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• *Old Kingdom – Memphite region – Landscape evolution*

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Analysis of Past and Present Landscapes Surrounding the Necropolis of Dahshur

Analyse der vergangenen und rezenten Landschaft im Umland der Nekropole von Dahschur

With 9 Figures and 12 Tables

The landscape evolution of the area surrounding the necropolis of Dahshur (Egypt) is analysed on the basis of geomorphological investigations and the integration of late Holocene sediment characteristics. Knowledge of the ancient landscape and palaeoenvironmental conditions allows a better understanding of spatial relationships between monuments and landscape. From altogether 41 sondages conducted mainly by archaeologists of the German Archaeological Institute (DAI), we selected eight sondages along three transects and one single sondage. Furthermore, the results of geomorphometrical analysis will be presented. The chosen sondages are characteristic of the typical landscape units of the study area: floodplain of the river Nile, limestone escarpment of the Western Desert and the desert margins east of the escarpment scarp. The geomorphology and channel geometry were also analysed. The results show that different processes influenced the relief of the study area. From the late Old Kingdom onwards, aeolian dynamics levelled the landscape mainly in the channel beds and in the desert margin east of the escarpment scarp. Human activities such as mining in the period of the Old Kingdom also shaped the relief. Depressions situated in a semicircular form around the Bent Pyramid are interpreted as quarries and give evidence of this activity.

1. Introduction

The necropolis of Dahshur (Egypt) is located approximately 30 km south of Cairo (*Fig. 1*). The necropolis belongs to the extensive burial fields of the Memphite region, all constructed during the Old and Middle Kingdoms. The monuments of the necropolis are located on the Egyptian Limestone Plateau, close to the floodplain of the river Nile.

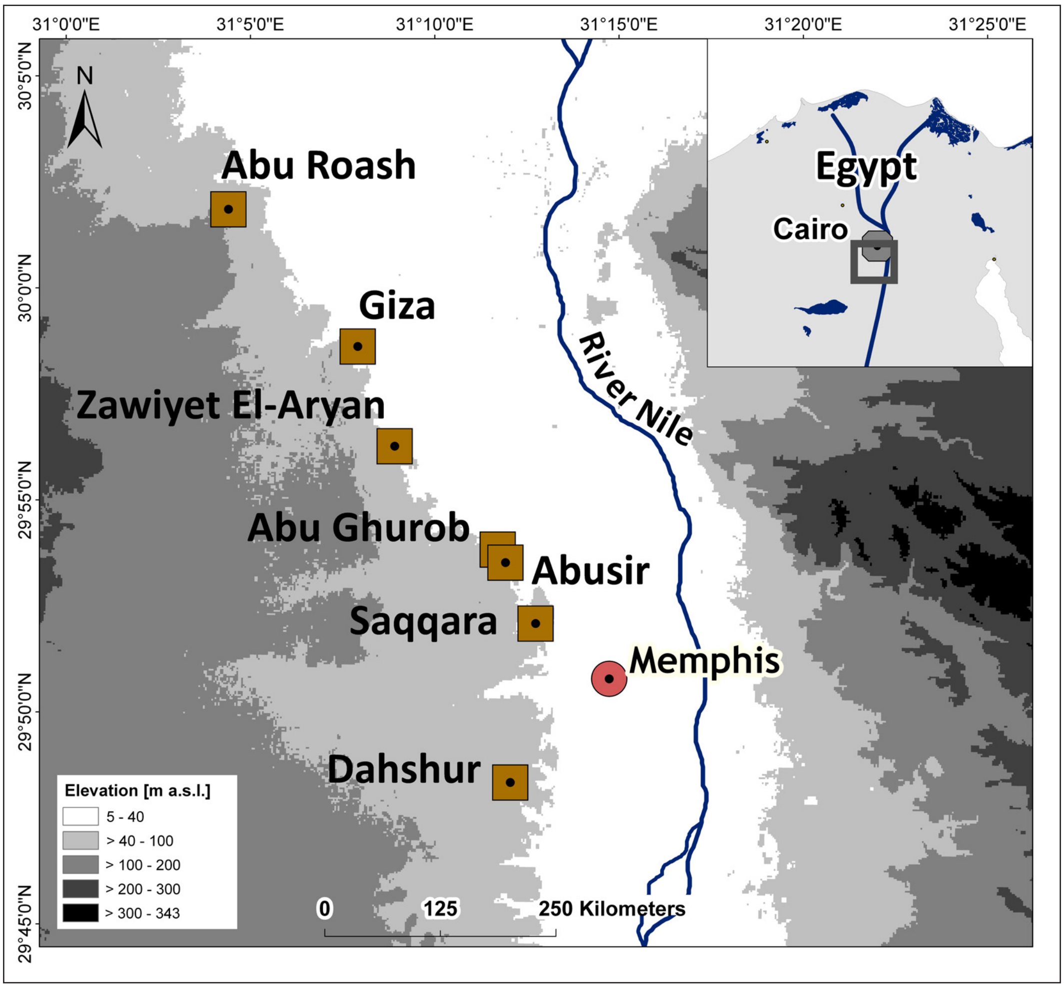


Fig. 1 Overview of the Memphite necropolises south of Cairo. Coordinate system: WGS 1984 (map source: Shuttle Radar Topography Mission, http://edc.usgs.gov/srtm/) / *Übersicht der memphitischen Nekropolen südlich von Kairo*

The cultural significance of the necropolis of Dahshur made it an integral part of numerous scientific expeditions. Archaeological research started during the 19th century (*Perring* 1838, *Lepsius* 1849-1859, *de Morgan* 1895) and continued throughout the first half of the 20th century (*Jéquier* 1925, *Varille* 1947, *Fakhry* 1951). From the 1950s until today Dahshur has been used as a military area. Scientific research has however been possible since the German Archaeological Institute (DAI) obtained a site concession in the 1970s and subsequently published results of several excavations (*Arnold* and *Stadelmann* 1975, 1977, 1997, *Arnold* 1980, 1982, 1987, *Stadelmann* et al. 1993, *Alexanian* and *Seidlmayer* 2000, 2002a, 2002b).

Until today, only little palaeoenvironmental research has been done in the valley of the river Nile and the adjacent areas of the Western and Eastern Deserts in the wider vicinity of Cairo. Such research is primarily limited to the region of the Faiyum depression located 50 km southwest of the study area. A special focus was set on the investigation of lake level changes of Lake Qarun. This saline inland lake – 40 km in length, 5.7 km in width and 43 m below sea level – represents the deepest part of the Faiyum depression. The Faiyum is supplied with fresh water by Nile floodwater via the Bahr Yousef canal. *Hassan* (1986) combined sedimentological, archaeological and historical data for the reconstruction of lake level changes. His results point to high lake levels during Palaeolithic (8.3-7.1 ky BP) and Neolithic times (6.2-5.1 ky BP). In the Nagada period (5.1-4.1 ky BP), lake levels were most likely low, followed by a period with high levels which lasted until 3.9 ky BP. The following decrease, which lasted until 3.6 ky BP, was correlated by *Hassan* (1986) with the decline of the Old Kingdom. More recent studies are based on the analysis of biological proxies from Lake Qarun (e.g. *Flower* et al., 2006, *Keatings* et al. 2007). *Baioumy* et al. (2010) present a sedimentological, mineralogical and geochemical approach to analyse lake level changes. The aim of the present study was to link their results with mid-Holocene climatic changes such as the shift of the Intertropical Convergence Zone (ICZ) after *Jung* et al. (2004) and the arid period in East Africa (partly the headwater area of the river Nile) due to the Indian monsoon according to *Russell* and *Johnson* (2005).

The landscape development of the northern neighbouring necropolis of Saqqara and the Old Kingdom's capital Memphis was investigated in the context of archaeological research by *Jeffreys* (1985). Results show that during the mid-Holocene the course of the river Nile ran close to Memphis, the capital of the Old Kingdom. Today the Nile runs 3 km east of the ancient capital of Memphis. *Butzer* (1976) described a predominantly eastward migration of the river Nile since Hellenistic times. During *Napoleon's* expedition to Egypt in 1798-1801, oxbow lakes and partly flooded sinks occurred in the Nile floodplain between Giza and Dahshur (*Said* 1993, *Lehner* 1997). During his 1842-1845 expedition, *Lepsius* (1849-1859) mapped a lake southeast of the pyramid plateau of the necropolis of Abusir. Today, only the oxbow lake west of Dahshur village, Lake Dahshur, is still visible in the landscape.

Little is known about the landscape history of the necropolis of Dahshur and about the possible interaction between the monument and the landscape (*Alexanian* and *Seidlmayer* 2000). Field surveys by the DAI indicate that ancient settlements are presently covered by as much as 7 m of alluvial and aeolian deposits (*Alexanian* et al. 2008). Since 2000 the DAI has conducted several hand auger sondages in the area of the necropolis of Dahshur, along the margin of the Nile floodplain and in the channel beds. Since 2008 these investigations have been systematically conducted by a joint project of the German Archaeological Institute (DAI) and the Physical Geography section of Freie Universität Berlin. Initial results show that the relief surrounding the necropolis has been modified by natural processes, human action and human-induced processes since the period of the Old Kingdom (*Alexanian* et al. 2008).

The overall aim of the geoarchaeological project is to reconstruct the ancient landscape with its monuments and to enhance the archaeological understanding of the spatial relationships between monuments and landscape (*Alexanian* and *Seidlmayer* 2000). The aim of this paper is to analyse the landscape evolution of the surroundings of the necropolis of Dahshur since the Old Kingdom (4,632-4,095 BP, after *Beckerath* 1997). In doing so, the paper gives a systematic overview of the present-day landscape characteristics and then sums up the landscape development of the area. As part of this research, the natural site characteristics of the necropolis are analysed. A major focus is set on the availability of natural resources and the accessibility of the pyramid plateau. Analysis is based on a geomorphological investigation of the area and the integration of late Holocene sediment characteristics known from the sondages carried out by the DAI since 2000.

2. Historical Overview of the Study Area

Construction of the necropolis of Dahshur began in the 4th dynasty of the Old Kingdom of Ancient Egypt (4564-4429 BP, after *Beckerath* 1997). After the formation of the nation within the Proto-Dynastic Period and its subsequent unification within the Early Dynastic Period, the necropolis of Dahshur was constructed at a time of economic and cultural prosperity. During the reign of King *Snefru* the pyramids were erected deep in the desert area (*Kemp* 1993). The burial field of the 3rd Dynasty, Saqqara, is located close to the ancient capital of Memphis. By choosing Dahshur as the location for his necropolis, King *Snefru* extended the Memphite cemeteries to the south (*Alexanian* and *Seidlmayer* 2000). The architectural structures that have dominated the appearance of the necropolis until today are the Bent Pyramid and the Red Pyramid. During the Middle Kingdom, the second period of increased construction activity occurred during the 12th Dynasty and subsequently during the Second Intermediate Period. Within that time, at least seven pyramid complexes were constructed at the necropolis of Dahshur. Today the pyramids of the Middle Kingdom are mostly damaged. The best visible ruin of the Middle Kingdom is the Pyramid of *Amenemhat* III (Middle Kingdom), located east of the Bent Pyramid. In addition, several private burial sites can be associated with this period. In contrast to the kings of the Old Kingdom, the kings of the Middle Kingdom preferred sites close to the Nile floodplain when choosing a suitable location for their pyramids. Although there are several indications of younger occupation within Dahshur, the beginning of the New Kingdom is attended by a significant decrease in the importance of the necropolis (*Jéquier* 1933).

3. Ancient Monuments and Building Materials

The geology of the study area mainly consists of Pliocene and Eocene sandstone and limestone. These formations are repeatedly intercalated with fossil banks (oysters and nummulites) and by shale or sandy shale. Fluvial sediments (mainly well-rounded pebbles and coarse sand) belonging to a former river system – the so-called Protonile (Q1) which occupied the present-day Nile basin in the early Pleistocene – built a relict river terrace at the western margin of the study area. In the middle Pleistocene the Pronile, also a predecessor of the present-day Nile, deposited fluvial sediments (Q2) east of the Q1 deposits, closer to the present-day floodplain of the river Nile. These sediments (Q1 and Q2) were deposited directly on top of the Eocene bedrock (*Said* 1981). The fault system of Egypt was laid out in Mesozoic times. During that time Egypt comprised two main structural units: a) an unstable shelf to the north with NE-SW transcurrent faults and fault-bounded basins, and b) a stable shelf in the south mostly covered with Palaeozoic and Mesozoic continental deposits (*Schlüter* 2006). The study area belongs to the former region of the unstable shelf as the main direction of the faults in *Figure 2* reveals.

The pyramids were constructed using two main building materials: The core material of the pyramids between Abu Roash and Meidum was mined in the direct vicinity of the respective pyramid location, irrespective of the quality of the material (*Klemm* and *Klemm* 2008). By contrast, the casing material consists of a high-quality white limestone which originates from the eastern bank of the river Nile between Gebel Mokkatam and Helwan (*Fig. 2*). Thus, the availability of building material was an important factor for the choice of the setting. *Klemm* and *Klemm* (2008) assume that the ancient architects conducted feasibility studies of potential pyramid locations to check the stability of the underground and the availability of suitable building material for the core of the monuments. Furthermore, infrastructural factors such as accessibility to the Nile floodplain and facility of transporting allochthonous building material were evaluated before an area was chosen. To reduce the amount of earth works or mining activity, geomorphological structures such as wadi beds were preferred as connecting paths between the construction area and the floodplain of the Nile.

Two large quarries were identified in the surroundings of the necropolis of Dahshur, west and northwest of the Red Pyramid (*Abu-Jaber* et al. 2009) (*Fig. 2*).

Alexanian and *Seidlmayer* (2000) assume that a third quarry is located east of the Bent Pyramid. Altogether more than $2.9*10^6$ m³ of stones were mined and transported during the reign of King *Snefru* to build the two largest monuments of Dahshur: the Bent Pyramid and the Red Pyramid (*Lehner* 1997) (*Tab. 1*). Today, ancient quarries are difficult to identify because they were partly used as burial sites or filled up with construction

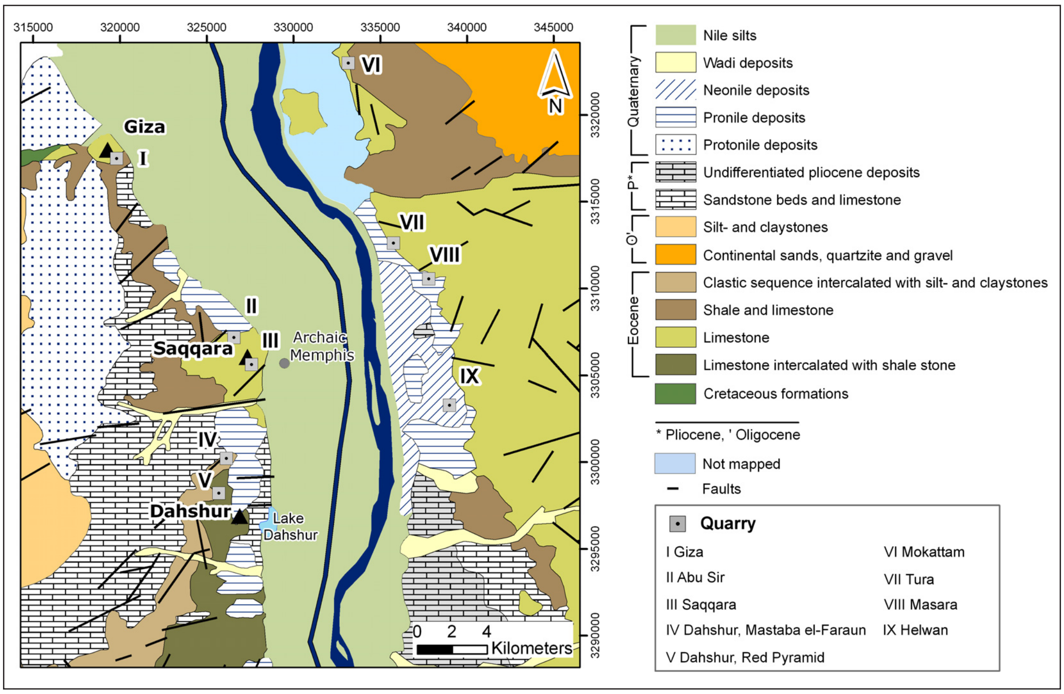


Fig. 2 Geological map of the Memphite region south of Cairo (data base: Geological Map of Egypt 1:500,000, Sheet NH 36 SW, Beni Suef, locations of quarries after *Harrell* and *Storemyr* 2009), Coordinate system: WGS 1984, UTM 36N / *Geologische Karte des memphitischen Raums südlich von Kairo*

Tab. 1 Major pyramid data of the necropolis of Dahshur (after *Lehner* 1997)
Kenndaten der Pyramiden der Nekropole von Dahschur (nach Lehner 1997)

Pharaoh	Dynasty	Location	Base length (m)	Height (m)	Volume (m^3)
Snefru	4	Dahshur	188 x 188	105	1,237,040
Snefru	4	Dahshur	220 x 220	105	1,694,000
Shepseskaf	4	Saqqara, S.	99.6 x 74.4	18	148,271
Amenemhat II	12	Dahshur	50 x 50	n/a	n/a
Senwosret III	12	Dahshur	105 x 105	78	288,488
Amenemhat III	12	Dahshur	105 x 105	75	274,625

rubble (*Klemm* and *Klemm* 2008, *Harrell* and *Storemyr* 2009). Because of fine layering and poor compaction of the local bedrock, chisel marks as clear evidence of mining activity are poorly preserved and frequently were completely destroyed by weathering processes.

Depending on the bedrock's textural and structural characteristics such as layering, jointing and veining, the exploitation techniques varied between opencast, gallery, trench, pit and every kind of mixed forms (*Harrell* and *Storemyr* 2009). A complete overview of the history of the exploitation of building material in ancient Egypt is given by *Klemm* and *Klemm* (2001, 2008).

4. Methods

4.1 Data processing

A digital elevation model, based on the topographical map Le Caire (1:5,000, sheets H24, H25, H26, and H27), was generated with a resolution of 5 x 5 m using the ArcGIS® function Topo to raster which enables the generation of hydrologically correct digital elevation models. Derivates such as slope, aspect and curvatures as well as calculations of catchment boundaries were calculated using ArcGIS 9.3®. The drainage network was digitised on the basis of the 1:5,000 topographical maps (Le Caire, sheets 1:5,000, sheets H24, H25, H26, and H27), which were generated from aerial photographs.

4.2 Fieldwork

Sondages were conducted using an Eijkelkamp hand auger and synthetic case tubes to stabilise the sondage hole. We used a bailer head in sandy sediments near or below the groundwater table, and an Edelmann auger in loamy to clayish sediments. With the bailer, 20 cm bulk samples were taken, whereas the Edelmann auger allowed sampling in 5 cm steps. The coordinates of the sondage locations were taken using a tachymeter (which allows an accuracy in a millimetre range) and a handheld global positioning system (GPS) (accuracy in a range of 3-4 metres) (*Tab. 2*). The sondages B1-B29 were carried out, archaeologically described, sampled and archived by the excavation team of the DAI during the archaeological field work in spring 2008. In spring 2009, these samples were reworked in the field laboratory of the excavation house as described for the sondages B30-B41. For the sondages B30-B41, sediment characteristics such as grain size, sorting, rounding, clast size and type, colour, and exceptional features (such as amount of charcoal) were de-

Tab. 2 Coordinates of sondages (WGS 1984, UTM 36 N) / Koordinaten der Bohrungen

No.	x-coordinate	y-coordinate	No.	x-coordinate	y-coordinate
1	328.780	3.297.319	**21**	328.946	3.297.760
2	328.943	3.297.464	**22**	327.777	3.297.381
3	328.944	3.297.518	**23**	327.778	3.297.378
4	328.736	3.297.444	**24**	327.661	3.297.388
5	328.770	3.297.320	**25**	327.840	3.297.333
6	328.766	3.297.290	**26**	327.730	3.297.381
7	328.768	3.297.259	**27**	n/a	n/a
8	328.885	3.297.364	**28**	327.841	3.297.380
9	328.925	3.297.357	**29**	327.775	3.297.376
10	328.999	3.297.361	**30**	327.806	3.297.377
11	328.819	3.297.342	**34**	328.437	3.296.226
12	328.966	3.297.361	**35**	328.695	3.296.454
13	328.952	3.297.406	**36**	328.678	3.296.516
14	328.979	3.297.335	**37**	328.419	3.296.353
15	328.986	3.297.304	**37**	328.419	3.296.353
16	328.997	3.297.242	**38**	328.294	3.296.300
17	328.880	3.297.202	**39**	329.057	3.297.368
18	328.879	3.297.297	**40**	329.169	3.297.417
19	328.878	3.297.259	**41**	329.409	3.297.404
20	328.876	3.297.225			

scribed by the authors directly in the field during the field campaigns in 2009. The Munsell soil colour chart was used for colour determination only in 2009. In the case of bulk samples, which were taken with the bailer, the colour was specified descriptively.

Two trenches were dug along the western and eastern slopes of a depression 140 m east of the Bent Pyramid. Channel geometry was recorded using a DGPS. The DGPS was a combination of two Ashtec Mobilemapper Pro™ as rovers and an Ashtec Promark™ as reference station. The software Mobilmapper Office was applied to postprocess the data. The DGPS enables the recording of point, line and area features, reaching horizontal and vertical submetre accuracy. Geomorphological features were mapped according to *Leser* and *Stäblein* (1980). Large parts of the area adjoining the pyramids were occupied by the military or used for industrial purposes. In these areas, field mapping was prohibited and the geomorphology was mapped on the basis of a Quickbird Image (203001002D4DA800, 21/02/2008, resolution: 0.6 m) and aerial photographs (Corona; DZB00402400058H020001, 23/01/1966, resolution: 2 to 4 feet).

4.3 Geochronology and methodological limitations

The choice of methods was limited to field methods because there was no permission to remove the samples from the sites. Consequently, dating methods such as OSL dating or radiocarbon dating were not applied. The chronological classification of the sondages is based on the dating of sherds, a technique that mainly requires sherds from the edge of a vessel – a precondition not met by most sherds found. Thus, the pottery in the sondages can be dated archaeologically to the period between the Old Kingdom and the beginning of the New Kingdom. As a consequence, it was not possible to generate absolute age models for the sondages. Nevertheless, the stratigraphy of the sondages with the cultural layers and the geologically identifiable layers, e.g. the shale, gives relative information about the date when the sediment was deposited.

If sherds are used as a chronological marker, the date is set after which the deposit was laid down (post quem). That means a sediment unit containing sherds of the Old Kingdom must have been deposited during or after the Old Kingdom (*Bunbury* et al. 2008). One advantage of using sherds as a chronological marker is that they were not transported over long distances in flowing water and that they were quickly buried by sediment after deposition (*Aslan* and *Behrensmeyer* 1996).

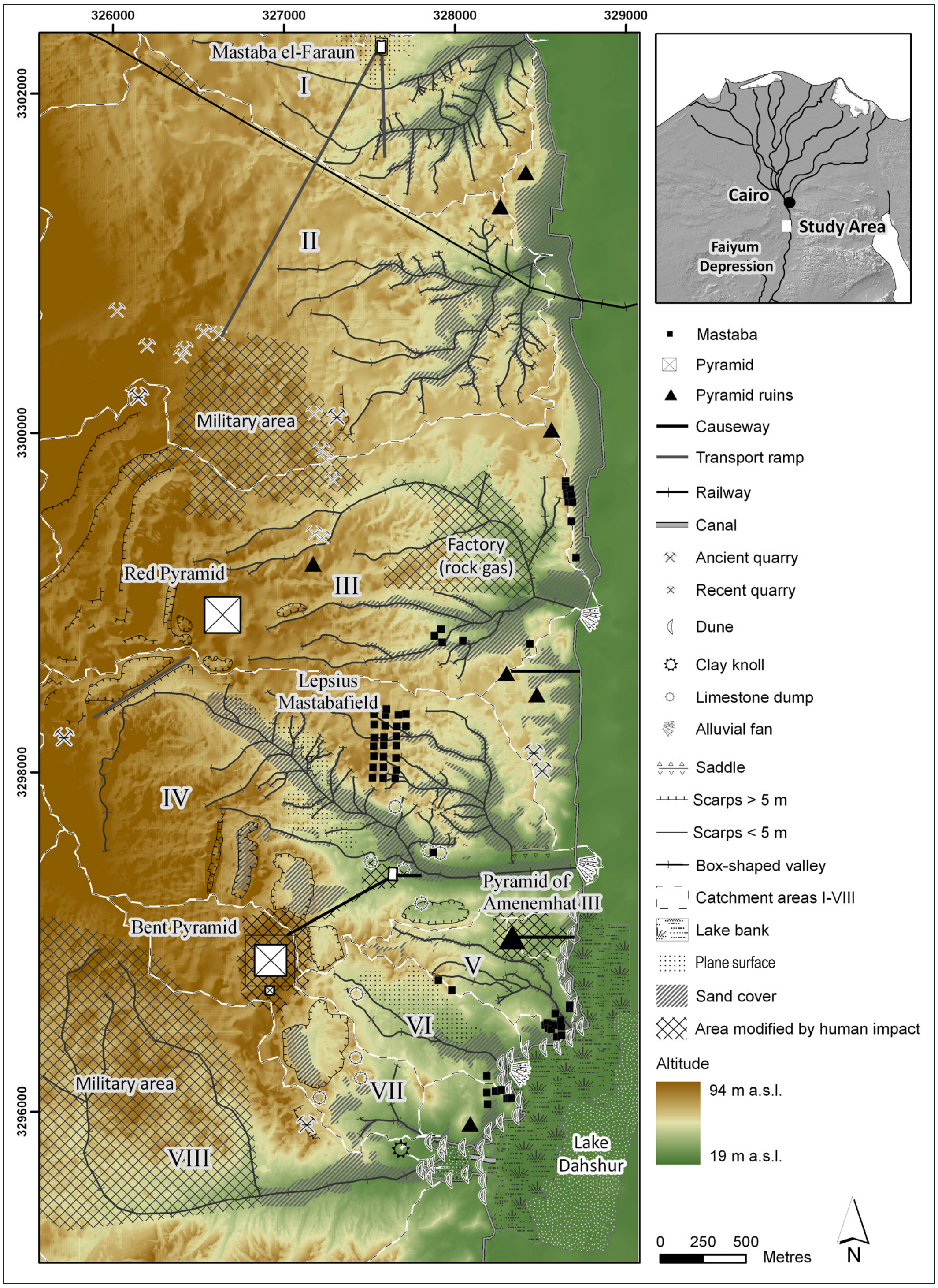
5. Results

5.1 Geomorphology

The landscape surrounding the necropolis of Dahshur comprises two major landscape units: a) the escarpment, and b) the floodplain of the river Nile (*Fig. 3*). The escarpment mainly consists of Pliocene and Eocene limestones and Eocene sedimentary rocks. All the study area is covered by well-rounded pebbles corresponding to Pleistocene Nile deposits. In the northern study area, the escarpment is defined as a sharply delimited linear structure. South of the pyramid ruin of *Amenemhat III*, the linear appearance of the escarpment is disintegrating (*Fig. 3*). The transition zone from the escarpment to the floodplain of the river Nile is widely covered by sand sheets extending 100-150 m from east to west. In the southern part of the study site, Lake Dahshur is located at the western margin of the Nile floodplain, directly at the foot of the escarpment. Irregular oval dunes (Kupsten), up to 5 m high, flank the western margin of Lake Dahshur. In the study area, the Nile floodplain is located at 18-30 m a.s.l., with an average elevation of 21 m a.s.l. (*Tab. 3*). The escarpment is drained by ephemeral channels originating in the Western Desert. These channels have deposited fans along the scarp face. Hydrographically the area of the escarpment is subdivided into eight catchment areas (*Fig. 3, Tab. 3*).

In the following, a general overview of the landscape features of catchments I-III is given, whereas the landscape inventory of the southern area will be presented in more detail. The drainage network of catchments I and II is dendritic, with tributaries merging at right angles. The Mastaba el-Faraun, dating to the Old Kingdom, is located at the northern margin of catchment I. A transport ramp of 2.5 km length connects the mastaba with the source area of its building material, an extensive quarry area SW of the mastaba (*Harrell* and *Storemyr* 2009). The pit-like quarries in catchment II are modern. The age of the quarry east of the military area, which is characterised by a north-south orientated scarp of 120 m, is unclear, but it must be older than 1966 because it was detected in the Corona aerial photograph

Fig. 3 Geomorphological map of the study area (map source: topographical map Le Caire 1:5,000, sheets H24, H25, H26, and H27. Archaeological findings: *Stadelmann* and *Alexanian* 1998)
Geomorphologische Karte des Untersuchungsgebiets


326000
327000
328000
329000
3302000
3300000
3298000
3296000
Mastaba el-Faraun
I
II
Military area
Red Pyramid
III
Factory (rock gas)
Lepsius Mastabafield
IV
Pyramid of Amenemhat III
Bent Pyramid
V
VI
VII
Military area
VIII
Lake Dahshur
Cairo
Study Area
Faiyum Depression
Mastaba
Pyramid
Pyramid ruins
Causeway
Transport ramp
Railway
Canal
Ancient quarry
Recent quarry
Dune
Clay knoll
Limestone dump
Alluvial fan
Saddle
Scarps > 5 m
Scarps < 5 m
Box-shaped valley
Catchment areas I-VIII
Lake bank
Plane surface
Sand cover
Area modified by human impact
Altitude
94 m a.s.l.
19 m a.s.l.
0 250 500
Metres
N

Tab. 3 Catchment parameters / Kennzahlen der Einzugsgebiete

No. Catchment	**Area**		**Elevation** (m a.s.l.)		**Slope** (°)		**Plan curvature**		**Profile curvature**	
	m²	%	Range	Average	Range	Average	Range	Average	Range	Average
I	1,713,725	5.9	21-66	44.0	0-24	2.5	-6 – 5	0.00	-6 – 7	0.01
II	5,087,900	17.6	21-90	55.0	0-23	1.7	-6 – 6	0.00	-5 – 7	0.00
III	4,220,425	14.6	19-94	52.2	0-29	2.5	-10 – 12	0.00	-9 – 13	0.00
IV	4,100,225	14.2	21-89	49.5	0-25	3.4	-11 – 5	0.01	-5 – 9	-0.01
V	408,325	1.4	22-54	36.5	0-14	3.4	-7 – 5	0.01	-4 – 5	-0.01
VI	585,725	2.0	23-57	37.8	0-18	3.4	-3 – 3	0.01	-3 – 5	0.00
VII	967,925	3.4	22-76	51.5	0-21	2.2	-4 – 6	0.01	-6 – 5	0.00
VIII	3,833,275	13.3	20-90	49.5	0-19	2.4	-7 – 7	0.00	-7 – 5	0.00
Floodplain	3,403,650	11.8	18-30	21.2	0-21	1.2	-8 – 8	0.05	-12 – 9	0.02
Others	4,537,850	15.7	21-93	43.2	0-32	5.0	-9 – 11	0.03	-13 – 12	0.03

(Corona; DZB00402400058H020001, 23/01/1966, resolution: 2 to 4 feet).

The drainage systems of catchments III and IV are longitudinal. The headwater area of catchment III spreads across an area from 200 m north to 200 m south-east of the Red Pyramid. Scarps characterise the relief of catchment area III. The NE-SW orientated, step-like scarps west of the Red Pyramid were identified as quarries of the Mastaba el-Faraun and the Red Pyramid (*Harrell* and *Storemyr* 2009). Circular depressions, up to 150 m in diameter, are located west, south and east of the Red Pyramid. The floors and hillsides of these structures are covered with sand sheets. Two smaller pyramids of the Middle Kingdom and linearly arranged grave monuments are located at the edge of the escarpment and in the south-eastern area.

Catchment IV is drained by one main channel fed by two source tributaries. The main channel has a box-shaped cross profile. Its source is located at the border of the geological limestone formation Mokkatam group, here represented by the Wadi Rayan formation. The contour line of the main wadi is bounded by a ramp leading in a NE-SW direction from the pyramid plateau to the quarry area of the Red Pyramid. The quarry of the Red Pyramid is characterised by step-like, partly circular scarps. The upper reach of the main channel is flanked by planar areas with slope angles between 1 and 3.5°. The channel beds of the main wadi and its tributaries are covered with sand sheets. Circular depressions, 200 to 500 m in diameter, are located in a semicircle around the Bent Pyramid. The floors of these landforms are covered with limestone debris up to 3 cm in diameter as well as with manganese and iron chips of equal size. The slopes adjacent to the pyramid plateau are covered with limestone debris. All other slopes are covered with aeolian sand. Different levels of altitude occur in these structures, building scarps less than 5 m high. The plateau of the escarpment in a 100 m radius around the Bent Pyramid is covered by a layer of limestone rubbish. Limestone dumps with a radius of 300 m are located in the vicinity of the valley temple of the Bent Pyramid, documenting the human activity in this area. The *Lepsius* mastaba field is located on top of the plateau north of the main channel of catchment IV. The causeway linking the Bent Pyramid and the valley temple is located in the second tributary of the main valley.

The catchments V and VI have a longitudinal drainage network. With a size of $408*10^3$ m², catchment V is the smallest catchment in the study area (*Tab. 3*). The remains of the pyramid of *Amenemhat* III are located in the north of the catchment. The surroundings of the pyramid ruin are covered with limestone debris from broken casing stones and were mapped as an area modified by human impact. Grave monuments dating to the period of the Old Kingdom are situated close to the channel mouth.

Catchment VI covers 2 % of the study area and is the second smallest catchment (*Tab. 3*). It is drained by a single channel, running from northwest to southeast. The upper reach is flanked by parallel scarps. Catchment VII

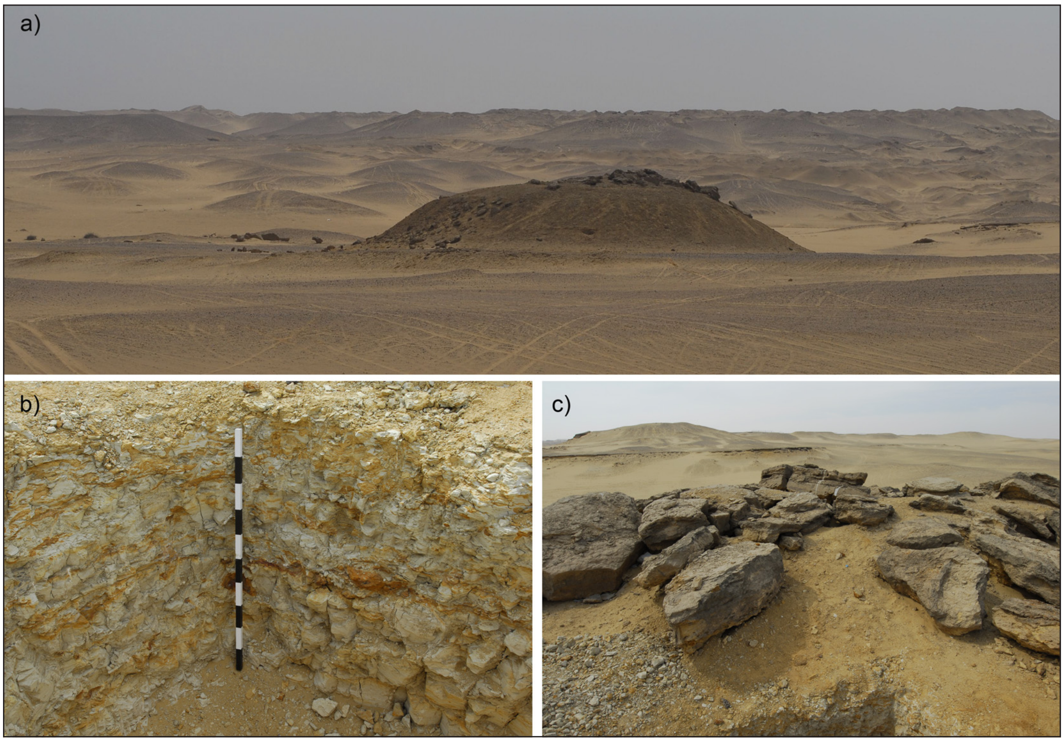


Fig. 4 a) Shale knoll as a singular landform in catchment VIII (view from north to south), the area behind the knoll is a modern quarry area for clay; the knoll is visible on the Corona aerial photos. b) Pot-hunter pit on top of the knoll, proving that it consists of solid shale. c) Limestone blocks on top of the knoll (diameter: 2 m). (Photographs taken by *Diana Härtrich*, DAI) / *Tonkuppe als Einzelform im Einzugsgebiet VIII mit Blick nach Süden, der Bereich hinter der Kuppe ist ein moderner Tonsteinbruch. Die Kuppe ist bereits auf den Corona-Luftbildern sichtbar. b) Ein Grabräuberloch auf der Kuppe schließt den anstehenden Tonschiefer auf. c) Kalksteinblöcke mit einem Durchmesser von 2 m liegen auf der Kuppe.*

covers 3 % of the study area. The main channel with a length of 200 m originates from the merging of two tributaries.

The source channels of catchment VIII are located in the northern part of the catchment with the channels running strictly south. After the confluence of the source channels, the main channel deviates rectangularly to the east after 1,200 m.

A knoll consisting of shale, 6 m high and 56 m in diameter, is the predominating singular landform in the catchment area VIII. The shale is characterised by alternations in colour from grey to orange and by gypsum precipitation. Limestone blocks up to 2 m in diameter are situated on top of the knoll (*Fig. 4*).

5.2 Channel geometry

The locations of longitudinal and cross-sections of channels in catchments IV and VI are shown in *Figure 5*. Cross-sections of the main channels of catchment areas IV and VI are plotted in *Figure 6*.

The main channel of catchment IV has a length of 3,175 m (*Fig. 6d*) and bridges an altitude of 33.6 m from its source at 55 m a.s.l to the river mouth (21.4 m a.s.l.), with a resulting mean gradient of

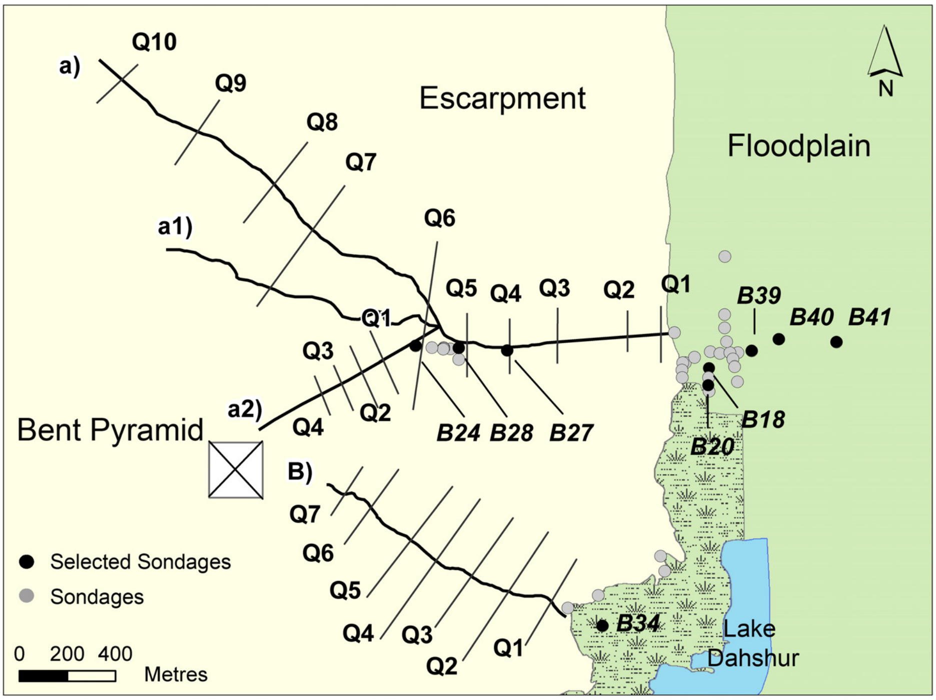
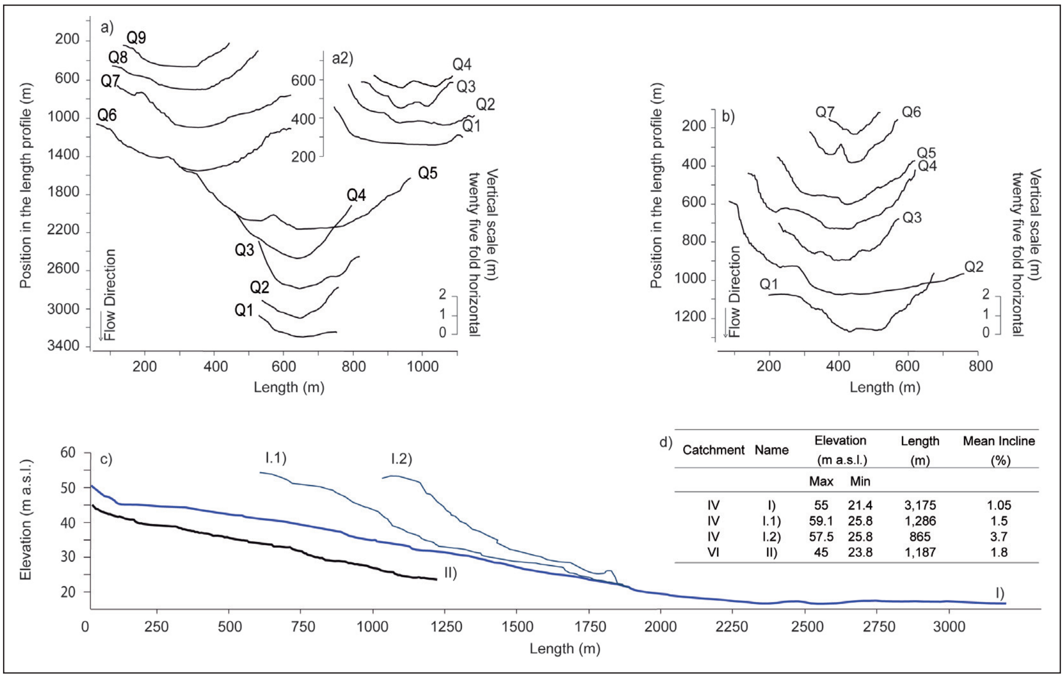


Fig. 5 Location of longitudinal and cross-sections, location of sondages
Lage der Längs- und Querprofile sowie der Bohrungen

1.05 % (*Fig. 6d*). The longitudinal section can be subdivided into four major zones in terms of inclination and shape: a) headwater area (channel metre 0-90 m) with a gradient of 8 %, characterised by a straight shape, b) middle reach (channel metre 90-1800 m) with a mean gradient of 3 % and a convex shape, c) lower course (channel metre 1,800-2,360 m) with a mean gradient of 1.5 % and a straight shape and d) convex-shaped alluvial fan (channel metre 2,360 and 3,175 m).

The gradient of the tributaries in catchment IV is highly variable, with 1.5 % for the first tributary (I.1) and 3.7 % for the second tributary, which connected the Bent Pyramid and the wadi temple (I.2), and is steeper than the inclination of the receiving channel.

The channel of catchment VI totals 1,187 m in length, and the channel gradient averages 1.8 %. The longitudinal section can be subdivided into



Catchment	Name	Elevation (m a.s.l.) Max	Elevation (m a.s.l.) Min	Length (m)	Mean Incline (%)
IV	I)	55	21.4	3,175	1.05
IV	I.1)	59.1	25.8	1,286	1.5
IV	I.2)	57.5	25.8	865	3.7
VI	II)	45	23.8	1,187	1.8

Fig. 6 Cross- and longitudinal sections of valleys in catchments IV and VI (data base: digital elevation model, resolution 5 m). a) Cross-sections of main channel in catchment IV; a2) Cross-sections of its second tributary, where the causeway connecting Bent Pyramid and valley temple is located. b) Cross-sections of the channel in catchment VI. c) Longitudinal sections. I: Main channel catchment IV, I.1: First tributary of main channel in catchment IV, I.2: Second tributary of main channel in catchment IV. II: Main channel of catchment VI. d) Statistical parameters of the longitudinal sections. Location of sections is shown in *Figure 5*. / *Talquer- und -längsprofile der Einzugsgebiete (EZG) IV und VI (Datengrundlage: Digitales Geländemodell, Auflösung 5 m). a) Querprofile des Haupttals und des zweiten Tributärs a2) des EZG IV. b) Talquerprofil des EZG VI. c) Längsprofile. I: Haupttal EZG IV. I.1: Erster Tributär des Haupttals in EZG IV, I.2: Zweiter Tributär des Haupttals in EZG IV. II: Haupttal des EZG VI. d) Statistische Parameter der Längsprofile. Figur 5 zeigt die Lage der Profile.*

three major zones related to inclination and shape: a) headwater area (channel metre 0-140 m) with a gradient of 7 % and a concave shape, b) a straight section which alternates with a slightly convex part (channel metre 140-860 m), c) a section (channel metre 860-1,100 m) which is slightly convex, and d) a lower course (channel metre 1,101-1,187 m) which is straight.

The cross-sections of the lower course of the main channel in catchment IV are predominantly box-shaped and asymmetric with a steep slope at the right side (Q1-Q5), facing north (*Fig. 6a*). The cross-sections Q7, Q6 and Q5 show flattening at the right-hand channel side. The cross-sections of the tributary connecting the Bent Pyramid and the wadi temple (*Fig. 6, a2*) are asymmetric: Q1 and Q2 with steeper slopes along the right valley side and Q3 and Q4 with steep slopes along the left valley side. The ridges in the middle of the cross sections Q3 and Q4 correspond to the causeway between temple and pyramid.

The overall geometry of the valley cross-sections in catchment VI is box-shaped (*Fig. 6b*). Cross-sections Q1-Q5 are characterised by flattening along the right-hand valley side. The flattening varies in width between 25 m (Q1) and 100 m (Q5). The peak in cross section Q6 corresponds to a limestone dump.

5.3 Sondages

From the 41 sondages available for the study area, three transects, characteristic for the main landscape units, and one single sondage are selected and presented here: a) desert: transect 1 with sondages B 24, B 28 and B 27, b) floodplain: transect 2 with sondages B 39, B 40 and B 41, c) desert margin east of the escarpment scarp: transect 3 with the sondages B 18 and B 20 and d) margin of Lake Dahshur sondages B 34 (*Figure 5* shows the location of the sondages).

5.3.1 Sondage transect 1: main channel of catchment IV

Sondage B 24 is located in the Snefru valley inside the walls of the valley temple of the Bent Pyramid, 120 m upstream of the inflow of trib-

Tab. 4 Sondage B 24 / *Bohrung B 24*

Depth (m)	Unit	Description
0-0.16	**1**	Yellow fine-grained sand, poorly compacted
0.17-0.87	**2**	Brownish sandy loam, partly intercalated with detritus of dark grey clay, from top to bottom: increase of clay content
0.88-2.93	**3**	Dark grey, partly yellowish-reddish clay

Tab. 5 Sondage B 28 / *Bohrung B 28*

Depth (m)	Unit	Description
0-4.46	**1**	Yellowish fine-grained sand poorly compacted with rare appearance of small brownish-grey loam lenses of up to 1 cm at 2.00-3.40 m depth
4.47-8.25	**2**	Yellowish well-sorted fine-grained sand, changing to a yellowish-brown colour from top to bottom; at a depth of 7.54 m, charcoal particles occur throughout the exposed material.

utary 2 into the main channel. Sondage B 24 totals 2.93 m in depth, showing three different depositional units (*Tab. 4, Fig. 7*).

Sondage B 28 is located 183 m east of sondage B 24 and totals 8.25 m in depth. It shows two different depositional units (*Tab. 5, Fig. 7*).

Sondage B 27 is located 200 m east of sondage B 28 and totals 8.75 m in depth, showing eleven different depositional units (*Tab. 6, Fig. 7*).

5.3.2. Sondage transect 2: Floodplain of the river Nile

Transect 2 is orientated in west-east direction in the floodplain of the river Nile, 300 m east of the mouth of the main channel of catchment IV (*Fig. 7*) and consists of the sondages B 39, B 40 and B 41.

Sondage B 39 is located in the western area of the village of Dahshur, on top of a canal embank-

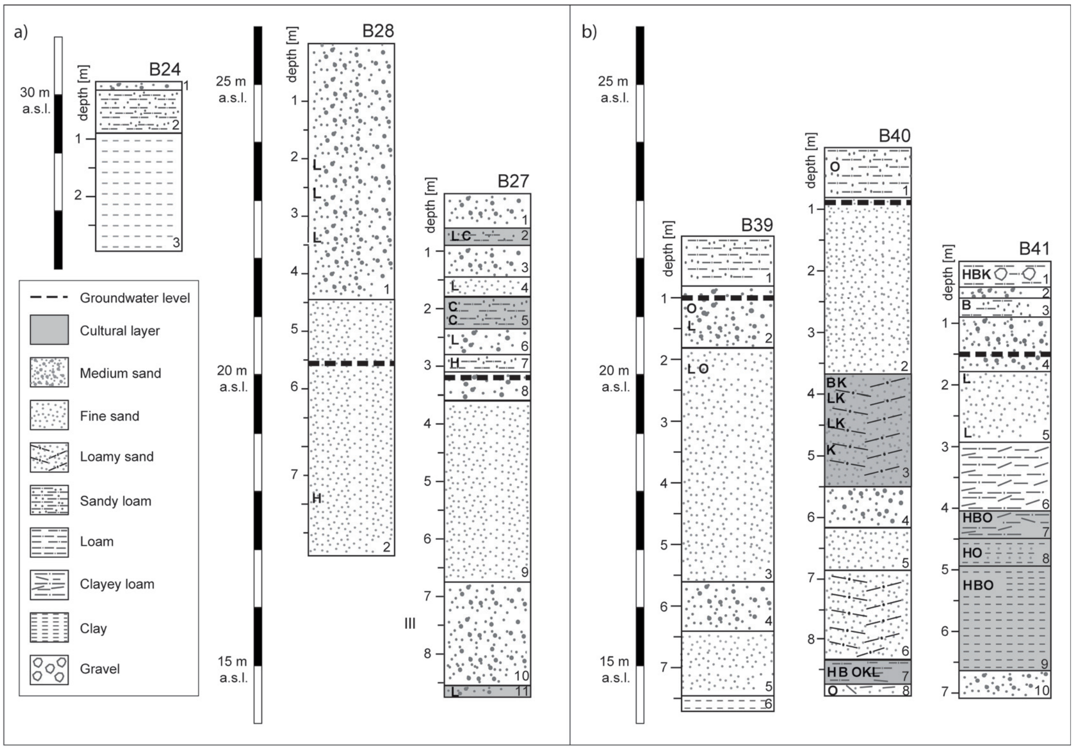
Tab. 6 Sondage B 27 / *Bohrung B 27*

Depth (m)	Unit	Description
0-0.60	**1**	Yellowish medium-grained sand
0.61-0.91	**2**	Brown-yellowish sandy loam with loam lenses and small ceramic fragments
0.92-1.43	**3**	Yellowish medium-grained sand, well-sorted
1.44-1.80	**4**	Yellowish fine-grained sand, well-sorted
1.81-2.37	**5**	Brown-yellowish sandy loam with loam lenses and small ceramic fragments
2.38-2.79	**6**	Yellowish medium-grained sand with loam lenses, well-sorted
2.80-3.10	**7**	Brown-yellowish sandy loam with charcoal
3.11-3.61	**8**	Yellowish medium-grained sand, well-sorted
3.62-6.74	**9**	Yellowish fine-grained sand
6.75-8.55	**10**	Yellowish medium-grained sand, partly intercalated with small lenses of loam
8.56-8.75	**11**	Yellowish medium-grained sand, partly intercalated with small lenses of loam, scattered cultural remains such as ceramic fragments or sherds

Tab. 7 Sondage B 39 / *Bohrung B 39*

Depth (m)	Unit	Description
0-0.81	**1**	Pale brownish sandy loam, intercalated with modern rubbish
0.82-1.81	**2**	Yellowish medium-grained sand, sporadically intercalated with loam lenses and small organic fragments at a depth of 1.47-1.73 m
1.82-5.61	**3**	Yellowish fine-grained sand, well-sorted at a depth of 2.30 m intercalated with loam lenses and small organic fragments
5.62-6.42	**4**	Yellowish medium-grained sand, well-sorted
6.43-7.46	**5**	Yellowish fine-grained sand, well-sorted
7.47-7.75	**6**	Dark brownish to greyish clay

Fig. 7 Lithostratigraphy of sondage transects 1 (a) and 2 (b). B: bricks, H: charcoal, L: loam lenses, O: organic remains, K: limestone / *Lithostratigraphie der Bohrtransekte 1 (a) and 2 (b). B: Ziegel, H: Holzkohle, L: Lehmlinsen, O: Makroreste, K: Kalkstein*



ment between a path and the canal. Sondage B 39 totals 7.75 m in depth, showing six different depositional units (*Tab. 7, Fig. 7*).

Sondage B40 is located 250 m east of sondage B 39 in a garden. It consists of eight depositional units (*Tab. 8, Fig. 7*).

Sondage B 41 is located 200 m east of sondage B 40 and was taken on a path in the village of Dahshur. It totals a depth of 7.10 m and consists of 10 units (*Tab. 9, Fig. 7*).

5.3.3. Transect 3: Transition area between floodplain and desert

The third transect is located 200 m southeast of the mouth of the Snefru valley. The distance between the sondages is 50 m (*Fig. 5, Fig. 8*).

Sondage B 18 is located in a garden 300 m southeast of the mouth of the main channel of catchment IV, in a distal area of the channel's alluvial fan. It totals a depth of 9.11 m and consists of 10 units (*Tab. 10, Fig. 8*).

Tab. 8 Sondage B 40 / *Bohrung B 40*

Depth (m)	Unit	Description
0-0.87	**1**	Greyish sandy loam, rich in organic remains
0.88-3.69	**2**	Yellowish fine-grained sand in the upper 20 cm of layer 2, badly sorted
3.70-5.50	**3**	Yellowish sandy loam, single bricks, loam lenses, limestone detritus
5.51-6.20	**4**	Yellowish medium-grained sand
6.21-6.80	**5**	Yellowish fine-grained sand
6.81-8.40	**6**	Light brownish loamy fine-grained sand, increasing silt and clay content towards the bottom
8.41-8.70	**7**	Dark brownish clay, mixed with weathered bricks, sharp-edged detritus up to 5 cm, charcoal, organic remains and weathered limestone detritus up to 1 cm
8.71-8.94	**8**	Dark brownish clay, intercalated with lenses of slightly orange sand or silt, organic remains

Tab. 9 Sondage B 41 / *Bohrung B 41*

Depth (m)	Unit	Description
0-0.40	**1**	Brown loam intercalated with sharp-edged limestone debris up to 1 cm, well-rounded pebbles up to 5 cm and modern rubbish
0.41-0.60	**2**	Brownish medium-grained sand
0.61-0.95	**3**	Brownish sandy loam, intercalated with small brick fragments
0.96-1.80	**4**	Pale brownish to yellowish medium-grained sand; the sorting of the material improves from top (poorly sorted) to bottom (well-sorted).
1.81-2.95	**5**	Yellowish well-sorted fine-grained sand, loam lenses occur on top and at the bottom of this unit.
2.96-4.05	**6**	Dark brown clayey loam (Munsell colour 2.5Y 3/1-2.5Y 3/2), brick fragments, charcoal pieces (up to 2 cm) and lenses of sand (up to 1.5 cm)
4.06-4.52	**7**	Dark brown clayey loam (Munsell colour 2.5Y 3/1-2.5Y 3/2), many brick fragments up to 5 cm, and small, partly weathered ceramic pieces, charcoal fragments, organic remains (roots) up to 2 cm
4.53-4.96	**8**	Dark brown, slightly sandy clay (Munsell colour 2.5Y 3/1-2.5Y 3/2), small, partly weathered ceramic pieces, charcoal fragments, organic remains (roots) up to 2 cm
4.97-6.68	**9**	Dark brown clay (Munsell colour 2.5Y 3/1-2.5Y 3/2), many brick fragments up to 5 cm, and small, partly weathered ceramic pieces, charcoal fragments, organic remains (roots) up to 2 cm
6.69-7.12	**10**	Pale brownish medium-grained sand

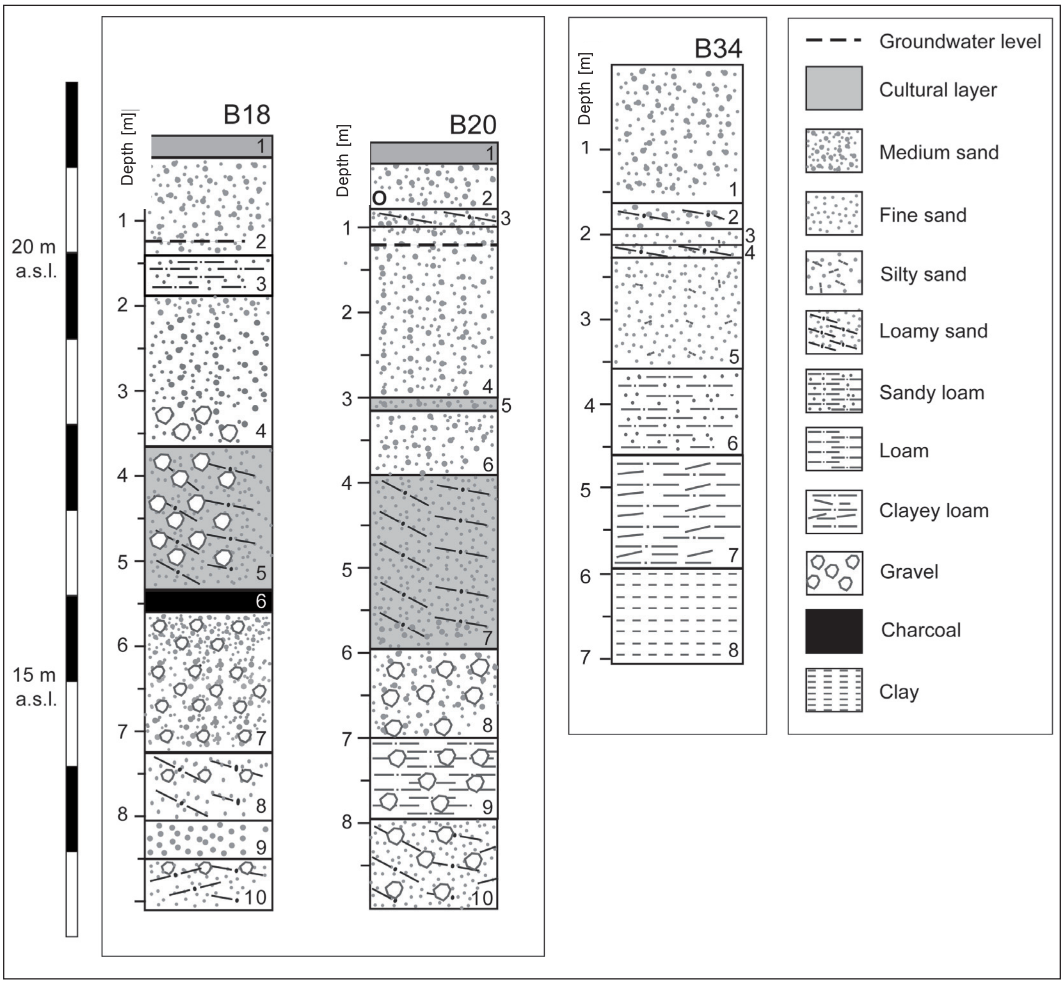


Fig. 8 Lithostratigraphy of sondage transect 3 and of sondage B 34
Lithostratigraphie des Bohrtransekts 3 und der Einzelbohrung B 34

Sondage B20 is located 50 m south of sondage 18, totals 9 m and consists of 10 units (*Tab. 11, Fig. 8*).

Sondage B34 is located 150 m east of the valley mouth of the main channel of catchment VI. It totals a depth of 7.05 m and consists of 8 units (*Tab. 12, Fig. 8*).

5.4 Trenches

Trench 1 was dug in the eastern slope debris of the depression east of the Bent Pyramid (*Fig. 9a*) – depth 1.5 m, width 3.3 m and length 8.4 m. It bottoms out at the shale bedrock, which is intercalated with gypsum precipitation. On top of the shale, limestone is intercalated with a 20 cm thick

Tab. 10 Sondage B 18 / *Bohrung B 18*

Depth (m)	**Unit**	**Description**
0-0.24	**1**	Pale brownish medium-grained sand
0.25-1.36	**2**	Yellowish medium-grained sand
1.37-1.98	**3**	Pale brownish sandy loam
1.99-3.66	**4**	Yellowish to pale brownish medium-grained sand, at the bottom of this unit: badly sorted yellowish medium-grained sand with sharp-edged detritus up to 2 cm
3.67-5.34	**5**	Pale brownish loamy sand with poorly rounded, partly sharp-edged detritus up to 2 cm, sherds, probably dating to the Old Kingdom, ceramic fragments and charcoal
5.35-5.58	**6**	Charcoal layer
5.59-7.37	**7**	Yellowish to pale brown, poorly sorted medium-grained sand with well-rounded pebbles
7.38-8.02	**8**	Yellowish loam with moderately rounded pebbles up to 2 cm
8.03-8.48	**9**	Yellowish medium-grained sand and gravel up to 1 cm
8.49-9.11	**10**	Yellowish loamy sand and gravel up to 1 cm

Tab. 11 Sondage B 20 / *Bohrung B 20*

Depth (m)	**Unit**	**Description**
0-0.25	**1**	Pale brownish medium-grained sand
0.26-0.79	**2**	Yellowish medium-grained sand, with isolated organic remains, mostly fragments of grass-like vegetation and roots
0.80-0.98	**3**	Yellowish to pale brownish loamy sand
0.99-3.01	**4**	Yellowish to pale brownish medium-grained sand
3.02-3.15	**5**	Yellowish to pale brownish medium-grained sand with ceramic fragments
3.16-3.80	**6**	Yellowish to pale brownish medium-grained sand
3.81-5.97	**7**	Pale brownish loamy sand with poorly rounded, partly sharp-edged detritus up to 2 cm, sherds, probably dating to the Old Kingdom, ceramic fragments and charcoal
5.98-7.03	**8**	Yellowish to pale brown badly sorted medium-grained sand with well-rounded pebbles
7.04-7.96	**9**	Yellowish loam with moderately rounded pebbles up to 2 cm
7.97-9.01	**10**	Yellowish loamy sand with moderately rounded pebbles up to 2 cm

Tab. 12 Sondage B 34 / *Bohrung B 34*

Depth (m)	Unit	Description
0.00-1.66	**1**	Yellowish medium-grained sand
1.67-1.94	**2**	Grey loam
1.95-2.16	**3**	Yellowish fine-grained sand
2.17-2.31	**4**	Grey loam
2.32-3.59	**5**	Pale brownish silty fine-grained sand; towards the bottom: change of colour to yellowish silty fine-grained sand
3.60-4.62	**6**	Yellowish to orange sandy loam
4.63-5.95	**7**	Pale brownish loam, increasing clay content towards the bottom, partly mottled with greyish silt, oxidation and reduction marks
5.96-7.05	**8**	Grey clay with a few oxidation marks and gypsum precipitation

layer of shale (*Fig. 9*). The strata are horizontal. The limestone is vertically structured by veins of iron and manganese; it is slightly weathered and of a yellowish to brownish colour. The exposed bedrock is shaped like a rectangular step. Pottery, probably dating to the period of the Old Kingdom, was found at the bottom of the trench. The debris at both sides of the trench consists of thin layers of sandy, partly cross-bedded materials and layers of limestone detritus < 1 cm. The upper 100 cm of the sandy material contain roots.

Trench 2 was dug at the western edge of the depression east of the Bent Pyramid, depth 2 m, width 1.0 m, length 31 m; the bedrock was not reached. The slope debris consists of coarser unweathered sharp-edged limestone detritus, intercalated with layers of silty limestone detritus. Several quarry marks on the limestone, wood and sherds (dated to the Old Kingdom) were found.

6. Discussion

Although a geochronology based on absolute dating techniques such as radiocarbon or luminescence dating was not possible due to the restrictions made by the Egyptian Antiquity Authority, results of the geomorphological mapping and the sondages point to dynamic changes of environmental conditions during the past 5,000 years, since the start of the Old Kingdom. Nearly all channel beds are covered by sand sheets. The lowermost sediment unit in sondage B27 (transect 1), which is a cultural layer, gives evidence that the deposition of the aeolian sand sheet in the main channel bed of catchment IV is associated with the period of the Old Kingdom and before the beginning of the New Kingdom. An archaeological trench was dug by the DAI excavation team in this sand sheet east of the valley temple of the Bent Pyramid. The trench reveals an extensive structure of loam bricks, identified as the lower causeway connecting valley temple and floodplain of the river Nile (*Alexanian* et al. submitted). At the wall of this structure, several offering places were located more than 1 m above the original walking horizon. The pottery found there was dated to the Old Kingdom (*Alexanian* et al. submitted). These new results reinforce the chronological classification of sondage B 27. The eastward extent of

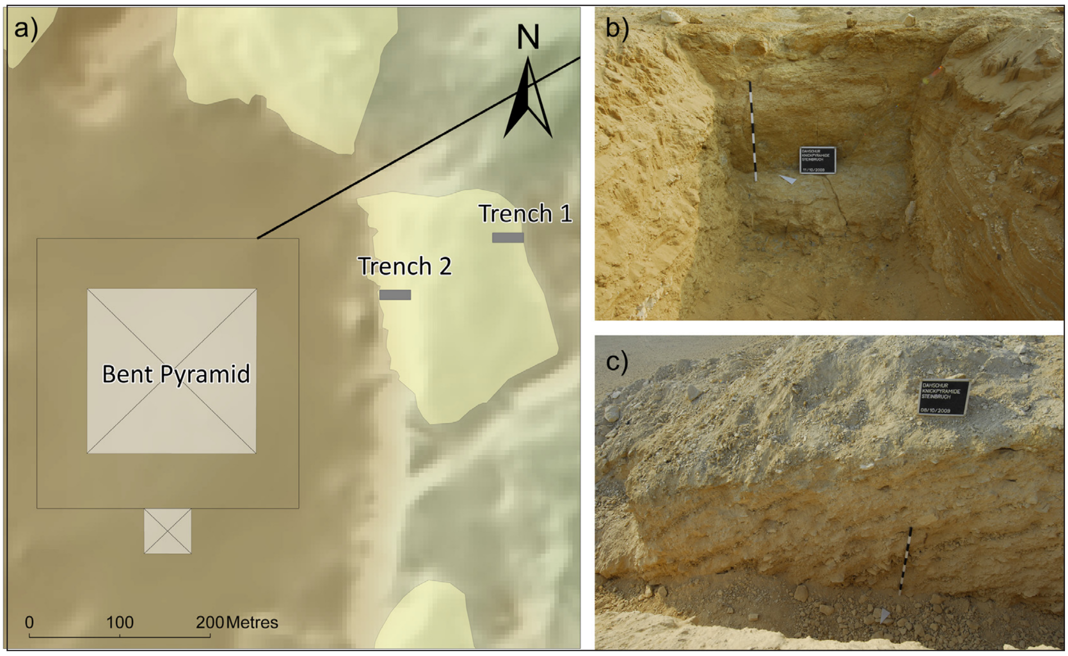


Fig. 9 a) Location of trenches 1 and 2 (map source: topographical map Le Caire 1:5,000, Sheet H 26), b) Trench 1, photograph shows the step-like edge in the limestone bedrock, c) Trench 2, photograph shows the alternating layers of coarser and finer limestone debris. / *a) Lage der Schürfe 1 und 2, b) Schurf 1, das Foto zeigt die stufenförmige Kante im anstehenden Kalkstein, c) Schurf 2, das Foto zeigt die Wechsellagen von feinerem und gröberem Kalksteindetritus.*

the sand sheet with its typical sequences of alternating medium- and fine-grained sand layers was detected in the easternmost sondage B 41 in the most recent floodplain of the river Nile. The occurrence of middle Holocene sand sheets is not limited to the necropolis of Dahshur; evidence of an increase in aeolian dynamics was also found at Saqqara (*Jeffreys* and *Giddy* 1992). The early Holocene climatic optimum lasted from 10,000 to 7,000 BP (*Nicoll* 2004, *Haynes* 2001); *Bubenzer* and *Riemer* (2007) date the beginning of aridisation at about 6,300 BP. It can be assumed that stable climatic conditions occurred after the aridisation of the Sahara in the study area (*Nicoll* 2004, *Brooks* 2006). The reconstruction of lake levels for Lake Qarun by *Hassan* (1986) is based on a combination of radiocarbon dates, stratigraphic age estimations and historical data. Consequently, the chronology of the curve contains several uncertainties which make a derivation of palaeoenvironmental proxy data difficult. The chronological resolution of the lake level curve of *Baiomy* et al. (2010) is not sufficient to derive reliable data, especially for the decline of the Old Kingdom. Thus, also the lake levels of Lake Qarun give no implication of a deterioration of the climatic conditions. However, without reliable age models further interpretations of aeolian dynamics have to be postponed to future research.

Cultural layers probably dating to the Old Kingdom period are situated below the sand sequence in sondage B 41 (sediment units 7-9). These cultural layers consist of dark brown clay, which is interpreted as fluvial deposits of the Nile. In the region around Luxor, Nile deposits have been described as fining upward sequences with an olive-brown, silty sand matrix at the bottom and a very dark greyish-brown silt at the top (*Bunbury* et al. 2008). The clay units in sondage B 41 show no graded stratigraphy, and their grain size is finer than around Luxor. The cultivated ancient Nile floodplain in the Memphite region was structured by levees of different ages, forming a micro-relief of basins and sinks in the floodplain. During a Nile flood, which lasted approximately from mid-July to mid-September (*Hassan* 2007), these sinks and basins contained stagnant water bodies, in which the suspended load was deposited.

Several sedimentation rates were calculated and published for the floodplain of the river Nile, varying between 1.03 mm a^{-1} (*Ball* 1939), 1-1.5 mm a^{-1} (*Borchardt* 1907) and 1.2-1.3 mm a^{-1} for sites younger than 3,500 years in the Memphis-Abusir area (*Jeffreys* and *Tavares* 1994). Rates of 1.2 mm a^{-1} and around 0.85 mm a^{-1} were reported for the central strip and the edge of the floodplain, respectively (*Hassan* 1997). Evidently, sedimentation rates are highly variable and depend on the geomorphological and geographical location and on the assumption that the sediments have no hiatus (*Knox* 1989, *Walling* and *He* 1998). Owing to the lack of an age model, the calculation of deposition periods on the basis of sedimentation rates allows only a rough estimation of the accumulation period of the 2.6 m thick cultural layer in sondage B 41: The sediment unit might have been deposited during a period of 3,060 years, assuming a conservative sedimentation rate of 0.85 mm a^{-1}, or 2,170 years, assuming a deposition rate of 1.2 mm a^{-1}. The sand unit on top of and below the clay layers implies that the sondage location is, and also was, located at the desert margin.

The sandy loam and loamy sand units found in B 18, B 20, B 27, B 34 and B 41 give evidence that Nile flood events reached the area of the sondage sites. This hypothesis is also substantiated by a historical photograph showing a flood event that extends almost as far as the pyramid district of Dahshur (http://www.orientfotograf.de/galerie_memphis.php, 27/06/2010).

Sondage transect 2 is located on the fan of the main channel of catchment IV. *Mills* (1979) had proved that the rounding of clastic materials increases with the distance of transportation in a river. Consequently, the sharp-edged detritus found at a depth of 3.10 m in sondage B 18, and at 6.00 m in sondage B 20 (transect 3), indicates a short transportation distance and shows that the fan of the main channel of catchment IV is located in that area. In sondage B 18, fan deposits of the wadi are found in a cultural layer (unit 5) indicating a wadi activity in the last 5,000 years and consequently single heavy rainfall events sufficient to generate runoff in the main channel.

From the geomorphological viewpoint, sondage B 34 is also located on a fan, namely on the fan of the main channel of catchment VI. In the stratigraphy of sondage B 34, fan-related deposits, like those described for sondages B 18 and B 20, are missing. The chronology of the sondage is based on its lowermost sedimentary unit consisting of dark grey clay, intercalated with gypsum precipitation. Comparable clay units with gypsum particles are found in trench 1, in the lowermost shale unit of the trench, and in the outcroppings of the shale knoll (*Fig. 4*). Against this background, the chronology of the lowermost unit in sondage B 34 is set to the Eocene. Unfortunately, further relative age markers are missing in the sondage. It remains uncertain whether the fan deposits were eroded by Nile floods.

Bubenzer and *Riemer* (2007) investigated the palaeodrainage systems in the Western Desert and dated them to the late Tertiary or the Pleistocene. They remarked that the lower discharge during the Holocene wet phase was not sufficient to erode the drainage network. According to these results, it is much more likely that the phase of channel erosion in the study area also dates to one of those periods. The geological map shows the fault system (*Fig. 2*). It is very likely that the development of the drainage system followed the faults.

Beside the drainage network, the most characteristic landscape features are the depressions, partly circular in their geometry and all located between Red Pyramid and Bent Pyramid. Trench 1 clearly reveals a rectangular step, which is interpreted as a result of human sculpturing. Also the manganese, iron and limestone chips on the bottom of this structure substantiate the assumption that this landform was built by human mining activity. This hypothesis is also in accordance with earlier research by the DAI indicating that this structure was an ancient quarry (*Seidlmayer* and *Alexanian* 2000) and is also transferable to the other depressions located in a semicircle round the Bent Pyramid. The quarries shape the straight and rectangular scarp of the plateau on which the Bent Pyramid is located. Thus, the pyramid plateau is exposed and isolated from the surrounding eastern area (*Alexanian* and *Seidlmayer* 2000). Also the causeway located in tributary II of the main channel in catchment IV seems to be part of this concept. The causeway is clearly recognisable in the cross-sections Q3 and Q4 (*Fig. 6*). Both slopes of the channel consist of the same geological formations as those mined in the surrounding quarries. It is not clear whether tributary 2 was completely modified by human impact during the construction period of the Bent Pyramid. Against the background of our results, this question cannot be clearly answered at the moment.

In summary, several indicators point to an extensive mining activity in the direct vicinity of the pyramid plateau. An archaeological survey of the study area identified several small quarry sites in catchment VI and IV, and a large number of dolerite hammers were found in that area (results of the survey published in *Stadelmann* and *Alexanian* 1998, original field maps were produced by *N. Alexanian*). The relief of catchment VI is characterised by an extensive plain nearly reaching the northern catchment margins. To the south, the area is flanked by a scarp. In view of the extent of this landscape feature, a wadi terrace seems to be unlikely. Furthermore, the headwater area of the valley is covered with the same material that is found in the depressions: limestone chips and iron or manganese chips. It can be confirmed that ancient quarries are difficult to identify today. Concerning the necropolis of Dahshur, our results can only point to the assumption that the relief of the landscape of the necropolis was modified not only by natural processes but also by human impact (*Klemm* and *Klemm* 2008, *Harrell* and *Storemyr* 2009).

7. Conclusions

The analysed terrestrial archives in the surroundings of the necropolis of Dahshur and morphometrical terrain parameters used as proxy data allow conclusions about landscape evolution in the past 5,000 years. Two main relief-forming factors were identified: mining as a factor lowering the relief on a small scale, and aeolian dynamics as a factor with a levelling effect. The depressions located semicircularly around the Bent Pyramid are identified as quarries. Evidence of mining activities, probably during the Old Kingdom, was also found in the wider vicinity of the Red Pyramid and Bent Pyramid. On the basis of the data presented here, it is difficult to verify the hypothesis that extensive areas in the catchments between the Bent and Red Pyramids were modified by mining. Nevertheless, our results show that the exploitation of natural resources, namely of building material for the construction of the monuments, played a major role for the landscape development of the last

5,000 years. The wadis draining the limestone plateau must have been a suitable route for the transportation of allochthonous building material from the floodplain of the river Nile. The question whether these activities accelerated natural processes such as soil erosion, sediment production and runoff during the construction period of the Bent Pyramid cannot be answered on the basis of the results presented here. Further research, for example applying the analysis of fractal dimension, has to be carried out.

Without the levelling effect of the partly 8 m thick sand sheet on top of the wadi floors, the pyramid plateau must have made a stronger impression in ancient times than today.

Nevertheless, a reliable age model is essential for a detailed analysis of palaeoenvironmental conditions and relief evolution. Consequently, absolute dating methods such as OSL dating or radiocarbon dating and laboratory analysis are required for a more comprehensive reconstruction of the ancient landscape. But the results presented here show that the relief of the surroundings of the necropolis underwent changes that should be taken into account when the monuments are analysed in their original setting.

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Summary: Analysis of Past and Present Landscapes Surrounding the Necropolis of Dahshur

The necropolis of Dahshur (Egypt) is located approximately 30 km south of Cairo and belongs to the extensive burial fields of the Memphite region, all constructed during the Old and Middle Kingdoms. Until today, only little palaeoenvironmental research has been done in the valley of the river Nile and the adjacent areas of the Western and Eastern Deserts. Field surveys by the German Archaeological Institute (DAI) indicate that ancient settlements are presently covered by as much as 7 m of alluvial and aeolian deposits. This result shows that the relief surrounding the necropolis has been modified by natural processes since the period of the Old Kingdom. The paper analyses the landscape evolution of the surroundings of the necropolis of Dahshur since the Old Kingdom. A special focus is set on the question whether direct or indirect human impacts on the topography can be detected during the construction of the pyramids and the intensive use of channel beds as transportation routes. The following methods were applied: description of sediment characteristics of hand auger sondages, analysis of morphometrical parameters, geomorphological mapping and digging of trenches. The chronological classification of the sondages is based on the dating of sherds, a technique that mainly requires sherds from the edge of a vessel – a precondition not met by most sherds found. Five depressions, all located on top of the pyramid plateau close to the Bent Pyramid, were identified as the most significant features of the geomorphological mapping. The floors of these landforms are covered with limestone debris up to 3 cm in diameter as well as with manganese and iron chips of similar size. A trench was dug in the slope debris of one of these forms. The exposed bedrock is shaped like a rectangular step. Pottery, probably dating to the period of the Old Kingdom, was found at the bottom of the trench. These forms were identified as limestone quarries. The selected sondages are characteristic of the typical landscape units of the study area: floodplain of the river Nile, channel beds of the limestone escarpment of the Western Desert and the desert margins east of the escarpment scarp. The drillings in channel beds reveal 7.5 m thick alternating layers of medium- and fine-grained sand. These layers were also detected on top of fluvial layers in the floodplain of the river Nile. The analysed terrestrial archives in the surroundings of the necropolis of Dahshur and morphometrical terrain parameters used as proxy data allow conclusions about landscape evolution in the past 5,000 years. Two main relief-forming factors were identified: mining as a factor lowering the relief on a small scale and aeolian dynamics as a factor with a levelling effect. Without the levelling effect of the partly 8 m thick sand sheet on top of the wadi floors, the pyramid plateau must have made an even more dominant impression in ancient times than today.

Zusammenfassung: Analyse der vergangenen und rezenten Landschaft im Umland der Nekropole von Dahschur

Die Nekropole von Dahschur (Ägypten) liegt etwa 30 km südlich von Kairo und gehört zu den ausgedehnten Gräberfeldern der memphitischen Region im Alten und Mittleren Reich des antiken Ägyptens. Bis heute liegen nur wenige Paläoumweltstudien im Niltal und den angrenzenden Bereichen der Western und Eastern Desert vor. Geländearbeiten des Deutschen Archäologischen Instituts (DAI) weisen darauf hin, dass die antiken Siedlungen heute von bis zu 7 m mächtigen äolischen und fluviatilen Ablagerungen überdeckt sind. Dieses Ergebnis zeigt, dass das Relief im Umland der Nekropole seit dem Alten Reich durch natürliche Prozesse überprägt ist. Dieser Aufsatz analysiert die Landschaftsgenese im Umland der Nekropole von Dahschur seit dem Alten Reich. Ein besonderer Fokus liegt dabei auf der Frage, ob während der Bauphase der Pyramiden und der damit verbundenen intensiven Nutzung der Gerinnebetten als Transportweg direkte oder indirekte menschliche Einflüsse auf das Relief festgestellt werden können. Die folgenden Methoden wurden angewendet: Beschreibung von Sedimentcharakteristiken von Sondierungen, die mittels eines Handbohrers durchgeführt wurden, Analyse von morphometrischen Parametern, geomorphologische Kartierung und die Anlage von Schurfen. Die Datierung der Bohrungen basiert auf archäologischen Artefakten. Ein Verfahren, das überwiegend Randscherben benötigt – eine Voraussetzung, die die meisten Scherben in den Bohrungen nicht erfüllten. Bei der geomorphologischen Kartierung wurden fünf Geländedepressionen identifiziert, alle auf dem Pyramidenplateau in der Nähe der Knickpyramide gelegen. Der Boden dieser Formen war bedeckt mit Kalksteinschutt bis zu einer Größe von 3 cm und Magnesium- und Eisenchips in gleicher Größe. Es wurde ein Schurf in die Schuttablagerungen, die die Seiten einer der Depressionen bedeckt, gegraben. Das so exponierte anstehende Gestein war wie eine rechtwinklige Stufe geformt. Keramik, die wahrscheinlich in das Alte Reich datiert, wurde am Boden des Schurfs gefunden. Auf der Grundlage dieser Ergebnisse wurden die Depressionen als Steinbrüche identifiziert. Die Bohrungen sind charakteristisch für die typischen Landschaftseinheiten des Untersuchungsgebiets: die Aue des Nils, die Gerinnebetten der Kalksteinschichtstufe und der Übergangszone zwischen Wüste und Nilaue. Die Bohrungen im Gerinnebett ergaben 7,5 m mächtige alternierende Schichten von Mittel- und Feinsand. Diese Sandschichten konnten ebenfalls in den Bohrungen in der Nilaue identifiziert werden. Die Analyse der terrestrischen Archive im Umland der Nekropole von Dahschur zusammen mit den Ergebnissen der geomorphologischen Kartierung erlaubt Schlussfolgerungen über die Landschaftsgenese der letzten 5000 Jahre. Zwei Hauptfaktoren, die auf das Relief einwirken, wurden identifiziert: der Abbau von Baumaterial als ein Faktor, der das Relief kleinräumig mindert und äolische Dynamik, die ausgleichend auf das Relief wirkt. Ohne den nivellierenden Effekt der teilweise 8 m mächtigen Sandschicht, die in den Gerinnebetten liegt, müssen die

Pyramiden einen noch imposanteren Eindruck in der Vergangenheit hinterlassen haben, als es heute der Fall ist.

Résumé: Analyse des paysages anciens et récents situés aux alentours de la Nécropole de Dahchour

La Nécropole de Dahchour (Égypte) est située à environ 30 km au sud du Caire et fait partie des grands champs sépulcraux de la région memphite dont la construction eut lieu au cours de l'Ancien et du Moyen Empire de l'Égypte ancienne. Jusqu'à aujourd'hui, peu d'études paléoenvironnementales ont été effectuées dans la vallée du Nil et sur les territoires environnants des déserts est et ouest. Les travaux sur le terrain dirigés par l'Institut Allemand d'Archéologie (DAI) révèlent que les cités antiques sont recouvertes aujourd'hui d'une couche de dépôts éoliens et fluviaux pouvant atteindre jusqu'à 7 m d'épaisseur. Ce résultat montre que des processus naturels sont à l'origine de la formation du relief environnant la nécropole depuis l'Ancien Empire. Cet article analyse la genèse du paysage environnant la nécropole de Dahchour depuis l'Ancien Empire. Un accent particulier est mis sur la question de savoir si des influences humaines directes ou indirectes peuvent être constatées sur le relief pendant la phase de construction des pyramides et de l'utilisation intensive des lits de cours d'eau comme voie de transport en relation avec à ces travaux de construction. Les méthodes utilisées ont été les suivantes: la description des caractéristiques sédimentaires des sondages exécutés au moyen d'une tarière à main, l'analyse des paramètres morphométriques, l'établissement d'une carte topographique géomorphologique et le creusement de tranchées. Afin de déterminer la date des prélèvements de forage, nous avons pris pour base les artefacts archéologiques. C'est un processus qui nécessite principalement de dater les débris – une condition que la plupart des débris ne remplissent pas dans les prélèvements des forages. Lors de l'établissement de la carte topographique géomorphologique, cinq dépressions de terrain ont été identifiées; elles se trouvent toutes sur le plateau des pyramides à proximité de la pyramide pliée. Le sol de ces formations était couvert de débris de pierres calcaires pouvant atteindre jusqu'à 3 cm de diamètre et d'éléments de manganèse et de fer d'une grosseur similaire. Nous avons creusé une tranchée dans les couches de débris qui recouvrent les côtés d'une des dépressions. La roche ainsi exposée a été formée comme une marche à angle droit. Au fond de la tranchée, nous avons trouvé de la céramique datant sans doute de l'Ancien Empire. Sur la base de ces résultats, les dépressions ont été identifiées comme carrières de pierres. Les forages nous livrent des éléments caractéristiques pour les unités de paysages typiques de la région étudiée, à savoir pour la plaine alluviale du Nil, pour les lits des cours d'eau dans les côtes de pierres calcaires et pour la zone de transition entre le désert et la plaine alluviale du Nil. Les forages effectués dans les lits des cours d'eau ont révélé la présence de couches alternées de sable moyennement fin et de sable fin d'une épaisseur totale de 7,5 m. Ces couches de sable ont pu être identifiées également dans les forages effectués dans la plaine alluviale du Nil. Les résultats de l'analyse des archives terrestriques issues des alentours de la nécropole de Dahchour et ceux livrés par la carte topographique géomorphologique nous autorisent à tirer des conclusions sur la genèse du paysage au cours des 5000 dernières années. Nous avons identifié les deux facteurs principaux qui ont eu une influence sur le relief: il s'agit d'une part du transport de matériel de construction en tant que premier facteur réduisant le relief à l'échelle locale et d'autre part, de la dynamique éolienne exerçant un effet équilibrant sur le relief. Sans l'effet nivelant de la couche de sable épaisse de 8 m dans laquelle se trouve le lit des cours d'eaux, les pyramides doivent avoir fait au passé une plus dominante impression sur les hommes qu' aujourd'hui.

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