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The Archaeology of the Middle Pleistocene Deposits of Lake Eyasi, Tanzania



Manuel Domínguez-Rodrigo, Fernando Díez-Martín, Audax Mabulla, Luis Luque, Luis Alcalá, Antonio Tarriño, José Antonio López-Sáez, Rebeca Barba & Pastory Bushozi

Abstract

Ongoing archaeological research at North Lake Eyasi has produced a wealth of information, including a new hominid fossil and several archaeological sites dating to the end of the Middle Pleistocene. One of the sites (WB9) has been excavated and has produced evidence of multiple processes in its formation, including evidence of functional associations of stone tools and faunal remains which are scarce for this time period. The stone tool industry is based on a core and flake industry, which is not very diagnostic and attributed to MSA. Earlier heavy-duty tools classified as Sangoan may derive from the underlying Eyasi Beds. The stratigraphic provenience of previous fossil hominids is unknown. Surface collections from the Eyasi lake, thus, comprise two different sets of stone tools and fossils, which can only be clearly differentiated in the field. This advises against the use of previously curated collections as a homogeneous sample. Earlier definitions of the Njarasa industry should be revised. This work presents results on the paleoecology of the area and of its paleontological and archaeological information, with special reference to the excavation of WB9, the most complete site discovered in the area so far. This contributes to the limited information available about site functionality and hominid subsistential behaviour in East Africa during the end of the Middle Pleistocene. A technological study from WB9 also shows the variability of stone tool traditions at this time.

Résumé

Les recherches archéologiques en cours au Nord du Lac Eyasi ont permis de rassembler une grande quantité de données et de découvrir quelques sites de la fin du Pléistocène Moyen et un nouvel hominidé. La fouille de l'un de ces sites (WB9) a permis de mettre au jour l'association spatiale d'outils lithiques et des restes fauniques, ce qui est très rare pour cette période. L'industrie lithique est composée de nucleus et d'éclats attribués au MSA. La recherche antérieure sur les dépôts du lac Eyasi avait attribué ces industries au Sangoan. Cependant, on a découvert que cette classification était le résultat de l'étude des vestiges provenant de plusieurs unités géologiques. Par conséquent, les définitions antérieures de l'industrie Njarasa doivent être révisées. L'étude d'un des sites fouillés (WB9) montre la diversité technologique de cette époque. Cet article présente les résultats de l'étude paléontologique et archéologique réalisée dans le cadre de notre projet et leurs implications pour la connaissance du comportement des hominidés à la fin du Pléistocène Moyen, dans une période qui témoigne l'apparition des premiers Homo sapiens.

Keywords: East Africa, Middle Pleistocene, Homo sapiens, Middle Stone Age, Sangoan

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Introduction

Lake Eyasi is an important fossiliferous area situated at the southern end of the eastern rift valley system in northern Tanzania (***Fig. 1***). Several skull remains of three individuals of archaic *Homo sapiens* were discovered by Kohl-Larsen´s expeditions early in the twentieth century in the Middle Pleistocene lake sediments (Reck & Kohl-Larsen 1936). Another skull fragment of a different individual was discovered in 1993 (Bräuer & Mabulla 1996). These remains were found in association with stone artefacts and fossilized animal bones.

Establishing the age of the hominid remains, stone artefacts and fossilized animal bones has been problematic. Chemical micro-analysis of bones by Protsch (1976, 1981) and amino-acid racemisations by Bada & Protsch (1976), suggesting an Upper Pleistocene age of 35,000 years bp for the hominid remains and associated fauna and stone artefacts, have been found to be in error. On the basis of stone tool typology, geological deposits, the occurrences of some extinct species and correlation with radiometrically dated deposits of Mumba Rockshelter, Mehlman (1984, 1989) suggested that "the age of the deposits correlated to the hominid crania is at least 100,000 years old, and most likely older than 130,000 years bp" (Mehlman 1984: 98). These hominids and their dates are important because of the limited number of fossils attributed to early *H. sapiens* in sub-Saharan Africa. Recently, a new hominid fossil was found by our team overlying the stratum where the previous hominids were discovered. The Uranio-Thorium and SPIN analysis on mammal teeth from the same stratum yielded an age of 118,000 years (Domínguez-Rodrigo *et al*. *in prep.*). This supports Mehlman's assertion that Protsch's (1976, 1981) date estimates for Lake Eyasi were incorrect.

The Lake Eyasi region is also important because it contains several archaeological sites where the Acheulian-MSA and the MSA-LSA transitions can be observed (Mehlman 1989; Mabulla 1996), and has significant occurrences of rock art (*e.g.* at Mumba). Since the pioneering work by Kohl-Larsen (1943) and the research carried out in the 1970´s and 1980´s by Mehlman (1977, 1979, 1984) and more recently by Mabulla (1996), no systematic work has been undertaken along the lakeshore´s Middle Pleistocene deposits. Information regarding the geology, paleontology and archaeology of the Middle Pleistocene deposits remains preliminary. Our research aims to fill this gap. Here we present results of our work in the Middle Pleistocene sediments of Lake Eyasi, including the excavation of a site and the analyses carried out to reconstruct the ecological context in which this site appeared. This information is significant for understanding the behaviour of early *H. sapiens*, given that there are very few sites of this age in East Africa that have yielded undisturbed associations of lithics and faunal remains. Classical sites of this age where the Acheulian-MSA transition has been reported are either in disturbed contexts, or lack fauna. Others, where fauna exists, lack any taphonomic analyses that convincingly show any functional association between fauna and stone tools (*see* ***Tab. 1***). In brief, the range of hominid behaviours for this time period remains unknown.

The geology of the Middle Pleistocene deposits

Kohl-Larsen (1943) divided the fossiliferous lake deposits into 2 different areas (***Fig. 1***): the West Bay (West-Bucht) (henceforth WB) and the Northeast Bay (Nordost-Bucht) (henceforth NEB). Mehlman (1984) noted that fossilized faunal remains and artefacts were collected at both places, which are separated by more than 5 km. The previously reported hominid remains were collected in West Bay. The hominid that our team discovered, as well as a mandibular fragment discovered by a Japanese team in the 1980´s (which remains unpublished), come from Northeast Bay.

An intensive survey carried out by us shows that fossils in NEB are differentially distributed in sandy lenses, the margins of small streams and the eroded front of the outcrops. Fossils are hardly found at the bottom of channels or the clayish lacustrine floodplain. Most fossil localities seem to have been exposed following the erosion of sediments by modern streams emptying into the lake, as well as on the front of the outcrops eroded by the lake itself and by rain. Distribution of fossil localities in the WB is different. Fossils appear because the fossiliferous deposit is not overlain by any recent sediments and deflation is eroding it, horizontally exposing former land surfaces and the fossils that they contain (***Fig. 2***). Therefore, fossils appear over a more extensive area than in NEB. This, together with the fact that WB has richer archaeological materials, prompted us to carry out extensive excavations there, whereas in Northeast Bay we only carried out basic test trenching.

Geological context

Eyasi is one of the East African Gregory Rift Valley sedimentary basins that cross Kenya and northern Tanzania. It consists of a half-graben basin developed on the pre-Cambrian and Archaean substrate of the Tanzanian Shield and the Mozambique Belt (Ebinger *et al*. 1997) (***Fig. 1, top***). Volcanoes are also

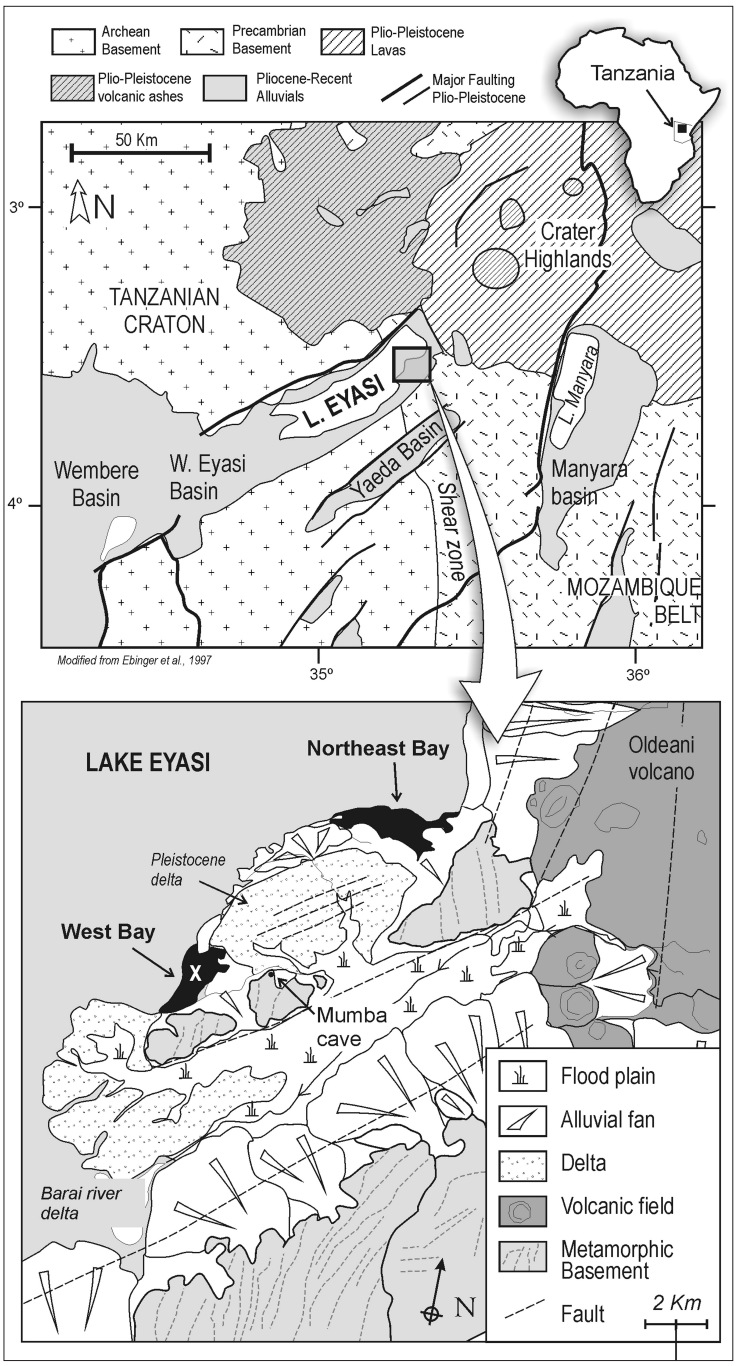


Fig. 1. Location of the Middle Pleistocene fossiliferous areas in northern Lake Eyasi, including the Eyasi Beds outcrops in Northeast (NEB) and West (WB) Bays.

common in the northern basin near the Crater Highlands, erupting during the Early Pliocene to Early Pleistocene in the tectonic context of the Rift Valley formation. These volcanoes consist mainly of basic to ultrabasic lavas formed between 5 to 2 Ma (Pickering 1961; Fairhead 1980; Dawson 1992; Foster *et al*. 1997). The basin morphology 1 Ma ago was similar to that of the modern basin (Pickering 1961; MacIntyre *et al*. 1974; Foster *et al*. 1997). Minor faulting and subsidence intermittently occurred from the beginning of the Pleistocene (Hay 1981). The half-graben is oriented from NE to SW showing the largest tectonic escarpment in the northwest. From a structural point of view, the Eyasi basin is the western branch of the Northern Tanzania Divergence Zone, where the other two branches separated north-south (Natron-Manyara) and west-east (Meru-Kilimanjaro) (Dawson 1992).

Older rocks like schists, gneiss, diorite and quartzites widely outcrop on the rift slopes and in a net of horst and grabens of the flexure area to the east. These horsts separate the Eyasi basin from the neighbouring Yaeda basin. Volcanics consist of lava from the largest volcanoes and ashes and pumice from smaller eruptive cones. Some lava flows outcrop into the basin through the most recent sediments, which are affected by recent faulting. A great number of smaller faults occur in the area east of Lake Eyasi both along the Oldeani slopes and in the pre-Cambrian substrate near the Barai River (Pickering 1961).

Old sedimentary deposits are scarce in the Lake Eyasi basin and are not older than Middle Pleistocene in age (Mehlman 1989). Pleistocene sediment exposures are flat and are mainly covered by recent lacustrine, aeolian and alluvial deposits. This infilling of the basin has produced a very flat relief of the lakeshore. The area where the fossiliferous deposits have been studied is located in the northeast, in the lake mudflat resulting from an old fan delta created by the Paleo-Barai river. Exposures are conditioned both by horst and graben and by volcanic relief distribution. As Kohl-Larsen (1943) noted in his initial exploration of the area, there are two embayments where fossiliferous deposits are more widely exposed: WB and NEB (***Fig. 1, bottom***). Both are located at the foot of the Lagangharel-Ishimijega hills, some of the horst reliefs that run parallel to the Barai River alluvial plain and delta. These metamorphic and intrusive reliefs contain rock shelters, including Mumba.

Site	undisturbed or unaffected by transport	artefacts + bones	lithic + bone functional association taphonomically demonstrated
Sango Bay (Uganda)	NO	NO	-
Nsogenzi (Tanzania)	NO	YES	NO
Mumba (Tanzania)	YES	YES	NO
Nasera Rock (Tanzania)	YES	YES	NO
Ndutu Beds (Tanzania)	-	YES	NO
Cartwright´s Farm (Kenya)	YES	NO	-
Lenderut (Kenya)	YES	YES	NO
Koobi Fora MSA sites (Kenya)	-	YES	NO
Muguruk (Kenya)	-	NO	-
GuJh19 Kanyugi (Kenya)	-	NO	-
GuJh12 Ntuka River 4 (Kenya)	-	YES	NO
Kapthurin MSA sites (Kenya)	YES	YES	NO
Simbi (Kenya)	YES	YES	NO
Olorgesaile MSA sites (Kenya)	YES	YES	NO
Aduma MSA sites (Ethiopia)	YES	YES	NO
Gademotta MSA sites (Ethiopia)	YES	YES	NO
Herto (Ethiopia)	YES	YES	YES
Garba III (Ethiopia)	-	YES	NO

Tab. 1. List of the main late Middle Pleistocene sites in East Africa including information on their context (disturbed or undisturbed), association between lithics and bones, and functional link between lithic and stone tools taphonomically demonstrated. References: Cole (1967), Mehlman (1989), Mabulla (1990), Kelly (1996), Waweru (2002), Cornelissen (1995), McBrearty (1988, 1991, 1999), Barthelme (1991), Brooks & Yellen (2005).

Previous geological data

Geological data are relatively abundant. During the Kohl-Larsen excavations, stratigraphic and sedimentological studies were carried out by Reeve (1946) and Rafalski *et al*. (1978). Kohl-Larsen's earliest studies defined five sedimentary units in the lake sandstone, shale and clay deposits (Kohl-Larsen 1943, later synthesis in Mehlman 1989). Previously, Reck & Kohl-Larsen (1936) had identified superficial reddened sandstone and marls (Upper Sandstone) as the source of the *Homo sapiens* skulls. This superficial layer corresponds to the Upper Sandstone unit, also described as lateritic material by Reeve (1946) and later defined by Mehlman (1989) as a reddish-brown, zeolite-cemented, clay-pellet aggregate. It is important to note that the hominid remains were found on the mudflat surface.

Rafalski carried out granulometric as well as mineralogical analyses on samples obtained in cores and trenches made between the skull site and Mumba Rockshelter. Rafalski divided the lacustrine deposits into four units: "capping horizon", "upper sandstone", "lower sandstone" and "clay bed". Pelletoidel clays were interpreted as the result of mud dessiccation in an arid environment. Authigenic minerals like zeolites suggested a highly alkaline environment.

Mehlman (1989) studied the geology of the lake deposits distinguishing two alternating sedimentary units divided into six members (A to F). He defined the Eyasi Beds and then correlated them with the Mumba cave units. Following Mehlman (1989), the Eyasi Beds are 11.5 m thick, and contain reddened, zeolite-cemented, clay-pellet aggregates (Members A, C and E) alternating with lacustrine clays, sands and gravels (Members B, D, and F). Mehlman's interpretation was that the Eyasi Beds were deposited in the lacustrine mudflat under fluctuating low (Members A, C, E) to moderate (Members B, D, F) lake levels and under alkaline waters influenced by an arid climate. Following Mehlman, Member C is the origin of the hominid skulls reported by Kohl-Larsen. He estimated that these deposits date to the late Middle Pleistocene, based on stratigraphical correlation with the Mumba Beds. Based on sedimentation rates and correlation with the Mumba units, the ignimbrite deposit at the base of the Eyasi Beds may date from 275 ka to 372 ka. However, these previous interpretations are purely speculative, since the formation

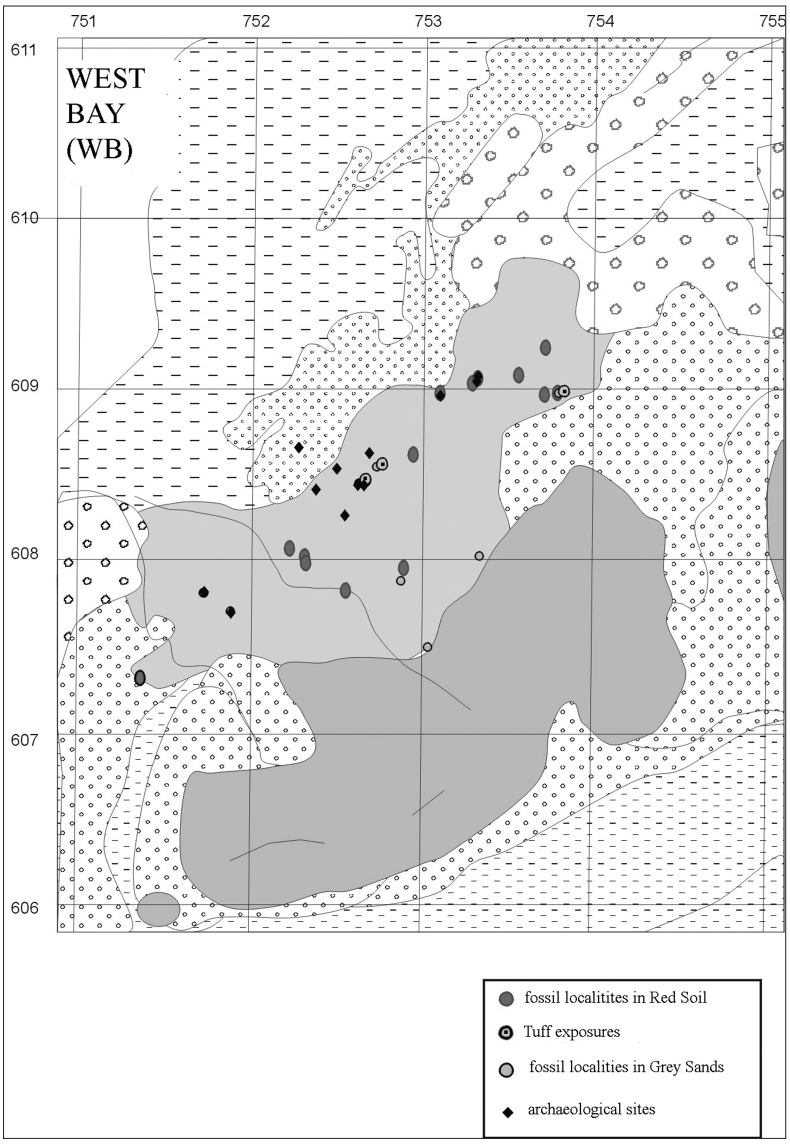


Fig. 2. Distribution of geological, paleontological and archaeological localities in West Bay.

Results of our study

Field surveys and geomorphological studies have been carried out to identify the extent of the fossiliferous deposits and to locate the best outcrops where the stratigraphy of the uppermost units could be determined. Following previous works, these units are Members A, B and C of the Eyasi Beds and the overlying brown clayey sands and clays. As previously reported, exposures are scarce and due to the low relief of the basin, there are no deep gullies cutting through the stratigraphical sequence. A number of stratigraphical sections have been done through the northeast sector of the Lake Eyasi mudflats, covering all the exposures. Granulometrical and mineralogical analyses were conducted on samples taken from these outcrops, using X-Ray diffraction, thin sectioning and sieving.

Two main units have been described in the area where a large number of lithic artefacts and fossils have been recovered: Red Soils and Grey Sands. Red Soils correspond to the Eyasi Beds, mainly to Mehlman's (1989) Members A, B and C and to the Capping Horizon of Rafalski *et al*. (1978). Grey Sands correspond to the sediments overlying the Eyasi Beds briefly described by Mehlman (1989) (***Fig. 3***).

of layers from different sedimentary environments and sedimentary rates in terrestrial reduced environments are rarely constant.

Another sedimentary unit overlying the Eyasi Beds was defined both by Mehlman and Kohl-Larsen: a dark gray clay containing fish bones, brown clayey sand and at least 40 cm of clay. The thickness of this unit was highly variable, reaching a maximum of 4.7 m in one of the trenches. Derived tuff fragments also occur at the sand/clay interface in coarse sands. These deposits were correlated with units VI-A and VI-B of the Mumba Beds. The age of these deposits would be around 130,000 ± 5000 years bp, based on uranium-series dating of Bed VI-B (Mehlman 1989), and assuming again a constant deposition rate.

Red Soils are equivalent to the description of Units A and C of Mehlman (1989). These consist of more than 3 m of thick clays and sandy clays, reddened, pelletoidal and highly edaphic, showing intense bioturbation mainly due to roots. Rootmarks are evident in well-cemented coarse- to medium-grained sand casts. Locally, some tuffaceous clayey thin layers are interbedded. Soil development is common, giving rise to successive hardgrounds. Some thin sandy layers as well as coarse channel fill deposits are also interbedded. Red layers include a large number of fossil remains including bones of hippopotamus, lion, hyena, bovids or equids as well as crocodiles, ostrichs and catfish, suggesting a near-lakeshore environment. This description includes the so-called "Skull site" (Mehlman 1989).

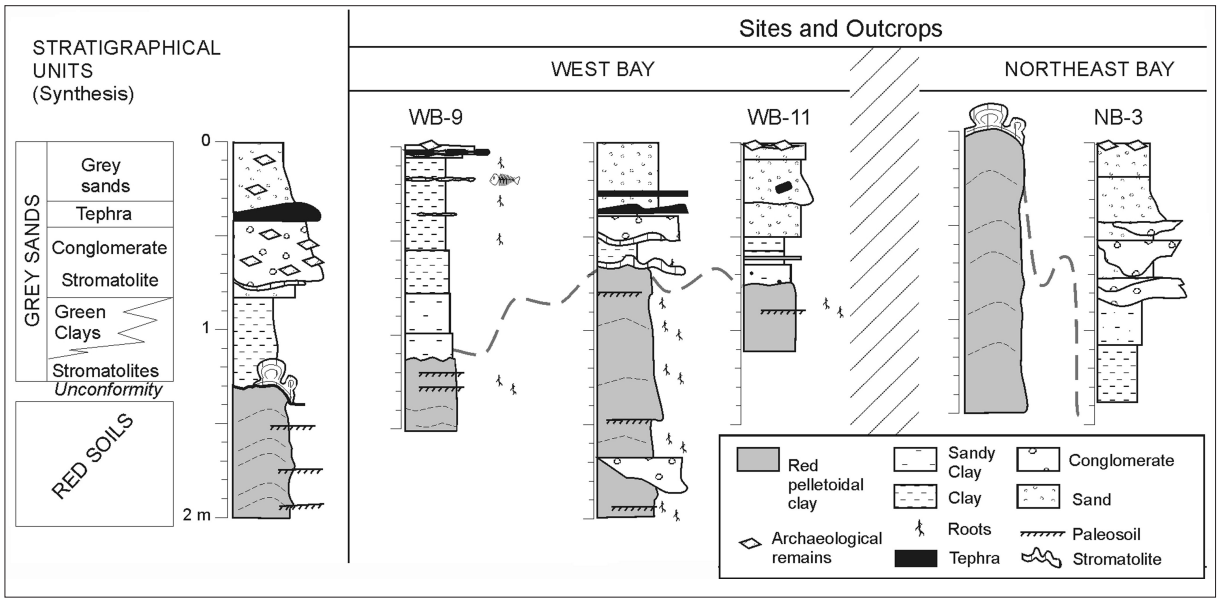


Fig. 3. Synthetic stratigraphical section of the fossiliferous quaternary exposures in Notheast Eyasi lake-shore both at Northeast and West Bays. Stratigraphical section of some Eyasi sites and outcrops.

The sedimentological features of the Red Soil unit suggest periods of subaerial exposure, iron oxidization, plant colonization, bioturbation, cementing and hardening giving rise to soil formation, alternated with flooding of the alkaline lake. Channel incision and the development of small sand dunes occurred during low lake level periods. The Red Soils must have been formed during a Pleistocene high lake level, and variations in the unit are due to lake level oscillations during this time.

The formation of the Red Soils was followed by a time of tectonic deformation and later erosion. The Red soils were folded after deposition following a direction parallel to the main rift (NE-SW). Taking into account that this slight ground movement runs parallel to the major faults, sediment folding is more likely due to land-sliding or solifluction of the unconsolidated mudflat than to any compressive tectonics. A lower lake level and seismic activation may be the source of this solifluction process. After that, erosion affected the deposits, reinforcing the interpretation of a low lake level giving rise to a sharp erosional surface over the Red Soil deposits. Our observations run counter to previous work which suggested that regional faulting and volcanism had ceased earlier, and that shoreline deposits were approximately undeformed and horizontal (Reck & Kohl-Larsen 1936). Mehlman (1989) noted that this area was tectonically unstable, and susceptible to tilting and deformation.

After the Red Soils, a heterogeneous new sedimentary unit was deposited: Grey Sands. Right over the erosional disconformity previously described, we find a large stromatolite development or a greenish clay layer coating (varies locally). Stromatolites are widely exposed in Northeast Bay, where a greater development of the Grey Sand unit has been observed. Bioherms usually are more than 1 m in height, but smaller hemispheric domes are also common. These bioherms were encrusted in previously eroded and well-cemented Red Soil reliefs. These stromatolites show at least two generations of stromatolite growth separated by a period of erosion and local breakage. Stromatolite growth suggests a period in which lake levels rose more than 4 m higher than the current level (following zonation proposed by Casanova 1987) after the erosion of the Red Soils. Thorium excess in its carbonate prevented us from estimating the age of the formation.

Clastic sediments of the Grey Sand unit consist of different units that can be fully represented in the same place or not depending on local sedimentary conditions. The first deposit following the disconformity is the Green Clay unit. Green clays have not been found together with stromatolites, suggesting that areas without decantation and with clearer waters were an optimum for biohermal growth, whereas temporary muddy waters were not. Green clays are massive to laminated, including sandy layers in a fining upward general trend that reach 1.6 m in thickness. Some fish bones have been found inside, usually related to fish bone aggregate limestone patches. Clays consist of palygorskite and analcime zeolite with some K-feldspar and plagioclase grains. Palygorskite and analcime are

usually secondary minerals formed, respectively, in semiarid environments exposed to desiccation and under highly alkaline waters (Hay 1978).

Unconformably over the clays, a wide conglomerate was deposited, reaching up to 0.4 m in thickness. Boulders, gravels and coarse sands comprise more than 50 % of the deposit, which contains a great number of fossil bones and lithic tools. Clasts are well-rounded but fossils and lithics show two degrees of abrasion: from highly rounded to sharp, almost intact edges. This deposit probably includes remains from Red Soils and *in situ* remains. In fact, Mehlman (1989) mentioned the possibility of reworking of the Kohl-Larsen collections. Sands and gravels mainly consist of quartz, K-feldspar, plagioclases and amphibols, suggesting a mixed volcanic and metamorphic source.

In some places, a thin limestone crust covers the Green Clays. Only in one point a well developed stromatolite bioherm as well as a number of oncolithes have been found at the base or into the conglomerate layer, suggesting a fast lake level rise or a minor oscillation at the beginning of this period. After the deposition of coarse alluvial sediments, a volcanic eruption occurred in the basin. In many places, 0.2 m of fine volcanic ashes covering the conglomerate layer are recorded. This microcrystalline ash deposit is locally folded, strongly weathered, and shows traces of partial reworking, as cross bedding or allochthonous minerals. It consists of analcime (authigenic zeolite) and plagioclas. A minor occurrence of muscovite and salts is also found. This tephra layer was described by Mehlman (1989).

Overlaying the tephra or conglomerate deposit are 0.5 m of grey to brown, clayey, medium to coarse sands. This homogeneous layer includes scattered fossils and artefacts. Its mineralogical composition consists of quartz, plagioclase and amphiboles in a palygorskite-rich clayey matrix.

The Grey Sand unit is the thickest in the Northeast Bay, but it is also widely exposed both in NEB and WB as well as near the Barai River deltaic fan. The geomorphology of the area suggests that an old deltaic fan of the Paleo-Barai river discharged through a low-lying relief between horsts of the Lagangharel-Ishimijega hills. Grey Sands surround this old deltaic fan deposited on Red Soils and was slightly affected by tectonics. Today, the Barai River delta discharges southwards and at a lower level, but during the rainy season, part of the older deltaic fan is still flooded. This observation, together with stromatolite development, clay decantation and later deltaic fan progradation indicates that the Grey Sand unit was deposited during high lake stands, and the later clastic deposits were formed during a relatively lower-to-moderate lake level. This deltaic fan was probably oriented slightly northwards, as shown by the greater coarser deposit accumulation in the Northeast Bay. In contrast, WB shows a larger deposition of basal Green Clays and a condensation of later layers. It is clearly seen in the excavated sites, where deposits of less than 10 cm thick include coarse sands, tephra boulders, thin limestone crusts with fossil remains and lithic artifacts (***Fig. 3***). Some faulting in the Paleo-Barai deltaic fan is observable in aerial photographs, indicating that later tectonics affected the deposits. It is possible that these movements subsided in the south-eastern part of the area, changing the direction of the Barai river to its actual position.

The faunal localities and their paleoecological meaning

The Middle Pleistocene fauna from Lake Eyasi is generally modern, with the exception of five extinct taxa. These are: *Theropithecus oswaldi*, *Pelorovis* sp., *Hipparion* sp., *Sivatherium* sp. and *Hippopotamus* cf. *gorgops*. An extinct form of *Alcelaphus* and an extinct carnivore were previously reported (Leakey 1936) but there is some controversy regarding the identification of these fossils (Dietrich 1950). Current estimates of LAD (Last Appearance Documented) for *Hipparion* are around 400 Ka (Harris 1983). Even if *Hipparion* remains at Eyasi were estimated as "derived", their presence in the form of uneroded semi-articulated elements and not just teeth has been confirmed contradicting the idea that they were re-worked transported fossils. This would make current dates for the Eyasi deposits too young or, alternatively, the Eyasi specimens could be the youngest occurrence of this genus so far.

Faunal collection was limited to Mehlman´s Members C and D. ***Table 2*** shows all the species discovered in the fossiliferous lacustrine deposits by previous and current research. A diversity of habitats is represented, with a predominance of open spaces suggested by the abundance of alcelaphini, antilopini and equids. These open spaces must also have been in part arid plains since oryx and roan antelope are also present. Bushy or forested habitats must have occurred in the vicinity of the multiple small streams running through the lacustrine floodplain, as suggested by the presence of giraffes, bush pigs and kudu. Well-watered habitats probably were also present given the presence of reduncini such as waterbuck, reedbuck and kob.

In sum, both the NEB and the WB seem to have been fairly open grassy alluvial plains with small

Taxa	Common name	
Theropithecus sp.	baboon	x
Cercocebus sp.	small monkey	
Panthera leo	lion	x
Panthera pardus	leopard	x
Caracal caracal	caracal	
Crocuta crocuta	spotted hyena	x
Hyaena cf. *brunnea*	brown hyena	x
Canis sp.	jackal	
Herpestes sanguineus	mongoose	
Orycteropus cf. *aethiopicus*	aardvark	
Hystrix sp.	porcupine	x
Loxodonta cf. *africana*	elephant	
Equus burchelli	zebra	x
Hipparion sp.	equid	
Ceratotherium simum	white rhinoceros	x
Diceros bicornis	black rhinoceros	x
Hippopotamus cf. *gorgops*	hippopotamus	x
Phacochoerus aethiopicus	wart hog	x
Sus sp.	pig	
Giraffa cf. *jumae*	giraffe	x
Giraffa camelopardis	giraffe	x
Pelorovis sp.	giant buffalo	
Syncerus caffer	buffalo	x
Taurotragus oryx	eland	
Tragelaphus strepsiceros	kudu	x
Gazella granti	Grant's gazelle	x
Gazella thomsoni	Thomson's gazelle	x
Kobus ellipsiprymnus	waterbuck	x
Kobus kob	kob	
Redunca redunca	reedbuck	x
Hippotragus equinus	roan antilope	x
Oryx beisa	oryx	
Aepyceros sp.	impala	
Alcelaphus sp.	alcelaphini bovid	x
Beatragus sp.	alcelaphini bovid	
Damaliscus sp.	alcelaphini bovid	x
Connochaetes taurinus	wildebeest	x
Cephalophus sp.	duiker	x

Tab. 2. List of faunal fossils discovered in the Eyasi lake deposits as identified by Leakey (1936), Dietrich (1943), Cooke (1963), Mehlman (1989) and our team (marked by "x").

streams cutting through NEB towards the lake and with the former Barai River entering the lake through WB. This would have made WB more wooded than NEB, given the size of the river and accompanying gallery forest. Accordingly, the highest diversity of tragelaphini as well as hippo remains is reported in WB. Mehlman (1989) reported remains from a total of 21 hippos, most of which came from WB. Most of the fossil hippos that our team has found were also discovered at WB. Fairly complete specimens occur in the NW corner of WB (***Fig. 4***), in exactly the same location where Kohl-Larsen discovered the three hominid skulls. This location also preserved abundant tree roots (***Fig. 5***), which are the only direct evidence for forested areas in both fossiliferous zones.



Fig. 4. Complete mandible of *Hippopotamus* cf. *gorgops*.



Fig. 5. Fossil tree root in West Bay.

When comparing the frequencies of bovids adapted to open and closed vegetation, it can be observed that even if open-habitat taxa are still predominant, WB shows a higher percentage of bovids from bushy environments than does NEB. This is supported by the fact that all rhino specimens and most equid specimens found by our team come from NEB. Overall, thus, NEB seems less bushy than WB, although both seem fairly open according to faunal indicators.

Trophic dynamics must have been similar to those documented in open ecosystems like the modern Serengeti. Carnivore taxa are well represented: lions, leopards, spotted hyenas, brown hyenas, jackal

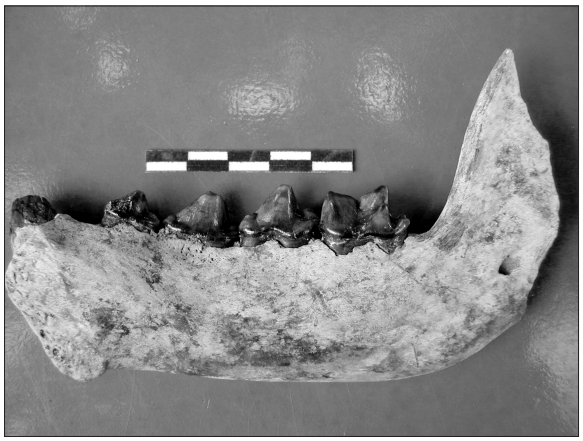


Fig. 6. Mandible of fossil brown hyena (*Hyaena* cf. *brunnea*).

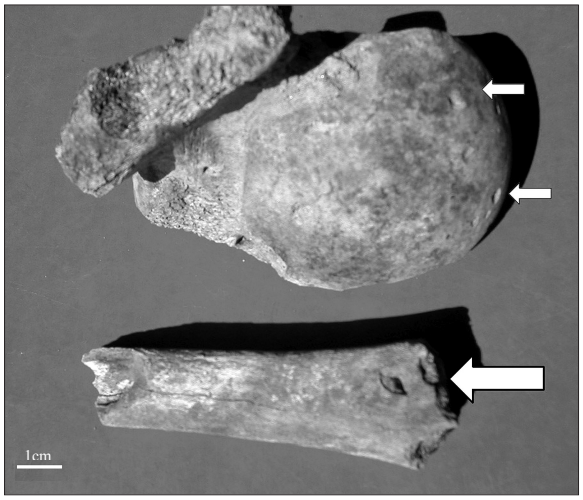


Fig. 7. Some bone specimens bearing tooth marks (arrows).

and caracal seem to have been part of the predatory guild. Crocodiles are also well represented. They probably were part of the predators adapted to riverine settings. Carnivore remains appeared in both bays. Hyenas (*Crocuta crocuta* and *Hyaena* cf. *brunnea*) were discovered in NEB (***Fig. 6***) and lion remains were found in the same locality where hippo fossils abound, near the hominid site in WB. We believe there was no spatial separation of the home ranges of hyenids and felids given the small size of both fossiliferous zones and their proximity to one another. However, if the Eyasi taphocenoses represent communities deposited over the areas most frequently used by those biocenoses, it is not surprising to find lion remains in WB given their adaptive preference for woodland savanna (Schaller 1972). The abundance of carnivores further supports our interpretation of a very open landscape.

Bones in paleontological localities show differential preservation. At some localities, axial bones are abundant and carnivore modification of bones is low to moderate. In other localities, carnivore ravaging of bones appears more intense. Bone scatters across the landscape frequently show carnivore modification in the form of tooth marks, punctures and conspicuous furrowing of cancellous tissue (***Fig. 7***).

In summary, in the 6 km^2 comprised by both areas, there is a complete representation of the typical biomass that can be found in a modern savanna ecosystem. All major taxa are well represented. NEB and WB were part of a more extensive, alluvial, lacustrine plain with several microhabitats occurring in a predominantly open grassland.

The paleovegetation of the Northeast and West Bays

Methods and sample

Five pollen samples were analysed from the Middle Pleistocene deposits (***Tab. 3***). Pollen preservation was generally good, excluding sample 2, which had poor preservation due to clay-dominated soil. Samples 1 and 2 (Eyasi skull site) come from the top of the Red Soils (members A–C). Sample 3 (WB9 site) comes from the overlying stratum (overcapping member) in WB. Samples 1 and 2 are separated by 30 meters; samples 1–2 and 3 by 800 meters. Samples 4 (NEB3 hominid) and 5 (NEB3) are of the same overcapping stratum in NEB, 3 km from the WB9. Sample 4 (NEB3 hominid) was taken at the point where our team found a cranial fragment of archaic *H. sapiens* (EH6) (Domínguez-Rodrigo *et al*. 2007).

The sediments were sampled 50 cm inside the front of each profile in order to avoid modern contaminants. The samples were carefully sealed and transported for analysis to the Laboratorio de Arqueobotánica in Madrid, Spain. Approximately 30 g of sediments were processed from each sample. Chemical treatment for pollen extraction followed methods developed by Girard & Renault-Miskovsky (1969). Pollen concentrations were estimated by adding Thoulet solution to the sediments (Goeury & de Beaulieu 1979). All pollen grains and spores encountered were identified according to Bonnefille (1971a, 1971b) and Bonnefille & Riollet (1980). Non-pollen palynomorphs were identified according to Jarzen & Elsik (1986). The results of the pollen counting (up to 450 grains per sample) are presented as percentages of the total count of terrestrial pollen (***Tab. 3***), excluding the herbaceous aquatic plants

Palynomorph/Non-pollen palynomorph	Sample 1	Sample 3	Sample 4	Sample 5
Pollen sum	481	459	508	537
Montane forest and highlands	16.0	15.9	14.2	9.9
Brucea	0.2	0.4	0.6	0.0
Celastraceae	0.2	0.4	0.4	0.0
Ericaceae	0.6	0.4	0.2	0.2
Juniperus procera	2.7	4.6	2.2	1.5
Hagenia abyssinica	0.6	0.4	0.8	0.9
Hypericum	0.4	0.0	0.4	0.0
Olea capensis	2.3	1.3	2.6	1.3
Olea europaea subsp. *africana*	0.4	1.1	0.6	0.7
Podocarpus	8.5	7.2	6.5	5.2
Somalia-Masai	10.8	12.6	11.4	14.5
Acacia group III	2.3	2.8	1.6	2.8
Commiphora africana type	1.7	0.9	1.6	1.1
Salvadora persica	6.9	8.9	8.3	10.6
Riparian vegetation	8.9	10.0	6.9	8.8
Rhus	4.4	5.0	3.5	5.8
Moraceae	4.6	5.0	3.3	3.0
Other herbaceous taxa	64.2	61.4	67.5	66.9
Asteraceae liguliflorae	0.6	0.4	0.4	0.7
Asteraceae tubuliflorae	3.1	4.6	4.3	3.4
Chenopodiaceae/Amaranthaceae	4.8	5.4	6.9	6.1
Plantago	0.8	1.1	1.0	0.6
Poaceae	50.7	46.6	52.6	52.0
Hygrophytic herbaceous plants and ferns	23.3	26.4	24.0	18.6
Cyperaceae	10.2	13.7	8.9	10.1
Typha	11.4	10.7	13.0	6.1
Pteridophyta	1.7	2.0	2.2	2.4
Undetermined	4.2	3.3	2.4	4.1
Non-pollen palynomorphs				
Chaetomium sp	0.0	0.0	1.6	2.0
Dicellaesporites	0.4	0.2	0.4	0.0

Tab. 3. Relative percentages of the palynological taxa identified at Eyasi site.

and fern spores (Cyperacae, *Typha* and Pteridophyta) as well as non-pollen palynomorphs. The percentages reported of these taxa were calculated with respect to the total pollen counts (Domínguez-Rodrigo *et al.* 2001). Twenty-one distinct pollen taxa were identified, as well as two species of non-pollen palynomorphs and fern spores (***Tab. 3***).

Results and Discussion

The microflora identified are well preserved (excluding sample 2) and relatively homogenous, with only 21 identifiable pollen taxa. This is fairly common in this type of deposit (Bonnefille & Vincens 1985). Pollen spectra of four of the samples are very similar, possibly reflecting a similar chronology. The spectra are characterised by the high abundance of herbaceous taxa (61.4 to 67.5 %) among which Poaceae is dominant (46.6 to 52.6 %). Other important herbaceous taxa identified are Chenopodiaceae/Amaranthaceae (4.8–6.9 %), both Asteraceae liguliflorae (0.4–0.7 %) and tubuliflorae (3.1–4.6 %), and finally Plantago (0.6–1.1 %).

Among the modern arboreal markers of the Somalia-Masai phytogeographic region (10.8 to 14.5 %), three pollen types have been documented: *Acacia* (1.6–2.8 %), *Commiphora africana* (0.9–1.7 %) and *Salvadora persica* (6.9–10.6 %). Comparing this data with modern pollen rain in the nearby Lake Natron area (Vincens 1987), there is a significantly higher representation of *Salvadora persica* in the fossil record than in the modern sediments, sug-

gesting the possibility that this species was fairly common in the arboreal range in the Eyasi Basin at that time. This does not mean that *Salvadora* was dominant over *Acacia* or *Commiphora,* since both are weaker pollinisers while *Salvadora* is a strong polliniser.

Some elements of montane forest and highlands from the Afromontane phytogeographic region (White 1983) have been also identified, among which the most abundant are *Podocarpus* (5.2–8.5 %), *Juniperus procera* (1.5–4.6 %) and *Olea capensis* (1.3–2.6%), but also including *Brucea*, Celastraceae, Ericaceae, *Hagenisa abyssinica* (an excellent marker of the limit of evergreen montane forests), *Hypericum* and *Olea europaea* subsp. *africana*.

Some riparian elements, such as *Rhus* (3.5–5.8 %) and Moraceae (3.0–5.0 %) are also present; as well as swampy taxa like Cyperaceae (8.9–13.7 %) and *Typha* (6.1–13.0 %).

Ascospores of the *Chaetomium* type have been recorded in at least two samples. Species of Chaetomium are cosmopolitan cellulose decomposers common on a variety of plant debris, such as dung, straw, cloth, etc. (Jarzen & Elsik 1986).

The floral composition of four samples clearly indicates that the environment in the Eyasi Basin area was very open, dominated by grasses and with only a few trees. It was, thus, a landscape very similar to the one that can be observed in the area today: extended open grasslands (savanna-like) with scattered shrubs, which are elements of the Somalia-Masai phytogeographical region; narrow arboreal riparian formations (possibly in the form of gallery forest) restricted to river or lake margins; and, finally, Afromontane forest and highlands in the mountain systems surrounding the lake basin, which never extended to the lake margins because the percentage of plants belonging to Afromontane forest is lower than 25 % (Vincens 1986).

The very important representation of aquatic taxa, especially Cyperaceae (13.7 % in sample 3) or *Typha* (13.0 % in sample 4), as well as the riparian vegetation in the four samples, could represent a humid palaeoclimatic phase with a higher water table level. This supports Vincens' (1989) argument, based on a Lake Tanganyika pollen core, that the massive contribution of fern spores could be related to a progressive increase of the annual half-temperature as well as of the humidity during the Late Glacial interstadial. Modern pollen rain from the Lake Natron area (Vincens 1987) shows that the percentage of Pteridophyta is usually lower than 2 %, while in our samples from Eyasi its percentage (excluding sample 1) is always higher.

Both data sets suggest that the four studied samples might represent a particularly humid and thermal phase that could belong to the beginning of the Eemian interglacial for the chronology to which these deposits belong. However, these data contrast with the high representation of the pollen types characteristic of the Somalia-Masai phytogeographical region (10.8–14.5 %), and particularly with the very high abundance of Graminae, indicating a prairie-type savanna.

The high proportion of aquatic taxa equally could be interpreted as the result of an arid phase, in which the lake level decreased, and areas formerly submerged would be revealed at the margins of the lake, being possibly colonised by Cyperaceae or *Typha*. The low quantities of halophilous indicators such as Chenopodiaceae/Amaranthaceae (4.8–6.9 %), whose pollen is today largely produced locally on exposed flats around lakes in arid areas (Vincens 1984), could suggest that Lake Eyasi was not surrounded by large alkaline plains at this time. This indicates that the catchment around the lake was not extremely arid (Vincens *et al.* 2005).

In any case, the relative abundance of Cyperaceae suggests the existence of swamp environments close to where the samples were taken; while the significant frequencies of *Typha* also indicate a local input of fresh surface water that probably corresponds to the beginning of more humid climatic conditions (Vincens *et al.* 2005). Comparing samples from the WB (1 and 3) with those from NEB (4 and 5), *Typha* pollen percentage is relatively higher in sample 4 (13.0 %) than in samples 1 (11.4 %) and 3 (10.7 %), but lower in sample 5 (6.1 %), so it is very difficult to ascertain significant differences in the evolution of the lacustrine level among the samples of the West and Northeast Bays. It is not feasible to hypothesise about diachronic changes in lake levels from this data, since the samples are relatively contemporaneous.

The low percentage of Afromontane forest could be also interpreted as the result of an arid phase, because high percentages of *Podocarpus*, in some cases, can represent a descent of the lower limit of the forest toward lower altitudes as consequence of higher rainfall (Vincens 1986), but this is not the case here. The high abundance of Poaceae in the samples demonstrates that the lake catchment had never been densely wooded during the time period sampled.

The archaeological research in West Bay

Archaeological remains were slightly more abundant in WB than in NEB. This, together with the different erosive processes operating in both areas, made us select WB and focus on the distribution of archaeological materials from a landscape approach. Erosion in NEB is mostly restricted to riverine ravines. A landscape approach there would imply digging through thick deposits of modern alluvial sediments. Very little modern sedimentation overlies the Middle Pleistocene deposits in WB, which are subjected to extensive erosion by deflation, exposing a large horizontal fossil-rich area. In some areas, surveys of materials appearing on the surface and, in other areas, minor excavations through a thin section of the sedimentary strata are sufficient to study fossil and archaeological material distribution over the landscape. However, erosion of fossiliferous strata is not even. Substantial areas of the deposits were eroded during the Middle Pleistocene prior to the deposition of younger sediments. Recent erosive processes, including transgressive and regressive cycles of the lake have produced extensive erosion and filling with lacustrine sediments of what appears to be an old horizontal exposure (made by deflation). This suggests that the distribution of materials in the landscape has as much to do with hominid and ecological dynamics as with the biasing processes of erosion. A traditional landscape archaeological approach would probably draw incorrect conclusions about land use if these differential erosive processes were not properly taken into account.

WB was systematically surveyed and fossil localities were documented with GPS coordinates and aerial photographs (***Fig. 2***). Fossils derive both from the Grey Sand and Red Soil Units, in the latter mostly from Member C (Mehlman 1989). As can be seen in ***Figure 2***, the location of sites at WB is not related to modern riverine erosion. Only localities with more than 50 faunal remains were plotted in the map. In between localities, abundant numbers of scatters appeared in the landscape, consisting either of isolated lithic or faunal specimens or of small clusters thereof. Occurrences of lithic artefacts without spatially associated fauna were documented in these scatters, as well as clusters of bones without artefacts and bearing no hominid-imparted modifications. Occasionally, isolated bones bearing cut marks were found in the landscape. This initially suggests that trophic dynamics could account for most of the fauna deposited in the form of scatters (and also in more dense patches) and that hominids were responsible for the deposition of lithic materials. On occasion, hominids were also responsible for the deposition of artefacts and functionally-associated bones.

The WB made a perfect testing background for several hypotheses:

1. In older chronological contexts, the spatial association of lithics and bones has been seriously questioned (see Domínguez-Rodrigo *et al*. *in prep.*), but this has not been the case for any bone and artefact occurrences in more recent time periods, especially during the Middle Pleistocene, where these associations have traditionally been considered to be functionally related. The examples are numerous. For instance, at the abundant Middle Pleistocene Acheulian sites in Middle Awash (Ethiopia), it has been suggested that lithics and spatially associated bones share a similar depositional history (Heinzelin *et al*. 2000). The WB is an ideal testing ground for the relatedness of depositional histories of bones and stone tools.

2. Following the previous point, the WB was also a good testing background for what has been called the archaeology of early *Homo sapiens* and the origins of modern human behavior. To what extent, if we ignore the chronological framework and the associated hominids, could we interpret sites from a strictly behavioral point of view and obtain different interpretations from earlier archaeological sites not associated with *Homo sapiens*? What do sites from the terminal Middle Pleistocene reveal that is distinct from what is already known from older Oldowan and Acheulian sites in terms of carcass acquisition, exploitation, lithic curation and overall adaptive patterns?

3. The transition between the Acheulian and the MSA (for some understood as Sangoan) is a crucial period. It coincides with the emergence of *Homo sapiens*. Very few sites of this time period contain both stone tools and fauna in undisturbed contexts (*see* ***Tab. 1***). Eyasi has fortunately preserved assemblages of stone tools and fauna in moderately to low disturbed contexts. Mehlman (1989) defined the local version of Sangoan at Lake Eyasi as Njarasa industry. What can be argued about this transition at Lake Eyasi and what is its behavioural meaning?

In summary, a behavioural approach to this period requires an answer to the question: what do we know about the subsistence behavior of hominids in the younger half of the Middle Pleistocene? As can be seen in ***Table 1***, the answer is not optimistic. At several sites, the post-depositional disturbance has prevented researchers from extracting information in this regard. At other sites, fauna does not exist or was not preserved. Finally, at those sites with low

to non-existent post-depositional disturbance and where fauna appears associated with stone tools, the lack of taphonomic studies prevents us from even knowing whether there is a functional link between both types of materials. Researchers working with this time period have been mostly focused on changes in lithic assemblages and have interpreted spatial associations of lithics and fauna as functionally related. We will see in the present work that such an assumption is unwarranted. We will also show that we know less about the adaptive behaviour of early *Homo sapiens* than we do about that of some of their ancestors.

The WB9 site

The most important surface patch observed in the course of fieldwork was WB9. Here, a 9 m^2 test excavation was carried out in 2004 (WB9A) and abundant *in situ* materials were found. Several faunal remains retrieved inside a small channel cutting through the excavated surface showed traces of water transport (*see below*), but most of the lithic remains showed fresh surfaces lacking polishing or abrasion. This, together with a representation of both small and large artefacts, supports the interpretation that the accumulation of lithics at WB9 was not the result of water transport, although the small amount of debris retrieved suggests some post-depositional disturbance of the site. The main goal of the work conducted in 2005 was therefore to extend the excavation in the area around the WB9A trench. A total area of 57 m^2 was opened around WB9A (named WB9D), where excavation depth rarely extended beyond 10 cm (***Fig. 8***). In order to reconstruct the local stratigraphic sequence (***Fig. 3***), two square meters located in the westernmost area of the trench were excavated until the water table was reached. The site lies in the top sequence of the exposed sediments of the Grey Sand unit, in the same stratigraphic interval as NB3 where the hominid cranial fragment (EH06) was found. ***Figure 9*** shows the reconstruction of artefact distribution at WB9 within the opened trenches. Locations of archaeological objects were recorded using both a handheld GPS and a total station. ***Figure 9*** shows a discontinuous distribution of lithics and bones. High density patches occur in two discrete areas; there are also many squares where no materials were found. The north patch has an area of about 4 m^2, with a density of artefacts that varies from 37 to 18 objects/m^2 (***Fig. 10***). The central patch is visually less obvious, where highest density values are 28 objects/m^2. General distribution of archaeological materials in the opened area shows a limited human impact, probably affected by fluvial post-depositional processes.

Along with the excavation at WB9, four other nearby areas were selected for excavation based on surface findings: WB11, WB12, WB13 and WB14. Test excavations measuring 6 m^2 were carried out in each of them. WB11 and 12 produced a few archaeological scatters (with very low density of lithics and bones), while the other two sites were archaeologically sterile.

General characteristics of the lithic sample and raw materials

A total number of 208 lithic artefacts have been retrieved from excavations in WB: 172 from the WB9 site, 6 from WB11, and 30 from WB12. WB13 and WB14 did not yield archaeological remains. ***Table 4*** shows the distribution of lithic artefacts and percentage frequencies by artefact category at the three studied sites. Due to small sample sizes, the three assemblages have been studied together in the analysis presented here. Detached pieces (flakes, flake fragments and retouched flakes) are the most abundant objects, representing 61 % of the sample. Fragments are the second most abundant category (30.3 %), being mainly core fragments, although in three cases the fragments are probably thick detached pieces. Cores represent just 8 % of the studied sample. Counting the weight of all the artefacts recovered at the West Bay sites, it can be argued that 4.8 kg of stone have been manipulated by hominids. When technical categories are sorted by their weight, detached objects show once again the highest percentage values (43.6 %), followed by cores (25.2 %) and fragments (25. 1 %).

A representative sample of the different lithologies was selected for petrological study. First, a macroscopic analysis has been carried out using a stereomicroscope (magnification: 7.5–112.5). This preliminary study was completed with petrographic thin section and X-ray diffraction analyses in five rock samples. The studied samples show that the lithic assemblage includes three types and six different groups (***Tab. 5***):

- Igneous rocks: 1. Sub-volcanic mafic rocks. A) *Pyroxenic microgabbro* is a micro-granulated, massive and apparently isotropic rock (***Fig. 11: A, p. 77***). A pattern made up of small and abundant tabular plagioclase crystals of yellowish grey colour (5Y 8/1) and a greenish black matrix (5GY 2/1) can be observed. It is formed by mafic minerals (mainly pyroxene). It shows a fine-grained (<2 mm) doleritic texture. This rock type is usually present as tabular structures (dikes, sills, *etc*.), associated with sub-volcanic mafic complexes. Exceptionally, this type of texture occurs in the internal areas of basaltic defiles; 2. Volcanic-lavic rocks, formed by magma solidification when the Rift was formed. This

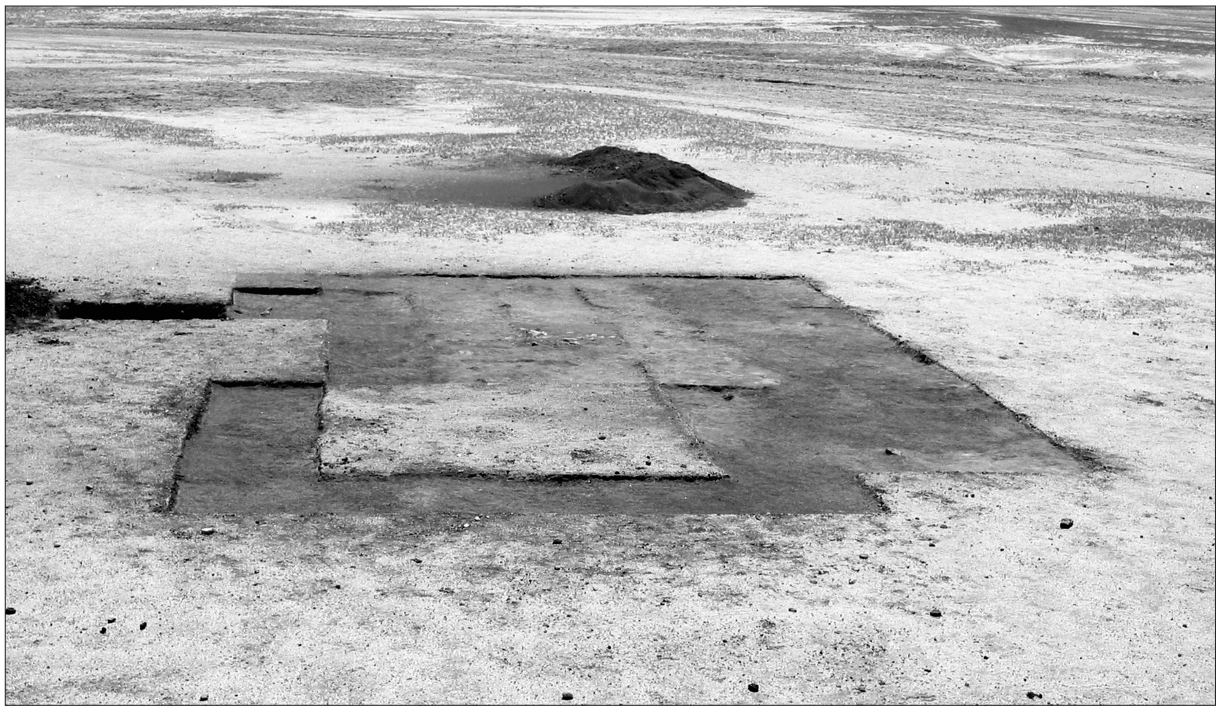


Fig. 8. Excavation of WB9.

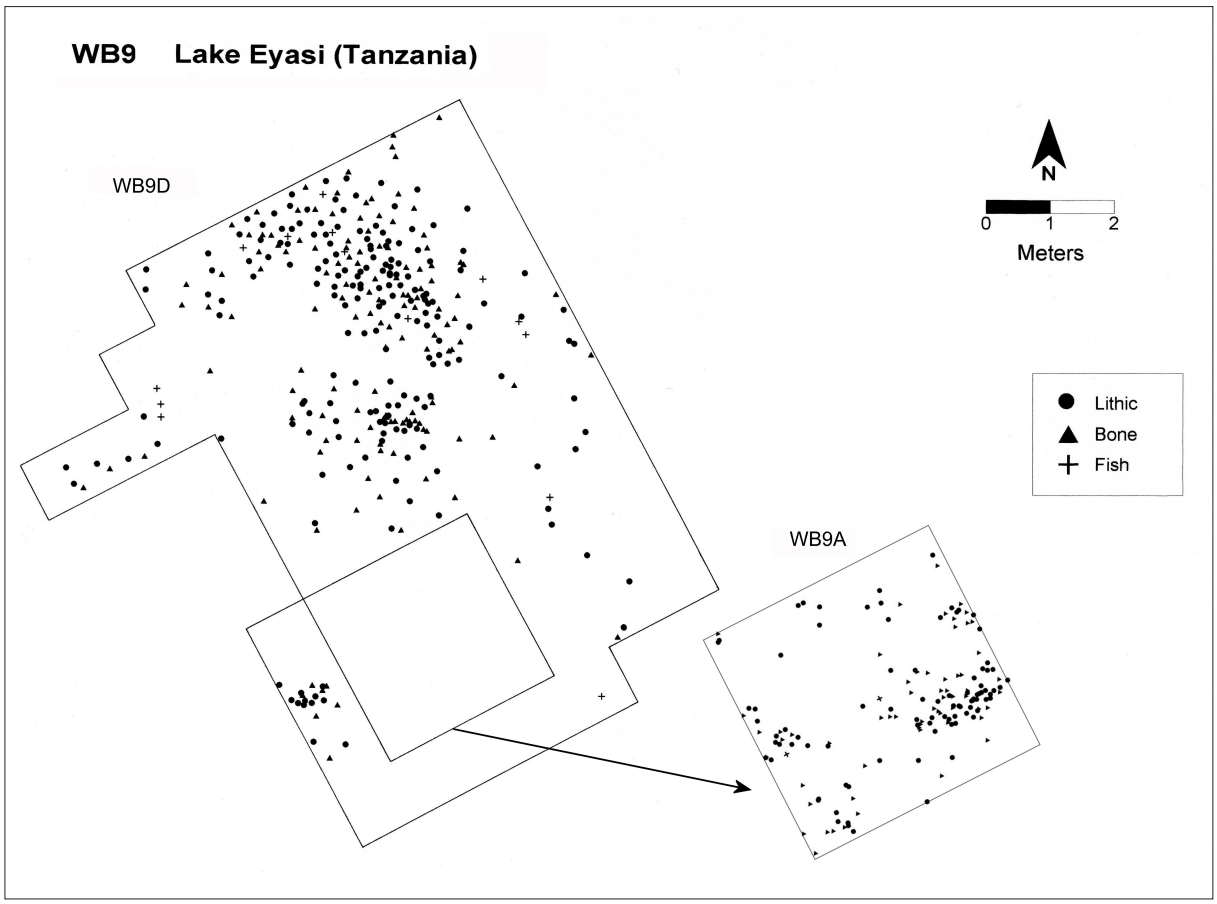


Fig. 9. Spatial distribution of bones and stone tools at WB9.



Fig. 10. Close-up of a cluster of stone tools at WB9.

	WB9		WB11		WB12		Total	
	n	%	n	%	n	%	n	%
Nodules	1	*0.6*	-		-		1	*0.5*
Cores	17	*9.9*	-		-		17	*8.2*
Fragments	50	*29.1*	5	*83.3*	8	*26.7*	63	*30.3*
Flakes	97	*56.4*	1	*16.7*	21	*70.0*	119	*57.2*
Retouched f.	7	*4.1*	-		1	*3.3*	8	*3.8*
Total	172		6		30		208	

Tab. 4. Distribution of technical categories by site at Lake Eyasi. West Bay.

Type	Group	Class
IGNEOUS ROCKS	Sub-volcanic Volcanic-lavic Volcanic-clastic	Pyroxenic microgabbro Nephelinite, basalt Vitreous ignimbrite Tuffaceous sandstone
METAMORPHIC ROCKS	Tectonites Regional metamorphism	Protomylonite Amphibolite
HYDROTHERMAL DEPOSIT		Hyaline quartz

Tab. 5. Diversity of raw material types, according to type, group and class, present in the WB9 lithic materials.

is a heterogeneous group made up of rocks with a variable basic composition: A) *Basalt* and B) *Pyroxenic nephelinite*. The latter is a massive and apparently isotropic rock of a greenish black colour (5GY 2/1). When altered, this rock shows colourations that vary from light olive (10Y 4/2) to greyish olive (10Y 6/2). Black tabular phenocrystals (sphena, <2 mm) and feldspathoids (nepheline, <0.5 mm) can be observed; 3. Volcanic-clastic rocks. These rocks, formed by clastic accumulation after volcanic explosion, are generically named pyroclastic, but when defiles rich in vitroclasts and pumicites are deposited they are called ignimbrites (Schmid 1981; Fisher & Schmincke 1984): A) *Vitreous ignimbrite* or vitreous tuff, a very fine-grained rock, similar in aspect to flint (***Fig. 11: B***). The colour is light olive grey (5Y 6/1) and shows small inclusions of opaque minerals oriented in thin lamination. B) *Tuffaceous sandstone*, a hard rock with arenaceous aspect (***Fig. 11: C–D***). Sand grains vary from 0.1–1 mm. Occasionally, some quartzes and/or feldspars can be longer than 2 mm. Vitreous laminations are intercalated with detrital laminations that include pumiceous clasts

Category	Proto-mylonite	Basalt	Tuffaceous sandstone	Vitreous ignimbrite	Hyaline quartz	Nephelinite	Amphibolite	Pyroxenic microgabbro
Nodules	-	1	-	-	-	-	-	-
Cores	13	1	2	-	-	1	-	-
Fragments	42	10	7	4	-	-	-	-
Flakes	67	18	15	8	6	2	2	1
Ret. flakes	-	2	3	2	-	1	-	-
Total *(%)*	122 *(58.65)*	32 *(15.38)*	27 *(12.98)*	14 *(6.73)*	6 *(2.88)*	4 *(1.92)*	2 *(0.96)*	1 *(0.48)*

Tab. 6. Distribution of frequencies of each artifact category according to raw material type.

larger than 1 cm. Colour varies from yellowish olive grey (5Y 6/1) in the vitreous bands to yellowish grey (5Y 7/2) in the arenaceous areas.

• Metamorphic rocks: 1. Tectonites. Rock type formed by deformation; only certain conditions of dynamic metamorphism can create this type of rocks. In the studied sample, laminated and texturally deformed tectonites have been found. According to Sibson's (1977) classification, these types of rock that show an anisotropic fabric are called mylonites. *Quartz protomylonite* is a clastic rock with micro-conglomerate grain size (>2 mm). Clasts show elongated morphology and a coarse lamination (***Fig. 11: E–F***). It is made exclusively of quartz, hyaline in aspect. Its colour tends to be greyish (from yellowish grey, 5Y 8/1 to light grey, N8). Occasionally smoky quartz clasts show colours that vary from dark grey (N3) to black (N1). 2. Medium to high regional metamorphism rocks: A*mphibolite* is a massive, dense, apparently isotropic and fine-grained (<2 mm) rock (***Fig. 11: G–H***). Dark colours vary from olive grey (5Y 4/1) to olive black (5Y 2/1). It shows a huge variety of black and shiny crystals (amphibole) in a lighter matrix (plagioclase).

• Quartz dikes: 1. *Hyaline quartz*. This group includes hyaline quartz probably originated from hydrothermal deposits or from the infilling of geode-type cavities.

Table 6 shows the distribution of artefacts and percentage frequencies by raw material. Quartz protomylonite is by far the most abundant (N=122), representing 58.6 % of the total count. It is the most used rock type in the flake, core and fragment categories. In fact, most of the nodules exploited for the production of flakes are protomylonites, evidence that is in agreement with the high percentage of unretouched flakes and fragments included in this rock type group. Although 56.3 % of the flakes have been obtained from protomylonites, no retouched tools have been produced from this raw material type, which might account for the fact that this material is not the most suitable rock type to carry out configuration processes. In fact, a wide range of fine to medium-sized grained rocks had been used for flake retouching activities (basalt, tuffaceous sandstone and nephelinite), none of them being particularly representative. Basalt is the second most abundant raw material type (15.4 %). This raw material is most abundant in the flake and fragment categories. However, one basalt core has been recovered in the studied sample, a ratio that contrasts with the fairly abundant number of flakes detached from this type of rock. Vitreous ignimbrite has been used for the production of detached objects and has been observed in fragments too. Hyaline quartz (2.9 %), nephelinite (1.9 %), amphybolite (1.0 %) and pyroxenic microgabbro (0.5 %) are residual in the general counts and are mainly recorded in the detached object categories. However, one core created from nephelinite has been encountered. In sum, regarding flaking properties, the coarse-grained protomylonite has been widely used in the knapping processes directed to core exploitation. However, a variety of medium- and fine-grained rocks (basalt, tuffaceous sandstone, vitreous ignimbrite, quartz and nephelinite) have also been used for flake production and configuration, although in lower numbers. The preferred selection of high quality rocks is most evident in the small sample of flakes that have been the subject of configuration processes.

With regard to the degree of abrasion observed on the external surfaces of the lithic objects, two groups have been established. Fresh artefacts, where no signs of abrasion have been observed, are the most abundant group (77.3 %), while slightly eroded objects, where some signs of patination can be seen in edges and surfaces, represent 22.7 %. As a general rule, lithic artefacts recovered at WB sites are in fresh condition. ***Figure 12*** shows the distribution of objects sorted by abrasion group and site. Signs of slight abrasion are more common at WB11 and WB12, the latter being a scatter found in a gravel environment, altered to some degree by fluvial forces.

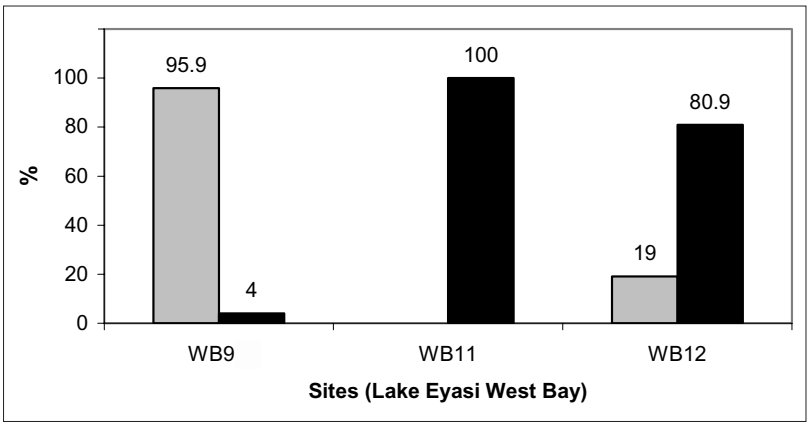


Fig. 12. Percentage distribution of lithic artefacts by abrasion and site. No abrasion (grey), slight abrasion (black).

	minimum	maximum	mean	std. deviation
length (mm)	36	67	47.35	8.68
width (mm)	32	64	41.58	8.21
thickness (mm)	16	42	31.41	8.11
weight (g)	24	162	71.17	42.23

Tab. 7. Core dimensions and weight.

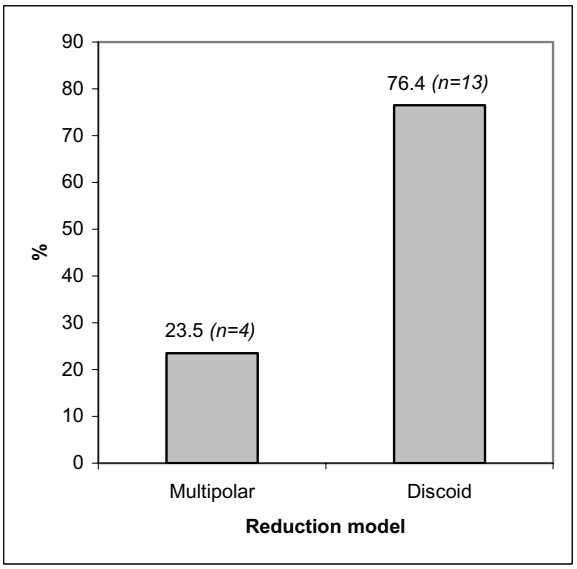


Fig. 13. Exploitation strategies observed at West Bay sites.

Reduction sequence

Nodules and hammerstones

At WB9 one basalt nodule, 69x60x49 mm, 286 g. has been retrieved. This object shows surface scars in multiple directionalities, a pattern that has been interpreted as the result of percussion activities.

Cores and reduction strategies

A total number of 17 cores have been retrieved at WB, all of them from WB9. ***Table 7*** shows the mean measurements and weight of the artefacts included in this category. As it can be seen in ***Table 7***, all these pieces are small and, therefore, all of them have been subjected to intense reduction on both surfaces. Three cores are considered exhausted: 82 % show no signs of cortical areas on both surfaces while the remaining 18 % retain small amounts of cortex on their lower surfaces (1/4). Core support is in most cases a nodule, although two examples can be reported where the support could have been a large flake. Mean number of negative scars per core is 7.74 (scar interval recorded is 4-10). Although 76 % of the cores have been derived from coarse-grained protomylonite, reduction patterns are easily observable. Core classification has been carried out based on two attributes: faciality and scar directionality or polarity. Through the combination of these criteria, two exploitation models have been observed; their percentage distribution is shown in ***Figure 13***:

- Multifacial/multipolar. Known as polyhedral cores, this type consists of cores that show negative scars on more than three faces and striking platforms (***Fig. 14: A and B***). A total number of 4 protomylonite nodules have been exploited in this fashion. The mean number of negative scars observed in multipolar cores is 7.6.

- Discoid. This reduction model consists of cores in which a radial flaking pattern has been recognized. Radial exploitation constitutes the most abundant reduction type in the analyzed sample. Centripetal exploitation at WB sites has always been performed on the two surfaces of the nodule (***Fig. 14: C and D, p. 78***). Bifacial discoid cores share the patterns that commonly define the bifacial non-hierarchical discoid flaking method (Boëda 1995). The mean number of negative scars observed in discoid cores is 7.6. In four cases the intersection plane defining bifacial discoid reduction creates a semi-abrupt angle with the lower face which produces a pyramidal morphology.

	minimum	maximum	mean	std. deviation
length (mm)	18	66	38.44	10.93
width (mm)	13	48	28.34	8.21
thickness (mm)	6	34	18.09	5.59
weight (g)	4	78	25.08	20.23

Tab. 8. Fragment dimensions and weight.

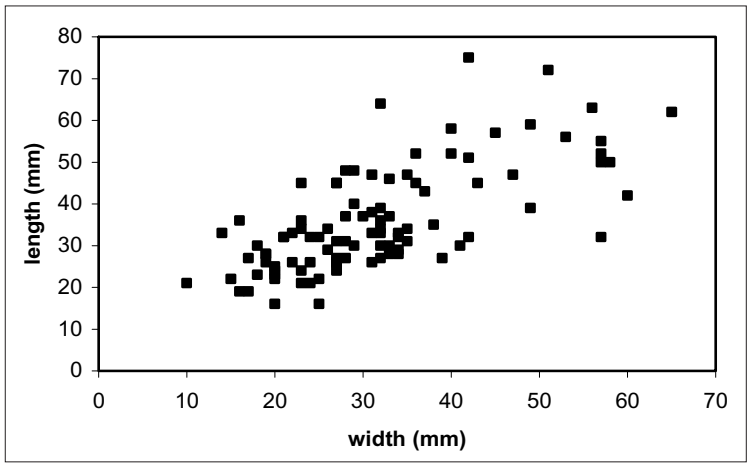


Fig. 15. Size scatter diagram of flakes (length and width).

Two of these pyramidal discoid cores have been exploited to exhaustion. However, another object has been observed with a possible hierarchisation of both surfaces, although the characteristics that define the production of predetermined flakes are not clearly distinguished.

A total number of 20 negative scars has been measured within the core sample. Mean dimensions of these scars are 29 (range 19–52) x 25 (11–47) mm. These values are clearly lower than the mean measurements observed in whole flakes, a point that confirms that the core sample retrieved represents the later stages of the reduction sequence. However, at WB9, core to flake ratio is 5.7, a bit lower than the mean number of negative scars observable in cores. Taking into consideration that cores were highly exploited, this might mean that the small flakes related to later reduction stages are missing.

Fragments

Fragments constitute the second most important lithic category at WB sites, representing 30 % of all artefacts recovered. Mean dimensions and weight of fragments are shown in ***Table 8***. 9 % of these objects are core fragments preferentially made from protomylonite, although there are three that might be detached objects. In 27 % of the cases it has been possible to recognize the reduction pattern from which these fragments derive. A centripetal model predominates (65 %), although some pieces with polyhedral patterns have also been observed.

Flakes

A total number of 119 artefacts has been included within the flake category: 97 whole flakes, 6 fracture flakes and 16 flake fragments (***Fig. 14: E***). Among the unretouched flakes, 8 pieces can be considered blades or bladelets *sensu lato* (***Fig. 14: F***): their length is always two times greater than their width, although they do not show parallel negative scars on their dorsal surface that could suggest the use of a specific blade technique. Unretouched flakes are by far the most abundant objects, representing 57 % of the studied collection. ***Figure 15*** shows the size scatter diagram (length and width) of plain non-fragmented flakes and ***Table 9*** shows their mean measurements and weight. As can be deduced from the scatter diagram, most of the unretouched flakes fall within a fairly homogeneous dimensional module, ranging from 21 to 60 mm in length. In fact, 64 % of detached products show a length between 21 and 40 mm; 24 % between 41 and 60 mm; and 5 % between 61 and 75 mm. Only 4 % of the pieces included within this technological category can be considered to be debris (length less than 20 mm). Raw material type seems to correlate with the dimensional values of by-products. When mean measurements are sorted by rock type, it appears that nephelinite flakes are the largest (51x51 mm), followed by basalt (40x38 mm), protomylonite (37x30 mm), tuffaceous sandstone (34x27 mm) and vitreous ignimbrite (26x23 mm). Hominids were, then, producing their largest (nephelinite and basalt) and smallest (vitreous ignimbrite) products from rocks showing better flaking qualities. However, this point

	minimum	maximum	mean	std. deviation
length (mm)	16	75	36.10	12.58
width (mm)	10	65	31.69	11.82
thickness (mm)	5	33	12.69	4.82
weight (g)	1	122	21.34	24.16

Tab. 9. Measurements and weight of flakes.

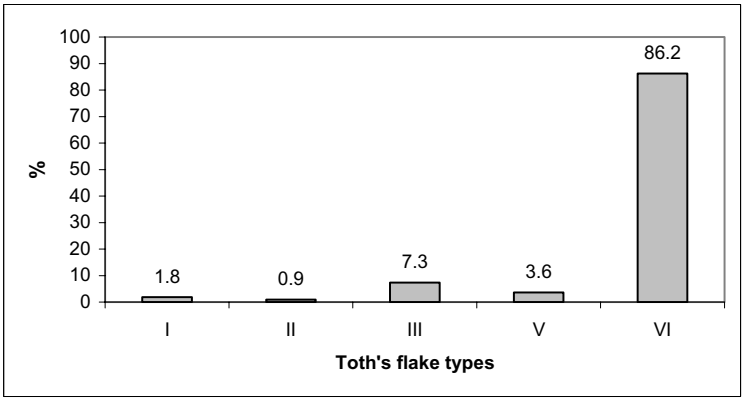


Fig. 16. Percentage distribution of flake types according to Toth's (1982) model.

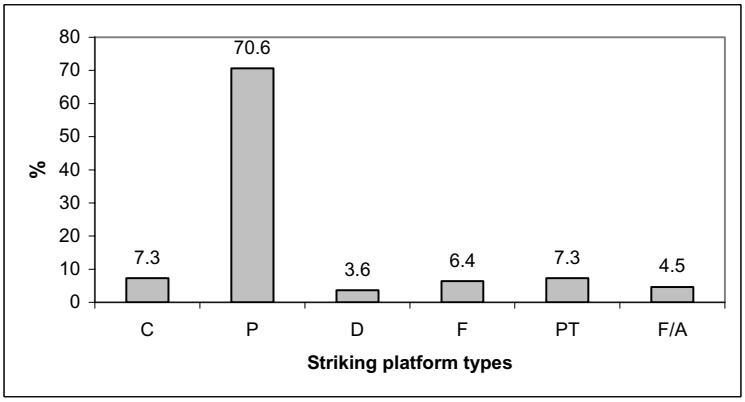


Fig. 17. Percentage distribution of striking platform types in flakes (C: cortical; P: plain; D: dihedral; F: faceted; PT: punctiform; F/A: fractured/absent).

cannot be confirmed by the core collection analyzed because this sample is mainly comprised of protomylonite nodules. In summary, the flakes recovered at WB sites tend to be medium-sized, which might be indicative of fairly homogeneous reduction strategies carried out at these sites (confirmed by the recurrent use of the bifacial discoid technique). However, small chips and debris are clearly underrepresented, evidence that should be taken into consideration regarding site function interpretations. At WB9 some flaking activities would have been carried out on site, as is confirmed by the exploited cores and core fragments discarded here. However, the lack of debris and small by-products might be indicative of some sort of post-depositional disturbance processes, although this cannot be clearly confirmed by surface abrasion patterns. On the other hand, at WB11 and WB12, flake dimensional modules and absence of cores indicate that flaking activities did not take place here.

With regard to their position in the reduction sequence, the majority of flakes are indicative of secondary reduction. ***Figure 16*** shows the distribution of flakes sorted by their amount of cortical surface according Toth's (1982) classification. Specimens retaining cortical areas on their dorsal surfaces are very scarce (6.4 %) and only 1.8 % of them are pieces that belong to the initial flaking stage. In summary, the majority of these objects can be classified as non-cortical flakes (type VI). These morphological parameters show that at WB9 only later stages of core reduction were performed, while initial flaking had taken place elsewhere. The degree of core exploitation and the dimensions of negative scars in cores support the idea that a number of non-cortical flakes discarded here could have been produced outside the site. Regarding striking platform areas (***Fig. 17***), 81 % of flakes are not cortical (plain, dihedral and faceted platforms), while only 7.3 % are cortical. This pattern is in agreement with the use of

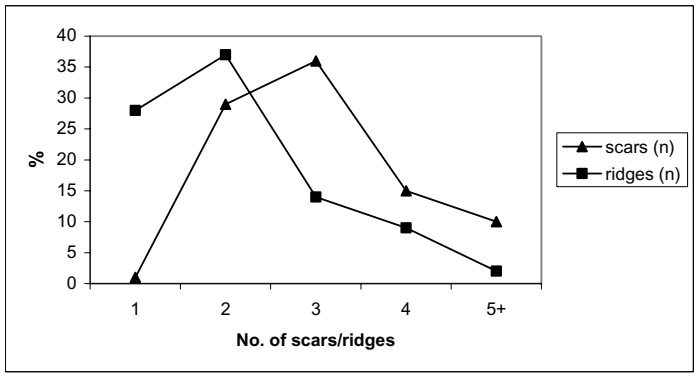


Fig. 18. Percentage distribution of flakes by dorsal scars and ridges.

	minimum	maximum	mean	std. deviation
length (mm)	27	72	41.00	16.26
width (mm)	19	40	30.12	8.21
thickness (mm)	6	18	11.62	4.34
weight (g)	3	45	17.71	14.49

Tab. 10. Measurements and weight of retouched flakes.

reduction strategies that imply some sort of platform preparation. Bifacial discoid technology (predominant in the analyzed sample) is accommodated within this model. The presence of dihedral and faceted striking platforms suggests that platform preparation was rather elaborate in a number of cases. Dorsal surface characteristics (number of previous scars and ridges) have also been studied (***Fig. 18***). Flakes showing three or more negative scars on the dorsal surfaces represent 67 % of the sample, three being the most frequent number recorded (40 %). The arrangement of previous scars on the flakes' dorsal surfaces shows that flakes that come from reduction models where a centripetal rotation of the core was performed are common (*i.e.* discoid cores). One basalt predetermined flake could have been obtained from a Levallois-like core, although it is difficult to clearly distinguish this type of by-product from a dominant non-hierarchical discoid environment. Another four objects (4 % of complete flakes) show very thick striking platforms (or, more accurately, core platform surfaces) and can be interpreted as being core tablets or rejuvenation platform flakes (***Fig. 14: G***).

Retouched flakes

Flakes and flake fragments that have been transformed by retouch are scarce at WB sites, representing 3.8 % of the sample: 7 objects from WB9 and 1 from WB12. ***Table 10*** shows the dimensions of the retouched flakes. Mean dimensions show that these objects are slightly larger, thinner and lighter than unretouched flakes, although the sample is not large enough to confirm that flakes selected for later retouch follow a particular dimensional pattern. Retouched objects show characteristics similar to those observed in unretouched flakes. Seven tools had been made from non-cortical flakes (Toth's type VI) and one retains some cortex on the dorsal surface (type II). When preserved, striking platforms are plain (n=5) and cortical (n=1). The mean number of previous dorsal scars is 3. Location of retouch is both left- (n=4) and right-sided (n=3). Retouch is mainly denticulate, semi-abrupt and marginal. Equal numbers of pieces show exterior and interior retouch. From a typological point of view, most tools have been fashioned into notch types (n=6; single or double, ***Fig. 14: H***), although a side scraper and a trimmed flake (with irregular retouch) have been also recorded (***Fig. 19***).

Conclusions

Recent archaeological work carried out at West Bay of Lake Eyasi has enabled the study of a lithic sample from the WB9 site and from other scatters in the vicinity of this patch. Although this collection is small in number, its technological characteristics can provide basic information on the knapping activities and mobility strategies carried out by hominids in this area of the lake during Late Middle/Early Upper Pleistocene times. The main traits of the lithic sample recovered at WB9, WB11 and WB12 (n=208) can be summarised as follows:

- At WB, a wide number of volcanic rocks were utilized by hominids in their knapping activities: protomylonite, basalt, tuffaceous sandstone, vitreous ignimbrite, nephelinite and hyaline quartz. However, although this evidence confirms that hominids were using different types of igneous and metamorphic raw materials for knapping purposes, most of these rocks

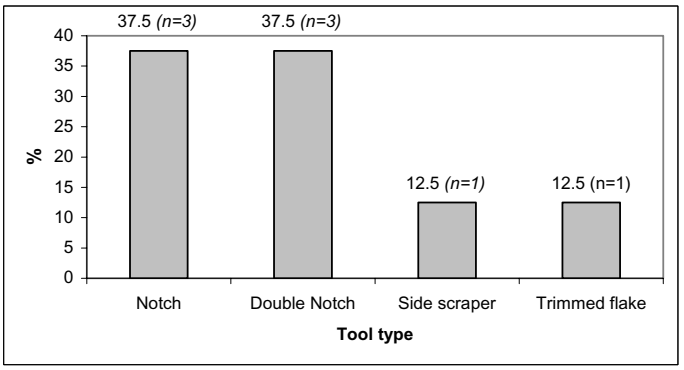


Fig. 19. Distribution of retouched objects by tool type.

are rare, represented in the sample by a very limited number of artefacts. Quartz protomylonite, a rock that shows obviously poor qualities for knapping due to its textural characteristics, was the most abundant rock type used here (59 % of artefacts were made of this type of rock). This raw material was recurrently used for exploitation sequences: the majority of cores and a high percentage of core fragments and unretouched flakes. Taking into account that debris is the dominant technical category in the studied sample, this selection might account for the general morphological characteristics observed in the sample. On the other hand, configuration sequences (carried out through small tool retouching) are always performed on higher quality rocks (basalt, tuffaceous sandstone, vitreous ignimbrite and nephelinite). Although retouched tools are scarce, it seems probable that there was a differentiated selection of rock types and textures for carrying out exploitation and configuration processes. This selective pattern can also be supported when product dimensions are taken into account: the largest and the smallest flakes were always made on the best types of rocks (nephelinite or basalt and hyaline quartz, respectively).

• The majority of lithic artefacts recovered can be included in exploitation sequences (core, fragments and flakes), which means that flake production was the main focus of the knapping processes carried out. Cores were only retrieved at WB9. Here they represent 9.9 % of the lithic sample. Exploitation techniques used are limited to multipolar and centripetal reduction models. In fact, the bifacial non-hierarchical discoid method seems to have been recurrently applied. This tendency can be observed, not only in the high percentage of discoid cores, but also in the number of core fragments and flakes where radial traits can be observed. Although the presence of predetermined reduction models and predetermined flakes can be suggested, it seems evident that the Levallois technique would have played a very limited role (if any) in the reduction models performed by hominids. Cores are small and show a high degree of exploitation and/or exhaustion.

• Primary flakes are almost absent in the flake category. Most flakes belong to secondary flaking sequences and, therefore, preserve no cortex on dorsal surfaces. Butts are non-cortical (preferentially plain, although dihedral and faceted striking platforms have always been recorded). Products are medium-sized, the majority of which fall within the range of 21–40 mm in length.

• It seems that small flake retouching activities were not a main objective here. Retouched tools are scarce and flakes were fashioned in a very limited number of types. Single or double notches predominate, although a single side scraper was also retrieved. Notch or scraper retouch is always semi-abrupt and preferentially marginal.

• The morphological and technical characteristics observed in the three lithic samples studied here can provide some information about site function (basic tool flow around the landscape) and the implication of post-depositional disturbance processes. At WB9, a cluster where lithics and bones were accumulated in relatively high numbers, it seems that knapping activities did take place on the spot. Discoid and multipolar cores, flakes and some core tablets suggest this behavior. However, the scarcity of cortical flakes shows that primary flaking did took place elsewhere outside the opened trench or outside the spot. Discarded cores belong to the later stages of reduction and it is not possible to assess the original characteristics of the blank formats selected by hominids to perform their exploitation activities. Taking this limitation into account, the relationship between flake and negative scar dimensions, and the absence of cores exploited in residual rock types suggest that a number of flakes discarded here (preferentially the larger on basalt and nephelinite and those produced on the most exotic rocks) were actually obtained somewhere else. Small debris, resulting from flaking, are almost absent from the collection. This might indicate that the intensity of flaking was very limited or that fluvial disturbance processes played a role here, although

	NISP	%
Bovidae	45	55.5
Suidae	1	1.2
Hippopotamidae	10	12.3
Chelonia	3	3.7
Pisces	22	27.1

Tab. 11. Frequencies of specimens of each faunistic group represented.

	Bovid	Suid	Hippo
horn			
skull	3		1
teeth		1	5
mandible			
vertebra	3		
ribs	14		2
pelvis	1		
scapula	1		
humerus	6		2
radius-ulna			
carpals-tarsals	3		
metacarpal	7		
femur	1		
tibia-fibula	3		
metatarsal	2		
patella			
phalanges	1		
other			

Tab. 12. NISP of the faunal assemblage at theWB9 (Eyasi).

	NISP size 1/2	size 3	size 4/5
Humerus complete			
Humerus prox.			
Humerus prox.+ shaft			
Humerus shaft	2	3	2
Humerus dist.		1	
Humerus dist.+ shaft			
Radius complete			
Radius prox.			
Radius prox.+ shaft			
Radius shaft			
Radius dist.			
Radius dist.+ shaft			
Metacarpal complete			
Metacarpal prox.		1	
Metacarpal prox. + shaft		1	
Metacarpal shaft	2	3	
Metacarpal dist.			
Metacarpal dist.+ shaft			
Femur complete			
Femur prox.			
Femur prox. + shaft			
Femur shaft		1	
Femur dist.			
Femur dist. + shaft			
Tibia complete			
Tibia prox.			
Tbia prox. + shaft			
Tibia shaft	1	2	
Tibia dist.			
Tibia dist. + shaft			
Metatarsal complete			
Metatarsal prox.			
Metatarsal prox. + shaft			
Metatarsal shaft		2	
Metatarsal prox. + shaft			
Metatarsal dist. + shaft			
Total	**5**	**14**	**2**

Tab. 13. NISP of each long limb bone portion according to element type and carcass size at the WB9 (Eyasi).

this latter possibility contradicts the fact that most lithic materials are preserved in fresh conditions. WB11 and WB12 have rendered very small lithic collections. These scatters seem to have been spots where non-cortical flakes, produced elsewhere, were discarded. Although samples of core fragments have been retrieved at both sites, it is not apparent that tool-making activities did take place here. Slight signs of surface abrasion are abundant at WB11 and 12, which suggest that fluvial forces might have affected their integrity.

• To sum up, the lithic sample retrieved at WB is a fairly non-diagnostic example of MSA tool-making. Hominids were focusing on the production of medium-sized flakes through bifacial discoid reduction techniques. The products obtained were only occasionally transformed into retouched tools, preferentially notches.

The analysis of the fauna

A total of 81 identifiable (to anatomical part and faunal group) bone remains (***Tab. 11***) plus 116 indeterminable bone fragments were excavated at the site. Only identifiable remains were used in the analysis of skeletal part profiles. Most of them (n=56) are from macro-mammals and the remainder are fish and turtle remains (***Tab. 11***). There are four individuals represented: one hippo, one suid and two bovids. One bovid is Bunn's (1982) size 2, while the larger one (*Connochaetes*) is Bunn's (1982) size 3. Only the size 3 bovid is represented by several anatomical parts, especially long limb bones (***Tabs. 12–14***). An initial observation of specimen size distribution suggests that the assemblage was not transported by water since the small fragments are very well represented, in proportions similar to those expected at sites with *in situ* broken bones (Blumenschine 1988) (***Fig. 20***). However, a total of 31 fragments (69 if adding unidentifiable specimens) showed intensive surface abrasion and polishing. That means that one third of the macro-mammal assemblage suggests water transport. This is further supported by the fact that all abraded specimens are smaller than 4 cm. Therefore,

	carcasses 1-2		carcasses 3		carcasses 4-5	
	epiphysis	shaft	epiphysis	shaft	epiphysis	shaft
humerus			1	1		2
radius						
metacarpal		1	1	1		
femur				1		
tibia		1		1		
metatarsal				1		

MNE AXIAL	size 1-2	size 3	size 4-5
scapula			
ribs	1	1	2
pelvis		1	
vertebrae	1	1	

Tab. 14. MNE represented at the WB9 (Eyasi) according to ephipyses estimates and shaft estimates in small and large carcasses. Small carcasses are those that fit Bunn´s sizes 1 & 2 (including size 3 infantiles and early juveniles). Large carcasses are size 3 and higher.

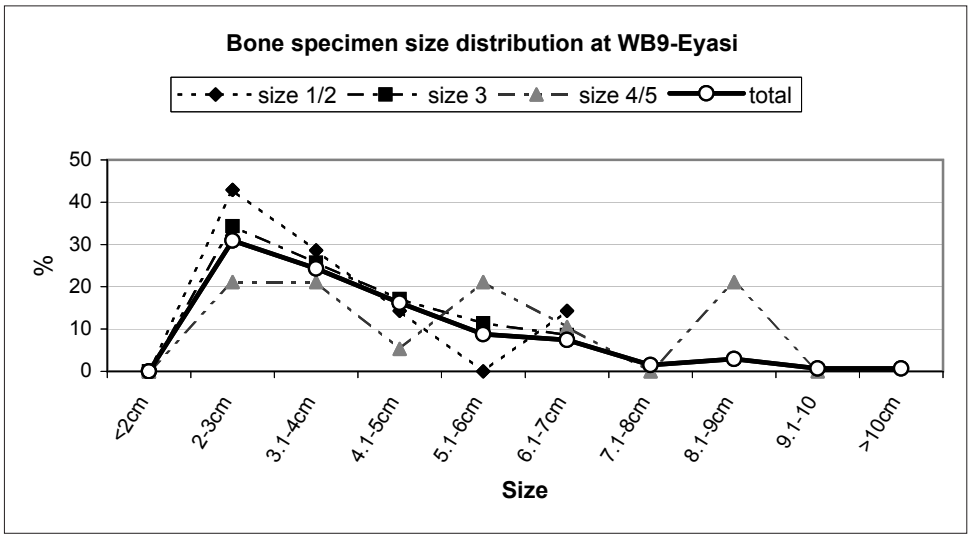


Fig. 20. Bone specimen size distribution at WB9.

almost half of the sample of fragments smaller than 4 cm were transported into the site by water, thus rendering the bone assemblage disturbed and lacking in small specimens, probably due to the same water disturbance that introduced small polished fragments into the site. The polishing and abrasion are not due to exposure to the intensive sand-bearing winds which cross the lake today, since the larger exposed specimens do not bear similar characteristics. The intensive abrasion also accounts for the large number of specimens that could not be identified to skeletal part.

As can be observed in ***Tables 12*** and ***13***, most bones represented are either isolated teeth or shaft sections of appendicular bones, *i.e.* the densest skeletal elements. Axial bones are virtually unpreserved. Limb bones are generally represented by shaft fragments, with only three epiphyseal fragments retrieved (***Tab. 13***). This suggests carnivore ravaging of the assemblage. Most of the bone assemblage (93.6 % of the macromammal assemblage; n=107) shows diagenetic breakage with only 7 specimens (6.1 %) showing green fractures. To study bone surface modifications, not a single specimen was discarded since all of them have well-preserved cortical surfaces. Only one cut-marked specimen was documented. It was a fragment of humeral shaft from the size 3 bovid. Only two tooth-marked specimens were observed. One was a tibia shaft from the size 2 bovid and the other one was a rib fragment from the size 3 bovid. Percussion marks, as described by Blumenschine & Selvaggio (1988), were documented on a humerus shaft and the shaft section of a metacarpal epiphysis of the size 3 bovid. Percussion notches as defined by Capaldo & Blumenschine (1994) were also documented on a humerus shaft and on metacarpal and metatarsal shafts of the same bovid. This suggests that the size 3 bovid could have been exploited by hominids. However, none of the bones

belonging to the size 2 bovid, the suid and the hippo showed any evidence of hominid manipulation, being very likely the result of natural deposition at the site. This could be supported by the different skeletal representation of these animals in contrast to the size 3 bovid, which might have been transported partially or complete to the site by hominids.

The taphonomic analysis of WB9 shows that the site was occupied very briefly by hominids contributing less than a third of the few animals accumulated therein. Natural processes seem to have played a major role in the accumulation of the faunal remains. This seems to be especially true for the hippo remains, which once again appear in association with stone tools but bear no evidence of hominid manipulation. Given that the hippo remains are so scanty and that no partial or complete carcass was present, the very limited evidence of bone breakage by hominids and of any hominid-imparted bone surface modification indicates that multiple processes contributed to the formation of the bone assemblage at the site.

The small size of the cut mark and percussion mark sample does not allow any interpretation of carcass obtainment and manipulation behaviour by hominids. This is interesting, since although most archaeologists would suggest that early *Homo sapiens* was an experienced hunter, we still lack any proof thereof during the Middle Pleistocene, since bone assemblages with large numbers of hominid-imparted surface modifications are lacking. We have some exceptional information from Porc-Epic in Ethiopia (Assefa 2006) and Die Kelders and Klasies River Mouth in South Africa during the Upper Pleistocene (Milo 1998; Marean *et al*. 2000), where early access to carcasses and hunting behaviour has been defended.

There is not much evidence of hominid carcass-manipulation behaviour in Middle Pleistocene sites in East Africa and WB9 can only contribute in a limited way to this debate.

Discussion

Between 1935 and 1938 the Kohl-Larsen expedition to the Lake Eyasi lakeshore found the fossil remains of at least three hominid individuals at the West Bay Area. The most complete human cranium (Eyasi I) has been attributed to *Homo rhodesiensis* and Mehlman's (1989) interpretation of the original field data led him to locate the findspot some 3.5 km west of Mumba Rockshelter (the so-called "Skull site"). The Kohl-Larsens also found remains of fossil mammals and lithic artefacts. Concerning the cultural attribution of the lithic samples recovered in the vicinity of the hominid site, much confusion has been created. Between 1936 and 1937 Leakey collected artefact samples at the site and studied the materials recovered by Kohl-Larsen and preserved in Berlin and Tübingen. He described the assemblage as "Levalloisian" (Leakey 1946), including typical Levallois cores and flakes (mainly unretouched) along with some broken Acheulean handaxes that in later contributions by the same author (Leakey 1952), were reconsidered to be of dubious evidence. Rafalski *et al*. (1978) studied the original 1935-1938 surface materials recovered at WB and NEB and carried out new test excavations at the WB area near the "Skull site". In total, these authors analyzed 3060 lithic artefacts (including 292 *in situ* objects recovered in the course of their field expeditions). Lithic analysis of both excavated and surface materials show some contradictory results. The excavated sample from WB included a meagre collection of retouched objects (some trimmed flakes and one unifacial point), some Levallois cores, a large sample of cores whose technical characteristics were not specified (defined as "sundry" cores) and flakes, including some Levallois ones. Raw material was mainly quartz (over 60 %), followed by basalt and quartzite. On the other hand, the surface collection (1604 objects from WB and 1164 from NEB) did not resemble the excavated sample at all. To start with, heavy-duty tools (core-axes, chopping tools and core scrapers) are present, while there is a variety of light-duty retouched tools (diverse point types, scrapers, bifacial tools, backed blades and trimmed flakes). Once again, abundant undefined "sundry" cores are represented alongside Levallois cores. The bulk of both samples are formed by flakes, including Levallois forms. Artefacts were mainly made of basalt or quartzite (both rock types are represented with more than 30 %) and quartz in lesser proportions. Such disparate typological characteristics led Rafalski *et al*. to conclude that the *in situ* collection, where heavy-duty tools were absent, could be defined as MSA. This interpretation was in agreement with the last definition proposed by Leakey (1974) to define the Eyasi lakeshore collections. However, basing their interpretation on the heavy-duty component found in surface aggregates, other authors have argued that the Eyasi industry is Late Acheulean/Sangoan (Grahmann & Müller-Beck 1967).

Between 1977 and 1981, Mehlman (1989) collected scattered artefacts from a 4000 m^2 area around the Eyasi I "Skull site", where he did not find bone or artefact patches. His collection (535 objects) included discoid and some Levallois cores, a large amount of

débitage (including some predetermined flakes) and a number of retouched types (scrapers, bifacially retouched tools, becs and trimmed flakes). No core-axes were found, although heavy-duty core scrapers (medium-sized pieces where retouch was performed on core fragments) were some of the most distinctive retouched implements. By far, generically defined "lava" was the most common raw material used, followed by quartz, quartzite and chert in considerably less proportions. From the traits observed in his surface collections, Mehlman concluded that the materials he recovered were not obviously Sangoan because of the lack of core-axes (Mehlman 1989: 164). However he argued that, taking into account that a heavy-duty component is present in the 1937 sample, core-axes seem to be part of the Eyasi lakeshore industry, although the terms of their contribution to this industry remain unclear. Considering the apparent internal contradictions observed within the various lakeshore collections (which could be referred to as Sangoan or unspecified MSA depending on the sample we consider), Mehlman preferred to define this industry with the neutral label of Njarasa industry and he characterised it as follows (Mehlman 1989: 165): "*In this industry, primary raw materials are lavas and perhaps quartz. Cobble and blocks of these stones have been radially flaked to produce relatively large flakes and simple flake tools. Other angular chunks and cobbles have been trimmed to form core scrapers and choppers. Core-axes are a probable component of this industry; retouched points are doubtful*". Despite the considerable amount of doubts and ambiguities that emerge from the status of the Eyasi industry, the different contradictory opinions by a number of authors, the cautions proposed by Mehlman in his comprehensive study and finally the fact that to date the issue remains unclear, some authors still refer the Eyasi aggregates associated with *Homo* remains to the Sangoan industry *sensu stricto* (McBrearty & Brooks 2000) or to a local variant of it (Tryon & McBrearthy 2002: 213).

In general terms, our observations from the *in situ* materials recovered by us are consistent with those of Mehlman. The production of medium-sized flakes, through bifacial discoid reduction strategies, seems to be the most obvious goal of the local knappers. A predetermined reduction technology is doubtful in our sample, and we think that it could have played a limited role in the exploitation strategies. Retouched objects are scarce and not very diagnostic. Contradicting data, however, emerge from the raw material information. Rafalski *et al*. observed in their excavated collection the predominant use of quartz (63 %), followed by basalt (26 %) and quartzite. Their analysis of surface materials showed that the primary raw material was basalt and quartzite. These proportions are in agreement with Mehlman's counts of his surface aggregates, where basalts predominate (91.2 %), followed at a long distance by quartz (5.4 %). It seems that, in terms of raw material use, a different picture emerges from excavated and surface samples. Our rock type classification does not correspond with any of them. However, we suggest the possibility that what Rafalski *et al*. put in their rock category named generically "quartz" might be included in the rock type defined by us as protomylonite. Coarse-grained mylonite or protomylonite is a rock type that in fact is formed by quartz minerals. Therefore, a macroscopic inspection of this raw material might account for some sort of terminological confusions, where a particular mineralogical composition (quartz) is erroneously used to define a metamorphic rock type (protomylonite).

We very much agree with Mehlman's (1989: 165) observation that "*local units having integrity in time and space must be the foundation for a precise nomenclature which may ultimately allow a new regional synthesis of prehistoric data.*" Certainly, we cannot reject earlier claims of the presence of Late Acheulean/Sangoan at the shores of Lake Eyasi. This might probably mean that coherent Late Acheulean/Sangoan assemblages might be found somewhere on the lake shore and that hominids here were producing these tools along with other MSA-like core and flake artefacts. Behavioural, temporal and spatial relationships between both industries are far from being clear. However, excavated local units to date (showing both temporal and spatial integrity) do not unambiguously confirm this point. Taking into account the technological and typological traits observed from our excavated sites reported here and recent ESR/230 Th/234 U dating carried out on tooth samples found at the Grey Sand Unit (Mehlman's Overcapping member), where fossil bones and artefacts have been recovered at WB9, WB11 and WB12 (that have furnished an age of 118 ka), we define our lithic sample as an unspecific MSA industry. Our interpretation is in agreement with Clark's (1988: 277) assessment of the Lake Eyasi assemblages.

In Africa the period comprised between 300 and 100 ka can be defined as a very dynamic time, where dramatic changes can be observed in the archaeological record, both at anatomic (Bräuer 2001) and cultural levels. New fossil forms (formerly included in the species *H. helmei*, Foley & Lahr 1997: 27) are a prelude to the origin of *H. sapiens* proper. From the technological point of view, we witness the disappearance of the Acheulean techno-complex at about

200 ka, its apparent substitution by the Sangoan, an unsatisfactorily known entity (McBreaty 1991: 159) that has been seen as a variant of the Terminal Acheulean (Cole 1967; Cormack 1997; McBrearty & Brooks 2000; Roe 2001) or the starting point of the MSA universe (Cornelissen 1995), and finally the origin of the MSA techno-complex. Chronological sequences and cultural relationships of these processes of technological transformation are confusing, as has been recently noted (Tryon & McBrearty 2002). Early examples of MSA assemblages (dated between 285 and 200 ka) can be found at the Kapthurin Formation in Kenya (Tryon & McBrearty 2002), Gademotta and Kulkuletti in Ethiopia (Wendorf *et al*. 1994), Twin Rivers Kopje in Zambia (Clark & Brown 2001), Florisbad in South Africa (Kuman *et al*. 1999) or Bir Tarwafi, Bir Sahara West and Rufuq Pass in Egypt (Wendorf *et al*. 1993; Clark 1999). At a basic level, MSA industries can be defined by the disappearance of configured large tools (handaxes, cleavers and picks) present in the Acheulean techno-complex and the increasing development of exploitation sequences and flake-based components in lithic assemblages. Taking into account this formal background, the main trends observed in MSA aggregates are the following: increasing development of predetermined reduction models (Levallois technique) and discoid exploitation methods (Wendorf *et al*. 1993: 361; Wendorf *et al*. 1994: 131); appearance of the blade technique (Wendorf *et al*. 1994: 131; Cornelissen 1995: 65; Van Peer 1998: 130); and increasing development and diversification of small-format tool types, the most representative of which are the points (McBrearty & Brooks 2000: 496). These technological trends, however, do not clearly emerge in all places at the same time and it seems that the ESA/MSA transition is arbitrary. As Clark (1988: 237) has already noted, MSA patterns vary widely from one assemblage to another. Levallois technology, for example, is not necessarily present in all collections. In fact, predetermination strategies (that were not a MSA innovation) do not seem to be the most significant trait of this period (Klein 2000: 24). In terms of chronology, there does not appear to be a clear unidirectional evolution towards sophistication. At Kapthurin, the oldest MSA site dated to present, most of the characteristics cited above (Levallois technology associated with blade technology and a diversity of points) are included in the same sedimentary context in which other Terminal Acheulean traits occur (Tryon & McBrearty 2002: 228). At Florisbad, however, the MSA sequence shows that an early unspecific flake-based toolkit at 279 ka is followed by a highly retouched small tool assemblage at 157 ka and once again a rather expedient assemblage at 121 ka (Kuman *et al*. 1999). Rather than Levallois or blade technology and small retouched tool diversity, it seems that common characteristics identifying the local MSA sequence at Florisbad (expanding some 160 ka) are the emphasis in exploitation operative sequences (production of flakes using a variety of techniques and, not in all cases, the subsequent configuration of small products). Once again this evidence underscores the highly heterogeneous and variable nature of MSA diagnostic trends, at least in its earliest periods. In this context it is easier to understand the attribution of the unspecific industry excavated by us on the lakeshore of Lake Eyasi to the MSA. A flake-based assemblage produced through discoid reduction techniques, where small retouched tools are scarce, can fit within the heterogeneous, sometimes rather chaotic technical behaviours observed in Africa between the Late Middle Pleistocene and the Early Upper Pleistocene. It remains unclear, however, whether the expedient MSA assemblage from WB9 is the result of a particular functional local response to a particular type of activities or a fragmented opened window in the background of a more complex technological pattern carried out on the lakeshore (where probably large tools could have played a functional role), a complete picture of which has not been as yet comprehended.

However, the Njarasa industry was defined because it had affinities with the Sangoan from Sango Bay. Kohl-Larsen (1943) showed that there were clusters of heavy-duty tools similar to those from the Acheulian and even handaxes. This was also reported by Mehlman (1989). Our research has found none of these heavy-duty implements. However an alternative scenario to the one presented here is possible. It has been argued that the Eyasi skulls are too primitive looking for the chronology derived from EH06 (Domínguez-Rodrigo *et al*. *in prep.*). It could alternatively be argued that even if there is no certainty as to the exact provenience of those skull fragments (which could be recent erosion from the Red Soils or erosion from the remnants of Grey Sands found in the area), if they came from the Red Soils, they could be substantially older than reported here. The Red Soils, currently undated, are separated from the overlying Grey Sands by a disconformity created by an erosive period whose duration is unknown. If they correspond to an extension of the lake, it could be correlated with similar processes documented on most East African lakes between 300 ka and 200 ka. If this chronology would be applicable to the Red Soils, the Eyasi skulls would conform to the skull morphology documented in similarly aged fossils in Africa. Thus, a progressive evolution from the Eyasi morpho-pattern to the more advanced Omo and Herto could be supported. Likewise, this chronology would support the sporadic oc-

currences of late-Acheulian/Sangoan materials in the Red Soils. However, we have documented no traces of it in our extensive surveys in the area. For this hypothesis to be supported, morphological change should be recorded in hominid fossils from younger strata at Eyasi. However, the frontal bone discovered in the Grey Sands Unit (EH06) is visually indistinguishable from Eyasi 1. This is suggestive of stasis in morphological change or limited usefulness of frontal pieces to assess the change.

WB and NEB were very open lacustrine grasslands at the end of the Middle Pleistocene. Mehlman (1989) suggested that hominid presence in those spaces was marginal and conditioned by the strong winds that still sweep these plains today. Mehlman suggested that hominids used the spring or marshland habitats as a hunting area, taking their prey back to a home base, which was never established there. Our work supports this assertion. Stone tools appear always in small scatters along both bays. At WB9, the stone tool density is higher but still significantly small when compared to other contemporary sites in other parts of Africa. The bone elements retrieved at WB9 suggest either a partial transport of a carcass to the site or the selection of the non-preserved parts to a home base away from the area. No indication is provided for WB9 which could suggest a prolonged stay there. Most of the faunal remains seem to have been the result of natural processes, and no hominid accumulation or modification occurred despite close spatial proximity to stone tools.

In summary, the behavioural meaning of WB9 as well as of most other Middle Pleistocene sites remains unknown. The archaeology of early *Homo sapiens* still has a long way to go to provide insights into the origins of modern human behaviour (in terms of subsistence and adaptation) in the Middle Pleistocene.

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References

Assefa, Z. 2006. Faunal remains from Porc-Epic: paleoecological and zooarchaeological investigations from a Middle Stone Age site in southeastern Ethiopia. *Journal of Human Evolution* 51, 50–75.

Bada, J.L. & Protsch, R. 1976. Racemization reaction of aspartic acid and its use in dating fossil bones. *Proceedings of the National Academy of Sciences* 70, 1331–1334.

Barthelme, J. 1991. Lenderut: a new Acheulian site in Southern Kenya Rift. *Nyame Akuma* 35, 21–23.

Blumenschine, R.J. 1988. An experimental model of the timing of hominid & carnivore influence on archaeological bone assemblages. *Journal of Archaeological Science* 15, 483–502.

Blumenschine, R.J. & Selvaggio, M. 1988. Percussion marks on bone surface as a new diagnostic of human behavior. *Nature* 333, 763–765.

Boëda, E. 1995. Levallois: a volumetric construction, methods, a technique. In: Dibble, H. & Bar-Yosef, O. (eds.), *The Definition and Interpretation of Levallois Technology*. Prehistory Press, Madison, pp. 41–68.

Bonnefille, R. 1971a. Atlas des pollens d'Ethiopie, principales espèces des forêts de montagne. *Pollen et Spores* 13 (1), 15–72.

Bonnefille, R. 1971b. Atlas des pollens d'Ethiopie. Pollens actuels de la basse vallée de l'Omo, récoltes botaniques 1968. *Adansonia,* ser. 2, 11 (3), 463–518.

Bonnefille, R. & Riollet, G. 1980. *Pollens des savanes d'Afrique orientale*. CNRS Éditions, Paris.

Bonnefille, R. & Vincens, A. 1985. Apport de la palynologie à l'environnement des Hominidés d'Afrique orientale. In: *L'environnement des Hominidés au Plio-Pléistocène*. Masson, Paris, pp. 237–278.

Bräuer, G. 2001. The KNM-ER 3884 hominid and the emergence of modern anatomy in Africa. In: Tobias, P., Raath, M., Moggi-Cecchi, J. & Doyle, G. (eds.), *Humanity from African Naissance to Coming Millenia*. Firenze University Press, Florence, pp. 191–197.

Bräuer. G. & Mabulla, A.Z. 1996. A New Fossil Hominid from Lake Eyasi, Tanzania. *Anthropologie* 34 (1–2), 47–53.

Brooks, A. & Yellen, J. 2005. The Middle Stone Age of East Africa and Modern Human Origins. Paper held at the Conference of the National Museums of Kenya, July 17th–25th.

Bunn, H.T. 1982. *Meat-Eating and Human Evolution: Studies on the Diet and Subsistence Patterns of Plio-Pleistocene Hominids in East Africa.* Ph.D. dissertation, University of California, Berkeley.

Capaldo, S.D. & Blumenschine, R.J. 1994. A quantitative diagnosis of notches made by hammerstone percussion and carnivore gnawing in bovid long bones. *American Antiquity* 59, 724–748.

Casanova, J. 1987. Stromatolites et hauts niveaux lacustres pléistocènes du bassin Natron-Magadi (Tanzanie-Kenya). *Sciences Geologiques Bulletin* 40 (1-2), 135–153.

Clark, J.D. 1988. The Middle Stone Age of East Africa and the beginnings of regional identity. *Journal of World Prehistory* 2, 235–305.

Clark, J.D. 1999. Cultural continuity and change in hominid behaviour in Africa during the Middle to Upper Pleistocene transition. In: Ullrich, H. (ed.), *Hominid Evolution. Lifestyles and Survival Strategies*. Archaea, Berlin, pp. 277–292.

Clark, J.D. & Brown, K. 2001. The Twin Rivers Kopje, Zambia: stratigraphy, fauna, and artefact assemblages from the 1954 and 1956 excavations. *Journal of Archaeological Science* 28, 305–330.

Cole, G.H. 1967. The Later Acheulian and Sangoan of Southern Uganda. In: Bishop, W.W. & Clark, J.D. (eds.), *Background to Evolution in Africa*. Chicago University Press, Chicago, pp. 481–528.

Cooke, B. 1963. Pleistocene mammal faunas of Africa, with particular reference to Southern Africa. In: Howell, F.C. & Bourliere, F. (eds.), *African Ecology and Human Evolution.* Aldine, Chicago, pp. 65–116.

Cormack, J. 1997. Are the Sangoan and Acheulean 'industrial complexes' distinct? In: Sinclair, A., Slater, E. & Gowlett, J. (eds.), *Archaeological Sciences 1995*. Oxbow Monographs, Oxford, pp. 395–399.

Cornelissen, E. 1995. Indications du Post-Acheuléen (Sangoen) dans la Formation Kapthurin, Baringo, Kenya. *L'Anthropologie* 99, 55–73.

Dawson, J.B. 1992. Neogene tectonics and volcanicity in the northern Tanzania sector of the Gregory rift valley: contrasts with the Kenya rift sector. *Tectonophysics* 204, 81–92.

Dietrich, W.O. 1943. Säugetierefauna der Njarasa Bank (jungdiluviale Fauna). In: Kohl-Larsen, L. (ed.), *Auf den Spuren des Vormenschen*. Vol. II. Strecker und Schroeder, Stuttgart, pp. 391–392.

Dietrich, W.O. 1950. Fossile Antilopen und Rinder Äquatorialafrikas (Material aus der Kohl-Larsen Expeditionen). *Palaeontographica Abt*. A99, 1–62.

Domínguez-Rodrigo, M., López-Sáez, J.A., Vincens, A., Alcalá, L., Luque, L. & Serrallonga, J. 2001. Fossil pollen from the Upper Humbu Formation of Peninj (Tanzania): hominid adaptation to a dry open Plio-Pleistocene savanna environment. *Journal of Human Evolution* 40, 151–157.

Domínguez-Rodrigo, M., Mabulla, A., Luque, L., Thomson, J., Rink, J., Diez, F., Bushozi, P. & Alcalá, L. *in prep*. A new archaic Homo sapiens fossil from Lake Eyasi. Submitted to the *Journal of Human Evolution*.

Ebinger, C., Poudjom, Y., Mbede, E.A., & Dawson, J.B. 1997. Rifting archaean lithosphere: the Eyasi-Manyara-Natron rifts. *Journal of the Geological Society, London* 154, 947–960.

Fairhead, J.D. 1980. The structure of the cross-cutting volcanic chain of northern Tanzania and its relation to the East African Rift System. *Tectonophysics* 65, 193–208.

Foster, A.N., Ebinger, C.J., Mbede, E. & Rex, D. 1997. Tectonic development of the Northern Tanzanian sector of the East African Rift System. *Journal of the Geological Society, London* 154, 689–700.

Fisher, R.V. & Schmincke, H.U. 1984. *Pyroclastic Rocks*. Springer, Berlin.

Foley, R. & Lahr, M. 1997. Mode 3 technologies and the evolution of modern humans. *Cambridge Journal of Archaeology* 7, 3–36.

Girard, M. & Renault-Miskovsky, J. 1969. Nouvelles techniques de préparation en palynologie appliquées à trois sédiments du Quaternaire final de l'Abri Cornille (Istres, Bouches-du-Rhône). *Bulletin de l'Association française pour l'Etude du Quaternaire* 4, 275–284.

Goeury, C. & de Beaulieu, J.L. 1979. À propos de la concentration du pollen à l'aide de la liqueur de Thoulet dans les sédiments minéraux. *Pollen et Spores* 21, 239–251.

Grahmann, R. & Müller-Beck, H. 1967. *Urgeschichte der Menschheit*. Hohlhammer, Stuttgart.

Hay, R.L. 1978. Geologic occurrence of zeolites. In: Sand, L.B. & Mumpton, F.A. (eds.), *Natural Zeolites: Occurrence, Properties, Use*. Pergamon Press, New York, pp. 135–143.

Hay, R.L. 1981. Paleoenviromnent of the Laetolil Beds, northern Tanzania. In: Rapp, G. & Vondra, C.F. (eds.), *Hominid Sites: Their Geologic Settings*. *American Association for the Advancement of Science Selected Symposia* 63, pp. 7–24.

Heinzelin, J., Clark, J.D., Schick, K.D. & Gilbert, W.H. (eds.) 2000. The Acheulean and the Plio-Pleistocene Deposits of the Middle Awash Valley Ethiopia. Royal Museum of Central Africa (Belgium). *Annales Sciences Geologiques* 104, 5–10.

Jarzen, D.M. & Elsik, W.C. 1986. Fungal palynomorphs recovered from recent river deposits, Luangwa Valley, Zambia. *Palynology* 10, 35–60.

Kelly, A. 1996. *Intra-regional and Inter-regional Variability in East Turkana (Kenya) and Kenya Middle Stone Age*. Ph.D. dissertation, Rutgers University.

Klein, R. 2000. Archaeology and the evolution of human behavior. *Evolutionary Anthropology* 9, 17–36.

Kohl-Larsen 1943. *Auf den Spuren des Vormenschen* (2 vols.), Strecker und Schröder, Stuttgart.

Kuman, K., Inbar, M. & Clarke, R. 1999. Paleoenvironments and cultural sequence of the Florisbad Middle Stone Age hominid site, South Africa. *Journal of Archaeological Science* 26, 1409–1425.

Leakey, L. 1936. *The Stone Age Africa: An Outline of Prehistory in Africa*. Oxford University Press, London.

Leakey, L. 1946. Report on a visit to the site of the Eyasi skull found by Dr. Kohl-Larsen. *Journal of the East Africa Natural History Society* 19, 40–43.

Leakey, L. 1952. The age of the Eyasi skull. In: Leakey, L. & Cole, S. (eds.), *Proceedings of the Pan-African Congress on Prehistory, 1947*. Philosophical Library, New York, pp. 133–134.

Leakey, L. 1974. *By the evidence: memoirs, 1932–1951*. Harcourt-Brace Jovanovich, New York.

Mabulla, A. 1990. Preliminary report on an archaeological survey of the Ndutu Beds, Olduvai Gorge, Tanzania. *Nyame Akuma* 33, 20–24.

Mabulla, A. 1996. *Middle and Later Stone Age land-use and lithic technology in the Eyasi Basin, Tanzania.* Ph. D. dissertation. Department of Anthropology, University of Florida, Gainesville.

MacIntyre, R.M., Mitchell, J.G. & Dawson, J.B. 1974. Age of Fault Movements in Tanzanian Sector of East African Rift System. *Nature* 247, 354–356.

Marean, C.W. (ed.) 2000. The Middle Stone Age at Die Kelders Cave 1, South Africa. Published as a special issue of the *Journal of Human Evolution* 38, 233 pages.

Mehlman, M.J. 1977. Excavations at Nasera Rock, Tanzania. *Azania* 12, 111–118.

Mehlman M.J. 1979. Mumba-Hole revisited: the relevance of a forgotten excavation to some current issues in East African prehistory. *World Archaeology* 11, 80–94.

Mehlman, M.J. 1984. Archaic Homo sapiens at Lake Eyasi, Tanzania: recent misrepresentations. *Journal of Human Evolution* 13, 487–501.

Mehlman, M. 1989. Later Quaternary archaeology sequences in Northern Tanzania. Unpublished PhD. dissertation. University of Illinois, Urbana-Champaign.

McBrearty, S. 1988. The Sangoan-Lupemban and the Middle Stone Age sequence at the Muguruk site, western Kenya. *World Archaeology* 19, 379–420.

McBrearty, S. 1991. Recent research in western Kenya and its implications for the status of the Sangoan industry. In: Clark, J.D. (ed.), *Cultural Beginnings: Approaches to Understanding Early Hominid Lifeways in the African Savanna*. Römisch-Germanisches Zentralmuseum, Bonn, pp. 159–171.

McBrearty, S. 1999. Archaeology of Kapthurin Formation. In: Andrews, P. & Barham, P. (eds.), *Late Cenozoic Environments and Hominid Evolution; a Tribute to Bill Bishop.* Geological Society of London, London, pp. 143–156.

McBrearty, S. & Brooks, A. 2000. The revolution that wasn´t: a new interpretation of the origin of modern human behavior. *Journal of Human Evolution* 39, 453–563.

Milo, R.G. 1998. Evidence for hominid predation at Klasies River Mouth, South Africa, and its implications for the behaviour of early modern humans. *Journal of Archaeological Science* 25, 99–133.

Pickering, R. 1961. The geology of the country around Endulen. *Records of the Geological Survey of Tanganyika* XI, l–9.

Protsch, R. 1976. The position of the Eyasi and Garusi hominids in East Africa. In: Tobias, P.V. & Coppens, Y. (eds.), *Les plus anciens hominids*. *IX Congres de l'Union Internationale des Sciences Prehistoriques et Proto-historiques.* Colloque VI. Editions du CNRS, Paris, pp. 207–238.

Protsch, R. 1981. The paleoanthropological finds of the Pliocene and Pleistocene. In: Müller-Beck, H. (ed.), *Die archäologischen und anthropologischen Ergebnisse der Kohl-Larsen Expeditionen in Nord-Tanzania, 1933–1939*. Tübinger Monographien zur Urgeschichte 4.

Rafalski, S., Schröter, P. & Wagner, E. 1978. Die Funde am Eyasi-Nordostufer. In: Müller-Beck, H. (ed.), *Die archäologischen und anthropologischen Ergebnisse der Kohl-Larsen Expeditionen in Nord-Tanzania, 1933–1939*. Tübinger Monographien zur Urgeschichte 4 (2).

Reck, H. & Kohl-Larsen, L. 1936. Erster Überblick über die jungdiluvialen Tier- und Menschenfunde von Dr. Kohl-Larsen im Norddöstlichen Teil des Njarassa Grabens (Ostafrika). *Geologische Rundschau* 27, 401–441.

Reeve, W.H. 1946. Geological report on the site of Dr. Kohl-Larsen's discovery of a fossil human skull, Lake Eyasi, Tanganyika Territory. *Journal of the East African Natural History Society* 19, 650.

Roe, D. 2001. A view of the Kalambo Falls Early and Middle Stone Age assemblages in the context of the Old World Palaeolithic. In: Clark, J.D. (ed.), *Kalambo Falls Prehistoric Sites III*. Cambridge University Press, Cambridge, pp. 636–647.

Schaller, G.B. 1972. *The Serengeti Lion: A Study of Predator-Prey Relations*. The University of Chicago Press, Chicago.

Schmid, R. 1981. Descriptive nomenclature and classification of pyroclastic deposits and fragments. Recommendations of the UIGS subcomission on the systematics of igneous rocks. *Geologische Rundschau* 70, 749–799.

Sibson, R.H. 1977. Fault rocks and fault mechanism. *Journal of the Geological Society, London* 133, 191–213.

Toth, N. 1982. The Stone Technologies of Early Hominids at Koobi Fora, Kenya: An Experimental Approach. Unpublished Ph.D. Dissertation, University of California, Berkeley.

Tryon, C. & McBrearty, S. 2002. Tephrostratigraphy and the Acheulean to Middle Stone Age transition in the Kapthurin Formation, Kenya. *Journal of Human Evolution* 42, 211–235.

Van Peer, P. 1998. The Nile Corridor and the Out-of-Africa model. *Current Anthropology* 39 (supplement), 115–140.

Vincens, A. 1984. Environnement végétal et sédimentation pollinique lacustre actuelle dans le bassin du lac Turkana (Kenya). *Revue de Paléobiologie,* vol. sp., 235–242.

Vincens, A. 1986. Diagramme pollinique d'un sondage Pléistocène supérieur-Holocène du lac Bogoria (Kenya). *Review of Palaeobotany and Palynology* 47, 169–192.

Vincens, A. 1987. Recent pollen sedimentation in lake Natron, Tanzania: a model for the interpretation of fossil spectra in arid regions. *Sciences Geologiques Bulletin* 40, 155–165.

Vincens, A. 1989. Paleoenvironnements du bassin nord-Tanganyika (Zaire, Burundi, Tanzanie) au cours des 13 derniers mille ans: apport de la palynologie. *Review of Palaeobotany and Palynology* 61, 69–88.

Vincens, A., Buchet, G., Williamson, D. & Taieb, M. 2005. A 23,000 yr pollen record from Lake Rukwa (8º S, SW Tanzania): new data on vegetation dynamics and climate in Central Eastern Africa. *Review of Palaeobotany and Palynology* 137, 147–162.

Waweru, V. 2002. New excavations at the Midle Stone Age Cartwright's site, Kenya. *Nyame Akuma* 58, 26–33.

Wendorf, F., Schild, R. & Close, A. 1993. *Egypt during the Last Interglacial. The Middle Palaeolithic of Bir Tarwafi and Bir Sahara East*. Plenum Press, New York.

Wendorf, F., Close, A. & Schild, R. 1994. Africa in the period of *Homo sapiens neanderthalensis* and contemporaries. In: de Laet, S., Dani, A., Lorenzo, J. & Nunoo, R. (eds.), *History of Humanity, 1: Prehistory and the Beginnings of Civilization*. Routledge, New York, pp. 117–135.

White, F. 1983. *The Vegetation of Africa. A Descriptive Memoir to Accompany the UNESCO/* AETFAT/UNOS Vegetation Map of Africa. UNESCO, Paris.

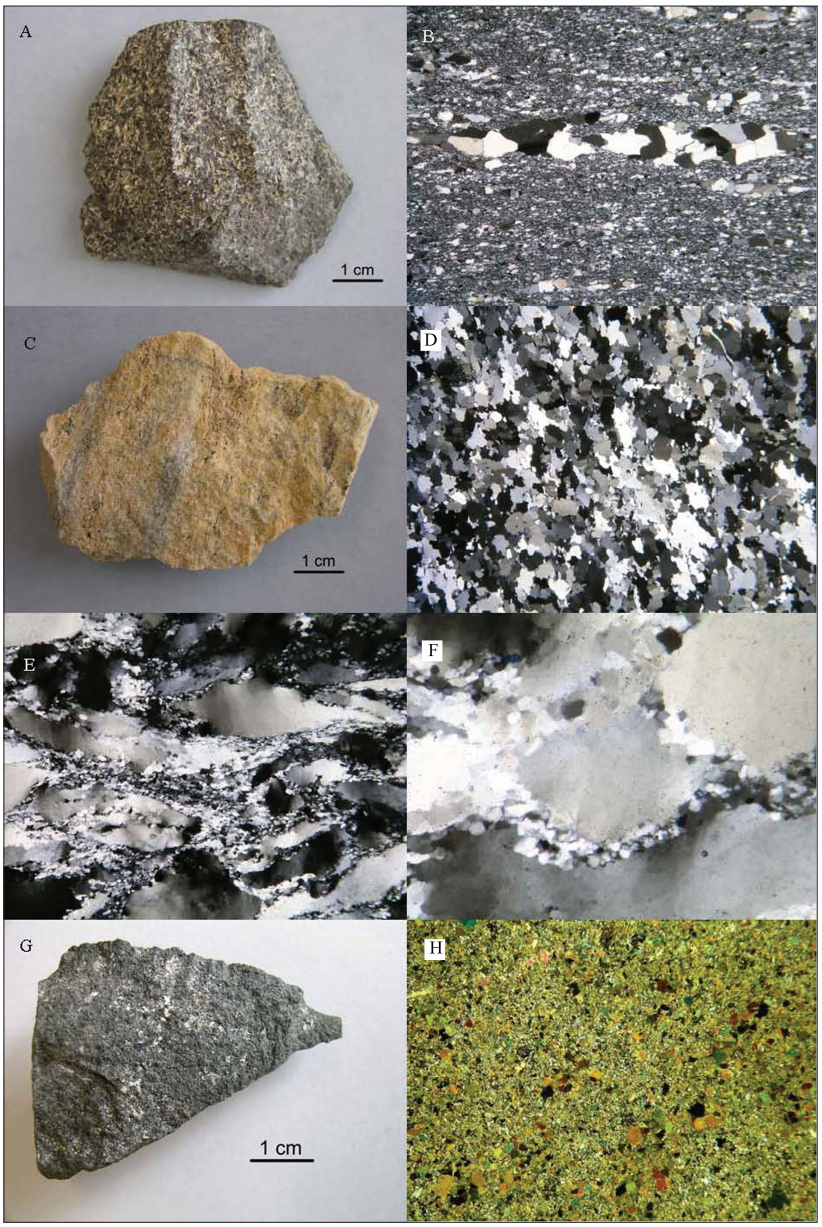


Fig. 11. A, Pyroxenic microgabbro (unretouched flake). B, Vitreous ignimbrite, thin section. Microcrystalline rock (<50 µm). It shows a laminated fabric (crystal elongation and phenocrystal lengthening). Its main component is quartzite, although it shows considerable proportions of albite. Accessory minerals are opaques and muscovite (oriented as well). C, Tuffaceous sandstone (unretouched flake). D, Tuffaceous sandstone, thin section. Quartz-feldspathic composition. Granoblastic isogranular texture with xenomorphic quartz crystals. Accessory minerals are opaques and muscovite. E and F, Quartz protomylonite, thin section. Rock composed exclusively by quartz. Fabric formed by large (0.2 to 10 mm.), deformed and oriented clasts. Contact between clasts is cemented by small non-deformed quartz crystals (<50 µm) that form a granulated texture in thin wall shape resulting from sub-grain crystallization. G, Amphybolite (unretouched flake). H, Amphybolite, thin section. Granoblastic and micro-crystalline texture (50–200 µm), composed mainly of amphibole (hornblende) and, filling blanks, a matrix of small plagioclase crystals. Accessory minerals are opaques.

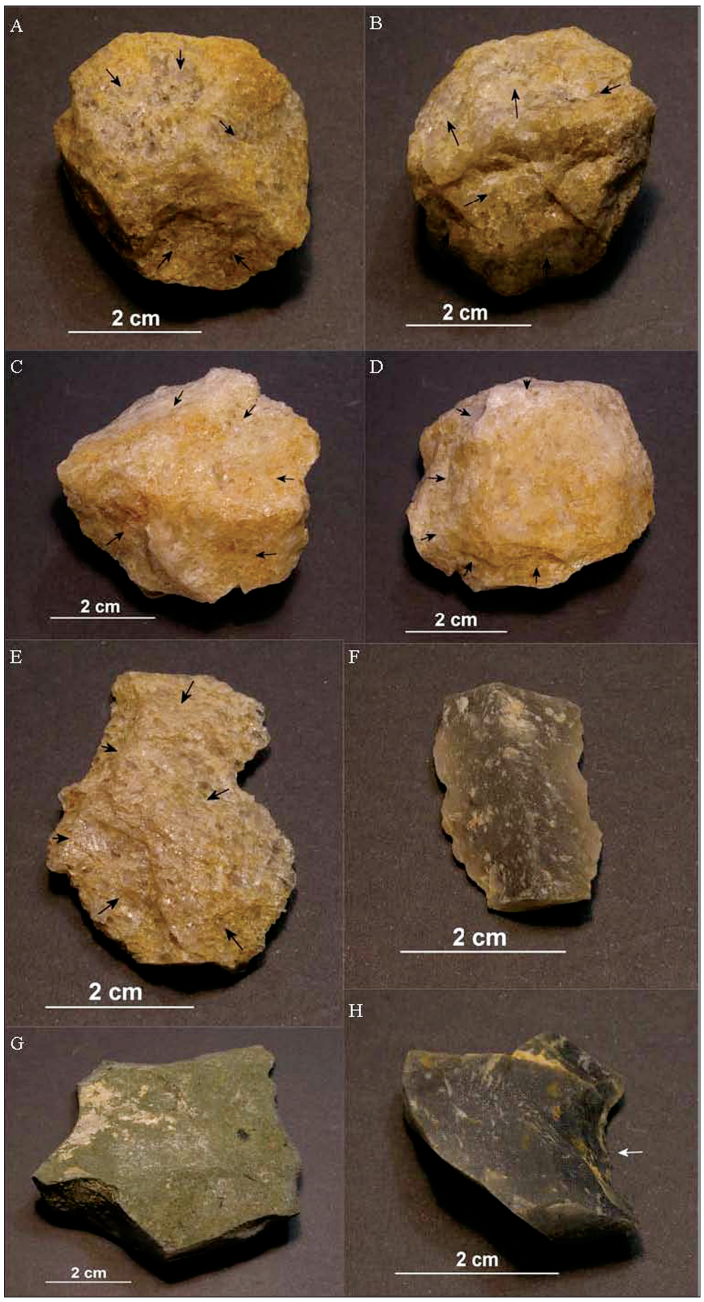


Fig. 14. Artefacts from WB9. A and B, Multipolar core (protomylonite). C and D: Bifacial discoid core (protomylonite); E: Type VI flake with radial scars (protomylonite); F: Blade distally fragmented (vitreous ignimbrite); G: Core tablet (nephelinite); H: Notch (vitreous ignimbrite).