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Acheulean technological behaviour in the Middle Pleistocene landscape of Mieso (East-Central Ethiopia)

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ABSTRACT

The Mieso valley is a new paleoanthropological sequence located in East-Central Ethiopia. It contains Middle and Upper Pleistocene deposits with fossil and lithic assemblages in stratified deposits. This paper introduces the Middle Pleistocene archaeological sequence, attributed to the late Acheulean. Low density clusters of artefacts suggest short-term use of the landscape by Acheulean hominins. In Mieso 31, one of the excavated assemblages, refit sets indicate fragmentation of the reduction sequences and enable study of the initial stages of biface manufacture. Mieso 7, also a stratified site, is primarily characterized by a small concentration of standardized cleavers, and portrays another dimension of Acheulean technology, that related to final stages of use and discard of large cutting tools. Available radiometric dates place the Mieso Acheulean around 212 ka (thousands of years) ago, which would make this sequence among the latest evidence of the Acheulean in East Africa, in a time span when the Middle Stone Age is already documented in the region.

Introduction

Our knowledge of the Early Stone Age in East Africa has increased substantially over the last few decades. Intensive fieldwork in Kenya, Ethiopia and Tanzania has enabled the establishment of a solid radiometric and archaeological framework for Oldowan and Acheulean contexts. This is particularly true of the Ethiopian Rift Valley, where systematic surveys (e.g., Asfaw et al., 1990) led to the discovery of key sites, unknown to paleoanthropology prior to the 1990s (WoldeGabriel et al., 2000). Over the last few years, however, the pace of discovery of new sequences has slowed down, and a substantial part of archaeological fieldwork is conducted in areas already known.

Here we introduce the archaeological sequence of Mieso, discovered during our surveys in 2008, and systematically investigated in consecutive field seasons between 2009 and 2012. The Mieso valley is named after the town of Mieso (c. 300 km east of Addis Ababa), on the road from Awash town to Asebe Tefari and Dire Dawa (Fig. 1). The Mieso valley is located approximately 60 km south-east of Chorora, well-known for the discovery of Miocene great ape fossils (Suwa et al., 2007). Mieso also lies between two sites discovered by Desmond Clark during his surveys across the Main Ethiopian Rift in the 1970s (Clark and Williams, 1978), namely Aladi Springs (a stratified Middle Stone Age site 26 km to the north-east), and Arba (an Acheulean surface site 30–40 km to the south-west). Despite its proximity to known archaeological sites, the Mieso deposits nonetheless remained unreported until the beginning of our field project.

During our surveys across the Mieso valley, Middle and Upper Pleistocene deposits were documented including fossils and artefacts attributable to the Acheulean, Later Stone Age and putatively also to the Middle Stone Age. The geology and chronology of the Mieso Middle Pleistocene deposits are presented elsewhere (Benito-Calvo et al., submitted for publication), while emphasis will be given here to the archaeological contexts. Thus, this paper will introduce the archaeological sequence of the Mieso valley, focusing on the archaeo-stratigraphy of the Acheulean sites and, particularly, on the lithic assemblages. Our aim is to present a detailed account of the Acheulean technology in this previously unreported Middle Pleistocene sequence, and discuss the significance of well-preserved low density assemblages for the reconstruction of Acheulean hominin behaviour. In this context, our technological analysis will discuss methods of handaxe production and data derived from refit studies, the implications of assemblage structure

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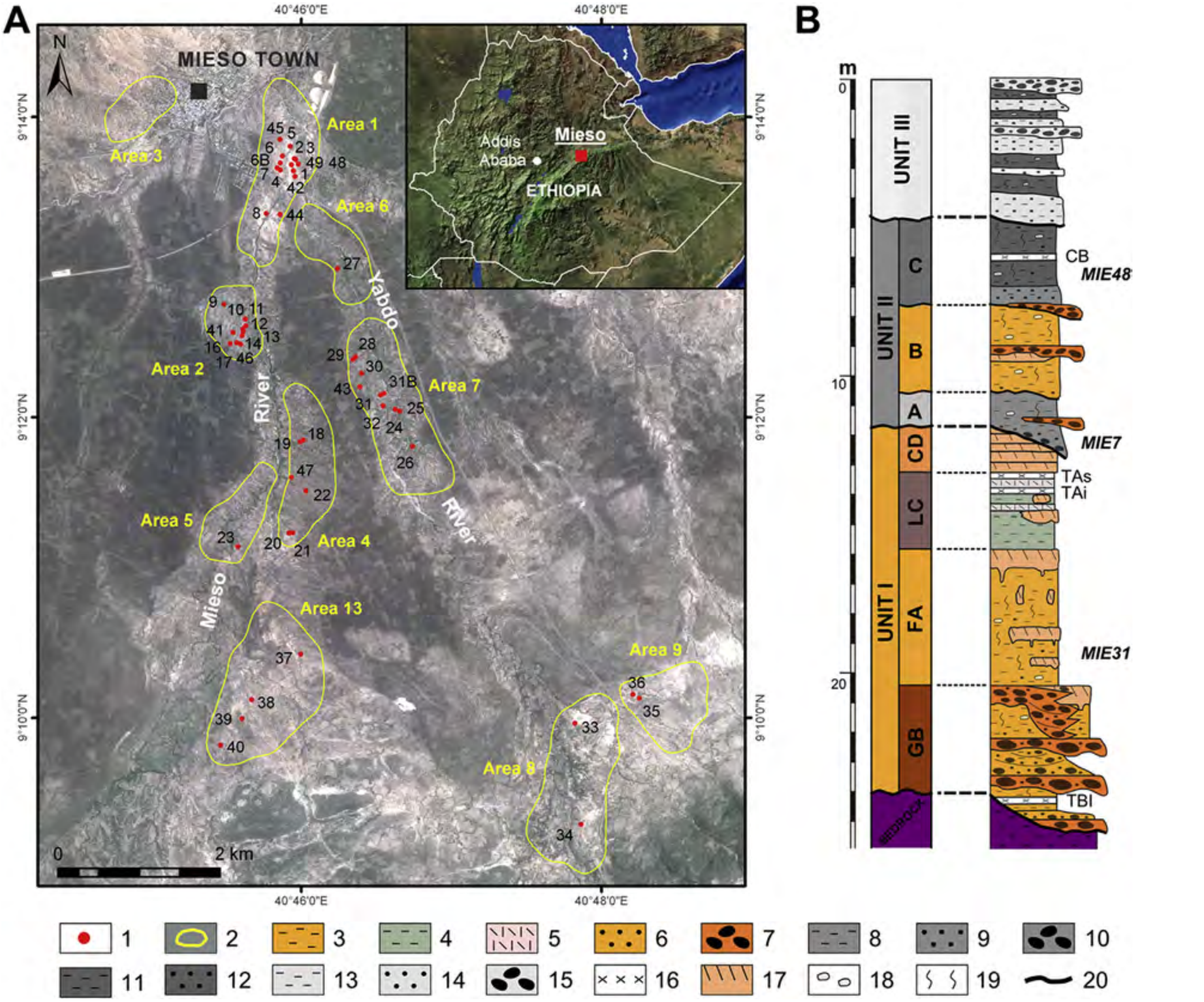

Figure 1. A) Location of the Mieso study area and position of the archaeological sites on Google Earth imagery (see also video clip in SOM 3). B) General stratigraphic sequence of the Mieso valley, based on descriptions by Benito-Calvo et al. (submitted for publication). Legend: 1, sites; 2, surveyed outcrop areas; 3, yellowish-brown silty clays; 4, greenish-grey clays; 5, white calcareous tufas; 6, yellowish-brown sands; 7, gravels with yellowish-brown matrix; 8, light brownish grey clays; 9, light brownish grey sands; 10, gravels with light brownish grey matrix; 11, greyish-brown silty clays; 12, greyish-brown sands; 13, pale grey clays; 14, pale grey sands; 15, gravels with pale matrix; 16, volcanic tuffs (TBI, TAi, TAs and CB); 17, calcretes; 18, carbonated nodules; 19, pedogenetic features; 20, disconformities.

and inter-site variability for the reconstruction of mobility patterns across the Mieso landscape, and the relevance of the Mieso Acheulean sequence for the understanding of Middle Pleistocene human behaviour in East Africa.

Chronostratigraphic context of the Mieso valley

The Mieso area is located in the foothills between the SE Ethiopian Plateau and the Afar Rift. In the escarpment, the bedrock comprises Mesozoic sedimentary rocks (Triassic, Jurassic and Cretaceous) and Oligocene-Miocene volcanic rocks (basalts, rhyolites and trachytes), while the Rift includes the Afar Series (basalts and rhyolites) and the volcanic edifices of Asebot (2539 m above sea level [a.s.l.]) and Afdem (2125 m a.s.l.). The foothill area (Mieso valley) is dominated by a gentle alluvial piedmont, which has been incised by the Mieso River and its tributary, the Yabdo. These fluvial courses are currently eroding a Pleistocene sedimentary sequence about 24 m thick, formed by alluvial, palustrine and volcanic materials, where a number of fossil and/or artefact localities have been found (Fig. 1A).

Fig. 1B shows the three sedimentary units documented in the Mieso valley sequence (see details in Benito-Calvo et al., submitted for publication). Unit I sits on bedrock, and contains four beds; GB (boulder, cobble and gravel conglomerates, mainly), FA (silty clays, clays and sands), LC (clays, marls and tufas), and CD (silty clays with calcretes). Unit II sits discordantly over bed CD and contains three beds (A, B and C) separated by erosive contacts, mainly composed of silty clays, sands and gravels. The base of Unit III is also erosive, and overall the unit is of alluvial origin, with sands, grey silty clays and gravel layers.

Unit III belongs to the Upper Pleistocene, as suggested by a number of stratified Later Stone Age assemblages dated by accelerator mass spectrometry (AMS) to < 20 ka (thousands of years ago) (Mora et al., in progress). Argon–argon ($^{40}Ar/^{39}Ar$) dating of tuffs from Units I and II (Benito-Calvo et al., submitted for publication) indicates a Middle Pleistocene age for the sequence. Tuff TA has yielded a date of 212 ± 0.016 ka, which provides a minimum age for assemblages in Beds GB, FA and LC (see Fig. 1B). Acheulean assemblages above tuff TA are more recent than 212 ka. One of the samples (M43-CB) from the upper tuff (Tuff CB) has

Table 1
Trenches dug in the Mieso valley Middle Pleistocene localities. Density of lithics refers to stratified material only.

Area	Locality	Surface		Stratigraphy		Area excavated (sq. m)	Thickness (m)	Density of lithics per area	Density of lithics per cubic meter
		Fossils	Lithics	Fossils	Lithics				
Area 1	MIE4	42	38	0	0	1	1.0	0.0	0.0
Mieso River	MIE6B	39	82	5	2	2	0.6	1.0	0.8
	MIE7	69	63						
	Trench 5			0	0	17	0.1	0.0	0.0
	Trench 6			0	0	3	0.8	0.0	0.0
	Trench 7			64	50	58	1.0	0.9	0.8
	MIE48	40	12	38	0	14	1.2	0.0	0.0
Area 7	MIE31	7	160						
Yabdo River	Trench 1			9	179	41	1.2	4.4	4.2
	Trench 8			0	0	1	0.5	0.0	0.0
	MIE43	5	39						
	Trench 2			0	0	14	0.4	0.0	0.0
	Trench 3			0	0	1.5	0.6	0.0	0.0

yielded a date of 800 ± 0.05 ka, which is likely due to contamination of much younger ashes. In fact, another sample from the same tuff and locality (M43-CB-1) yielded one peak at 760 + 0.04 ka and another close to 210 ± 0.03 ka, which is consistent with the date from tuff TA (Benito-Calvo et al., submitted for publication). Therefore, according to the available radiometric results some of the Acheulean sites in the Mieso valley, including Mieso 7, one of the most relevant assemblages, should be younger than 212 ka.

Materials and methods

The study commenced with geomorphological and geological interpretation of aerial photographs and topographical maps of the Mieso valley, from which suitable outcrops were divided into smaller geographic units (areas 1–13) in order to facilitate field survey. Within each area surveyed, a locality name was given to relevant surface fossil and/or stone artefact finds, and their location was recorded with hand-held GPS devices (Supplementary Online Material [SOM] 1). In localities where excavations were not conducted, surface finds were collected according to their general stratigraphic position in the outcrops.

At those localities where trenches were dug (Table 1), relative coordinate systems were created with a total station in order to achieve higher resolution than from GPS networks. Within each of the four local coordinate systems established (Mieso 4, 6, 6B and 7; Mieso 48; Mieso 7; and Mieso 43), modern terrain features were surveyed with a total station, and each surface fossil and lithic artefact was first individually 3D positioned and then collected, following the methodology outlined by de la Torre and Mora (2004).

Trenches were positioned within each relative coordinate network and the location of all stratified artefacts (regardless of size) and of some lithological features was also 3D recorded with a total station. Sediment was dry-sieved with a 5 mm mesh to improve recovery rate of smaller artefacts.

All surface and excavated lithic artefacts were measured and classified according to the technological categories used by de la Torre (2011), and the terminology of large cutting tools (LCTs) proposed by Kleindienst (1959) and Isaac (1977). A more in-depth study of relevant material was made, which included thin section identification of mineral and rock types (Spectrum Petrographics Inc. laboratory), use-wear analysis of LCTs (Ollé et al., in progress), drawing and 3D modelling of selected artefacts for illustration purposes, and refit study (following terminology by Cziesla, 1990) for spatial and technological analysis.

Table 2
Breakdown of lithic categories in the Acheulean assemblages of the Mieso valley. Localities with * include both surface and stratified artefacts, the rest are surface assemblages only.

Area	Locality	Small cores		Small retouched tools		LCT cores		Bifaces and knives		Cleavers		Unmodified large flakes		Smaller flakes		Total	
		N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Area 1	MIE1							3	37.5					5	62.5	8	100.0
Mieso River	MIE2	2	22.2					6	66.7					1	11.1	9	100.0
	MIE4	3	7.9	5	13.2			8	21.0	2	5.3			20	52.6	38	100.0
	MIE6	5	11.1	3	6.7	1	2.2	6	13.3					30	66.6	45	100.0
	MIE6B*	7	8.5	7	8.5			5	6.0	1	1.2			62	75.6	82	100.0
	MIE7*	7	6.3	5	4.5			11	9.7	11	9.7			78	69.7	112	100.0
	MIE44	1	5.0					2	10.0	3	15.0	4	20.0	10	50.0	20	100.0
	MIE45							4	50.0	1	12.5			3	37.5	8	100.0
	MIE48	4	33.3	2	16.7			3	25.0			1	8.3	2	16.7	12	100.0
	MIE49							1	50.0					1	50.0	2	100.0
Area 7	MIE24											2	33.4	4	66.6	6	100.0
Yabdo River	MIE25							1	50.0					1	50.0	2	100.0
	MIE28	2	18.2					3	27.3	1	9.1	1	9.1	4	36.4	11	100.0
	MIE29	2	22.2					2	22.2	2	22.2	1	11.1	2	22.2	9	100.0
	MIE30							4	26.7	1	6.7	4	26.7	6	40.0	15	100.0
	MIE31*	10	3.0	7	2.1	1	0.3	10	3.0	3	0.9	8	2.4	300	88.4	339	100.0
	MIE31B			1	5.3			9	47.4			2	10.5	7	36.9	19	100.0
	MIE32							2	40.0	1	20.0			2	40.0	5	100.0
	MIE43	7	17.9	2	5.1			6	15.4					24	61.6	39	100.0
	Total	50	6.4	32	4.1	2	0.3	86	11.0	26	3.3	23	2.9	562	72.0	781	100.0

The Mieso archaeological sequence

The Mieso localities (see full description in SOM 2 and Benito-Calvo et al., submitted for publication) are spread across the outcrops eroded by two fluvial courses, the Mieso River and its tributary the Yabdo (Fig. 1A). Most localities (70.6%) were documented in the Mieso River, particularly in the geographic zones named Area 1 (27.5% of the total sample of localities) and Area 2 (21.6%). Area 7 clusters (19.6%) are the most relevant finds along the Yabdo River. Unit I assemblages are mainly located in Area 7, while nearly all Unit II localities are clustered in Area 1 (see Fig. 1B, SOM 1 and SOM 3). Unit III sites are all located in Area 2.

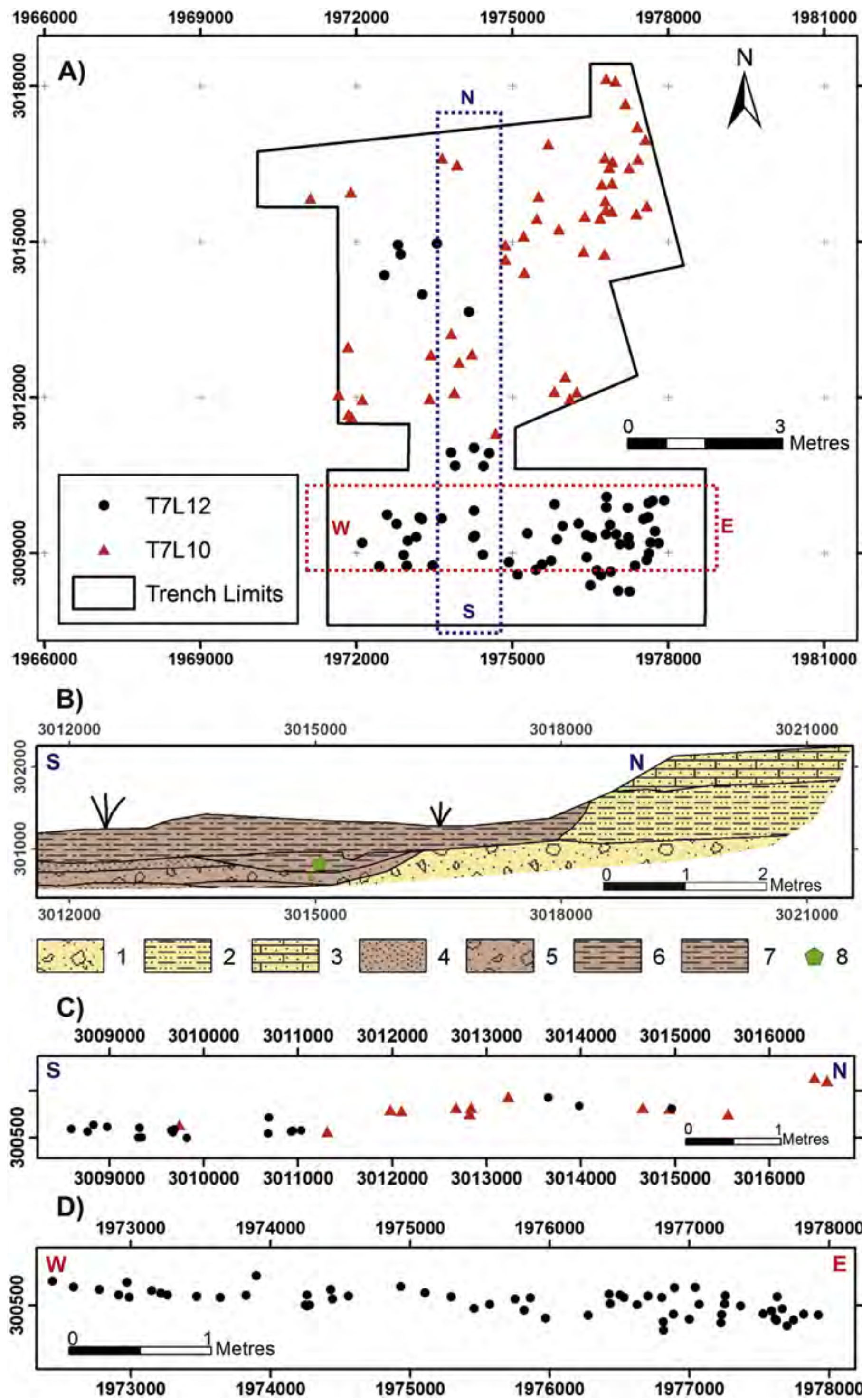

Figure 2. A) Plan of excavated materials in Mieso 7 Trench 7. B) N–S stratigraphic section of Trench 7. Stratigraphic levels of Unit I: 1, gravels and coarse sands (Bed GB); 2, laminated sands and silts (Bed FA); 3, calcrete (Bed FA). Stratigraphic levels of Unit II (Bed A): 4, sands; 5, gravels; 6, muds; 7, muds and sands; 8, stratigraphic position of archaeological material. C) N–S cross-section of plotted artefacts in Trench 7 (triangles = T7L10; circles = T7L12). D) E–W Section (see Fig. 2A for location of cross-sections C and D).

As shown in Fig. 1B and Table 2 (see also video clip in SOM 3), Acheulean localities are clustered in two zones, Area 1 (Mieso River) and Area 7 (Yabdo River). Elsewhere across the Mieso valley outcrops, Middle Pleistocene evidence is only recorded in low density scatters. A number of trenches were dug across the Mieso exposures (see Table 1 and description in SOM 2), but here we will focus on the two most relevant sites, Mieso 7 and Mieso 31.

The Mieso 7 site

Mieso 7 is the most relevant locality of Area 1 (see SOM 6). In this part of the left margin of the Mieso River, Unit I is heavily eroded by incision from Unit II (Fig. 2B). Unit I is composed of pebbles and cobbles (Bed GB), and is overlaid by laminated silts and sands from Bed FA, which are cemented at the top by calcrete. Unit I deposits are eroded by Unit II- Bed A, which consists of a succession of rounded and subrounded gravels, sands, and silty clays that fill an E–W trending paleogully.

Three trenches (5–7) were dug at this site (Table 1). Trench 5 was a step trench to sample the entire stratigraphy of the outcrop and Trench 6 was positioned at the top of the hill (SOM 7). No material in stratigraphy was found in trenches 5 and 6, although the former was important in recording the local sedimentary sequence, which is characterized by thick yellow sands and silts from Bed FA (Trench 5) underlying the silty clays, sands and gravels of Bed A documented in Trench 6. Trench 7 was excavated in the lower part of the outcrop, where two small modern ravines currently cut through Pleistocene deposits with fossils and stone tools.

The archaeological material in Trench 7 was documented in three sedimentary contexts. The upper stratigraphic level is a medium-grained sandy unit, which only contained scattered ($n = 3$) fragmentary fossils (recorded as T7L8; Trench 7 Level 8) but no stone tools. The archaeological material is mainly concentrated in the underlying layer (T7L10) of silty clays filling a small circular pool over a WSW-ENE shallow channel. Silty clays and gravels are found in lateral contact within the same stratigraphic position, and fossil and lithic artefacts were assigned to the same archaeological level (T7L10). Layer T7L12 includes material found exclusively in the sands and gravels surrounding and below the clay lens. The thickness of deposits in Table 1 refers to trench depth, and hence the resulting gross density of artefacts is very low (0.8 per cubic meter). Nonetheless, cross-sections (Fig. 2C and D) show that stratified items are vertically clustered in just 0.5 m. Therefore, density of artefacts within the archaeological units is higher than modelled in Table 1.

Fossils comprise 47.1% and 61.7% of material recovered from T7L10 ($n = 51$) and T7L12 ($n = 60$), respectively. Nonetheless, apart from a few bovid specimens the bones are too fragmentary for taxonomic or taphonomic identification. The breakdown of lithic categories (Table 3) shows an uneven distribution between T7L10 and T7L12, with all of the LCTs documented in the upper level only, and nearly all of the cores in Level 12. A skew towards larger- sized lithic artefacts dominates the whole assemblage (Fig. 3C), and shows similar distribution across the two levels (Fig. 3D).

Underrepresentation of the smaller fraction is normally associated with fluvial disturbance, and indeed water action over the Trench 7 lithic assemblage can be deduced from the gravel context in which some of the artefacts lie, and potential edge abrasion on a few pieces. Nonetheless, rounding is not easily quantifiable, as rounding by weathering of lavas is also observed, making it difficult to distinguish from fluvial abrasion. On the other hand, most of the stone tools (particularly the LCTs, which generally show very fresh edges) are not altered (Fig. 3F). Even though the number of LCTs is not high enough to provide statistically meaningful orientation patterns, their fabric is planar (girdle fabric) and does not indicate a preferred strike and dip (Fig. 3B). This is consistent with the remarkably good preservation of LCT edges and their gentle deposition in the sedimentary context; all but one of the LCTs listed in Table 3 were found on top or within the T5L10 clay lens (Fig. 3E). The small debitage is generally fresh as well, and part of it may belong to shaping processes associated with the LCTs from the clay lens.

In short, the presence of rounded fossil fragments and rounded/weathered artefacts in the gravel contexts of T5L10 and T5L12, and their co-occurrence with fresh stone tools, indicate several depositional events. Such episodes potentially include lateral reworking via stream erosion of part of the assemblage originally deposited on a clay pond, and jumbling of this reworked assemblage with rolled artefacts and fossils derived from the gravel deposit. In other words, cleavers and bifaces, plus some small flakes and cores, are found in (or very close to) their original discard position on a clay context, but there seems to be some lateral erosion of the clay level, and clear evidence of lateral and vertical aggregation of further cores and flakes from unrelated depositional episodes.

The Mieso 31 site

Mieso 31 (Fig. 4A) is the most prominent assemblage from Area 7. Pleistocene deposits outcrop in an area of approximately 7400 m^2, and surface artefact density was the highest across the Mieso valley (Table 1). Surface material was densely clustered in the central–north section of the outcrop, where Trench 1 was positioned (Fig. 4B). Trench 8 was dug 16 m to the SE of Trench 1, and

Table 3
Breakdown of lithic categories in Mieso 7 and Mieso 31. * Broken biface.

	Small debitage					Large debitage					Total	
	Cores	Flakes	Flake frag.	Debris <2 cm	Retouched tools	LCT cores	Unmodified large flakes	Bifaces	Cleavers	Other LCTs	*n*	%
MIESO 7												
Surface	2	23	22		4			6	4	2	63	56.3
Level 10	1	3	13					2	7	1	27	24.1
Level 12	4	5	12		1						22	19.6
Total	7	31	47		5	0	0	8	11	3	112	100.0
Total %	6.3	27.7	42.0		4.5	0.0	0.0	7.1	9.8	2.6		100.0
MIESO 31												
Surface	2	17	2		2	1	4	8	3		39	11.5
Level 0	4	58	49	6	1		2	1			121	35.7
Level 1	4	50	103	13	4		2	1*			177	52.2
Level 5		1	1								2	0.6
Total	10	126	155	19	7	1	8	10	3	0	339	100.0
Total %	2.9	37.2	45.7	5.6	2.1	0.3	2.4	3.0	0.9	0.0		100.0

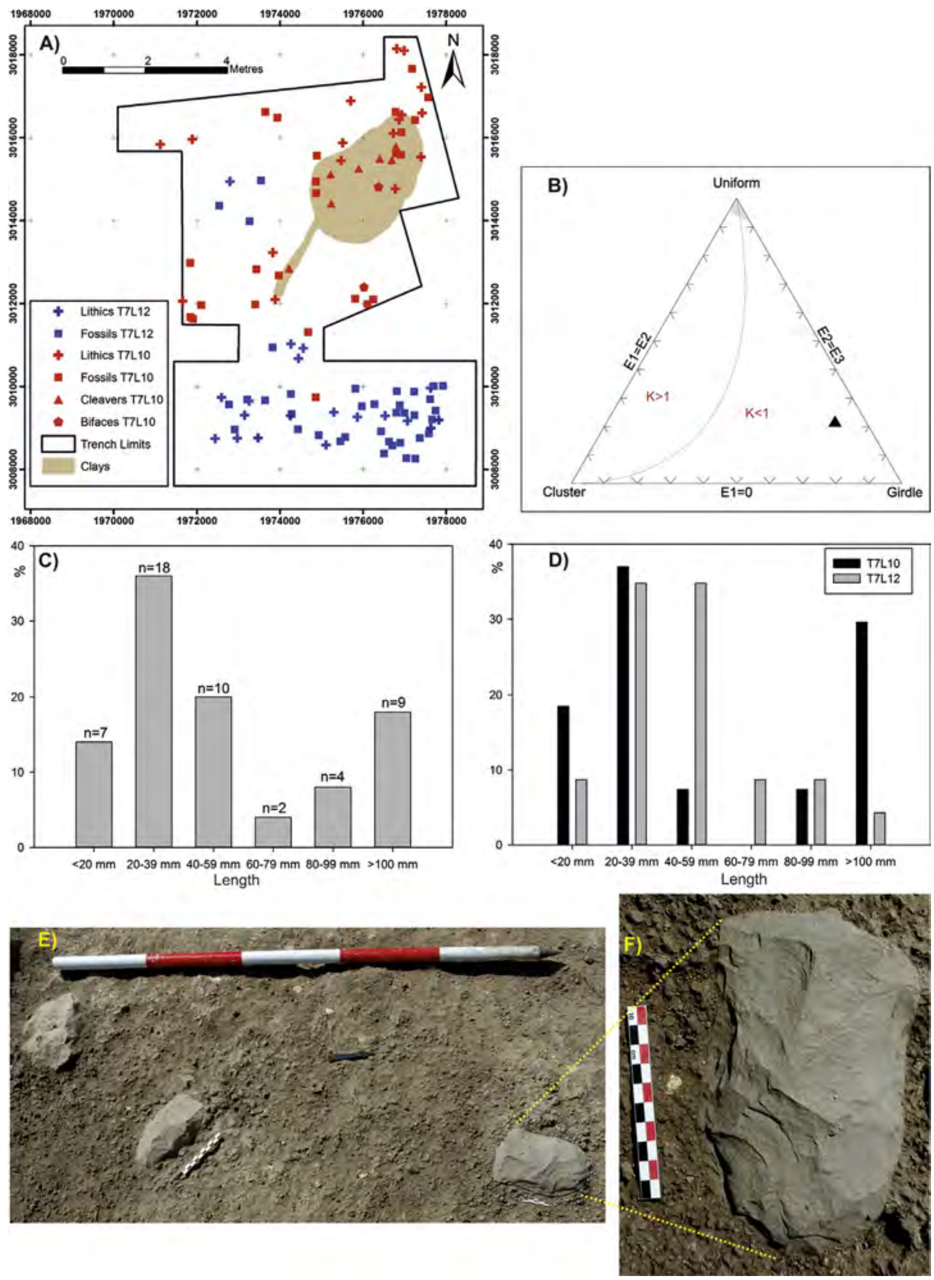

Figure 3. A) Plan view of fossils, LCTs and other lithic categories in Trench 7, with limits of the clay sheet surrounded by sands and gravels. B) Fabrics of T7L10 LCTs. C) Length ranges of all stratified lithic artefacts from Trench 7. D) Length ranges of lithic artefacts per level. E) and F) Cleavers on the T7L10 clays.

was set specifically to check lateral continuity of the sedimentary layers documented in Trench 1.

The Mieso 31 archaeological material was found in four positions (Table 3). Unit T1L1 is the main archaeological unit, where nearly all of the material ($n = 177$, 97.2%) is lithics, and bones (2.2%) are represented only by fragmentary bovid teeth. Artefacts are found in clusters distributed unevenly across the 41 m^2 surface of Trench 1 (Fig. 4C and D), and are well-constrained vertically into one single layer, c. 10 cm thick (Fig. 5A and B). Level T1L5 revealed scattered bones and lithics above T1L1 in the SE part of the trench, which are likely to be reworked. Non-stratified material clearly belonging to recent erosion of the Trench 1 site was collected as T1L0, while artefacts not readily attributable to the Trench 1 assemblage were coded as surface material (see Table 3).

Mieso 31 contains a cyclic alluvial aggradation sequence composed of silty clays, sands and gravels attributed to Bed FA (Unit I). Four lithological layers were differentiated (A–D) during the excavation of Trench 1 (Fig. 5C). The bottom layer (A) is composed of massive sands, including sub-rounded and rounded gravels, which are overlaid by layer B, made of 2–5 cm thick prismatic grey muds. The T1L1 archaeological unit is located at the top of this lithological layer B, which is partially eroded by the upper layer (C). Layer C consists of channel facies (gravels and sands with cross-stratification) located at the south of the trench, changing to overbank muds to the north and west. This channel facies is buried by an overlying level of muds (layer D).

The composition of the T1L1 lithic assemblage also indicates a gentle depositional environment. For instance, although some

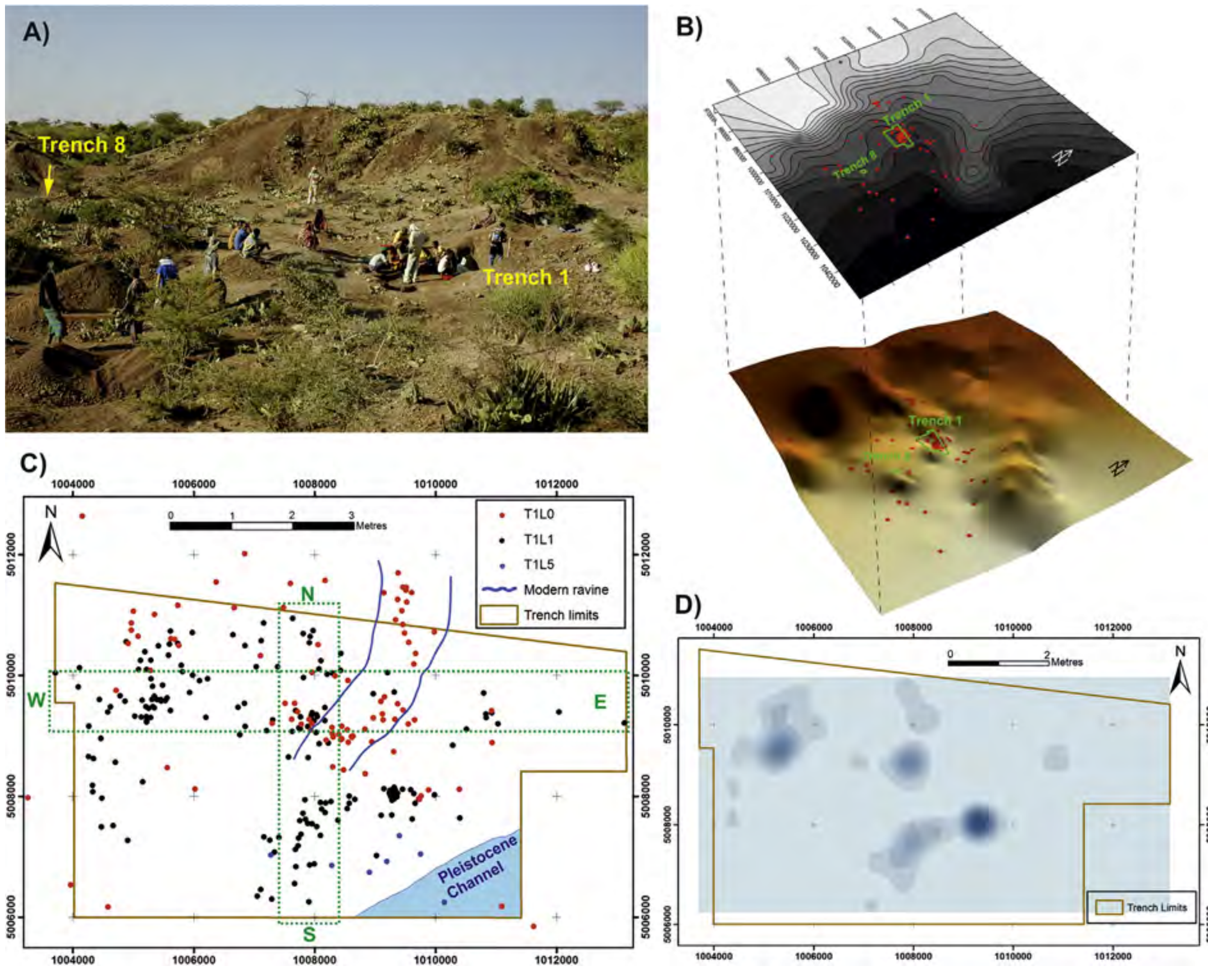

Figure 4. A) Excavations at the Mieso 31 outcrop. B) DEM and contour map of Mieso 31 and the location of surface material around Trench 1. C) Plan view of stratified artefacts in Trench 1 (levels 1 and 5) and of material directly eroding from the trench area (Level 0). D) Density plot of T1L1 artefacts.

pieces are slightly weathered, most of the artefacts show intact edges. The length of 67.6% of lithics is <40 mm, although <20 mm debris are not as well represented (24.6%), which could suggest sheet wash over the clay surface that removed part of the smallest lithic fraction (Fig. 6A). The wealth of conjoining pieces (Table 4 and Fig. 7A) and the spatial grouping of each refit set in distinctive clusters (Fig. 7B) rules out extensive fluvial reworking of artefacts.

The rose diagram indicating orientation of refit lines (Fig. 6B) shows a preferred directional pattern ($n = 49$, $p = 0.018$; Mean vector = 36°; Rayleigh's test $Z = 3.9$, $p = 0.01$; Kuiper's test $V = 1.7$, p=<0.05). This unimodal pattern may be influenced by the anisotropy typical of any flaking process, but the sheet wash event/s that removed part of the <20 mm fraction potentially could have also slightly displaced the artefacts (the mean connection distance in T1L1 is 74 cm, see Table 5). Although there were no lithological indicators to enable a reconstruction of the clay surface micro-topography over which T1L1 artefacts rest, transversal cross-sections of refit connections (Fig. 5E) suggest a flat E–W depositional surface. Both the sagittal (Fig. 5D) and transversal (Fig. 5E) vertical plots indicate that this surface followed a gentle N–S slope, which may also have contributed to the short displacement of refit connections.

All proxies suggest that, even though the Pleistocene channel documented in the southeast of Trench 1 could have eroded the artefact level at that corner of the site, any potential syn-sedimentary water reworking across the preserved area of the clays was not severe. Thus, the main disturbance agent is the modern ravine that cuts through the north-central part of Trench 1 (Fig. 4C). This stream is eroding artefacts from the archaeological assemblage, as demonstrated by the number of refit connections between the stratified level (T1L1) and T1L0 surface lithics (Fig. 7A), but has not affected the main area of the site.

In short, the low energy clay context, fresh condition of artefacts and preservation of original clusters of knapping episodes (as suggested by the spatial segregation of individual conjoining sets) support the proposal that T1L1 artefacts remain in (or close to) their primary position, although some post-depositional processes (particularly depletion of smallest debris by sheet wash) may have taken place.

Refits are particularly relevant for the understanding of Mieso 31 site formation. Table 4 shows that refits occur frequently both within the stratified unit (T1L1) and between T1L1 and the recently eroded artefacts (T1L0). Frequencies are high in both assemblages; 30.0% of T1L1 artefacts >20 mm ($n = 133$) and 21.2% from T1L0 (total of all >20 mm artefacts, $n = 108$) conjoin. In total, 64 stone tools conjoin in 19 refit sets with 73 refit lines (Table 4). Siret refits ($n = 12$) make up most of the conjoining lines of broken pieces ($n = 15$). Among dorsal/ventral refit connections ($n = 58$), 22.4% are core-flake lines, and 77.5% are conjoining technological sequences of flake/flake fragments.

Conjoining lines also yield valuable spatial data. Connection distance within T1L1 ranges between 8 cm and more than 3 m

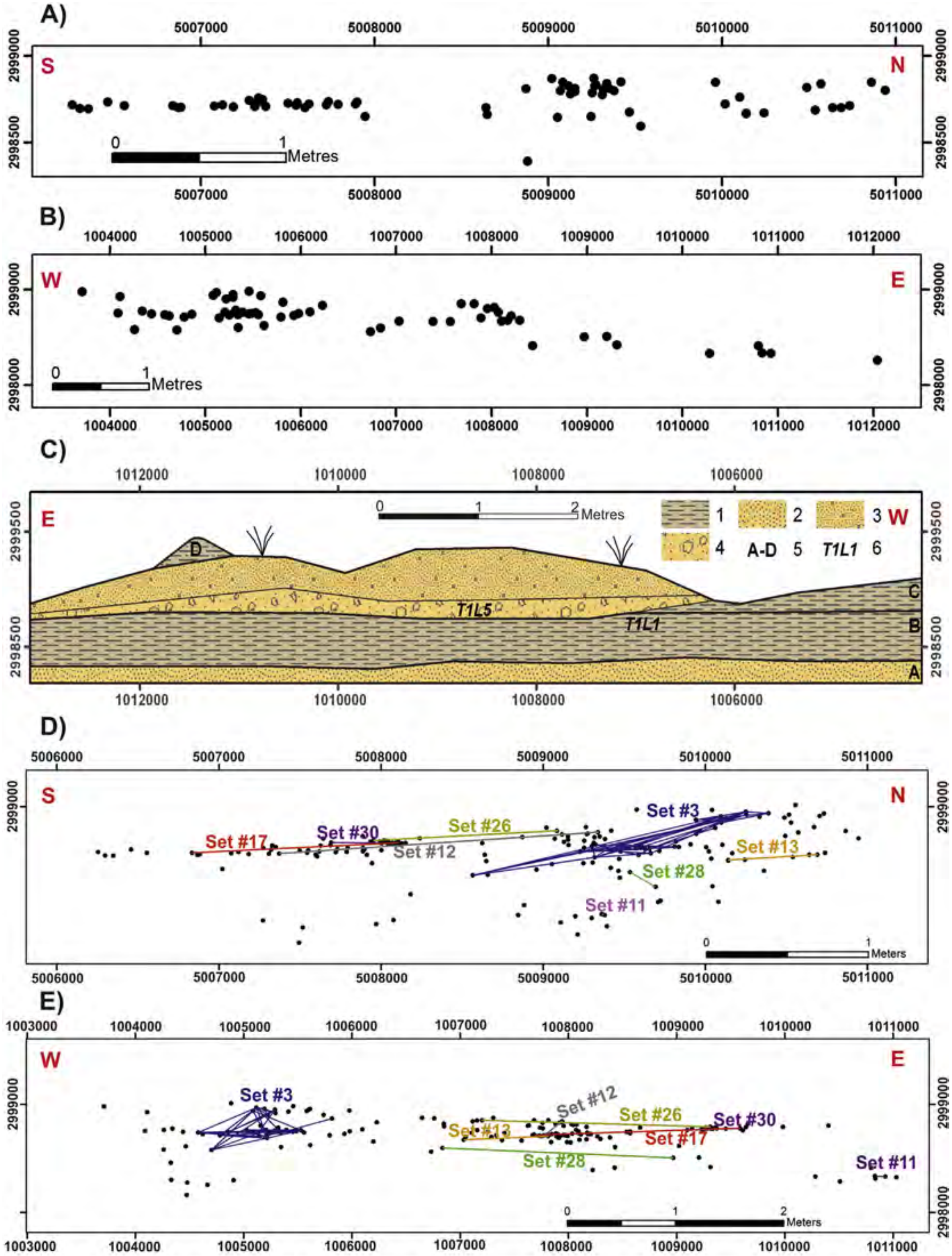

Figure 5. A) North-South cross section of T1L1 artefacts. B) East-West cross section. A) and B): see plan view in Fig. 4C for position of cross sections. C) Litho-stratigraphic section of Trench 1. Legend: 1, muds; 2, massive sands, local gravels; 3, sands and gravels; 4, gravels; 5, stratigraphic units; 6, archaeological levels. D) North-South cross section of refit lines in T1L1. E) East-West vertical plot of T1L1 conjoining pieces.

(Table 5). The low values of minimum distance mainly correspond to broken artefacts produced by knapping accidents; transversally broken refitted artefacts (e.g., snapped flakes and step fractures) are separated by an average of 29.3 cm. Sagittal fractures (i.e., Siret flakes) show a refit mean distance of 76 cm. Technological conjoining distances (i.e., dorsal/ventral refits) from T1L1 are on average (75.9 cm) longer than those of fractures (65.6 cm) (see Table 5). Among technological refits, core-product conjoins have a mean distance of 52.3 cm, while dorsal/ventral refits of products average 81.8 cm. The longest distance lines are a dorsal/ventral connection of small debitage flakes within set #17 (distance 3.15 m), and a sequence of dorsal/ventral flakes from set #26 (maximum distance 2.39 m) (see Fig. 7A). Both refit series contain relatively large-sized pieces, which rule out the possibility that long connection lines are due to water disturbance, but rather indicate the size of the knapper's disposal area.

Unit T1L1 shows spatial clustering of several refit groups that not only suggests the relatively undisturbed character of the assemblage (see discussion above), but also enables us to isolate different knapping episodes (see refit set distribution in Fig. 7A). Of

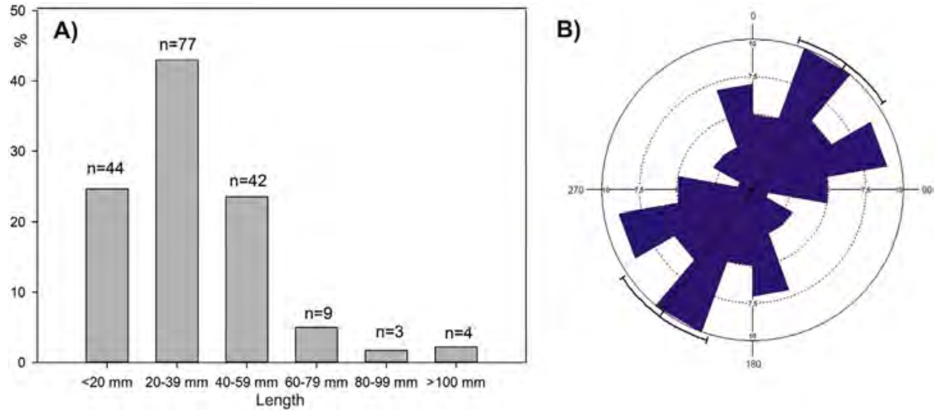

Figure 6. A) Size ranges of stone tools from Mieso 31 (only stratified artefacts). B) Rose diagrams of refit connection orientations in plan view.

particular relevance is set #3, which is strongly clustered in the central-west area of Trench 1. This set conjoins 22 lithic artefacts, and corresponds to the roughing out and subsequent failed shaping of a handaxe.

In summary, flaking sequences are well represented in Mieso 31. As shown in Table 3, these include production of LCT blanks (as with Mieso 6, there is an LCT core in the Mieso 31 surface assemblage), handaxe roughing out, façonnage, and abundant small debitage flaking. On-site knapping episodes, and particularly handaxe shaping, can be studied in detail thanks to the refit evidence from T1L1, and will be discussed in more depth below.

The Mieso lithic assemblages

Raw materials

Most of the Mieso stone tools are made of volcanic rocks. Whilst the Later Stone Age assemblages are dominated by obsidian artefacts, raw materials in the Acheulean sites show an absolute predominance of lavas. From a total of 117 kg of artefacts (see lithic categories in Table 2), only 63 g of obsidian are represented in the Mieso Acheulean (three artefacts in Mieso 31 and three in Mieso 7) and 8 g of chert (four artefacts from Mieso 7, plus two natural chert fragments from Mieso 31). The remaining stone tools are in lava. Sources of obsidian are unknown, and provenance studies will be required to match the Mieso artefacts with documented obsidian sources in nearby areas such as Lake Beseka (Negash et al., 2007) and Kone (Morgan et al., 2009). Unlike the Later Stone Age obsidian artefacts, the sourcing of which is not local, rare occurrences of both obsidian and chert small pebbles in the Middle Pleistocene sequence derive from local conglomerates and hence no long distance transport of these raw materials is documented.

Lavas used for the Acheulean artefacts were sourced from conglomerate beds in the Yabdo and Mieso Rivers, and were also available locally. Boulders and cobbles of all dimensions are abundant in a number of beds throughout the Middle Pleistocene stratigraphic sequence and across most of the Mieso valley (see Benito-Calvo et al., submitted for publication). This suggests that any required size for raw material sourcing was readily available to Acheulean knappers within a short distance. Nonetheless, variations are observed locally; maximum length analysis of lava cobbles from conglomerates close to Mieso 31 ($n = 100$) and Mieso 7 ($n = 100$) (located <250 m and <100 m from the sites, respectively), indicate statistically-significant size differences between the two randomly-collected samples (Kruskal–Wallis $p \leq 0.0001$; alpha $= 0.05$), with larger cobbles available nearer to Mieso 31 (mean length = 118 mm) than in Mieso 7 (93 mm).

Within the lavas, de visu inspection permits basalts and other more leucocratic extrusive rocks to be distinguished. Focusing on the most relevant sites, the Mieso 7 handaxes (particularly cleavers) are made of fine-grained lavas (mostly basalts), clear evidence of selection of high-quality raw materials for LCT production. At Mieso 31, most of the artefacts are also made of very fine grained lavas, but patination (which also affects part of the Mieso 7 assemblage) complicates hand-specimen identification. For that reason, samples from Mieso 31 and Mieso 7 were characterized petrographically through thin section analysis (SOM 10). Results indicate the presence of basalt in both Mieso 7 and 31, dacite ash-flow tuff in Mieso 31, and dacite welded tuff and vitric ash-flow tuff in Mieso 7 (full description in SOM 10). Nonetheless, petrographic variety is likely to be higher than identified in thin section, since due to its destructive nature, thin sectioning was limited to a few samples from each assemblage.

In summary, the Mieso valley contained a variety of lava raw materials readily accessible to the Acheulean knappers within the immediate area of the sites. Availability of boulders and cobbles of all sizes is observed in our sampling of Pleistocene conglomerates, and supported by the presence of LCT cores in both the Mieso and Yabdo Rivers (see Fig. 8A and B). The latter also suggests that blank production from LCT cores was, at least partially, made in the immediate area surrounding the main archaeological assemblages. Selection of high quality, fine-grained basalts for the production of some LCTs is observed, particularly in the case of the Mieso 7 cleavers. The abundance of refits in Mieso 31, located <250 m away from the modern river bank, seems to indicate stone tool production activities nearby raw material sources. This is also supported by percentage of cortex; 48.9% of a sample of complete flakes ($n = 47$ artefacts) from Mieso 31 bear some cortex, including Toth's (1982) types II (4.3%), IV (2.1%) and V (42.6%), indicating that roughing out (in the case of handaxes) and initial flaking of smaller cobbles were performed on the spot at Mieso 31.

Table 4
Types of refits in Mieso 31.

	Dorsal/Ventral	Fractures	Total refit lines	Total refit sets	Total pieces
Surface	1	0	1	1	2
T1L0	3	3	6	6	12
T1L1 with T1L0	17	3	20	7	21
T1L1	37	9	46	5	30
Total	58	15	73	19	65

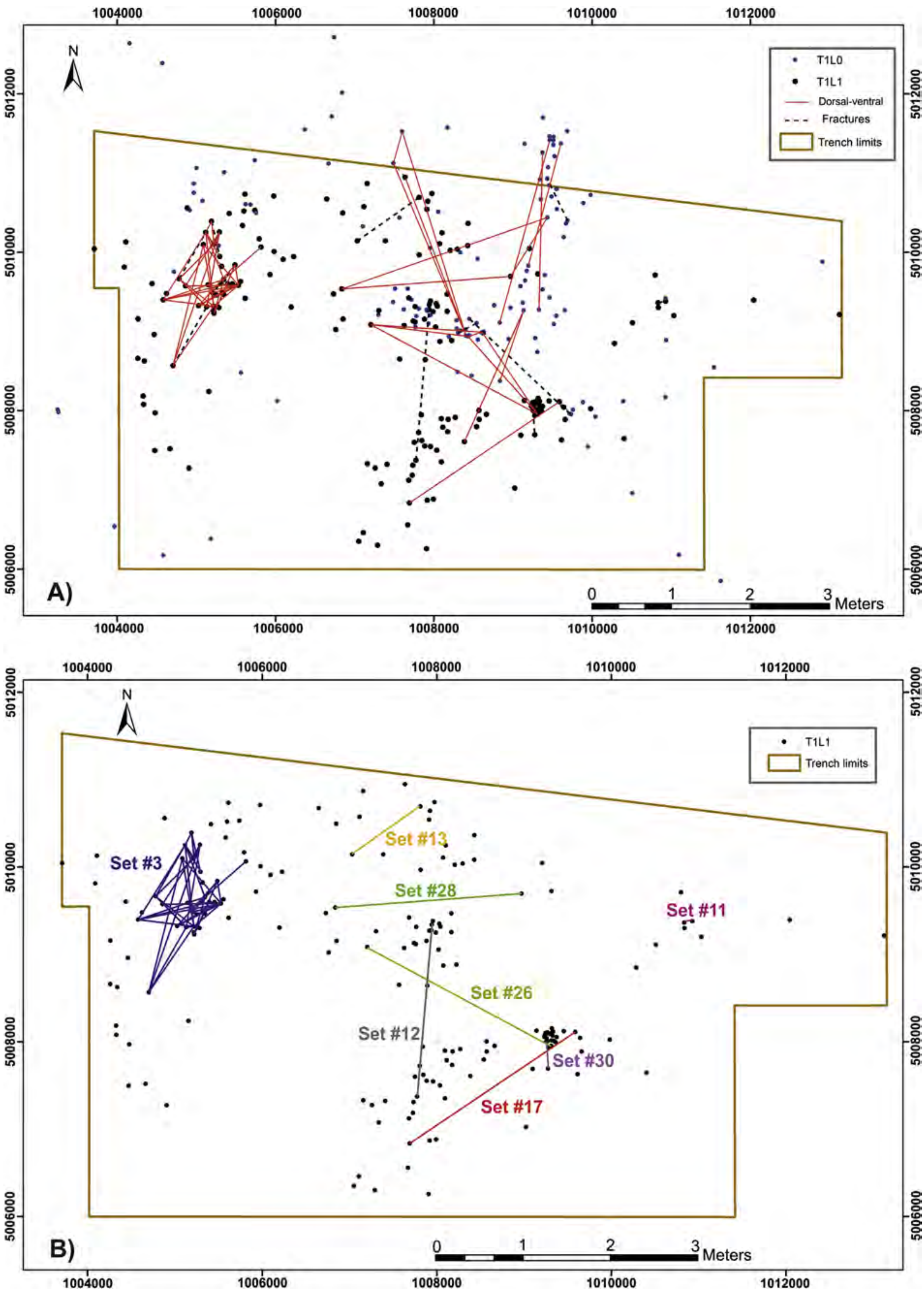

Figure 7. A) Plan view of refit connections in Mieso 31 T1L1 and T1L0, according to Cziesla's (1990) conjoining types. B) Spatial distribution of refit sets in T1L1.

Table 5
Refit distances (in mm) in Mieso 31.

		Dorsal-ventral	Fractures	Total
T1L0	Total refit lines	8	3	11
	Minimum distance	56	264	56
	Maximum distance	2701	1744	2701
	Mean	1331	866	1204
T1L1 with T1L0	Total refit lines	9	3	12
	Minimum distance	877	40	40
	Maximum distance	3172	231	3172
	Mean	1775	163	1372
T1L1	Total refit lines	40	9	49
	Minimum distance	87	97	87
	Maximum distance	3153	1973	3153
	Mean	760	657	741

Small debitage production

The chaîne opératoire of Acheulean small debitage is present in most of the Mieso assemblages, normally co-occurring with handaxes (Table 2). The breakdown of metrics (Table 6) shows variable mean dimensions between the two main sites, with larger cores in Mieso 7 (average length = 8.4 cm; weight = 484 g) than in Mieso 31 (average length = 6.9 cm; weight = 216 g).

The low frequencies of small debitage cores favour a qualitative assessment of this lithic category; core blanks are varied, and in Mieso 31, flakes, cobbles and angular fragments were used as cores. At Mieso 7, most cores were made on angular fragments of coarser grain lavas than those used for LCTs. Small debitage flaking methods are relatively unstructured. In Mieso 7, the bifacial peripheral system (sensu de la Torre, 2011) is the most common, and attests to the production of small flakes (average length = 4.7 cm and weight = 22 g) in parallel to the presence of >10 cm bifaces and cleavers (see metrics in Table 6), usually made on flake blanks from a completely different chaîne opératoire, that of LCT production.

Fig. 8C shows some of the Mieso 31 small debitage cores, which exemplify one of the two typical reduction systems in the assemblage, i.e., bifacial centripetal flaking. These cores usually show alternating flaking platforms, which do not cover the entire circumference. Cores are not heavily reduced, and cortex is partially preserved on part of the area separating the two flaking surfaces, and often also on the debitage surfaces.

Some refit sets of flakes correspond to a centripetal reduction as deduced from core analysis. Nonetheless, the abundance of refits in Mieso 31enables the identification of another reduction system indiscernible through the study of cores only; refits from Fig. 9A indicate that flaking was also undertaken on cores with two opposite striking platforms and organized through bidirectional, rather than centripetal, removals. However, such cores are missing from the assemblage.

Large cutting tools

Four main aspects of LCT technology can be explored through the Mieso artefact assemblages: methods of LCT blank production, shaping (i.e., façonnage) of handaxes, their typology and use wear. We focus here on the technological aspects (blank production and façonnage), although comments will be made on the functionality (use-wear analysis, in progress) and typology of the Mieso assemblages.

Production of LCT blanks LCT blank production can be discussed on the basis of the large cores from Mieso 6 and Mieso 31, and the technological features of the LCTs from Mieso 7. The two LCT cores from Mieso 6 and Mieso 31 (Fig. 8A and B) were made on large boulders, which preserve substantial amounts of cortex. Neither shows long sequences of reduction. Flaking of the Mieso 31 LCT core (18 cm length and 3.9 kg) followed a unidirectional abrupt unifacial pattern (sensu de la Torre, 2011), in which the flaking platform remained largely cortical and reduction was constrained to a fraction of the core circumference, over which large flakes potentially used as LCT blanks were removed (see Fig. 8B).

The huge (>6 kg and over 19 cm length) LCT core from Mieso 6 shows a longer reduction sequence, with four flaking surfaces organized across two bifacial edges. While there is no hierarchical organization of the volume of the core, on each of these two bifacial edges one debitage surface seems to have served as preparation for the removal of larger flakes (potential LCT blanks) on the associated surface. Some scars on the Mieso 6 core show metric ranges between 10 and 15 cm in length, remarkably similar to the dimensional range of the blanks used for LCT façonnage at Mieso 7 (see handaxe metrics in Table 6), which gives further support to the technological connection between the two assemblages.

Even though no LCT cores were found at Mieso 7, insights on LCT blank production can be deduced from the technical attributes of handaxes. Contrary to the LCT cores from Mieso 6 and Mieso 31 (which show little preparation of convexities), several of the Mieso 7 handaxes suggest a more elaborate organization of debitage surfaces and flaking platforms. While all of the cleavers had their butts thinned through façonnage, preparation of LCT core flaking platforms can be seen in Fig. 10A. This knife (sensu Kleindienst, 1959) shows a multifaceted butt, with large scars on the sides and smaller ones right on the centre of the striking platform. The latter are associated with the point of impact and provide evidence for careful preparation of the core's flaking platform before removing the LCT blank. Other LCTs with thinned butts preserve part of the flaking platforms (Fig. 10B), and therefore can be considered as éclat débordants. The shape of the cleaver in Fig. 10B helps understand better the geometry of LCT cores, as three out of the four ends of a core are present on the LCT blank. The flake's transverse cutting edge (cleaver bit), the (thinned) striking platform, and the débordant flake edge suggest that in this particular case, an elongated boulder/block of around 18 cm was used to remove a flake extending over most of the debitage surface.

Differentiating between extractions belonging to debitage from those produced during façonnage in handaxes is admittedly difficult. Despite this, the analysis of the dorsal surfaces of LCTs can be informative with regards to blank production when cores are missing, as is the case in Mieso 7. The knife in Fig. 10A, for instance, bears flake scars removed from the proximal end of the core to prepare convexities prior to the extraction of the LCT blank. A number of flake scars on the cleaver in Fig. 10C may potentially belong to the core debitage phase before the removal of the LCT blank, and might indicate radial preparation of the boulder flaking surface. This flaking pattern becomes more evident in Fig. 10E, a cleaver with large scars belonging to previous stages of core reduction. Inferred directionality based on the dip of negatives and the presence of step scars unveils a radial pattern that once again suggests considerable preparation of core debitage surfaces before removal of LCT blanks.

In summary, both unstructured and structured methods of LCT blank production are documented in the Mieso assemblages. The two large cores indicate unifacial (Mieso 6) and bifacial (Mieso 31) methods to remove large blanks, but are relatively unstructured. In some instances, the dorsal surfaces of Mieso 7 handaxes also speak of short sequences prior to LCT blank removal. Figs. 10B and 11A are short and wide flakes from elongated cobbles/boulders that remove most of the core debitage surface. Despite the relatively simple preparation of surfaces in these cases, there is remarkable similarity in the methods of production of these handaxes, which

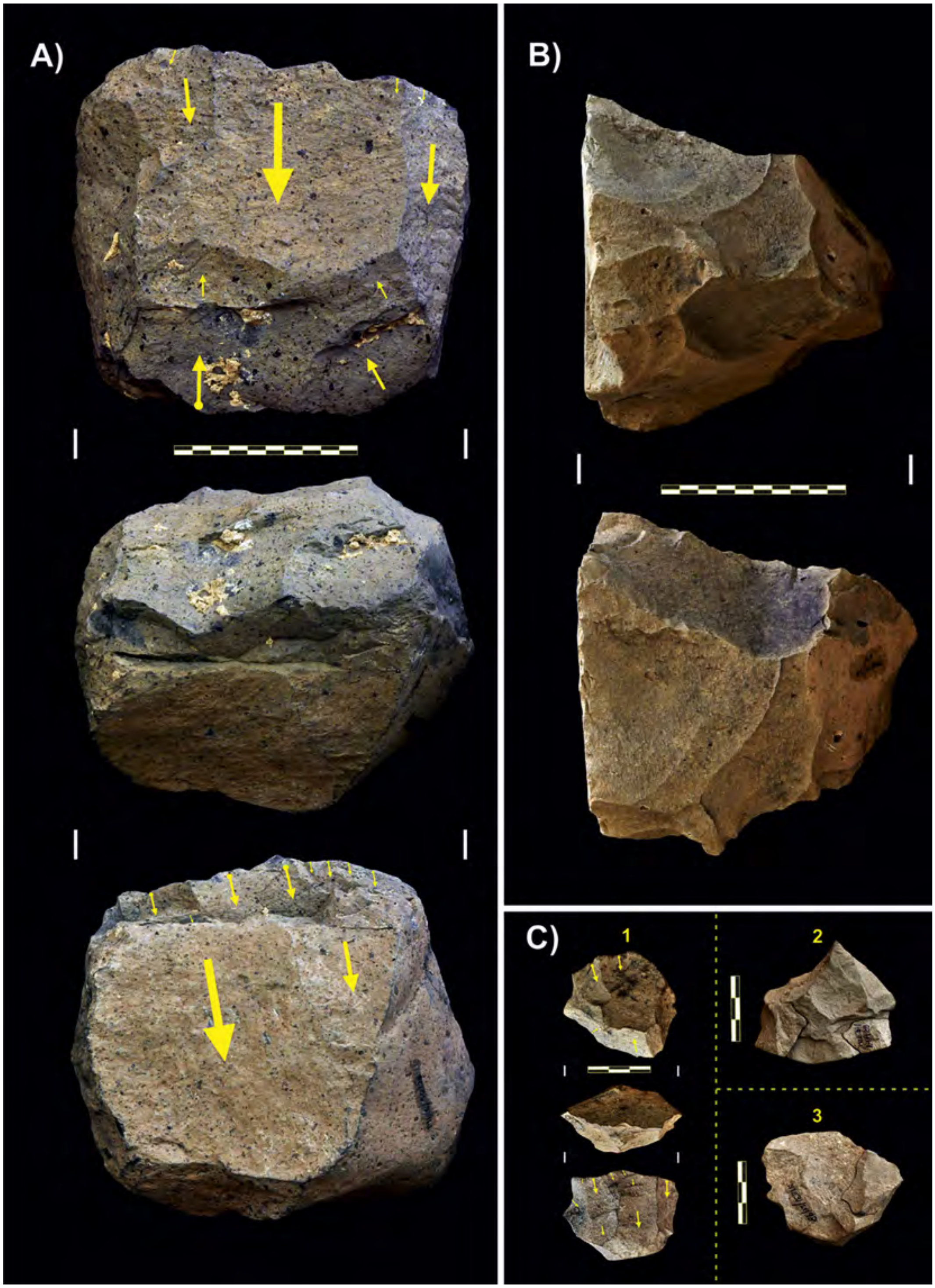

Figure 8. Cores from Mieso Acheulean assemblages. A) LCT core from Mieso 6. B) LCT core from Mieso 31. C) Small debitage cores from Mieso 31. #1 Core from T1L1; #2 Core from surface collection (T1L0) refitting with T1L0 and T1L1 flakes; #3 Core from T1L1 refitting with flake from T1L0.

reinforces the notion of cleaver blank standardization. Furthermore, other Mieso 7 handaxes suggest a more structured preparation of LCT cores. As mentioned above, radial flaking of cores in order to arrange convexities is evident (e.g., Fig. 10E and possibly also Fig. 10C), and so is careful preparation of striking platforms in bifacially flaked LCT cores (Fig. 10A).

Shaping of handaxes The shaping of handaxes in Mieso can be assessed through analysis of the thinning and finishing of LCT flake blanks, and through the study of handaxes directly shaped from cobble blanks. Mieso 31 offers a unique opportunity to investigate the latter, as the whole process of reduction of a failed handaxe has been reconstructed via refit analysis. Fig. 12 details each of the reduction stages involved, which started with the on-site roughing-out of a complete cobble, via alternate series of removals from natural platforms to remove large cortical areas on the opposite sides (see also SOM 11 for animation of the biface

Table 6
Dimensions (mm) and weight (g) of stone tool categories from Mieso 7 and Mieso 31. Broken artefacts are excluded from the metric analysis.

			Mieso 7									Mieso 31								
			Surface			Stratigraphy			Total			Surface			Stratigraphy			Total		
			n	Mean	Std. D.	*n*	Mean	Std. D.	*n*	Mean	Std. D.	*n*	Mean	Std. D.	*n*	Mean	Std. D.	*n*	Mean	Std. D.
	Flakes		23			8			31			75			51			126		
		Length		45.6	16.2		34.6	10.8		42.8	15.6		47.6	17.5		43.5	19.8		45.9	18.5
		Width		40.7	12.3		31.5	9.9		38.4	12.3		40.6	17.8		39.7	18.3		40.3	17.9
		Thickness		11.3	3.7		8.1	2.5		10.5	3.8		13.6	6.8		12.4	7.3		13.1	7.0
		Weight		26.5	21.5		11.2	10.4		22.5	20.2		37.9	63.3		34.2	46.2		36.4	56.9
Small debitage	Cores		2			4			6			6			4			10		
		Length		100.5	34.6		76.0	36.5		84.1	34.6		69.8	18.1		69.5	29.1		69.7	21.5
		Width		87.0	24.0		60.2	16.7		69.1	21.7		56.5	17.6		62.0	25.9		58.7	20.1
		Thickness		64.5	34.6		38.5	9.4		47.1	21.7		35.6	8.8		35.2	16.7		35.5	11.7
		Weight		1007.5	933.4		223.2	227.9		484.7	607.8		209.1	198.9		227.4	270.0		216.4	215.4
	Retouched		4			1			5			3			4			7		
		Length		69.0	11.1		57.0			66.6	11.0		67.3	22.2		30.0	2.1		46.0	23.7
		Width		43.0	6.7		54.0			45.2	7.6		43.6	6.4		21.7	5.7		31.1	12.9
		Thickness		20.8	5.5		21.0			20.8	4.8		18.6	5.5		8.0	5.4		12.5	7.5
		Weight		68.0	32.3		57.2			65.8	28.4		55.8	40.4		6.1	5.2		27.4	35.5
Large debitage	Bifaces		6			2			8			9						9		
		Length		117.6	10.1		122.5	34.6		118.9	15.8		119.5	30.9					119.5	30.9
		Width		70.1	6.3		72.5	9.2		70.7	6.4		77.3	17.5					77.3	17.5
		Thickness		32.0	4.0		42.5	0.7		34.6	5.9		42.4	10.4					42.4	10.4
		Weight		268.7	45.2		346.9	8.1		288.3	52.7		430.0	317.6					430.0	317.6
			4			7			11			3						3		
	Cleavers	Length		200.7	20.1		172.4	29.5		182.7	29.1		130.0	19.9					138.0	7.9
		Width		117.5	5.8		10.2	20.8		107.3	18.3		110.3	21.5					102.3	11.6
		Thickness		44.5	7.9		41.4	5.5		42.5	6.3		33.0	6.2					33.0	6.2
		Weight		1219.5	139.0		920.1	350.8		1029.0	320.1		507.4	103.0					507.4	103.0

reduction process). Alternating flaking followed in Series III and IV, in such a way that negatives left on one debitage surface were consecutively used as flaking platforms for extractions on the opposite plane. Series V and VI involved longer sets of removals from each flaking platform before flipping over the handaxe preform. These sets indicate that the knapper began shaping of the tip before beginning to work the opposite cortical end, and before having thinned out much of the handaxe. It thus seems that the target was firstly to achieve a pointed preform before undertaking most of the thinning. Series VII sees the beginning of a regularization of edges, during which the tip broke, and the handaxe was discarded.

While the Mieso 31 broken biface enables investigation of the initial steps of handaxe shaping, the LCTs from Mieso 7 provide relevant insights on later stages of thinning and finishing. The Mieso 7 bifaces are in general less carefully trimmed than the cleavers. Fig. 11B shows a poorly shaped biface in which alternating, discoid-like façonnage produced step scars and only partial management of the central volume, and no regularization of edges was made. Although it is not possible to establish whether this roughing-out stage appearance resulted from the piece being an unfinished biface or whether it was actually the intended end result, Fig. 11B and some other Mieso 7 bifaces contrast with the careful façonnage of the cleavers. At least two stages of façonnage (which, in some instances, seem to be made with soft hammer) can be observed in nearly all of the Mieso 7 cleavers; firstly thinning of central and lateral volumes, and then planform shaping via edge trimming.

The first shaping stage involves volume thinning on the dorsal face of LCT flake blanks, and/or thinning of butts. Shaping of central volumes through flat invasive extractions is well documented (e.g., Fig. 11C; Fig. 13A), but is not universal within the sample of Mieso 7 cleavers. Thus, several examples (e.g., Fig. 10B and C) show prevalence on the dorsal faces of open-angled large removals that do not penetrate the central volume of LCT blanks, and rather seem to be associated with preparation of edges. Conversely, thinning of flake striking platforms is systematic; 100% of the cleavers had their butts and bulbs of percussion removed. Given that the remaining part of the ventral face of the cleaver blank normally shows no other retouching, this suggests that thinning of the butt and bulb of percussion was consubstantial to cleaver making during the façonnage stage, and was as standardized as the preparation of the cleaver bit during the production of the LCT blanks. This butt and bulb removal, coupled with the thinning of the dorsal faces, enabled Mieso 7 knappers to obtain a symmetrical biconvexity across the entire edge of cleavers, and epitomizes a geometrical depiction and technical execution of LCT blank shaping that is remarkably sophisticated.

Another stage of façonnage involved trimming of cleaver edges via small, non-invasive retouch flakes. This stage of façonnage does not necessarily follow chronologically central volume/butt thinning, but in a number of instances it can be recognized that such was the case. For instance, retouch over the cleaver's ventral face in Fig. 11C removed all of the impact points from the larger invasive extractions on the dorsal side, and was aimed at regularizing the edges transversal to the cleaver bit. The other type of edge trimming involved semi-circular shaping of the end opposing the cleaver bit. This rounded end is usually associated with the area where the thinned butt was positioned, reinforcing the notion that edge trimming normally (but not always) followed volume/butt thinning. As with butt and bulb removal, round shaping of the end opposite the cleaver bit is also normative, with all except two cleavers showing this exact pattern.

In summary, the shaping of cleavers at Mieso 7 followed a remarkably standardized pattern, which always involved removal of butts and bulbs of percussion on the flake blanks, almost invariably followed by regularization of parallel straight edges transverse to the cleaver bit, and shaping of a rounded edge opposite this bit. Apart from butt/bulb thinning and some marginal retouching of edges, the ventral faces of cleavers are largely

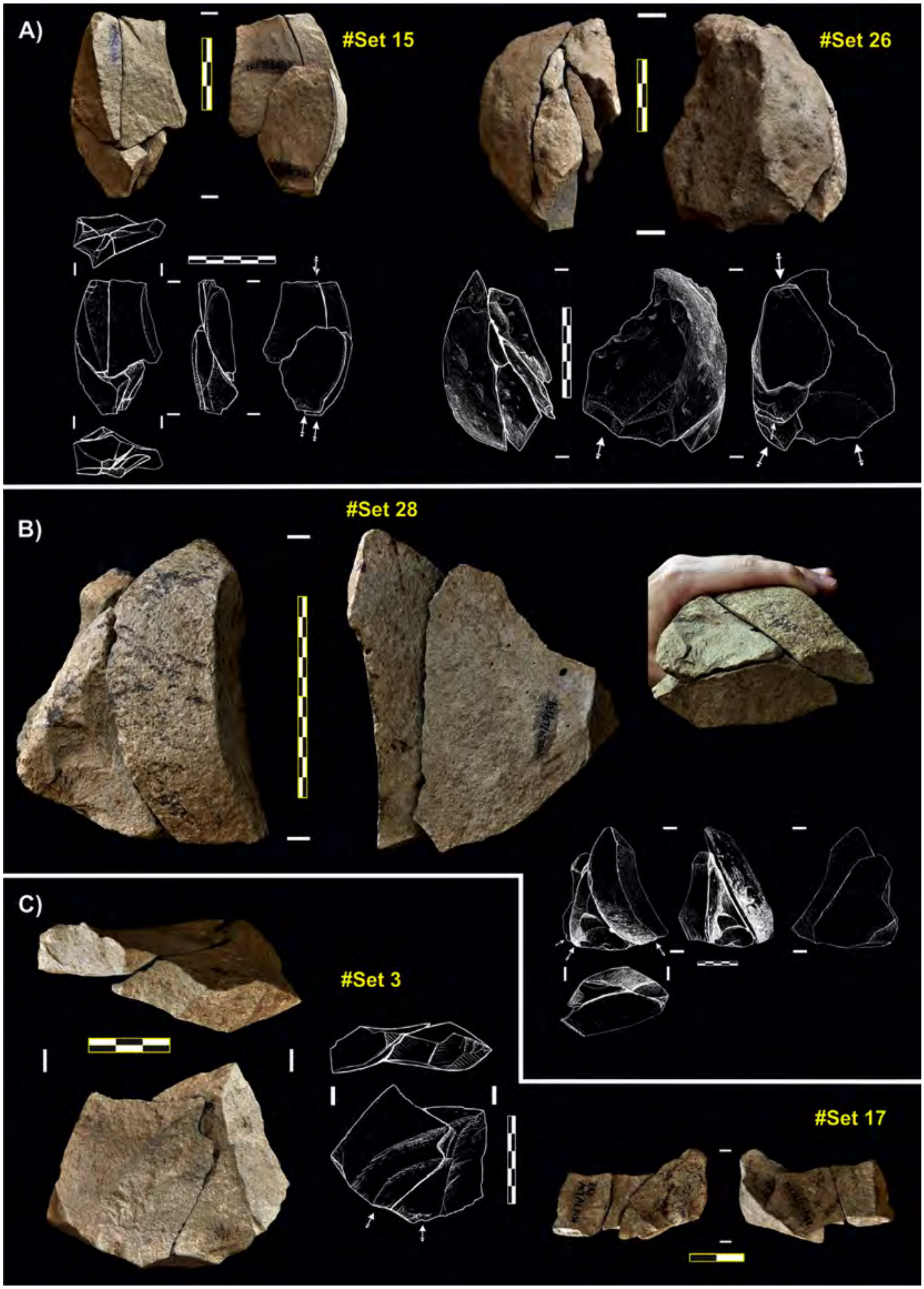

Figure 9. Examples of flake refit sets in Mieso 31. A) Conjoining flake sets indicating bidirectional removals from opposite core platforms. B) Refit series of large flakes (T1L1 and T1L0) suggesting either core preparation for LCT blank production or, more likely, early stages of handaxe roughing-out. C) Refit sets from biface façonnage sequences.

unmodified, and dorsal sides are also not heavily shaped. With the exception of the butt thinning areas, alternating bifacial retouch (i.e., consecutive exchange of flaking surfaces) is rare in favour of alternate shaping (an edge on one of the two flaking surfaces is worked, and then the handaxe is flipped over to shape the other surface).

Form and function of the Mieso handaxes Having described methods of production and façonnage of the Mieso handaxes, their functionality and typology remain to be discussed. A relatively optimal preservation of edges in the Mieso 7 handaxes allows study of use-wear formation (in progress), which will shed light on the significant damage observed in these LCTs. This use-wear is clearly not postdepositional, as it concerns one group of LCTs only (i.e., cleavers), and is concentrated on a specific area of such artefacts (the cleaver bit), while the rest of the edges are fresh and undamaged. Macroscopically, only one of the cleavers shows

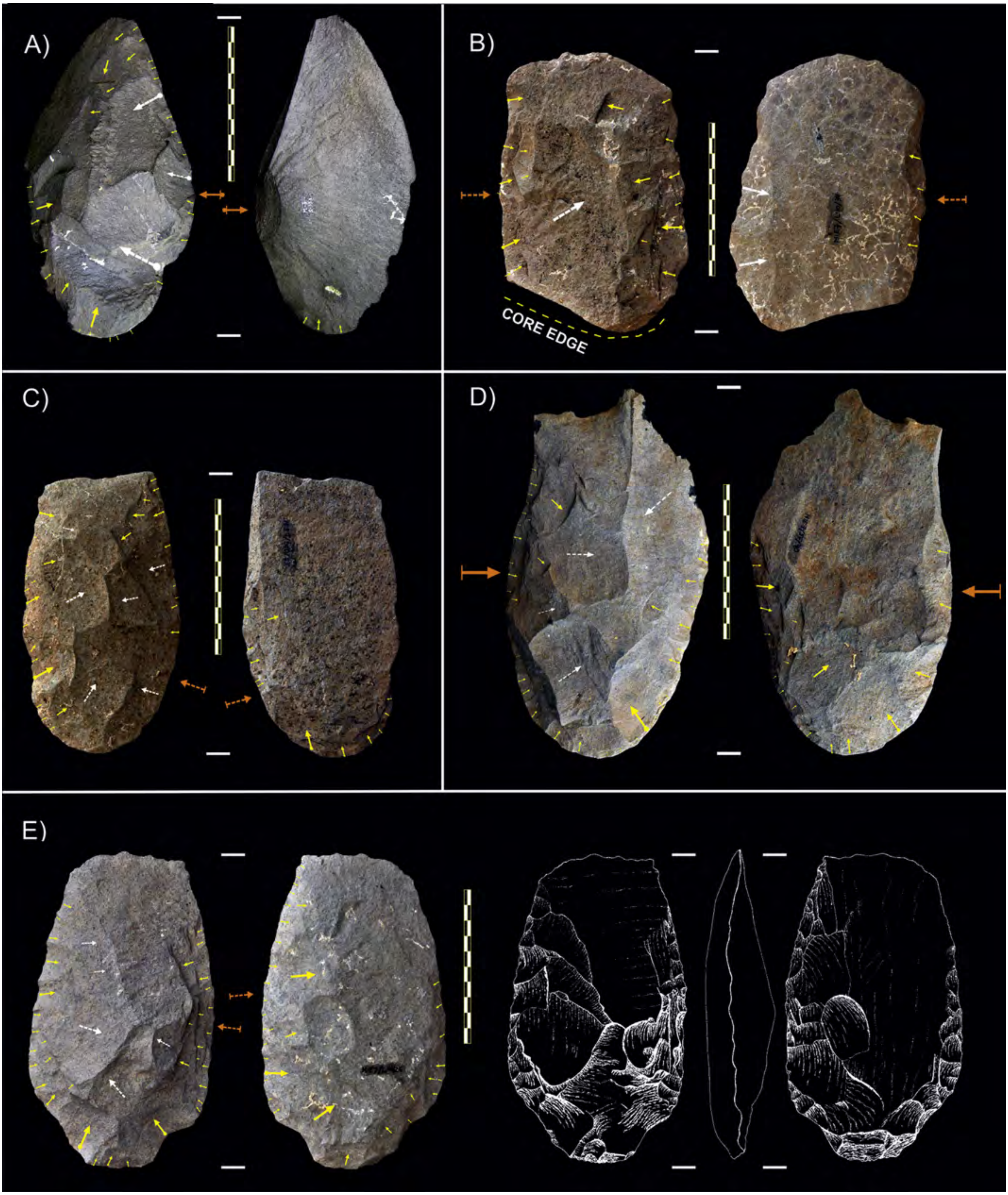

Figure 10. Knife (A) and cleavers (B–E) from Mieso 7. Solid arrows indicate façonnage. Dashed arrows refer to extractions interpreted as belonging to the stage of LCT core debitage. Solid butt arrows indicate observed position of the striking platform. Dashed butt arrows indicate inferred position of the striking platform.

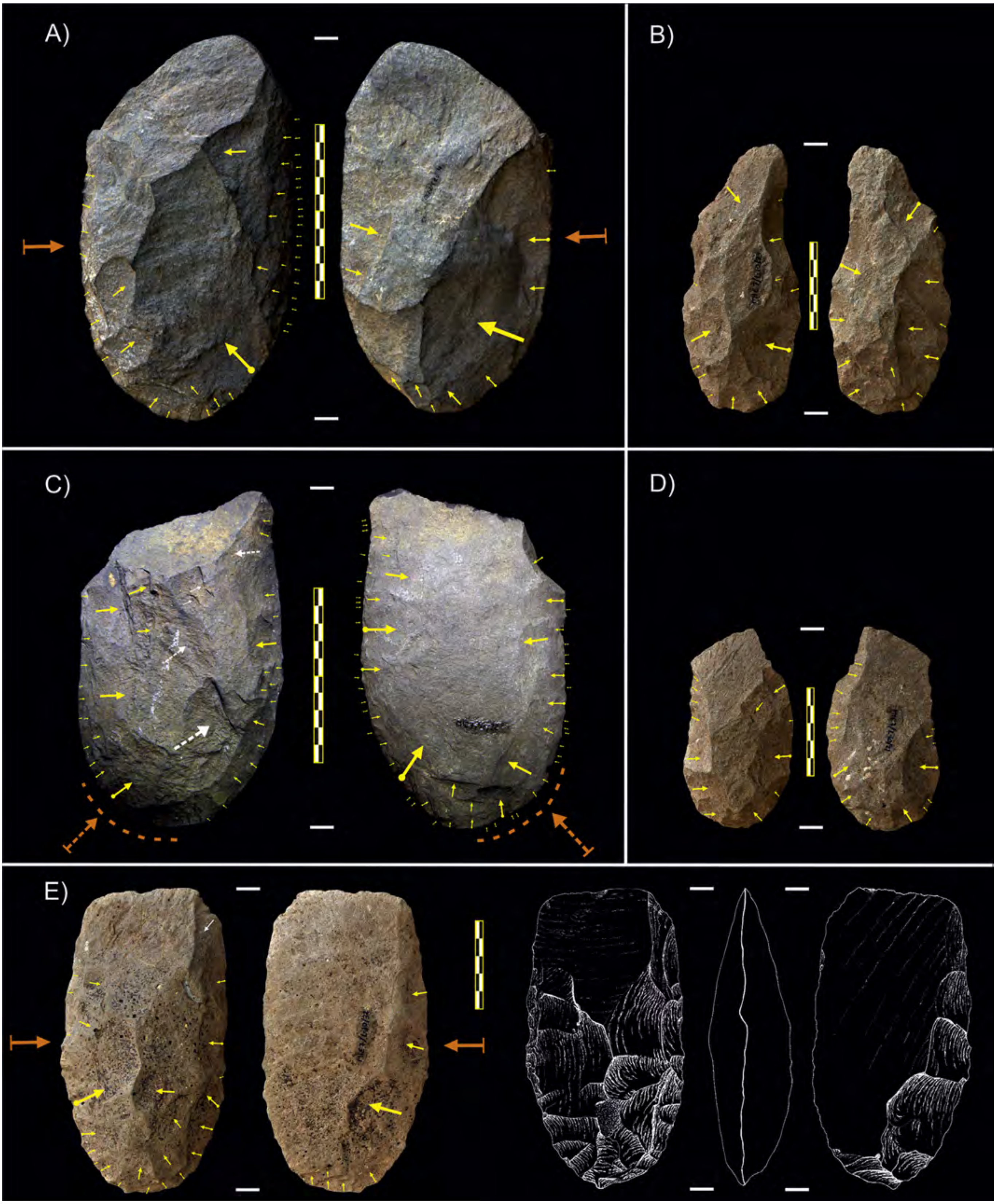

Figure 11. Cleavers (A, C–E) and biface (B) from Mieso 7. See caption of Fig. 10 for arrow keys.

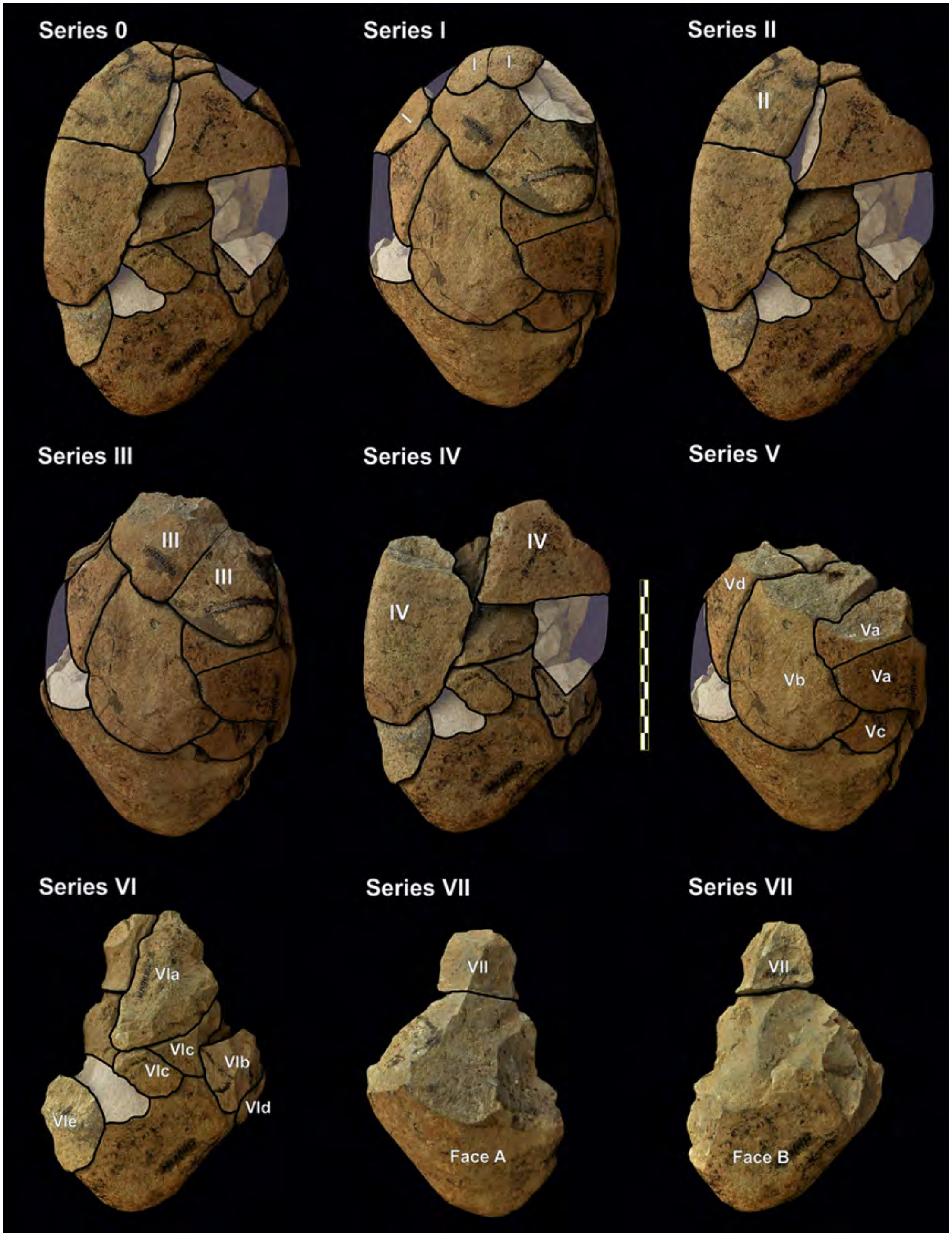

Figure 12. Refit Set #3 from T1L1, an example of handaxe shaping in Mieso 31. A video clip of the handaxe reduction sequence is available in SOM 11. This refit set consists of 20 flakes, plus one core (broken handaxe) and a fractured tip. Refitted artefacts were classified in series, considering as such a set of flakes that involved no flipping of the core (i.e., each series involves a change of flaking platform). Series 0: The original cobble presented a flat surface opposed to a convex surface, had maximum length of 220 mm and weighed over 2 kg, although the original weight of the cobble is unknown as some flakes are missing (transparent colour in the photos). Series I: Reduction starts with Surface B (flatter surface) as flaking platform for clockwise removals of large cortical flakes on Surface A. Series II: The cobble is flipped over, and the area of Surface A cleared of cortex in Series I now becomes the flaking platform for just one flake on Surface B. Series III: The handaxe preform is flipped over once again and the Series II scar is used as a striking platform (Surface B) for flakes on Surface A. Series IV: Repetition of the same gestures as in the previous sequence; Surface A scars from Series III are now used as striking platforms for flake removals on Surface B. Series V: Flaking only on Surface A, which shows a longer sequence of extractions than in the earlier series. Three flakes removed in sequential order (Series Va, Vb and Vc) show no rotation of the flaking axis. The handaxe preform is then rotated counter-clockwise and a Siret flake (two fragments, one of which is missing) is removed from the opposite edge. Series VI: The preform is turned over once again. Reduction on Surface B starts by using the Siret flake scar from Surface A as a striking platform to remove flakes (several of them missing) from the same flaking axis (Series VIa and VIb). Rotation follows clockwise (Series VIc and VId), and then counter-clockwise (Series VIe) over the same edge, accompanied by flaking on the opposite edge. Series VII: small removals (refits missing) over the biface edge indicate beginning of the regularization process, and scars on the tip show attempts to refine the pointed shape of the preform. It is during this stage that a knapping accident occurs (the tip is broken) and the handaxe preform is discarded. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

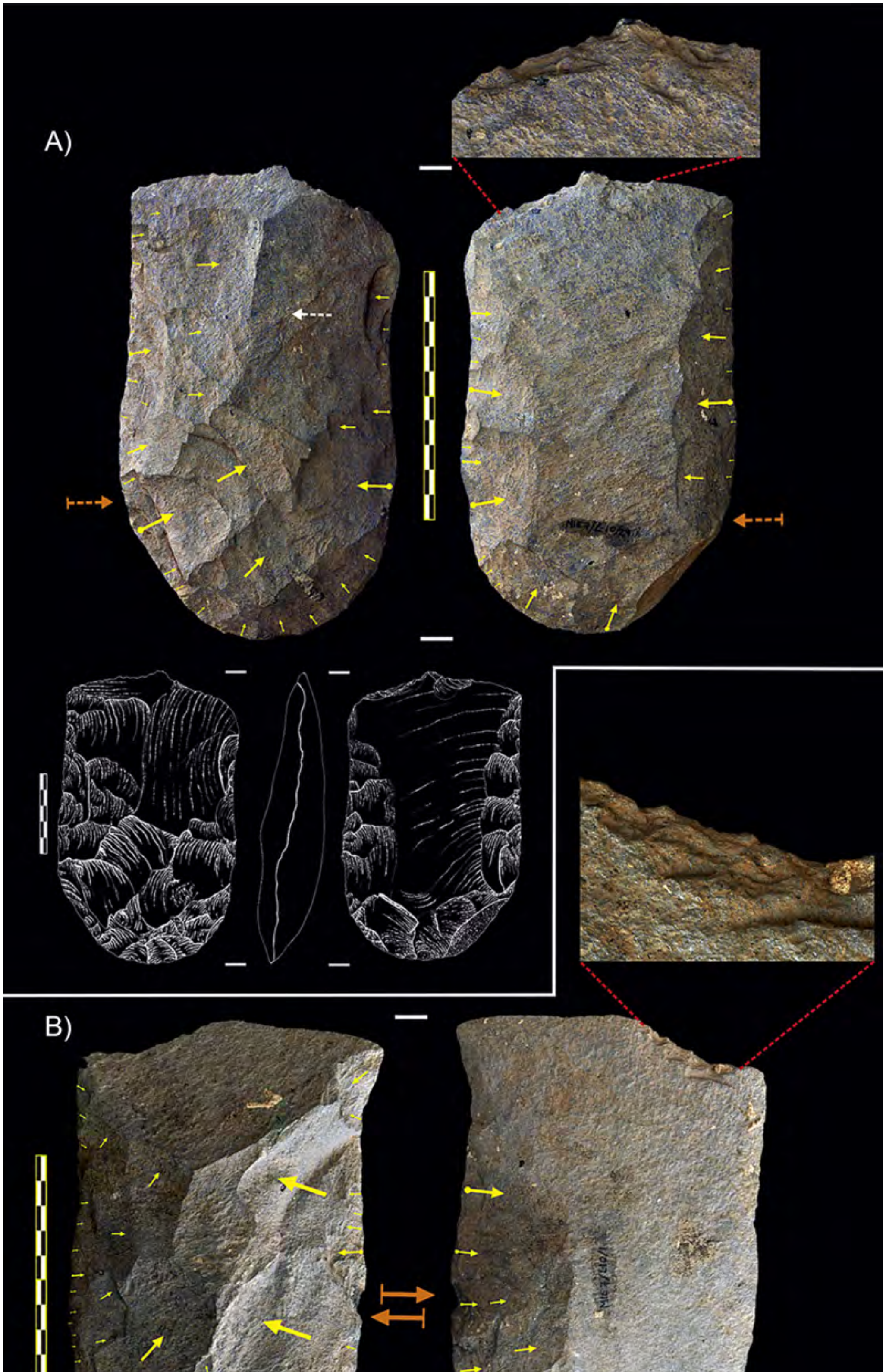

Figure 13. Cleavers from T7L10 at Mieso 7, with close-ups of the edge damage on cleaver bits.

Table 7
Dimensions (mm), weight (g), and Length/Breath (L/B), Thickness/Breath (T/B) and Breath/Length (B/L) of LCT categories (only complete specimens) from the entire Mieso valley (top), and in the two main areas (bottom).

	LCTs from the Mieso valley									
	Bifaces	$n = 60$	Cleavers	$n = 26$	Knives	$n = 11$	Other LCTs	$n = 4$	Total	$n = 101$
	Mean	Std. D.	Mean	Std. D.	Mean	Std. D.	Mean	Std. D.	Mean	Std. D.
Length	123.7	27.6	164.6	32.7	152.6	25.9	129.5	21.4	137.6	33.6
Width	76.6	14.4	102.0	15.3	104.3	16.3	81.5	7.6	86.3	19.1
Thickness	38.9	10.5	38.2	7.7	39.1	8.7	29.0	5.5	38.3	9.6
Weight	413.5	267.7	804.6	343.5	668.6	272.1	394.5	84.0	541.2	331.4
Elongation (L/B)	1.62	0.23	1.62	0.21	1.48	0.25	1.59	0.23	1.60	0.23
T/B	0.51	0.10	0.38	0.07	0.38	0.08	0.36	0.07	0.45	0.11
B/L	0.63	0.09	0.63	0.09	0.69	0.11	0.64	0.08	0.64	0.09

	Area 1 (Mieso River)				Area 7 (Yabdo River)					
	Bifaces	$n = 32$	Cleavers	$n = 18$	Bifaces	$n = 26$	Cleavers	$n = 8$	Total	$n = 84$
	Mean	Std. D.	Mean	Std. D.	Mean	Std. D.	Mean	Std. D.	Mean	Std. D.
Length	123.5	24.4	176.7	32.0	122.4	31.9	137.4	10.9	135.9	35.0
Width	76.1	15.8	102.7	17.5	77.2	13.3	100.3	9.3	84.5	18.9
Thickness	37.5	10.6	40.3	8.1	39.8	10.3	33.3	3.7	38.4	9.6
Weight	402.7	288.8	913.1	356.1	421.8	253.8	560.5	123.0	533.0	345.9
Elongation (L/B)	1.64	0.20	1.72	0.14	1.58	0.24	1.38	0.12	1.61	0.22
T/B	0.49	0.08	0.40	0.07	0.52	0.11	0.33	0.03	0.46	0.10
B/L	0.62	0.08	0.58	0.05	0.65	0.10	0.73	0.07	0.63	0.09

an intact bit, while use-wear damage is documented on the rest, from substantial (e.g., Figs. 10B, 13A and B) to moderate (Figs. 10C and 11E) chipping, localized almost exclusively on the cleavers' transverse edges. This considerable edge damage in nearly all of the cleavers should probably correspond to heavy duty tasks performed at Mieso 7, as yet to be determined (Ollé et al., in progress).

Typologically, the most abundant LCT forms in the Mieso valley are cleavers, bifaces and, to a lesser extent, knives (Table 2, Table 3). Bifaces are on average smaller than any other type of LCTs (mean length = 123 mm), and usually less heavy as well (see details in Table 7). Some bifaces show careful trimming and bilateral and planform symmetries (e.g., SOM 8C, SOM 9), with small cordiform bifaces being common among the better shaped ones. Nonetheless, there is high variation in biface forms, from finely finished (SOM 8C) to roughly shaped ones (Fig. 11B), which attest to the diversity of biface forms. Normality tests of metrics and weight of handaxes (SOM 12) stress the considerable variation of bifaces, which show strong dimensional disparities and do not constitute a homogeneous sample.

Cleavers are consistently larger than bifaces (Table 7, Fig. 14A and B), and their dimensions and weight show normal distribution across the sample (see Shapiro–Wilk tests in SOM 12). In general, the Mieso cleavers form a fairly homogeneous group with remarkably standardized features. Focusing on the Mieso 7 cleavers, 100% of them can be assigned to Tixier's (1956) Type II. From a sample of 10 of these cleavers, 80% show a rounded butt plan, 70% of edge plans are straight (complemented by 30% oblique), and 70% of the overall cleaver shapes are parallel (followed by two convergent and one divergent), according to Clark and Kleindienst's (2001) classification of cleaver forms. All of the cleaver flake blanks are side-struck, with a preference (60%) for the transverse edge to be located to the right of the knapping axis. Total cutting edge ($n = 10$) ranges from 280 to 564 mm, with an average of 440 mm (standard deviation 87.1), and a cutting edge/weight index (mm/g) ranging between 0.27 and 1.17 (mean 0.49, standard deviation 0.25). The cleaver bit ($n = 9$) varies between 38 and 123 mm, averaging 80 mm (standard deviation 29.2).

Overall, the Mieso bifaces and cleavers seem to follow different technological and morphometric patterns, with cleavers normally longer than bifaces and on average twice as heavy (see Table 7). A principal component analysis of metrical attributes (SOM 13) confirms separation of these LCTs into two distinct morphometric groups. With regard to technological features, while all cleavers were made on flakes, blanks for bifaces included both flakes and cobbles. Disparity of blanks might be one of the reasons explaining biface size heterogeneity, but other factors such as variable intensity of shaping processes should also be considered. As a whole, biface forms were simply not as standardized as cleavers, were also consistently smaller (Table 7, Fig. 14A and B), and showed different elongation (Fig. 14C), breadth/length (B/L) (Fig. 14D) and thickness/breadth (T/B) (Fig. 14E) indices.

Interpretation of the Mieso archaeological sites

From the site perspective, the most relevant Acheulean assemblages discovered in the Mieso valley are from Mieso 7 and Mieso 31. These two assemblages show distinctive features that could potentially point to a range of different activities across Acheulean landscapes.

Mieso 31 is mainly characterized by the abundance of refits from debitage and shaping sequences. Within the stratified material alone, 30% of lithics >2 cm conjoin. This percentage is considerably high, for in Acheulean assemblages of similar characteristics refit proportions range between 2.5 and 15.0% (Hallos, 2005). Remarkably well-preserved assemblages such as Unit 4c at Boxgrove-Quarry 1 Area A, where 31.2% of >2 cm artefacts conjoin (Austin et al., 1999), provide a better match to Mieso 31 in terms of refit success. The low-energy context, sharp edge preservation and individual clustering of some refit sets (Fig. 7B) indicate that the Mieso 31 assemblage did not experience severe post-depositional disturbance. Nonetheless, sheet-wash and/or down-slope movement could have removed the smallest fraction, and perhaps have orientated the refit connections (Fig. 6B) in a fashion similar to that observed at Elveden (Ashton et al., 2005).

Tasks undertaken at Mieso 31 were centred on knapping. Small debitage cores are present (Table 3) and indicate that production of small flakes took place on site. However, the focus of activities seems to have been the production of handaxes, even though not a single complete handaxe was recovered from the

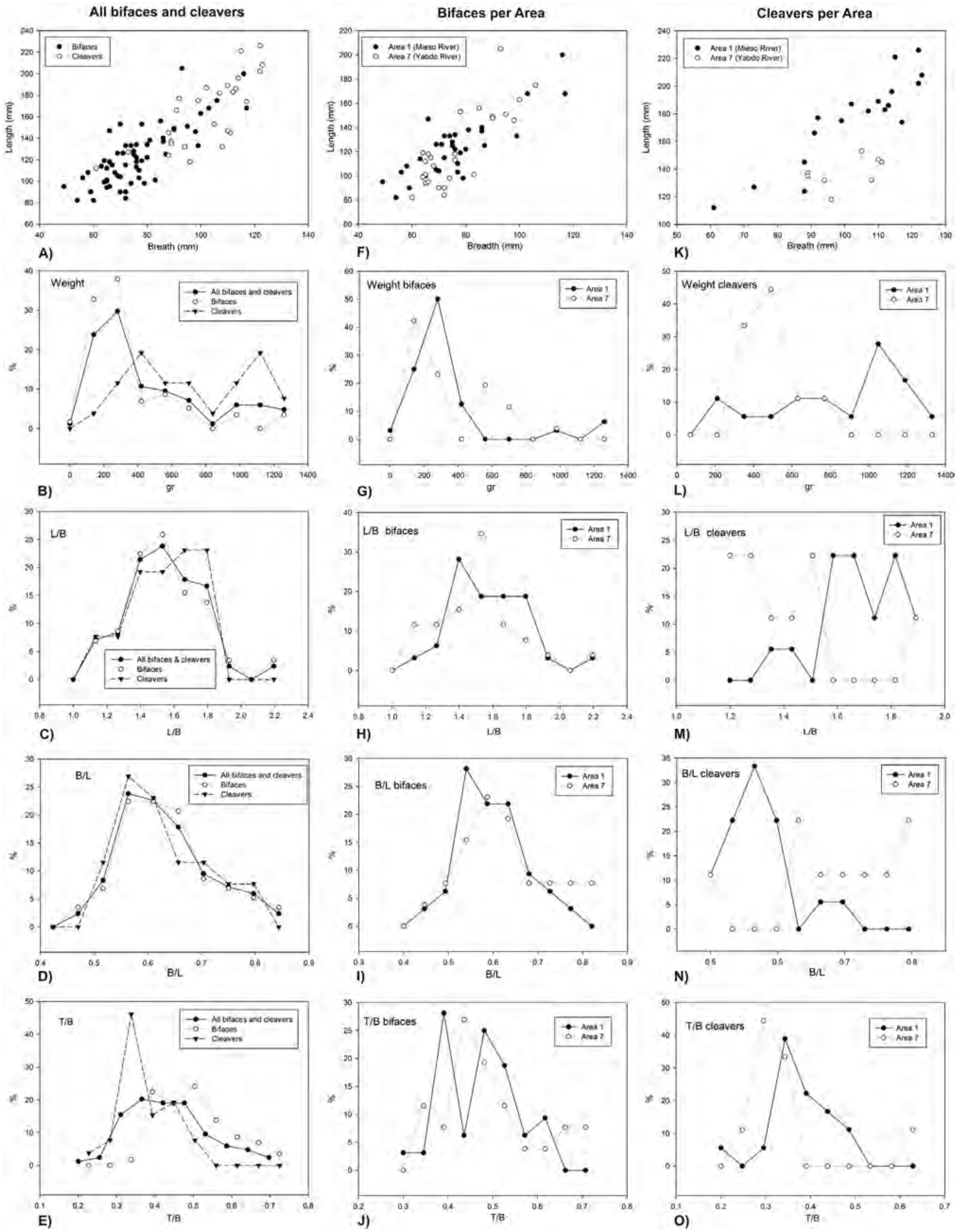

Figure 14. Maximum length (mm), weight (g), and Length/Breath (L/B), Thickness/Breath (T/B) and Breath/Length (B/L) of bifaces and cleavers in the Mieso valley. All data from Table 7 (see also SOM 12 and SOM 13).

stratified deposits. Evidence for handaxe production is given, for instance, by the conjoining set in Fig. 9B. These refitting large flakes are related to handaxe production either as part of the debitage of a LCT core or, more probably, as part of the roughing-out stage of a biface made on a cobble blank. The best example of on-site handaxe shaping in Mieso 31 is provided by the broken biface described in an earlier section (see also Fig. 12), which constitutes one of the few instances in the Acheulean record where an almost complete sequence of biface production can be reconstructed. Preservation of the whole flaking sequence on site is probably due to the fact that the knapper failed to obtain the desired product; otherwise, the finished artefact likely would have been transported elsewhere, as probably occurred in the case of Fig. 9B.

All of the above strongly suggest that the Mieso 31 assemblage corresponds to production activities. Proximity of the Yabdo River, where cobbles identical to that used for the failed handaxe from Fig. 12 are available, provided the required raw materials for bifaces made on cobble blanks. Initial roughing out was done on site and then handaxes exported (Fig. 9B), or abandoned when knapping mistakes occurred (Fig. 12).

The structure of the record at Mieso 31 closely resembles Elveden, a site close to a chert source where a number of handaxe rough-outs were abandoned due to knapping mistakes, but finished bifaces are missing (Ashton et al., 2005). To a minor extent, Mieso 31 shares some features with Boxgrove GTP17-Unit 4b, where flake refit series prove on-site manufacture of bifaces and rough-outs that are nonetheless missing (Pope, 2004), Boxgrove Quarry 2-Area A, where refitting series of handaxe rough-outs are common (Austin et al., 1999), Beeches Pit (Gowlett et al., 2005), and others.

More generally, Mieso 31 aligns with late Acheulean assemblages that yield moderate to high frequencies of refit sequences, for which a number of common features have been proposed (Hallos, 2005). These include, in the first place, the presence of two reduction strategies: one for small core and flake production, and another for handaxe manufacture. Also, dorsal/ventral refit series outnumber fracture sets, but rarely include long conjoining sets. As described by Hallos (2005), most dorsal-ventral refits appear 'orphaned' and are made of two to three flakes, often disassociated from their cores. Complete reduction sequences are normally absent, and when they do appear, they belong to minimally flaked pieces or rough-outs, which are abandoned due to raw material flaws or knapping mistakes. Hallos (2005) highlighted the fact that in these assemblages, with which Mieso 31 closely aligns, refit sets are spatially restricted, reduction sequences are very fragmented, and have a deficit of small cores, finished artefacts and hammerstones, all indicating a high segmentation of the chaîne opératoire. Mieso 31 shares all of these features, providing an excellent example of episodic handaxe manufacture in the Middle Pleistocene: one single event of initial roughing-out, shaping and discard of a handaxe is preserved within an area of barely one square metre (see animation in SOM 11), and co-occurs with an assemblage where short refit series indicate a high fragmentation of the reduction sequence, which almost certainly involved transport of cores and handaxes elsewhere.

Whilst the Mieso 31 assemblage can be summarily interpreted as a manufacturing site where handaxe rough-outs and core flaking were undertaken, Mieso 7 probably represents the other end of the spectrum within the Acheulean chaîne opératoire, that related to extraction activities involving use, rather than production, of stone tools. The structure of the Mieso 7 archaeological assemblage is intriguing. With only 50 lithic artefacts preserved in stratigraphic context (see breakdown of categories in Table 3) within a nearly 60 m^2 trench (Table 1), the density of stone tools in Mieso 7 is very low. Artefacts were originally deposited over a clay paleo-surface (T1L10), and some were subsequently reworked within a gravel channel (T1L12) that may also contain stone tools and fossils transported by water from other locations. The T1L10 artefacts show remarkably well-preserved edges (Figs. 10, 11 and 13), are randomly orientated (Fig. 3B), and were deposited over a low-energy mud surface, so it is reasonable to assert that they are in (or close to) primary position.

Under this premise, the low density of artefacts and idiosyncratic composition of the Mieso 7 lithic assemblage are tantalizing. Small debitage activities are certainly represented (see Table 3), but they sum to less than 1 kg of flaked lithics, as opposed to LCTs, which in total weigh over 7 kg. In fact, some of the small flakes potentially belong to the façonnage process for handaxes, and therefore the relevance of small debitage activities could be even lower. Despite this, LCTs were not fully manufactured on site. Handaxe blanks were clearly obtained somewhere else and, given the paucity of small flakes potentially related to façonnage, it is also likely that most of LCT shaping occurred prior to their transport and final discard at Mieso 7.

Predominance of LCTs in terms of raw material investment is complemented by a strong prevalence of cleavers among handaxes (see Table 3). In addition, the technological and typological features of cleavers discussed in an earlier section suggest that cleaver production was highly standardized, in contrast to bifaces, which were poorly made (e.g., Fig. 11B). One further point that reinforces the relevance of cleavers in the Mieso 7 assemblage is the presence of macroscopically-visible damage on nearly all of them, which is consistently located across the cleaver bit, and suggests engagement of cleavers in heavy-duty activities.

In summary, composition of the assemblage indicates transport of a few high-quality lava, well-shaped, highly standardized cleavers, which in conjunction with a more expedient set of bifaces and small cores and flakes, were employed in activities involving forceful use of the cleavers' transverse edges. Albeit scarce, fossils are present in the small clay pond where the Mieso 7 lithic assemblage was originally deposited, but poor surface preservation does not allow confirmation of a contextual relationship between artefacts and bones. Nevertheless, it is plausible to interpret the Mieso 7 assemblage as a short-lived event where highly standardized cleavers produced elsewhere were used on the spot and then abandoned.

As such, Mieso 7 represents a type of site without very many obvious parallels. Cleaver assemblages are spread all over the Acheulean world (see review by Mourre, 2003), and damage on cleaver bits has been reported (albeit rarely studied systematically) in a number of African assemblages, including Olorgesailie (Isaac, 1966), Ternifine (Balout et al., 1967), Northwest Sahara (Alimen, 1978), and others. Although the predominance of cleavers over bifaces is observed in a number of sites, e.g., Isenya Level VI (Roche et al., 1988), Cave of Hearths Beds 1–3 (McNabb, 2009), such assemblages represent much larger aggregates of handaxes than Mieso 7, and therefore cannot be readily compared. One of the few potentially similar examples is Gesher Benot Ya'aqov (GBY) layers V-5 and V-6, where handaxes are scarce in general and dominated by cleavers (Goren-Inbar and Sharon, 2006). These handaxes are highly standardized and were likely made elsewhere (Goren-Inbar and Sharon, 2006), and are associated with *Dama* remains butchered by the GBY hominins (Rabinovich et al., 2008). Even though the two archaeological assemblages are different in many ways, GBY layers V-5 and V-6 may serve as a parallel to Mieso 7 to understand the formation of low-density cleaver patches manufactured elsewhere and discarded in the locality of use, hence providing further insights in addition to Mieso 31 on the life history of the Mieso valley Acheulean artefacts.

The Mieso valley Acheulean landscape

The Mieso 31 and Mieso 7 sites represent two end members of a same Acheulean system, providing an excellent opportunity to study the segmentation of the chaîne opératoire from quarry to discard. Both assemblages indicate large fragmented reduction sequences in time and space, strengthening the notion that the Middle Pleistocene Acheulean was characterized by highly mobile patterns of artefact transport (Pope, 2004; Hallos, 2005; Goren-Inbar and Sharon, 2006).

Recognition of site function as an element to explain inter-assemblage variability does not necessarily exclude other additional, potentially-differentiating components such as age or geographic/environmental position. For instance, Mieso 31 is stratigraphically lower than Mieso 7 (see Fig. 1B), although it is unlikely to be substantially older, but instead being within a similar timeframe (see discussion in Benito-Calvo et al., submitted for publication). Therefore, it is assumed that functionality, rather than chronology, better explains the differences between the two assemblages in this case.

While the study of environmental proxies is still in progress, geographic constraints can be summarily considered here. Separated from one another by 3 km, both Mieso 31 and Mieso 7 are at similar altitudes (approximately 1370 and 1320 m a.s.l., respectively), and at similar distances (<100 m) from river bed conglomerates. The predominance in Mieso 7 of handaxes on flakes and of handaxes/rough-outs on cobbles in Mieso 31 is therefore not readily explainable by raw material availability. In addition, it should be remembered that LCT core technology is present in Mieso 31 (Fig. 8B), and that the high quality basalts preferentially used for the Mieso 7 cleavers do not necessarily derive from the local conglomerate (in which such finely grained lavas were not documented during our sampling). Thus, functionality again seems to explain inter-assemblage variability better than geographic location.

More broadly, potential geographic differences can also be explored through comparison of handaxes between the two main aggregates of Acheulean materials, i.e., Area 1 in the Mieso River and Area 7 in the Yabdo River. Considering the handaxe sample from Table 2, it is observed that size, and elongation, B/L and T/B indices of bifaces (Fig. 14F–J) and cleavers (Fig. 14K–O), do not differ greatly. This is confirmed by the Levene's test, which indicates geographic homogeneity of the biface sample in all of the indices, and of all the indices but one (T/B) among the cleavers (see values in SOM 12). Therefore, it can be stated that, as far as the most idiosyncratic category of artefacts (i.e., handaxes) is concerned, no significant metrical differences exist between Area 1 and Area 7.

Another common feature of the entire Mieso Acheulean record is the staggeringly low density of stone tools across the valley. The entire Mieso Acheulean collection, including all sites from SOM 1, comprises just around 780 pieces and only weighs just over 118 kg. Interestingly, handaxes are ubiquitous across the surface, and yet densities are always very low. The fact that the area covered by Middle Pleistocene outcrops in Fig. 1 is roughly 10.1 km^2 reinforces the scarcity of Acheulean stone tools across the landscape. There were no artefacts in most test pits, and even in fertile trenches stone tool densities were very low (see Table 1).

This low density of artefacts across the landscape is rarely documented in Acheulean contexts, and contrasts sharply with other <1 million year sequences in East Africa. Any one of the post-Bed II Acheulean sites in Olduvai (Leakey and Roe, 1994), for instance, contains more artefacts in just a single assemblage than the whole of the Mieso sequence. Large handaxe clusters are reported in Kilombe (Gowlett, 1982), Olorgesailie (Isaac, 1977), Middle Awash (Heinzelin et al., 2000), Chilga Kernet (Todd et al., 2002), Isimila (Howell et al., 1962), Kariandusi (Gowlett and Crompton, 1994), and others. Landscape variation of stone tool frequencies is well attested both in East Africa, e.g., Olorgesailie (Potts et al., 1999), and elsewhere (Tuffreau et al., 1997; Lhomme et al., 2004; Pope, 2004; Goren-Inbar and Sharon, 2006), but even so densities are normally higher than those documented in the Mieso valley.

Reasons for the low density of stone tools in Mieso may be varied. For instance, time-averaging factors associated with the formation of large artefact concentrations in other East African assemblages could have had a lower impact in the Mieso valley. Here, sites such as Mieso 31 indicate short-lived episodes that were buried soon after deposition, hence preventing formation of large scale, time-averaged palimpsests. On the other hand, human presence in the Mieso Middle Pleistocene deposits is not restricted to one single layer but is documented throughout the stratigraphy (see Fig. 1B). Therefore, even if dealing with rapid rates of sedimentation (for which, however, there is no evidence), a higher density of artefacts would be expected had occupation dynamics been similar to patterns observed elsewhere.

Leaving time-averaging aside, another explanation for the low artefact density at Mieso potentially could be related to environmental constraints. Although paleoecological analyses of fossils and sediments are still in progress, some observations are already available. For instance, most of the fossil vertebrates are bovids and equids. Hippos, which are ubiquitous in nearby Acheulean sequences such as Middle Awash (Heinzelin et al., 2000), have not yet been documented in Mieso. This absence has been interpreted in the nearby Middle Pleistocene sequence of Asbole as evidence of drier, open landscapes (Alemseged and Geraads, 2000), and confirmed by isotope analysis (Bedaso et al., 2010). Preliminary analysis of sediment features (e.g., calcretes) also indicates a prevalence of dry conditions in the Mieso valley where, as today, ephemeral streams coming down from the highlands would have supplied water seasonally.

In short, preliminary paleoecological observations suggest that the Mieso valley had an open and arid or semiarid landscape during the Middle Pleistocene. Under this premise, it could then be argued that the extremely low density of Acheulean artefacts in the Mieso valley might be related, at least partially, with the discontinuous and brief character of hominin occupation during the deposition of Units I and II. Sedimentation processes would preserve stratified evidence both of artefact (e.g., Mieso 31, Mieso 6B and Mieso 7) and natural, purely paleontological, depositional events (e.g., Mieso 48 Level 2), in a landscape that would only occasionally be visited by hominins. The archaeological sites in the Mieso basin are located only 6 to 9 km north of the entrance to the Ethiopian Plateau (see SOM 3), which would have provided a complementary, wetter environment for hominins in transit between the two settings.

It can then be summarized that the Mieso valley was only rarely visited by Acheulean hominins. Relatively speaking, Mieso is not too different from sites such as Lainyamok, where human presence is attested, but is nonetheless negligible (Potts et al., 1988). This is in itself a relevant point, as it enables comparison of low density sites like Mieso with stratified sequences such as Isimila (Howell et al., 1962), Olorgesailie (Isaac, 1977; Potts et al., 1999), Kalambo Falls (Clark, 2001), Middle Awash (Heinzelin et al., 2000), Olduvai (Leakey and Roe, 1994), Melka Kunture (Chavaillon et al., 1978) and others, where depositional, paleoecological and human agency factors led to the accumulation of highly dense assemblages. In contrast, the Mieso valley Acheulean is characterized by episodic and brief occupations, and excavated assemblages seem to relate to different stages of the Acheulean techno-economic system. Mieso 31, with only 10.3 kg of stone tools in stratigraphic position, is interpreted as a handaxe-manufacturing site, from which shaped artefacts were transported elsewhere. Mieso 7, where density (Table 1) and total weight of stone tools (9 kg) is even lower than in Mieso 31, represents curation, use and discard of highly standardized LCTs that were made elsewhere. As such, these low-density assemblages contribute to a better understanding of Middle Pleistocene Acheulean behaviour, which in Mieso was represented by highly mobile activities that were temporally and geographically segregated.

Mieso in the context of the late Acheulean in East Africa

The end of the Acheulean and the beginning of the Middle Stone Age (MSA) have been the subject of considerable attention in recent times (e.g., Clark, 1999; McBrearty and Brooks, 2000; Tryon and McBrearty, 2002). Focusing on East Africa, there is wide agreement that this transition took place between 300 and 200 ka, when MSA assemblages are reported at Gademotta (Wendorf et al., 1975), Twin Rivers (Barham and Smart, 1996), and the Kapthurin Formation (Deino and McBrearty, 2002). With regards to the dating of the late Acheulean, Clark (2001) estimated an age of 300–200 ka for Kalambo Falls; the late Kapthurin Acheulean is older than 285 ka (Deino and McBrearty, 2002), while available ages for Isimila (albeit outdated and in need of reconsideration) place this sequence at 260 ka +70–20 ka (Howell et al., 1972). Such dates are consistent with the ages for the late Acheulean in the Lower Herto Member (Middle Awash), dated at 260 ± 16 ka (Clark et al., 2003). Handaxes on the surface in the Upper Herto Member are attributed an age of 160–154 ka (White et al., 2003), and have been considered as the latest Acheulean bifaces in Africa (McBrearty, 2003).

Available dates for the Mieso sequence (Benito-Calvo et al., submitted for publication) place the Acheulean sites described in this paper at the end of the late Acheulean. According to $^{40}Ar/^{39}Ar$ results, sites like Mieso 7 would be more recent than 212 ± 0.016 ka (age of the tuff TA over which Mieso 7 is placed), therefore becoming one of the latest examples of Acheulean technology in Africa. If confirmed, this recent age for the Mieso Acheulean poses interesting questions for the disappearance of the Early Stone Age (ESA) in East Africa; Gademotta, only 270 km from Mieso, demonstrates that before 276 ka (Morgan and Renne, 2008; Sahle et al., 2014) MSA technologies were established in the Main Ethiopian Rift. The MSA industries associated with *Homo sapiens* remains are documented in Omo Kibish at 195 ± 5 ka (McDougall et al., 2005), and between 160 and 154 ka in Herto Upper Member (White et al., 2003), thus confirming that MSA technology and anatomically modern humans were widespread across Ethiopia in the 200–150 ka interval.

The Mieso Acheulean assemblages, however, do not show any transitional features. The Levallois technique, which is well documented in final Acheulean/transitional assemblages (Tryon et al., 2005), is not present in the Mieso sites described in this paper. Points and blades, also present in handaxe-bearing sequences such as Kapthurin (e.g., Tryon and McBrearty, 2002) and Upper Herto Member (Clark et al., 2003), are nonetheless absent from the Mieso Acheulean sites. Mieso bifaces are small and show significant morphometric variation, features that have been considered as typical of the African late Acheulean (Clark, 1982). Cleavers are often on prepared blanks and show a high degree of morphometric and technological standardization, very similar to that documented in the Cave of Hearths (McNabb, 2009), for instance. Nonetheless, the Mieso cleavers are not on Levallois flakes as in Kapthurin (Tryon et al., 2005) or Herto (Clark et al., 2003), hence separating Mieso again from other latest handaxe-bearing sequences in the region.

Technological features of the Mieso assemblages thus seem to be at odds with radiometric dates (Benito-Calvo et al., submitted for publication) that place Mieso < 200 ka years ago, for MSA industries were present in Ethiopia from at least 275 ka ago and were well established after 200 ka. Two alternative explanations are available: one is that the actual age of Mieso is older than reported by the first attempt to date the sequence (Benito-Calvo et al., submitted for publication). If that were the case, the technology of Mieso could be placed within the wider context of East African sites such as Isimila (Kleindienst, 1959), Isenya (Roche et al., 1988), and other Middle Pleistocene assemblages. As in Mieso, in these Acheulean toolkits there is co-occurrence of non-prepared small cores with LCT technology, handaxes are normally made on large flake blanks, and highly standardized cleavers are abundant.

The alternative explanation is that the Mieso Acheulean assemblages effectively represent endurance of the Acheulean in the region well after the emergence of the MSA. The possibility that the ESA–MSA transition in East Africa lasted for more than 125 ka has been discussed elsewhere (e.g., McBrearty and Brooks, 2000; McBrearty, 2003), and portrayed as a long and complex process of change, rather than an episodic replacement event (Tryon and McBrearty, 2006), with temporal and geographic overlap of distinct industries (Tryon et al., 2005). In this scenario, the Mieso Acheulean could be aligned with sites such as Kalambo Falls, considered by Clark (2001) to be around 300–200 ka, or the Upper Herto Member at Middle Awash (Clark et al., 2003), dated at 160–154 ka (White et al., 2003). Within this context, Mieso would become one of the areas with the latest evidence of Acheulean technology in Africa.

Based on the existing chronometric evidence (Benito-Calvo et al., submitted for publication), a late age for the Mieso Acheulean is favoured in this paper. Nonetheless, caution must be exerted over interpretation of the available data. Current evidence for very late (<200 ka) Acheulean occurrences in East Africa is meagre, and somewhat circumstantial. The only other example in Ethiopia of radiometrically dated <200 ka Acheulean in the Upper Herto Member (Clark et al., 2003) refers to bifaces that were all surface collected. With this background, and bearing in mind that by 200 ka the MSA was widespread across East Africa, the remarkably late age of the Mieso Acheulean will require further local and regional contextualization.

Conclusions

Most current fieldwork in the Early Stone Age of East Africa is conducted in sedimentary basins that have been known for many decades. In this paper, one of the few newly discovered Pleistocene archaeological sequences in East Africa, the Mieso valley, is presented. The Mieso valley contains fossiliferous and artefact-bearing beds from the Middle and Upper Pleistocene, and includes stratified archaeological assemblages. The geology and chronology of the Mieso valley is discussed elsewhere (Benito-Calvo et al., submitted for publication), while here we have introduced the archaeological sequence, focusing on a description of the Acheulean excavated sites and the study of their lithic assemblages.

The Mieso Acheulean is characterized by varying quantities of handaxes and small cores and flakes across the valleys of the Mieso and Yabdo Rivers. Stone tools are invariably made on lavas, which were readily available from local conglomerates located close to the sites. The low density character of the Acheulean occurrences is one of the most conspicuous features of the Mieso record. Artefacts appear scattered across the valley and rarely form clusters. Even in the denser concentrations (Mieso 7 and Mieso 31), stone tool densities are considerably low, which might reflect brief and episodic human occupation in the area.

The character of lithic assemblages is in agreement with short episodes of site formation. Mieso 31 is interpreted as a production site where handaxes were manufactured and then exported elsewhere. A conjoining set from this site also enables identification of an occurrence rarely available in the Acheulean record, in which the whole manufacturing process of a handaxe is preserved due to a knapping mistake that led to the abandonment of the biface on site. Mieso 7 likely corresponds to the other end of the Acheulean chaîne opératoire; the LCT blanks were obtained offsite, and most of the shaping stage was probably made before they were transported to Mieso 7. Intense damage is observed on cleaver bits, which is clearly associated with use-wear and potentially was produced during heavy duty tasks at Mieso 7. As a whole, the Mieso record provides evidence of high fragmentation of reduction sequences, and supports the notion that the Middle Pleistocene Acheulean was characterized by complex dynamics of transport and discard of artefacts within a highly mobile technological system.

Finally, available dates (Benito-Calvo et al., submitted for publication) suggest that the Mieso assemblages could be among the latest evidence of Acheulean technology in Africa, less than 212 ka ago. In this scenario, Mieso would represent endurance of an archaic technology in a timeframe where anatomically modern humans associated with an MSA technology were widespread across the region. As such, the Mieso sequence has important implications for the disappearance of the Acheulean and the emergence of modern human behaviour in Africa.

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Supplementary Online Material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jhevol.2014.06.008.

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