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LATE QUATERNARY FLUVIO-LACUSTRINE ENVIRONMENTS OF WESTERN NUBIA

by

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Teilprojekt E1: Quartärgeologie

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5. LOWER WADI HOWAR (S. Kröpelin)

The favourable environmental conditions at the lower Wadi Howar during the early and middle Holocene and their significance for the palaeoclimate on a regional scale have already been described in several earlier publications (PACHUR & RÖPER 1984; PACHUR & KRÖPELIN 1987, 1989; PACHUR et al. 1987). There the main emphasis was on the widespread lake carbonates and calcretes that were formed in a series of lakes, swamps and springs along the wadi during the pluvials, and the numerous faunal remains of savanna species that are demanding in their ecological requirements.

This chapter, however, will be limited to a short overview of the direct evidence of fluvial sediment transport along Wadi Howar during the Holocene and late Pleistocene. A detailed description in an overall context will be given elsewhere (KRÖPELIN 1990b). Here the spatial emphasis will be placed on the valley sections which are not characterized by lake carbonates even though these often display fluvial sediments at their base. These sections have already been described in the above-mentioned reports.

Main fluvial facies variants will be shown on the basis of type sections following the 450 km long lower course of Wadi Howar between Gebel Rahib and the Nile (Fig. 7): first, the fluvial deposits in the interior delta of the middle Wadi Howar west of the Gebel Rahib bottleneck which is blocked by a broad dunefield (site K 153); second, the former affluent wadis on the east side of Gebel Rahib; third, the fine-grained fluvial facies containing alluvial soils which are characteristic of a long section of the wadi (K 142). These are followed in the east by sandy terraces occurring 170 km west of the Nile. They are situated in structurally induced channels and help to explain a presumably very late wadi discharge (K 136).

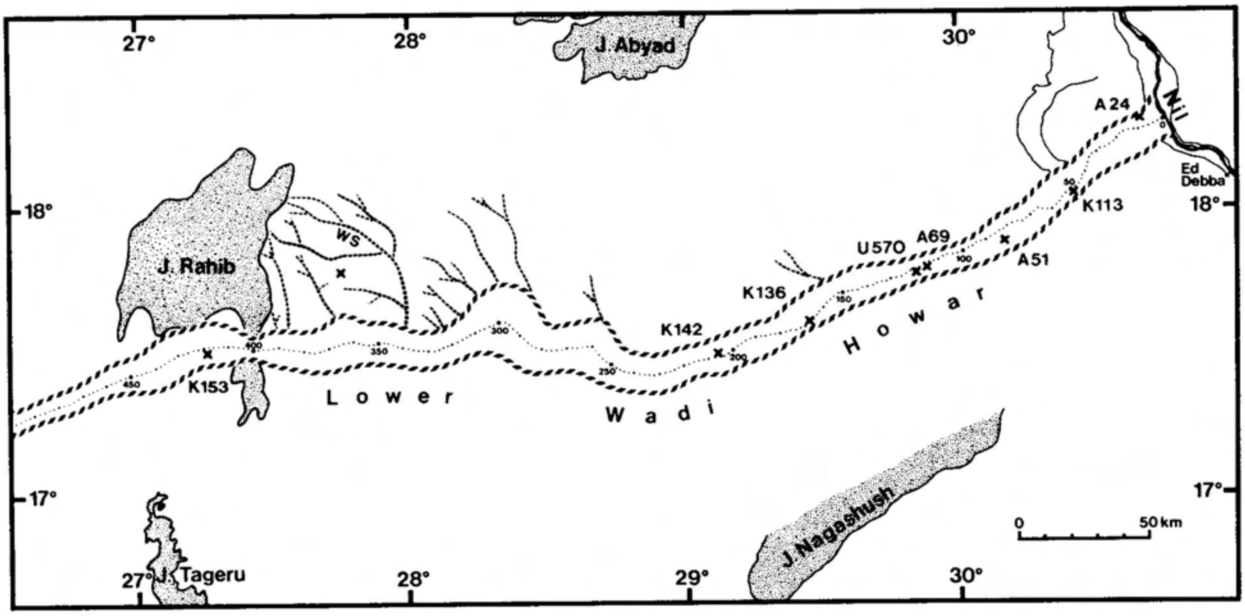


Fig. 7: Sketch map of lower Wadi Howar showing locations of sections mentioned in this chapter. Numbers along presumed thalweg give distance in kilometres from former Nile junction. Within this positioning system, e. g. position 205/1 indicates a locality 1 km perpendicularly north of a point 205 km west of the Nile, position 205/-7 a locality 7 km south of it. WS: Wadi Saiyal.

The cobble terraces (U 570) next described are also located in the channel section and attest to Pleistocene wadi discharge. However, local displacement and redeposition occurred as late as the Holocene (A 69). For a provenance study, the petrographic spectrum of cobble deposits 85 km west of the Nile as well as the heavy mineral content of their sandy matrix have been analysed (A 51). Gravelly sequences in an area 50 km away from the Nile exemplify the close interlocking of fluvial and limnic environments (K 113). Probably pre-Holocene bank conglomerates near to the former junction with the Nile are the final examples of stratigraphic results on the fluvial history of the lower Wadi Howar (A 24). Special importance is attached to evidence pointing to fluvial transport from remote catchments. In addition, biological indicators of flowing water are considered.

5.1 Fluvial deposits in the interior delta

Site K 153 is located roughly in the centre of the wide interior delta of the middle Wadi Howar (Fig. 7). Easily distinguishable on the satellite imagery, the area is already shown fairly accurately as the presumed end of Wadi Howar on older 1:250,000-scale topographic maps (Sheet NE 35J Zalat el Hammad, Sudan Survey 1942). In the field it is interrupted by 5-15 m high slopes.

Section K 153 was dug in the middle of approximately 4 to 6 m wide accumulations of calcareous concretions forming gravel bars about 40 cm higher than the surrounding terrain and extending discontinuously over several hundreds of metres in an east-west direction, roughly parallel to Wadi Howar (Plate 5, Fig. 1). Such carbonate concretions occur at many other locations along the Wadi Howar and have also been reported from several sites along the Sudanese Nile where they have been named 'kankar' and described as rounded nodules or root-like cylindrical growths of white to greyish calcium carbonate (ANDREW 1948). However, there are few references concerning their origin and formation in the literature. In the Wadi Howar these deposits may be considered as alluvial detritus derived from Holocene and possibly even mostly pre-Holocene lacustrine calcretes (Plate 5, Fig. 1a). The lower part of the section consists of cross-bedded medium- and coarse-grained sands. Like the overlying fine sands, these typical sandy wadi deposits are evidence of fluvial transport. Apart from the top layer, the gravel content exceeds 10 % by weight only in the stratum underlying it.

Because of the fundamental difficulty involved in dating transport phases, the early to middle Holocene age postulated for the deposits was inferred from their freshness, lack of consolidation, and considerations of plausibility. This difficulty is due to the fact that datable material such as charcoal is only very rarely to be found stratified in clastic sequences - unlike lake deposits - and overlying archaeological artifacts or faunal remains provide at best a minimum age. In many cases the chronology can only be inferred from facies-interlocks with lake deposits or from reliably dated sites.

5.2 Eastern foreland of Gebel Rahib

The entire eastern foreland of Gebel Rahib exhibits broad pebble and gravel beds as well as extensive gravel-covered plains, so the area is a serir in both the morphological and genetic senses of the term (Plate 5, Fig. 2). Its predominantly quartzitic material originates in Gebel Rahib. Several of these interconnected pebble and gravel belts are as much as 3 km wide, with generally blurred transitions between adjacent strips. The broader belts are visible as dark strips on standard-processed Landsat imagery in spite of their light colour in the field. The gravel beds are in turn subdivided by sand-filled channels. Several main branches show a fairly close third- and fourth-order dendritic network whereas the wide gravel-covered plains are probably due to high-dynamic anastomosing streams.

The maximum grain size clearly diminishes with increasing distance from Gebel Rahib, with exceptions only in the proximity of several white quartzite outcrops. For example, at the location of the photo (Plate 5, Fig. 2) lying about 8 km east of the edge of Gebel Rahib and 11 km north of Conical Hill, there are rounded pebbles of granitoid rocks and various metamorphites in addition to the dominant quartzite which mainly belong to the medium to coarse gravel fraction with maximum diameters of about 10 cm.

The largest potential collector channel is Wadi Saiyal, part of which is already shown on the 1:250,000-scale maps as a result of SHAW's survey in 1935 (SHAW 1936). The name refers to the numerous Saiyal acacias in the middle course of the wadi, some of which are being buried by migrating, 15-20 m high barchans that cross the wadi in several places. Following the general southward dip, the flat, up to almost 1 km broad wadi bed joins Wadi Howar after 85 km. Other smaller valleys enter the upper part of Lower Wadi Howar between positions 400 and 250 (Fig. 7); it is stressed that palaeolake carbonates are mainly to be found at these junctions. In the middle segment of Lower Wadi Howar, too, carbonates tend to occur in the junction areas of secondary valleys.

Because of the widespread distribution of these fluvial deposits and landforms, it is assumed that after heavy rainfall the entire area east of Gebel Rahib was flooded over a distance of at least 50 km in the surroundings of the wadi channels and water-logged in the areas in between. This was probably the reason for the formation and human occupation of parabolic dunes in this area (GABRIEL & KRÖPELIN 1986).

5.3 Potamogenic marsh deposits

Locality K 142 can be seen as typical of very extensive and widespread deposits in the middle segment of Lower Wadi Howar, which even represent a specific landform. Single continuous depositional areas are as much as 10 km wide and up to tens of kilometres long. At position 205/1, a 4 m deep representative trench was excavated.

Section K 142 is located in the middle of a horizontal surface mostly covered by windblown sand and measuring several square kilometres about 14 km ESE of a three peaked hill ('Dreizack') at an altitude of about 415 m a. s. l. (Plate 5, Fig. 4). These deposits are very dark greyish brown (Munsell 10 YR 3/2) appearing almost black in the field. They are covered by a distinct network of polygonal desiccation cracks which are filled with recent windblown sand in their upper part. A hierarchic structure with different orders is visible, the highest-order mud-crack polygons being fairly regular with diameters of up to several metres and more than 15 cm wide desiccation cracks, whereas the secondary casts are more irregular in pattern with diameters in the decimetre-range and only a few centimetres thick cracks. The edges of the individual polygonal fields do not arch up, in contrast to the 'gilgai' microrelief of most Egyptian playas (KRÖPELIN 1989).

Several epipalaeolithic and neolithic artifacts are scattered over the surface. 'Dotted wavy line' pottery (det. GABRIEL and KUPER) may be attributed to the Early Khartoum complex (ARKELL 1949; ADAMSON, CLARK & WILLIAMS 1974). In fact, most of the coarse material on the surface derives from lithic industry and raw material transported by men and locally redistributed by running water. In many places there are specimens of the large land snail *Limicolaria cailliaudi* (Pfeiffer, 1850) which is a Nile species different from the West African species *L. flammea* (MEAD, Tucson, in litt.; also cf. HAYNES & MEAD 1987).

Plate 5, Figure 3 shows the upper part of section K 142 the description of which is given in Figure 8 showing the highly variable clay content (fraction $< 2\ \mu m$) reaching a maximum of 25 % at a depth of 60 cm. Several sand layers have an enhanced gravel content as evidence of higher flow velocities. The grainsize triangle after FOLK (Fig. 8) nevertheless shows the generally sandy structure of all layers, which means that the term 'cotton soil', originally used for the trap-rock-derived alluvial clay plains of India, is not appropriate here. Of the predominantly sandy material in the profile, only the top layers K 142-1 to -5 in the upper quarter stand out because of their enhanced proportion of pelite, as one of the intercalated gravel-bearing layers (K 142-15) is remarkable for its gravel content of almost 30 % by weight.

Carbonate mottling in the upper part with a 3.5 % $CaCO_3$ content points to pedogenetic processes. These relatively high values, too, contrast with the almost carbonate-free playa deposits in Egypt (KRÖPELIN 1987). Conductivity reaches a maximum of 7 mS at 0.8 m below top, dropping continuously to 0.35 mS both towards the top and towards the base at a depth of 4 m. According to the FAO soil classification the upper horizons may be named a takyric yermosol.

The extensive valley deposits corresponding to section K 142 are thus potamogenic sediments whose base mainly consists of wadi deposits, and whose pelite-rich top layers resemble floodplain deposits indicating a very extensive marshy environment left after flooding at high water. The available radiocarbon dates of carbonate rhizoconcretions suggest that the sandier material was deposited before and after 6,400 ± 250 B.P. (Hv 15587), whilst the clay-rich alluvial sediments were deposited after 4,765 ± 130 B.P. (Hv 15586; cf. Fig. 9, Plate 5, Fig. 3). Charcoal dated at 3,140 ± 380 B.P. (Hv 15584) - obtained at 70 cm below top from the comparable section K 140 situated 34 km downvalley - also shows the finer deposits to be younger. However, this interpretation implies that the above-mentioned early Neolithic pottery was washed down from lateral higher terrain at a later date.

Incidentally, these deposits have their equivalent further south in the valleys of western Darfur, which feature a uniformly dark cracking-clay floor with depths over 4 m without apparent bedding or lamination (ANDREW 1948: 108). SANDFORD (1935: 369) also mentions 'cotton soil' in the upper course of the Wadi Howar and north of Mellit, where run-off from qoz accumulations round the Tagabo volcanic hills descend on to a clay-floored wadi.

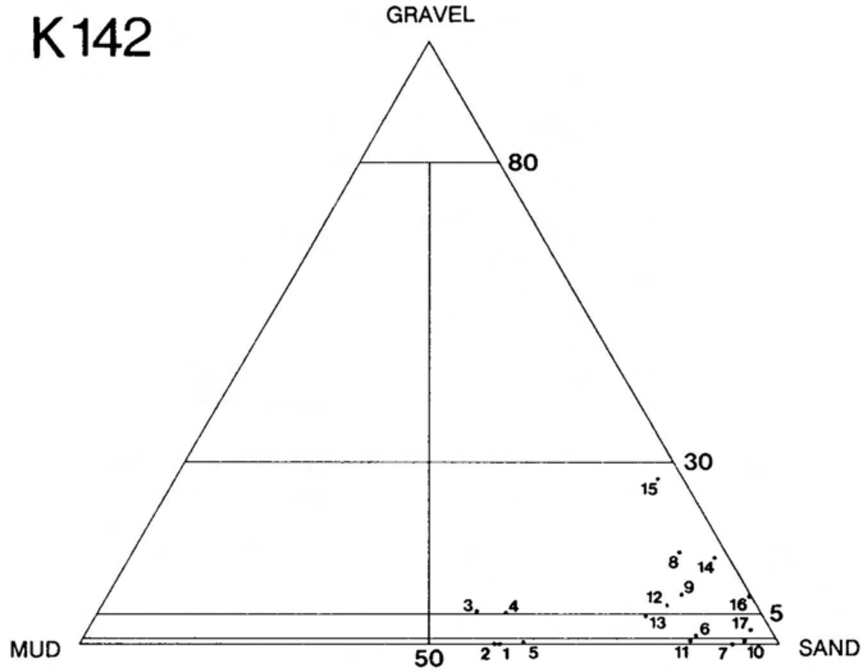


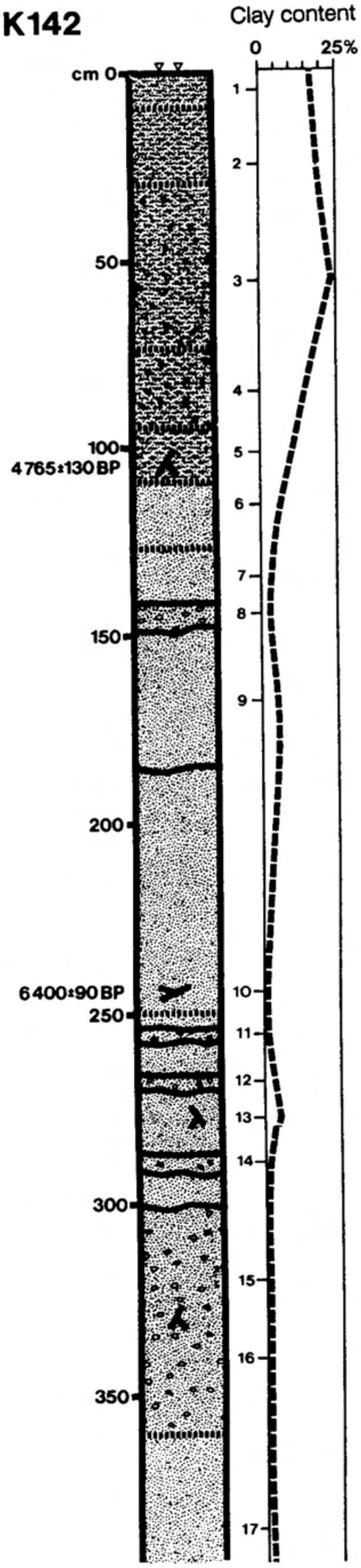
Fig. 8: Grain size classification after FOLK (1954) of strata K 142-1 (top) to -17 (base).

5.4 Sandy alluvium

The palaeochannel segment between 210 km and 90 km west of the junction with the Nile is of crucial importance for the function of the Lower Wadi Howar as a Holocene drainage line. On Landsat imagery the valleys resemble channels seeming recently cut into the alluvium; in fact, however, they are structural features. Field observations and evaluation of Landsat imagery also led to the conclusion that these braided inset channels within the 10 kilometres wide bedrock valley of the lower Wadi Howar represent an open-air analogue to types 2 and 3 of the sand-covered 'radar rivers' in the Selima Sand Sheet some 450 km further north (KRÖPELIN 1990a; cf. McCAULEY et al. 1982, 1986). In contrast to the radar rivers, however, the evidence mentioned below indicates that this part of the Lower Wadi Howar was functioning as a drainage line as late as the Holocene.

A suitable locality for the reconstruction of the depositional environment is provided by an isolated terrace in the middle of one of the valleys at an elevation of about 380 m a.s.l. (position 168/0). Sections K 136 and K 137 are situated on a roughly 30 by 80 m terrace remnant in the middle of the 150 m wide channel (Fig. 10, with backhoe trenches K 136-139). On the terrace surface, about 4 m above the present valley floor, there are 15 circles of excavated material, 0.3-3 m in diameter and 10-30 cm high. Seventeen similar features on two levels were counted at position 171/0, 3 km upvalley.

Figure 11 shows the stratigraphy, texture, sorting and mean of all strata distinguishable in section K 136. In the field their fine lamination and cross-bedding indicated dune sands, an assessment confirmed by the sorting curve, which shows that the gravel-free fine sandy layers 14 and 11 are the best sorted. In the case of layers 15, 9, 8 and 2 the parameters point to water-laid aeolian sand, deposited either as genuine wadi load or by sand slope flooding. Layer 5, classified as wadi sediment on the basis of its texture, overlies the alluvial windblown sand with a basal erosion plane. The texture of layer 10 shows that it is also a wadi deposit. Irrespective of the mode of transport, each non-aeolian deposition required a continuous plane link to the source area indicating a complete sedimentary fill of the channel at the respective levels. Only after the last such depositional event did extensive fluvial and aeolian action set in, removing most of the ample accumulations from the more than 100 m wide channel and leaving only a narrow isolated remnant.



DESCRIPTION:

10-0: muddy sand; very dark greyish brown (10 YR 3/2); columnar, platy crumb structure; well consolidated; desiccation cracks filled with wind-blown sand; diffuse lower boundary

30-10: muddy sand; very dark greyish brown (10 YR 3/2); columnar structure; well consolidated; recent rootlets

74-30: gravelly muddy sand; very dark greyish brown (10 YR 3/2); compact; consolidated; many carbonate concretions; some rock fragments < 10 mm ø (granite)

95-74: gravelly muddy sand; brown (10 YR 5/3); consolidated; very calcareous; close-set root casts < 2 mm ø; ox/red mottling covering about 60 %

109-95: muddy sand; brown (10 YR 5/3); moderately consolidated; very calcareous; close-set root casts < 2 mm ø; some ox/red mottles

127-109: slightly gravelly muddy sand ; light brownish grey (10 YR 6/2); moderately consolidated; very calcareous; close-set calcareous root casts max. ø 3 mm; burrows < 5 cm ø filled with brown (7.5 YR 5/2) medium to coarse sand

142-127: sand; pale brown (10 YR 6/3); slightly calcareous; bioturbational features with burrows ø < 4 cm filled with brown (7.5 YR 5/2) medium to coarse sand; root casts < 2 mm ø

150-142: gravelly sand; light yellowish brown (10 YR 6/4); well rounded pebbles < 10 cm ø (quartzite, granite, greenish metamorphites); pebble layer on erosional lower boundary (possibly deflation lag)

175-150: gravelly muddy sand; pinkish grey (10 YR 6/4); several gravels < 10 mm; moderately consolidated; slightly calcareous; bioturbational features; root casts < 10 mm ø; isolated carbonate concretions; weathered granite particles < 3 mm ø; irregular lower boundary

300-175: sand; light grey (10 YR 7/2); at 3 levels isolated quartzite pebbles < 5 cm ø; intense bioturbation; burrows filled with grey mud; mostly vertical calcareous root casts < 3 cm ø; irregular lower boundary

360-300: gravelly sand with isolated, very well rounded pebbles and cobbles; very pale brown (10 YR 7/3); carbonate mottling; calcified root casts < 5 cm ø ; irregular lower boundary

395-360: slightly gravelly sand; light yellowish brown (10 YR 6/4); cross-bedded

Fig. 9: Stratigraphy, radiocarbon ages, and clay content (< 2µm) of section K 142.

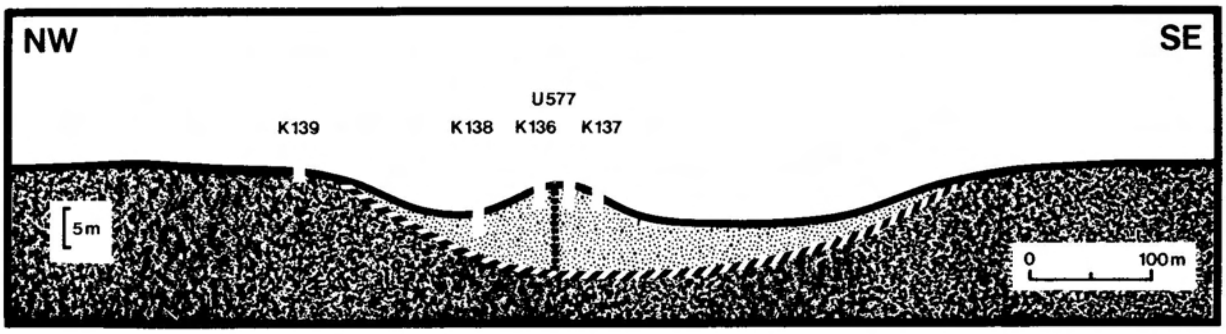


Fig. 10: Cross-section of braided inset channel within Lower Wadi Howar showing terrace remnant with trenches K 136-139 and bore-probing U 577. Scales are approximate.

The high silt content of layer 4 may mark a short stillwater phase, or result from mechanical infiltration of fine particles from the overlying stratum 3 mentioned below. The top layer of fine sands has the typically laminated platy structure of an aeolian cover sand. Consisting mainly of sand and angular, coarse-grained lag gravels, the very poor sorting and bimodality of the surface layer K 136-0 is due to selective removal by deflation.

The bimodal grain-size frequency distribution of layer 3, however, indicates an anthropogenic origin. Thin sections of this layer show very poorly sorted and angular fragments of biotite- and plagioclase-bearing granite and other basement rocks, as well as quartz sand in a carbonate matrix. X-ray diffraction shows the presence of calcite and feldspars of the albite-anorthite varieties besides the dominant quartz. Both this carbonate-rich layer and the earth circles may be explained by a former occupation level and huts with a composition floor. Consequently there may have been a settlement at this site with at least 10 huts made of twigs and branches anchored at the base by earth rings. Such a sedentary lifestyle must have required a permanent and near-surface water supply, probably from the wadi floor.

The particular significance of the inferences drawn from this site lies in the unexpectedly recent radiometric age of 2,075 ± 175 B.P. (Hv 15583) of charcoal from a fireplace found in layer 15 at a depth of 160 cm. The charcoal fragments were identified as *Capparis decidua* (tundub), *Acacia seyal/raddiana* and *Boscia* cf. *senegalensis* (det. NEUMANN, Frankfurt). In Sudan, the dominant *Capparis decidua* is the species best adapted to extreme aridity and isolated specimens are to be found even below 20° north along the slopes of Wadi Shaw and Wadi Sahal 400 km farther northwest. As mentioned above, numerous *Acacia seyal* were observed in Wadi Saiyal on a survey in January 1984, many of which, however, were already dried up. *Boscia senegalensis* still occurs at Gebel Tageru (NEUMANN 1987) and Gebel Nagashush (Table 2).

In conclusion it may be inferred that considerable fluvial activity occurred in this segment of lower Wadi Howar as late as the late Holocene, i. e. after 2,000 B.P., and that relatively favourable living conditions in the wadi still allowed fairly lengthy occupation within a desert environment. Independent evidence is provided by a probably contemporaneous fortress situated 110 km away from the wadi junction with the Nile (KUPER 1988).

5.5 Cobble terraces

Cobble terraces, about 100-200 m wide and 9 m high, border the widened and approximately 10 m deep channels between positions 110-120 (Fig. 7; Plate 6, Fig. 1). On-lying Acheulean handaxes and other palaeolithic artifacts provide the only clue so far to their chronological position. By analogy with recent U/Th dates of calcretes containing Acheulean artifacts in the Great Selima Sand Sheet (McHUGH et al. 1988a, b; SZABO et al. 1989) or other dates from elsewhere (SZABO & BUTZER 1979), a minimum date of about 200,000 B.P. for their formation seems likely, thus putting them at least into the later Pleistocene. There are also indications of more recent human occupation of the terraces, for example stone circles.

The generally well-rounded polymict cobbles consist mainly of quartzite and other resistant metamorphites. They measure 5-20 cm in diameter and are embedded in a reddish, sandy-gravelly matrix

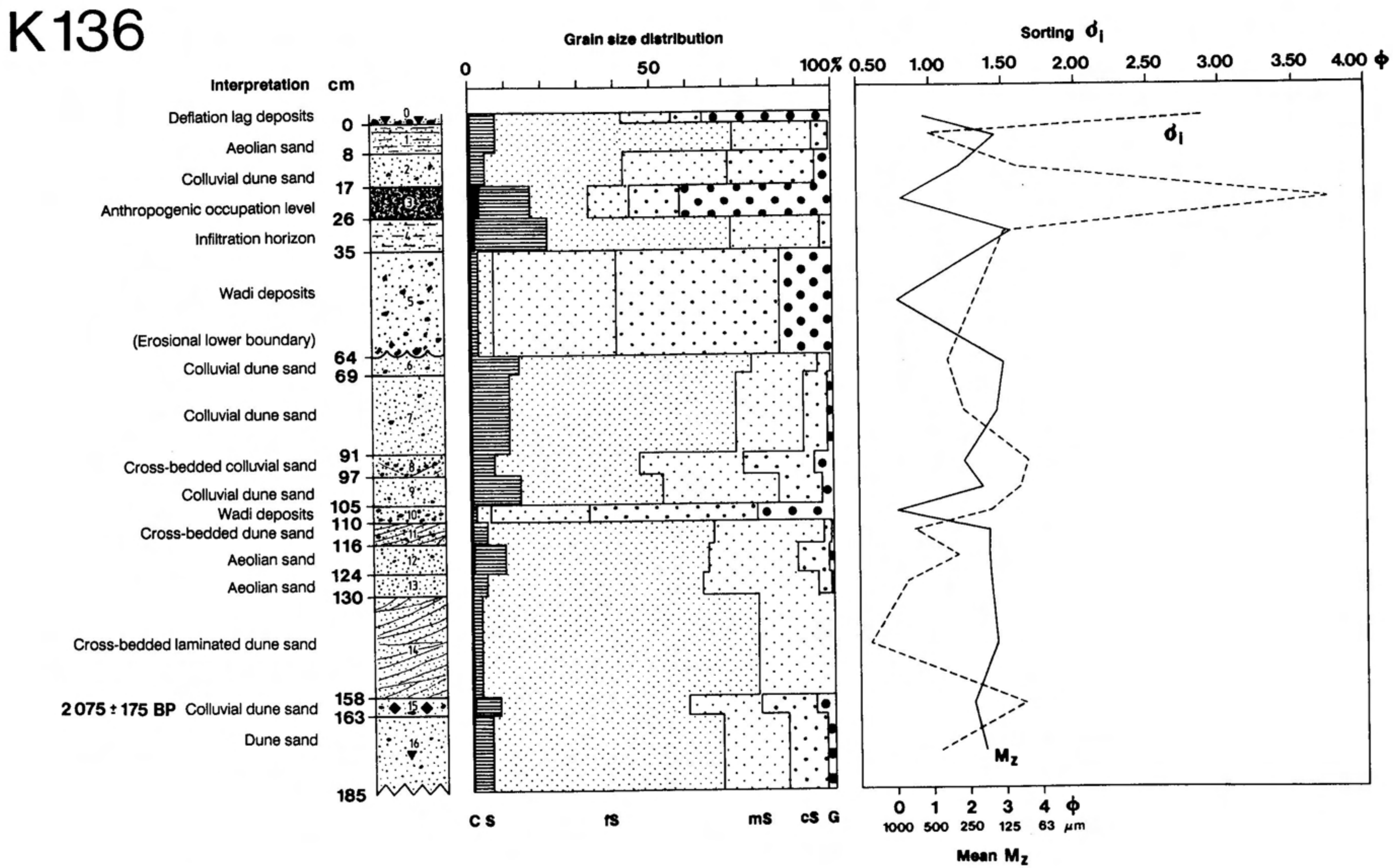


Fig. 11: Stratigraphy, grain size distribution, sorting and mean of section K 136.

containing less than 25 % of sand. Quartzitic cobbles on the surface are generally heavily patinated and wind-polished whereas less-resistant rocks such as sandstone exhibit strong traces of corrasion.

Thin sections of selected gravels from the gravel fraction of section U 570 (position 120/-5) were examined under the polarizing microscope. The petrographic spectrum includes amphibolite-bearing (5-15 %) alkali-feldspar-gneisses, some of which are heavily mylonitized, as well as genuine amphibolites containing 60-80 % amphibolite, and quartzites with a mosaic texture or extremely elongated quartz grains. There are minor quantities of poorly sorted sandstones, siltstones with narrow bands of epidote, and microcline- and orthoclase-bearing breccias. Many of the thin sections exhibit strong alteration. Since gneisses occur throughout the region, their exact provenance cannot be traced; according to the most recent geological map (JAS et al. 1989) sandstones first occur upvalley only a few kilometres north of the locality, or much further west behind Gebel Rahib. We have also detected sandstone remnants in the southern part of the Abu Tabari bend some 200 km to the west.

Of particular interest is the occurrence of a porphyry with idiomorphic sanidine crystals in a devitrified and partly recrystallised groundmass (Plate 6, Fig. 2). In spite of heavy alteration and the devitrification-induced microfelsic structure of the hyaline groundmass the flow texture is unequivocally revealed under the microscope. The presence of an acid volcanic rock in the middle of an extensive metamorphic basement surrounded by large areas of sandstone is clear evidence of a transport over considerable distance. According to FRANZ and SCHANDELMEIER (Berlin, pers. comm.), such acid volcanic rocks are unknown in the entire region surrounding lower Wadi Howar, including Gebel Rahib. Since the samples are not from the surface but from the excavated middle section of the terrace, the possibility of anthropogenic transport may be discarded.

5.6 Cobble redeposition

At the locality A 69 (position 122/0), only 2 kilometres downvalley, there are extensive deposits of terrace cobbles due to high-energy transport which according to their fresh morphology most probably are Holocene (Plate 6, Fig. 3). The several metres thick cobble deposits overlie finely laminated alluvial and dune sands and stand out as ridges on the wadi floor owing to their resistance to deflation. Apparently older terrace cobbles have been rebedded locally after having been transported over a distance of only several kilometres.

Evaluation of vertical photographs of the surface gives an average size of 59 x 36 mm for the coarse pebble and cobble fraction (> 20 mm). The mean value of the 10 biggest cobbles is 113 x 58 mm. An orientation of the cobble long axes or an imbricated structure does not occur which in the latter case might be a consequence of the high degree of roundness. In any case, such high kinetic energy deposits indicate swell-like water flow after exceptionally heavy rainfall.

5.7 Heavy mineral content of fluvial deposits

Site A 51 (position 84/-7) exhibits a 60 cm thick coarse cobble layer with only about 10 % matrix of sand and gravel on unweathered white sandstone bedrock. The overlying stratum consists of 40 cm of yellowish, fine-gravelly medium sands and is covered by cobble litter at the surface. The petrographic spectrum comprises well- to very well-rounded cobbles of basalt, quartzite, granite, sandstone, silicified wood, slate (also greenish), and various other metamorphites. This broad range already indicates different provenances and hence long-distance transport, since the bedrock of the surrounding catchment consists of Upper Cretaceous sandstone (JAS et al. 1989) with a few basalt outcrops.

For a more detailed provenance study the heavy minerals within the sand fraction of the cobble layer have been extracted by gravity separation. Some of the grains were then selected under the polarizing microscope and analysed by the rotating crystal diffraction method using a Gandolfi camera. This method is used when the sample quantity is too small for classical X-ray diffraction analysis. Defined sample positions are not necessary, which is a considerable advantage considering the often complete rounding of the fluvial heavy minerals. X-ray scannings were made of the 125-250 µm and 250-315 µm heavy mineral fractions taken from the sandy-fine gravelly portion of the terrace at 50-60 cm below surface.

Table 5 gives an overview of the results from both grain size fractions of sample A 51-1. The X-ray spectra of the mineral assemblage rutile, tourmaline, amphibole, disthene, garnet and staurolite are typical of a metamorphic source area, although mica, amphibole, epidote, zircon and ilmenite can also be of magmatic origin. Consequently, the provenance cannot be local as the surrounding bedrock exclusively consists of sandstone and some basalts. The eastern limit of the metamorphic basement lies about 40 km upvalley.

Up to now, disthene-staurolite rocks have not been reported in the metamorphic basement north of lower Wadi Howar nor along the wadi itself. A possible source area could therefore be the southern to western part of Gebel Rahib, where staurolite has been found (FRANZ, pers. comm.).

Table 5: Heavy minerals determined with the Gandolfi Camera (Analyses by HALSBAND and KRÖPELIN).

A 51-1 125-250 µm		A 51-1 250-315 µm	
Mineral type	No.	Mineral type	No.
rutile	6	actinolite	5
tremolite	3	zircon	4
tourmaline	3	tourmaline	3
disthene	3	iron oxide	2
ilmenorutile	2	ilmenorutile	1
epidote group	2	ilmenite	1
zircon	1	titanite	1
staurolite	1	gahnite	1
ilmenite	1	mica	1
garnet	1	epidote group	1
cupric chloride	1	Ca-Al-Fe phosphate	1

Gahnite (zinc spinell, $ZnAl_2O_4$) mostly occurs in granitic pegmatites, but also has been described from altered contact-metasomatic carbonate rocks, high-temperature metamorphic rocks or Al-rich xenoliths (HALSBAND 1988). Metamorphic limestones have been found as bluishly banded marbles some 50 km upvalley.

The copper chlorite consists of crystals of a complex copper salt which indicates secondary mineral formation by ascending water, confirming observations of efflorescence in the surroundings.

In conclusion it may be stated that even though there is - in contrast to the results gained by thin section microscopy of gravels from the cobble terraces - no unequivocal evidence of minerals or mineral assemblages within the analysed spectra of the fine sand fraction which indicate a provenance far beyond Gebel Rahib, e. g. in the Gebel Marra area; a transport from Gebel Rahib, however, over a distance of about 320 km seems likely.

5.8 <u>Gravelly deposits</u>

At many localities along the lower Wadi Howar there are gravel bars rising slightly above the surrounding, mostly sand covered plain. At position 50/-1, 50 km away from the Nile, there is one such site (K 113) with a gravel bank standing about 40 cm high above the surface (Plate 6, Fig. 4). These typical fluvial features give the impression of a unique depositional event. The backhoe section shows, however, that the pebble bars outcropping at the surface are merely the last event of a multiple fluvial cycle. The 270 cm deep trench at this site produced a total of 11 gravel layers. It was not possible to reach the bedrock; however, an enhanced kaolinite content in the basal sands may signalize the proximity of sandstone. In this case, the entire Holocene fluvial sequence of this site would be documented in this section, as no unconformities extending through the entire thickness of any of the intercalated sand layers could be detected.

The photo mosaic of section K 113 (Plate 6, Fig. 5) shows the position and structure of the subsurface gravel layers labelled A to K and the interlayering silty sands. The seven coarse gravelly layers have irregular basal faces (striped lines on photo), showing the effect of fluvial erosion on the respective underlying surface. Both the matrix and interlayered sands are loose. They do not display any signs of pedogenetic or diagenetic changes.

The early to mid-Holocene age assumed for these sediments is based on their interlocking with adjacent Holocene lake sediments, in and on which there are numerous Neolithic sites, including burials with associated objects and large areas scattered with pot sherds. At this site, numerous bones of large mammals have been identified as elephant (*Loxodonta africana*), giraffe (*Giraffa camelopardalis*), roan antilope (*Hippotragus equus*) and other big bovids (det. BOESSNECK, München). Collagen dating of an elephant's jawbone yielded 5,430 ± 180 B.P. (Hv 15576).

5.9 Bank conglomerates

Location A 24 is situated in position 8/4 at the roughly west-east trending northern banks of the Lower Wadi Howar in the former junction area. The gentle valley slope in the sandstone bedrock is bordered by up to 1 m high erosional remnants of a gravel conglomerate with a marlaceous matrix. In the thin section subangular to rounded particles of the sand and fine-gravel fraction in a micritic carbonate matrix can be seen (Plate 7, Fig. 1). Among the coarse sand and pebble skeleton, sanidine-bearing rhyolithic rock particles (Plate 7, Fig. 2) indicate longe range fluvial transport, as do similar occurrences in the gravel fraction of the above mentioned cobble terraces of site U 570 110 km upvalley. Of particular interest are components of graphitic quartzite (Plate 7, Fig. 3). The only known outcrop of such rocks in the region is in Gebel Rahib (BERNAU, Berlin, pers. comm.). This find thus may be further indication of a fluvial transport over 400 km down to the Nile.

Until the chronological position of this bank formation aligned perpendicularly to the Nile has been clarified, a connection with the postulated early-Pleistocene Proto-Nile loop reaching 40 km further west (PACHUR & KRÖPELIN 1987) cannot be excluded completely. Kaolinization features within the matrix (Plate 7, Fig. 4) may indicate a pre-Holocene age. Independently of this question, this site is geological proof of fluvial activity also in the lowest parts of Wadi Howar, thus backing up the geomorphological evidence.

5.10 Biological indicators

The geological and geomorphological evidence supporting a fluvial environment in lower Wadi Howar is also confirmed by biological indicators. These include large amphibians (*Hippopotamus amphibius*), reptiles (*Crocodylus niloticus*) and other wet biotope species such as toads (*Bufo regularis*), found along the course of the wadi (KUPER 1981, PACHUR & RÖPER 1984, GABRIEL et al. 1985, PACHUR & KRÖPELIN 1987). Apart from several Nile fish species like the pebbly fish *Alestes*, the perch *Tilapia zillii* and the shield-head catfish *Synodontis* (KRÖPELIN & SOULIE-MÄRSCHE 1990; identified by VAN NEER, Tervuren), river bivalves indicating running water are particularly interesting in this context.

The river bivalve *Aspatharia rubens* (Plate 8, Fig. 4), up to 15 cm in size, is reported here as the first record for the Sudan (SCHÜTT, Düsseldorf, in litt.). In Egypt it has been found in fairly great numbers only once, in pools caused by Nile flooding (before the construction of the Aswan dams) near Gizeh in 1875. Later only the slightly smaller *Aspatharia arcuta* was identified, which has also been found at several sites in lower Wadi Howar. Probably because of its rarity, *Aspatharia rubens* had previously been considered restricted to West Africa (SCHÜTT, in litt. 1987). Although *A. rubens* is large it is not limited to deep water habitats, but can also survive in shallow pools if they are regularly flooded.

Of special interest are the occurrences of the Nile oyster *Etheria elliptica* near the gravel banks of the locality K 113 mentioned above (Plate 8, Fig. 5). The 2-3 cm thick shells of the specimens found there are as much as 15 cm long and 10 cm wide. These river oysters need clear, well-oxygenated and hence flowing water, and mainly occur at the Nile cataracts. Like marine oysters, they are attached to rocks by one valve and can form sizable banks (HILTERMANN 1964).

Mutela nilotica (Plate 8, Fig. 1) is the largest known bivalve of the Nile and is to be found in the entire river basin excluding the Blue Nile. It also lives on rocky ground and generally prefers greater water depths which is why, with the present even flow of the Egyptian Nile, it only seldom reaches the banks (SCHÜTT 1986). *Corbicula fluminalis* (Plate 8, Fig. 3) is by far the most frequent Nile bivalve mainly occurring in the back-swamp areas. *Caelatura aegyptica* (Plate 8, Fig. 2) presently occurs in the entire Nile below Khartoum. It can be found in brushwood along the banks including those of Lake Nasser, where, however, the shells are twice as big as the specimens from lower Wadi Howar.

The malacofauna of lower Wadi Howar differs in very few respects only from the present-day Egyptian Nile fauna (SCHÜTT 1986). SCHÜTT (in litt. 1987) sums up the inferences drawn from the mollusc spectrum from lower Wadi Howar as follows: 'The [molluscan] fauna collected in lower Wadi Howar is the typical fluviatile Nile fauna basically still inhabiting the middle and lower Nile today. It shows that this part of Wadi Howar has been a branch of the Nile' (our transl.).

5.11 Palaeoenvironmental inferences

The Lower Wadi Howar constitutes a complex depositional environment containing a variety of fluvial sediments interlocking closely both in facies and age. Fluvial erosion and accumulation occurred repeatedly during the Pleistocene and up to the late Holocene. Taking into consideration the lacustrine and playa environments not mentioned here, there must have been a chain of wadi sections, interconnected flood pools and lakes stretching over a length of 400 km between Gebel Rahib and the Nile. From this, there emerges an episodic break in the endorheic state of the region and a long-term link with the Nile by means of standing and moving water, a conclusion that is supported by evidence of a rich fluvial and amphibian palaeofauna. The charcoal date from section K 136 apparently indicates that extensive processes of accumulation and erosion were active up to about 2,000 B.P.

The hypothesis of the dune barrier south of Gebel Rahib having been active during the whole Holocene will be discussed at length in another report (KRÖPELIN 1990b). This interpretation does not reduce the palaeoclimatic importance of the Lower Wadi Howar but rather enhances it, since it implies that all fluvial processes have resulted from local rainfall from the catchment area north of the wadi, between Gebel Rahib and the Nile, as the west-east oriented valley apparently had no southern tributary channels according to satellite imagery and field observations. Hence the fluvial processes reflect an exclusively subparallel shift of the palaeo-isohyets. During the Holocene Wadi Howar exclusively received local rainfall which fell in the north. Unlike Wadi Melik or Wadi Magrur, it was not an exotic river at least partly supported by rainier catchments in the south or at higher elevations, but rather an autochthonic drainage network in a presently extremely arid region, and therefore an excellent indicator of palaeoclimate.

A special problem is tracing the provenance of the pebbles, since at present there are no detailed petrographic maps of northern Sudan enabling us to localize the source area of the porphyry from site U 570 in the Wadi Howar catchment. Possible explanations and further implications will be discussed elsewhere (KRÖPELIN 1990b). Nevertheless, the presence of one 'exotic' pebble alone is sufficient evidence of supraregional fluvial long-distance transport within the Lower Wadi Howar, even if the accurate time of deposition is unknown. All fluvial transport seems to have taken place in stages, with parts of the bed load accumulating and being moved on by the next wadi flow, possibly caused by local rainfall restricted to certain wadi sections only. A long-distance transport of any sedimentary particle can therefore have taken a considerable span of time. Consequently, the Lower Wadi Howar during the Holocene can be characterized as a dry wadi with intermittent flow in both a temporal and spatial sense.

The fundamental difficulty of dating fluvial events has already been mentioned. However, periods of fluvial activity probably occurred throughout the early and mid-Holocene, and even the late Holocene. Indications of early Holocene fluvial processes are provided by the fact that pebbles often occur at the base of lake sediments or are encrusted with calcsinter dated to 7,825 ± 100 B.P. (PACHUR et al. 1987; KRÖPELIN 1990b).

Figure 12 gives an overview of the radiocarbon dates currently available from Lower Wadi Howar with their distribution between 9,300 and 2,075 B.P. Of course, the synchronous occurrence of individual sedimentary events of a fluvial or lacustrine nature cannot be inferred from these dates. In an order of magnitude of centuries, however, there is increasing evidence of a fully developed amphibian and savanna ecotope between 17° and 18° N during the entire early and mid-Holocene, during which parts of a large, now extremely arid region drained into the Nile via Lower Wadi Howar.

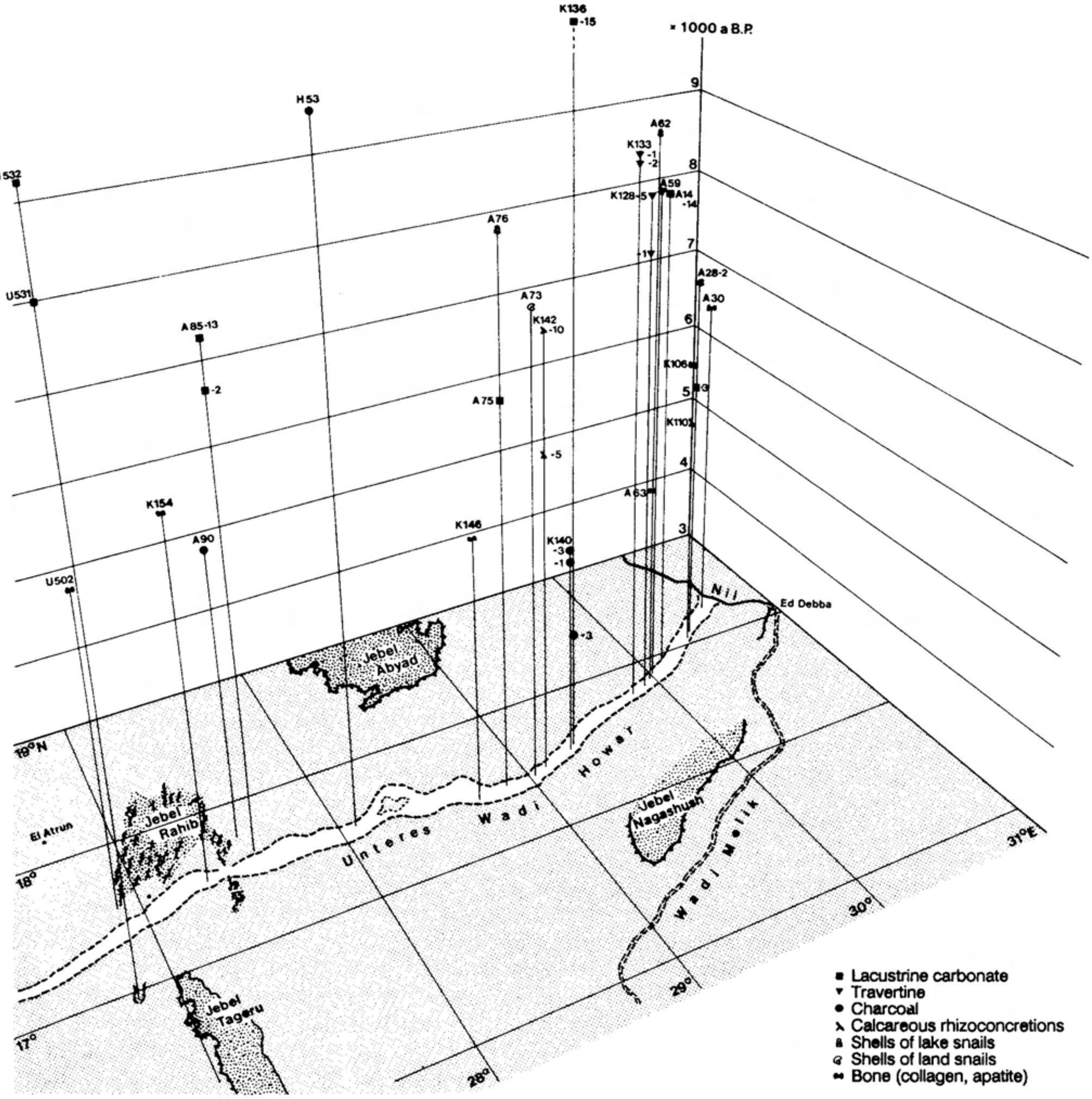


Fig. 12: Sites and ages in years B.P. of radiocarbon-dated materials from lower Wadi Howar. Vertical time-scale is isometric.

6. Rivers and lakes of the western Nubian basin (H.-J. Pachur & P. Hoelzmann)

6.1 Drainage patterns and lakes influenced by the Ennedi mountains

The Erg of Ennedi is the continuation of the Erg of Tageru to the north of Wadi Howar. Preliminary fieldwork has shown river valleys that crossed the erg up to about 18°25'. Further north-east they dissappear like the erg of Ennedi. Presumably they fed the groundwater in the depression which stretched as far as the Nukheila scarp. This basin has a catchment area of about 90,000 km² (Fig. 1). Its centre is an area of about 12,600 km², in which lacustrine sediments occur in extensive deposits and isolated outcrops. There are lake sediments at the northern end of the middle channel crossing the Erg of Ennedi about 15 km away from the northern edge of the erg. This stillwater zone belongs to a meandering drainage network with periodic to episodic discharge, where lacustrine sedimentation conditions prevailed only intermittently. The sandy carbonate mud, about 0.8 m thick and overlying bleached dune sand, contains molluscs and mammalian bone remains as well as numerous bones of the fish species *Lates niloticus* (up to 1.3 m long), *Clarias spec., Synodontis schall* and *Tetraodon fahaka* (det. DRIESCH, München); finds included *Crocodylus niloticus*, *Hippopotamus amphibius* and *Trionyx triunguis*, a lake turtle. At the former lake shore bones of *Redunca redunca*, some antilopes and a complete skull of a domesticated bovine (*Bos taurus*) were excavated (det. BOESSNECK, München). Another hippopotamus specimen was found 90 km south, in the channel of the southernmost wadi (Fig. 1). The lacustrine sedimentary environments developed along the SW-NE axis of the inner basin.

About sixty kilometres further north-east of the site described before limnic carbonates cover the area. These are 2.4 m thick limnites which are being shaped into yardangs by the prevailing NE trade winds. The structural characteristics of the sediment indicate changing water levels; temporarily the lake was dry and crack patterns formed in the calcareous muds. The cracks have been filled by detritus, i.e. compact fragments of lake chalk and a carbonate mud. The cracks were relatively wet and provided a refuge for *Clarias* (Plate 9, Fig. 1). In addition, bones of *Lates niloticus* and *Synodontis schall* were found as well as *Geocholone pardalis* and domesticated cattle (*Bos taurus*).

The water budget of these lakes was evidently dependent on the rise and fall of the groundwater table, indirectly recharged surface water from the above-mentioned rivers, and by local rainfall. Insoluble residue contains mainly diatom valves and quartz grains after 10 % HCl treatment (see Plate 9, Fig. 2), it shows > 26 % at the top and < 7 % at the base, as a result of overland flow or heavy fluvial discharge. The entire central basin contained a sometimes flooded, sometimes marshy amphibious landscape characterized by belts of reeds and rushes surrounding the shallow lakes. This reveals that there was no playa stage with sedimentation of silica muds.

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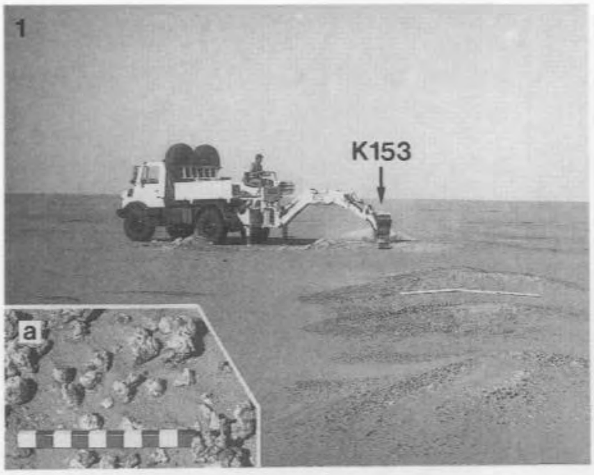
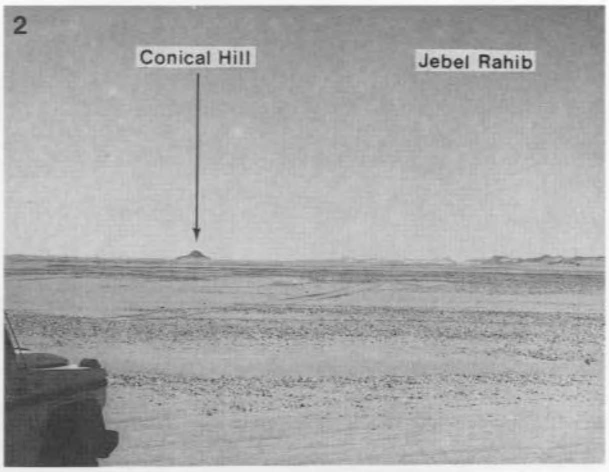




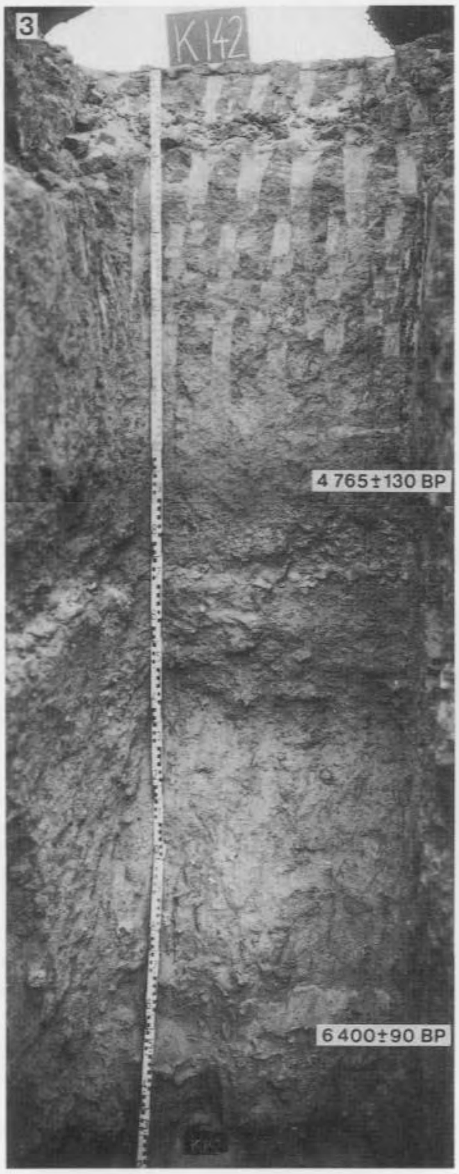


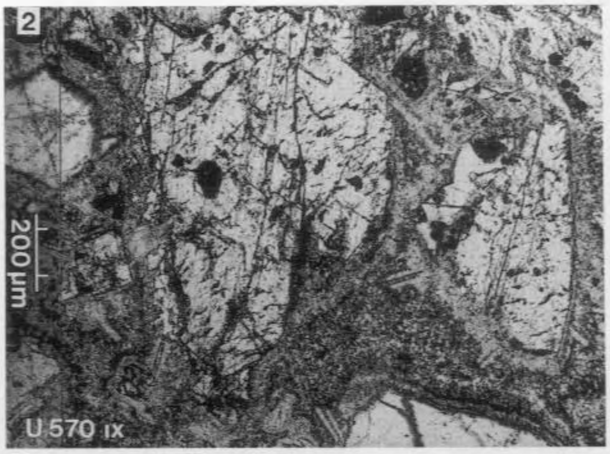
Fig. 1 Section K 153 in centre of former interior delta south of Gebel Rahib. Gravel bars of calcareous concretions. Inlet a) gives detail of such 'kankar' nodules; scale 10 cm.

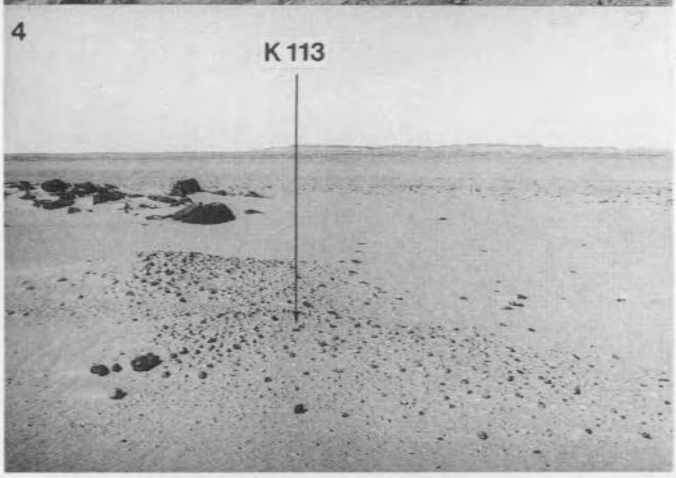
Fig. 2 Gravel beds and gravel-covered plains in the eastern foreland of Gebel Rahib 11 km north of Conical Hill.

Fig. 3 Photo mosaic of section K 142 showing positions of radiocarbon-dated rhizoconcretions and sandy-silty alluvial facies.

Fig. 4 Site K 142, situated 14 km ESE of three peaked hill (position 205/1), is typical of very wide spread dark-coloured potamogenic swamp deposits in the middle part of Lower Wadi Howar.

(Photographs: S. Kröpelin)





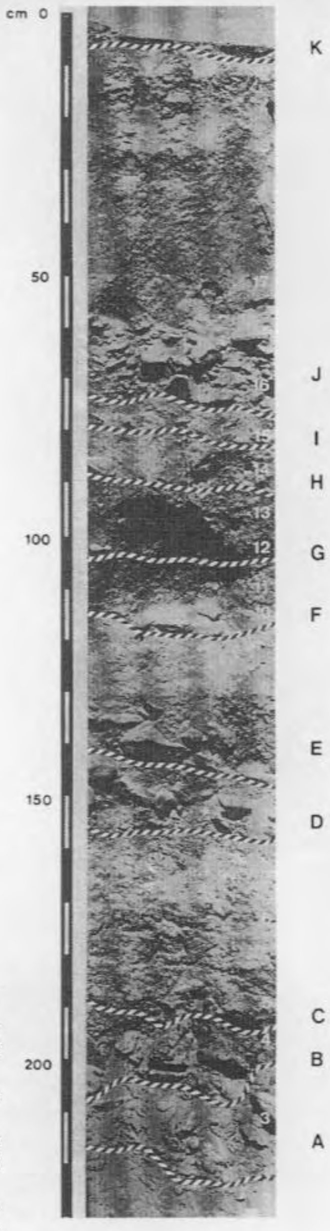


Fig. 1 Site of section U 570 at slope of 9 m high cobble terrace with a minimum age of 200 000 yrs B.P. (position 120/-5).

Fig. 2 Thin section of pebble from section U 570 showing alterated porphyry with idiomorphic sanidines in partly devitrified and recrystallized groundmass with flow texture. Such rhyolithic acid volcanic rocks do not occur in the entire region surrounding Lower Wadi Howar.

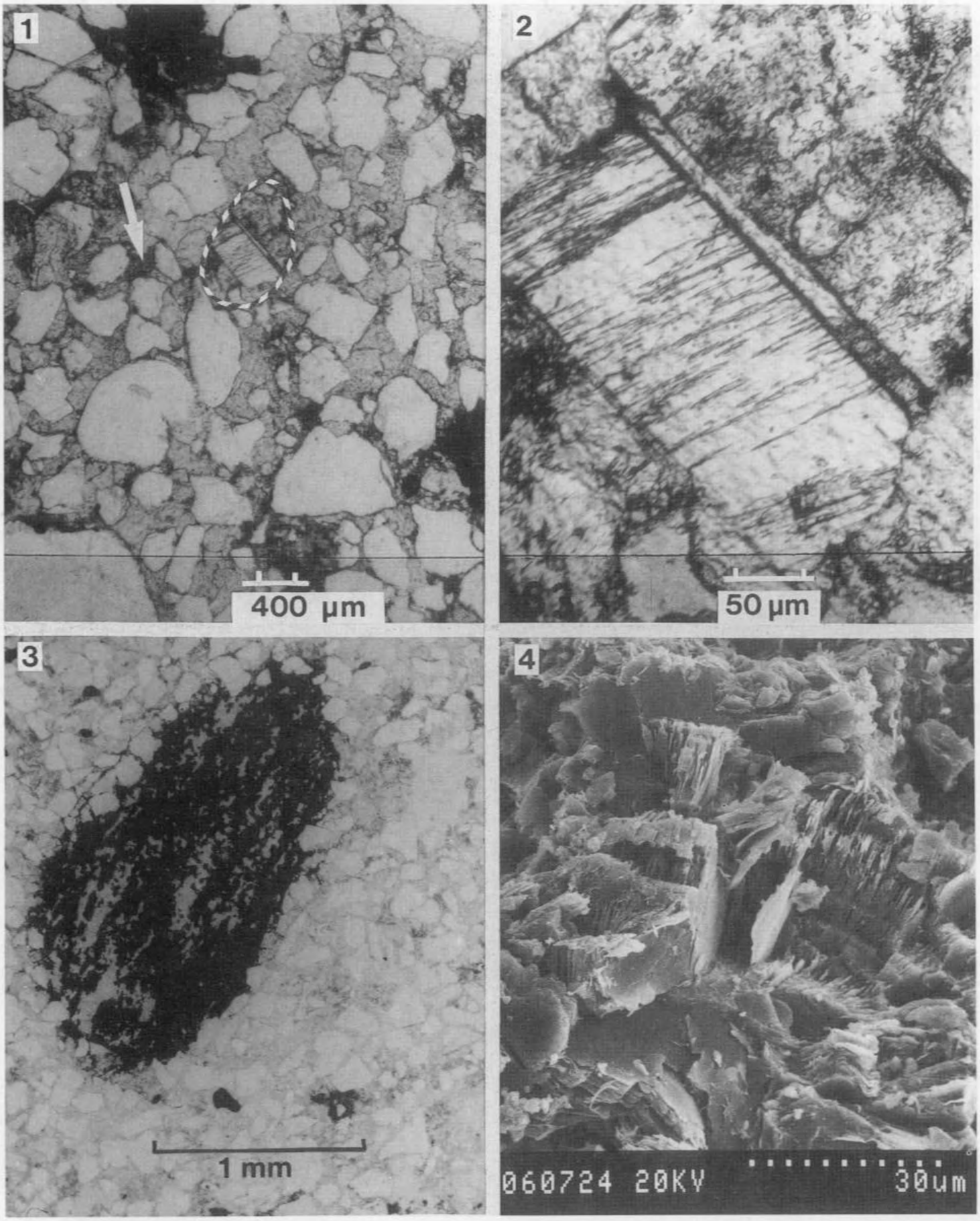
Fig. 3 Locality A 69 (position 122/0) showing redeposited cobble deposits on aeolian sands indicating high-velocity fluvial transport presumably as late as the Holocene.

Fig. 4 Gravel bank of site K 113 (position 50/-1) as example for wide-spread similar features along Lower Wadi Howar which due to facies interlocking with adjacent Holocene lake deposits and Neolithic sites are of early to mid-Holocene age.

Fig. 5 Photo mosaic of section K 113 displaying position and structure of subsurface gravel layers labeled A to K, and interlayering silty sands. Striped lines underline irregular lower boundaries of the seven coarse gravel layers due to bedload erosion.

(Photographs: S. Kröpelin)

Plate 7



Thin sections and SEM photo from samples of bank conglomerates of site A 24 (position 8/4).

Fig. 1 Subangular to rounded particles in micritic matrix. Striped line indicates sanidine-bearing rhyolithic component shown in Fig. 2. Arrow indicates kaolinization of matrix shown in Fig. 4.

Fig. 2 Detail of idiomorphic sanidine within rounded particle.

Fig. 3 Graphitic quartzite particle possibly originating from Gebel Rahib.

Fig. 4 SEM photo showing kaolinization features within the marly matrix. (Photographs: S. Kröpelin)

Plate 8

1 Mutela nilotica

2 Caelatura aegyptiaca

3 Corbicula fluminalis

4 Aspatharia rubens

5 Etheria elliptica

Bivalves from Lower Wadi Howar
Fig. 1: Site A 62 (position 100/0); Figs. 2, 3: Site A 14 (pos. 79/2); Fig. 4: Site A 28 (pos. 28/-3); Fig. 5: Site K 109 (pos. 50/-1). All scales in centimetres. (Photographs: S. Kröpelin, K. Wolfermann)