Mesolithic Site Formation and Palaeoenvironment Along the White Nile (Central Sudan)

Article *in* African Archaeological Review · September 2011

DOI: 10.1007/s10437-011-9095-3

3 authors:

Sandro Salvatori
Centro Studi Sudanesi e Sub-Sahariani, Treviso, Italy

Donatella Usai
Centro Studi Sudanesi e Sub-Sahariani

Andrea Zerboni
University of Milan

Afr Archaeol Rev (2011) 28:177–211
DOI 10.1007/s10437-011-9095-3

ORIGINAL ARTICLE

Mesolithic Site Formation and Palaeoenvironment Along the White Nile (Central Sudan)

Sandro Salvatori · Donatella Usai · Andrea Zerboni

Published online: 16 June 2011

Abstract The Mesolithic period represents a key stage in the human history of Sudan, but its complexity is not yet fully understood. Since the beginning of prehistoric research in this region, efforts were made to understand Mesolithic site formation processes and post-depositional disturbances. Responsibility for the destruction of most Mesolithic sites' deposits rests mainly on later use of the ancient mound-like settlements as burial places by Meroitic and post-Meroitic people. Excavations at several sites in the El Salha and Al Khiday areas (White Nile, south of Omdurman) have provided recent progress in our knowledge of Mesolithic living structures in their palaeoenvironmental contexts. Detailed stratigraphic and geoarchaeological investigations enabled us to distinguish, within the sequences identified at excavated mounds, the existence of basal archaeological strata still in situ that had remained unaffected by subsequent anthropogenic disturbances and to understand the functional aspects of several archaeological features associated with Mesolithic living floors. This offers the opportunity to reassess the Mesolithic cultural sequence in the region and reconsider some statements on the economic and social aspects of Mesolithic life and landscape exploitation strategies.

Résumé La période mésolithique représente une étape clé dans l'histoire humaine du Soudan, mais elle n'est pas encore comprise dans toute sa complexité. Depuis le début des recherches préhistoriques dans cette région, les travaux ont cherché à élucider les processus de formation et perturbations post-dépositionnelles des sites mésolithiqes. Malheureusement, les dépôts de la plupart de ces sites sont perturbés. Ces destructions resultent en majorité de la réutilisation postérieure des buttes

S. Salvatori · D. Usai
Is.I.A.O.—Istituto Italiano per l'Africa e l'Oriente, Via U. Aldrovandi 16, 00197 Rome, Italy

A. Zerboni
Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Via Mangiagalli 34, 20133 Milan, Italy

D. Usai (✉)
Via di Canizzano 128/D, 31100 Treviso, Italy
e-mail: usai.salvatori@alice.it

d'habitat en tant que nécropoles par les peuples Méroitiques et post-Méroitiques. Les fouilles menées sur de nombreux sites des régions d'El Salha et d'Al Khiday (Nil Blanc, sud d'Omdurman) ont pourtant ouvert de nouvelles perspectives dans notre connaissance des structures d'habitat du Mésolithique par rapport à leur contexte paléo-environnemental. Les recherches stratigraphiques et géo-archéologiques détaillées permettent non seulement de distinguer, dans les séquences d'occupation étudiées sur les buttes fouillées, l'existence de couches archéologiques basales in situ restées intouchées par les perturbations anthropogéniques subséquentes, mais aussi de comprendre les aspects fonctionnels de plusieurs structures fixes associées aux sols d'habitats mésolithiques. Ceci offre l'opportunité de réévaluer la séquence culturelle mésolithique de la region et de reconsidérer quelques constats sur les aspects économiques et sociaux du Mésolithique ainsi que les stratégies d'exploitation du milieu.

Keywords Central Sudan · Khartoum Mesolithic · Multi-stratified site · Site preservation · Post-depositional processes · Micromorphology

Introduction

The Mesolithic period of central Sudan is known from a number of sites excavated in the last 65 years. Unfortunately, its complexity is not yet fully recognised, mainly because of the poor preservation of archaeological sites and persistent uncertainty about human burials that can be assigned to this period.

At Khartoum Hospital, the first excavated site dated to the Mesolithic period, Arkell (1949: 4) underlined that "not a hearth, posthole, or other trace of any building could be distinguished." Other archaeologists after Arkell described similar circumstances for most of the other sites investigated (Caneva 1983; Fernández et al. 2003; Haaland 1987; Haaland and Magid 1995; Krzyzaniak 1975, 1976, 1979, 1984). This situation induced most archaeologists to adopt excavation methods based on arbitrary spits of 5, 10, 20 and, in some cases, even 60 cm. Whilst this choice can be easily explained as an attempt to reconstruct possible stratigraphic and chronological trends, there is no trace of any effort to explain deposit formation processes. However, a somewhat different approach was adopted by Caneva (1983). She pointed out that the secondary use of prehistoric sites as Meroitic/post-Meroitic/Christian cemeteries, with the excavation of pit graves and the building of earthen tumulus-like structures above them, was mainly responsible for the high disturbance rate observed in the archaeological deposits (Caneva 1983).

The Is.I.A.O. El Salha project (2000–2010) tested and excavated some of the prehistoric sites located along the White Nile, a few kilometres south of Omdurman, with the use of the stratigraphic method (Barker 1977), resulting in the discovery of multi-stratified archaeological sites. These sites corresponded to both Mesolithic base camps and more permanent sites with hearths, living floors and multi-stratified graveyards, even if affected by later anthropogenic and natural disturbances. Thanks to these discoveries, it was possible to develop a model to describe natural and anthropogenic syn- and post-sedimentary formative processes that could have affected most of the prehistoric sites distributed along the White Nile between

Omdurman and the Jebel Aulia dam. At a more general level, survey and excavations allowed insights into the Mesolithic settlement pattern in central Sudan and established a more detailed chronological framework. Moreover, geomorphological investigations and geoarchaeological analyses provided reliable information on Late Quaternary climatic changes in the area, their effect on palaeoenvironmental transformations and the evolution of the Nile.

Archaeological Background

Prehistoric archaeology in Sudan started with the discovery of a Mesolithic settlement at a location that was to become the first hospital of Khartoum (Arkell 1949). Since then, archaeological activities in the country multiplied and in three decades, from the 1970s to the 1990s, several monographs appeared, illustrating some of the peculiarities of the Sudanese Mesolithic culture and of the later Neolithic "pastoral" society. Sites like Saggai 1 (Caneva 1983), Kabbashi, El Qal'a, Umm Singid (Caneva et al. 1993), Abu Darbein, Aneibis and El Damer (Haaland and Magid 1995), Shaqadud (Marks and Mohammed-Ali 1991), Sorurab 2 (Hakem and Khabir 1989), all to the north of Khartoum, Al Mahalab and Sheik Mustafa to the southeast (Fernández et al. 2003), and Shabona to the south (Clark 1973, 1989) are the most representative of the Mesolithic period of central Sudan.

With the exception of Shaqadud, a cave and midden, all sites present as a huge dispersal of archaeological material in the form of mounds flanking the banks of the River Nile, or its main tributaries. Excavations at these sites have been more or less extensive, usually starting from the highest part of the mound where deepest anthropogenic deposits were expected. According to the excavators, most of the sites revealed a total absence of stratified deposit and structures. Some examples are useful to elucidate the problem of site preservation, the quality of collected data, as well as excavation methods:

> Because the settlement deposit was not stratified in all these pits and trenches, it was excavated by arbitrary levels of 0.2 m each. Virgin soil was reached at a depth of up 0.4 m below the surface. [Krzyzaniak 1979: 246]

> Digging operations followed soil indications or, failing these, arbitrary levels 10 cm thick…although disturbed, the deposit was excavated in levels, in the hope that through the quantitative study of extensive archaeological material it would nevertheless be possible to recognise general stratigraphic trends.…Our assumption was that, although it is unlikely that all the objects maintain their stratigraphic position in a sandy matrix, the frequency of different artefacts would nevertheless be significant. In this respect we are less pessimistic than Arkell who did not believe in any significant stratigraphy in the deposit. [Caneva 1983: 11, 15]

> The first squares excavated were divided into arbitrary levels of 10 cm each since there was no natural stratigraphy. The material however turned out to be homogenous from the surface to the sterile soil; and since most of the squares were disturbed by later Meroitic burials, it was decided to excavate the remaining squares in one layer only.…In the centre around square 100*x*/100*y* the cultural debris was c. 50 cm deep. [Haaland 1987: 40]

> There is no stratigraphy on the sites and the cultural debris is homogenous from the surface down to the sterile soil; the latter consists of river gravels from the earlier course of the river. The sites were than excavated in arbitrary levels of 10 cm each. [Haaland and Magid 1995: 22]

Material and Methods

The geoarchaeological survey of the El Salha project located approx. 200 sites, representing an archive spanning from the Acheulean to the Historical Period (Usai and Salvatori 2005). Site labelling followed the rules established by Hinkel (1977). Among the many archaeological sites placed along the western bank of the Nile and more inland, some of those bearing Mesolithic and Neolithic materials were tested (sites 10-X-8, 10-X-4 and 10-X-3). A few sites showing a better state of preservation and the widest dispersion of archaeological materials were selected for extensive stratigraphic excavations: 10-X-6, 10-W-4, 16-D-5 (settlements) and 16-D-4/16-D-4b (cemetery and activity areas).

During the excavations, archaeological materials (pottery, lithics and faunal remains) were systematically collected and studied. Lithics have been analysed based on the typological system proposed by Tixier (1963) which is generally accepted by Africanists. Pottery has been classified according to the typo-technological system of Caneva (1983, 1988). Moreover, the characterization of some new ceramic types is discussed here in terms of decoration and chronometric attribution.

The main deposits and sections have been described and sampled, undisturbed sediment and soil samples from selected anthropogenic and natural deposits in the area of sites 16-D-4/16-D4b and 16-D-5 have been collected, and thin sections have been prepared at the Department of Geology and Soil Science of Ghent University (Belgium). Micromorphological studies of undisturbed sediment thin sections allow understanding the natural and anthropogenic contributions to their formation, including the functional interpretation of specific structures and their association with geological processes, on the basis of their optical properties and the spatial relationships between organic and mineral components (Courty 2001; Goldberg and Macphail 2006). Micromorphological studies of sediment thin sections employed an optical petrographic microscope (Olympus BX41, with a digital camera Olympus E420); thin sections were observed under plane-polarized light (PPL) and cross-polarized light (XPL). The terminology of Brewer (1964), Bullock et al. (1985) and Stoops (2003) was used for the description of thin sections. Notwithstanding the existence of specialized terms, general explanations have been given to facilitate the access and comprehension of micromorphological interpretation to a wider audience.

Organic matter-rich sediment samples, charcoal and faunal remains have been collected for both conventional and accelerator mass spectrometry (AMS) ^{14}C dating in order to obtain radiometric age determinations for palaeoenvironmental features and cultural horizons. The latter is particularly significant as the occurrence of *in situ* and undisturbed Mesolithic layers allows for the description of variation in pottery and lithic assemblages previously attributed to an undifferentiated cultural phase. Conventional and AMS radiocarbon dating results, 1 and 2σ calibration according to INTCAL09 (Reimer et al. 2009) with OxCal4 (Bronk Ramsey 2009) software, are presented in Tables 1 and 2 and discussed on the basis of regional archaeological and palaeoenvironmental contexts.

Site Location and Morphology

The investigated area is located in central Sudan, along the western bank of the White Nile between the Jebel Aulia dam and the confluence with the Blue Nile; it roughly corresponds to the municipalities of El Salha and Al Khiday, in the vicinity of the Khartoum–Omdurman conurbation (Fig. 1). The climate of the region is arid with mean annual temperatures of approx. 30°C and annual mean precipitation of approx. 100 mm; seasonality is marked and precipitation mainly (80–90%) occurs in summer, from July to September (El-Tom 1975).

Large Mesolithic sites are represented by low mounds, located at a distance ranging from 1 to 3 km from each other on the contour line of 382 m a.s.l. and at a distance ranging from 2.5 to 4 km from the present main Nile course, confirming the distribution of prehistoric sites located by Caneva (1983) north of Khartoum along the eastern bank of the Nile. The surface of the mounds shows wind deflation and water erosion, but is still littered with archaeological materials. Furthermore, the topography of the mounds resulting from their use as Meroitic and post-Meroitic graveyards seems to have been only slightly modified afterwards, as it was protected from wind erosion due to the occurrence of a large amount of archaeological materials minimizing dismantling, as typically occurs in arid lands (Cremaschi and Zerboni 2009). The presence of archaeological materials at the top of hillocks (Caneva 1983) is not surprising: in Sudan, prehistoric settlements and cemeteries are commonly located in this topographic position since they are elevated a few metres above the White Nile and Nile flood plains.

Table 1 Radiocarbon dates from the 16D5 Mesolithic and Neolithic site and 10W4 Mesolithic site

Lab. n.	Site SU	Material	Lab. date BP	1σ cal BC	2σ cal BC	Period
Beta-201728	16D5 SU 6	Charcoal	7980±40	7036–6827	7050–6750	Early Mesolithic
Beta-279538	16D5 SU 250	Org.Sed.	7960±40	7029–6788	7042–6699	Early Mesolithic
Beta-239622	16D5 SU 455a	Charcoal	7940±40	7023–6700	7032–6690	Early Mesolithic
Beta-213892	16D5 SU 48	Charcoal	7870±40	6768–6646	7019–6604	Early Mesolithic
Beta-239621	16D5 SU 455b	Shell	7830±40	6691–6606	6814–6572	Early Mesolithic
Beta-257255	16D5 Peat	Org.Sed.	7740±50	6629–6505	6648–6471	Middle Mesolithic
Beta-213891	16D5 SU 37	Charcoal	7710±40	6591–6501	6633–6467	Middle Mesolithic
Beta-201726	10W4 SU 12	Charcoal	6490±40	5488–5379	5529–5367	Late Mesolithic
Beta-213890	16D5 SU 5	Shell	5470±50	4360–4261	4449–4235	Neolithic

Org.Sed. organic sediment, *SU* stratigraphic unit

Table 2 Radiocarbon dates

Lab. n.	Site feature	Material	Lab. date BP	1σ cal BC	2σ cal BC	Period
Beta-239619	16D4 Pit 6A[a]	Shell	7760±90	6678–6477	7002–6433	Middle Mesolithic
Beta-239620	16D4 Pit 29[a]	Shell	7770±40	6647–6532	6679–6496	Middle Mesolithic
Beta-279537	16D4 Pit 75	Shell	7640±110	6602–6407	6697–6238	Middle Mesolithic
Beta-257258	16D4 Pit 52	Shell	7620±50	6505–6427	6591–6406	Middle Mesolithic
Beta-279536	16D4 Pit 74	Shell	7600±90	6569–6390	6634–6254	Middle Mesolithic
Beta-257257	16D4B Pit F 6	Charcoal	7540±50	6455–6380	6456–6256	Middle Mesolithic
Beta-279535	16D4 Pit 73[a]	Shell	7530±100	6466–6255	6597–6213	Middle Mesolithic
Beta-257256	16D4 SU 61	Charcoal	1940±40	19–123 AD	45 BC–136 AD	Late Meroitic
Beta-239618	16D4 Grave 47	Charcoal	1900±50	29–210 AD	3–236 AD	Late Meroitic

[a] Pit cutting grave with extended-prone individual; SU 61 = fireplace

Results

The Palaeoenvironmental Evidence

Most of the multi-stratified sites are located at the top of preexisting discontinuous ridges rising up to 4 m above the level of the surrounding plain and a few tens of metres long; hillocks (and sites) are clustered in discontinuous alignments oriented north–south, roughly parallel to the Nile course. They are distributed at the western limit of a dark belt evident in satellite images that corresponds to the limit of alluvial silt (Nile silt) deposited by the Holocene flooding of the White Nile (Fig. 2). This distribution is almost coincident with the position of an older fluvial terrace, ranging from the Jebel Aulia dam up to 5 km from the confluence with the Blue Nile, where it is hidden by recent anthropization (Omdurman municipality); southwards, due to the presence of the dam, the terrace is no longer visible. The river terrace is indicative of a higher level of the White Nile. In the same area, several meandering palaeochannels are also evident west of the present course of the White Nile; they underscore the presence of longitudinal fluvial sandy bars. In the surveyed area, the thickness of the alluvium varies from a few tens of centimetres (in association with the longitudinal fluvial bars) up to 2 m in the area corresponding to palaeochannels; Meroitic and post-Meroitic sites have been found within the dark alluvium.

Ridges hosting sites consist of a sequence of massive to weakly plain laminated coarse to fine, yellow sand (5Y 7/6 to 5Y 7/3; Munsell® 1994), interlayered with small, planar lenses of fine gravel; the upper part of the sandy bodies is deeply cemented by calcium carbonate concretions. Upon the Nile terrace, the flat area surrounding the hillocks is characterised by a very dark sediment (2.5Y 3/2 to 10YR 2/2); it is a sandy deposit, very rich in organic matter and up to 0.5 m thick, with a

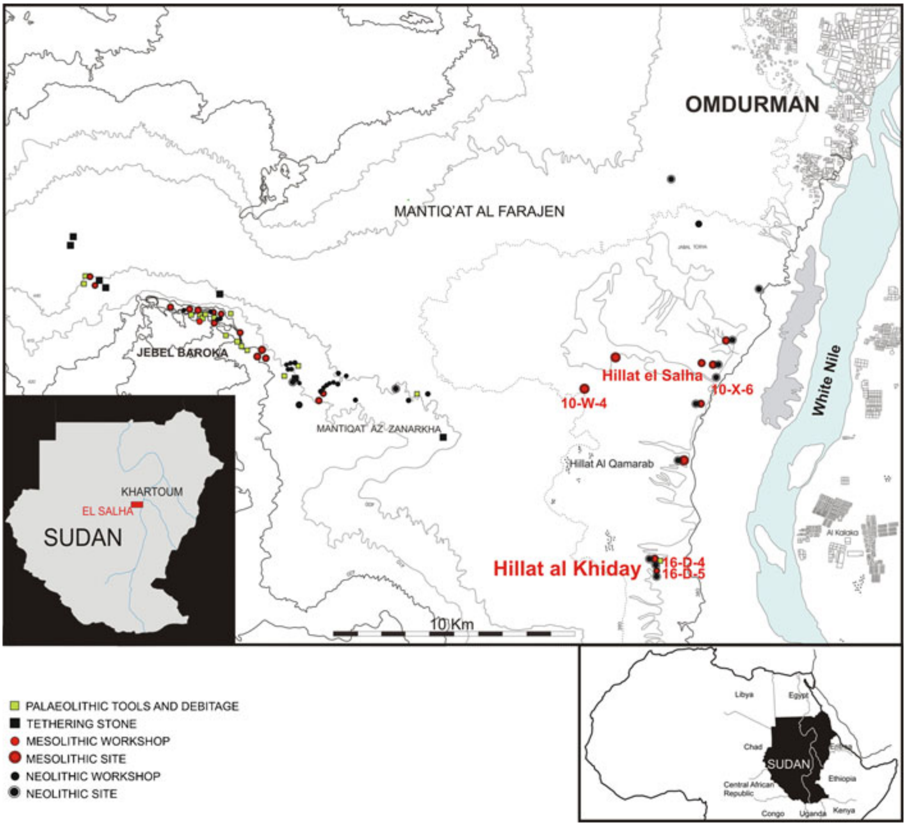

Fig. 1 Map of the area under concession and location of prehistoric sites with the Mesolithic ones mentioned in the text

well-expressed polyhedric aggregation and calcium carbonate cement increasing from the top to the base. It is not ubiquitously distributed as a consequence of wind erosion and its limits are not clear, but dark sandy spots dot a long belt corresponding to the distribution of mounds. In thin section, the deposit reveals a blocky microstructure, with a groundmass consisting of amorphous organics, whilst the coarse fraction is represented by common sandy quartz grains and minute fish bones, locally cemented by calcite. Some former elongated voids (channel) filled with the organic groundmass are related to bioturbation. Radiocarbon determination dated the formation of the deposit to 6629–6505 1σ cal years BC (Beta-257255, 7740±50 years BP; Usai et al. 2010).

The Excavation at Site 10-X-6

Site 10-X-6 is a multi-stratified mound, up to 4 m above the level of the surrounding plain, and approx. 9 ha large (Fig. 3). The excavation of this site started in 2001 and was carried out for three field seasons (Usai and Salvatori 2006a, b). After an instrumental mapping and surface collection with thorough examination of the material distribution, an excavation trench was opened at the highest point of the

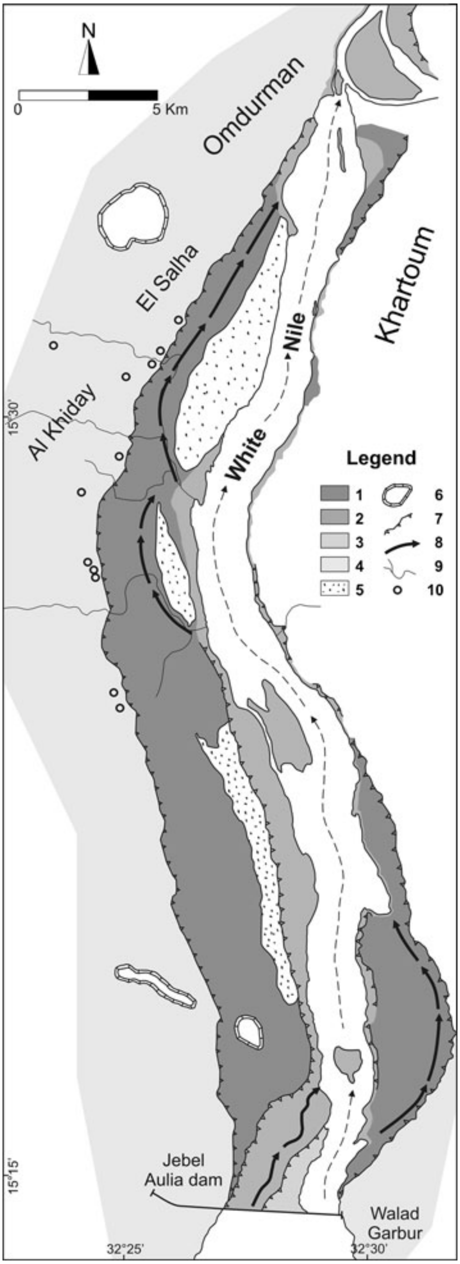

Fig. 2 Simplified geomorphological map of the investigated area; main localities are indicated. *1–3* Nile alluvium (silt). *4* Glacis (sand to gravel). *5* Longitudinal bar (sand). *6* Bedrock outcrops. *7* Terrace. *8* Palaeochannel. *9* Active fluvial net. *10* Mesolithic sites

mound. Remarkable concentrations of Mesolithic pottery and lithic material were also found along the western slope of the mound, nowadays used as a cemetery and for this reason not excavated.

Within a 4×10-m trench, traces of a post-Meroitic earthen tumulus-like grave of large dimensions with a residual mud-brick structure were found; a small test trench, 2×1 m, was excavated to evaluate the depth of the deposit in this area. The trench,

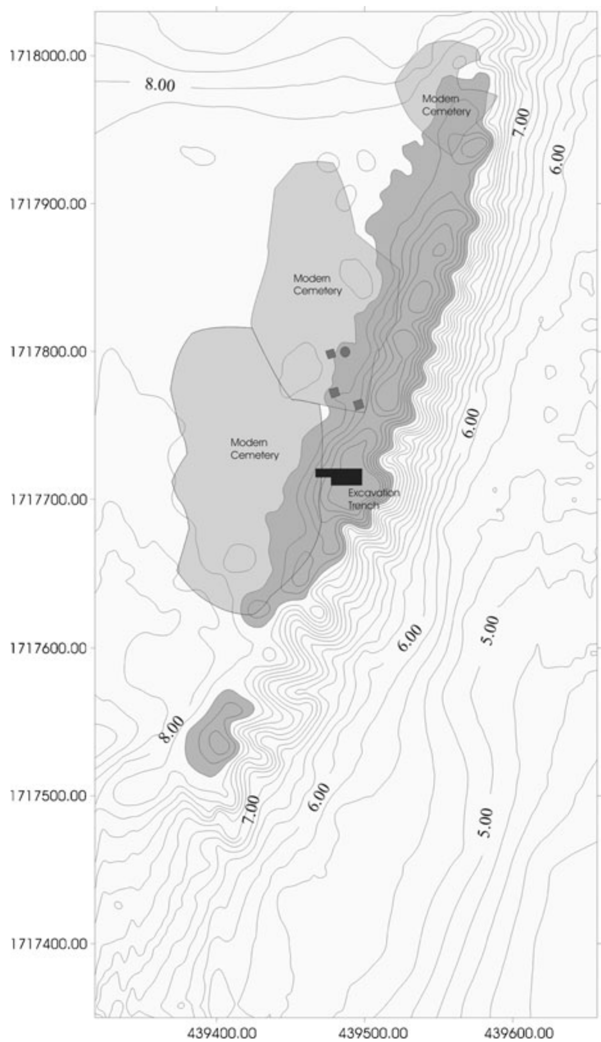

Fig. 3 Map of the Mesolithic site 10-X-6

notwithstanding the difficulties of detecting variations in sediment deposition in such a small space, revealed a 2.5-m-thick anthropogenic deposit (Fig. 4). For a full detailed investigation of the post-Meroitic funerary structure, the excavation area was doubled (8×10 m). Ancillary post-Meroitic graves were located around the main, deeper burial chamber. They were mainly graves of children, clearly connected with the main shaft and its mostly destroyed mud-brick structure (Usai and Salvatori 2006b). Later, a series of brown sediment layers were excavated and found to be heavily disturbed by large animal burrows. These layers provided a very low amount of mixed Neolithic and Mesolithic materials and faunal remains. The sequence of brown deposits was lying on the bedrock, represented by a sandy ridge rising approx. 2 m above the flood plain (Fig. 4). From the western border of the bar, a V-shaped water drain was cleaned, filled with prehistoric material (mainly stone grinders and grinding stone fragments). Similar features produced by seasonal water

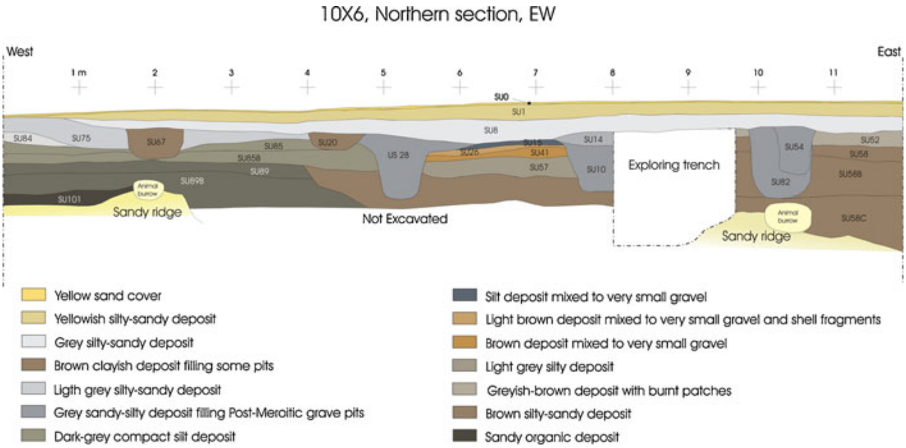

Fig. 4 Stratigraphic section of site 10-X-6

erosion are commonly observable along the slopes of the archaeological mound-like sites in the area.

Having established that no in situ prehistoric deposit was preserved at the highest elevation of the site, it appeared reasonable to enlarge the excavation trench towards the gentle western slope of the mound and the modern cemetery. Although disturbed by the cemetery, a poorly preserved thin layer of anthropogenic deposit bearing traces of a fireplace and archaeological material apparently *in situ*, according to the associated pottery sherds, was found immediately above the bedrock.

The Excavation at Site 16-D-5

The experience made at site 10-X-6 was useful to design a different approach to the excavation of site 16-D-5 (Fig. 5). It is a smaller mound (0.9 ha) compared to 10-X-6 and other Mesolithic sites, but the surface evidence suggested that it was frequented

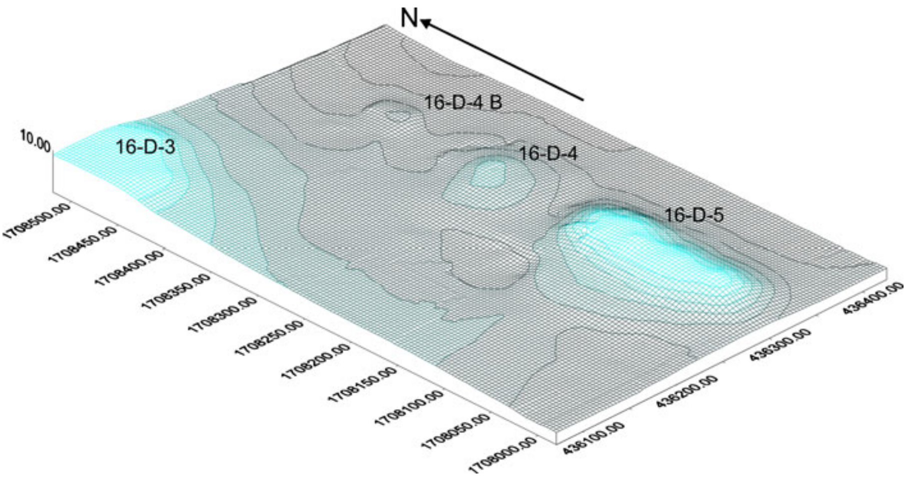

Fig. 5 Digital model of sites 16-D-4 (Al Khiday 2), 16-D-4b, 16-D-5 (Al Khiday 1)

during Mesolithic and Neolithic times. There was also no modern cemetery, which would have prohibited excavation. The highest part of the mound, with stone structures made with assembled grinding stone fragments, together with the slightly domed morphology, suggested that it had been used in post-Meroitic times as a cemetery and for this reason was excluded as an excavation area.

The first excavation at the site, a 4×4-m trench, opened on the western slope of the approx. 4-m-high mound, brought to light a silty to sandy, greyish brown deposit very rich in archaeological materials similar to the deposits excavated at 10-X-6 site. The deposit was loose and powdery without any traces of detectable features, except for recent animal burrows. At approx. 0.5 m under the surface, the top of a pit capped by a number of grinding stone fragments, pestles and grinders mixed with mostly Neolithic and Mesolithic potsherds was identified and excavated. This proved to be an ancillary post-Meroitic grave, possibly associated with the main earthen tumulus grave located to the east of it. The loose sediment covering the top of the pit grave and part of the similar deposit into which the pit was excavated resulted to be of colluvial origin, as a consequence of remodelling the earthen post-Meroitic tumulus grave to the east.

At the base of the post-Meroitic pit-grave, a deposit with substantial traces of ashes, coarse charcoal and shell fragments (gen. *Pila*; Girod 2008) was encountered. Inside this layer, a fireplace with a concentration of shells, lithic, pottery and burnt animal remains was found; radiocarbon dating on charcoal gave an age of 7036–6827 1σ cal years BC (Stratigraphic Unit[1] 6: Beta-201726, 7980±40 years BP). This feature (Fig. 6a), together with the fireplace at Qoz excavated by Arkell (1953) and an ashy-pit excavated at Shabona (Clark 1989), represented one of the extremely rare Mesolithic archaeological structures found in central Sudan.[2] Furthermore, the excavation of this feature revealed fragments of Mesolithic pottery belonging to a type never before attested in the region (Usai and Salvatori 2005). A pebble with the schematic representation of a boat (Salvatori and Usai 2007) and a grinding stone with clear traces of red and yellow ochre were also collected.

After we found a possible *in situ* Mesolithic deposit, a wider excavation was planned and a larger trench, which included the area previously excavated, was opened. At the interface, a semi-circular feature with associated traces of burnt deposits and poorly fired mud concentrations were detected. These and similar structures brought to light in the following field seasons have been interpreted as mud structures (SU27, SU33, SU64 and SU410) that are the remains of low walls (Fig. 6b) built by piling up mud, a technique called in Sudanese Arabic *jalous*. These structures belong to a Mesolithic settlement phase, as confirmed by the associated archaeological materials and a radiocarbon date (using charcoal) of 6591–6501$1\sigma$ cal years BC (SU37: Beta-213891, 7710±40 years BP). In thin section (Fig. 7), the structure shows sandy to coarse silty quartz grains in a brown amorphous organic matter matrix, producing a very dense groundmass (close to single-spaced porphyric

[1] Afterwards indicated as SU.

[2] "...several circular aggregation of artefacts that suggest the presence of small storage or rubbish pits in the site" (Fernandez et al. 2003:278) were noticed at Sheik Mustafa Mesolithic site, but not particularly well documented and contextualised. We wonder if this can be attributed to the "artificial levels" excavation method adopted when investigating the site (Fernandez 2003: 277).

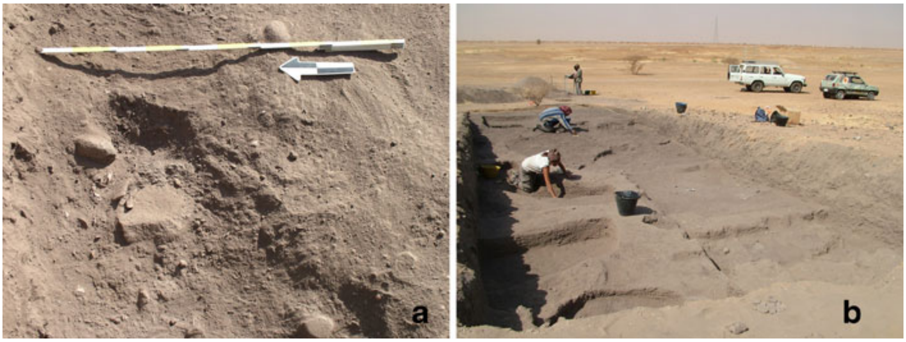

Fig. 6 Archaeological evidence at site 16-D-5. **a** Fireplace with grinding stones. **b** View of the excavated area with mud structures

c/f-related distribution; Stoops 2003). Organics are common and consist of burnt fish bones and mollusc shells; however, vegetal remains (including seeds and silica phytoliths) are scarce. Fragments of former soil material aggregates (pedorelicts; Brewer 1964) were identified. We notice two different types of soil aggregates: one possibly inherited from the organic deposit surrounding the site and the other consisting of fragmented sandy to clay surface crusts.

The structural remains described above pertain to a second phase of the Mesolithic sequence at the site, whilst the first one is represented by fireplaces. One of them, rich in faunal and pottery remains, was radiocarbon dated 7020–6700 and 6691–66061σ cal years BC (SU455: Beta-239622, 7940±40 years BP, on charcoal; Beta-239621, 7830±40 years BP, on shell).

An extension of the excavation area to the east towards the highest part of the mound was decided upon and the more eastern squares produced evidence of heavily damaged mud structures, almost unrecognisable in a mass of loose sediments. Their chronological attribution remains to be ascertained, whilst it is certain that the deep disturbance was produced by at least two post-Meroitic ancillary pit graves so far identified in the area. In the very western part of the trench, below a 10-cm-thick deposit of packed Neolithic pottery fragments intermixed with shell and faunal remains (radiocarbon dated to 4360–42611σ cal years BC; Beta-213890, 5470± 50 years BP), a natural organic matter-rich deposit was identified.

On the basis of samples taken from a section at site 16-D-5, the deposit can be divided into two main units accumulated starting from the sandy bedrock of the

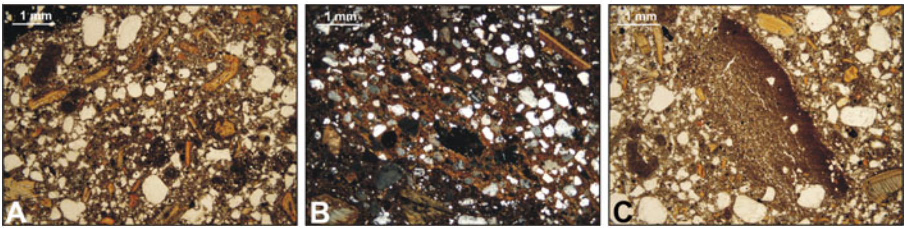

Fig. 7 Photomicrographs from site 16-D-5, SU 410 (mud wall). **a** Compact groundmass with clastic and organic components (bones) without textural selection (PPL). **b** One fragment of reworked preexisting soil material (pedorelicts; Brewer 1964), poorly preserved (XPL). **c** Fragment of surface crust; notice the fining upwards trend (PPL)

ridge (Figs. 8 and 9). The lower part of the anthropogenic deposits reaches a maximum thickness of approx. 0.7 m and has a moderately firm sandy to silty matrix, rich in finely subdivided organic matter and showing weak planar lamination; the dominant colour is 5Y 4/1 to 5Y 4/2 (dark grey to olive grey). The coarser fraction is represented mainly by pottery fragments, mollusc shells and minute to large faunal remains (fish bones) and less common are fragments of stones (recognisable as former artefacts: hammers, pestles and grinding equipments); anthropogenic constituents are mostly aligned, forming horizontal, evanescent stone lines. In the micromass, we noticed some evidence for ash lenses and few calcium carbonate concretions.

The upper macro-unit has a thickness shifting from approx. 0.6 m in the east to 0.1 m in the west and is represented by a loose sandy to silty matrix, massive, but locally showing large oblique lenses juxtaposing each other. Disturbances due to bioturbation are evident and consist of burrows, filled by yellow sand and modern vegetal remains. The coarse fraction comprises a chaotic mix of pottery fragments, burnt bones and stone fragments (vertically and horizontally oriented). The transition between the two macro-units is clearly distinctive.

Differences between the two macro-units were detected also at the microscope (Fig. 9). In thin section, the lower unit has sandy to silty quartz grains in a dark to brown amorphous organic matter matrix filling all interstitial spaces between the coarser constituents (close to single-spaced porphyric c/f-related distribution; Stoops 2003). The groundmass is sometimes cemented by microcrystalline calcite. Organic remains are common and consist of fish bones and mollusc shells; few fragments of pottery and former soil material aggregates were identified. Throughout the section, a moderate lenticular lamination is detectable, resulting in preferential alignments of bone and shell fragments and sand lenses. On the contrary, a thin section from the upper part of the deposit has coarse and fine sandy and silty quartz grains (with a bimodal sorting); the amount of organics in the groundmass is much reduced compared to the lower layers and is present in the shape of sub-rounded amorphous, distinct micro-aggregates in the intergranular spaces between the coarser components (close fine/single-spaced equal enaulic c/f-related distribution; Stoops 2003). Pedorelicts (Brewer 1964), coarse grains and bone fragments are rounded and sometimes present an amorphous organic coating. Elongated, wavy internal

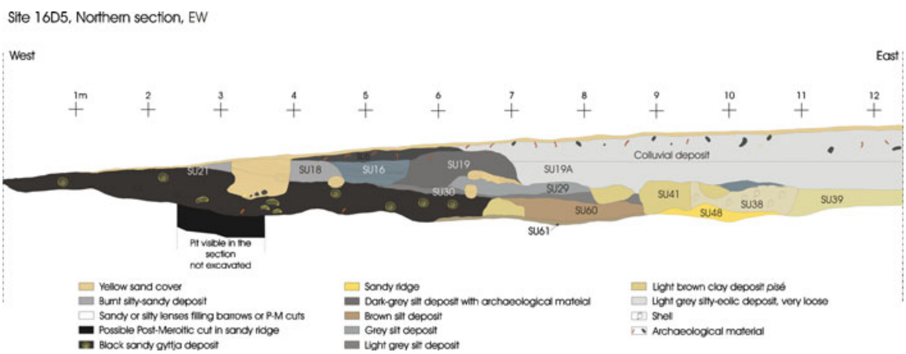

Fig. 8 Stratigraphic section at 16-D-5

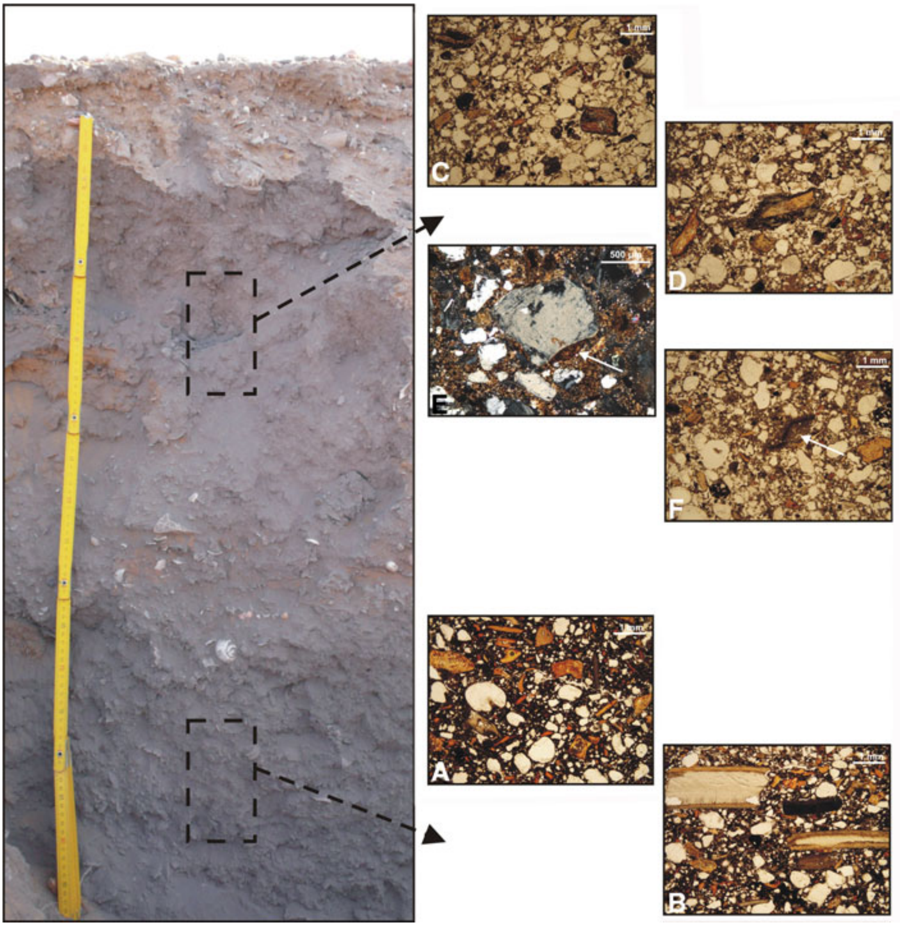

Fig. 9 Photomicrographs comparing the micromorphological properties of the upper and lower macro-units at 16-D-5. **a** Groundmass of the lower macro-unit; note the finer material filling all interstitial spaces (i.e., porphyric c/f relative distribution) and the organic amorphous micromass (PPL). **b** Preferential alignments of shell fragments and minute components (e.g., bones) in the lower macro-unit (PPL). **c** Groundmass of the upper macro-unit, with a sandy bimodal texture; note the substantial lack of organic micromass compared to (**a**). **d** Upper macro-unit: bone fragment with a reworked calcite coating (PPL). **e** Upper macro-unit: large quartz grain with a residual organic amorphous coating (XPL). **f** Upper macro-unit: wavy internal concentration of given size fractions (intercalation; Stoops 2003; PPL)

concentration of given size fractions (intercalations; Stoops 2003), coarse coatings and reworked micritic coatings on mineral and organic components are also present.

The Excavation at Sites 16-D-4 and 16-D-4b

Site 16-D-4 is located 50 m to the north of site 16-D-5. The site surface was characterised by the presence of an impressive amount of fragmentary stone artefacts (grinders, grinding stones, stone rings, stone hammers), together with scattered human bones, and few potsherds. Almost 1,000 m^2 have been excavated and 154 graves were recovered; according to direct and indirect dating, the graves belong to at least three different phases: pre-Mesolithic, Neolithic and Meroitic (Usai et al. 2010; Fig. 10).

Nearly 70 graves belong to a pre-Mesolithic phase, showing an unusual ritual of body deposition (Usai et al. 2010). The individual was buried in a prone and elongated position, a rare ritual only attested to in Africa at Wadi Kubbaniya (Wendorf and Schild 1986) and Jebel Moya (Addison 1949; Brass 2009 and personal communication 2010),[3] as well as in the Near East at several Natufian sites (Bocquetin 2005) and in Europe at Dolni Vestonice (Klima 1987). Pre-Mesolithic burials contained no grave goods, apart from the individual in Grave 153 who had an ivory bracelet at the right wrist (Fig. 11). Unfortunately, despite many attempts, no direct radiometric date is yet available for the prehistoric prone skeletons of the first burial phase (Usai et al. 2010). In fact, all skeletons have suffered from a heavy diagenetic process, possibly due to peculiar climatic conditions occurring in the Holocene, favouring a continuous recycling of calcium carbonate in the form of subsequent calcite dissolution and recrystallization (Usai et al. 2010). This phenomenon would have disruptive effects on the inner structure of bones, which therefore did not preserve a sufficient amount of collagen for dating. The mineralogical, inorganic parts of bones also suffered weathering as an effect of independent environmental processes.

In contrast, the Neolithic burials are all in a flexed contracted position. Whilst most of them have no grave goods, some were furnished with pottery vessels and/or ornamental and possibly ritual objects. The pottery vessels, mainly bowls, belong to the Shaheinab Neolithic horizon (Arkell 1953; Salvatori and Usai 2009: Plate IV, c).

The Meroitic graves have a very elaborate structure: a trapezoidal/rectangular pit, usually measuring 2–3 × 1–2 m, with a short ramp bearing to a chamber that can be round or oblong. The trapezoidal pit cuts through the deposit down to bedrock, partially incising it, and the chamber is usually cut into bedrock. Another type of grave structure is identified by a large circular pit (the largest located at the site has a diameter of almost 10 m) and a chamber placed on a side (Fig. 12). The circular pit, as well as the chamber, incises the bedrock. Four of these graves have been located and one was fully excavated, but unfortunately, all of them, judging from the filling, seem to have been robbed in antiquity. Meroitic graves disturb many of the more ancient burials, destroying them completely or leaving only part of the skeleton. The Meroitic graves have been dated between the first century BC and the second

[3] The single skeleton found at Wadi Kubbaniya has been dated to the Late Pleistocene, between 30000 and 20000 BP, on sedimentological grounds (Wendorf and Schild 1986: 71–74), but as it was found on the surface, this chronological attribution should be considered with caution. Graves at Al Khiday 2 may be as ancient, but until discrete confirmation is obtained, the "pre-Mesolithic" label will be adopted. Graves following the same funerary ritual were found also at Jebel Moya (Addison 1949), but the poor recording standard during the excavation and the lack of a systematic approach in the publication does not allow proper evaluation of the context. However, a few observations can be supplied that indicate how the association between the two sites is not congruent: (a) One grave following this ritual (Addison 1949: 61) was accompanied by pottery and other grave goods, whilst among the more than 70 individuals recorded at 16D4, *only one* had an ivory bracelet. (b) The two radiocarbon dates available for Jebel Moya (Clark and Stemler 1975) place the site in a much later chronological setting (2750±100 BC) than the early burials at site 16D4. An Early Khartoum phase at this site has been estimated (only on pottery analysis from mixed deposits) not to go further back than 5000 BC (Caneva 1991; Gerharz 1994), still 2000 years later than the context at Al Khiday 1 and 2.

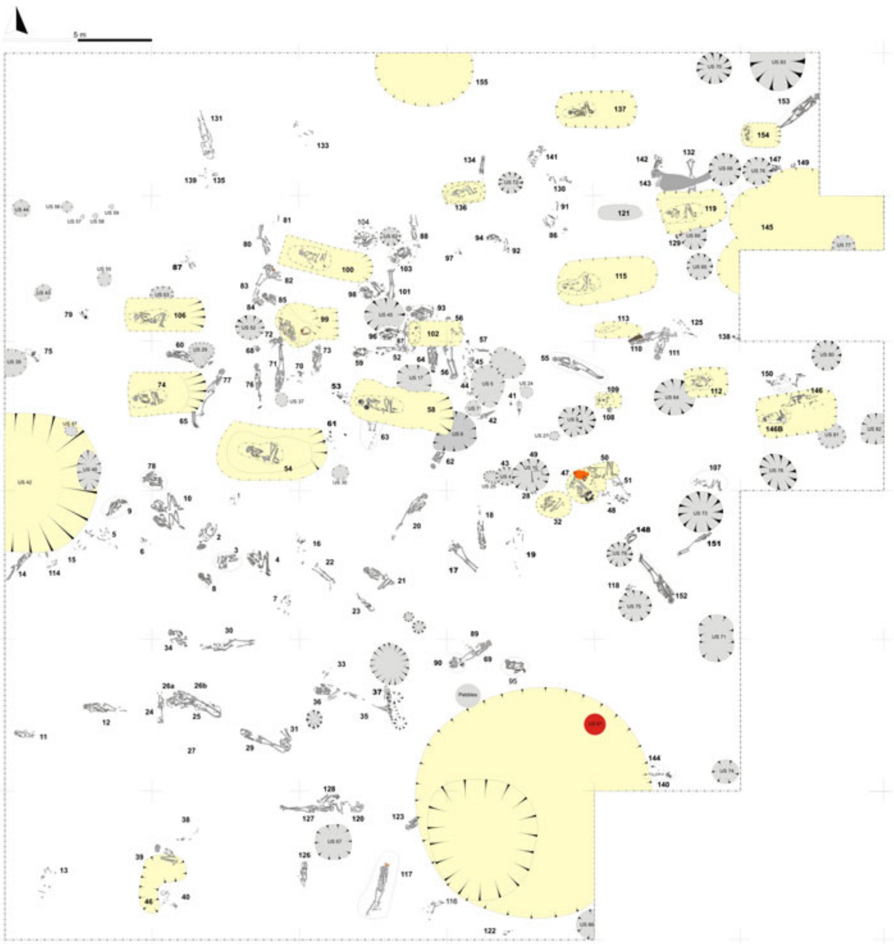

Fig. 10 Plan of cemetery 16-D-4 updated to 2009 field season

century AD (Grave 47 Beta-239618: 1900±50 years BP and SU 61[4] Beta-257256: 1940±40 years BP, both on charcoal).

During the excavation, it was noticed that a number of the elongated-prone burials had been cut by pits (Fig. 13a, b) pertaining to a Mesolithic use of the area and dated at ca. 6700–6500 cal years BC (Table 2). The importance of these pits is twofold. Firstly, as above stated, they helped define an *ante quem* date for the prone burials; secondly, they represent the most interesting, and unique, structural and functional remains of the Mesolithic period in Sudan. These features are contemporaneous, from ^{14}C dates and from the cultural material, to the second cultural phase recognised at site 16-D-5 (Tables 1 and 2). The pits are visible soon after a surface clearing and, whilst limited, the dispersal of the upper part of their content shows that the original level, from which they had been excavated, has been eroded. A more consistent erosion process has surely affected the area in the time

[4] SU 61 is a fireplace associated to Grave 124.

Fig. 11 Prone-extended individual of Grave 153 with a focus on the ivory bracelet in situ

elapsed between the burial of the prone-elongated individuals and the second quarter of the seventh millennium BC Mesolithic exploitation of the mound. This is witnessed by the fact that most of the prone burials have been found just 0.1–0.3 m beneath the modern surface. The preservation of most of the human bones and other archaeological evidence, such as the presence of residual burial pits, led us to assume that the dead were buried in pits and not just placed on the surface.

A total of 27 Mesolithic pits were found at 16-D-4 (Fig. 13a), with depths varying from 0.5 to 0.8 m. The pits contain hard deposits, with calcium carbonate cement including a large amount of archaeological material: pottery, grinding stones, faunal and botanical remains. However, lithic tools are rare. A block obtained from the upper infilling of a pit (SU45) shows a mixture of calcite and sediments. The groundmass consists of carbonate cement, including mainly quartz grains, resulting in a crystallitic b-fabric (Fig. 14). Voids are represented mostly by irregular chambers, which are up to 1 cm in width, giving a chamber microstructure. Most of the voids present a continuous microcalcite coating and in many cases are completely filled by micro- or macrocrystals of calcite. Pedorelicts (Brewer 1964), burnt bones, vegetal remains, phytoliths (in many cases vitrified), residual wood fragments and microcharcoals are also present. In the carbonatic micromass, it is

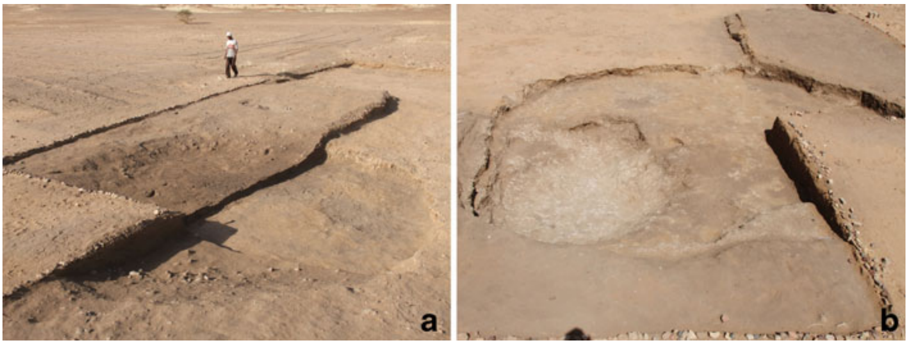

Fig. 12 Meroitic Circular Grave 142 under excavation (**a**) and completely cleaned (**b**)

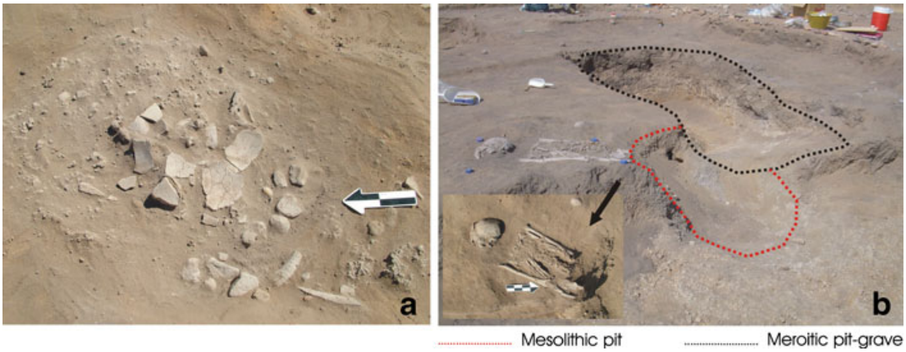

Fig. 13 **a** Mesolithic pit with pot sherds, fragment of grinding stones and animal bones. **b** Pre-Mesolithic grave cut by a Mesolithic pit cut by a Meroitic rectangular pit grave at 16-D-4

possible to identify several calcite crystals resulting from wood ash (pseudomorphs after Ca oxalate crystals; Courty et al. 1989).

More pits, with a different fill, and supposedly of different function, were excavated at site 16-D-4b, 70 m to the north of 16-D-4 (Fig. 15). The surface in this area does not show any archaeological evidence; the only find on the surface was a small bone fragment. Yet a surface cleaning around the bone produced a very regular pit filled with a dark deposit containing animal bones and pottery, almost cemented in a sandy matrix. Lenses of charcoal were also identified. A 5×5-m area was cleaned and four more pits were found; they have different dimensions, but all are very regular. The filling is made of dark greyish sandy sediment, and often, faunal remains were recovered as part of anatomically connected skeletons of mammals and fishes. In a block sampled from the

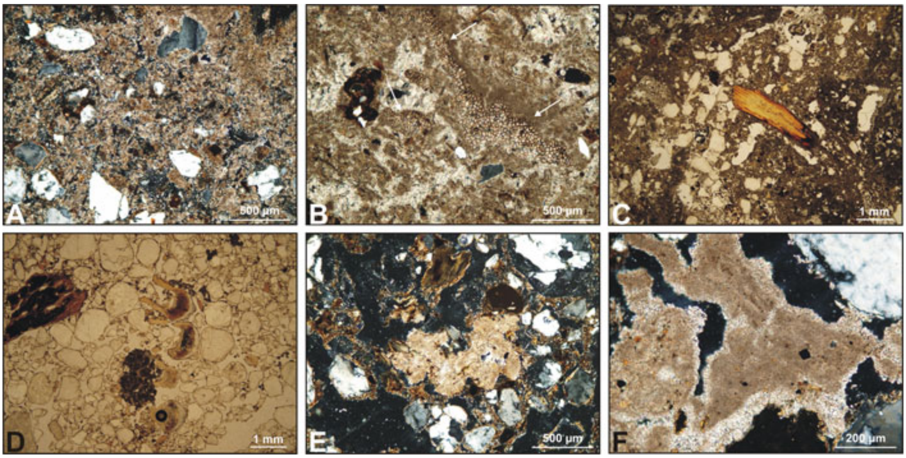

Fig. 14 Photomicrographs from the infilling of the pits at 16-D-4 and 16-D-4b. **a** 16-D-4, SU45: groundmass with calcite crystals originating from wood ash. Note the crystallitic b-fabric (XPL). **b** 16-D-4, SU45: wood remains in a calcite micromass. Note voids filled by calcite macrocrystals (XPL). **c** 16-D-4, SU45: burned bone fragment in the calcite micromass (PPL). **d** 16-D-4b, F6: the finer material occurs as coatings surrounding the sandy components, or at least creating bridges linking the coarser constituents (chitonic to gefuric c/f-related distribution). Stoops 2003). Note the presence of fish bones almost in anatomical connection. **e** 16-D-4b, F6: reworked calcite nodule (XPL). **f** 16-D-4b, F6: microcharcoals within a micro-calcite nodule (XPL)

Fig. 15 One of the pits at site 16-D-4b; the fill contains pottery fragments and faunal remains

upper part of pit F6, the finer material occurs only as coatings surrounding the coarser components, or at least creating bridges linking the coarser constituents (gefuric to chitonic c/f-related distribution; Stoops 2003). The coarse fraction is represented by rounded sandy quartz grains and includes bones and former sediment fragments. Calcite coats all the components and locally forms irregular microcrystalline nodules. Few vegetal remains are in the groundmass, including microcharcoals and very few vitrified phytoliths. A radiocarbon determination on charcoal (Beta-257257, 7540± 50 years BP, 6455–6380 1σ cal years BC) and the associated pottery confirm that these pits are roughly contemporaneous to those found at 16-D-4.

The Excavation at Late Mesolithic Site 10-W-4

The site is located on the southwestern border of the ancient swamp that occupied a vast area west of the Nile during the Early and Middle Holocene (Cremaschi et al. 2006). It appears as a hump covered by patches of homogeneous archaeological material covering a surface of about 2 ha. The excavation revealed a series of sub-rectangular (Fig. 16), semi-subterranean huts, two of which were clearly distinguishable. Inside one of the huts, a pit produced a large sample of faunal remains, containing mainly mammals and a few fish bones. The occupation at site 10-W-4 has been dated ca. 5488–5379 1σ cal years BC (Beta-201726, 6490±40 years BP, charcoal). The site is unique since it belongs to a single cultural phase. The ongoing study of the faunal remains will help in understanding the peculiar location of the site. However, the scarcity of fish, compared to sites on the Nile bank, may suggest a seasonal occupation.

The Archaeological Material

The Pottery Assemblages

The systematic study of pottery assemblages from the sites mentioned above is still ongoing, but we can provide an initial description of the new data that have been

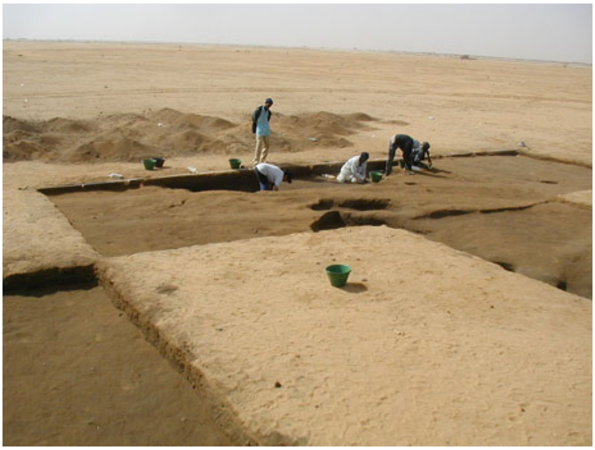

Fig. 16 One of the hut excavated at the 10-W-4 Late Mesolithic site

collected and an evaluation of their potential role in deciphering variation and complexity in the long history of the Khartoum Mesolithic culture.

The excavation at site 16-D-5 provided a first, though incomplete, pottery sequence of the local Mesolithic culture. The most ancient levels at the site (SU6, 48, 455, 462) dating to the first quarter of the seventh millennium BC are characterised, together with a feldspar-tempered Wavy Line pottery, by a pottery decorated both with deep incisions that we have provisionally called "Lunula-shaped" motifs with an ochre (red or yellow) slip a sandy and ochre temper (Fig. 17 and *7* in Fig. 18), and very deep drops (rocker stamp technique). Classic Wavy Line pottery is characterised by different surface treatments (rare but present is an ochre or grey coat), whilst temper is characterised by medium-sized angular feldspar grains (*1–6* and *8* in Fig. 18). A third class, which becomes more common in later stratigraphic units, has been called proto-Dotted Wavy Line (even if other researchers would not hesitate to label it as proper Dotted Wavy Line; see Jesse 2000: 83; *5–7* in Fig. 19). Only slightly later, in the second quarter of the seventh millennium BC, we see the introduction of Rocker Stamp Dotted Zigzag, Rocker Stamp Plain Zigzag and Rocker Stamp Drops motifs (*1–4* in Fig. 19) and the disappearance of the Lunula-shaped motifs. The Rocker Stamp Dotted Zigzag is characterised by angular feldspar grain temper (*9* in Fig. 18), whilst ochre temper is still consistently present only with Rocker Stamp Drops and Rocker Stamp Plain Zigzag decorated ware. Wavy Line pottery has an angular feldspar temper of medium- to small-sized grains (*9* in Fig. 18). The presence of a proper Dotted Wavy Line ochre-tempered fragment bears mentioning as well.

With time (around the mid-seventh millennium BC) new pottery decoration patterns appear as external scraping and much less deep Rocker Stamp Drops impressions in a fan-like pattern (*2* and *3* in Fig. 19). Proto-Dotted Wavy Line is now very well represented. Wavy Line pottery is still feldspar-tempered (with a standard proportion between medium-angular and small-angular grains). Rocker Stamp Dotted Zigzag motifs are still associated with medium- and small-angular feldspar grains temper, whilst ochre-tempered ware is associated with Rocker Stamp Plain Zigzag and Rocker Stamp Drops decoration motifs.

Fig. 17 Fragments of pottery with "Lunula type" decoration from early levels at 16-D-5

In the upper stratigraphic units, we noticed a trend that helps to join the 16-D-5 sequence to the Late Mesolithic site of 10-W-4 (Usai and Salvatori 2006a). For the first time, we see small-sized, angular feldspar grain temper exceeding the medium-sized one. Ochre-tempered ware is still present, whilst very rare, in co-occurrence with Rocker Stamp Drops, Rocker Stamp Plain Zigzag and proto-Dotted Wavy Line patterns, but we can note an appreciable increase in the use of large rounded sand grains temper. The most impressive trend at 16-D-5 is described by the increasing percentage of Rocker Stamp Drops and Rocker Stamp Plain Zigzag decoration patterns, and the equivalent decrease of Lunula and Wavy Line decoration patterns.

Almost all types of pottery decoration and temper detected in the 16-D-5 sequence are recorded at the later site of 10-W-4, but with major changes in

Fig. 18 Wavy Line pottery fragments from 16-D-5 (*1–6*) and fabric types (*7–10*)

frequencies and the absence of the Lunula and Rocker Stamp Drops deep decoration patterns. Rocker Stamp Dotted Zigzag and Rocker Stamp Drops decoration patterns dominate the pottery assemblage (*1* and *2* in Fig. 20). Wavy Line is constantly decreasing whilst Alternately Pivoting Stamp and Dotted Wavy Line (*3–5* in Fig. 20) are well represented (much more than in the 16-D-5 sequence), but still below 10%. Ochre temper is no longer present (whilst ochre pebbles are well represented in the excavation inventory). As we noted above for the later stratigraphic units at site 16-D-5, tempers are now largely dominated by a sand temper of different granulometry (10 in Fig. 18), associated with small quantities of chaff, calcareous stone grains and fine-sized feldspar angular grains.

As noticed above and clearly illustrated in the graphics, the pottery material, at a technological and decorative level, shows a strong coherence with the inner process

Fig. 19 Rocker Stamp (*1–4*) and proto-Dotted Wavy Line (*5–7*) pottery fragments from site 16-D-5

of change accompanying the archaeological seriation of layer deposition and their chronometric determinations.

Pottery from 16-D-4 and 16-D-4b pits fits well in the sequence described above. The first site covers the second quarter of the seventh millennium and partly the third, whilst the latter site approximately covers the third quarter of the seventh millennium BC.

A completely different picture comes from mixed deposits at Mesolithic sites like 10-X-6. By comparing Fig. 21a and b, it is obvious that in the latter no meaningful distribution pattern can be detected along the stratigraphic unit physical sequence. Consequently, from this, as well as from most of the Mesolithic sites excavated in central Sudan heavily affected by Meroitic and post-Meroitic anthropogenic disturbances, one might get the wrong impression of cultural stagnation, both at the level of pottery production as well as subsistence strategies.

Fig. 20 Rocker Stamp Packed (*1*, *2*), Dotted Wavy Line (*3*) and Alternately Pivoting Stamp pottery fragments from site 10W4

The Lithic Assemblages

Differences in Early Mesolithic lithic production are not as clear-cut as those evidenced in the pottery assemblages. A measure of the "uniformity" of an industry has been provided recently by the analysis of a closed context, such as that of a Nubian Neolithic cemetery (Usai 2008). At R12, an assemblage covering a 400-year span did not show any change, whilst pottery analysis highlighted different stylistic phases, even with some sub-phases (Salvatori 2008a, b). Notwithstanding, the study of lithic samples from 10-X-6, 16-D-5 and 10-W-4 offers some important information.

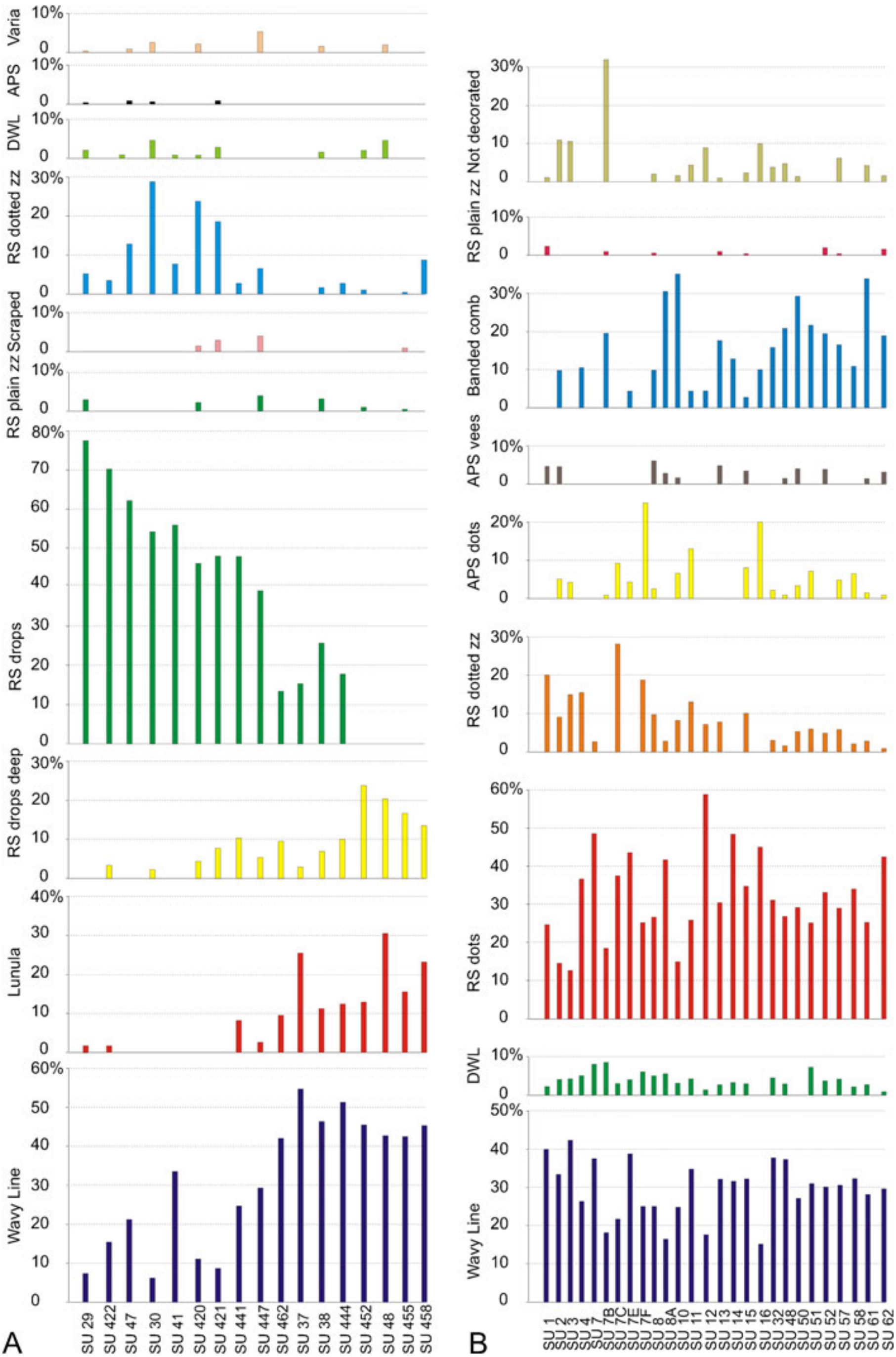

Fig. 21 Pottery distribution from 16-D-5 stratigraphic sequence (**a**) and from 10-X-6 stratigraphic sequence (**b**)

The first important aspect concerns the quantity of the material (tools, debitage and cores) recovered in each stratigraphic unit at site 10-X-6, where no structures

Fig. 22 Sample of quartz tools—backed blades, lunates and triangles—from site 10-X-6

and features were identified, and at sites 16-D-5 and 16-D-4. At 10-X-6, each of the stratigraphic units produced samples ranging from 1,000 to 2,500 pieces, whilst samples from the other two sites never exceed 200–300 pieces. The raw material used at site 10-X-6 is quartz (Fig. 22), whilst at 16-D-5 we recorded also other raw

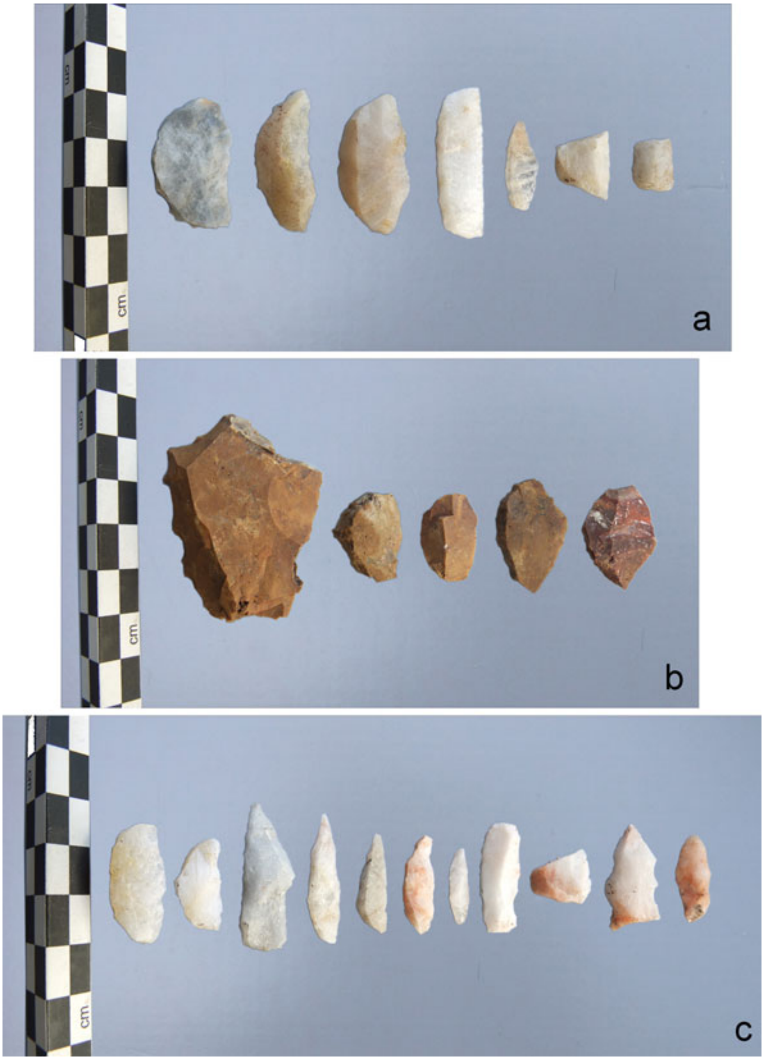

Fig. 23 **a** Quartz stone tools from 10-W-4. **b** Jasper stone tools from 10-W-4. **c** Quartz stone tools from 16-D-5

materials (ferruginous sandstone and sandstone), more in continuity with a Palaeolithic tradition. The quartz exploitation techniques are similar, but other raw materials show a more elaborate knapping approach.

There are no appreciable differences between materials from the first and the second Mesolithic phase identified at 16-D-5, covering approx. 400–500 years, and the small amount of material recovered at 16-D-4, contemporaneous with the second phase of 16-D-5.

The greatest differences existed between Early/Middle and Late Mesolithic productions, as evidenced by the material recovered at site 10-W-4 where only a Late Mesolithic phase is represented (Fig. 23a, b). The Early/Middle Mesolithic lithic industry of 16-D-5 (Fig. 23c) and 16-D-4 is characterized by backed pieces, mainly backed blades; geometrics are present, but they are not as common as in the Late Mesolithic phase recorded at 10-W-4. Another characteristic distinguishing the two tool productions concerns the dimensions of tools and especially lunates. They are, on average, smaller in the Late Mesolithic (Fig. 23a) compared to the earlier phases (Fig. 23c). Core exploitation techniques used in both phases are similar, but Late Mesolithic cores seem to have been bigger.

At the Late Mesolithic site of 10-W-4, the appearance of a lithic industry produced from reddish yellow jasper pebbles is most interesting, since such production reappears in the Neolithic sites recorded in the region. Lunates are the most frequent tools (Fig. 23b), but other geometrics are also present. Double-backed perforators and scrapers are the other most frequently found tool types. The most striking difference between the two series, made from quartz and jasper, occur in the dimensions of tools, as well as the debitage and cores.

Discussion

Palaeoenvironmental Setting in the Mesolithic Period

From a palaeoenvironmental point of view, the research in the northernmost area of the White Nile revealed the geomorphological and sedimentological evolution of the region, mainly due to river dynamics and the landscape during the Mesolithic period.

On the basis of morphology and distribution of sandy ridges and thanks to the stratigraphy showing a homogeneous coarse sandy body interlayered with fine gravel lenses, it is possible to ascribe the mounds hosting Mesolithic multi-stratified sites to the remnants of longitudinal sandy river bars. The attribution of the substrate of Mesolithic sites to older fluvial dynamics is confirmed by Marcolongo (1983) who interpreted similar sedimentary structures found north of Khartoum at Geili and Saggai 1 as fluvial bars dating to the same phase. This is consistent with the hypothesis of a much more active and meandering Nile in the Upper Pleistocene (Williams et al. 2000, 2003; Williams 2009; Williams and Talbot 2009).

Macroscopic and microscopic observations point to the attribution of the organic sediment surrounding sites to a sandy gyttja (a sediment very rich in finely subdivided organics; Hansen 1959) deposited by a former swamp seasonally fed by the flooding of the White Nile, an activity that is radiocarbon dated to 6629–6505 1σ cal years BC (Table 2). The formation of this type of sediment required a hydrological regime with alternating and contrasting seasons. During the wet seasons (corresponding to the seasonal flooding of the White Nile), small basins were filled with water, leading to the formation of organic deposits in the water. On the contrary, in the arid seasons, the area suffered a general reduction in water availability, with consequent desiccation of the basins, as confirmed by the vertic structure of the sediment (polyedric aggregates, blocky microstructure, desiccation cracks) and the occurrence of crystalline pedofeatures related to subsequent cycles of dissolution and recrystallization of calcite. Moreover, Williams and Adamson (1980) also discussed the occurrence of seasonally active swamps in the western White Nile region, dated to ca. 7800–5900 cal years BC (Williams and Adamson 1980); this phase was related to a higher White Nile flood level in central Sudan during the Early to mid-Holocene. Finally, general higher water availability in the region during this phase is recorded in different palaeohydrological records documenting the activity of the eastern African monsoon and distributed both in Sudan and near to the drainage basin of the Nile (Gasse et al. 1990; Gasse 2000; Hoelzmann et al. 2000; Thompson et al. 2002).

On the basis of radiocarbon dates, we can assume that the swamps were present during the Mesolithic occupation of the region and the sites where located upon ridges a few metres above the level of the swamps. The chronological correspondence between the sites' occupation and swamp activity is independently confirmed by the occurrence (in thin section) of common to abundant fragments of minute fish bones incorporated in the groundmass of the sandy gyttja; the deposition of fish bones in the sandy matrix was syn-depositional, and therefore this process was related to fish processing activities, independently testified at Sudanese Mesolithic sites.

Finally, the distribution of Mesolithic sites in relation to temporary (seasonal-fed) swamps in central Sudan does not represent an isolated case. Few kilometres to the west of the city of Omdurman, we recently discovered (Cremaschi et al. 2006) that the Mesolithic and Neolithic sites were placed along the former shores of a lake, presumably fed by the seasonal flooding of the Nile and, more in general, by the higher regional water availability during the Holocene African Humid Period. The extent of the palaeo-lake roughly corresponds to the central and most depressed parts of wadi Habu Hashem where a sandy-loam sediment, very rich in organic matter and mollusc shells and up to 0.4 m in thickness, is present. At this site, the mollusc assemblage (Girod 2008) is indicative of a temporary to permanent shallow water environment. The occurrence of archaeological sites along the former shores of the basin allowed us to date the activity of the lake to an Early to mid-Holocene phase. Williams and Adamson (1980) confirmed the existence of a series of small basins situated in the area of wadi Habu Hashem whose sediments entomb an abundant freshwater mollusc fauna.

Site Formation, Disturbance and Preservation of the Archaeological Record

Archaeological investigation in this region of central Sudan has brought to light diverse archaeological structures and living floors dating to the Mesolithic period, allowing us to discriminate between disturbed and undisturbed features. Furthermore, the geoarchaeological approach made it possible to confirm the archaeological interpretation of stratigraphic data and to identify the specific use of different features.

Formation and destruction of sites in the area rests with the reuse of the main place for a long duration that spans (even with long interruptions) from a pre-Mesolithic horizon to historical times (Usai et al. 2010). The first human use of the ridges was identified at 16-D-4 and consists of a number of pit graves where the dead were buried in an unusual way. As stated above, there is no conclusive hypothesis yet concerning the age of this population, but on the basis of the available data, it would seem appropriate to place these prone burials between the very late Pleistocene and the beginning of the Holocene. Even if no direct connection can be reasonably offered, several large lithic tools dating from the Middle to Late Palaeolithic were found in the area surrounding 16-D-4 and 16-D-5, indicating that the area was inhabited during the Late Pleistocene.

The second exploitation of the region occurred during the Mesolithic period and was related to fisher–hunter-gatherer communities; they occupied the hillocks at least from the beginning to the end of the seventh millennium BC. During this period, the White Nile had a higher flood level and was closer to the sites as they are distributed along a main Nile terrace. Later, the same areas were chosen by Neolithic groups for both settlements and cemeteries, and finally by Meroitic and post-Meroitic communities as cemeteries.

Layers found at 16-D-5 are the first, although limited, evidence of Mesolithic stratified layers. By comparing the two identified macro-units on the basis of soil properties, both at macroscopic and microscopic scales, and evaluating ceramic assemblages for consistency/inconsistency, it is possible to show that the lower part of the archaeological deposit represents Mesolithic layers in situ. First, the upper section of the deposit shows a loose structure where no traces of discrete archaeological features were present. Mesolithic and Neolithic pottery sherds and other diagnostic materials were mixed together without any recognisable pattern. Sedimentological data confirm that the upper part of the stratification should be regarded as heavily affected by anthropogenic and natural disturbance (pedoturbation) and colluviation. In general, the deposit is very loose, cut by animal burrows, and the coarse components (bones and sherds) are chaotically (even vertically) dispersed in the matrix that is mostly represented by sand. The organization of the deposit is mainly in oblique lenses, which can be interpreted as the results of colluvial phenomena; the same processes were also responsible for the almost complete lack of organic groundmass, as detected in thin sections: organic groundmass was removed mostly by degradation phenomena and, in part, by pedogenetic alteration. Colluviation occurred presumably under arid conditions and a certain wind input of silt and fine sand is evident from the bimodal distribution of quartz grains found in thin sections. Further confirmation of runoff and pedoturbation is given by the occurrence of reworked bone fragments, with organic amorphous coatings, and intercalation pedofeatures.

On the contrary, the lower anthropogenic macro-unit has a significant lamination that involves archaeological material and testifies to the prolonged use of the ground as living floor, with contextual trampling; in thin sections, we also noticed a preferential alignment of bone and shell fragments (sometime showing *in situ* breakage) and sand lenses. A second point to take into account is the abundance of amorphous groundmass, which originates from human activity, as much as the huge concentration of shells and unburnt/burnt bone fragments. The presence of sediment fragments originating from the swamp deposits attests to intentional cleaning of the surface. Moreover, in the lower macro-unit, a number of discrete archaeological features (fireplaces, mud wall structures, preserved sections of well-compacted earthen floors) have been recorded and their functional facets can be interpreted. Archaeological material (mainly pottery) is culturally homogeneous (Mesolithic), and the few intrusive Neolithic sherds were only found inside animal burrows cutting the deposit from the above. At site 16-D-5, SU64 can be interpreted as the remnants of a small dike intentionally built to separate the settlement living floor from the seasonal marsh area to the west of the site. It was built along the western flank of the ridge, at the interface between the shore of the swamp and the area used as settlement; in thin section, it displays evidence of ripening of the sediments (dense groundmass), accumulation of the deposits found nearby (recurrent fragments of former soils and sediments) and anthropogenic elements from the site (seeds and bones), resulting from the cleaning of the surrounding surfaces. Other significant structures are pits that can be distinguished into two main types. At site 16-D-4, there were pits with hard crusts cementing the filling whose origin is possibly related to former fireplaces; this attribution is confirmed by the occurrence in thin section of microcharcoals, vitrified phytoliths and wood remnants. Furthermore, the micromass originated from the substitution of calcite from Ca-oxalate pseudomorphs and subsequent recrystallization (Courty et al. 1989). These pits were possibly present at site 16-D-5 also, as witnessed by hard crust remnants found scattered all over the surface and in a few highly disturbed cases in the deposit. Fireplaces were possibly related to cooking and processing food, as certified by the large amount of fish bones and shells found in the fire pits. Pits with different functions are found at site 16-D-4b. Although their archaeological content is similar to that found within settlements, in this case, bones are often found in anatomical position; furthermore, in thin section, we noticed a very low content of calcite cement, microcharcoals and other evidence for fire, whereas bones (in many cases unburnt) and fragments of the pond deposit into which pits were cut are common. Our interpretation is that in this Mesolithic phase, several pits have been excavated outside the limits of the living area of the settlements; these pits were used as dumping areas for residual ashes and animal bones, and therefore these sediments indicate an area of human waste disposal (Courty et al. 1989; Weiner 2010).

A further implication of the identification of preserved structures and definition of their uses is the confirmation of the main subsistence strategies adopted by Mesolithic groups, at least during the seventh millennium BC along the Nile. Traditionally, in the Nile Valley, Mesolithic groups were considered to be hunters and/or fishermen (Caneva 1983; Haaland 1993). In the study area, we can confirm evidence for fishing, as proven by the presence of specific stone and bone tools and the abundance of fish remains in both fireplaces and dumping pits, whilst the evidence for wild plant exploitation is still scanty.

On the basis of our data, we can draw the following sequence of events. Initially, Late Palaeolithic people (or at least pre-Mesolithic) chose an elongated mound close to the banks of the White Nile to bury their dead. Later on (at the beginning of the seventh millennium BC), a Mesolithic group decided to place base camps on top of ridges that at this time were surrounded by seasonally flood-fed swamps; their subsistence strategy mostly relied on fishing. The Mesolithic occupation induced an in-site accumulation and accretion of living floors. After this phase, the mounds were a well-preserved example of multi-stratified sites, but their subsequent use in the Neolithic period started the anthropogenic disturbance and dismantling of the stratification. Degradation processes reached their peak with the construction of Meroitic and post-Meroitic pit- and tumulus-like graves. Paradoxically, this last practice partly destroyed the stratigraphic record, but also provided protection against natural erosion of the lower archaeological layers.

The excavations at the Al Khiday Mesolithic sites provided a set of patterned data that finally helps reconstruct and understand prehistoric site formation and destruction processes in this part of the Nile valley. Whether this new model can be applied to other sites in the valley can only be proven by future work.

Conclusions

Excavations at sites 10-X-6, 16-D-5 and 16-D-4 provided substantial evidence to produce an explanatory model of central Sudan Mesolithic site formation and dismantling processes. Not only did the construction of earthen tumuli above post-Meroitic graves have a devastating effect on the prehistoric deposit, as already suggested by Caneva (1983), but other invasive activities, such as Meroitic graves, also had their impact on them.

One more remark on the Mesolithic and Neolithic archaeological deposits along the Nile Valley can be added on the basis of the evidence from El Salha and Al Khiday sites. When looking at the archaeological material, including faunal remains, from the excavation at site 10-X-6, it was rather surprising to find that all were covered with a grey, hard and thin crust. This can also be seen on the material recovered from the ashy pits excavated at site 16-D-4. It seems that the phenomenon is connected to ash concentrations and to specific chemical transformations, but it is worth noting that comparable preservation conditions are described for archaeological materials found at the Atbara sites (Haaland and Magid 1995: 34, 123) and at Saggai 1 (Gautier 1983: 51, 90). It is highly possible that features of the same kind as those excavated at 16-D-4 were also present at those sites.

Anthropogenic disturbances, whilst substantial, are not the only post-depositional agents affecting site preservation. Animal disturbances also have had a large impact. Water and wind erosion added to these processes. This is well illustrated by site 16-D-4b where the recovery of the highly eroded black pits was mostly due to chance.

These conclusions suggest more caution when interpreting Mesolithic (and Neolithic) data from previously excavated sites and point to the necessity to revisit previously published data. In addition, we have to recognise the very limited descriptive and explicative power of archaeological and chronometric data from mixed deposits and abandon the current attitude to draw middle-range theory inferences from them (Caneva et al. 1993; Garcea and Hildebrand 2009; Haaland 1993; Haaland and Magid 1995). Nevertheless, our experience shows that at least some of the original deposits have survived and, when found, can positively contribute to the identification of cultural processes and variance and provide a less simplistic picture of the Mesolithic period.

The geoarchaeological analysis of data from the sites presented here demonstrates beyond any doubt that the understanding of site formation and post-depositional disturbances is basic to proper use of the archaeological and sedimentological data. Subsequently, it contributes to reconstructing the way of life of the Khartoum Mesolithic prehistoric population and its changing social, economic and demographic assets during a period of at least three millennia.

If site formation processes are not fully understood, the archaeological materials collected from such heavily disturbed Mesolithic and Neolithic sites can be extremely misleading. This became clear when comparing pottery analysis based on the 10-X-6 and the 16-D-5 site samples. In the first case, it is impossible to identify any meaningful pattern, whilst in the second case we can start to measure variability in material production both along synchronic and diachronic dimensions and thus possibly perceive changing behavioural trajectories in the local society. Excavations carried out at a single-phase Mesolithic site such as 10-W-4, dating to the second half of the sixth millennium BC, allow us to cautiously trace a pottery sequence encompassing 2,000 years of the Mesolithic period.

In-depth studies of the overall archaeological evidence collected from these sites and from the accomplished regional survey will provide information on possibly changing settlement patterns and on residential and mobility strategies of the local Mesolithic groups over time.

The excavation at the multi-stratified cemetery of 16-D-4 provides a bulk of information on the ancient population of the area. Together with the ongoing archaeological, bioarchaeological and zooarchaeological studies, a well-advanced programme of isotopic analyses provides information on the diet of these populations and the palaeoenvironmental conditions, providing a changing scenario of their life from the pre-Mesolithic to the post-Meroitic period (Usai et al. 2010).

Acknowledgments We gratefully acknowledge the Sudanese Department of Antiquity and the Italian Embassy in Khartoum for their continuous support in organizing our research. The project has been supported by Ministero degli Affari Esteri (2000–2010), Istituto Italiano per l'Africa e l'Oriente (2000–2010), Università degli Studi di Parma (2005–2010), Michela Schiff Giorgini Foundation (2002–2003, 2005, 2007) and GASID of Torino (2000–2009). We also thank Tina Jakob, the physical anthropologist of the project, for editing the English and for her invaluable comments on the text. Two anonymous reviewers are acknowledged for providing valuable suggestions to improve the manuscript; the Editor A. LaViolette is also thanked for useful discussion. Preliminary information on pottery temper (mineralogy and grain size) was kindly furnished by Lara Maritan (Dipartimento di Geoscienze, Università di Padova).

References

Addison, F. (1949). *Jebel Moya*. London: Oxford University Press.

Arkell, A. J. (1949). *Early Khartoum. An account of the excavation of an early occupation site carried out by the Sudan Government Antiquities Service in 1944–5*. Oxford: Oxford University Press.

Arkell, A. J. (1953). *Shaheinab. An account of the excavation of a neolithic occupation site carried out for the Sudan Antiquities Service in 1949–50*. Oxford: Oxford University Press.

Barker, P. (1977). *Techniques of archaeological excavation*. London: Batsford.

Bocquetin, F. (2005). *Pratiques funéraires, paramètres biologiques, et identités culturelle au Natoufien: Un analyse archéo-anthropologique*. Unpublished PhD thesis, Université Bordeaux 1.

Brass, M. (2009). Towards an archaeology of social organization at Jebel Moya, 5th–1st millennium BC. *Sudan & Nubia, 13*, 120–125.

Brewer, R. (1964). *Fabric and mineral analysis of soils*. New York: Wiley.

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. *Radiocarbon, 51*, 337–360.

Bullock, P., Fedoroff, N., Jongerius, A., Stoops, G., Tursina, T., & Babel, U. (1985). *Handbook for soil thin section description*. Albrighton: Waine Research Publication.

Caneva, I. (1983). Pottery using gatherers and hunters at Saggai (Sudan): Preconditions for food production. *Origini, 12*, 7–271.

Caneva, I. (1988). *El Geili. The history of a middle Nile environment 7000 B.C.–A.D. 1500*. BAR International Series 424, Oxford.
Caneva, I. (1991). Jebel Moya revisited: A settlement of the 5th millennium BC in the middle Nile basin. *Antiquity, 65*, 262–268.
Caneva, I., Garcea, E. A., Gautier, A., & Van Neer, W. (1993). Pre-pastoral cultures along the central Sudanese Nile. *Quaternaria Nova, 3*, 177–252.
Clark, D. J. (1973). Sudan. *Nyame Akuma, 3*, 55–64.
Clark, D. J. (1989). Shabona: An Early Khartoum settlement on the White Nile. In L. Krzyzaniak & M. Kobusiewicz (Eds.), *Late prehistory of the Nile Basin and the Sahara* (pp. 387–410). Poznan: Poznan Archaeological Museum.
Clark, J. D., & Stemler, A. (1975). Early domesticated sorghum from central Sudan. *Nature, 254*, 588–591.
Courty, M.-A. (2001). Microfacies analysis assisting archaeological stratigraphy. In P. Goldberg, V. T. Holliday, & C. R. Ferring (Eds.), *Earth sciences and archaeology* (pp. 205–239). New York: Kluwer.
Courty, M.-A., Goldberg, P., & Macphail, R. (1989). *Soils and micromorphology in archaeology*. Cambridge: Cambridge University Press.
Cremaschi, M., & Zerboni, A. (2009). Early to Middle Holocene landscape exploitation in a drying environment: Two case studies compared from the central Sahara (SW Fezzan, Libya). *C. R. Geoscience, 341*, 689–702.
Cremaschi, M., Salvatori, S., Usai, D., & Zerboni, A. (2006). A further "tessera" to the huge "mosaic": Studying the ancient settlement pattern of the El Salha region (south-west of Omdurman, central Sudan). In K. Kroeper, M. Chłodnicki, & M. Kobusiewicz (Eds.), *Archaeology of the Early Northeastern Africa* (pp. 39–48). Poznan: Poznan Archaeological Museum.
El-Tom, M. A. (1975). *The rains of the Sudan*. Khartoum: Khartoum University Press.
Fernández, V. M., Jimeno, A., Menéndez, M., & Lario, J. (2003). Archaeological survey in the Blue Nile area, central Sudan. *Complutum, 14*, 201–272.
Garcea, E. A. A., & Hildebrand, E. A. (2009). Shifting social networks along the Nile: Middle Holocene ceramic assemblages from Sai Island, Sudan. *Journal of Anthropological Archaeology, 28*, 304–322.
Gasse, F. (2000). Hydrological changes in the African tropics since the last glacial maximum. *Quaternary Science Reviews, 19*, 189–211.
Gasse, F., Tenhet, R., Durand, A., Gibert, E., & Fontes, J. C. (1990). The arid–humid transition in the Sahara and the Sahel during the last deglaciation. *Nature, 346*, 141–156.
Gautier, A. (1983). Animal life along the prehistoric Nile: The evidence from Saggai 1 and Geili (Sudan). *Origini, 12*, 50–115.
Gerharz, R. (1994). *Jebel Moya. Meroitica 14*. Berlin: Akademie Verlag.
Girod, A. (2008). Paleo-environmental consideration about the molluscs of wadi Abu-Hashem, SW Omdurman (Sudan). *Triton, 17*, 9–14.
Goldberg, P., & Macphail, R. I. (2006). *Practical and theoretical geoarchaeology*. Oxford: Blackwell.
Haaland, R. (1987). *Socio-economic differentiation in the Neolithic Sudan*. BAR International Series, 350, Oxford.
Haaland, R. (1993). Aqualithic sites of the middle Nile. *Azania, 28*, 47–86.
Haaland, R., & Magid, A. A. (1995). *Aqualithic sites along the Rivers Nile and Atbara, Sudan*. Bergen: Alma Mater Forlag.
Hakem, A. M., & Khabir, A. R. M. (1989). Sarourab 2: A new contribution to the Early Khartoum tradition from Bauda site. In L. Krzyzaniak & M. Kobusiewicz (Eds.), *Late prehistory of the Nile Basin and the Sahara* (pp. 381–386). Poznan: Poznan Archaeological Museum.
Hansen, K. (1959). The terms gyttja and dy. *Hydrobiologia, 13*, 309–315.
Hinkel, F. (1977). *The archaeological map of the Sudan, a guide to its use and explanation of its principles*. Berlin: Akademie Verlag.
Hoelzmann, P., Kruse, H.-J., & Rottinger, F. (2000). Precipitation estimates for the eastern Sahara palaeomonsoon based on a water balance model of the West Nubian Palaeolake Basin. *Global and Planetary Change, 26*, 105–120.
Jesse, F. (2000). Early Khartoum Ceramics in the Wadi Howar, Northwest Sudan. In L. Krzyzaniak, K. Kroeper, & M. Kobusiewicz (Eds.), *Recent research into the Stone Age of Northeastern Africa* (pp. 77–87). Poznan: Poznan Archaeological Museum.
Klima, B. (1987). Une triple sépulture du Pavlovien à Dolni Vestonice, Tchécoslovaquie. *L'Anthropologie, 91*, 329–324.
Krzyzaniak, L. (1975). Kadero (first season, 1972). *Ètudes et Travaux, 8*, 361–366.

Krzyzaniak, L. (1976). Kadero (second–third season, 1973–1973/1974). *Ètudes et Travaux, 9*, 283–287.
Krzyzaniak, L. (1979). Kadero (fourth–sixth season, 1975–1976). *Ètudes et Travaux, 11*, 245–252.
Krzyżaniak, L. (1984). The Neolithic habitation at Kadero (central Sudan). In L. Krzyżaniak & M. Kobusiewicz (Eds.), *Origin and early development of food-producing cultures in north-eastern Africa* (pp. 309–316). Poznan: Poznan Archaeological Museum.
Marcolongo, B. (1983). Late Quaternary Nile and hydrology of the Khartoum–Sabaloka region (Sudan). *Origini, 12*, 39–46.
Marks, A., & Mohammed-Ali, E. (1991). *The late prehistory of Eastern Sahel. The Mesolithic and Neolithic of Shaqadud, Sudan*. Dallas: Southern Methodist University Press.
Munsell®. (1994). *Soil color charts. 1994 revised edition*. New Windsor: Munsell® Color.
Reimer, P. J., Baillie, M. G. L., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., et al. (2009). IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP. *Radiocarbon, 51*, 1111–1150.
Salvatori, S. (2008a). Pottery for the dead: A survey of grave goods. In S. Salvatori & D. Usai (Eds.), *A Neolithic cemetery in the northern Dongola Reach (Sudan): Excavation at Site R12* (pp. 9–19). London: The Sudan Archaeological Research Society Publications.
Salvatori, S. (2008b). Relative and absolute chronology of the R12 cemetery. In S. Salvatori & D. Usai (Eds.), *A Neolithic cemetery in the northern Dongola Reach (Sudan): Excavation at Site R12* (pp. 139–146). London: The Sudan Archaeological Research Society Publications.
Salvatori, S., & Usai, D. (2007). The oldest representation of a Nile boat. *Antiquity*, *81*(314). http://antiquity.ac.uk/ProjGall/usai/index.html.
Salvatori, S., & Usai, D. (2009). El Salha Project 2005: New Khartoum Mesolithic sites from central Sudan. *KUSH, 19*, 87–96.
Stoops, G. (2003). *Guidelines for analysis and description of soil and regolith thin sections*. Madison: Soil Science Society of America.
Thompson, L. G., Mosley-Thompson, E., Davis, M. E., Henderson, K. A., Brecher, H. H., Zagorodnov, V. S., et al. (2002). Kilimanjaro ice core records: Evidence of Holocene climate change in tropical Africa. *Science, 298*, 589–593.
Tixier, F. (1963). *Typologie de l'Epipaleolithique du Maghreb*. Mémoires du Centre de Recherche Anthropologique et Ethnographique, n. 2, Arts et métiers graphiques, Alger-Paris A.M.G.
Usai, D. (2008). Lunates and micro-lunates, cores and flakes: The lithic industry of R12. In S. Salvatori & D. Usai (Eds.), *A Neolithic cemetery in the northern Dongola Reach (Sudan): Excavation at Site R12* (pp. 33–52). London: The Sudan Archaeological Research Society Publications.
Usai, D., & Salvatori, S. (2005). The IsIAO archaeological project in the El Salha area (Omdurman South, Sudan): Results and perspectives. *AFRICA, 60*(3–4), 474–493.
Usai, D., & Salvatori, S. (2006a). Survey and excavations in Central Sudan: The el-Salha project. In I. Caneva & A. Roccati (Eds.), *ACTA NUBICA—Proceedings of the X International Conference of Nubian Studies, Rome, 9–14 September 2002* (pp. 117–124). Rome: Libreria dello Stato Istituto Poligrafico e Zecca Dello Stato.
Usai, D., & Salvatori, S. (2006b). Archaeological research south of Omdurman. A preliminary assessment on ceramic and lithic materials from 10-X-6 multi-stratified mound site along the western bank of White Nile in central Sudan. *Archéologie du Nil Moyen, 10*, 203–220.
Usai, D., Salvatori, S., Iacumin, P., Di Matteo, A., Jakob, T., & Zerboni, A. (2010). Excavating a unique pre-Mesolithic cemetery in central Sudan. *Antiquity*, *84*(323). http://www.antiquity.ac.uk/projgall/usai323/.
Weiner, S. (2010). *Microarchaeology. Beyond the visible archaeological record*. New York: Cambridge University Press.
Wendorf, F., & Schild, R. (1986). *The Wadi Kubbaniya skeleton: A Late Paleolithic burial from southern Egypt*. Dallas: Southern Methodist University Press.
Williams, M. A. J. (2009). Late Pleistocene and Holocene environments in the Nile basin. *Global and Planetary Change, 69*, 1–15.
Williams, M. A. J., & Adamson, D. (1980). Late Quaternary depositional history of the Blue and White Nile rivers in central Sudan. In M. A. J. Williams & H. Faure (Eds.), *The Sahara and the Nile. Quaternary environments and prehistoric occupation in northern Africa* (pp. 281–304). Rotterdam: Balkema.
Williams, A. J., & Talbot, M. R. (2009). Late Quaternary environments in the Nile basin. In H. J. Dumont (Ed.), *The Nile: Origin, environments, limnology and human use* (pp. 61–72). Dordrecht: Springer Science.
Williams, M. A. J., Adamson, D., Cock, B., & McEvedy, R. (2000). Late Quaternary environments in the White Nile region, Sudan. *Global and Planetary Change, 26*, 305–316.
Williams, M. A. J., Adamson, D., Prescott, J. R., & Williams, F. M. (2003). New light on the age of the White Nile. *Geology, 31*, 1001–1004.