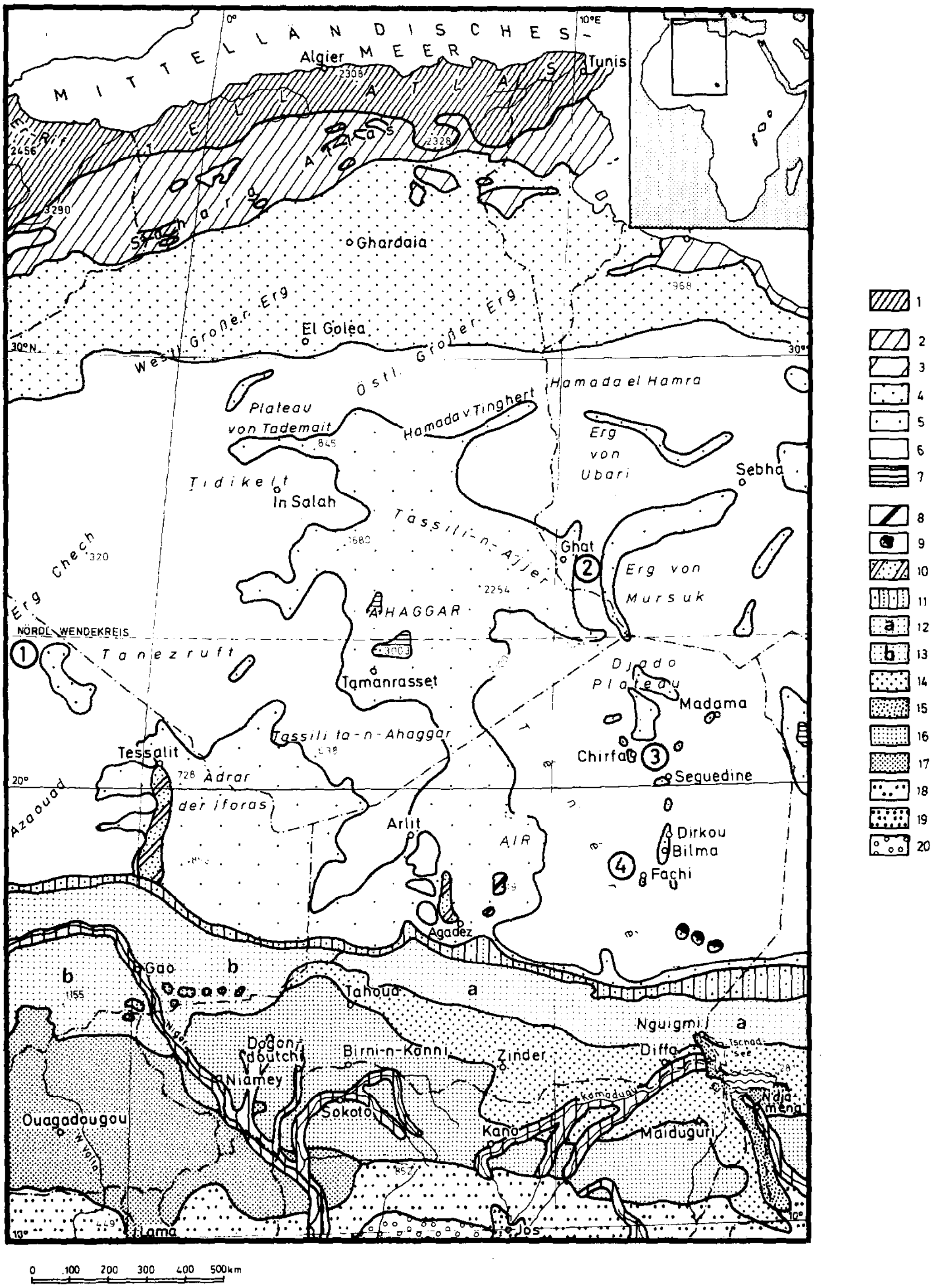

Fig. 1. Schematic vegetation map of the Sahara and the surrounding areas also shown are the sites of the holocene records. (Schulz, 1987). Inset shows the study area within Northern Africa.
1. Medit. shrub and forest (*Quercus*, *Pistacia*, *Pinus*, *Cedrus*). 2. Medit. steppe (*Stipa*, *Lygeum*). 3. Chenopodiaceae vegetation of the coast and the chotts. 4. Semidesert (*Artemisia*, *Ephedra*, Chenopodiaceae). 5. Contracted vegetation of the desert (*Acacia*, *Panicum*, *Tamarix*, *Stipagrostis*). 6. Ephemeric vegetation of achabs. 7. Diffuse *Artemisia-Ephedra* vegetation of the high mountains of the central Sahara. 8. Acacia-Commiphora-Rhus savanna of the high plateaus of S-Air. 9. Maerua-savanna of the plateaus

modified Livingstone corer for the lower part. The Segedine core was drilled and samples were taken directly from the inner part of the helix. The samples from Dj. Acacus come from archaeological excavations in the rock shelters of Uan Muhuggiag and Tin-n-Torha. All samples were prepared using the classical combination of HF-, HCL-, and acaetolysis treatments. The pollen spectra were counted to the point of consistancy of the percentages.

Present conditions

All corings and excavations were made in a desert environment where, at present, the permanent vegetation is restricted to wadis and depressions. In these localities groundwater and runoff can compensate the insufficiant annual precipitation. This kind of vegetation is mainly composed of *Acacia-Panicum* or *Tamarix-Stipagrostis* communities. The present rainfall in the area ranges between 5 and 30 mm per year. The monsoonal summer rain regime is predominant but intrusions of atlantic cyclones also occur.

The southern boundary of the desert is marked by the transition to diffuse vegetation of the *Acacia-Panicum* type (Fig. 1). This transition is relatively sharp and is clearly visible across the continent (Schulz, 1988). The region receives an annual precipitation of about 250 mm. To the South, the sahelian and sudanian savannas are characterised by the different tree layer and by a variable understorey of annual and permanent grasses and herbs. The floristic composition and density of the sahelian and sudanian savannas are for the most controlled by anthropogenic factors. They provide only a restricted model for the interpretation of former environments. The desert-savanna bondary on the other hand seems to be mainly climatically controlled.

Investigations of the present pollen rain (Cour & Duzer, 1976; Schulz, 1984, 1987) provide information about the dispersal of the different floristic elements. A certain part of the pollen, such as *Alnus*, *Pinus*, *Ephedra* or Combretaceae, is transported over long distances, but the bulk derives from local or regional vegetation. In the dune areas of southern Niger the transition zone of desert to savanna is clearly marked in the pollen spectra by the combination of high percentages of Gramineae and Cyperaceae (*Cyperus conglomeratus* as the typical dune plant). These differences enable the desert-savanna transition to be reconstructed.

Holocene conditions

Both the Taoudenni and Segedim records start in the middle Holocene. Cores and samples of the Taoudenni sequence were taken in the center of the depression of Taoudenni in the Agorgott salt mines. The depression is surrounded by cuestas of marine carboniferous clay and silt stones. The Taoudenni record is built up of alternating layers of salts and clays covered by a thick layer of reddish clays (Fabre & Petit-Maire, 1988).

The pollen diagram is divided into three parts (Fig. 2). The lower part (III) covers the period from about 8000 to 6000 BP. It is characterised by high percentages of Gramineae and Cyperaceae and the continuous presence of *Acacia*, *Capparis*, *Cassia*, *Fagonia* and especially *Grewia*. This indicates the proximity of the desert-savanna boundary to the site and the saharan *Acacia-Capparis-Panicum* savanna as the main vegetation type. The Sudanean as well as the temperate or mediterranean elements in the pollen spectra are due to long distance transport.

During a transition phase (II) between ca. 6000 and 4000 BP there was still a continuous presence

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of SE-Niger. 10. Semi-diffuse *Acacia-Panicum* vegetation (enlarged wadi vegetation). 11. *Acacia-Panicum* savanna. 12. *Commiphora-Acacia* savanna. 13. *Acacia-Leptadenia-Commiphora* savanna. 14. *Piliostigma-Bauhinia-Acacia* savanna. 15. *Acacia* thornbush around Lake Chad. 16. Combretaceae savanna. 17. *Parkia-Butyrospermum-Terminalia* savanna. 18. *Isoberlinia-Daniella-Pterocarpus* savannas. 19. *Isoberlinia-Carissa-Ficus* savannas on the Jos-Plateau. 20. *Afzelia-Lophira* savannas and open forests.
Sites: 1 Taoudenni 2 Tadrart Acacus 3 Segedim 4 Fachi-Dogonbolo

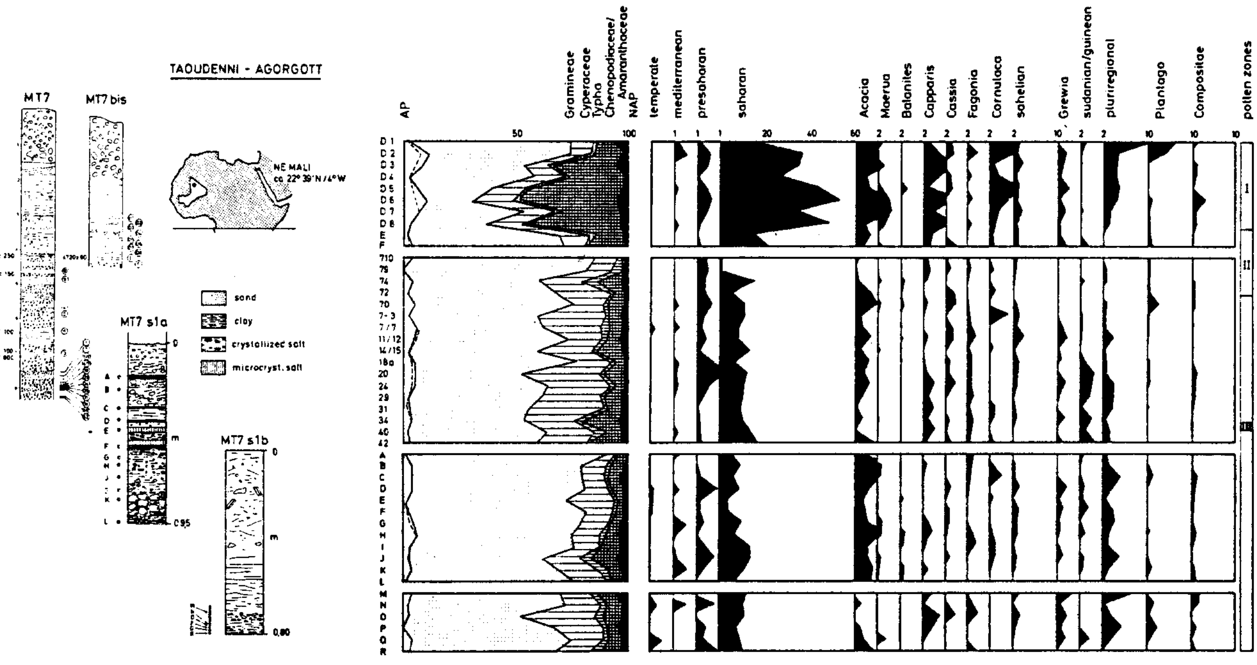

Fig. 2. Simplified pollen diagram of the Taoudenni-Agorgott record. The columns MT7 and MT7 bis represent the stratigraphy taken in the Agorgott salt mines. MT7 s1 and MT7 s2 refer to corings taken in the same pits. The correlation is based on the stratigraphy of the different salt layers. Numbers on the pollen spectra refer to those on the sediment columns.

of *Acacia*, *Capparis*, *Fagonia*, *Cassia* and in lesser extend *Grewia* but the percentages of Cyperaceae were decreasing. Also, the proportion of the long distance transport component diminished. This shows that during this period the savanna-desert boundary had moved to the South but that a remarkable *Acacia-Maerua-Capparis* vegetation remained in the depression.

At about 4000 BP there is a distinct change in the composition of the pollen spectra (I). The sharp rise of the Chenopodiaceae/Amaranthaceae together with *Balanites* and *Cornulaca* represents the establishment of the saharan desert vegetation which has degraded from ca. 2000 BP to its present condition. Elements characteristic of a very open vegetation such as *Plantago* and *Compositae* are predominant but trees like *Acacia*, *Balanites* and *Capparis* were still present in the local vegetation.

The Segedim core was taken in the center of the depression of Segedim (NE-Niger) in front of the Emi Bao cuesta made of karstified cretaceous sand and siltstones. The record consists of blueish fresh water clays in the lower part and sandy sebhka sediments in the upper part (Fig. 3). Only the lower part of the core provided pollen bearing sediments from the period from ca. 8000 to 7000 BP. The pollen spectra are characterised by the combination of high percentages of the Gramineae and Cyperaceae and the presence of *Acacia*, *Maerua*, *Capparis* and *Grewia*. Again this indicates the presence of the desert-savanna transition zone and a plant cover of a loose Acacia-Maerua-Panicum savanna. These savannas occur today on the sandstone plateaus of Se-Niger ca. 600 km to the South (Schulz, 1988). The long distance transport component is relatively low in the pollen spectra.

Archaeological excavation in the central and southern Djebel Acacus (SW-Libya) (Barich, 1987) yielded a pollen sequence covering the middle Holocene. However, samples from

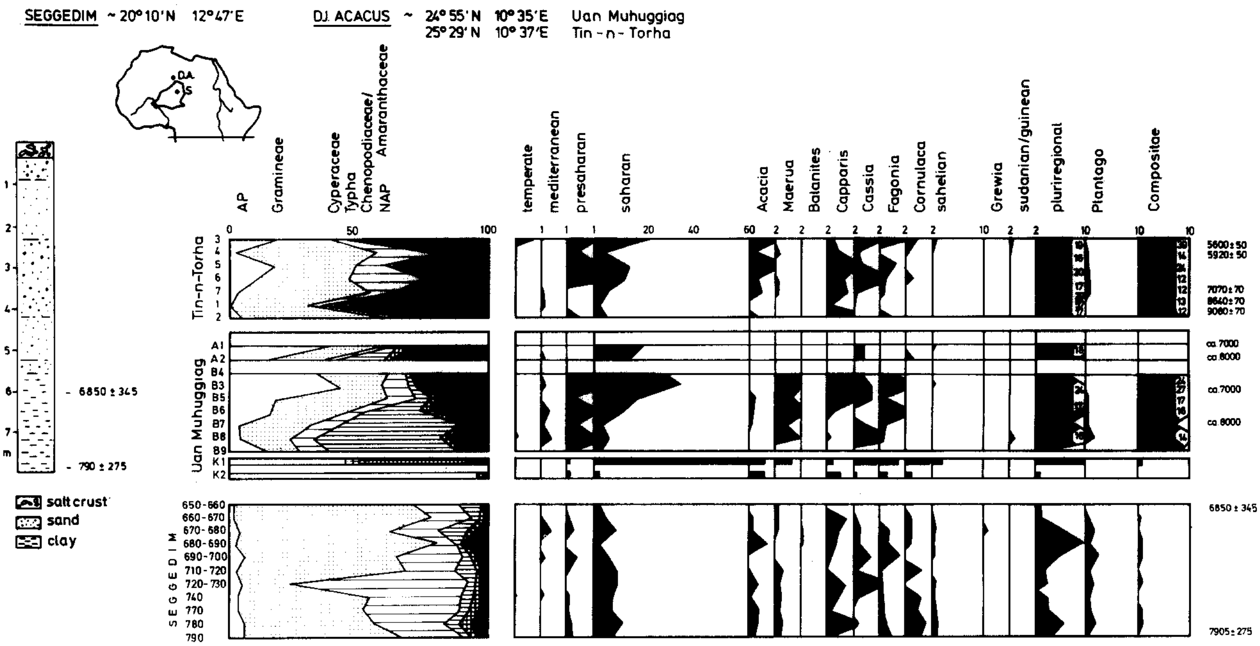

Fig. 3. Simplified pollen diagrams of the Segedim record and the Djebel Acacus excavations. The sediment column gives the stratigraphy of the Segedim core. Numbers on the pollen spectra refer to depth in the core. The Uan Muhuggiag and Tin-n-Torha sequences represent the excavations in rock shelters. The sample numbers refer to the original field numbers. K1 and K2 are coproliths from the lower layers of the Uan Muhuggiag.

excavations are not completely comparable to continuous cores but they give information about regional vegetation types and human influences. The pollen spectra (Fig. 3) of both sites show an open saharan vegetation dominated by Gramineae and pre-saharan elements like *Artemisia* or *Ephedra* as well as *Plantago* and Compositae. The high frequency of *Typha* in the Uan Muhuggiag record indicates a nearby swamp or even material collected by man. Two coprolites of sheep (K1) and goat (K2) gave pollen spectra which show the differences between grasers and browsers feeding on the same vegetation.

A charcoal flora from Fachi-Dogonbolo in the eastern Ténéré (Niger) dated to 7010 BP consists of sudanian elements like *Terminalia*, *Annona*, *Crataeva*, *Celtis*, *Ximenia*, *Ficus* etc. (Neumann, 1988). This gives direct proof of a sudanian savanna at 19° N during the middle Holocene.

Comparing the pollen records and the charcoal flora indicates that there was an ecological gradient along the Niger-Libya transect ranging from the sudanian, sahelian and saharan savannas to an enriched desert vegetation during the middle Holocene.

Holocene landscape and Holocene climate

The main difference between the mid-Holocene plant cover and that of present day is caused by the northward shift of the savanna-desert boundary to about 20°–22° N in Niger and Mali. This region was formerly covered by a saharan savanna composed of *Acacia*, *Capparis* and *Maerua* and tussock grasses as well as a denser herb cover. A large number of achab floras – short life therophyte communities – variable in time and space, were also characteristic of the region. Together with the tree elements, they stabilised the landscape with a loose root mat and made soil formation possible. Depending on relief and on increasing continentally to the East, the vegetation consisted of a complicated mosaic of different types rather than a simple northward sequence of vegetation belts.

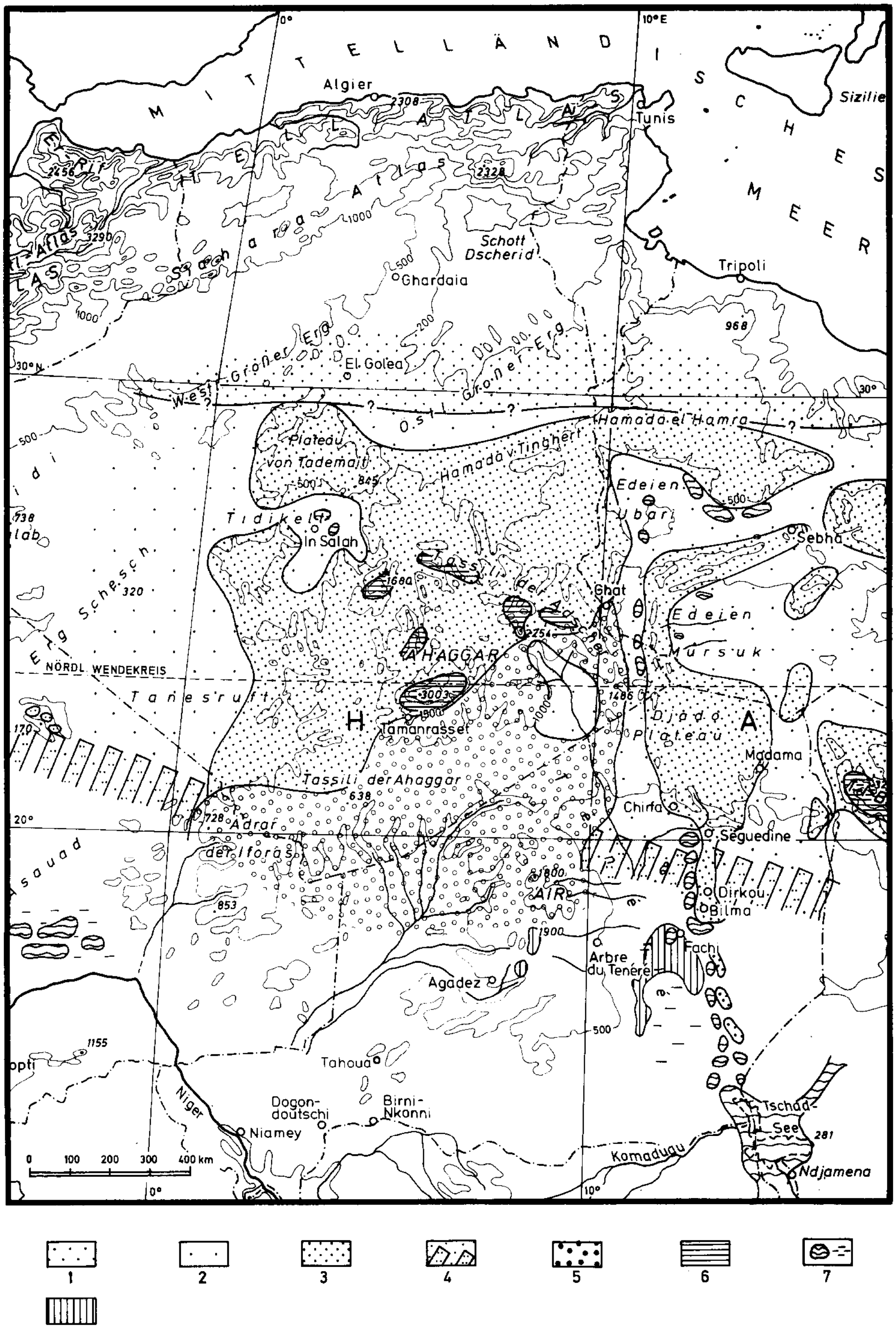

Fig. 4. Schematic map of middle holocene vegetation of the central and southern Sahara (Schulz 1987). 1. semideserts. 2. tussock grass and Chenopodiaceae vegetation, achabs. 3. Maerua-Acacia savannas and Acacia-Panicum/Tamarix-Stipagrostis communities of the central Sahara. 4. desert-savanna transition. 5. Acacia-Commiphora Celtis savanna. 6. Artemisia-Ephedra semidesert of the high mountains of the central Sahara. 7. lakes and swamps in different extensions. 8. sudanian savannas.

The second important point concerning the former landscape was the presence of an organised hydrological system with various lakes and swamps which were mostly groundwater fed. Also, the karstic systems played an important role in the formation of the aquifers (Sponholz, 1989).

From the presence of the Savanna-desert boundary at 20°–22° N one may estimate, in comparison with present conditions, a climate dominated by monsoonal summer rain with an effective annual precipitation of about 250–300 mm for the region. The elements of long distance transport in the pollen spectra also indicate a strong interaction with atlantic cyclones giving the change of additional rainfall throughout the year.

Estimates of rainfall based on the evaporation rate of the salt-layers in the Taoudenni region (Petit-Maire, 1986) may be re-evaluated following the discovery of Holocene neotectonic activity in the depression of Taoudenni (Fabre *et al.*, 1989). Carboniferous salts might have been remobilised along the different dolomite dykes in the depression and deposited in the sebkhas. This underlines again the individuality of palaeolakes.

Acknowledgements

I am gratefully indebted to the Deutsche Forschungsgemeinschaft for the financial support.

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