The morphogenetic aspects of the Neolithic site of Kadero

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Introduction

Field studies of the environmental aspects of the Neolithic site of Kadero were conducted during three expeditions: in 1999, 2001 and 2003. The scope of these were respectively: lithological studies of the Kadero site and its nearest surroundings; a geological transect from the river Nile through the Kadero site to the border of the Umm Ruwaba deposits and the thick weathering covers of the Nubian Sandstones, situated east of Kadero; and an extensive study of an area east of Kadero up to Ibrahim Kabbashi Jebels. In the performed studies, the principal method was the heavy minerals analysis. In the author's view, the content and composition of heavy minerals can be very helpful to the understanding of the environmental development of the studied area as well as the dominant role of the input of fluvial and/or denudational processes.

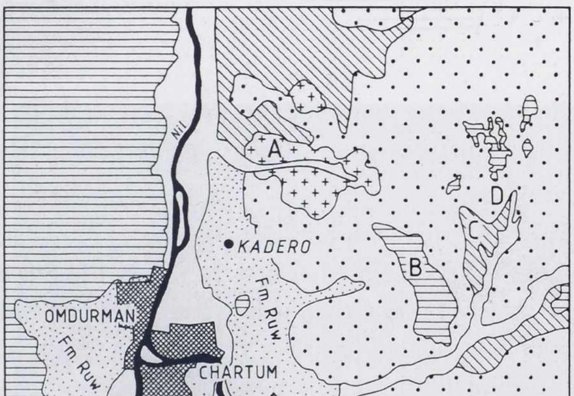


Fig. 1. The geology of the area around of the confluence of the White and Blue Nile (simplified from the map Robertson Res. 1988)
1-recent alluvium, 2-older alluvium, 3-Umm Ruwaba deposits, 4-weathering covers of varied thickness, often transformed by aeolian processes at the surface, 5-Nubian Sandstones Formation, 6-anorogenic granitic rocks of Jurassic age, 7-undifferentiated Proterosoic metamorphic rocks.
Jebels: A. Sileitat, B. Ibrahim Kabbashi, C. El Merikh, D. Mustor
Plains: Gezira - build of Gezira Formation, Butana – build of Umm Ruwaba Formation

The study of grain-size composition and heavy minerals was undertaken in cooperation with two students of geology taking their Masters' degrees at the Institute of Geology of the Adam Mickiewicz University: Abdelhai Abdelsawi 2001, Goliasz 2003 with supplementary data from 2004.

Geology and morphogenesis of the surroundings of Kadero

The geology and morphogenesis of the discussed area have not been investigated in detail yet. The background of this author's study were the papers: Adamson (1982), Vail (1982), Whiteman (1971), Williams & Adamson (1980), Williams (1982), Wickens (1982), Williams et al. (1982), Marcologno (1983), Krzyżaniak (1992a), as well as the geological maps: 1 : 1,000,000, sheet Khartoum (Robertson Res. Group 1988), and 1 : 100,000, sheet Khartoum.

Some results of the author's detailed geological and morphogenetic investigation have already been published (Stankowski 2003a & b). The present study supplements the earlier data with the results of the heavy minerals analyses and offers a further discussion of the paleoenvironmental development of the area in question.

The Butana Plain build of the Umm Ruwaba Formation, which stretches in a wide strip east of the Blue Nile and the Nile proper (Fig. 1 & 2), is built of deposits of Cenozoic gravel, sand, silt and clay. These deposits, which also constitute the geological material of the Kadero site (Krzyżaniak 1992), are considered to originate from overflows/floods of the Nile, which continued into the times of the Neolithic settlement.

On the eastern outskirts of Ruwaba, there spreads the Nubian Sandstone Formation, a large area of gravel deposits cover the severely weathered sandstone of the Cretaceous and the oldest Paleogene (cf. Phot. 1-4). The gravel covers disappear very gradually under the deposits of the Ruwaba series. East of the Kadero site, the area of their occurrence coincides with the principal, meridional irrigation canal, running from the lower section of the river Soba. In the inner parts of the gravel series, outcrops of Nubian sandstone appear, which constitute residual hills and mountains ("Jebels"), barely noticeable in the relief. Further to the east, enclaves of undifferentiated Proterozoic metamorphic rock emerge from under the cover of the Nubian Sandstone Formation. The same rock forms the northern border of a series of gravel detritus and Ruwaba deposits, featuring a small area of magma rock called Jebel Sileitat (anorogenic granitic rocks of Jurassic age: ring complexes – cf. Phot. 7).

The deposits of the Ruwaba series are made of structureless, usually very dense/compact silty sands and silts with occasional packs of sand (cf. phot. 9, 10). The further east one goes, the more the material is enriched with gravel fractions and carbonate matter (cf. Phot.1, 3, 4). The content of carbonate in the Ruwaba deposits varies from <5% to ~21%. Among these predominantly structureless deposits, one notices linear structures of fairly thick sand filling small fossil valleys whose locations has not been exactly established yet. The available data suggest that these valleys run from the east to the west and from the south-east to the north-west.

At a depth of several meters (usually 3–5 m), there appears a fairly continuous layer of loess-like deposit, which constitutes a lithological, and probably also paleoclimatic, caesura.

The western border of the Ruwaba series is a narrow strip of characteristic Nile deposits very well seen in the Nile river cut (cf. Phot. 11, 12). These fill a deep crevice (of a depth of up to 10 m),

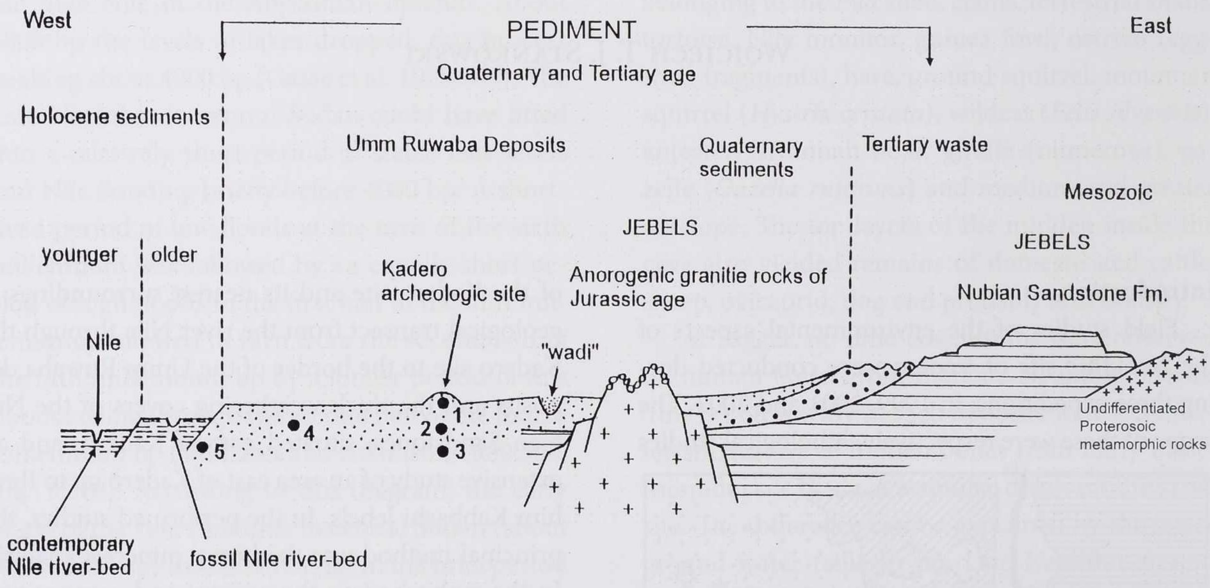
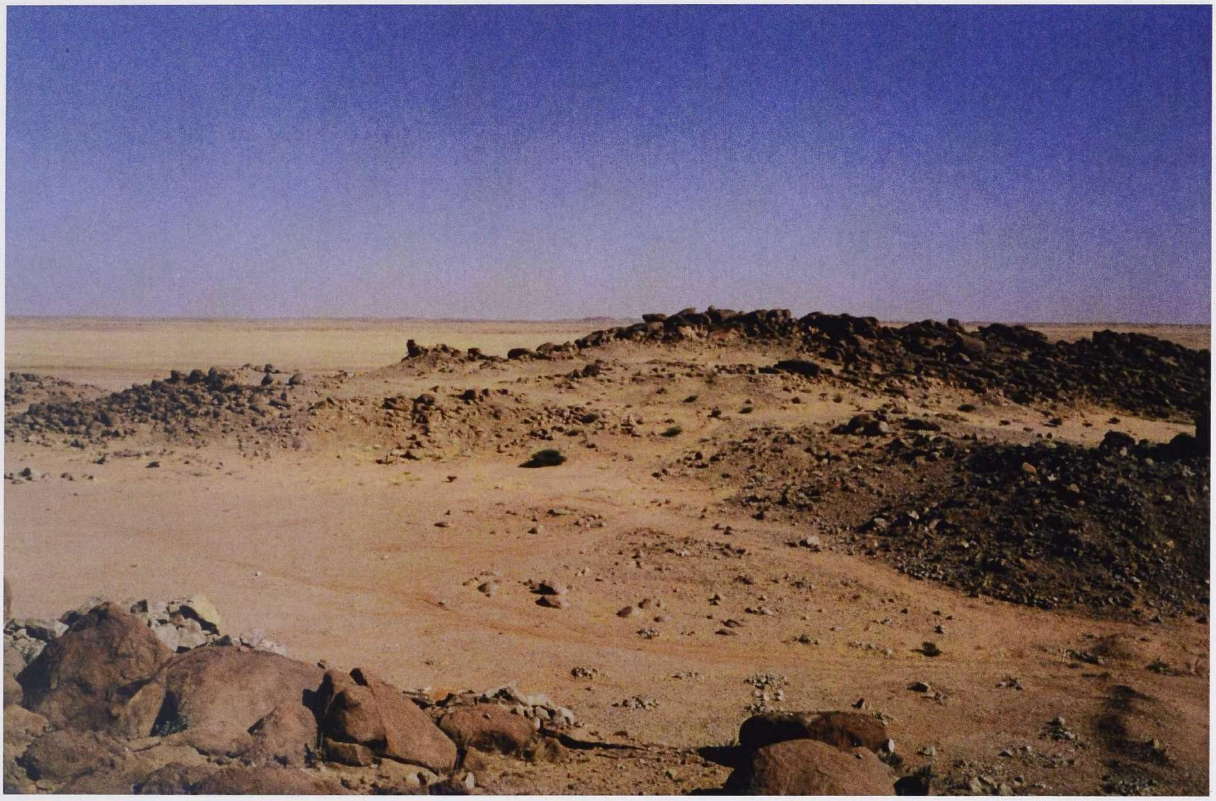


Fig. 2. Schematic cross section of Butana Plain in the area of Kadero with the position of the luminescence samples

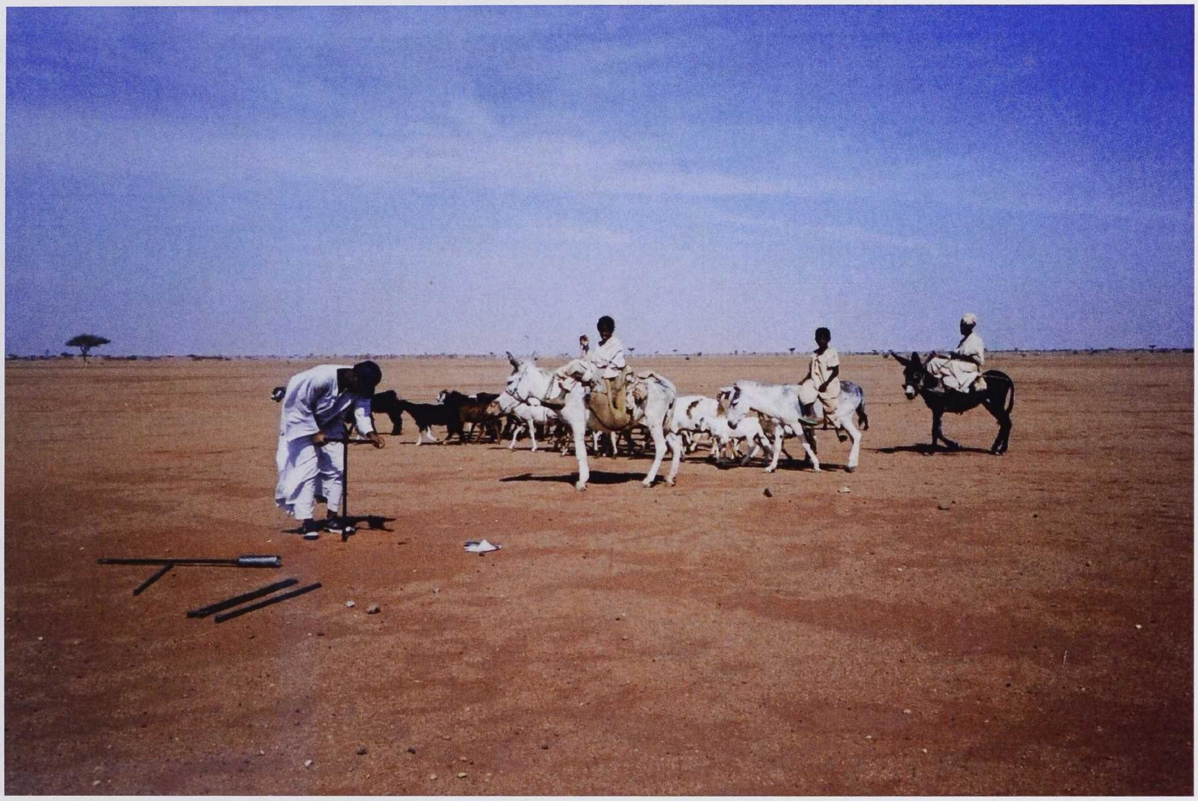


Phot. 1. Morphology and sediments of the area east of the Ruwaba Formation. Nubian Sandstone at the base

Phot. 2. Ruwaba Formation - samples of conglomerates (a), carbonate rocks (b), petrified woods (c)

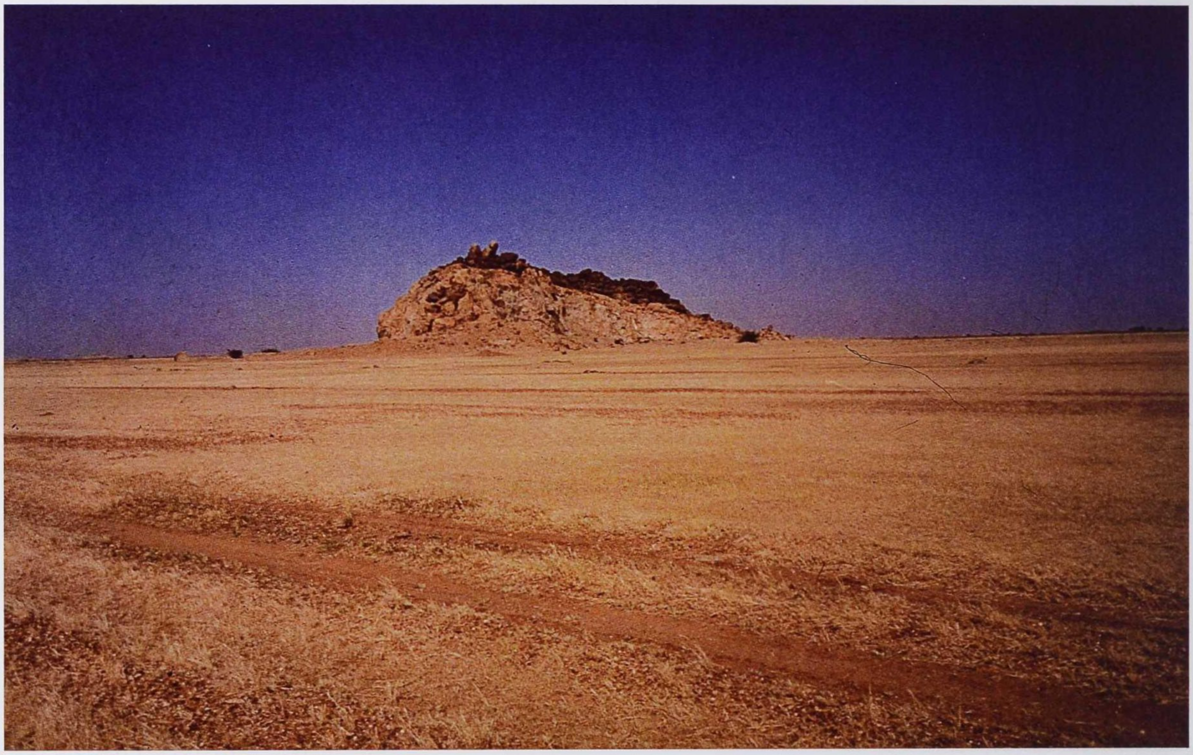
Phot. 3. Morphology and sediments of the area east of the Ruwaba Formation - gravel and cobles surfaces, wind blown fine material. Nubian sandstones at the base

Phot. 4. Morphology and sediments of the area east of the Ruwaba Formation - silty-sandy-gravelly sediments with the carbonate fragments. Nubian sandstones at the base



Phot. 5. Surface of the Butana plain, view from the east of Kadero site to Jebel Sileitat

Phot. 6. North-East surrounding of Kadero site – silty-sandy-gravelly sediments building this part of the Ruwaba Formation



Phot. 7. The surface of the Butana plains, view from the North of Kadero site to Jebel Sileitat

Phot. 8. Kadero site surface

Phot. 9. Kadero site - tipe of sediments builging the Ruwaba formation

Phot. 10. Sediments of Ruwaba formation at the Kadero site. Prof. Lech Krzyżaniak working

Phot. 11. Cultivated surface of Nile deposits

Phot. 12. The Nile river eastern bank

Tab. 1. Mean values of grain-size composition – in two groups: gravelly-sandy and silty-clayly. Together 105 samples

Sediments group	Fractions in %		Samples quantity
	Gravely-sandy	Silty-clayly	
Nile sediments			
a) horizontally stratified, flood type; mainly fine grained	45,3	44,7	6
b) small and medium fossil andsuperficial channels; sands with addition of fine gravels	93,4	6,6	4
Ruwaba formation			
a) main type pediment deposits; sands with addition of-gravels	91,2	8,8	51
b) fossil valleys deposits; mainly sands with addition of gravels	96,8	3,2	18
c) "less like" sediments; silty-sandy deposits	60,9	39,1	7
Nubian sandstones weathering cover sediments; different grained gravels and layers of sandy-silty materials	95,4	4,6	14

Tab. 2. Luminescence dating of samples from Ruwaba formation (OSL/TL)

Sample number	Depth in cm	Age (ka)
1	145	19,7±2,3 (GdTL-625)
2	430	22,7±1,4 (GdTL-705)
3	700	14,88±0,64 (GdTL-706)
4	185	13,34±0,76 (GdTL-707)
5	440	11,10±0,48 (GdTL-708)

on the bottom of which sandstone of the Nubian Sandstone Formation is exposed. Within these Nile deposits, one may distinguish two series of silt developed in two cycles and separated by a phase of erosion.

Tab. 1 lists the average indices of the grain-size distribution in the deposits around the Kadero site. This data confirms the previously described structure of the deposits in this area. Further information, illustrating the chronology of the morphogenetic phenomena in this area, has been provided by luminescence measurements (Tab. 2). Among the five obtained dates, three (Nos. 3–5) seem complementary and demonstrate that as early as at the end of the late glacial, the surface of the pediment had its present lithological form. It would be difficult to prove that the deposits constituting the roof of the Kadero hill are older. An inversion of the dates confirms that the studied area originates from the Pleistocene.

According to the data collected by the author, the archeological site of Kadero is located on a vast pediment, which at the time of the Neolithic community was outside the range of the overflows of the Nile. On the surface of the pediment Nile silts were not found anywhere.

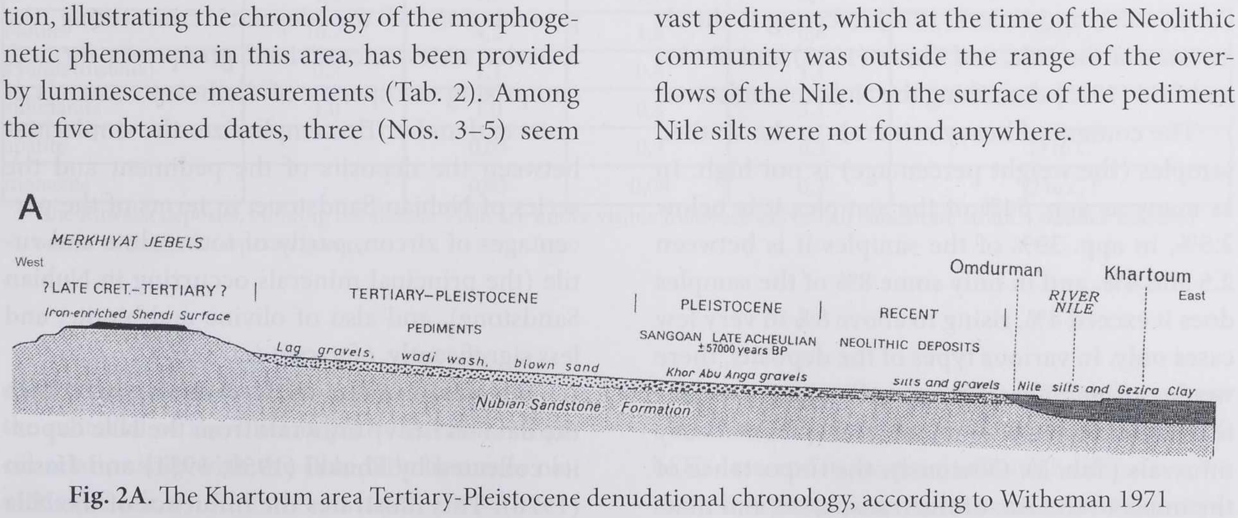


Fig. 2A. The Khartoum area Tertiary-Pleistocene denudational chronology, according to Witheman 1971

Tab. 3. The mean percentage values of heavy minerals in the cross section through Butana sediments from the Nile to weathered Nubian sandstones – Nontransparent/opaque (45), transparent (45)

Sediment groups						
Nile a	Loess like sediments b	Pediment fossil vall. c	Pediment mass sed. d	Kadero total e	Pediment E edge f	Sandstone waste g
72 **28**	78 **22**	67 **33**	63 **37**	52 **48**	71 **29**	85 **15**

The results of the analyses and the author's interpretation differ from Whiteman's earlier conclusions (1971 – cf. Fig. 2A). He interpreted the age of the individual segments of the pediment morphogenesis of Central Sudan, as exemplified by the eastern bank of the Nile in the area of Omdurman, as follows: (a) the farther away from the denudation base, the older they are; (b) the range of the overflows of the Nile was very large and amounted to many kilometers (cf. Fig. 2A). The present author interpretation is given on Fig. 2.

Heavy minerals as an indication of the origin of the Umm Ruwaba Formation

In order to determine the origin of the deposits constituting the material of the Ruwaba deposits, a study of the spectrum of heavy minerals was conducted. Its purpose was to establish the extent of the influence of both the Nile and the degradation of the Nubian Sandstone on the composition of heavy minerals. The analyses covered 107 samples collected from various groups of deposits during three seasons of exploration. The results of this study were compared with the data of Shukri (1950, 1951) and Hasan (1976) referring to the alluviums of the Nile, and Omer (1983) and Shukri and Said (1945) describing the Nubian sandstone.

The content of heavy minerals in the studied samples (the weight percentage) is not high. In as many as app. 54% of the samples it is below 2.5%, in app. 39% of the samples it is between 2.5 and 4%, and in only some 8% of the samples does it exceed 4%, rising to above 8% in very few cases only. In various types of the deposits, there were considerable differences between the content of transparent and non-transparent heavy minerals (Tab. 3). Obviously, the importance of the index of the size of the transparent and non-transparent fractions must not be either overestimated or ignored. These data reveal significant differences between the Nile deposits and those of the Nubian sandstone. The deposits of the pediment, including those of the Kadero site, are noticeably enriched with material originating from the Nubian Sandstone.

The results of the study of transparent heavy minerals are listed in Tables 4 & 5. The spectras of the composition of the heavy minerals of the Nile deposits (a) visibly differ from those of the detritus of the Nubian Sandstone (f, g). The series of the loess-like deposit (b) is more similar to the Nile deposits, although it contains markedly less pyroxene, rutile and biotite, and a less conspicuously lower proportion of staurolite and garnet. The loess-like deposit also features a small percentage of apatite and monazite, which also occur in the detritus of the Nubian Sandstones. Conversely, the composition of heavy minerals in the rock of the surface layer of the pediment, including the Kadero site (d, e), and to a smaller degree the fossil fluvial deposit (c), clearly resembles the Nubian sandstone. In order to offer a synthetic presentation of the deposits constituting the Ruwaba series, a combined group was formed, comprising the spectra of the heavy minerals of units c, d and e. This emphasizes the similarities between the deposits of the pediment and the series of Nubian Sandstone, in terms of the percentages of zircon, partly of tourmaline and rutile (the principal minerals occurring in Nubian Sandstone), and also of olivine and biotite, and less significantly, of garnet (cf. Tab. 4).

The results of this study were compared with the data on heavy minerals from the Nile deposits collected by Shukri (1950, 1951) and Hasan (1976). This illustrates the influence of the Nile

Tab. 4. Mean percentage values of transparent heavy minerals in the sediments groups (a-g like in tab.3) in the cross section trough Butana sediments, from Nile to weathered Nubian Sandstone

Mineral	Sediments groups like in tab.3						
	a	b	c	d	e	f	g
amphobole	53,5	69,6	59,4	64,2	61,3	27,6	9,0
epidote	13,7	12,3	17,0	15,2	5,2	12,8	0,1
pyroxene	9,1	5,6	6,8	7,6	5,3	18,5	11,7
zircon	1,5	1,3	4,9	4,9	11,9	17,6	52,9
tourmaline	0,4	0,1	1,0	0,6	1,2	1,3	1,9
rutile	4,8	1,6	0,7	1,1	3,2	7,0	12,8
staurolite	1,8	0,7	0,9	0,3	1,9	3,1	4,0
garnet	1,2	0,4	1,8	1,3	4,2	2,0	1,5
olivine	1,8	1,9	4,2	1,8	2,2	2,6	3,3
biotite	10,7	4,1	2,1	1,7	1,6	0,7	0,6
kyanite (distene)	0,7	1,1	0,4	0,4	0,9	1,3	0,9
apatite	-	0,03	0,1	0,4	0,4	-	0,6
monazite	-	0,03	0,2	0,04	-	0,1	0,2

Tab. 5. The mean percentage values of heavy minerals in the basik groups of sediments: A) Holocene Nile silts, B) "loess like" deposits, C) Butana plain deposits (sediments groups b, c, d, e), D) weathered Nubian sandstones and very eastern edge of Umm Ruwaba deposits. The relationships in between the groups of sediments.

Mineral	Group of sediments				Groups relationship (visible influence)
	A	B	C	D	
amphibole	53,5	69,6	61,6	18,3	A to B, C; D to B, C ?
epidote	13,7	12,3	12,4	6,4	A to B, C
pyroxene	9,1	5,6	6,6	15,1	
zircon	1,5	1,3	7,2	35,6	D to C
tourmaline	0,4	0,1	0,9	1,6	D to C
rutile	4,6	1,6	1,7	9,9	
staurolite	1,8	0,7	3,0	3,6	D to C
garnet	1,2	0,4	1,2	1,7	
olivine	1,8	1,9	2,7	2,9	D to C
biotite	10,7	4,2	1,8	0,6	D to C
kyanite(distene)	0,7	1,1	0,8	1,1	
sillimanite	1,0	1.0	0,4	3,1	
apatite	-	0,03	0,3	0,3	D to C
monazite	-	0,03	0,08	0,2	D to C ?

The Ruwaba deposits, building the Butana Plain are under visible influence of Nubian Sandstone strata. Loes like material seems to create the separate group.

on the composition of the Ruwaba series, or on the material of the Butana plain. A mineralogical relationship with the Blue Nile becomes obvious (cf. tab. 6).

Accordingly, the heavy minerals analysis demonstrates that the Butana plain including the hill of Kadero and its material of Ruwaba deposits owe their morphogenesis to processes of the emer-

Tab. 6. Spectrums of selected heavy minerals in Nile river, Atbara river (after Shukri 1950, 1951) and Kadero site with surroundings (after author data).

Mineral	River Nile sections			Atbara river*	Kadero
	White Nile	Blue Nile	Main Nile		
Amphibole	48	65	68	10	55
Epidote	37	13	15		28
Garnet	7	3	3		3
Silimanite	8				1
Pyroxene		19	14	83	11
Olivine				7	2

*Atbara – right side Nile tributary, flowing/operating on the Nubian sandstones and Palaeozoic, partly Proterozoic rocks, covered by thick weathering sediments of Ruwaba Formation

gence of pediments, while the influence of the fluvial phenomena of the Blue Nile is less apparent.

Discussion and conclusions

The very thick Nubian Sandstone Formation, which dates to the late Mesozoic and the early Cenozoic and covers a vast territory, has undergone extensive denudational developments, which in many locations have entirely obliterated these rocks. The elevating movements in this part of Africa were conductive to the emergence of flat surfaces related to the local bases of denudation and erosion. The basin of the Sudd and the region of the VI cataract of the Nile were the most significant for the studied area. Due to climatic fluctuations, the water level in the Sudd varied, which also affected the extent of the sedimentation. The White Nile, which for a long time ended in the southern part of the basin, did not play a major role in the development of the area north of Khartoum. In the northern part of the basin of the Sudd, the decisive factor was the impact of the Ethiopian arm of the Blue Nile: not only did it reach the present base of erosion, but also apparently bifurcated toward the north-west, e.g. from the area of Soba to Faki Hasim, and subsequently flowed to the region of the VI cataract of the Nile. Until the river eventually broke northward, which apparently happened at the turn of the Pleistocene into the Holocene, the region of the cataract blocked the running off of water from the extensive area of the Sudd.

The pediments emerging north of Khartoum, on both banks of the present Nile, obliterated the sequences of Nubian Sandstone Formation. In this author's view, Whiteman's morphogenetic conception (1971, cf. Fig. 2 A) is unacceptable. The pediment was continually developing, through Cenozoic time. Its surface was/is increasing and modeling under the influence of climate changes. Fig. 3 shows an present author synthetic geological profile, including the locations of the dated luminescence samples.

The period of the most important emergence of pediments started probably as early as in the Paleogene and continued into the Neogene and most of the Pleistocene. The present surface with a network of numerous small valleys, as well as the upper segments of the deposits (with fossil traces of the fluvial relief), were shaped during the last stage of the cold Pleistocene and in the late glacial, as the acquired luminescent data confirm. The climatic fluctuations of that time are in evidence through the structural and lithological diversity, and by the caesura of the layer of loess-like deposit and the sequence of silt above it. This was produced by the gravitational dislocation of masses of material, solifluctional processes and fluvial phenomena - valleys having springs on the area of degraded Nubian Sandstone and material transported over large distances by the Blue Nile). Testimony of this are spectra of heavy minerals, whose composition is similar to that of the Nubian Sandstone and the alluviums of the Blue Nile.

At the turn of the Pleistocene into the Holocene, as a deep erosional cut developed in the present axis of the Nile proper, water ran off from the basin of the Sudd to the north. In the Holocene, the ero-

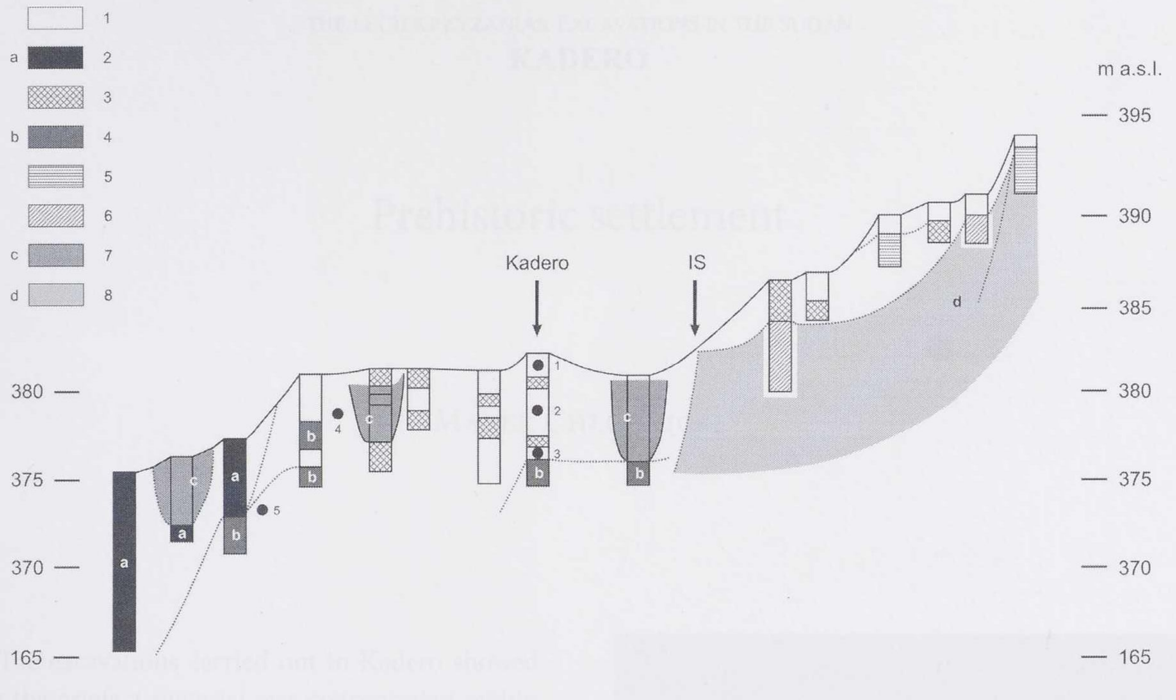


Fig. 3. Synthetic cross section of studied area. The main types of sediments, fossil valleys and position of the luminescence dating samples
1.sandy-silty sediments, 2.young Nile deposits , 3.carbonate muddy deposits, 4."loess-like" deposits, 5.coarse gravels with fine grained layers, 6.carbonate coarse grained deposits, 7.fossil valleys deposits, 8.Nubian Sandstones, IS. main irrigation canal,

sive cut was filled with Nile deposits, in two cycles separated by phenomena of erosion.

The studied section of the Butana plain, whose material are Ruwaba deposits, developed long before the time of the Neolithic community. Geological data attest that since the appearance of the erosional cut in the axis of the Nile proper (at the turn of the Pleistocene into the Holocene), the extensive and almost flat area east of the river, whose minor feature is the hill with the Neolithic site of Kadero, was not affected by the overflows of the Nile, as nowhere in it have recent Nile deposits been encountered.

The Neolithic colonization of Central Sudan was principally due to the immediate closeness of the river (Krzyżaniak 1992). Nevertheless, there were also settlements far away from the Nile. One of these was Kadero; we also know of other sites of the Khartoum Neolithic: Zahiab, Um Direiva, and the very inland site of Hatab. The Neolithic Kadero 1 and 2 communities used small hills on the surface of the pediment, near small valleys which were tributaries of the Nile. Favorable conditions continued for a long time, during a period of more humid climate in the first part of the Holocene until app. 5000 years B.P. The Neolithic communities were able to take advantage of this.

Acknowledgment

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