Archaeology and Context of Hugub, an Important New Late Acheulean Locality in Ethiopia's Northern Rift

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ABSTRACT

It is during the late Acheulean, approximately 600–300 kya, that post- *erectus Homo* becomes more Neanderthal-like in western Eurasia (culminating with the Middle Paleolithic Neanderthals) and progressively more human-like in Africa. In this paper we present the initial report of a new well-dated Late Acheulean assemblage from the Hugub open-air locality (Ethiopia). The Hugub Bed, an excavated 10–20cm archaeological unit, is rich with *in situ* artifacts and paleoenvironmental data. In this vast exposed area, the fauna and depositional context suggest a seasonally inhabited lakeshore environment adjacent to xeric grasslands. The studied lithic assemblage yields numerous, often diminutive broad-tipped ovate and pointed bifaces made on large flakes. These show the earliest evidence of intensive on-site resharpening as well as the earliest use of the plano-convex method. This emergent pattern of tool production, maintenance, and discard is typical for the post-Acheulean industries and has no analogs among earlier Acheulean-making populations of *Homo erectus*. Single crystal $^{40}Ar/^{39}Ar$ dates on tuffs bracket the Hugub Bed between 600 and 500 thousand years ago, making this locality the earliest securely dated Late Acheulean archaeology in Africa.

INTRODUCTION

The view that our species' origination in Africa is related with a behavioral and technological shift from the Late or Final Acheulean (referred to as a terminal phase of the Acheulean techno-complex and Early Stone Age, ESA) to the Middle Stone Age (MSA), occurring at approximately ~300–250 ka, is now commonly held (e.g., d'Errico and Henshilwood 2007; Heshilwood and d'Errico 2011; McBrearty and Brooks 2000; McBrearty and Tryon 2006; Morgan and Renne 2008; Sahle et al. 2014; Shea 2008). The African late Early Pleistocene and Middle Pleistocene Acheulean succession is witnessed most clearly in the rich, well-dated eastern African Rift. Several 'classic' dated sequences are particularly important. These include Olorgesailie in Kenya (Isaac and Isaac 1977), dating from ~1.0 Ma in Member 1 through ~650 ka in Member 11 (Deino and Potts 1990; Potts et al. 1999, 2004; Sikes et al. 1999); Bed IV/ Masek Beds at Olduvai Gorge, Tanzania (Leakey and Roe

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1994), controversially dated either approximately 800–500 ka (Hay 1976) or before the Brunhes/Matuyama boundary at 780 ka (Tamrat et al. 1995); Melka Kunture in the Upper Awash, Ethiopia (Chavaillon et al. 1979; Chavaillon et al. 1987; Chavaillon and Piperno 2004; Gallotti et al. 2010; Morgan et al. 2012; Mussi et al. 2013), which covers the early Middle Pleistocene (Gombore II, ~875–709 ka), Late Acheulean (Garba I), and Final Acheulean/early MSA (Garba III); and, the Kapthurin Formation in Kenya, which spans ~610 ka thru ~285 ka (Deino and McBrearty 2002; Johnson and McBrearty 2010, 2012; Leakey et al. 1969; McBrearty and Brooks 2000; McBrearty and Tryon 2006; Tryon and McBrearty 2002). These four long stratigraphic and cultural sequences comprise much of the basis for interpreting the sub-Saharan African early Middle Pleistocene archaeological record (e.g., Chavaillon and Berthelet 2004; Gallotti et al. 2010; Leakey and Roe 1994; Johnson and McBrearty 2012; Ludwig and Harris 1998; McBrearty 2001; McBrearty and Tryon 2006). More recently discovered archaeological sequences from Middle Awash areas Dakanihylo, Dawaitoli, Bodo, and Herto have relevant *in situ* assemblages ranging in age from ~1.0 Ma (later Early Acheulean) through 160 ka (Final Acheulean/MSA) (Clark et al. 1994, 2003; de Heinzelin et al. 2000; Schick and Clark 2003).

Of the eastern African Middle Pleistocene sequences with particular relevance to the Late Acheulean, the Bouri Formation's Herto Member and the Kapthurin Formation have had the greatest recent impact, showing that the Late Acheulean appears early (>500–400 ka) and persists until ~300–150 ka. In the lower parts of the Herto Member, below the well-known *idaltu*-bearing units, Late Acheulean localities are not yet precisely dated, but tentatively placed between ~400–225 ka (Clark et al. 2003; de Heinzelin et al. 2000; Schick and Clark 2003). In the Kapthurin Formation, Late Acheulean sites are found in sediments broadly bracketed by $^{40}Ar/^{39}Ar$ between ~545–285 ka (Johnson and McBrearty 2012; McBrearty 2001; McBrearty and Tryon 2006). In Africa, the oldest characteristically MSA archaeology is now most securely documented between 300 and 250 ka by single crystal $^{40}Ar/^{39}Ar$ dates of ~285 ka in the Kapthurin Formation (Deino and Potts 1990) and ~280 ka in the Gademotta Formation, Ethiopia (Morgan and Renne 2008). Also, the Omo Kibish Formation (Lower Omo Valley, Ethiopia) provides early MSA archaeology which has roughly the same age as Herto (Shea 2008).

Many of the material culture traditions that develop strongly during the early MSA and indicate the beginnings of behavioral modernity, like Levallois and laminar prepared core technologies and intensive use of ochre and organic materials, are clearly rooted in the Late Acheulean, a period which spans from ~650/600 ka to ~300/250 ka in Africa (see discussion). There is much biological interest in this time period (Arsuaga et al. 2014; Green et al. 2006, 2010; Hublin 2009; Meyer et al. 2014; Mounier et al. 2009; Noonan et al. 2006; Prüfer et al. 2014; Reich et al. 2010; Rightmire 2012), and the Late Acheulean is a period of high significance for understanding both biological and cultural dimensions of the divergence of African and Eurasian post-*erectus* Middle Pleistocene hominids.

However, in Africa, despite a relative abundance of sites documenting the Acheulean-MSA transition, the archaeological record of the beginning of the Late Acheulean is woefully incomplete because of the lack of precisely-dated and rich sites. Post-*erectus* hominids from Bodo have a pooled mean age of 630±30 ka and the weighted mean of single-grain $^{40}Ar/^{39}Ar$ dates of 550±30 ka, suggesting the age between ~600–500 ka (Clark et al. 1994; Millard 2008); however, the associated lithic assemblage is small and contains no large cutting tools (LCTs: bifaces, cleavers). The Kabwe (Broken Hill) cranium from Zambia and the Elandsfontein hominid remains from South Africa may represent a similar post-divergence population in Africa, but the ages of the fossil-bearing strata remain uncertain (Braun et al. 2013; Herries 2011), and the Elandsfontein site appears to represent an occupational palimpsest reworked by later erosion (Klein et al. 2007; McNabb et al. 2004). The sites of GnJh 42 and GnJh 50 in the Kapthurin, bounded by $^{40}Ar/^{39}Ar$ dates to ~550-500 ka, produced a rich lithic assemblage comprising numerous knapping products but lacking formal tools (Johnson and McBrearty 2010, 2012).

The Hugub occupation reported here is the first precisely-dated archaeological context with rich and definable Late Acheulean archaeology, comprising various artifact categories (from knapping debris to LCTs) and suggesting an emergent pattern of biface production, maintenance, and discard that has no analogs among earlier Acheulean-making populations of *Homo erectus*. The site is securely $^{40}Ar/^{39}Ar$ dated to between 600–500 ka ago and is sufficiently rich in artifactual/paleoenvironmental data and vast in the preserved *in situ* artifact-bearing unit to become a benchmark for the study of evolutionary changes in lithic technologies and socio-economic behaviors of hominids that occurred during the period covering the beginning of the Late Acheulean in Sub-Saharan Africa.

THE HUGUB LOCALITY CONTEXT

In the later 1980s, the Paleoanthropological Inventory of Ethiopia found and inventoried many areas of prehistoric significance in the northern segment of the Main Ethiopian Rift, including the Kesem and Kebena watershed areas (WoldeGabriel et al. 1992). Much of this watershed is situated in the Dulecha administrative region, and the Kesem-Kebena-Dulecha rescue area occupies an intermediate geographical position between the main concentrations of paleontological and archaeological localities in this region—Hadar and Middle Awash to the north, and Melka Kunture and Gadeb to the south.

The Kesem-Kebena-Dulecha rescue project operates west of the Quaternary rift axis volcanoes Dofan and Fentale in an area typifying the volcanogenic landscape of the Main Ethiopian Rift, with several major step-faulted blocks following the NE-SW rift axis and gently dropping from the rift escarpment toward the Awash River. A large series of both axis-trending and transverse faults dissect the area's deposits, and dense vegetational cover serves to isolate and locally distribute lithological units. Thus, while numerous tephra and lavas exist, there are relatively few broadly outcropping marker horizons (WoldeGabriel et al. 1992: Figures 2 and 3) in this highly active volcano-tectonic region. A series of K/Ar dates for basaltic lavas and $^{40}Ar/^{39}Ar$ dates for tephra horizons (WoldeGabriel et al. 1992: Tables 2 and 3) date the Kesem-Kebena-Dulecha Quaternary deposits from >3.7 Ma (Pliocene) to the Middle Pleistocene.

In 2007–2009, the Kesem-Kebena-Dulecha project's rescue and salvage mission in the Kesem Reservoir construction and agriculture development area discovered many small sites dispersed across a broad landscape of deeply-incised and vegetation-obscured sediments; thousands of artifacts and fossils ranging in age from the Pliocene to the Neolithic were collected and placed in the National Museum of Ethiopia. While small localities are numerous, the frequency of rich outcrops in the Kesem-Kebena-Dulecha area is low relative to more expansive, better-exposed sediments farther north in the rift, and fossil and artifact localities tend to be dispersed as isolated small concentrations of surface finds.

The Hugub locality reported here is unique in the area for its large exposure of surface and *in situ* fossils and artifacts from a rich, tightly-bounded Acheulean archaeological layer (the Hugub Bed) that broadly outcrops as loosely consolidated sandy carbonate, calcrete, and conglomerate across exposed surfaces. Excavations establish that the Hugub Bed is well-preserved *in situ* over a laterally vast area, and that there is a high potential for excavation of several adjacent ecological and hominid activity zones.

Discovered by the Kesem-Kebena-Dulecha project's rescue and salvage mission in 2009, the Hugub locality is formally designated KK 51 following the nomenclature established by the Paleoanthropology Inventory of Ethiopia, with localities designated by KK (Kesem Kebena) followed by a unique integer. KK 51, referred to informally as Hugub for a nearby Afar village, is situated in a small, fault-bounded valley northwest of the Dofan Volcanic Center. Recent uplift around Dofan has formed a series of NE-SW oriented normal faults down-dropping to the northwest, antithetic to most faults west of the rift axis. Erosional breeching of resistant layers capping an uplifted block southeast of the Hugub locality has resulted in rapid erosion into Middle Pleistocene sediments. Aside from this breech, the fault-bounded Hugub locality basin naturally drains along a gradual 2°–3° northwest dip, and the area of highest artifact concentration occurs where headward erosion from the breech contacts the deflation surface following the unit's dip northwest, exposing many fossils and unweathered artifacts at the drainage divide.

EXCAVATION AND SAMPLING METHODS

In 2011, archaeological material was surface-collected and recovered from two controlled excavations of $4m^2$ (2x2 m) each, a geological step-trench, a $25m^2$ controlled surface collection of all artifacts, and a broad-scale surface collection of at-risk bifaces (Figure 1). A large-scale (200m x 200m) grid was established, and recovered specimens were hand-plotted as an analog backup. The grid was initiated at Excavation 1 (Figures 1 and 2), chosen for the proximity of a dense concentration of artifacts (preserved *in situ* in a hard carbonated level) close to the surface. The archaeological layer was projected into a larger section, and a geology trench was excavated. Excavation 2 was established next to the geology trench, in which the archaeological layer is preserved very well. Two concrete datum points were established, one (main datum) adjacent to the richest concentration of surface material, another approximately 230m north of the main datum. A prism-based total station, a Topcon GTS-105N, was used for 3D coordinate acquisition at the main datum. Aside from 38 surface artifacts salvaged in 2009 with 2m GPS control, all collected material and site information was recorded in 2011 using both 3-dimensional coordinates derived from a total station and hand measurements taken relative to the grid. All excavated *in situ* artifacts were plotted in three dimensions (see Figures 1 and 2: B, C). Specimens recovered from Hugub (KK 51) were indexed following Gilbert and Carlson (2011) protocols. Except for the clearing of sterile overburden in the geological trench, all sediments were excavated in the controlled excavations and the trench with trowels and brushes, then dry-sieved through 5mm wire-cloth mesh. Students from Addis Ababa University assisted in excavation and workers from the nearby Hugub community assisted in screening.

Tuffaceous units potentially useful for geochemical and geochronological analyses were sampled (Figure 3). Root casts and modern roots were carefully avoided. Mineral separation procedures included sieving, water/hydrofluoric acid washing, magnetism, and heavy liquid separation. Samples were irradiated with the Alder Creek sanidine neutron flux monitor (Nomade et al. 2005; Renne et al. 2011) in Al disks at the Cd-lined CLICIT facility in the OSU TRIGA reactor. Samples were degassed using a Synrad CO_2 laser; resulting gas was purified using SAES getters and a Polycold cryocooler. Argon isotopic relative abundances were measured by peak hopping on a Mass Analyzer Products 215-50 mass spectrometer. Backgrounds were measured between every 1–2 analyses; corrections were made via long-term integration of background measurements. Mass discrimination was monitored via air pipettes run between every ca. 4–14 analyses; corrections were made via long-term average and standard deviation of background measurements. Production ratios used for nuclear interference reactions follow Renne et al. (2005). Decay constants and isotopic composition of the standard follow Renne et al. (2011); both these and values computed using Steiger and Jager (1977) and Renne et al. (1998) are provided in Table 1 to facilitate comparison with previously reported data. ^{39}Ar and ^{37}Ar were corrected for decay using decay constants from Stoenner et al. (1965) and Renne and Norman (2001), respectively. Uncertainties reported in the text and figures are provided at the 1σ level and include full analytical and systematic uncertainties; reported values are standard error of the mean (SEM) except where the MSWD >1, in which case uncertainties are SEM * $\sqrt{(MSWD)}$.

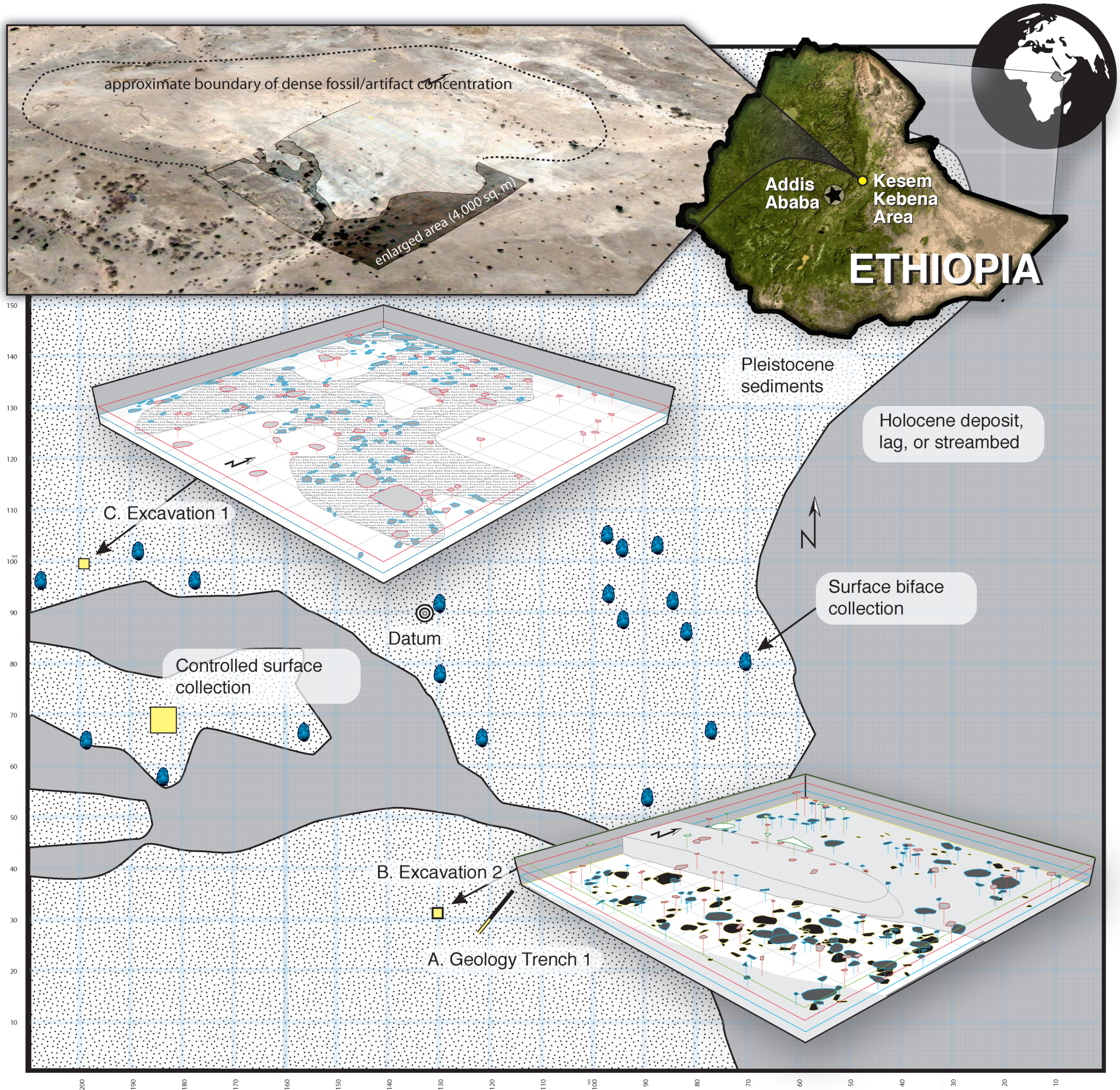

Figure 1. Map of KK 51 (Hugub) locality showing the grid, geology trench (A), Excavation 2 (B), Excavation 3 (C), and surface collection areas.

LOCAL GEOLOGY AND SEDIMENTOLOGY

Stratigraphy illustrated in Figure 3 is described in detail below, from bottom to top.

1. The section base, called the Lower Hugub Tuff is a thick (>1.6m; lower contact was not reached in trenching) blue-gray ash-fall tephra with pumices. The upper part (ca. 15cm) of this unit is somewhat bioturbated and reworked with fine sand channeling, rounded volcaniclastic grains and evidence in $^{40}Ar/^{39}Ar$ data for xenocrystic contamination. A sample of the pumices contains feldspars that are expected to yield a more significant juvenile age population.
2. The Hugub Bed, the Acheulean archaeological layer, is a variably indurated sandy unit with abundant fossils and artifacts that consistently overlies the Lower Hugub Tuff. This unit is the focus of excavation and analysis, and it is described in more detail in following sections.
3. Capping the Hugub Bed is a heavily bioturbated, loose to slightly consolidated blue-gray tephra, the Upper Hugub Tuff, with volcanic mineral

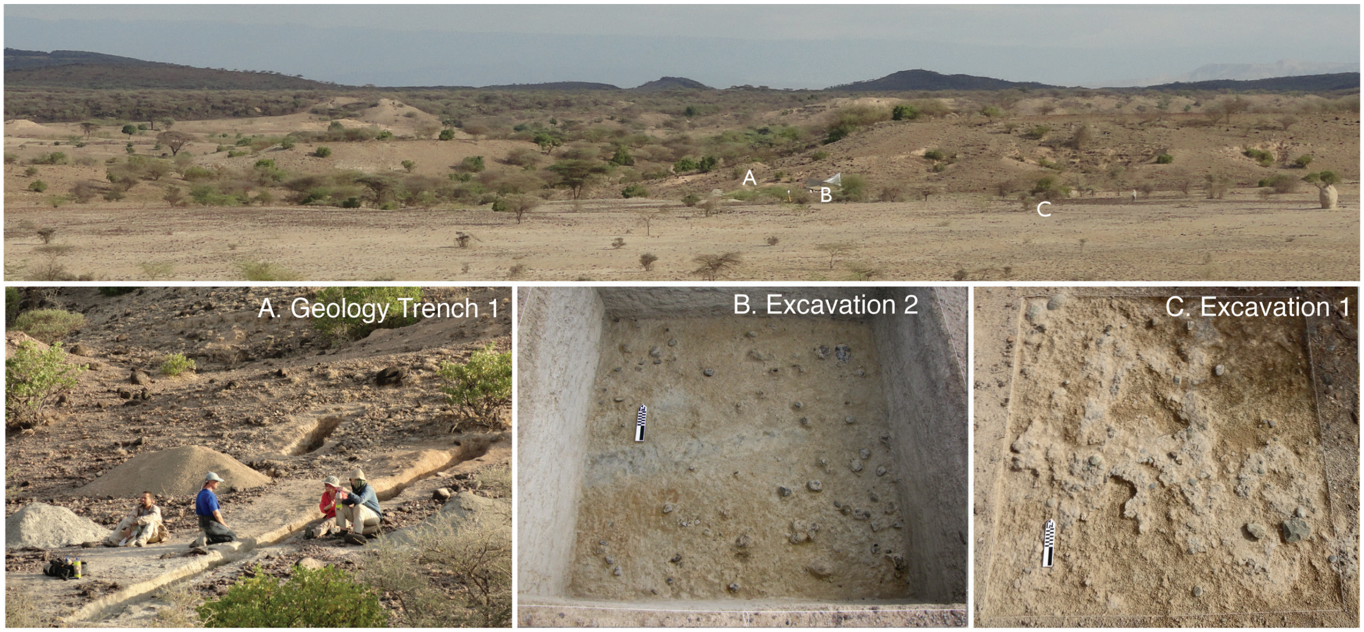

Figure 2. Photos of Hugub locality, view in top is to the southeast. Lower row shows the geology trench (A), Excavation 2 (B), and Excavation 1 (C).

grains. The Upper Hugub Tuff varies greatly in thickness and purity. At Geology Trench 1 (13m east from Excavation 2), it is thin (<20cm) and almost completely reworked; at Excavation 2, it is thick (ca. 50cm) and heavily bioturbated.

4. Just above the Upper Hugub Tuff is a thick (~1.8m) brown silty-sand with rounded mineral grains that grades up to brown silty clay.
5. The Nuru Tuff, named after Nuru Mohammed, Dulecha District Administrator and respected community leader, overlies the silty sand, and varies in thickness and purity. At Geology Trench 1 (see Figure 1) it is thin (8cm) and reworked; at a stratigraphically-correlated outcrop approximately 550m away it is blue-gray, glassy, and ca. 2m thick.
6. Brown silty-clays (2.5m thick) overlie the Nuru Tuff, interrupted by a 20cm basaltic tephra in some sections. This unit is not readily identifiable as tephra in samples but contains basaltic glass and basaltic fragments in a silty matrix.
7. Above the silty clay,s the depositional environment changes considerably, with a silty-sand unit (0.6m thick, variably present) followed by a laterally consistent cross-bedded pebble sandstone unit (0.5–2m thick). The sandstone unit contains grain sizes ranging from pebbles to silts and has conspicuous cross-bedding and laterally variable carbonate cement.
8. A reddish-brown silty sand, followed by a carbonate-cemented sandstone with rounded volcanic minerals and lithic fragments.
9. A thick (>2.4m) brown silt unit with pumices in its basal 2cm and large (5–20cm) carbonate nodules in its upper 1m.
10. Pebble and cobble lag deposit cap the section.

PALEONTOLOGY AND PALEOENVIRONMENT

The Hugub Bed ranges in thickness from ca. 10 to 20cm in excavated areas, and it appears thicker in areas north and south of the main surface concentration. In exposed areas, the Hugub Bed consists of poorly sorted silts and coarse or fine sands at various stages of calcareous cementation. As mentioned, abundant fossils and artifacts have variable preservation, ranging from being unabraded to presenting considerable mechanical weathering. Some retain calcareous matrix and fresh, unweathered edges. Lightly to heavily mechanically or chemically weathered pumice and obsidian pebbles are abundant in all excavation horizons of the Hugub Bed. There is abundant calcrete/calcareous silt or tephra matrix in some areas, and no calcification in others, and a few weathered basaltic cobbles. Excavation 2 has a channel-like feature (probably, representing a hippo track) filled with slightly coarser material and more abundant lithics, but no evidence of cyclothemic deposition or graded textures. Exposure of lateral variants of the Hugub Bed are more pumiceous and carbonate-rich to the north and expose larger (>20cm diameter) river cobbles to the west. Many of these river cobbles are surrounded by a thick calcareous crust.

All identifiable vertebrate teeth were collected, as were most identifiable postcrania. The fauna has not, at the time of this publication, been cleaned or analyzed in detail, but a conservative faunal list has been assembled.

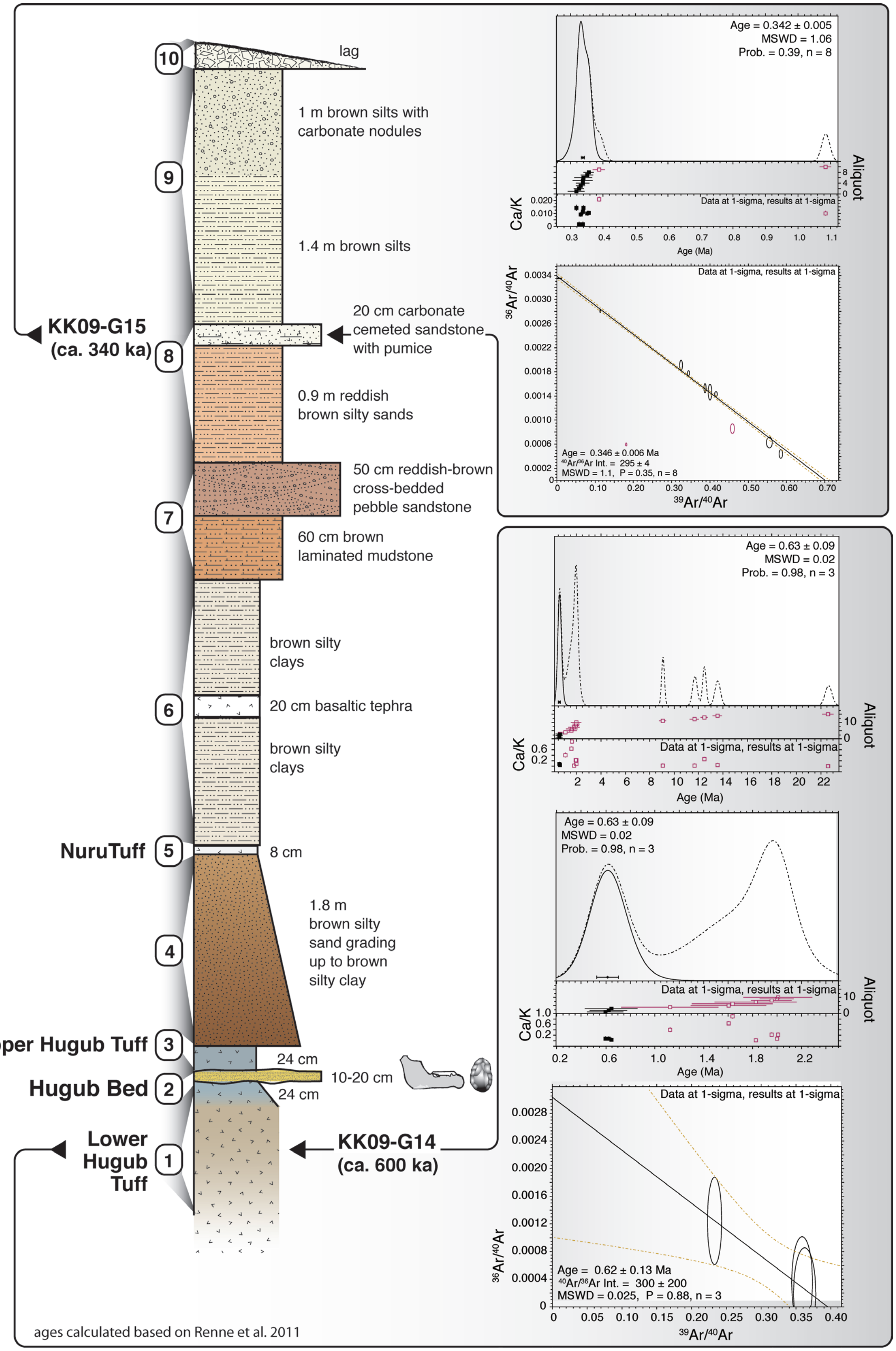

Figure 3. Composite section including the stratigraphy from within a geological trench and a deep erosional exposure of original outcrop adjacent to collection area. The detail in the lower part of the section (below the Nuru Tuff) is largely from the geological trench, while overlying sections are from the erosional exposure area. These two areas have been correlated by field relationships. Also shown are age probability and inverse isochron figures for the Lower Hugub Tuff and KK09-G15. Apparent xenocrysts are shown in purple.

TABLE 1. FULL Ar ISOTOPIC DATA, INCLUDING RELATIVE ABUNDANCES FOR ALL MEASURED ISOTOPES CORRECTED FOR BACKGROUNDS, DISCRIMINATION, AND DECAY (ages calculated using two sets of decay constants and standard ages, and ratios required for isochron construction).

		Relative Abundances													
Run ID	Sample	^{40}Ar	± ^{40}Ar (1σ)	^{39}Ar	± ^{39}Ar (1σ)	^{38}Ar	± ^{38}Ar (1σ)	^{37}Ar	± ^{37}Ar (1σ)	^{36}Ar	± ^{36}Ar (1σ)	^{40}Ar*/^{39}Ar	±^{40}Ar*/^{39}Ar (1σ)	%^{40}Ar*	±%^{40}Ar* (1σ)
36266-01	ACS	3.92389	0.004758	0.5345825	0.0008422	0.0070316	0.0000399	0.0024977	0.0000295	0.0042607	0.0000361	4.959286	0.035498	67.58833	0.3127635
36266-02	ACS	4.06691	0.0057479	0.6241416	0.0010019	0.007952	0.0000532	0.0027354	0.0000405	0.0032859	0.000038	4.942894	0.0301811	75.88573	0.3325192
36266-03	ACS	2.46191	0.004758	0.462804	0.000922	0.0055899	0.0000437	0.0021302	0.0000313	0.0004968	0.0000234	4.997833	0.0240154	93.98923	0.3914545
36266-04	ACS	2.80185	0.0032845	0.4656501	0.000912	0.0057783	0.0000493	0.0020586	0.0000295	0.0016473	0.0000287	4.959556	0.0278202	82.45617	0.3426654
36271-01	G-15	0.76482	0.0018542	0.0870004	0.0002866	0.0014893	0.0000309	0.0002952	0.0000191	0.0021479	0.0000193	1.419478	0.0899691	16.15254	0.7939816
36271-02	G-15	0.22893	0.0009223	0.0744877	0.0004938	0.0009517	0.0000283	0.000253	0.0000191	0.0004355	0.0000209	1.32717	0.0864284	43.20435	2.759345
36271-03	G-15	0.25779	0.000953	0.0997783	0.0005236	0.0013021	0.0000234	0.0000361	0.0000165	0.0003926	0.0000209	1.407901	0.0646313	54.52275	2.455808
36271-04	G-15	0.29967	0.0009593	0.1247822	0.0006031	0.0015883	0.0000292	0.0002724	0.0000184	0.0004266	0.0000148	1.380033	0.0382329	57.49676	1.521754
36271-05	G-15	0.37176	0.0016728	0.1281644	0.0003061	0.0016455	0.0000309	0.0000492	0.0000172	0.0006597	0.0000157	1.362749	0.0414663	47.00501	1.360621
36271-06	G-15	0.24707	0.0015837	0.1445089	0.0004541	0.0016514	0.0000309	0.0003556	0.0000184	0.0001074	0.0000185	1.487143	0.0403864	87.04019	2.399016
36271-07	G-15	0.71946	0.0012443	0.1311829	0.0003454	0.0017076	0.0000292	0.0003153	0.0000198	0.0004244	0.0000209	4.516872	0.0523009	82.3914	0.8957455
36271-08	G-15	0.14146	0.00141	0.0786207	0.0004442	0.0008884	0.00003	0.0001868	0.0000184	0.0000878	0.0000138	1.465011	0.0565636	81.47837	3.201928
36271-09	G-15	0.14251	0.0009722	0.0570861	0.000375	0.0007291	0.000025	0.0001544	0.0000184	0.0002078	0.0000193	1.408881	0.1032788	56.46587	4.11804
36271-10	G-15	0.21918	0.00141	0.1007791	0.0005434	0.0012577	0.0000309	0.0005055	0.0000205	0.0001878	0.0000185	1.618261	0.057815	74.45305	2.651505
36272-01	G-14	0.02474	0.0009344	0.0088804	0.0001014	0.0001318	0.0000192	0.0001556	0.0000184	8.86E-06	0.0000164	2.490401	0.5611497	89.42106	20.40169
36272-02	G-14	0.0269	0.000953	0.0062723	0.0001346	0.0000971	0.0000198	0.0000385	0.0000166	0.0000334	0.000017	2.698014	0.8283779	62.94308	19.40068
36272-03	G-14	0.05201	0.0009405	0.0034522	0.000077	0.000092	0.0000192	0.0005044	0.0000213	0.0000971	0.0000134	6.694777	1.206283	44.43784	7.967757
36272-04	G-14	0.01956	0.0007724	0.0070979	0.0000795	0.0000733	0.0000186	0.0001065	0.0000184	3.41E-06	0.0000134	2.613251	0.574504	94.88564	21.16492
36272-05	G-14	2.12691	0.0032845	0.0146469	0.0001436	0.0005357	0.0000335	-0.0000113	0.0000171	0.0024714	0.0000209	94.80726	1.198574	65.30722	0.3484393
36272-06	G-14	0.13374	0.0007952	0.003382	0.0000735	0.0001189	0.0000178	0.0007103	0.0000228	0.0003711	0.0000141	6.822979	1.304977	17.25396	3.216272
36272-07	G-14	0.03911	0.0008717	0.0043574	0.0000782	0.0000811	0.0000179	0.0002171	0.0000178	8.92E-06	0.0000156	8.371154	1.101872	93.28463	12.33279
36272-08	G-14	0.47448	0.0020392	0.0093398	0.0000842	0.0001397	0.0000212	0.0000267	0.0000178	0.0000608	0.0000193	48.84418	0.802685	96.17397	1.355973
36272-09	G-14	0.09746	0.0009986	0.0027779	0.0000795	0.0000809	0.0000176	0.0002593	0.0000184	0.0002829	0.0000141	4.692264	1.586645	13.37658	4.459552
36272-10	G-14	0.77032	0.0022267	0.0136069	0.0000982	0.0002337	0.0000212	0.0008038	0.0000228	0.0002059	0.0000193	52.09313	0.6101794	92.03627	0.8473087
36272-11	G-14	0.06674	0.0008416	0.006812	0.0000959	0.0000856	0.0000186	0.0003378	0.0000198	0.0000377	0.0000136	8.151006	0.6193055	83.22451	6.290376
36272-12	G-14	0.09518	0.0008368	0.0098348	0.0000921	0.0001129	0.0000192	0.0001781	0.0000166	0.0000443	0.0000164	8.332225	0.5110036	86.12369	5.265083
36272-13	G-14	0.03338	0.0007753	0.0037565	0.0000815	0.0000555	0.0000175	0.0000167	0.0000166	0.000016	0.0000164	7.613108	1.327898	85.70217	14.95736
36272-14	G-14	1.10374	0.0014961	0.0120585	0.0001258	0.0004133	0.0000234	0.0000766	0.0000178	0.0014083	0.000026	56.64725	0.9623532	61.90524	0.7217316
36272-15	G-14	0.53102	0.001763	0.0137817	0.0000906	0.0001812	0.0000205	5.35E-06	0.0000166	0.0000284	0.0000178	37.90444	0.4858689	98.40343	1.105258

	Renne et al. (1998), Steiger and Jager (1977):			**Renne et al. (2010, 2011):**		**Isochron**						
Run ID	Age (Ma)	± Age w/o J (1σ)	± w/ J (1σ)	**Age (Ma)**	**± (1σ), full systematic**	^{36}Ar/^{40}Ar	±% ^{36}Ar/^{40}Ar (1σ)	^{39}Ar/^{40}Ar	±% ^{39}Ar/^{40}Ar (1σ)	±% ^{39}Ar/^{36}Ar (1σ)	ρ ^{40}Ar/^{39}Ar	ρ ^{36}Ar/^{39}Ar
36266-01	1.191343	0.0085247	0.0101866	**1.203**	**0.009**	0.0010856	1.128106	0.1362864	0.2746186	1.023314	0.6090667	0.533925
36266-02	1.187406	0.0072479	0.0091336	**1.199**	**0.007**	0.0008077	1.377513	0.1535249	0.286412	1.291297	0.7414951	0.4418632
36266-03	1.200599	0.0057672	0.0080524	**1.212**	**0.006**	0.0002013	4.778169	0.18806	0.3393836	4.753602	0.9785923	0.1302051
36266-04	1.191408	0.0066809	0.0087025	**1.203**	**0.007**	0.0005876	1.894408	0.1662571	0.2976698	1.838077	0.8654298	0.3180045
36271-01	0.3410737	0.0216158	0.0216747	**0.344**	**0.022**	0.0028084	1.186158	0.1137921	0.458498	1.10559	0.6027946	0.5131532
36271-02	0.3188959	0.0207654	0.020819	**0.322**	**0.021**	0.0019023	4.866744	0.3255373	0.8174017	4.87208	0.9678316	0.1242776
36271-03	0.3382923	0.0155282	0.0156088	**0.342**	**0.016**	0.0015232	5.379972	0.3872627	0.6845108	5.371335	0.9770505	0.1161874
36271-04	0.3315967	0.0091858	0.0093161	**0.335**	**0.009**	0.0014236	3.560077	0.4166333	0.6231265	3.545974	0.9507037	0.1718469
36271-05	0.3274441	0.0099627	0.01008	**0.331**	**0.010**	0.001775	2.533442	0.3449279	0.5563927	2.454865	0.9069609	0.2879405
36271-06	0.3573308	0.0097031	0.0098462	**0.361**	**0.010**	0.0004341	17.29122	0.5852845	0.7588623	17.2747	0.9975983	0.0489246
36271-07	1.085096	0.0125606	0.0135487	**1.096**	**0.013**	0.0005898	4.976378	0.1824081	0.3719667	4.956746	0.979812	0.1219688
36271-08	0.3520135	0.0135898	0.0136894	**0.355**	**0.014**	0.0006204	15.8211	0.556162	1.195466	15.79068	0.9954226	0.0683231
36271-09	0.3385276	0.0248136	0.0248642	**0.341**	**0.025**	0.0014581	9.333373	0.4007854	0.9915324	9.318376	0.9894141	0.0845539
36271-10	0.3888325	0.0138902	0.014009	**0.393**	**0.014**	0.0008557	9.920673	0.4600805	0.8834988	9.901873	0.9916582	0.0800058
36272-01	0.5983538	0.1348018	0.1348309	**0.602**	**0.139**	0.0003543	186.6255	0.3590629	4.075949	186.5878	0.9997491	0.0202362
36272-02	0.6482268	0.198991	0.1990141	**0.648**	**0.205**	0.0012412	51.19682	0.2332941	4.272765	51.11087	0.9963491	0.0623829
36272-03	1.608065	0.2896167	0.2897145	**1.625**	**0.291**	0.001861	14.01014	0.0663769	2.95698	14.06359	0.9756421	0.0935341
36272-04	0.6278651	0.1380075	0.1380388	**0.636**	**0.140**	0.0001713	399.429	0.3630942	4.241216	399.4095	0.9999409	0.009926
36272-05	22.64021	0.284438	0.3033199	**22.855**	**0.288**	0.001162	1.130178	0.0068884	1.033267	1.42289	0.435687	0.3772481
36272-06	1.638845	0.3133068	0.3134007	**1.665**	**0.319**	0.0027715	3.931716	0.025288	2.317175	4.45019	0.82987	0.0968627
36272-07	2.010502	0.2644898	0.264657	**2.032**	**0.263**	0.0002249	177.7648	0.1114358	2.951892	177.7588	0.9998485	0.0106742
36272-08	11.69951	0.1916442	0.1992713	**11.815**	**0.196**	0.0001281	31.71037	0.01969	1.040581	31.71698	0.9990347	0.0174596
36272-09	1.127217	0.3810393	0.3810758	**1.143**	**0.380**	0.0029014	5.161943	0.0285077	3.122791	5.821422	0.8307875	0.1006741
36272-10	12.47504	0.1456203	0.1568239	**12.601**	**0.146**	0.0002667	9.41392	0.0176676	0.8183692	9.425699	0.9913887	0.057007
36272-11	1.957657	0.1486604	0.1489424	**1.981**	**0.152**	0.0005619	36.17866	0.1021034	1.951784	36.1807	0.9982168	0.0290437
36272-12	2.001157	0.1226603	0.1230172	**2.023**	**0.121**	0.0004648	36.99243	0.1033622	1.33352	36.99053	0.9990364	0.0232872
36272-13	1.828534	0.3187763	0.3188911	**1.846**	**0.319**	0.0004789	102.347	0.1125719	3.274405	102.3418	0.9994472	0.0181663
36272-14	13.56156	0.2295291	0.2380874	**13.692**	**0.230**	0.0012759	1.99108	0.0109282	1.093118	2.202418	0.7720215	0.2072938
36272-15	9.085714	0.1161709	0.1236787	**9.176**	**0.118**	0.0000535	62.55582	0.0259609	0.7776597	62.55662	0.999813	0.0091449

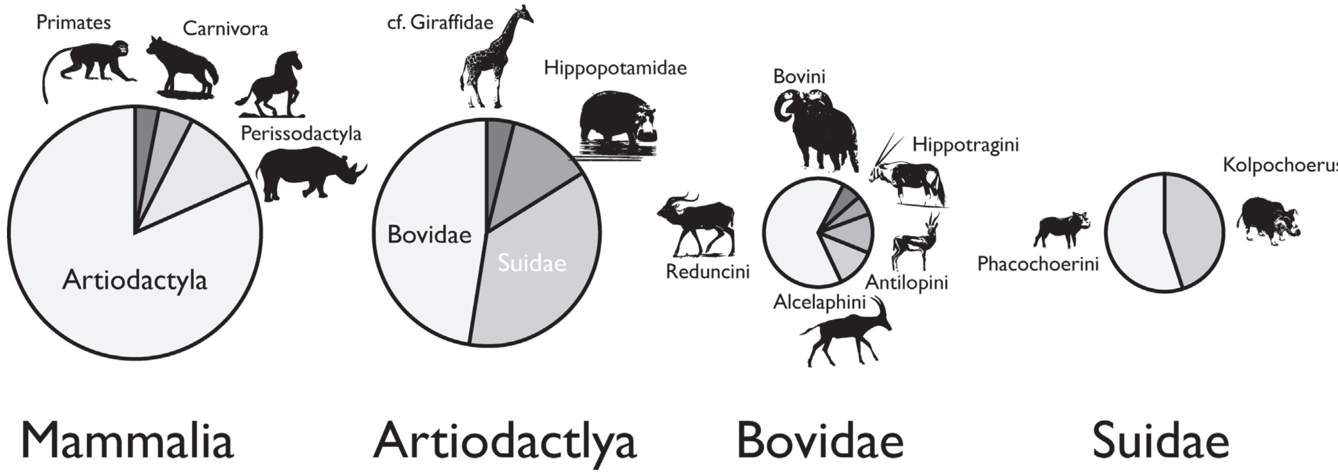

Figure 4. Faunal composition based on identified mammal specimens from the 2009 and 2011 surface collection over entire area of Hugub Bed exposure.

Terrestrial mammals dominate the fauna (Figure 4), with a large number of artiodactyls and several *Equus*, *Theropithecus*, and Colobinae specimens. Suids and bovids comprise the bulk of the artiodactyls, with fewer cf. giraffids and *Hippopotamus*. Suids are represented by similar numbers of cf. *Metridiochoerus modestus* and *Kolpochoerus majus*. Fossilization-prone hydrophilic reduncines, *Kobus* cf. *ellipsiprymnus* and *Kobus kob*, account for approximately 60% of the bovids, as is common in Pleistocene riverine/floodplain depositional environments in eastern Africa. *Kobus ellipsiprymnus* is present in the modern Awash gallery, but never in the more arid badlands and brushlands that currently prevail in the Ethiopian Rift adjacent to the Awash. Well-known to occur in riverine habitats spanning multiple biomes of sub-Saharan Africa, bovines are similarly vague indicators of paleoenvironment. Perhaps more meaningful are a significant number of dry grassland grazers, Hippotragini and Alcelaphini, and open country dwellers, Antilopini. Other mammals include *Crocuta*, the spotted hyaena, and *Hippopotamus*. *Hippopotamus*, crocodiles and siluriformes (catfish) indicate at least seasonal presence of open water, and the presence of both dedicated terrestrial and wholly aquatic fauna at Hugub suggest fluctuating lacustrine conditions. The Hugub assemblage lacks *Melanoides tuberculata* and other common benthic molluscs, a notable condition. *Melanoides* are not found in extremely saline or in extremely shallow lakes with thick mud (Leng et al. 1999).

^{40}AR/^{39}AR GEOCHRONOLOGY

Samples KK09-G14 and KK09-G15 were selected for initial geochronological work. KK09-G14 is from the upper part of the Lower Hugub Tuff directly underlying the Hugub Bed. Notably, the sampling of KK09-G14 did not include pumices, which were not identified in the unit until trenching during the 2011 field season. KK09-G15 is from a brown silt unit with large pumices near the base of the unit and overlies the Hugub Bed by ca. 7 meters.

Analyses were performed at the Berkeley Geochronology Center using methods and facilities described by Morgan and Renne (2008). Results are summarized in Figure 3 (A, B, C, D, and E). Full Ar isotopic data are provided in Table 1. KK09-G14 yielded multiple age populations with only three crystals representing a potential juvenile population with an inverse isochron age of 620±13 ka. KK09-G15 yielded a more significant juvenile population with a single analysis clearly representing xenocrystic contamination; a second crystal may also be xenocrystic as it is slightly older than the remainder of the population that has an inverse isochron age of 346±6 ka. This unit overlies the Hugub Bed by ca. 7 meters of diachronic sediments; it is possibly significantly younger than the anthropic occupation. Indeed, as shown above, analyses of the air-fall tephra immediately underlying the occupation level are suggestive of a juvenile population with an inverse isochron age of 620±13 ka. Several additional analyses are pending, including work on the Upper Hugub Tuff (which has yielded provisional dates of approximately 500 ka not reported in detail here), the Nuru Tuff, and pumices from the Lower Hugub Tuff; these will be reported in a future publication.

ARCHAEOLOGY

Only a small portion of the Hugub lithic assemblage that has been studied thus far is reported here. This collection includes the 1155 artifacts collected in 2009 and 2011 (Table 2). Some 552 artifacts are surface finds—474 pieces from 25m^2 controlled surface collection, 38 bifaces and flakes salvaged in 2009, and 40 bifaces salvaged in 2011. *In situ* Hugub Bed material includes the 603 artifacts from the geology trench, Excavation 1, and Excavation 2 (Figures 5 and 6). The *in situ* position of excavated artifacts is documented by the lithic assemblage composition, including numerous small debris and flake fragments, horizontal localization within the archaeological level and fine surface preservation of most lithics, showing no evidence of intensive water rolling or abrasion. However, some post-depositional processes have taken place.

TABLE 2. ARTIFACT COMPOSITION IN HUGUB ASSEMBLAGES.

		Flakes				Large Tools			Pebbles				
	Cores	Flakes	Laminar Flakes	Flake Tools	Chips	Bifaces	Cleavers	Choppers	Pebbles	Hammers	Broken Pebbles	Fragments	Total
Excavation 1	2	122	3	31	6	16	1	1	7	1	8	28	**226**
Excavation 2	4	99	-	43	9	9	-	-	31	-	19	123	**337**
Geological Trench	3	16	-	12	3	6	-	-	-	-	-	-	**40**
Surface collection	25	357	9	29	2	106	1	4	2	2	4	11	**552**
Total	**34**	**594**	**12**	**115**	**20**	**137**	**2**	**5**	**40**	**3**	**31**	**162**	**1155**

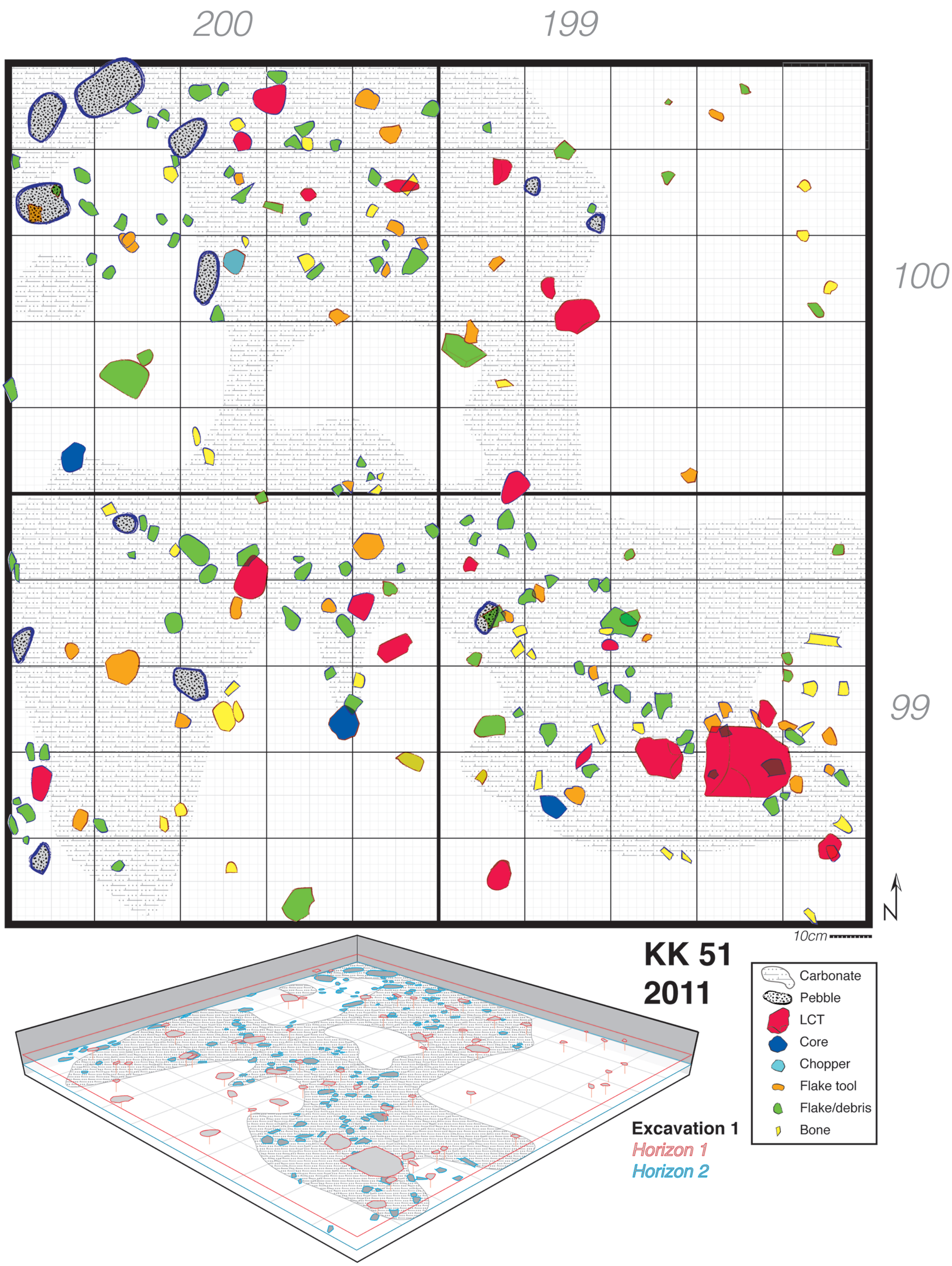

Figure 5. Excavation 1. Plan and 3D view of the Hugub Bed showing distribution of lithic artifacts and fossils over the excavated area; uncolored areas are where there is no carbonate cementation. The plan shows a composite distribution of specimens combined from two excavation horizons and colored by artifact categories; the 3D view shows an isometric distribution of finds colored by excavation horizons.

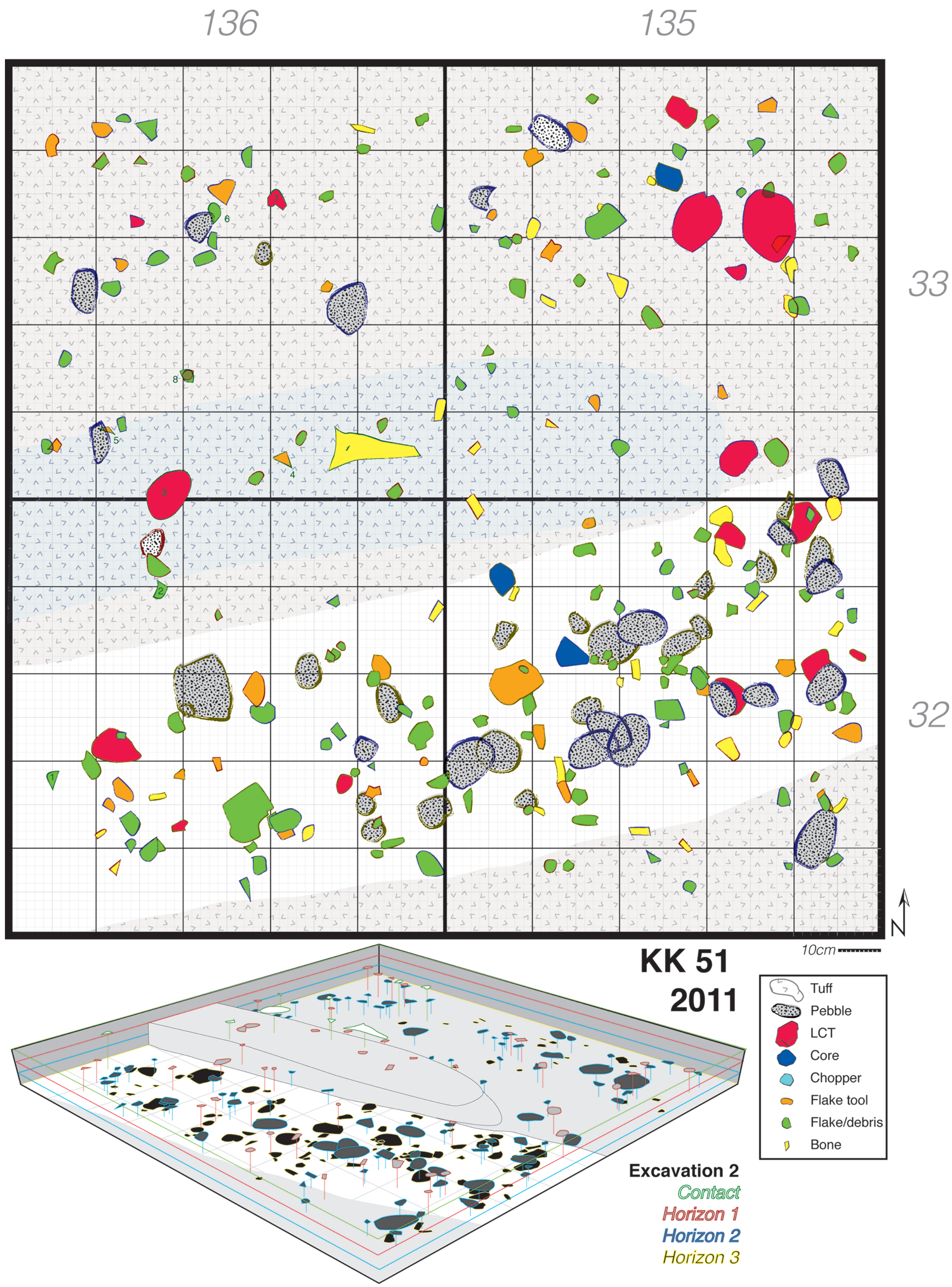

Figure 6. Excavation 2. Plan and 3D view of the Hugub Bed showing distribution of lithic artifacts and fossils over the excavated area; the uncolored area is a channel-like feature filled with coarser sand and more abundant volcanic pebbles and lithics. The plan shows a composite distribution of specimens combined from four excavation horizons and colored by artifact categories; the 3D view shows an isometric distribution of finds colored by excavation horizons.

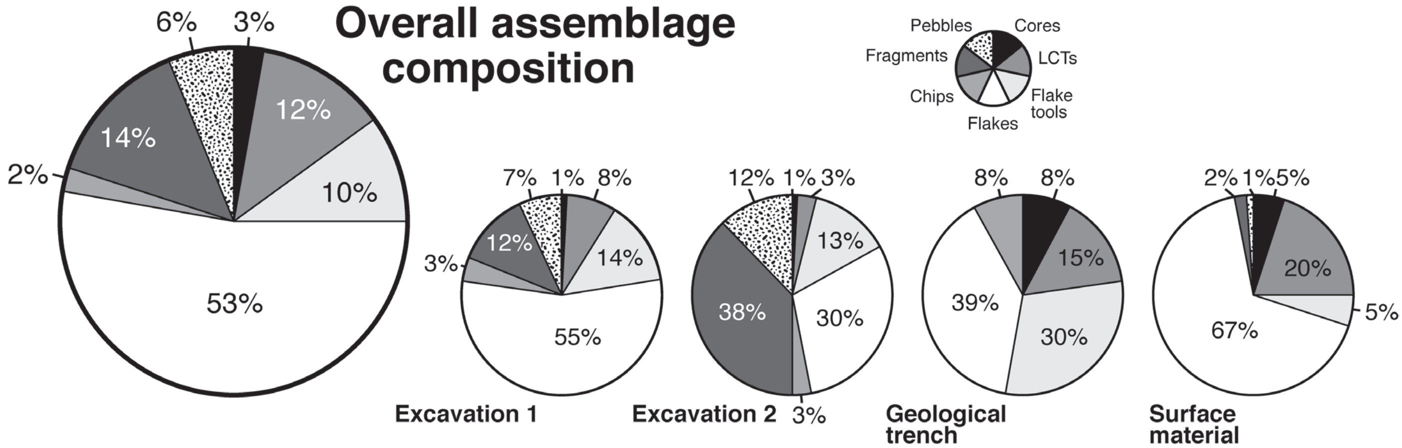

Figure 7. Composition of the overall lithic assemblage from the 2009 and 2011 surface collection and excavations at Hugub and assemblages from Excavations 1 and 2, geological trench, and surface.

ASSEMBLAGE COMPOSITION

Complete flakes and flake fragments comprise 53% of the total assemblage and these are the predominant finds in the surface collection, Excavation 1, and the geological trench (Figure 7). In the excavations there are more unidentifiable stone fragments and debris (usually broken on all sides and with a maximum dimension less than 20mm) relative to flakes. Fragments and debris are absent in the collected geological trench material and scarce in surface material (see Table 2), owing to the more rigorous methodology employed in the excavations. Whole or broken pebbles, comprising 7–12% of lithics from the excavations, are completely absent in the geological trench and surface materials. Three pebbles are probably hammerstones, as battered areas on their surfaces may indicate, and a few pebbles with waved breaks suggesting high energy blows appear to have made by hominids. There are few cores, which represent only <1% of the excavated assemblage (see Table 2; see Figure 7). Tools, including flake tools, large cutting tools (LCTs: bifaces, cleavers), and choppers, compose 22% of the assemblage. In Excavations 1 and 2, flake tools represent 14% and 13%, and bifaces 8% and 3%, respectively (see Figure 7), although LCTs compose 20% of the surface material and 15% of the geological trench material, figures that are clearly influenced by sampling strategy.

RAW MATERIAL

The majority of Hugub artifacts are made from igneous rocks such as rhyolite, basalt, ignimbrite (welded tuff), and obsidian. Silicified raw materials are rare. In the excavated material, basalt (36%) and rhyolite (29.5%) predominate, while ignimbrite and obsidian are less common (14.5% and 16.5%, respectively) (Table 3, Figure 8). The few excavated cores are made from every rock type described above, excluding rhyolite. Collected flakes are predominantly rhyolite and basalt (Figure 9). Most handaxes are made from rhyolitic raw material. There are some differences between excavated materials (including the geology trench) and surface materials. Excavated handaxes made of basalt or obsidian are more common, and chert bifaces occur only in surface collections. The cleaver and chopper from Excavation 1 are both made from basalt. Most flake tools are made on basalt or rhyolite, fewer from ignimbrite or obsidian, and chert tools are found only in Excavation 1 (see Figure 9). Numerous identifiable fragments and whole or broken cobbles of all rock types come from the excavations. Chips (<10mm) are well represented on all rock types in the excavated material (see Table 2).

KNAPPING PRODUCTS

Thirty-four cores were found in total, and the following core types were defined:

- small unipolar core with unidirectional removals from one platform and small unifacial discoid with centripetal removals from multiple platforms (Figure 10-3), in Excavation 1;
- unifacial bipolar (with opposite platforms) and unifacial orthogonal (with semi-crossed removals) cores, and 2 small unifacial discoids, in Excavation 2;
- small unifacial discoid and 2 unidentifiable reduced cores, in Geological Trench;
- unipolar (see Figure 10-1) and unifacial orthogonal (see Figure 10-2) cores, small bifacial discoid, 19 unidentifiable reduced cores and reduced core fragments, and 3 core fragments, in the surface collection.

Unidentifiable reduced cores and their fragments (i.e., usually small, formless, and heavily reduced cores on which it is hard to identify the removal pattern) absolutely prevail, but among identifiable cores represented by more than one specimen there is an approximately equal distribution between four unifacial discoids, and two unifacial orthogonal cores and two unipolar cores. This indicates a combination of the centripetal and recurrent flaking methods, something poorly documented in the earlier Acheulean, and the unifacial core reduction sequence. Other identifiable cores (a unifacial bipolar core and small bifacial

TABLE 3. ROCK TYPES BY ARTIFACT CATETORIES IN EXCAVATED ASSEMBLAGES.

		Rhyolite	Welded Tuff	Basalt	Obsidian	Chert	Total
Excavation 1	Cores	-	1	1	-	-	2
	Flakes	28	15	66	9	7	125
	Flake tools	4	2	16	3	6	31
	Chips	2	1	1	1	1	6
	Bifaces	5	1	7	3	-	16
	Cleavers	-	-	1	-	-	1
	Choppers	-	-	1	-	-	1
	Pebbles/Hammers	1/-	4/-	1-Jul	2/-	1/-	15/1
	Fragments	10	5	12	1	-	28
	Total	**50**	**29**	**113**	**19**	**15**	**226**
Excavation 2	Cores	-	-	2	1	1	4
	Flakes	39	18	19	21	2	99
	Flake tools	16	9	11	7	-	43
	Chips	3	-	2	3	1	9
	Bifaces	3	2	2	2	-	9
	Cleavers	-	-	-	-	-	-
	Choppers	-	-	-	-	-	-
	Pebbles/Hammers	15	6	26	3	-	50
	Fragments	40	18	27	37	1	123
	Total	**116**	**53**	**89**	**74**	**5**	**337**
	Overall	**166**	**82**	**202**	**93**	**20**	**563**

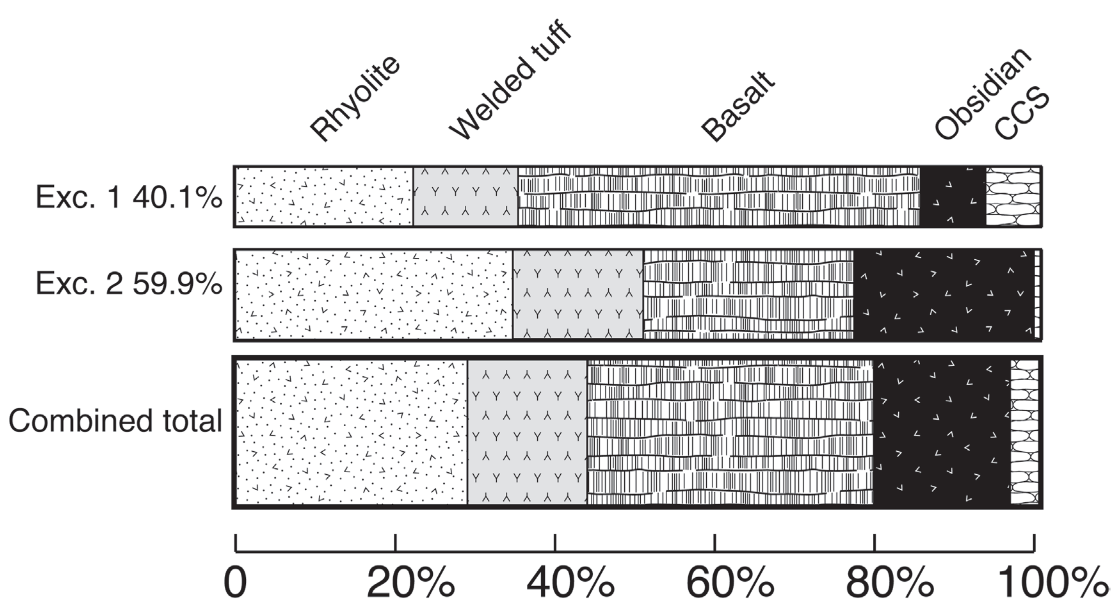

Figure 8. Rock types in lithic assemblages from Excavations 1 and 2, and combined total excavated material.

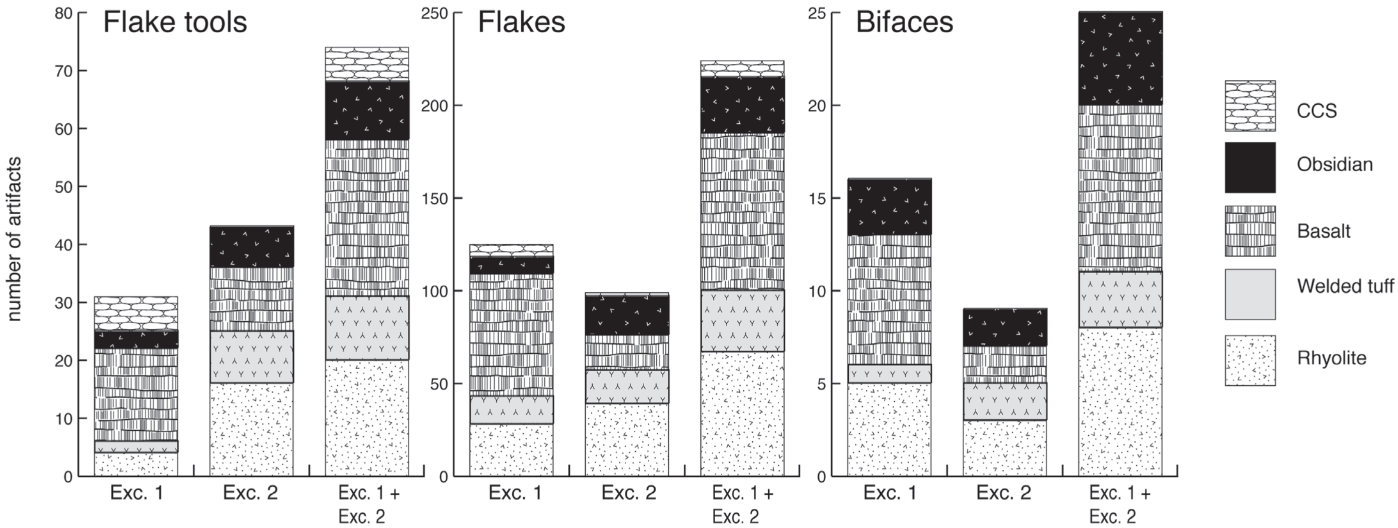

Figure 9. Number of flakes, bifaces, and flakes by rock type in Excavations 1 and 2. See Figure 8 for overall percentages of rock types.

discoid) are represented by single specimens.

Cortical (~100% cortex, 5%) and demi-cortical (>50% cortex, 4%) dorsal surface patterns from excavated flakes and flake tools are insignificant (Figure 11), as are retouched tools made on excavated cortical or demi-cortical flakes (Table 4). Cortical flakes do not have removals and demi-cortical flakes have only few incomplete removals making the pattern of directions hard to identify; they are thus not separated in Figure 11. Most flakes and flake tools (76%) have irregular dorsal surfaces (i.e., having an uncomplicated pattern of few removals from different directions that does not fit into any identifiable pattern or is hard to identify due to preservation), fewer exhibit parallel (including parallel-orthogonal removals struck from two perpendicular directions) and centripetal removals, and there are only a few (<1%) convergent removals. These show almost equal distribution among flakes and flake tools. Most excavated flakes (65%) have a fragmented striking platform (Figure 12). There are comparable numbers of plain (18%) and dihedral (14%) platforms; cortical or faceted platforms are very rare. Cortical platforms are absent on flake tools but faceted platforms (four items) are found exclusively on flake tools.

There is a large discrepancy between the six cores and 298 flakes/flake tools (the latter includes formal tools on flakes and retouched flakes, see below) in the excavated material. Also, there are insignificant numbers of flakes with cortical areas preserved on dorsal surfaces or striking platforms. The currently small collection of cores with identifiable flaking surfaces is insufficient to reveal details of the flaking technology or core reduction processes. A majority of cores are flaked on one surface, but most identifiable cores, including unifacial discoids, are small and heavily reduced, and apparently demonstrate late stages of the core reduction sequence. Flakes and cores consistently show a scarcity of the debitage from initial stages of core flaking or biface production. The small number of unipolar and bipolar cores correlates with a paucity (<10%) of flakes and flake tools with parallel and convergent removals; the small number of flakes and flake tools with centripetal removals (5%) relates to the rarity of discoidal cores. The overwhelming predominance of flakes and flake tools with irregular removals (76%) coincides with the prevalence of reduced cores. Such flakes could also derive from cores with unifacial orthogonal reduction, or biface rejuvenation that does not involve systematic, standardized flaking patterns. Bifaces do not seem to have been produced on location, rather appearing to have been rejuvenated or modified based on analyzed material. This is further supported by biface reduction trends discussed below.

RETOUCHED FLAKE TOOLS

Flake tools comprise 14% of Excavation 1 artifacts, 13% of Excavation 2, and 10% of the total assemblage (Table 5; see Figure 7). Almost a quarter (23%) of all tools are tool fragments (Figure 13). Identifiable tools are represented by five major groups—29% retouched flakes, 17% side-scrapers, 17% denticulates/notches/awls, 10% end-scrapers, 4% angled scrapers, and a convergent tool. Compositional differences between excavated and surface materials are insignificant.

Simple side-scrapers are the most common (see Table 5, Figure 14-1); transversal (see Figure 14-3), double (see Figure 14-2), and (a single) bifacial (Figure 15-1) side-scrapers are found only in the excavations. Some of the pieces present ventral thinning of the bases (see Figure 14-3). End-scrapers are found in Excavation 1 (5 pieces), Excavation 2 (3 pieces), and the surface material (4 pieces). They all are made on thick flakes and exhibit different types of retouching. The largest (69 x 77 x 32mm) end scraper, a surface find, has a circular outline and ventral retouch reducing a bulb of percussion (see Figure 14-4). The only convergent tool, a Mousterian-type point measuring 47 x 3 6x 11mm and made by semi-abrupt scale retouch on a small flake

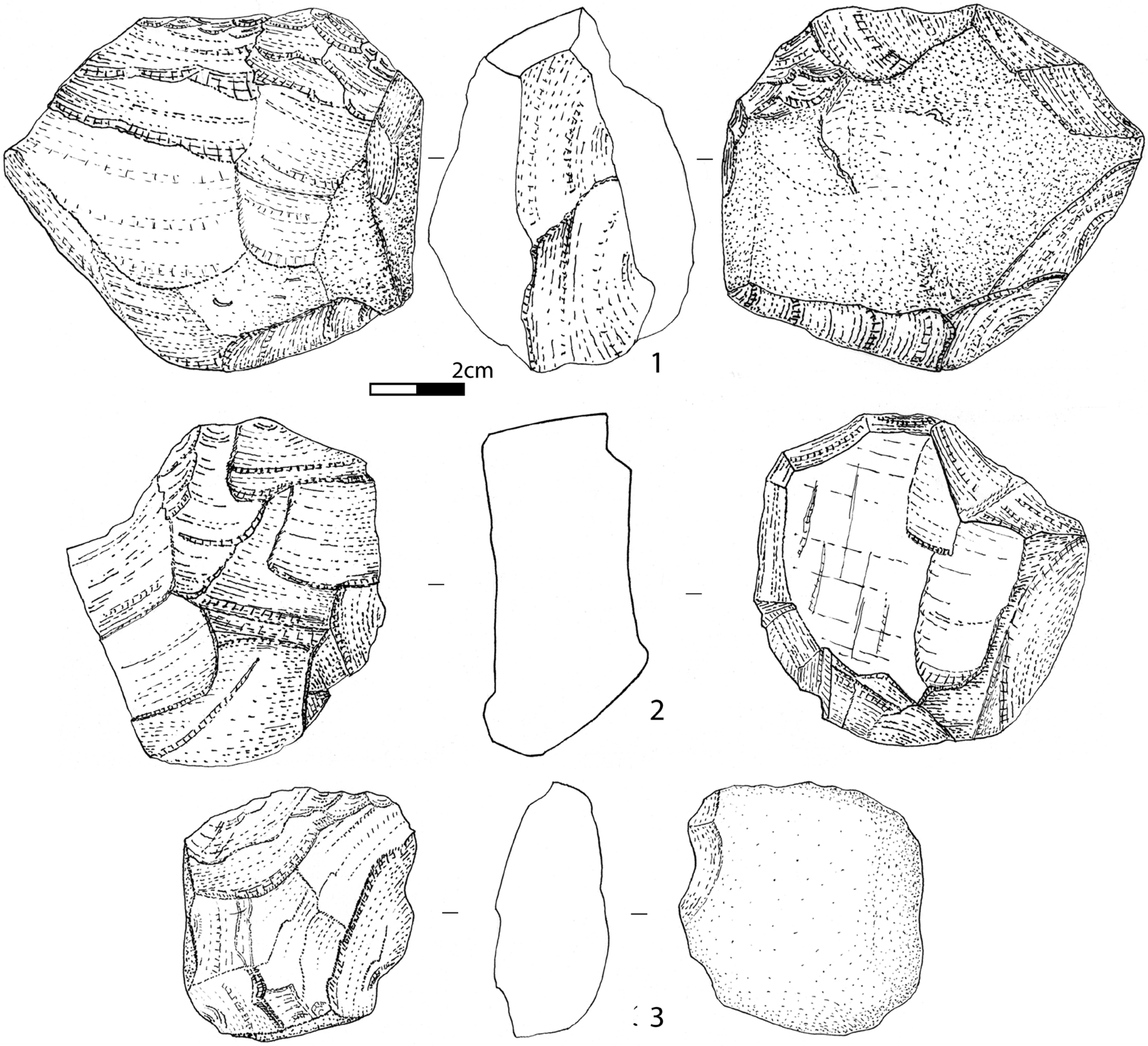

Figure 10. Cores. 1) single platform unidirectional core from surface material; 2) double platform semi-crossed unifacial core from surface material; 3) small unifacial discoid made on pebble from Excavation 1.

(see Figure 16-2 below), comes from Excavation 1. The tip is broken and the base is ventrally retouched. There are four atypical angled scrapers.

Denticulate tools are found only in excavated materials, four in Excavation 1, one in Excavation 2, and eight in the geology trench. Most have a rough denticulate retouch on one lateral side of a flake. Notched tools are less frequent, with one in Excavation 1 and three in Excavation 2; they all are made on flakes and have retouched notches. The three awls, on flakes with retouched tips, are from Excavation 2. Most retouched flakes (see Table 5) exhibit variable, irregular, or partial retouch, which might be a result of use-wear or edge damage. The largest specimen among retouched flakes is a large thick flake (105 x 73 x 23mm) with parallel-orthogonal removals on the dorsal surface and a faceted striking platform with lateral edges displaying a marginal and irregular retouch (Figure 15-2). Choppers are also rare (5 pieces), and most (4) are from the surface. The single excavated chopper is on a small, flat pebble (60 x 66 x 28mm) and has an edge knapped by a few small scars (Figure 16-1).

LARGE CUTTING TOOLS

Only two cleavers were found—one from the surface and the other from Excavation 1. The excavated cleaver (Figure

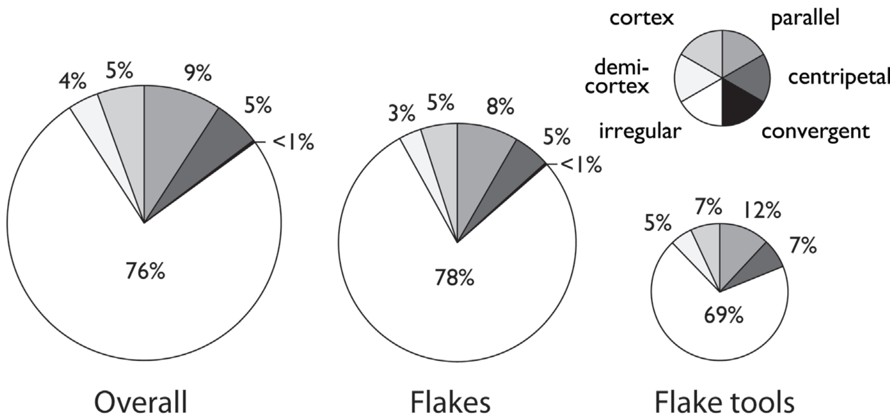

Figure 11. A diagram showing percentages of different dorsal surface patterns on overall flakes/flake tools, flakes, and flake tools from Excavations 1 and 2.

TABLE 4. DORSAL SURFACES ON FLAKES AND FLAKE TOOLS FROM EXCAVATIONS 1 AND 2.

		Dorsal Surfaces						
	Striking Platforms	**Parallel**	**Cenripetal**	**Convergent**	**Irregular**	**Demi-cortex**	**Cortex**	**Total**
Excavation 1	**Cortex**	-	-	-	-	-	1	1
	Plain	7	-	-	21	-	1	29
	Dihedral	4	-	-	16	2	1	23
	Faceted	-	-	-	-	-	-	-
	Fragmented	3	3	1	60	1	4	72
	Total Flakes	**14**	**3**	**1**	**97**	**3**	**7**	**125**
	Cortex	-	-	-	-	-	-	-
	Plain	2	-	-	2	1	1	6
	Dihedral	-	-	-	3	1	-	4
	Faceted	-	-	-	-	1	-	1
	Fragmented	1	-	-	16	1	2	20
	Total Tools on Flakes	**3**	**-**	**-**	**21**	**4**	**3**	**31**
Excavation 2	**Cortex**	-	-	-	1	1	2	4
	Plain	-	1	-	10	1	-	12
	Dihedral	1	-	-	8	-	-	9
	Faceted	-	-	-	-	-	-	-
	Fragmented	4	7	-	59	2	2	74
	Total Flakes	**5**	**8**	**-**	**78**	**4**	**4**	**99**
	Cortex	-	-	-	-	-	-	-
	Plain	-	1	-	4	-	2	7
	Dihedral	2	-	-	3	-	-	5
	Faceted	1	1	-	1	-	-	3
	Fragmented	3	3	-	22	-	-	28
	Total Tools on Flakes	**6**	**5**	**-**	**30**	**-**	**2**	**43**
	Grand Total Flakes	**19**	**11**	**1**	**175**	**7**	**11**	**224**
	Grand Total Tools on Flakes	**9**	**5**	**-**	**51**	**4**	**5**	**74**

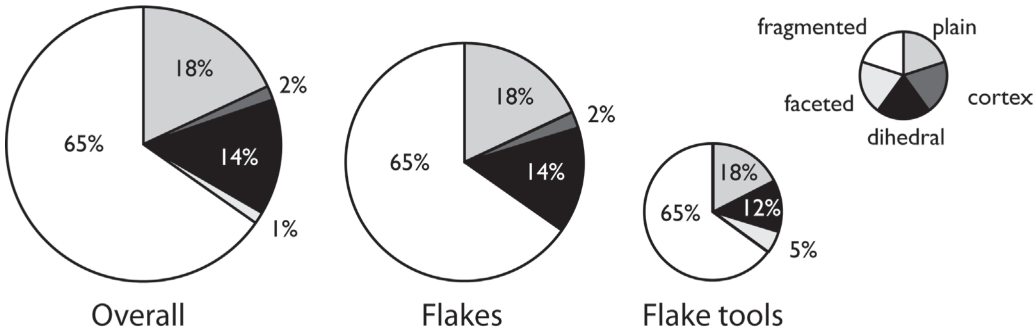

Figure 12. A diagram showing percentages of different striking platform types on overall flakes/flake tools, flakes, and flake tools from Excavations 1 and 2.

17) is on a large, thick flake (158 x 130 x 47mm). Large scars from the ventral face refine the right side, while the left side has dorsal retouch only on the distal part.

There are a total of 137 bifaces (including 5 unifaces), most (106) are from the surface and only 31 bifaces are found *in situ* (see Table 3). Most bifaces are amenable to morphometric analysis, but 3 fragmented bifaces and 42 biface fragments which were too damaged and fragmentary, and 15 formless, typologically indeterminate bifaces were excluded from this analysis. The latter have forms that are not classifiable into any of well-defined types established for LCTs and should be put into "miscellaneous" bifaces (see Debenath and Dibble 1994: 169), and thus are not informative for understanding the bifacial reduction. We employ terms and measurements defined by Bordes (1961: 49; Debenath and Dibble 1994: 130–132) with modifications. The procedure of morphometric analysis of bifaces, which we developed and apply in this paper, is aimed to study not only the technology of biface production, but also methods of biface renovation (thru shape modification and edge rejuvenation) used by hominids in the site before discard of these tools. We analyzed 72 complete bifaces and 5 unifaces, 56 from the surface and 21 excavated.

Gestalt visual sorting readily divides Hugub bifaces into broad-tipped ovates and pointed bifaces, and metrics confirm this apparent bimodality (Figure 18). Ovate bifaces with broad tips, with the *Index of Pointedness* (IP; the ratio of biface maximum width to the width of the tip measured at 3/4 of the overall length) varying from 1.1 to 1.4, are more abundant than pointed (pointed ovate, sub-cordiform and sub-triangular) bifaces with IPs between 1.6–1.9. The *Elongation Index* (EI; the ratio of biface maximum length to maximum width) varies in general from 0.9 to 1.5 (Figure 19), and truly elongated bifaces with EI>1.5 (e.g., limandes) are absent. Both ovate and pointed bifaces have dominant modes where EI is 1.3 (29 pieces) and 1.2 (18 pieces), respectively.

Biface *maximum length* (L) is moderate, varying from 41mm through 190mm, with most under 119mm (Figure 20). Maximum length distribution in ovate bifaces is trimodal, with large (125–190mm), medium (85–124mm), and small (50–84mm) groups. Biface *maximum thickness* (e) is moderate and correlates, in ovates, strongly with maximum length (Figure 21). Large (125–190mm) and thick (55–65mm) bifaces are exclusively ovates, medium (85–124mm) ovates are almost equally represented by thin (15–34mm) and moderate (35–54mm) tools, while thin tools predominate among small ovates. The interdependence between maximum length and thickness of ovate bifaces implies biface size reduction, which could result from modification and edge rejuvenation. It is unlikely that the reduction is the result of biface manufacturing because there is no evidence

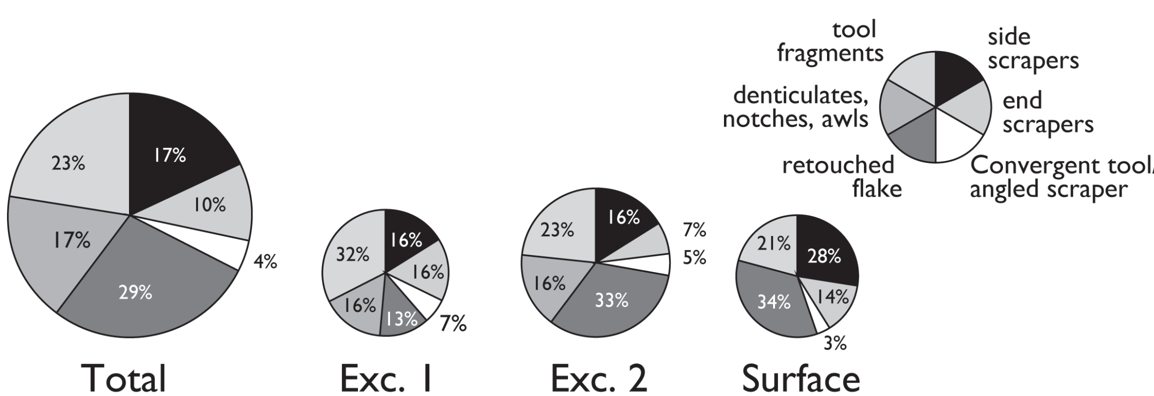

Figure 13. A diagram showing percentages of different categories of flake tools in the total lithic assemblage from the 2009 and 2011 surface collection and excavations at Hugub and assemblages from Excavations 1 and 2, and surface.

TABLE 5. COMPOSITION OF FLAKE TOOLS.

	Side-Scrapers												
	Simple	**Transversal**	**Bifacial**	**Double**	**End Scrapers**	**Convergent Tools**	**Angled Scrapers**	**Flakes with Retouch**	**Denticulates**	**Notches**	**Awls**	**Tool Fragments**	**Total**
Surface	8	-	-	-	4	-	1	10	-	-	-	6	**29**
Excav.1	2	2	1	-	5	1	1	4	4	1	-	10	**31**
Excav.2	6	1	-	-	3	-	2	14	1	3	3	10	**43**
Geol. Tr.	-	-	-	1	-	-	-	3	8	-	-	-	**12**
Total	16	3	1	1	12	1	4	32	13	4	3	26	**115**

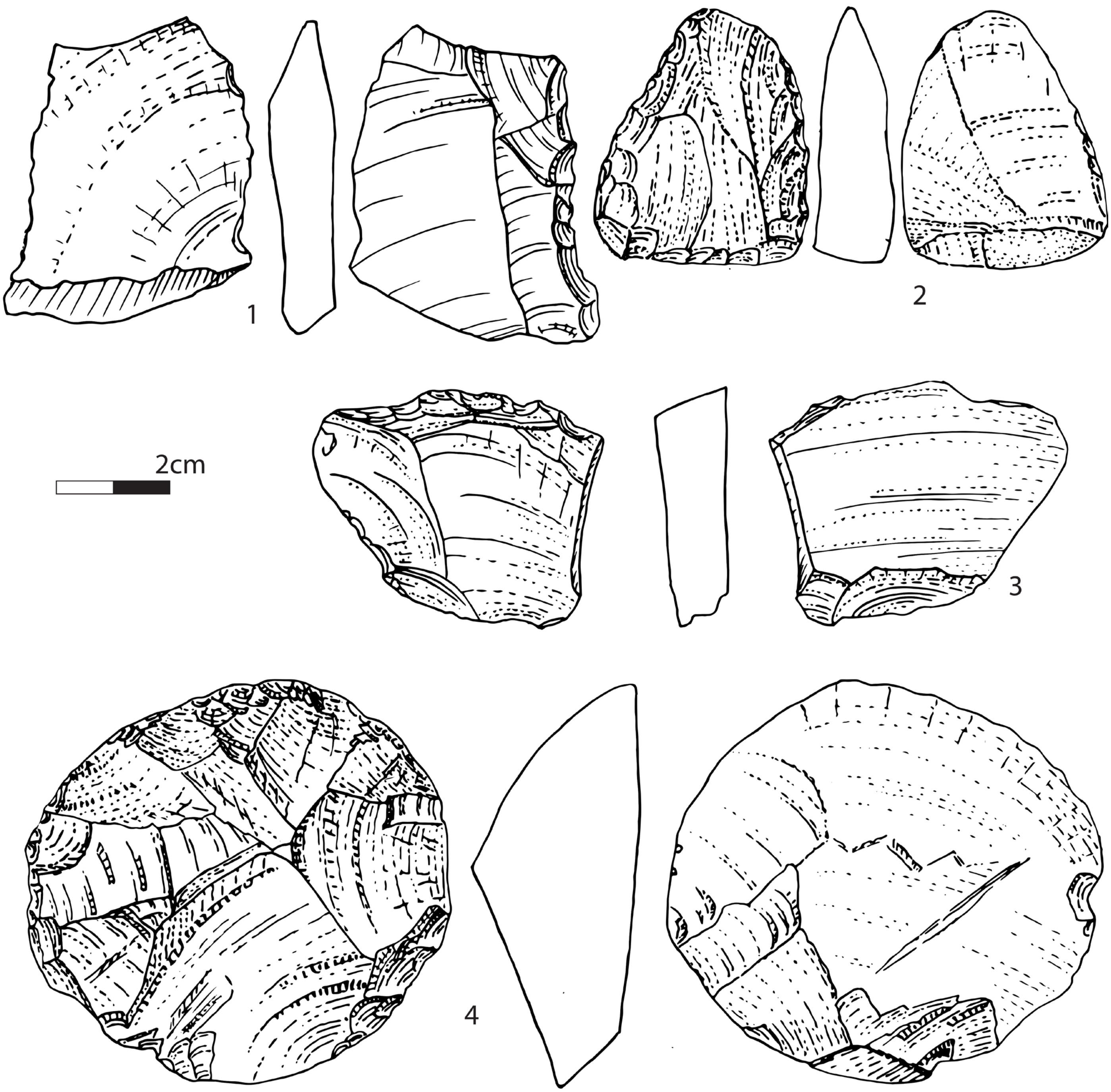

Figure 14. Flake tools. 1) simple concave scraper from surface material; 2) double scraper from the geological trench; 3) transversal scraper from Excavation 1; 4) rounded scraper, surface material.

of the initial stages (decortication and making preforms) of on-site biface production detected in the insignificant number of cortical and demi-cortical dorsal patterns in flaked debitage distribution (see above). Among pointed bifaces, medium (85–114mm) and small (41–89mm) size tools occur, but with only 21 pieces it is impossible to discern reduction trends. Small (41–85mm) and thin (10–34mm) tools dominate this group (see Figures 20 and 22). The smallest (<50mm, see Figure 20) and thinnest (<10mm, see Figure 22) tools (2 specimens) are found only among pointed bifaces, which grade in their size into MSA-typical points.

As determined by the *Base Shape Index* (BSI, the ratio of distance from biface base to maximum width (a) to the maximum length; Figure 23), most bifaces have rounded (a/L ratio 0.3–0.39) or oval (a/L ratio 0.4–0.49) bases. Typical triangular bifaces with straight bases (a/L ratio <0.2) are absent. Short rounded bases (a/L ratio 0.2–0.29) are more common among pointed bifaces. The presence of a maximum width closer to the midpoint of maximum length (a/L ratio of 0.4–0.49) is dominant among both ovates and point-

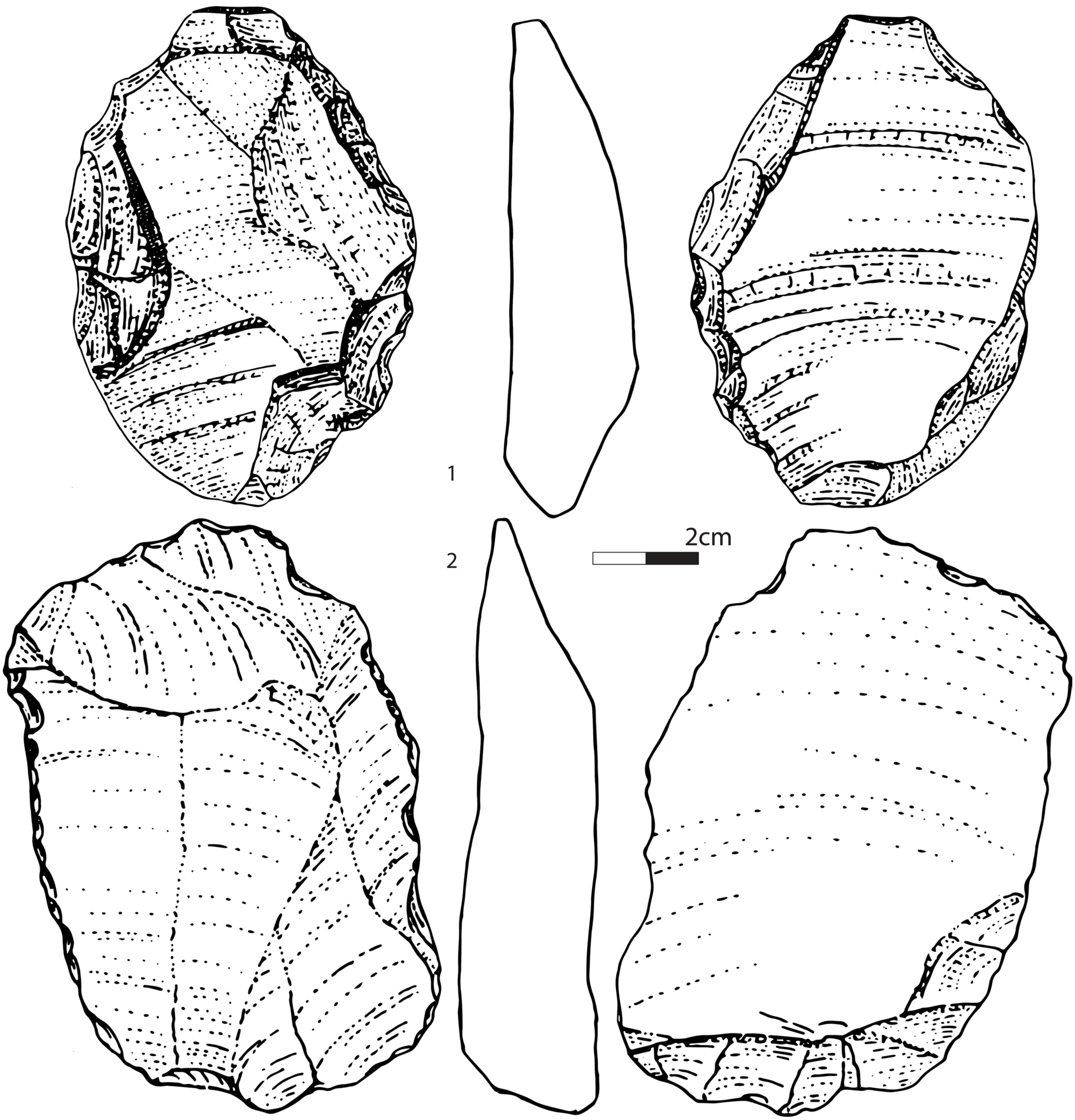

Figure 15. Flake tools from KK 51. 1) bifacial scraper from Excavation 2; 2) retouched flake from Excavation 2.

ed bifaces. Only ovates sometimes have a maximum width in the middle of the tool (a/L ratio is 0.5–0.54).

Bifaces almost always have retouched bases. Only three ovate and three pointed bifaces have cortical bases. There are bifaces with sharp (Figures 24-3 and 25) and blunt (see Figures 24-1, 2 and 26) retouched bases in both groups (see Figure 23). Sharp bases are common (81%) among pointed bifaces and less common (57%) among ovates. Sharp and blunt bases have almost equal distribution in different size groups of ovates. Shaping of biface bases is quite variable: base thinning via medium and small flake removal is present on convex or flat surfaces of bifaces (see Figure 25), and occasionally on both faces (see Figure 24-3). Blunted, thick bases are often formed by larger removals (see Figures 24-1 and 26).

Only some of the ovates are classic ovate handaxes (i.e., flat ovates using Bordes' typology; see Figures 24 and 25). All have a tip area shaped via a plano-convex method by

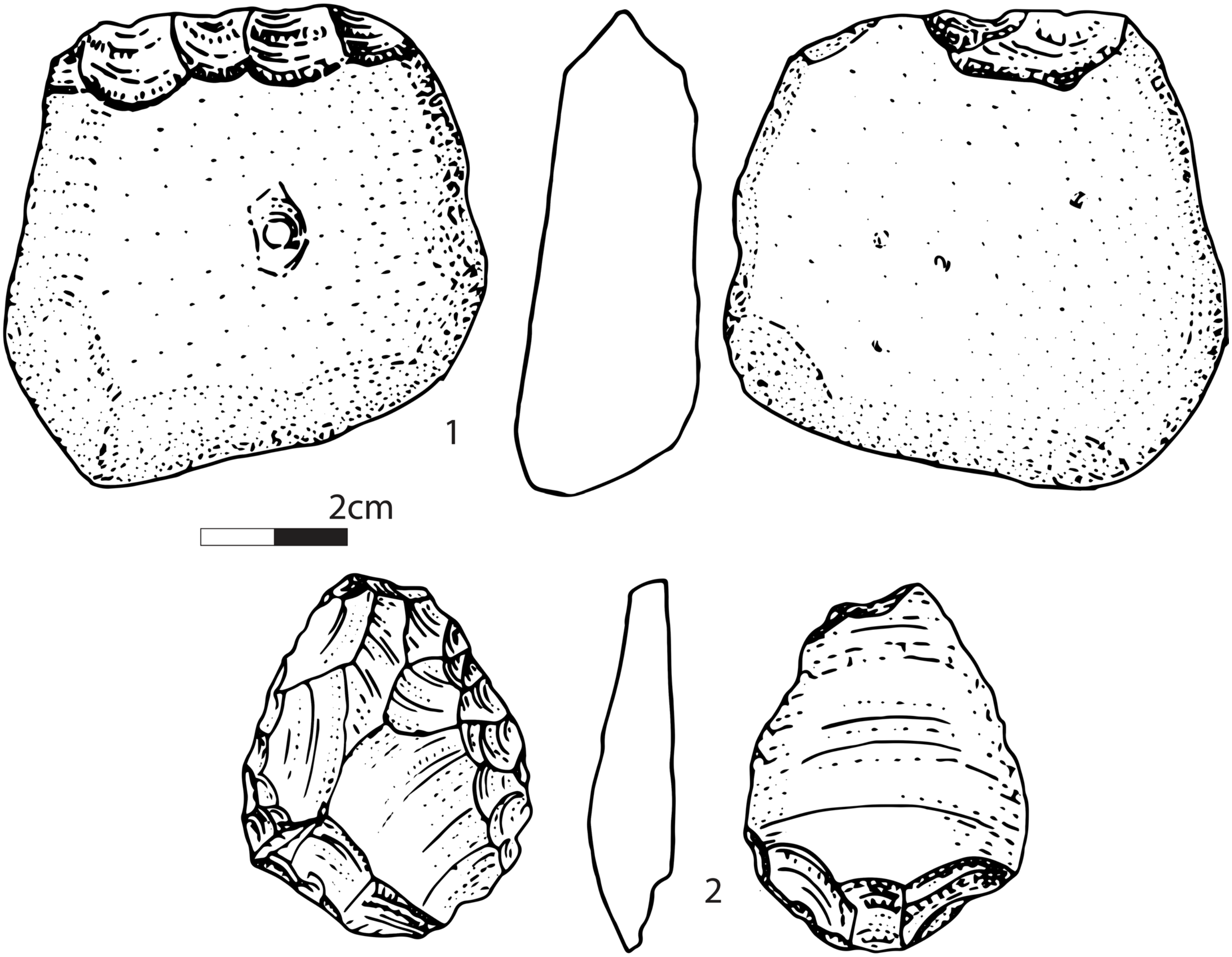

Figure 16. Excavation 1 tools. 1) chopper; 2) convergent tool.

large and flat removals from one side and then smaller and steeper removals from the other side. Some edges are very carefully refined with flat scars and laminar retouch (see Figure 24-2), and frequently the distal edge has an asymmetric outline. All pointed bifaces have two convergent edges refined by larger scars and retouch, and most are shaped in the plano-convex method (Figure 27-3). Only five tools (23.8% of pointed bifaces) are not shaped in this method; these all are made on large flakes (see Figure 27-1, 2) and are partial bifaces; their bases either sharpened by retouch from a dorsal (two pieces) or ventral (one piece, see Figure 27-2) face, or unworked (two pieces). The single excavated convergent scraper/unifacial point (see Figure 16-2) made on a small (<5cm) flake with the base reduced by ventral retouch closely resembles a pointed biface on a flake. Bifaces on flakes are underrepresented among ovates (14.3%), which are dominated by bifaces refined from both sides (85.7%). All ovates made on flakes are partial bifaces and have ventrally retouched bases. Flake bifaces are numerous among large ovates (38.5%), but their numbers decrease in medium-sized (11.8%) and small (3.9%) ovates. This pattern is consistent with the trend of ovate biface reduction outlined previously.

BEHAVIORAL AND PALEOENVIRONMENTAL INTERPRETATION OF THE HUGUB SITE

The combined stratigraphic and faunal signal of Hugub (see Figure 4) is interpreted as a lake margin with adjacent floodplain and a seasonally fluctuating water level in a largely xeric area. Large trees (Colobine monkeys) and grasses (Reduncine bovids) would have been present and, based on the presence of open-grassland grazing and xerophilic bovids (Hippotragines, Alcelaphines, and Antilopines), there would have been drier conditions away from the river margin. Occupation likely responded to fluctuating lacustrine conditions. It appears that the occupation surface, directly overlying the compact Lower Hugub Tuff, was at least seasonally firm. The fauna and depositional context suggest a seasonally inhabited lakeshore environment adjacent to xeric grasslands.

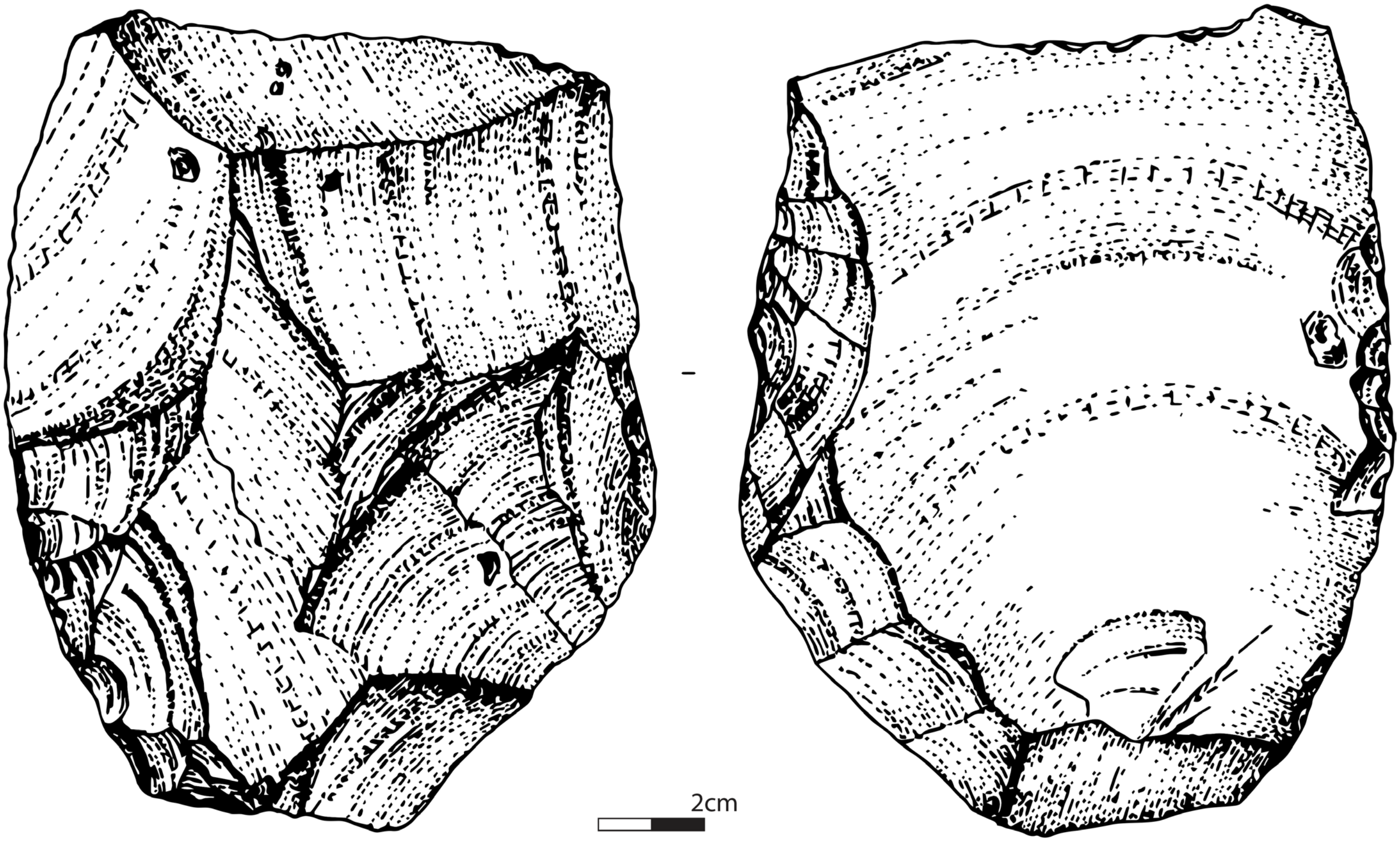

Figure 17. Cleaver from Excavation 1.

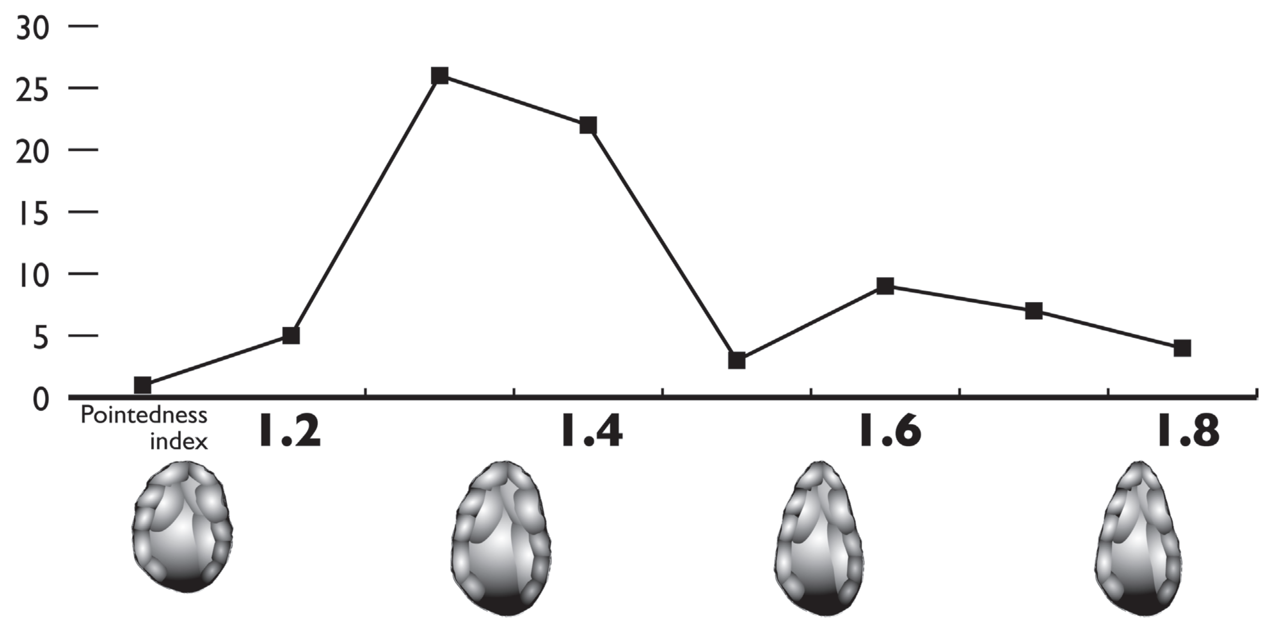

Figure 18. Biface distribution by the Index of Pointedness (see text): ovates (left pick) and pointed bifaces (right pick). The vertical axis shows the number of pieces and the horizontal axis shows the value of the parameter.

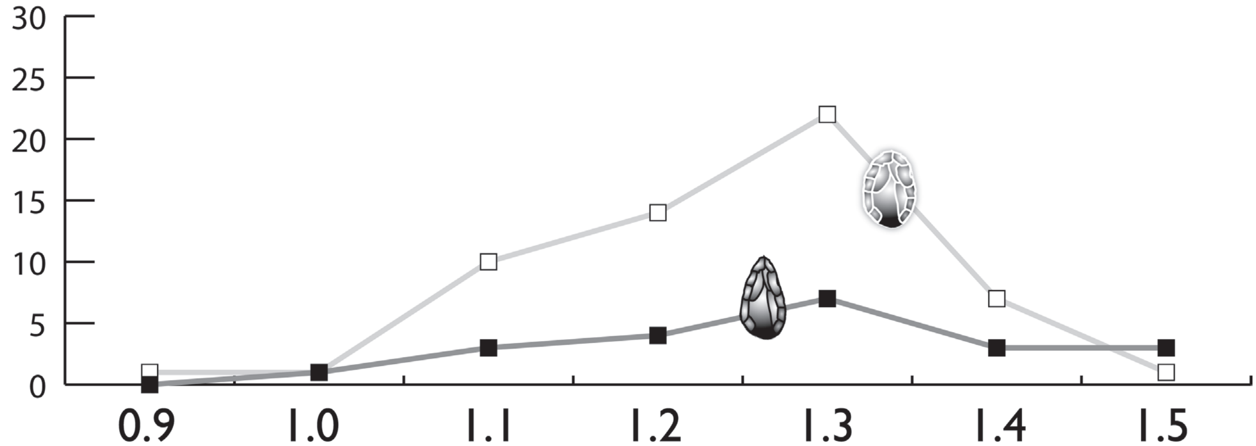

Figure 19. Biface distribution by the Elongation Index (see text): Lower line—pointed bifaces, upper line—ovates. The vertical axis shows the number of pieces and the horizontal axis shows the value of the parameter.

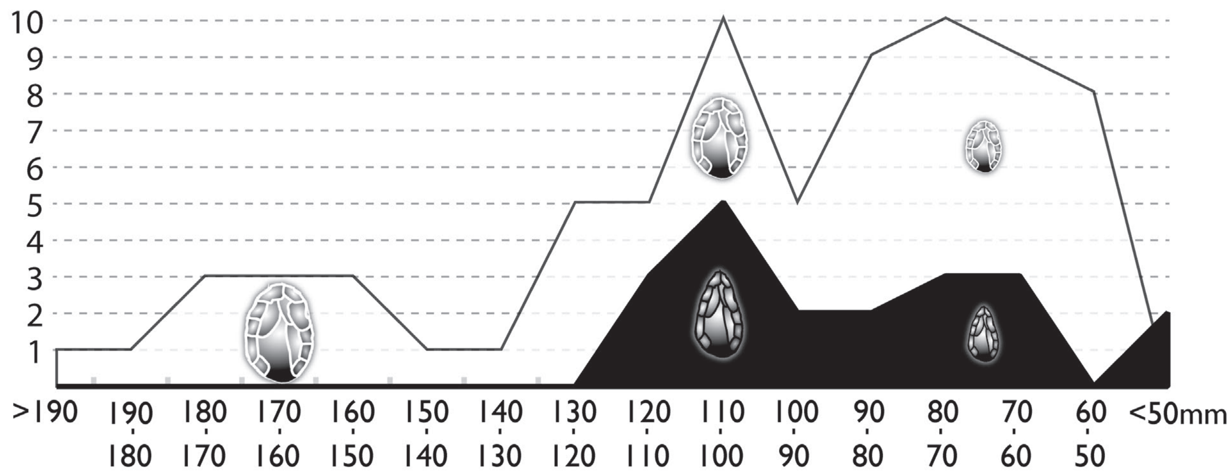

Figure 20. Biface distribution by the Maximum Length, in millimeters: Black area—pointed bifaces; white area—ovate bifaces. The vertical axis shows the number of pieces and the horizontal axis shows the value of the parameter.

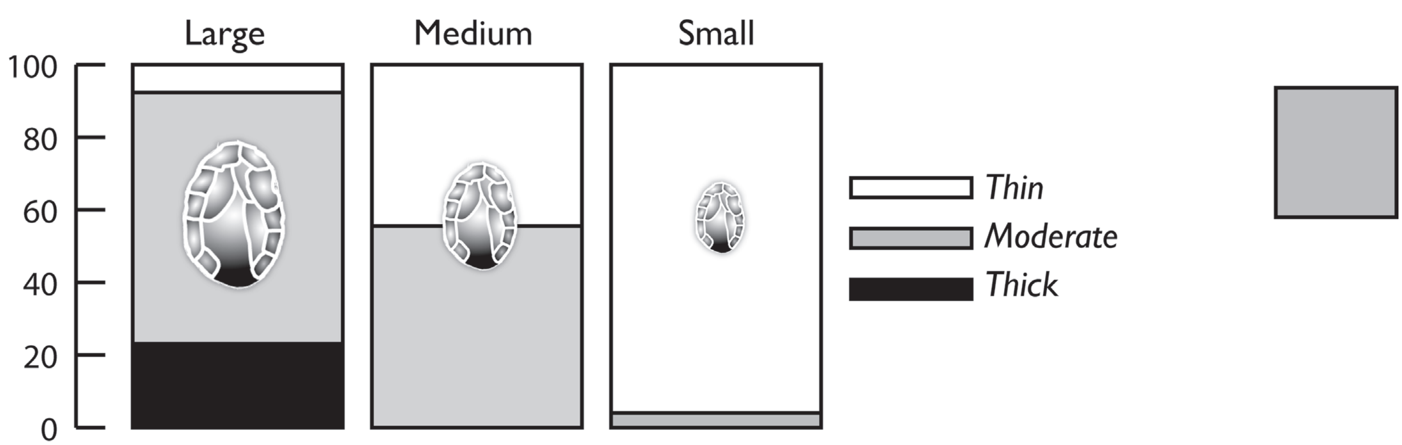

Figure 21. Histogram showing thickness distribution of ovate bifaces in three size groups: Large (13 pieces, length 125–190mm), Medium (18 pieces, length 85–124mm), and Small (25 pieces, length 50–84mm). Thickness of bifaces: black—thick (55–65mm), grey—moderate (35–54mm), white—thin (15–34mm). The vertical axis shows the percentage of thick, moderate, and thin specimens relative to the total number of bifaces (100%) in each size group.

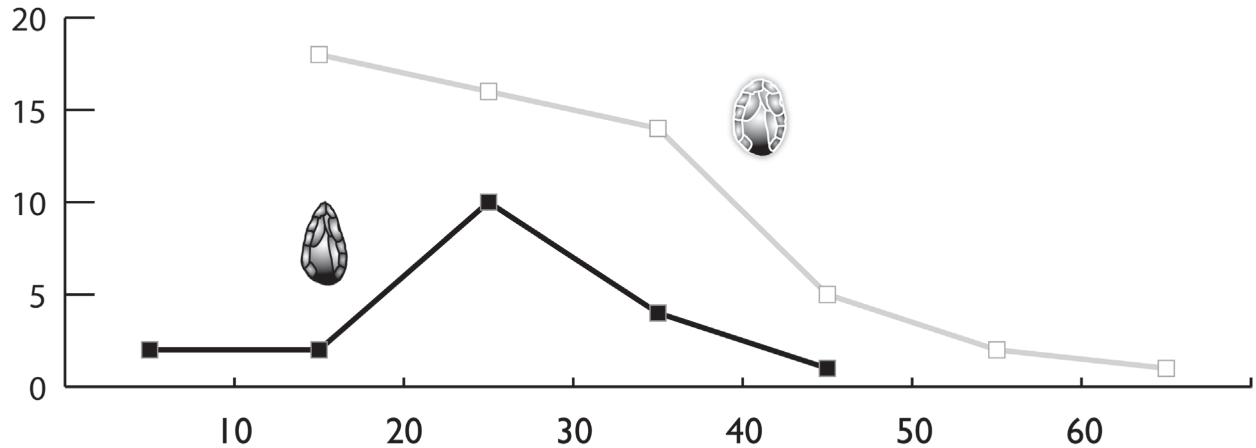

Figure 22. Distribution by the Maximum Thickness (in millimeters) in ovates (upper line) and pointed bifaces (lower line). The vertical axis shows the number of pieces and the horizontal axis shows the value of the parameter.

The Hugub Bed is extremely widespread fossil and artifact-bearing exposure with tight stratigraphic constraint, and recent excavations have confirmed it extends over at least 750m in one dimension. Artifact and fauna concentrations vary across exposed surfaces (see Figures 1, 5, and 6), and there is high potential for sampling several adjacent ecological and hominid activity zones. Excavated assemblages include numerous artifact groups, such as stone fragments/debris and whole or broken pebbles, that are absent in the geological trench and extremely rare in surface materials, and are thus better witnesses to actual assemblage composition. The presence of some rounded fossil fragments and abraded or weathered artifacts in the excavated materials, and their co-occurrence with fresh lithics, suggest several depositional events of the Hugub Bed.

The overwhelming majority of artifacts are made on volcanics, including rhyolite, basalt, ignimbrite, and obsidian—raw materials that absolutely predominate in the Acheulean sites across eastern Africa (see Table 3, Figures 8 and 9). Sources of these rocks are unknown, and source identification is scheduled for investigation. Apparently, some rocks used for the Hugub artifacts were available locally, and could be sourced from mainly medium-sized boulder/cobble conglomerates and large-sized stromatolites that are exposed in a number of outcrops along the north-western and northern boundaries of the Hugub site (see Figure 1).

The insignificant numbers of flakes with cortical or semi-cortical dorsal surfaces and striking platforms, and the low numbers of retouched tools made on such flakes

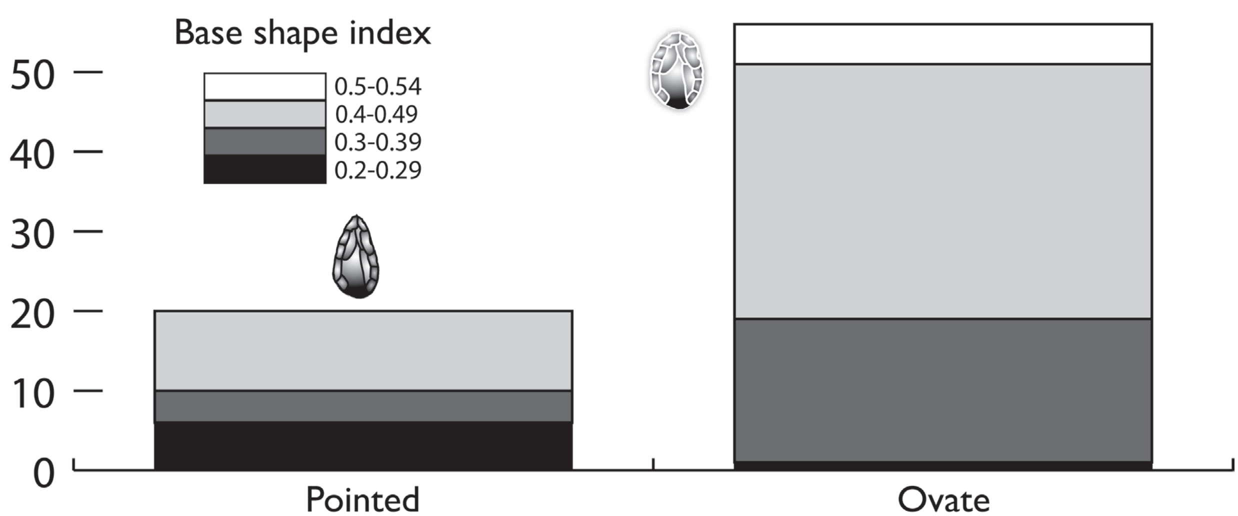

Figure 23. Biface distribution by the Base Shape Index (BSI; see text). Left: pointed bifaces, right: ovate bifaces. Base shapes according to BSI: 0.2–0.29—short rounded; 0.3–0.39—rounded; 0.4–0.49—oval; 0.5–0.54—elongated oval. The vertical axis shows the number of pieces.

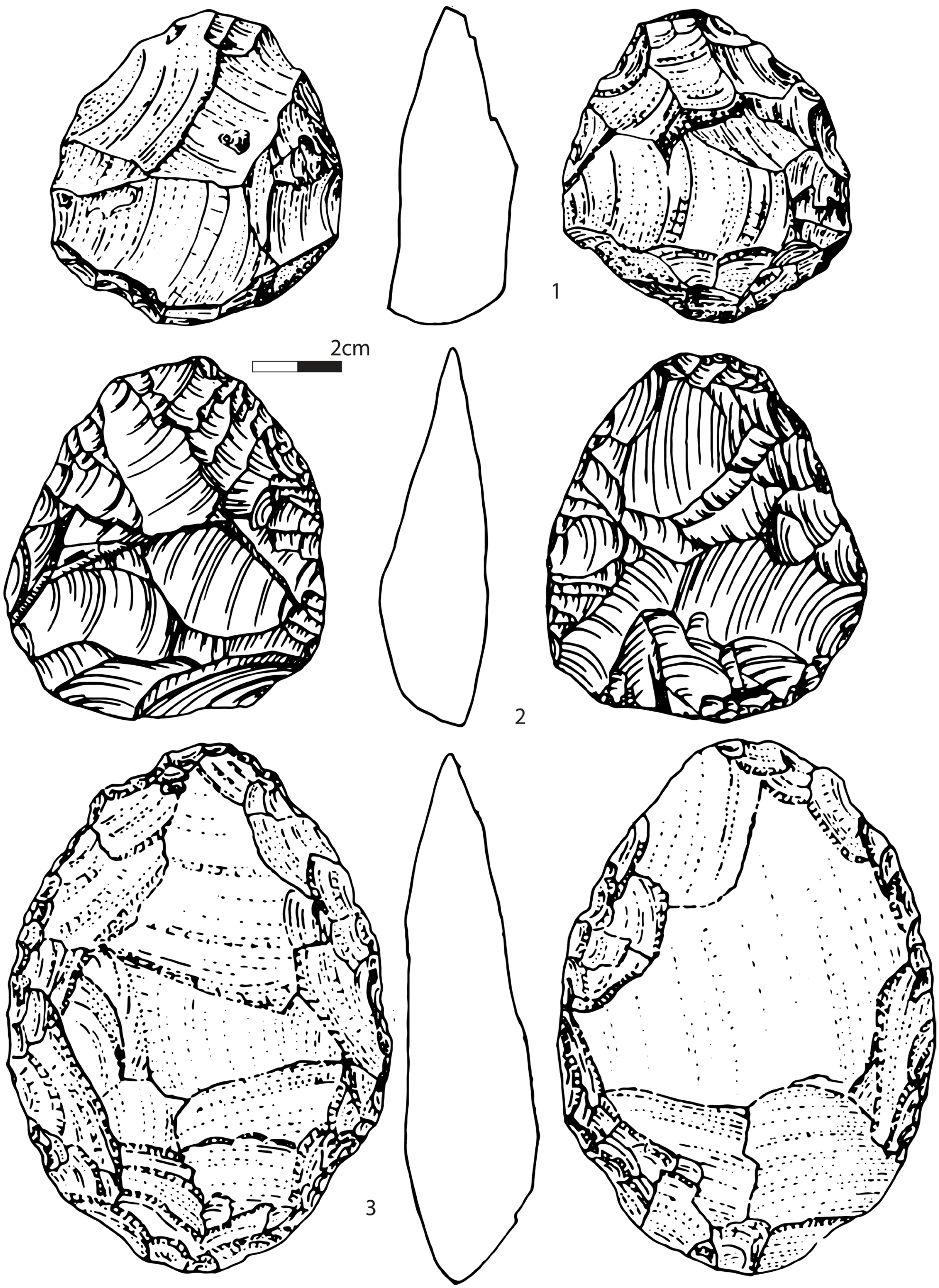

Figure 24. Ovate bifaces. 1) Excavation 1; 2) surface material; 3) surface material.

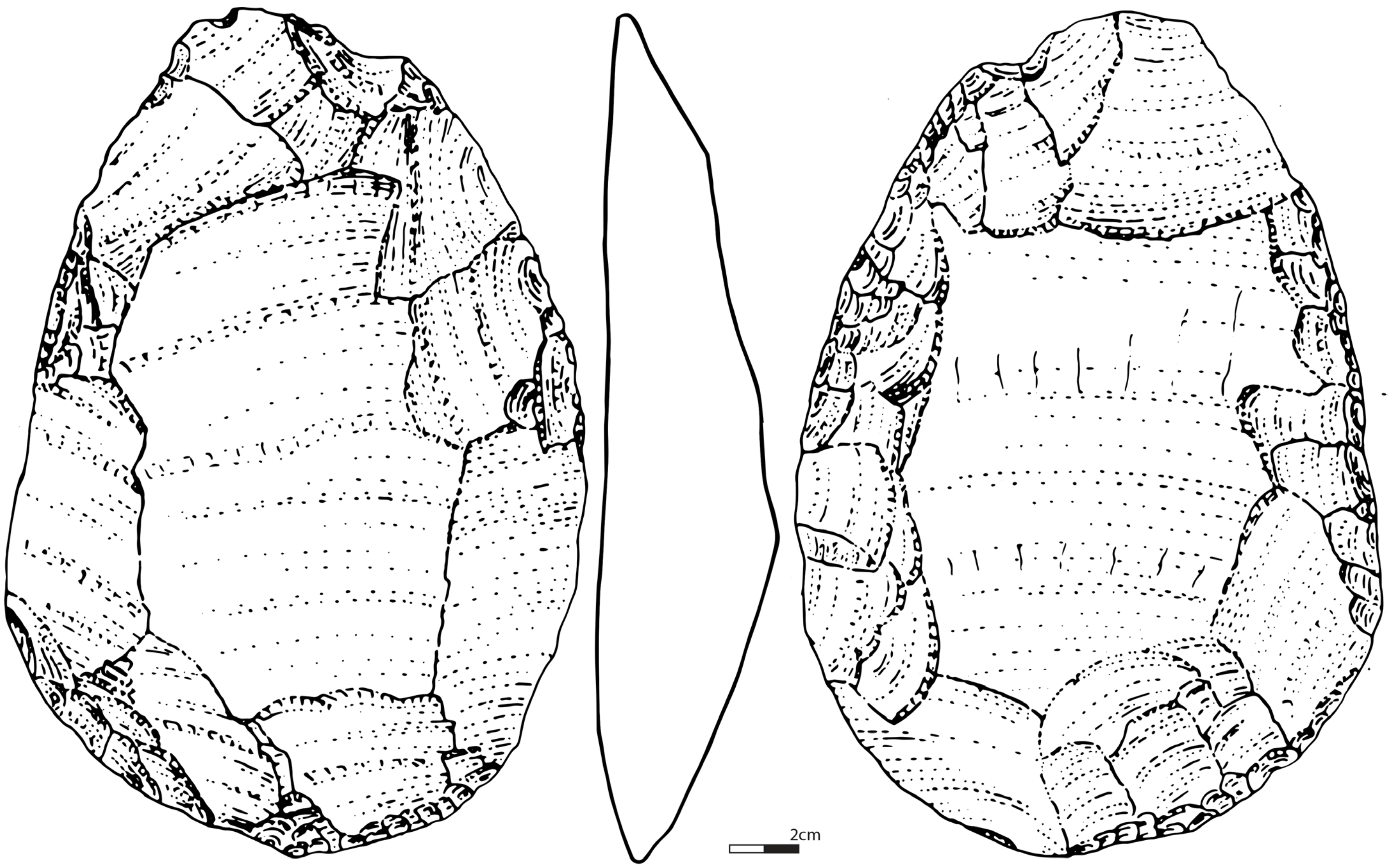

Figure 25. Ovate biface. Surface material.

in the excavated materials (see Table 4, Figures 11 and 12) suggest strongly that initial operations of testing, decortication, and preparation of cores and bifaces took place away from the excavated area, apparently, directly on raw material sources. The high frequency of small and reduced cores and their fragments among cores suggests a high rate of on-site core reduction to exhaustion, raw material scarcity for the Middle Pleistocene occupants of the site, and raw material transport (especially high-quality raw materials, such as obsidian) from distant sources.

Among identifiable core types there is an approximately equal distribution between unifacial discoids and unifacial orthogonal and unipolar cores, indicating the predominance of core reduction from one surface. Apparently, unifacial discoids present a late stage of the reduction sequence, when the production surface of a core is covered by overlapping removals struck from several platforms located around the perimeter of the core. Dorsal surfaces and striking platforms on flakes (see Figures 11 and 12) exhibit a predominance of uncomplicated and non-standardized (irregular) scar patterns and minimal preparation of striking platforms that are mostly plain or dihedral. Such flakes could derive from the prevailing reduced cores or in the course of opportunistic biface rejuvenation that does not involve systematic, standardized flaking patterns. The absence of typical Levallois debitage is significant, although a few Levallois-like flakes from unanalyzed recent excavations appear to be the product of exceptional cases of handaxe transformation into cores (see DeBono and Goren-Inbar 2001) or an accidental by-product of centripetal biface preparation/modification. A non-Levallois recurrent flaking method is clearly present. This coincides with the recent data from the Kapthurin Formation, where no evidence for Levallois reduction is found in earlier Acheulean assemblages dated to 545–510 ka (Johnson and McBrearty 2010; McBrearty and Tryon 2006).

A large discrepancy between core number (6) and flakes/flake tools (298), along with an increased number of LCTs (26 pieces) relative to cores in Excavations 1 and 2 suggests, as emphasized earlier, that many flakes may originate from on-site bifacial reduction thru modification and edge rejuvenation. Bifaces do not appear to have been produced in the excavated areas, instead it is evidence of tool maintenance, conservation, and transport between multiple places of use. Correlation of length and thickness of ovate bifaces is also evidence of on-site biface reduction (see Figure 21). Peculiarities caused by this reduction may include a predominance of ovates made on flakes among larger-sized bifaces, and a decrease of the bifaces on flakes among smaller ovates. The overwhelming majority of handaxes in Hugub are produced by the plano-convex technique (see Figures 24, 25, 26, and 27-3). Most seem to have been initially made on large flakes, as seen in the larger size ovates, but ventral surfaces of flakes are difficult to identify due to

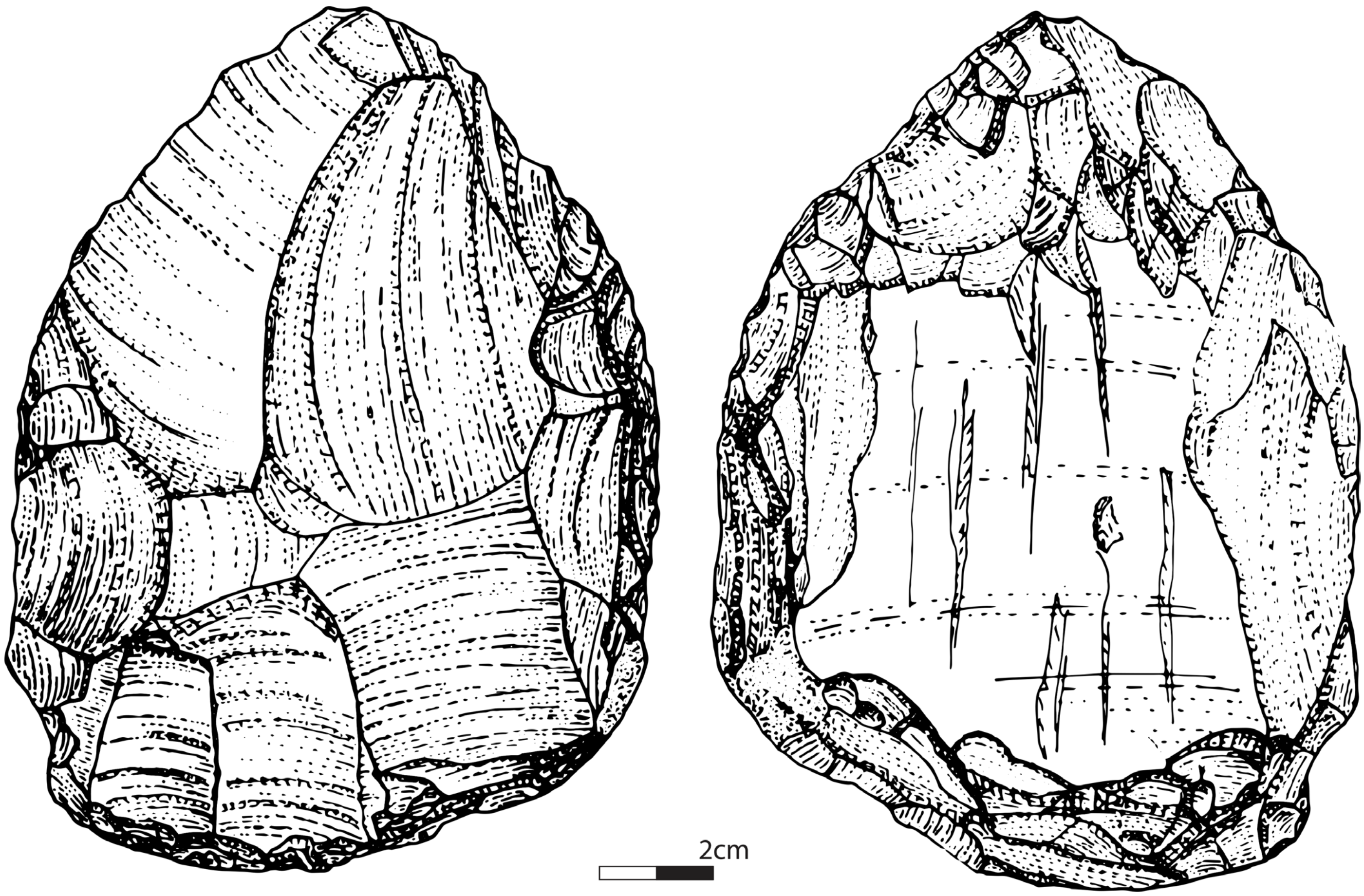

Figure 26. Ovate biface. Surface material.

heavy reduction of edges and faces. Almost all small-sized bifaces are completely bifacial tools, also likely the result of on-site reduction through rejuvenation.

As discussed below, the overall biface assemblage of Hugub shows peculiar features—cleavers are extremely rare, handaxes cluster bimodally into broad-tipped ovates and pointed (narrow-tipped ovate, sub-cordiform and subtriangular) bifaces, most bifaces are made on large flakes and produced by the plano-convex method, there is evidence of significant on-site biface resharpening, and some smaller size pointed bifaces grade into MSA-type points—that are indicative of the Late Acheulean. The absence of Levallois debitage would be consistent with an earlier age for the Hugub assemblage. This suggests assignment to the early Late Acheulean. The set of flake tools is small thus far, but characteristic features of its composition, such as the prevalence of simple scrapers and the extreme scarcity of convergent tools or angled scrapers do support this assignment.

DISCUSSION

In Africa, the emergence of Acheulean techno-economic innovations, including large flake production and the manufacture of LCTs, is now dated as early as ~1.75 Ma at Kokiselei 4 in West Turkana (Kenya) and KGA6 in Konso (Ethiopia), and ~1.7–1.6 Ma at Gona (Ethiopia). Some authors correlate the emergence of the African Acheulean with the origin of *Homo erectus sensu lato* (Mussi and Gallotti 2014). Several excavated Early Acheulean sites document the development of Acheulean technical innovations during the Lower Pleistocene, between 1.7 and 1.0 Ma. Among them, the rich assemblages from Konso and Gona show that the Early Acheulean toolkit includes unifacially- and bifacially-shaped LCTs, such as crude handaxes (bifaces and unifaces) and picks made on large flakes or cobbles, as well as cores and small and medium-sized flaked debitage similar to those known in earlier Oldowan sites (Beyene et al. 2013; Semaw et al. 2013). The Acheulean assemblage from Garba IVD (dated ~1.5 Ma and classified earlier as Developed Oldowan) at Melka Kunture (Ethiopia) reflects the emergence of simple core preparation for large flake production, including systematic preparation of striking platforms and some degree of predetermined morphology (Gallotti 2014). Early Acheulean assemblages have a relatively high frequency of crude handaxes and picks among LCTs, although cleavers are absent or rare, and the production of large flakes does not constitute a well-developed technological praxis (Sharon 2009, 2010).

Some Acheulean assemblages at Konso, with dates between 1.25 and 0.8 Ma, document the development of handaxe refinement and the technological evolution of LCTs resulting in the appearance of handaxes with advanced thinning and symmetry in the uppermost levels dating to 0.8–0.9 Ma (Beyene et al. 2013). Many authors note

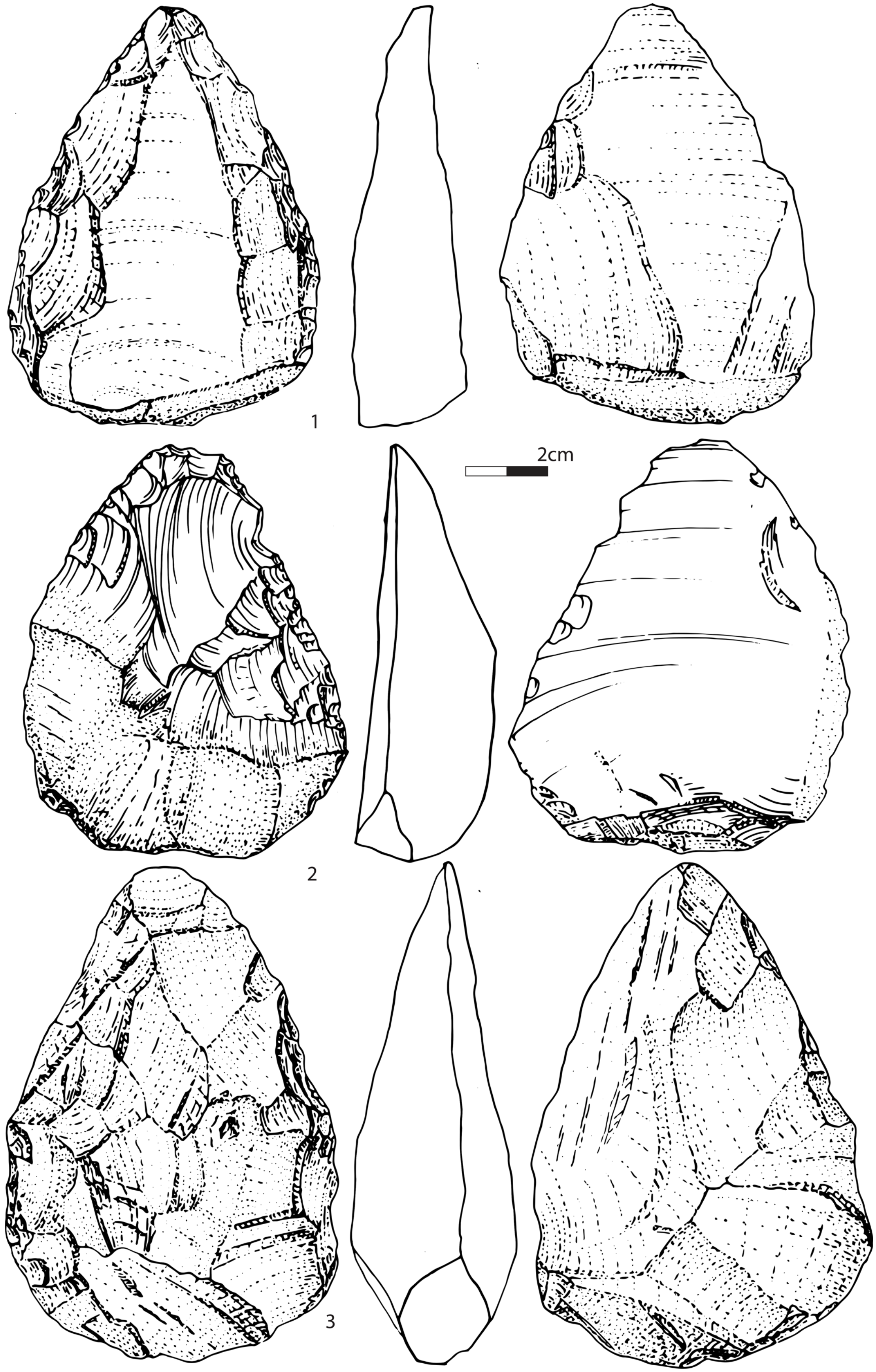

Figure 27. Pointed bifaces. 1) Excavation 2; 2) surface material; 3) surface material.

that minimalistic edge flaking, high standardization of sizes and shapes, increased symmetry, and thinning the flake blank's bulb of percussion characterize bifaces on large, frequently volcanic flakes produced by a large variety of often well planned and predetermined giant core techniques that are found in the Acheulean assemblages spanning this time period, approximately from 1.0 Ma to 0.6 Ma (Beyene et al. 2013; Goren-Inbar 2011b; McBrearty 2001; Schick and Clark 2003; Sharon 2007, 2009, 2010). Tear-shaped or pointed-tip ovate handaxes and significant frequencies of true cleavers made on large flakes are characteristic for these assemblages (Sharon 2007, 2010). Also, ficron handaxes and trihedral picks are noted in some sites (Gallotti et al. 2010; McNabb et al. 2004; Potts et al. 1999, 2004; Shipton 2011), although the crude handaxes and picks tend to be much more common in the Early Acheulean. Just as in the Oldowan, the Lower and early Middle Pleistocene Acheulean tool makers appear to have strongly targeted local (usually within 5km of a site) secondary sources, like streambeds, mostly volcanic raw materials, and only exceptionally exploited rock outcrops over 20–30km from a site (Mussi and Gallotti 2014; Noll and Petraglia 2003). Besides LCTs, many of the African earlier Acheulean assemblages contain typical Oldowan artifacts, such as spheroids, sub-spheroids, and a variety of polyhedral and discoid cores, knapped with bipolar or free-hand techniques to produce small flakes (McBrearty 2001; Mussi and Gallotti 2014).

Some authors note a clear discontinuity in Acheulean development with the emergence of new innovations around 1.0 Ma (Gallotti 2014). The proposal is made to term the Acheulean assemblages with developed technologies of large flake production and high values of standardized and elegantly made-on-large-flakes cleavers and handaxes that appear in Africa (as at Olorgesailie, Olduvai Gorge, Kilombe) and parts of Eurasia during this stage, beginning from about 1.0 Ma and continuing up to the Middle Pleistocene, as the 'Large Flake Biface' (LFB) Acheulean or the 'Large Flake Acheulean' (Sharon 2007, 2010). As noted above, the LFB Acheulean assemblages contain significant frequencies of LCTs made on large flakes, mostly ovate-shaped handaxes with pointed tips and cleavers; Acheulian sites that are not a part of the LFB Acheulean rarely have more than 1% of flake cleavers among their LCTs. Sharon (2010) notes that the LFB Acheulean may be termed 'Middle Acheulean', although the available chronological data are ambiguous and some suggest a later persistence of the LFB Acheulean assemblages until the end of ESA in Sub-Saharan Africa. Among the latest Acheulean sites that he assigns to this stage are Kalambo Falls (Clark and Cormack 2001) and Isimila (Howell 1961), both initially attributed to the Upper or Late Acheulean based on typological criteria. However, the geological age of both localities is poorly defined while the typological criteria indicating the attribution of these biface assemblages to the LFB Acheulean suggest an earlier age. For example, the biface assemblages from Beds III-IV/Masek Beds at Olduvai Gorge and Olorgesailie were formerly thought to represent Late Acheulean (Isaac and Isaac 1977; Leakey and Roe 1994) but actually date earlier to the Middle Acheulean period (Deino and Potts 1990; Sikes et al. 1999; Tamrat et al. 1995; Table 6).

It should be noted that some researchers reject any directional trends within the African Acheulean (e.g., McNabb and Cole 2015). Some authors argue that Meiso 7 in Ethiopia, which has a unit characterized by a high proportion of LCTs and a predominance of cleavers over handaxes, is evidence documenting the persistence of typical LFB Acheulean in eastern Africa (<200 ka) that spans into the early MSA (de la Torre et al. 2014). However, the proposed interpretation of the site's chronostratigraphic context and its correlation with the general stratigraphic sequence of the Mieso area is controversial. In Meiso 7, the authors have unreasonably correlated the Acheulean archaeology excavated in Levels 10 and 12 in Trench 7, in the bottom of the local sedimentary sequence, with the later deposits (named Bed A) lacking stone tools that were excavated in Trench 6, in the top of the sequence. In fact, in the site, few Acheulean artifacts (49 in total, including 10 LCTs) were found only in one sedimentary context, excavated in the lower part of Trench 7 and comprising coastal fluvial deposits (sands, gravels, and clays) with *in situ* artifacts. These deposits were stratigraphically correlative and horizontally adjusted to the stream deposits (gravels and coarse sands; named Bed GB) without artifacts (de la Torre et al. 2014: Figure 2). This suggests the Acheulean assemblage from Meiso 7 should be assigned to Bed GB; clear evidence of lateral reworking via stream erosion observed on some lithics supports this assignment. A general stratigraphic sequence of the Mieso area includes three distinct volcanic tuffs (TBI, TA and CB, from the bottom to the top). The reported $^{40}Ar/^{39}Ar$ results indicate the samples are highly contaminated and show the presence of two discrete groups of crystals, with ages suggesting that the total duration of the sequence is between 800/760 ka (older dates for the upper tuff CB) and 212/210 ka (younger dates for the middle and upper tuffs). The stratigraphic position of the excavated Acheulean assemblages in the lower part of the sequence, in Bed GB at Meiso 7 and Bed FA at Meiso 31, strongly suggests that the age of these sites should be closer to the older dates. It is indicative that the assemblage from Mieso 7 lacks technological and typological features (prepared Levallois or blade core debitage) typical for the Final Acheulean assemblages in eastern Africa, although it displays features characteristic to the LFB Middle Acheulean assemblages (see Table 6). In this regard, it is surprising that, contrary to the claimed post-200 ka age of the assemblage, de la Torre and co-authors (2014: 21) propose Gesher Benot Ya'aqov—the reference LFB Acheulean site in Israel dating ~780 ka in the type locality and as late as 650 ka in an additional locality (Goren-Inbar and Sharon 2006; Sharon 2010)—"as a parallel to Mieso 7."

At the Middle Awash, three stages of Acheulean development have been identified, including the later Early Acheulean, Middle Acheulean, and Late Acheulean (Schick and Clark 2003: Tables 1.1, 1.3). It is noted that each stage is characterized with distinct patterns observed in the assemblage composition, technological and typological charac-

TABLE 6. CHRONOLOGICAL SUMMARY OF THE LATE EARLY AND MIDDLE PLEISTOCENE ACHEULEAN LOCALITIES IN SUB-SAHARAN AFRICA*.

Locality	Area	Country	Chronological Limits		Chronology Notes	MSA Points, Small Handaxes	LCTs Present	Flaking Technology	Genus *Homo* Fossils Present	References
			Lower	Upper						
Period and specification: Late Acheulean, final phase = Final Acheulean (~0.45–0.25 Ma):										
prepared Levallois and blade cores; earliest evidence of MSA archaeology and intensive ochre use; origin of pre-modern *Homo sapiens*; ESA to MSA transition										
Garba III	Melka Kunture	Ethiopia	0.7	0.12	stratigraphic inference	MSA archaeology; retouched unifacial and bifacial points	several small handaxes and cleavers	Levallois cores and blanks	pre-modern *Homo sapiens*	Clark 1982; Chavaillon et al. 1987; Mussi et al. 2014
Upper Herto	Middle Awash	Ethiopia	0.3	0.15	*Homo* fossils ~160 kya on bounded Ar/Ar and geochemical correlation	Levallois points	5% bifaces: cleavers, ovate and triangular handaxes	centripetal discs and Levallois recurrent cores, 1% blades	*Homo sapiens idaltu*	Clark et al. 2003
					Ar/Ar age on tuff below Acheulean horizon 253±47 kya					White et al. 2003
Units N, O, P	Florisbad	South Africa	0.35	0.21	ESR/EU on hominid tooth in deposit 259±35 kya; OSL dates 281±73 and 279±47 kya	MSA archaeology			pre-modern *Homo sapiens*	McBrearty and Brooks 2000
										Herries 2011
Major Unit 3	Wonderwerk Cave	South Africa	0.32	0.25	U series, stratigraphic inference	small bifaces, Levallois points		Levallois cores, blades	genus *Homo*	Beaumont and Vogel 2006; Chazan et al. 2008
Stratum 4a	Kathu Pan 1	South Africa	0.51	0.25	bounded OSL 464±47 kya and U-series/ESR 542+140/-107 kya overlap and 291±45 kya above	MSA archaeology; Levallois and retouched points	handaxes are extremely rare	Levallois and prepared blade cores, blades and flakes		Wilkins and Chazan 2012

*using the following superscript abbreviations for methods: Uran (U-Series and U-Pb variants); Ar-Ar (Argon-Argon); pmag (Paleomag); Chem (Chemical Correlation); OIS (OIS Correlation); biostrat (Biostratigraphy); Infer (Stratigraphic inference or correlation); ESR (Electron Spin Resonance); OSL (Optically Stimulated Luminescence); TT-OSL (Thermally Transferred Optically Stimulated Luminescence); Estimate. Specifications of periods of the Acheulean culture development, in retrospective order:

(1) Late Acheulean, final phase = Final Acheulean (~0.45–0.25 Ma): It is Acheulean with frequent small ovate and pointed handaxes. This group of localities has the latest evidence of cleaver production and the earliest evidence of Levallois and blade prepared core technology with Levallois points and blades, and intensive ochre use in some sites. It holds the ESA to MSA transition and the earliest evidence of MSA archaeology in some regional contexts. Most workers identify the first pre-modern *Homo sapiens* as responsible for this industry.

(2) Late Acheulean, early phase (~0.65–0.45 Ma): It is Acheulean with frequent broad-tipped ovate and pointed handaxes and greatly reduced importance of cleavers. This group contains earliest evidence of intensive on-site resharpening of LCTs for reuse, including increased values of small (<10cm) ovate and pointed handaxes, and blade production from non-prepared cores. This industry is temporally associated with hominids (defined as *Homo rhodesiensis/heidelbergensis*) near the genetically-predicted divergence of Neanderthals and the group that became *Homo sapiens sapiens* in sub-Saharan Africa.

(3) Middle Acheulean (~0.95–0.65 Ma): It is LFB Acheulean as defined by Sharon (2007, 2010). This group of localities often has a high proportion of LCTs, refined handaxes with the prevalence of ovate handaxes with pointed tips; cleavers are frequent and often prevail over handaxes. This group has evidence that LCT production was a fast response to immediate needs and shows a high rate of LCT discard without resharpening for reuse; handaxe and cleaver production on large flakes is common, with variability of large flake technologies for production of LCT preforms from giant cores. Hominids responsible for this industry are generally assigned to *Homo erectus* and, by some authors, to forms similar/transitional to *Homo rhodesiensis/heidelbergensis* in some later sites.

(4) Early Acheulean (~1.75–0.95 Ma): This group of localities has high proportion of LCTs in some sites, among which crudely made handaxes are most common, with the prevalence of pointed (lanceolate) handaxes. Picks are frequent, although cleavers are not frequent. This group has evidence that LCT production was a fast response to immediate needs and shows a high rate of LCT discard without resharpening for reuse. Hominids responsible for this industry are commonly assigned to *Homo erectus sensu lato*.

TABLE 6. CHRONOLOGICAL SUMMARY OF THE LATE EARLY AND MIDDLE PLEISTOCENE ACHEULEAN LOCALITIES IN SUB-SAHARAN AFRICA* (continued).

Locality	Area	Country	Chronological Limits		Chronology Notes	MSA Points, Small Handaxes	LCTs Present	Flaking Technology	Genus *Homo* Fossils Present	References
			Lower	Upper						
Period and specification: Late Acheulean, final phase = Final Acheulean (~0.45–0.25 Ma):										
prepared Levallois and blade cores; earliest evidence of MSA archaeology and intensive ochre use; origin of pre-modern *Homo sapiens*; ESA to MSA transition										
GnJh-03	Kapthurin	Kenya	0.52	0.27	bounded Ar/Ar 284±12 kya above and 509±9 kya below		15 broad ovate handaxes & 6 cleavers	centripetal discs, Levallois and blade cores; 75 blades, 25% of all flakes; blade cores 20–30% of cores		McBrearty and Tryon 2006; Johnson and McBrearty 2010, 2012
GnJh 15	Kapthurin	Kenya	0.52	0.27	bounded Ar/Ar 284±12 kya above and 509±9 kya below	15 small handaxes		multiplatform and Levallois cores, blades, grindstones, red ochre pieces >5kg		McBrearty and Tryon 2006; Johnson and McBrearty 2010, 2012
Site C North	Kalambo Falls	Zambia	0.56	0.29	bounded TT-OSL from 455±103 kya above to 339±49 kya below		picks, handaxes and a few cleavers	prepared and blade cores; low percent of blades		Duller et al. 2015; Barham et al. 2015
Major Unit 4	Wonderwerk Cave	South Africa	0.51	0.35	U series, stratigraphic inference	Levallois points, a few small handaxes	ovate and pointed handaxes; a few cleavers	prepared cores, blades; abundant ochre fragments		Beaumont and Vogel 2006; Chazan 2015
Period and specification: Late Acheulean, early phase (~0.65–0.45 Ma):										
increased values of small (<10cm) handaxes and other evidence of intensive resharpening of LCTs for reuse; broad-tipped ovate handaxes are frequent; greatly reduced importance of cleavers; earliest evidence of blade production from non-prepared cores; origin of *Homo sapiens* sensu lato or *Homo sapiens heidelbergensis*										
Lower Herto (BOU A8, A9, A10, A11, A13)	Middle Awash	Ethiopia	0.48	0.27	Ar/Ar 374±103 kya and stratigraphic inference	often small ovate & sub-triangular handaxes	handaxes and cleavers	non-prepared cores, flakes		Clark et al. 2003 Schick and Clark 2003
GnJh 42, 50	Kapthurin	Kenya	0.55	0.5	bounded Ar/Ar 545±3 kya below and 509±9 kya above		no formal tools	blades 2.5–2.7% of total artifacts; non-prepared cores, flakes	genus *Homo*	Johnson and McBrearty 2010, 2012

TABLE 6. CHRONOLOGICAL SUMMARY OF THE LATE EARLY AND MIDDLE PLEISTOCENE ACHEULEAN LOCALITIES IN SUB-SAHARAN AFRICA* (continued).

Locality	Area	Country	Chronological Limits: Lower	Chronological Limits: Upper	Chronology Notes	MSA Points, Small Handaxes	LCTs Present	Flaking Technology	Genus *Homo* Fossils Present	References
Period and specification: Late Acheulean, early phase (~0.65 – 0.45 Ma):										
increased values of small (<10cm) handaxes and other evidence of intensive resharpening of LCTs for reuse; broad-tipped ovate handaxes are frequent; greatly reduced importance of cleavers; earliest evidence of blade production from non-prepared cores; origin of *Homo sapiens* sensu lato or *Homo sapiens heidelbergensis*										
Hugub	Kesem Kebena	Ethiopia	0.6	0.5	bounded Ar/Ar	high proportion of small ovate and sub-triangular handaxes, with evidence for intensive reuse	137 ovate and pointed handaxes; 2 cleavers	non-prepared cores dominating by unifacial discoids, few blades	genus *Homo* *heidelbergensis*	First publication here
Bodo (U-T Member)	Middle Awash	Ethiopia	0.66	0.52	Ar/Ar and stratigraphic inference		no LCTs	non-prepared cores, flakes	*Homo sapiens heidelbergensis*	Clark et al. 1994; de Heinzelin et al. 2000; Schick and Clark 2003
Elandsfontein	Western Cape Province	South Africa	?	0.6			*Homo* fossils recovered on a deflated surface were not directly associated with lithic artifacts		*Homo sapiens* *heidelbergensis*	Braun et al. 2013, Klein et al. 2007
Period and specification: Middle Acheulean (~0.95 – 0.65 Ma):										
LFB Acheulean as defined by Sharon (2007, 2010); refined handaxes with the prevalence of ovate handaxes with pointed tips; cleavers are frequent and often prevail over handaxes; high proportion of LCTs and other evidence of a high rate of LCTs discard; late *Homo erectus* sensu lato or forms transitional to *Homo sapiens* sensu lato in some sites										
Dawaitoli and Hargufia (U-2 & U-3 members)	Middle Awash	Ethiopia	0.67	?	Ar/Ar 0.64±0.03 Ma below and stratigraphic inference		bifaces, at some localities dominated by cleavers (DAW-A8) or handaxes (HAR-A4)	non-prepared cores dominated by discoids, flakes	*Homo erectus*	Clark et al. 1994; de Heinzelin et al. 2000; Schick and Clark 2003

TABLE 6. CHRONOLOGICAL SUMMARY OF THE LATE EARLY AND MIDDLE PLEISTOCENE ACHEULEAN LOCALITIES IN SUB-SAHARAN AFRICA* (continued).

Locality	Area	Country	Chronological Limits		Chronology Notes	MSA Points, Small Handaxes	LCTs Present	Flaking Technology	Genus *Homo* Fossils Present	References
			Lower	Upper						
Period and specification: Middle Acheulean (~0.95–0.65 Ma):										
LFB Acheulean as defined by Sharon (2007, 2010); refined handaxes with the prevalence of ovate handaxes with pointed tips; cleavers are frequent and often prevail over handaxes; high proportion of LCTs and other evidence of a high rate of LCTs discard; late *Homo erectus* sensu lato or forms transitional to *Homo sapiens* sensu lato in some sites										
Horizons IV-VI at Site A and V-VIII at Site B	Kalambo Falls	Zambia	?	0.17	no precise radiometric dates; U series rough estimate 182±10 kya	some small sub-triangular handaxes	high proportion of LCTs among shaped tools; ovate and pointed (lanceolate or sub-triangular) handaxes, cleavers; predominance of cleavers over handaxes at horizons V-VI at Site A & horizon VII at Site B	non-prepared cores dominating by discoids, few blades		Clark and Cormack. 2001; Roe 2001
Isimila	Isimila	Tanzania	?	0.19	no precise radiometric dates; U series rough estimate 260+40-70 kya		ovate and pointed (ficron) handaxes, cleavers; some localities are dominated by LCTs, others by small tools, like at Olorgesailie	non-prepared cores		Howell 1961, 1972; Sharon 2007

TABLE 6. CHRONOLOGICAL SUMMARY OF THE LATE EARLY AND MIDDLE PLEISTOCENE ACHEULEAN LOCALITIES IN SUB-SAHARAN AFRICA* (continued).

Locality	Area	Country	Chronological Limits		Chronology Notes	MSA Points, Small Handaxes	LCTs Present	Flaking Technology	Genus *Homo* Fossils Present	References
			Lower	Upper						
Period and specification: Middle Acheulean (~0.95–0.65 Ma):										
LFB Acheulean as defined by Sharon (2007, 2010); refined handaxes with the prevalence of ovate handaxes with pointed tips; cleavers are frequent and often prevail over handaxes; high proportion of LCTs and other evidence of a high rate of LCTs discard; late *Homo erectus* sensu lato or forms transitional to *Homo sapiens* sensu lato in some sites										
Mieso 7, Mieso 31	Mieso	Ethiopia	0.8	0.21	Ar/Ar and stratigraphic inference		handaxes and cleavers; predominance of cleavers over handaxes at Mieso 7	non-prepared cores; flake refits at Mieso 31 indicate centripetal or recurrent core reduction and handaxe shaping		de la Torre et al. 2014, Benito-Calvo et al. 2014
Beds 1-3	Cave of Hearths	South Africa	0.78	0.4	ESR on Bed 3 Homo mandible, paleomag,, biostratigraphy		~50/50% handaxes and cleavers or predominance of cleavers over handaxes	non-prepared cores dominating by discoids	genus *Homo*	McNabb et al. 2004; Herries 2011
Masek Beds/ Beds III-IV	Olduvai Gorge	Tanzania	1.19	0.49	Ar/Ar, biostratigraphic and stratigraphic data		handaxes, cleavers are frequent		*Homo erectus*	Leakey and Roe 1994; McBrearty and Brooks 2000
Elandsfontein	Western Cape Province	South Africa	1.1	0.6	biostratigraphic and stratigraphic inference; paleomag	some small handaxes	90% handaxes, 10% cleavers	non-prepared cores, flakes		McNabb et al. 2004; Klein et al. 2007; Herries 2011; Braun et al. 2013
Isenya	Isenya	Kenya	?	0.65			>800 bifaces and 1300 cleavers; predominance of cleavers over handaxes			Roche et al. 1988; Roche and Texier 1991

TABLE 6. CHRONOLOGICAL SUMMARY OF THE LATE EARLY AND MIDDLE PLEISTOCENE ACHEULEAN LOCALITIES IN SUB-SAHARAN AFRICA*(continued) .

Locality	Area	Country	Chronological Limits		Chronology Notes	MSA Points, Small Handaxes	LCTs Present	Flaking Technology	Genus *Homo* Fossils Present	References
			Lower	Upper						
Period and specification: Middle Acheulean (~0.95–0.65 Ma):										
LFB Acheulean as defined by Sharon (2007, 2010); refined handaxes with the prevalence of ovate handaxes with pointed tips; cleavers are frequent and often prevail over handaxes; high proportion of LCTs and other evidence of a high rate of LCTs discard; late *Homo erectus* sensu lato or forms transitional to *Homo sapiens* sensu lato in some sites										
Members 1-11	Olorgesailie	Kenya	1.03	0.66	bounded Ar/Ar		M10-11: mix of sites like M1 and M7;	non-prepared cores	*Homo erectus*	Isaac 1977
							M7: primarily handaxes and cleavers			Deino 1990
							M1: primarily scrapers, few handaxes and cleavers			Potts et al. 1999, 2004
Gombore II	Melka Kunture	Ethiopia	0.89	0.7	bounded Ar/Ar 0.88±0.01, 0.71±0.01 Ma	some small handaxes	142 handaxes, primarily ovates; 7 cleavers	non-prepared cores, flakes	*Homo erectus*	Morgan et al. 2012; Gallotti et al. 2010
Kariandusi	Kariandusi	Kenya	0.98	0.73	Ar/Ar and stratigraphic inference		handaxes; cleavers 17–22%	non-prepared cores		Shipton 2011, Durkee and Brown 2014
Period & specification: Early Acheulean (~1.75 – 0.95 Ma):										
crudely made handaxes with the prevalence of pointed forms; picks are frequent in some sites; cleavers are not frequent; high proportion of LCTs and other evidence of a high rate of LCTs discard in some sites; *Homo erectus* sensu lato										
Dawaitoli and Bodo (U-1 member)	Middle Awash	Ethiopia	?	0.67	Ar/Ar 0.64±0.03 Ma above and stratigraphic inference		crude handaxes & a few cleavers at MAK-A1; at others no LCTs	non-prepared cores, flakes		de Heinzelin et al. 2000; Schick and Clark 2003
Daka Member	Middle Awash	Ethiopia	1.05	0.96	bounded Ar/Ar and stratigraphic inference		crude handaxes and a few cleavers	non-prepared cores, flakes	*Homo erectus*	Schick and Clark 2003; Gilbert and Asfaw 2008

teristics of LCTs, particularly handaxes, and environmental contexts of sites. Some researchers propose that the post-1.0 Ma shift to more refined, thin, and symmetrical handaxes might be related to the transition from *Homo erectus* to a more advanced, post-*erectus* grade of the genus *Homo* (Beyene et al. 2013), referred to as *Homo sapiens sensu lato* by Braüer (1997, 2012) and often referred to as *Homo heidelbergensis* or *Homo rhodesiensis* (for African forms), but well-dated evidence of the beginning of Late Acheulean innovations (discussed below) is absent in Africa. Middle Pleistocene chronological and cultural sequences of the Acheulean are controversial, mostly because of the lack of precisely-dated and rich sites, and the discussion of Acheulean cultural development is largely based on typological criteria.

Many authors recognize a distinct phase of the Late Acheulean in eastern Africa characterized by fewer cleavers, LCTs that are more extensively flaked on both sides, soft hammer produced refined bifaces, the appearance of diminutive ovate and pointed handaxes, and with the introduction of novel flaking technologies, such as blade and Levallois core techniques (e.g., Chavaillon et al., 1979; Clark 1982; Isaac and Isaac, 1977; Johnson and McBrearty 2012; Leakey and Roe 1994; Schick and Clark 2003; Tryon and McBrearty 2002). In addition, some authors recognize the Late Acheulean by a higher frequency of retouched tools and greater selectivity of finer non-volcanic raw materials (Schick and Clark 2003). Also, the earliest evidence of ochre use suggesting the origin of decoration activity is reported from some Late/Final Acheulean sites in Africa (McBrearty 2001).

Some of these indicators should be reevaluated; studies strongly suggest that typological criteria of biface refinement are not sufficient indicators of antiquity (e.g., Deino and Potts 1990; McNabb and Cole 2015; Sikes et al. 1999; Tamrat et al. 1995). McBrearty (2001) proposed that the thinness and symmetric outlines of bifaces found in many African Middle Pleistocene sites might not indicate a greater degree of refinement, but rather the fact they are made on large flakes rather than on cobbles. Also, the soft hammer method and antler hammers do appear in some early Middle Pleistocene sites, as it is documented at Gesher Benot Ya'aqov (Goren-Inbar and Sharon 2006). The significance of Levallois technology also is controversial. Although the presence of Levallois prepared core debitage is a commonly recognized feature of many Late Acheulean sites in Western Europe, Western Asia, and Africa, this technology becomes fully developed only during the final phase of the Late Acheulean, from about 300–350 ka (MIS 9) in all the regions (Adler et al. 2014: Figure 1, Table S6). There are many speculations about how the eventual replacement of the Acheulean LCTs by flakes and blades shaped by prepared core methods denote the beginning of the MSA/MP in Africa and Eurasia (e.g., Baena et al. 2014; Goren-Inbar 2011a; Moncel et al. 2011; Shimelmitz and Kuhn 2013).

In Africa, many core reduction methods for large flake production are known in the Acheulean, and in some of them, including Victoria West, Tachengit, and Tabelbala techniques, cores were prepared to produce predetermined large flakes or even biface preforms requiring minimal refinement (Sharon 2007, 2009; and references therein), just as in the Levallois prepared core technology. However, Acheulean assemblages with typical Levallois products reliably dated older than 500–400 ka are not reported anywhere in Africa. In eastern Africa, the earliest evidence of Levallois production is found at the Kapthurin Formation, in assemblages assigned to Late Acheulean, although their age is not precise and rather broadly determined between ~500–300 ka. In the Kapthurin sequence, there is no Levallois debitage, with the earliest evidence for occasional blade production from non-prepared cores that is found in the earlier Acheulean assemblages dated to ~550-500 ka (Johnson and McBrearty 2010, 2012). Some authors propose a much earlier origin of blade production from prepared cores in the Fauresmith Industry, as in Stratum 4a at the Kathu Pan 1 site, in South Africa (Porat et al. 2010; Wilkins and Chazan 2012). At Khatu Pan, prepared blade cores occur together with classic MSA elements, such as typical Levallois retouched points, some of which functioned as hafted spear tips, and Wilkins et al. (2012) speculate that the evidence from Kathu Pan 1 may indicate the beginning of the MSA in South Africa at about ~500–450 ka (Bednarik 2013; Herries 2011), although the accuracy of dating and stratigraphic relationships of these MSA artifacts relative to the dated layers might be questioned. These estimates dramatically contradict both the well-established $^{40}Ar/^{39}Ar$ chronology of the early MSA in more securely dated eastern African localities (Deino and Potts 1990; Morgan and Renne 2008) and ESR and OSL estimates available for other well-dated Fauresmith-designated assemblages in South Africa (see Herries 2011), and Kathu Pan 1 stands outside the chronological limits of the appearance of blade production from prepared cores in any securely dated contexts throughout Africa and Eurasia (see Adler et al. 2014: Table S6). Thus, in Africa, although the presence of Levallois debitage is well-documented in many latest (Final Acheulean) sites (see Table 6), the origin of prepared core technology during the early Late Acheulean is thus far poorly constrained.

In contrast to the aforementioned remarkable uniformity observed in the morphology and technology among bifacial LCTs in Middle Acheulean/LFB Acheulean sites, Late Acheulean assemblages in Europe, West Asia ,and Africa, from approximately ~0.65–0.6 Ma, exhibit a greater variation in the shape and size of bifaces, comprising a mixture of pointed and rounded (oval-shaped) handaxes with the predominance of either pointed or ovate forms. In addition, flake cleavers are absent or rare in the Late Acheulean and large flake methods are not the primary technology for producing LCT blanks in most regional contexts (Bar-Yosef and Belmaker 2011; Santonja and Villa 2006; Sharon 2007, 2010; Sharon and Barsky in press). Although many explanations of this 'pointed' vs. 'broad' handaxe shape dichotomy refer to the selection of different raw materials used (e.g., Ashton and White 2003), Wynn and Tierson's (1990) comparative study of shapes of Late Acheulean bifaces from Africa and Eurasia suggests that the variation in size explains more than 90% of the variability of biface shape.

During the last twenty years, investigations into how the relationship between size and shape of Acheulean LCTs can determine the duration of repeated biface reduction and thus the presence and intensity of biface resharpening have proven important (e.g., Archer and Braun 2010; Braun et al. 2008; Goren-Inbar and Sharon 2006; Iovita and McPherron 2011; McPherron 1999, 2000, 2003; Noll and Petraglia 2003; Shipton and Clarkson 2015). However, that our knowledge of Acheulean hominid behavioral patterns is most clearly expressed in the production and utilization of bifaces, their function, transport, maintenance, and discard strategies "*is still in its infancy*", and some initial behavioral patterning information is only just emerging (Goren-Inbar and Sharon 2006: 129). In some Late Acheulean contexts in West Europe and West Asia, McPherron (1999, 2003) proposes a reduction model in which pointed bifaces represent an early stage of reduction and small and rounded bifaces are the result of intensive reduction. In contrast, Archer and Braun's (2009) study of the handaxe assemblage from Elandsfontein, South Africa, suggests that ovate and pointed handaxes in the site represent a continuum of shapes that blend into one another, but that pointed shapes appear later in the reduction sequence and are more extensively reduced. Also, some studies demonstrate that resharpening of the tip area may have been the main objective of biface rejuvenation in the Late Acheulean rather than a desired overall shape (Iovita and McPherron 2011).

In the Levant, handaxe resharpening has been argued to be present in some Late Acheulean sites (as at Tabun Cave and Revadim Quarry; Marder et al. 2006; McPherron 2003), but lacking at Gesher Benot Ya'aqov, dating 0.8–0.65 Ma. It has also been argued as representing the African LFB Acheulean tradition (Goren-Inbar and Sharon 2006; Sharon 2010). In Gesher Benot Ya'aqov, it was noted that areas with used and discarded bifaces are deficient in small flaked debitage, suggesting that bifaces were produced somewhere and subsequently transported into the areas where they have been used and discarded (Goren-Inbar 2011b). In Africa, relevant studies of LFB Acheulean assemblages spanning the later Early and early Middle Pleistocene, from ~1.0 thru 0.75 Ma, such as those from Members 1 and 6/7 at Olorgesailie and Kariandusi (Noll and Petraglia 2003; Shipton 2011), suggests that Middle Acheulean hominids employed little biface curation, long distance transportation, and on-site biface reduction or resharpening; they apparently used bifaces for a short time, seemingly as opportunistic and fleeting responses to immediate needs and discarded them immediately after a disposable use. More recently, Shipton and Clarkson (2015) have argued that although some handaxes from Kariandusi and Isenya (0.7 Ma), in Kenya, were probably resharpened (or rather more intensively reduced), that the resharpening was certainly not done extensively. Cave of Hearths in South Africa, dating between 0.7–0.4 Ma, most likely towards the older end of this age range, and Elandsfontein, dating between 1.1–0.8 Ma and apparently closer to 0.8 Ma, represent the most important LFB Acheulean sites that provide rich assemblages of LCTs dominated by mostly ovate handaxes and cleavers made on large flakes; however, the age of the Acheulean levels in both sites is still a matter of debate (Herries 2011). At Elandsfontein, Archer and Braun's (2009) study indicates no evidence of resharpening, but that the morphology of large flakes produced as the dominant LCT blank type and the flaking strategy (reduction sequence) used for biface production are clearly interrelated factors that influence LCT morphological variation. In Cave of Hearths, McNabb and co-authors (2004) note that only a few of more than 200 studied handaxes have been clearly modified after damage, probably, during the production process, although clear evidence of biface resharpening for reuse are absent.

The data discussed above suggest that intensive biface resharpening or reduction thru modification and edge rejuvenation (i.e., the deliberate extension of the life of the tool once it has become nonfunctional for some reasons) appears to emerge after ~0.7 Ma and most likely represents a meaningful behavioral innovation that was practically unknown to earlier Acheulean-making populations of *Homo erectus*. Biface resharpening is not a trait that is characteristic of LFB Acheulean assemblages, most of which are clearly dated to the Middle Acheulean stage (see Table 6). It is indicative that little or no evidence for resharpening was found among the Acheulean bifaces at Kalambo Falls (Edwards 2001). Consequently, there is strong evidence for the evolutionary relationship of the emerging of intensive bifacial rejuvenation/resharpening with the origin of post-*erectus Homo* and the beginning of the Late Acheulean in Africa.

Finalizing the discussion, we conclude, considering the aforementioned data from other sites, that the later Early Pleistocene – Middle Pleistocene Acheulean succession in sub-Saharan Africa includes two distinct cultural phases (see Table 6):

- An earlier phase, between approximately 1.0/0.95 Ma and 0.65/0.6 Ma, which is associated with late populations of *Homo erectus* and the LFB Acheulean, as defined by Sharon (2007, 2010), can be termed Middle Acheulean.
- The later phase, spanning the period from the origin of post-*erectus Homo* around 0.65/0.6 Ma through the ESA/MSA transition at about 0.35/0.3 Ma, defines the Late Acheulean. During this phase, LCTs also were frequently produced on large flake blanks, but final tool shaping involved a much higher intensity of retouch on both faces of the tool, and thus intensive bifacial resharpening emerged; both are related to the appearance of diminutive and intensively reduced handaxes in many sites. An increase in more complex (recurrent) core flaking technologies including the earliest evidence of blade and Levallois production from prepared cores at the end of the Acheulean documents the ESA to MSA transition associated with the appearance of typical MSA archaeology in some regional contexts in sub-Saharan Africa.

CONCLUSIONS

A cascade of significant Late Acheulean changes occurs approximately 600–500 ka, starting with higher intensity of retouch on both faces of LCTs due to resharpening. The earliest evidence of intensive bifacial resharpening in the early Late Acheulean is followed closely by the earliest evidence of blade and Levallois production from prepared cores in the Late Acheulean (specifically the Final Acheulean). The culmination of this technology in Africa is contemporaneous with the emergence of pre-diaspora modern humans, *Homo sapiens idaltu,* during the Acheulean/MSA transition. The African transition from Middle Acheulean to Late Acheulean, the birthplace of these changes, clearly mandates intensive research focus.

However, in Africa, the archaeological record from the beginning of the Late Acheulean is enigmatic because of the lack of precisely dated and rich sites. The Hugub occupation reported here provides the first securely dated *in situ* early Late Acheulean archaeology in Sub-Saharan Africa. Single crystal $^{40}Ar/^{39}Ar$ dates place the archaeological level (Hugub Bed) at 600–500 ka. Hugub is the largest archaeologically-rich paleolandscape known for the time period. It spans the important and poorly-studied interval between rich and well-dated Middle Acheulean sites, like those from the Olorgesailie Formation (Deino and Potts 1990), Dawaitoli Formation at Middle Awash (de Heinzelin et al. 2000), Bed IV/Masek Beds at Olduvai Gorge (McBrearty and Brooks 2000), Gombore II at the Melka Kunture Formation (Morgan et al. 2012), and Late/Final Acheulean sites from the Kapthurin Formation (Johnson and McBrearty 2012) and the Bouri Formation at Middle Awash (Clark et al. 2003; Schick and Clark 2003), and others (see Table 6).

The Hugub assemblage is without analogs in earlier Acheulean localities. In comparison to the Middle Acheulean, which is represented by LFB Acheulean assemblages, the African Late Acheulean, the first signs of which are represented by the early Late Acheulean archaeology of the Hugub locality, shows the earliest usage of plano-convex technique for biface production, the appearance of a significant number of small pointed handaxes (where smaller sub-triangular specimens closely resemble MSA points), a significant decrease in cleavers, and evidence of intensive biface resharpening though modification and edge rejuvenation. The evidence suggests a higher rate of biface curation, longer tool use, and a lower rate of biface discard. Recently recovered, but as yet unanalyzed, hominid teeth and clearly *in situ* evidence of hematite ochre with possible plant imprints further emphasize the importance of the locality. While the occurrence of ochre in the African Late Acheulean has been suggested by some as indicating symbolic behavior, others contend that it might actually be related to mastic preparation and hafting technology (Bednarik 2003, 2013; Lombard 2006; McBrearty 2001; McBrearty and Tryon 2006).

We conclude that the Hugub site documents the initial emergence of new patterns of biface manufacture, maintenance, use, and discard that are further developed through the Late Acheulean. This post-*erectus* African group, identified in the early MSA by highly-intelligent complex behaviors such as hafting, intensive tool curation, long-distance transport, projectiles, ochre use, and indications of symbolic expression, is presaged at Hugub. There is a high potential for Hugub to continue to yield deeply meaningful information about the transition from Middle to Late Acheulean, the origin of Late Acheulean behavioral and technological changes, and how these relate to the cultural environment surrounding post-*erectus Homo* in Africa.

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