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The Middle Stone Age archaeology of the Lower Omo Valley Kibish Formation: Excavations, lithic assemblages, and inferred patterns of early *Homo sapiens* behavior

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ABSTRACT

This paper describes the excavation, stratigraphy, and lithic assemblages of Middle Stone Age sites from the Omo Kibish Formation (Lower Omo Valley, southwestern Ethiopia). Three sites were excavated, two in Kibish Member I (KHS and AHS) and one at the base of Member III (BNS). The assemblages are dominated by relatively high-quality raw materials procured as pebbles from local gravels. The principal modes of core preparation are radial/centripetal Levallois and discoidal. Retouched tools are rare. Foliate bifaces are present, as are larger tools, such as handaxes, picks, and lanceolates, but these are more common among surface finds than among excavated assemblages. Middle Stone Age assemblages shed light on the adaptations of the earliest-known *Homo sapiens* populations in Africa.

Introduction

Archaeological research on modern human origins has long focused on the Middle–Upper Paleolithic transition in western Eurasia. Recently, however, it has increasingly focused on the African Middle Stone Age (MSA). The earliest skeletally modern-looking humans occur in African MSA contexts (Stringer, 2002). There is also evidence that derived behavioral features of the Eurasian Middle–Upper Paleolithic "human revolution" have a much greater antiquity in Africa (McBrearty and Brooks, 2000; Henshilwood and Marean, 2003). Unfortunately, many key African early *Homo sapiens* fossils lack reliable dates and good information about their archaeological associations. Until recently, the early *H. sapiens* fossils from the Kibish Formation of the Lower Omo River Valley, Ethiopia, were one such poorly dated and archaeologically undocumented set of remains. New $^{40}Ar/^{39}Ar$ dates on feldspar crystals within pumice clasts in the Kibish Formation (McDougall et al., 2005) have changed this picture dramatically. The age estimate of 195 ± 5 ka for Kibish Member I makes the Omo I and II fossils the earliest *H. sapiens* known to science. The Omo Kibish fossils' archaeological associations are clearly germane to recent debate about the mode and tempo of later Pleistocene human evolution.

In announcing their discovery of the Omo Kibish hominins, Leakey et al. (1969: 1132) reported that Omo I was associated with "flake debris." Butzer et al. (1969: 19–20) later elaborated, describing the fossils' archaeological associations thusly: "Some 69 stone artifacts were also recovered, 9% of them water-worn. They are undiagnostic, except for 5 utilized or retouched Levallois flakes." For more than thirty years nothing more was added to the archaeological record of the Omo Kibish humans.

This paper reports the results of renewed archaeological research in the Omo Kibish Formation between 2001 and 2003. It focuses on the excavation and lithic assemblages recovered from three main archaeological sites: KHS, AHS, and BNS (Fig. 1; Table 1). A description of the lithic analysis framework used in this study is presented in the Appendix. A separate paper in this volume by Sisk and Shea (2008) presents information about intrasite spatial patterning of lithic artifacts and refitting studies. Faunal remains associated with these lithic assemblages are reported separately in this volume by Assefa et al. (2008).

The MSA archaeology of the Omo Kibish Formation provides a glimpse of human behavior near the origin of our species. Comparison of the Kibish assemblages with other MSA assemblages suggests that the Kibish humans were part of a regional hominin

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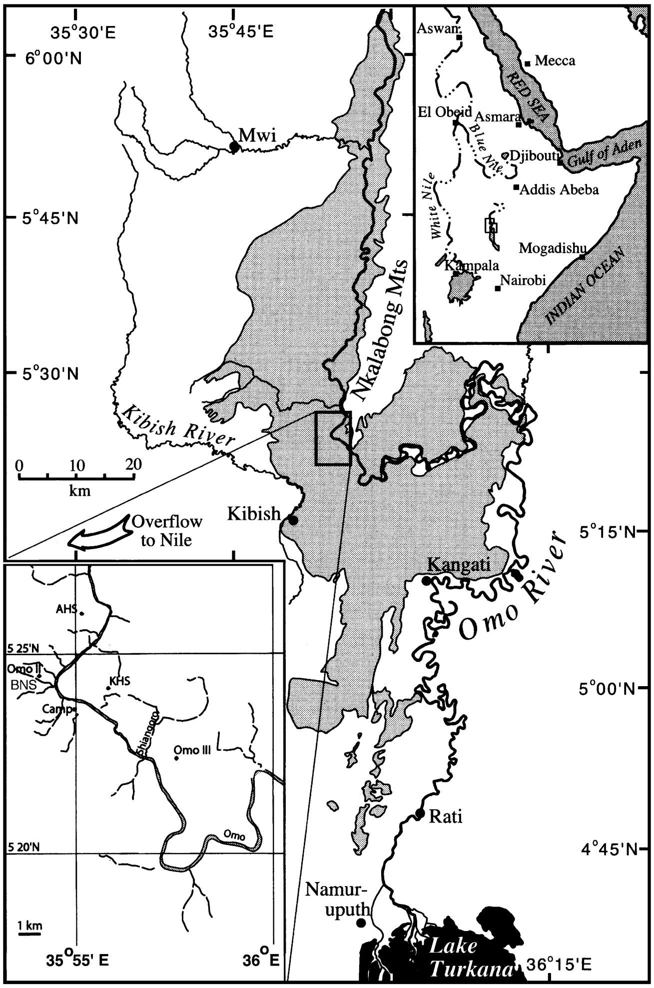

Fig. 1. Map Showing the Kibish MSA sites in relation to local landscape features.

population practicing broadly similar adaptations in eastern Africa between 250 ka and 50 ka.

Kamoya's hominid site (KHS)

Kyamoya Kimeu discovered KHS, the findspot of the Omo I fossil, during the 1967 Kenyan expedition to the Lower Omo Valley. The KHS locality is situated at 432 m above sea level on the northern side of the Omo River at N 05° 24.152′, E 35° 55.812′ (UTM 36 N E 0824747/N 0597940). The site is a low promontory of Member I sediments about 20 m long and 9 m wide jutting west from a hill capped by about 10 m of Member II sediments (Figs. 2 and 3). Although more than thirty years had passed since the Leakey excavations, it was still possible to detect the faint outlines of their trench on the south side of the promontory. However, because there was no sign of Leakey's site datum, we established our own datum at the westernmost edge of the promontory.

Excavation of KHS

Some fossils and artifacts were collected from the surface of KHS during 2001, but systematic surface collection and excavation began in 2002. Except for the clearing of sterile overburden in 2003, all sediments were excavated with trowels and screened through a 50-mm wire-cloth mesh. Workers from the nearby Mursi community assisted in clearing sediments and screening. The focus of our research was the "minor disconformity" that previous excavations reported as the source of the Omo I fossil and its associated archaeological assemblage (Leakey et al., 1969).

Our first step in 2002 was systematic surface cleaning in the declivity immediately south of the Leakey trench. This effort exposed a few nonhuman vertebrate fossils and a dense concentration of stone tools in and around square E7/S5, about 2 m below datum and roughly 0.5–0.7 m below Levels 2–3. The loose sand in which these artifacts were found suggested that they had been eroded into their present position during the last thirty years. Once we located the in situ deposits of Levels 2–3, our excavation proceeded northwards along a broad front, culminating (in 2003) with a narrow trench across the promontory. This excavation yielded small numbers of bone fragments and stone tools. By the end of 2003, excavations at KHS had exposed a total of 23 m^2 of KHS Levels 2–3. During those times when the excavation at KHS was stopped (the crew having been relocated to other sites), J. Trapani led a group of Mursi workers in systematically scraping and sifting the sediments in the gully to the south of KHS. This operation recovered several fragmentary hominin fossils, some nonhuman vertebrate fossils, and stone artifacts, all eroded downslope from KHS. The gullies to the east and north of the site were also surface-collected, mainly by J. Shea, Z. Assefa, and J. Fleagle.

Kamoya's Hominid Site encapsulates the uppermost 5 m of Kibish Member I (i.e., Leakey's beds g–h). These strata, previously described by Leakey et al., (1969), are correlated with our archaeological stratigraphy in Table 2. On the basis of McDougall et al.'s (2005) chronology for the Omo Kibish Formation, we estimate the date of the deposition of KHS Levels 2–3 to be 195 ± 5 ka.

The principal archaeological stratum at KHS is Level 3 (Fig. 4). Located roughly 1.5 m below datum, it overlies an erosional disconformity at the top of Level 4. Level 3 is typically no more than

Table 1
Overview of major sites in the Omo Kibish Formation

Site	KHS	PHS	AHS	BNS
Year discovered	1967	1967	2003	2002
Location and elevation (amsl)	N 05° 24.2′ E 35° 55.8′ +432 m	N 05° 25.5′ E 35° 55.5′ +435 m	N 05° 26.0′ E 35° 55.2′ +412 m	N 05° 24.5′ E 35° 54.0′ +424 m
Kibish Member	I	I	I	Top of II/base of III
Hominin fossils	Omo I	Omo II	Omo IV	None
Area excavated (m^2)	23	None, surface prospection only	17	46
Depth of cultural levels	2–6 cm	None	Levels 1–5 = 100 cm Levels 6–8 = 20 cm	2–10 cm
Archaeology	Small lithic assemblage associated with several vertebrate fossils (a bird, a bovid)	None. Some isolated cores and flakes found on same hillside, but several meters lower than the reported findspot of Omo II	Multicomponent site (10 levels) containing rich lithic and faunal assemblages; Omo 4 is from Level 6	Single-level site with rich lithic assemblage, sparse faunal remains

Fig. 2. KHS (view north) during 2003 excavations (J. Shea photo).

2–6 cm thick in any particular square. Level 3 is relatively soft, with a clayey consistency in its easternmost exposures. It is cemented by carbonate concretions in the western part of the site (i.e., west of E5), where it thins and eventually disappears. Level 3 is overlain by Level 2, a tan silty layer of variable thickness (but never more than 1–2 cm). Most of the artifacts and fossils (all nonhuman) recovered in situ were either embedded in Level 3 or at the contact of Levels 2 and 3. Further description of the KHS assemblage combines Levels 2 and 3. The total exposure of KHS Levels 2–3 was coterminous, amounting to approximately 23 m^2. A few nonhuman vertebrate fossils, including several articulated bones of a large bird, were recovered from baulk cleaning and test trenching in Level 4, but these were confined to the immediate surface of this level.

KHS lithic assemblage

A summary of the KHS lithic assemblage in terms of recovery zones, artifact types, and lithic raw materials is presented in Table 3. Nearly half of the KHS assemblage (48%) derives from the South Gully screening operation. A further substantial portion of the assemblage (26%) was recovered from controlled excavation of Levels 2–3. All of these artifacts derive from KHS Levels 2–3, and the remainder of this analysis will treat them, along with finds from the surface of KHS, as well as those from the East, South, and North gullies, together as components of the same “KHS” assemblage. In July 2005, the author traveled to National Museums of Kenya in order to examine artifacts from The excavation by Leakey and colleagues in 1967 at KHS (Leakey et al., 1969). These artifacts were measured, drawn, and are also included as part of the KHS assemblage.

The lithic raw materials of the KHS assemblage are predominantly fine-grained cryptocrystalline silicate rocks, jasper, chalcedony, and chert. Coarser-grained and less-siliceous rocks are less common. One of the less common lithic materials found at KHS merits special comment. Square S3/E6 preserved 26 fragments of a white-green highly siliceous rock in a small (5-cm-wide) cluster. Frank Brown (pers. comm.) later identified this material as opal silica. These fragments appear to reflect the in situ decomposition of an opal-silica artifact. Although it is bright and visually striking, this material has poor conchoidal fracture properties. The nearest source of such opal silica is precipitate deposits lining the hot springs 20 km north of our research area in the Omo National Park. This opal silica is unique among the lithic materials in the Kibish MSA assemblages in that we never encountered it in our surveys of Kibish Member I gravel deposits.

Technologically, the KHS assemblage is dominated by debris (44%) and flakes and flake fragments (43%). While there are a few tools with weathered edges and surfaces suggesting fluvial transport, the surfaces and edges of nearly all of the flakes from the KHS excavation are in fresh condition, as are a remarkably large proportion of the gully-collection artifacts. These observations suggest that KHS experienced minimal fluvial disturbance between the deposition of Level 3 and its burial under Level 2. Retouched tools are somewhat more abundant in the Kenya 1967 assemblage than in the 2002 collections, but unretouched flakes are present as well, suggesting that this difference is not the

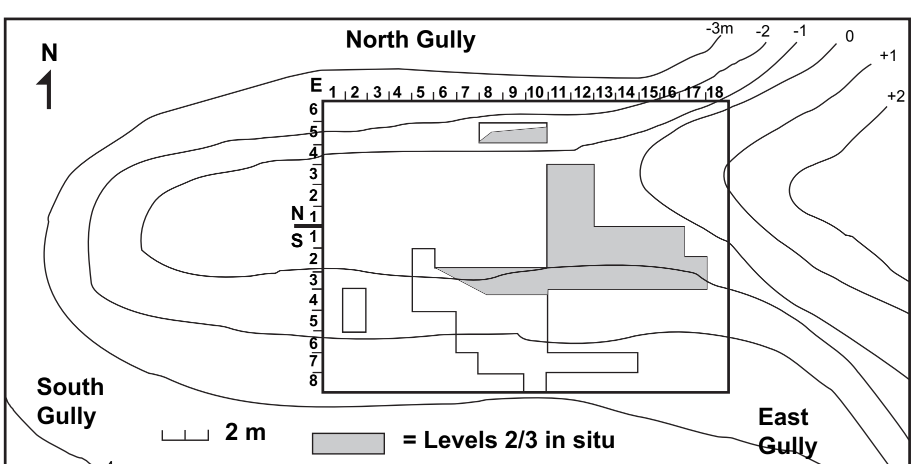

Fig. 3. Plan of KHS excavations.

Table 2
KHS stratigraphy

Level	Matrix and approximate elevation below datum in SW corner of E11/N1.	Lithics	Fossils
1	Pale-brown silty-clay loam with abundant limonitic staining (−0.5–1.70 m). Equivalent to Leakey et al.'s (1969: 1134) level (e). Total depth of Level 1 is approximately 1.5 m.	Absent	Absent
2	Pale-gray tan silt (−1.70–1.72 m).	Absent? (Base of unit only)	Absent? (Base of unit only)
3	Dark-brown clayey loam overlying an erosional (−1.72–1.75 m)	Present	Present
4	Pale-brown silty-clay loam with small ferruginous concretions (−1.75–1.80+ m). Equivalent to Leakey et al.'s (1969: 1134) level (d). Total depth of Level 4 is approximately 0.8 m.	Absent	Present on surface only

result of a systematic collection bias. Richard Leakey and Paul Abell report having piece-plotted artifacts recovered by their excavations. Sadly, and despite a concerted search, the records of this excavation cannot be located.

There are 24 cores in the KHS assemblage (Fig. 5). Most are made of high-quality rocks, jasper, chalcedony, and chert. Fully half of the cores in the KHS assemblage are Levallois cores. Of the latter, most are radially/centripetally prepared and less than 3 cm long. Many of the cores were abandoned after the removal of either a single central flake or an overshot/"plunging" flake. Table 4 presents the descriptive statistics for the measurements of the KHS core sample.

There are 294 debitage products in the KHS assemblage, of which nearly half are debris (Fig. 6). As with the cores, jasper, chalcedony, and chert predominate among the raw materials. The predominance of initial and residual cortical flakes among the whole flakes suggests that the primary reduction of raw material cobbles and pebbles played a significant role in the formation of the KHS assemblage. The noncortical component of the whole flakes features Levallois flakes, Levallois blades, core-trimming elements (mostly overshot Levallois flakes), and pseudo-Levallois points. Only 26 of the whole flakes from KHS are sufficiently large and complete to allow the full suite of technological measurements to be made on them (see also Table 4). (Whole flakes that were not measured possessed either cortical or crushed striking platforms whose dimensions could not be measured accurately.)

There are 20 retouched artifacts in KHS (Fig. 7). The largest of these is an ovate handaxe (KHS #57) collected a few meters downslope of the KHS Levels 2–3 outcrop in the South Gully. The remainder consists of retouched flakes. Among these, sidescrapers and backed knives are the most common. "Backing" among the KHS retouched tools is minimally invasive and does not appear to have altered the flake's original shape. Coarse-grained raw materials (rhyolite and basalt) are somewhat more common among the retouched tools than the rest of the assemblage, but small sample sizes preclude inferring much from this difference. The mean values for key technological variables on these retouched flakes (see also Table 4) do not differ significantly from those of the whole flakes in the KHS assemblage. This finding suggests that the retouched flake tools from KHS are not substantially modified or "curated" by resharpening.

There are two hammerstones in the KHS assemblage. One is a small use-pitted basalt cobble comprising two conjoining fragments that apparently split along a natural flaw (see Fig. 7i). The other is a large, circular basalt cobble with pitting and a set of large fractures (see Fig. 7h). This second hammerstone was found on the surface in the gully north of the site and is much larger than any of the other components of the KHS assemblage.

Postexcavation analysis of the KHS assemblage revealed 27 refitting "constellations" (sets of artifacts that refit to one another). These are described and illustrated in detail in Sisk and Shea (2008). Of these constellations, fifteen are "refits," or tools that were separated by conchoidal fracture. The remainder are conjoins, mostly fragments of the same flake. Among the refits, core preparation, exploitation, and rejuvenation/termination are about evenly represented. Only two constellations involve more than one of these technical operations. Scar-pattern variation on the refitting constellations from KHS suggest that initial pebble and cobble reduction involved unilinear flake removals that gradually became more radially and centripetally directed as core size diminished. Most refitting sets of flakes were either fragments of the same flake or flakes removed consecutively that conjoined along their lateral margins.

KHS faunal evidence

Nonhuman vertebrate faunal remains from KHS included those of *Kobus ellipsiprymnus*, *Phacochoerus*, *Hippopotamus*, and an unidentified suid. These remains are described in this volume by Assefa et al. (2008).

Interpretation of KHS

The KHS archaeological occurrence is, in essence, a small patch of lithic artifacts associated with a fragmentary human skeleton. The nature of this association has recently been called into question, largely on the basis of perceived morphological differences between

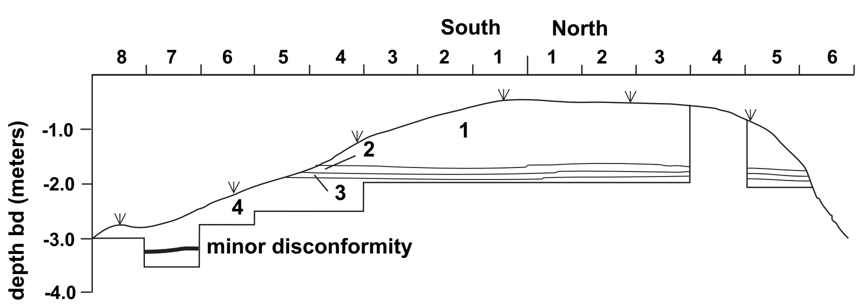

Fig. 4. Profile of KHS stratigraphy along E10/N6–S8.

Table 3
Summary of KHS assemblages: Artifacts by proveniences and rock types

Tool group	Tool type	*n* (subtotal %)	% without debris	KHS level 2/3	KHS surface	E Gully	N Gully	S Gully	NM Kenya	Jasper	Chalcedony	Chert	IOCCS	Shale	Rhyolite	Basalt	Ind. volc.
Core																	
	Unifacial chopper	1	0.5				1									1	
	Bifacial chopper	2	1.0	1					1		1				1		
	Core scraper	1	0.5						1							1	
	Polyhedron	1	0.5				1			1							
	Asymmetrical discoid	1	0.5	1							1						
	Levallois core	10	5.1	4				6		5	2	3					
	Other core type	2	1.0	1				1		1		1					
	Core fragment	6	3.1	1				3	2	3		2		1			
	Core subtotal	24 (7.0)	12.3	8			2	10	4	10	4	6		1	1	2	
Debitage																	
	Cobble fragment	3	1.5					1	2			1	1	1			
	Initial cortical flake	19	9.7	2				16	1	5	4	8				1	1
	Residual cortical flake	25	12.8	2		1	1	12	9	6	5	6		1	1	5	1
	Levallois flake	10	5.1	1				6	3	4	1	3		1		1	
	Levallois blade	2	1.0					2		1		1					
	Pseudo-Levallois point	5	2.6					2	3	2				1	1	1	
	Noncortical flake	13	6.7	3		1		4	5	2	1	2	2	2		2	2
	Core-trimming element	6	3.1	2				4		3	2	1					
	Flake fragment, proximal	22	11.3	5	1		2	12	2	5	7	5	1	1		1	2
	Flake fragment, other	40	20.5	8		5	3	19	5	8	7	10	1	1	2	8	3
	Blocky fragment	1	0.5						1							1	
	Flake subtotal	146 (42.6)	74.9	23	1	7	6	78	31	36	27	37	5	8	4	20	9
Debris																	
	Debris and subtotal	148 (43.1)	75.9	58	2			68	20	60	19	55	1	3	2	8	
Retouched tool																	
	Point/triangular flake	1	0.5						1	1							
	Sidescraper	4	2.1				1		3	1		1		2			
	Convergent scraper	1	0.5						1			1					
	Awl	1	0.5					1									1
	Backed knife	3	1.5	1				2				3					
	Notch	1	0.5						1						1		
	Denticulate	4	2.1					1	3			1			1		2
	Other retouched flake	4	2.1						4					2	2		
	Handaxe	1	0.5					1								1	
	Retouched tool subtotal	20 (5.8)	10.3	1			1	5	13	2		6		4	4	1	3
Hammerstone																	
	Hammerstone and subtotal	2 (0.6)	1.0				1	1								1	1
Total																	
	n	343 (100.0)		90	3	7	10	162	68	108	50	104	4	16	11	32	13
	% without debris		100.0	16	1	4	5	48	25	25	16	25	2	7	5	12	7

Note: IOCCS = indeterminate/other cryptocrystalline silicate, Ind. volc. = indeterminate volcanic.

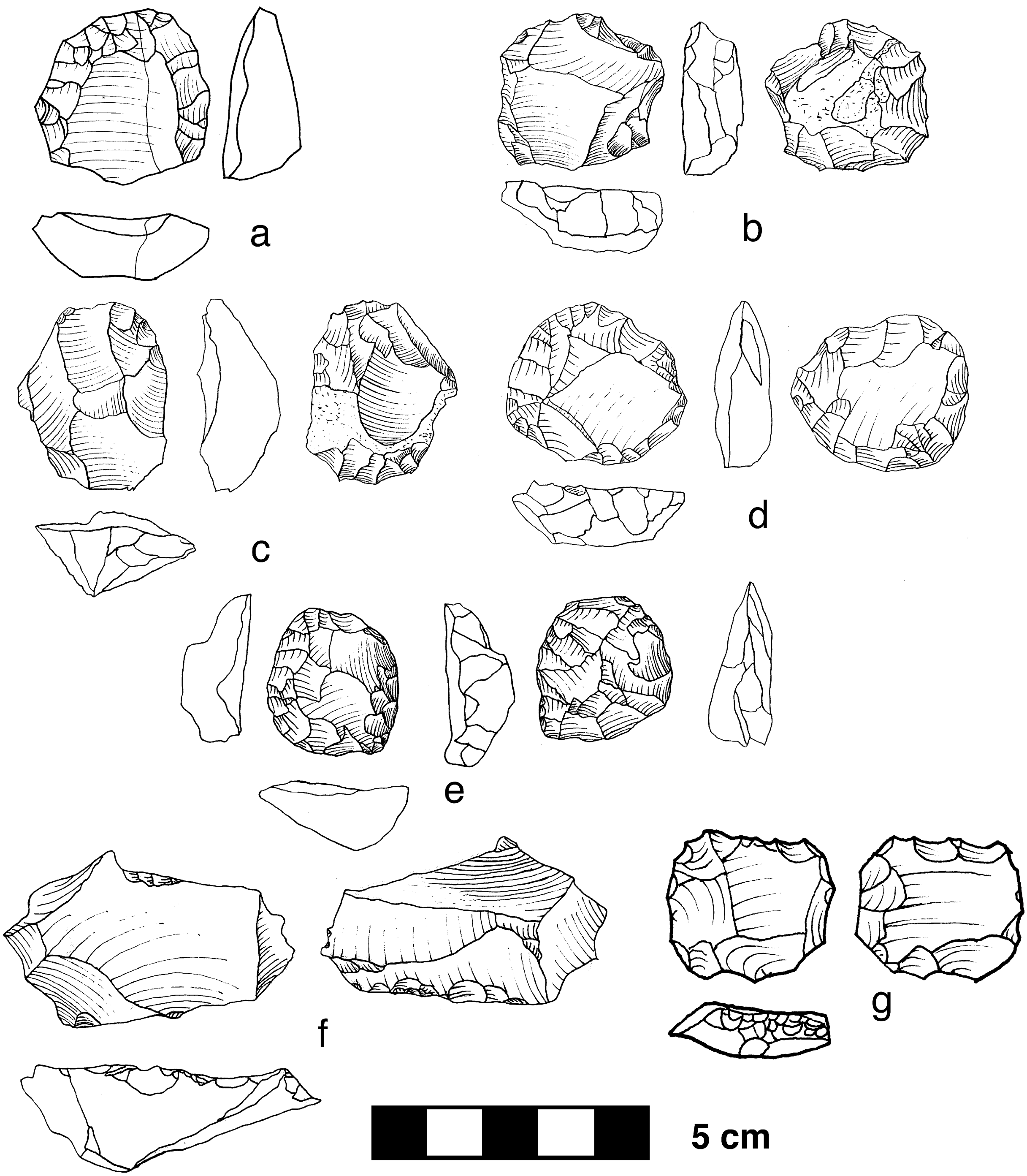

Fig. 5. Cores from KHS: (a–c) Levallois cores, (d, e) asymmetrical discoids, (f) core remnant of overshot flake, (g) core-on-flake fragment. (Note: g is from the Omo 1967 Collections in the National Museums of Kenya.)

Table 4
Descriptive statistics for measurements (in mm) of cores from KHS

	Length	Width	Thickness	Volume (cm^3)
Mean	45	37	18	86
Median	33	27	12	10
Standard deviation	30	24	15	202
Minimum	23	22	7	5
Maximum	120	104	56	699
Count	12	12	12	12

the Omo I and Omo II crania. "A stark morphological contrast between Omo-Kibish 1 and Omo-Kibish 2 may mean that one (or both) were intrusive into the stratigraphic unit they derive from, and Omo 1 (more modern) may be much more recent" (Klein, 1999: 397). Although our excavation did not recover any hominin remains in situ at KHS, all of the stone tools and nonhuman fossils we recovered were either from Levels 2–3 or (in the case of the human fossils we did recover) found in near-surface contexts at lower elevations than Levels 2–3. No archaeological residues were found in the immediate vicinity of the KHS excavation at an elevation higher than Levels 2–3. Thus, our findings reinforce Leakey et al.'s (1969: 1132) original observation that "the Omo I skeleton alone was associated with a small number of stone artefacts and some animal

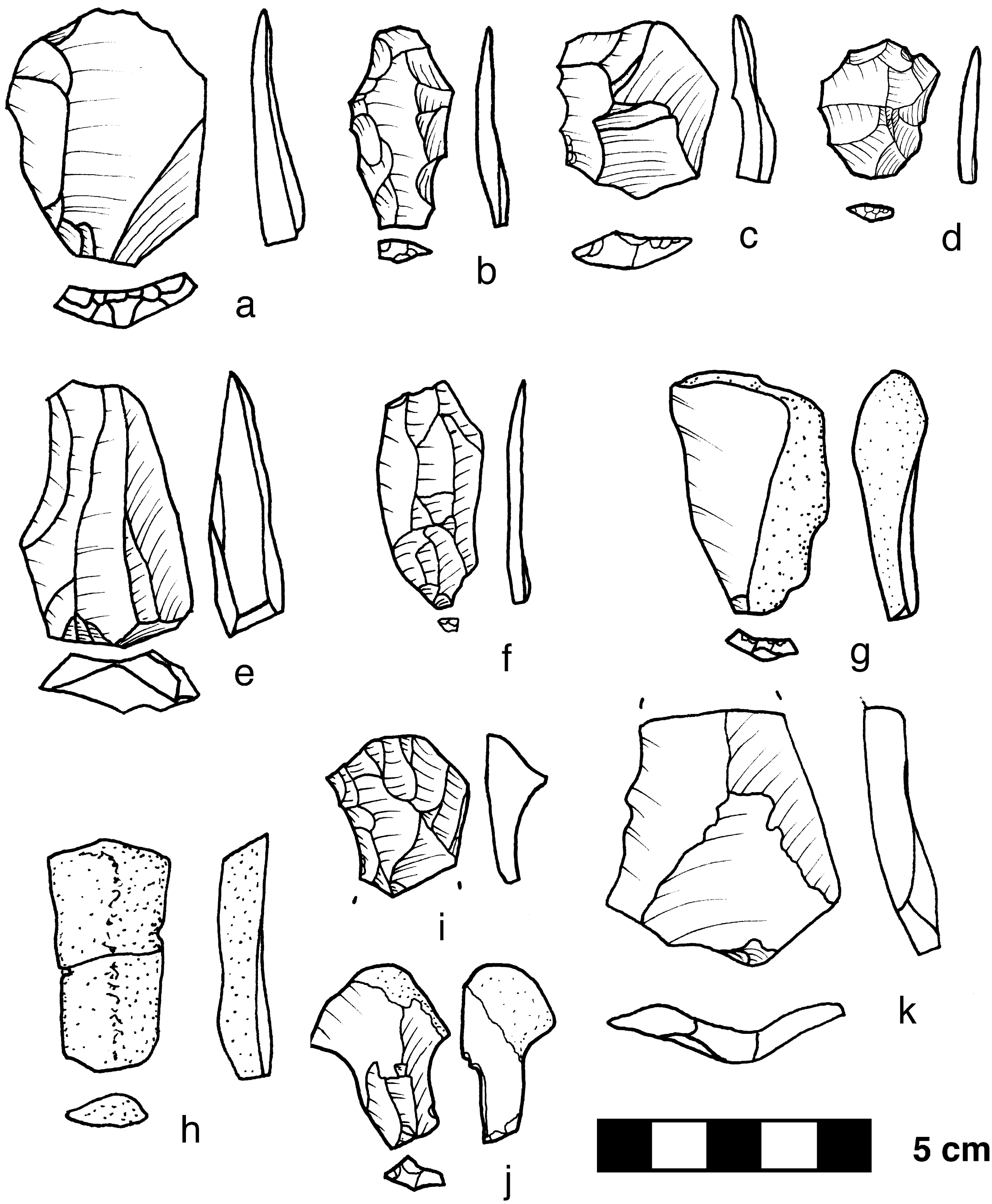

Fig. 6. Debitage from KHS: (a–d) Levallois flakes, (e, f) noncortical flakes, (g, h) cortical flakes, (i) core-trimming element (distal fragment of an overshot flake), (j) core-trimming element (overshot flake), (k) proximal fragment of Levallois flake or point. (Note: a, c, d, and k are from the Omo 1967 Collections in National Museums of Kenya.)

bone debris. Excavation of site KHS yielded some material *in situ* and established the provenance of the Omo 1 skeleton in the stratigraphy of the Kibish deposits." This fossil's relative completeness is unusual among African middle Pleistocene hominin remains, but it is not unique in the paleontological record of the Kibish Formation. Indeed, Leakey et al. (1969: 1132) recovered the complete skeleton of a buffalo "from the same horizon in which the Omo I skeleton was found," and our own excavations revealed relatively complete skeletal remains of a large bird at KHS (at the Level 3/4 interface) (see Louchart, 2008). The most likely scenario for the formation of this site is that the Omo I individual died and was rapidly covered by sediment at about the same time as the archaeological remains were deposited at KHS, ca. 195 ka ago. We cannot know if Omo I participated in creating the KHS assemblage; however, we can be confident that if Omo I was not among them, then he was a near contemporary of the KHS toolmakers.

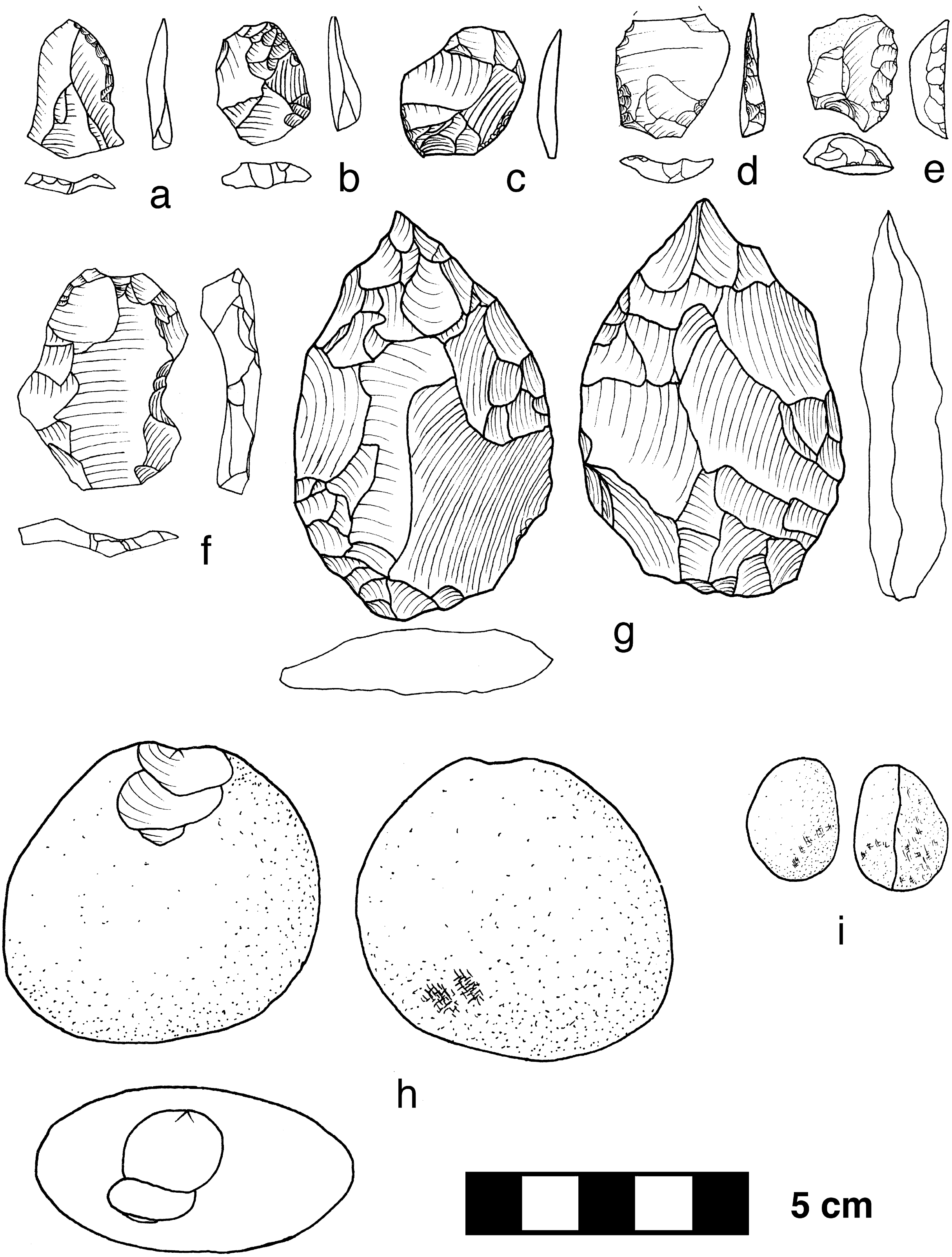

Fig. 7. Retouched tools and hammerstones from KHS: (a) retouched Levallois point, (b–d) scrapers, (e) scraper and notch, (f) notch on overshot Levallois flake, (g) handaxe, (h,i) hammerstones. (Note: a–d and f are from the Omo 1967 Collections in National Museums of Kenya.)

Awoke's hominid site (AHS)

Awoke's Hominid Site is located 412 meters above sea level at N 05° 26.037′, E 35° 55.171′ (UTM 36 N E 0823557/N 0601414) on the southern side of the Omo River. Awoke Amzaye discovered AHS in 2003, and collected a hominin tibial fragment from its surface. Archaeological sediments at AHS have eroded from the north-western side of a small hill about 0.5 km south of Mushu, an unoccupied Bumi village. The AHS hill is one of many clustered together in this area and was initially recognized because numerous fossils and stone artifacts were exposed on a level area on the side of the hill (Fig. 8). A fresh break on the hominin tibial fragment also suggested that more remains of this individual might be recovered. Because AHS was discovered in the last two weeks of the 2003 season, and because it was located a considerable distance from our base camp in Rhino Canyon, excavation at AHS was more exploratory than at KHS or BNS.

Excavation of AHS

The investigation of AHS began with a systematic surface collection carried out by J. Fleagle, A. Amzaye, and J. Shea. Four $5 \times 5\ m^2$ collection squares were set up, two to the north of the hominin fossil findspot (Collection Areas 1 and 2) and two to the south (Collection Areas 3 and 4). A fifth collection area (Collection Area 5) was set up to the west of Collection Area 4, on a steep, thorn-covered slope. Amzaye, Fleagle, and Shea made the surface collections over an area of about 117 m^2.

Excavations were carried out with hand tools and all sediments were sifted through a 50-mm wire-cloth mesh. Bumi workmen from Kibish assisted in the screening operation. The excavation datum for AHS was located approximately 9 m northwest (magnetic) of the hominin fossil findspot. The AHS excavation consisted of two trenches that were eventually linked at their origin (Fig. 9). The first was a narrow stratigraphic trench (S7/E1–8) running from about 1 m below the hominin tibia find to approximately 2 m above it, halfway to the crest of the hill (Fig. 10). The second trench focused on the area surrounding the hominin tibial fragment. The excavation of the latter trench was immediately successful, as a conjoining fragment of the same tibia and a fibular fragment from Level 6 were recovered on the first day of excavation. Our excavations at AHS exposed 17 m^2 to a depth of at least −2.0 m below datum.

The stratigraphy of AHS is a sequence of sand levels with varying silt and humus components. Ten major levels were recognized, though some of these were not originally distinguished during the course of excavation (Table 5). Peak densities of lithic remains and vertebrate fossils occur in Levels 3–4 and 6. Most of the rest of the AHS lithic assemblages come from levels contiguous to Levels 3–4 and 6 or from excavation units that were inadvertently combined with these excavation levels. Levels 8–10 were archaeologically sterile. The distribution of faunal remains also supports the conclusion that Levels 4 and 6 are the main anthropological horizons. One interesting aspect of the AHS stratigraphy noted in the profiles was the presence of "*terriers*," intrusive features that resemble shallow pits or post-molds. They might also include animal burrows. These features clearly require closer scrutiny in any future excavations at AHS.

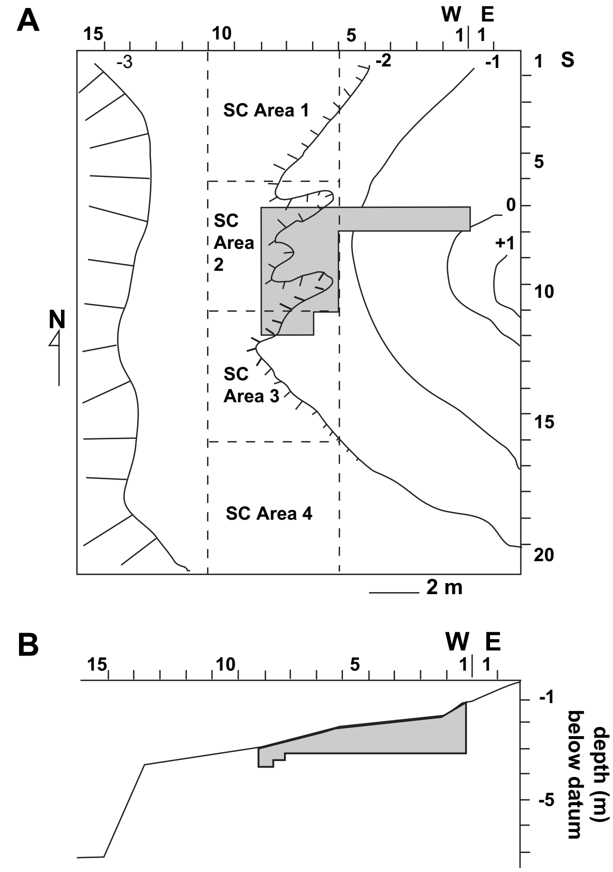

Fig. 9. AHS excavation: (A) plan view showing excavated area (shaded) and surface collection (SC) areas; (B) cross section.

Fig. 8. AHS (view east) at conclusion of 2003 excavations (J. Shea photo).

AHS lithic assemblage

Table 6 summarizes the contents of the AHS assemblage in terms of provenience, artifact categories, and raw materials. For the purpose of this analysis, the lithic artifacts from Levels 1–5 and those from Levels 6–8 will be treated separately as "AHS 1–5" and "AHS 6–8" assemblages. This presentation obviously conflates assemblages from separate levels, but it is a realistic reflection of the uncertainties we faced in excavation. Many of the stratigraphic levels at AHS are so similar to one another in appearance that the disconformities separating them could only be recognized in retrospect during profile cleaning. The surface-collected assemblage is tabulated separately, because its contents undoubtedly reflect collection biases. The AHS Surface, Levels 1–5, and Levels 6–8 are all dominated by debris, and thus, for clarity, tabulations of artifact categories are also tabulated without debris in the denominator. Time constraints precluded detailed analysis of the vast quantity of debris from this site, and thus the counts of raw materials are unaffected by the exclusion of debris from totals.

The AHS assemblages feature an extraordinary diversity of lithic raw materials. Chert is the most common material (43%) by several orders of magnitude over the other rock types. Rhyolite and shale

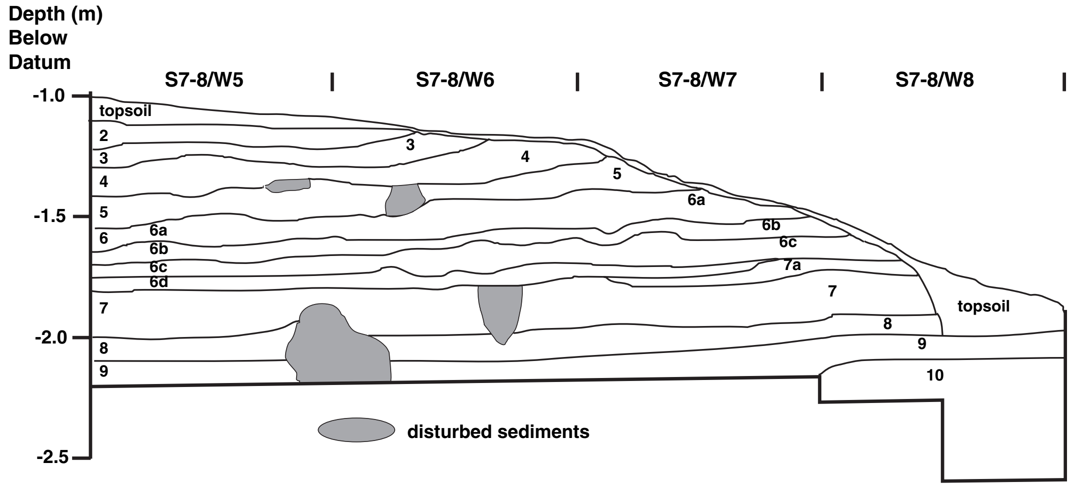

Fig. 10. AHS excavation profile along Units S7–8/W5–8. Shaded areas are intrusive features (either post-molds, pits, or animal burrows).

are the next most common raw materials. A substantial proportion of artifacts is classified as "indeterminate/other cryptocrystalline silicate" (IOCCS in tables). The latter remains are represented either by single artifacts or small numbers of flakes, very often ones from either the same or contiguous excavation squares. Fine-grained silicate rocks (jasper, chalcedony, chert) are somewhat more common in the AHS Surface and AHS 6–8 subassemblages (71% and 74%, respectively) than in AHS 1–5 (52%).

Two of the less common materials at AHS merit comment. Like KHS, AHS also preserves pieces of opal silica. One of these was a surface find. The other was recovered from AHS Level 6. These artifacts neither refit nor conjoin to one another, nor do they appear to have been knapped. Again, it is possible that this material had some other purpose than raw material for flaked stone production. Also notable at AHS is a variety of pink shale. This material has a very low silica content; nevertheless, it was the focus of considerable lithic reduction. One can only speculate that it may have been the color or some other property of this material that influenced its intense reduction.

Flakes and flake fragments dominate the nondebris subassemblage from AHS. Among the artifacts recovered by excavation, artifact surface preservation is generally excellent. Basalt artifacts are somewhat more weathered than those made of fine-grained silicate rocks, but this is the case in all of the Omo Kibish MSA samples. Retouched tools are more common among the surface collection. This could reflect collection bias, the equifinality of retouch and postdepositional surface modification, or both.

A total of 35 cores were recovered from AHS (Fig. 11). Asymmetrical discoids are the most common core type in both surface and excavated assemblages. The Levallois core component of this assemblage is composed exclusively of Levallois flake cores, typically ones with a single, relatively large preferential central flake scar. There are some differences in the frequencies of core types among the AHS Surface, Levels 1–5, and Levels 6–8 subassemblages, but the numbers of artifacts involved are so small as to preclude an assessment of the statistical significance of these differences. Descriptive statistics for the measurements made on the AHS cores are presented in Table 7.

The nondebris flake component of the AHS assemblage contains 1260 artifacts (Fig. 12). Initial and residual cortical flakes are prominent among the whole flakes from both assemblages (though slightly more common, proportionately, in Levels 6–8), suggesting either a nearby source of raw materials or transport of raw materials in the form of minimally reduced clasts. Levallois flakes and pseudo-Levallois points are also common. Pseudo-Levallois points are common by-products of discoidal core reduction (Clark, 1984: 254; Boëda et al., 1990), and their prominence in the AHS assemblages may be linked to the high proportion of discoids among the

Table 5
Descriptive statistics for variables measured (in mm) on cores, whole flakes, and retouched flake tools from KHS

Artifact category	Statistics	Length	Width	Thickness	Striking platform width	Striking platform thickness
Cores						
	Mean	45	37	18		
	Standard deviation	30	24	15		
	Range	23–120	22–104	7–56		
	Count	12	12	12		
Whole flakes						
	Mean	42	31	10	22	7
	Standard deviation	17	11	10	11	4
	Range	30–111	16-59	2–55	5–46	2–18
	Count	26	26	26	22	22
Retouched flake tools						
	Mean	43	30	9	29	7
	Standard deviation	17	8	4	8	2
	Range	14–81	20–45	4–17	19–43	4–11
	Count	13	13	13	8	9

Note: For cores, length, width, and thickness are morphological; for whole flakes and retouched flake tools, length, width, and thickness are technological (see Appendix).

Table 6
Summary of AHS assemblages: Artifacts by proveniences and rock types

Tool group	Tool type	*n* (subtotal %)	% without debris	AHS 1–5	AHS 6–8	AHS surface	Jasper	Chalcedony	Chert	IOCCS	Shale	Rhyolite	Basalt
Core													
	Bifacial chopper	1	0.1			1		1		0			
	Discoid	3	0.2	2		1			1	1	1		
	Core scraper	4	0.3		4		1		1	1	1		
	Asymmetrical discoid	9	0.7	1	4	4	1	2	5	1			
	Levallois flake core	4	0.3		3	1	2	1		1			
	Core on flake	3	0.2			3	1		2	0			
	Other core type	1	0.1		1					0	1		
	Core fragment	10	0.7		7	3	1	1	4	1	1	1	1
	Core subtotal	35 (1)	2.6	3	19	13	6	5	13	5	4	1	1
Debitage													
	Cobble fragment	27	2.0		14	13	4	4	15	1	1	2	
	Initial cortical flake	68	5.0	8	35	25	6	4	34	7	3	6	8
	Residual cortical flake	84	6.2	13	41	30	6	7	34	8	7	15	7
	Levallois flake	38	2.8	7	15	16	2	1	19	2	6	5	3
	Levallois point	8	0.6	1	6	1	1	1	3	3			
	Atypical Levallois flake	3	0.2		2	1			2	0		1	
	Atypical Levallois blade	1	0.1		1					1			
	Atypical Levallois point	1	0.1		1				1	0			
	Pseudo-Levallois point	45	3.3	10	17	18	5	2	19	3	4	4	8
	Kombewa flake	2	0.1	1	1					1	1		
	Blade	4	0.3		1	3			2	0		1	1
	Noncortical flake	248	18.2	48	114	86	11	12	122	30	21	38	14
	Biface-thinning flake	2	0.1		1	1			1	0	1		
	Core-trimming element	41	3.0	1	19	21	3	3	18	4	2	7	4
	Flake fragment, proximal	219	16.1	46	104	69	7	17	81	34	30	32	18
	Flake fragment, other	450	33.1	85	221	144	24	29	184	65	49	75	24
	Blocky fragment	19	1.4	5	9	5	2	3	9	1	3		1
	Flake subtotal	1260 (16)	92.6	225	602	433	71	83	544	160	128	186	88
Debris													
	Debris and subtotal	6377 (82)		997	4541	839				0			
Retouched tool													
	Point	2	0.1	1	1		1	1		0			
	Sidescraper	13	1.0	1	7	5	3	4	5	1			
	Double scraper	5	0.4	1	1	3		1		0	3	1	
	Transverse scraper	6	0.4	1	3	2		1	4	0	1		
	Awl	4	0.3	1	1	2	1	1	2	0			
	Backed knife	2	0.1			2			2	0			
	Notch	3	0.2		3			1	1	0	1		
	Denticulate	6	0.4	1	1	4	1	1	3	0	1		
	Bipolar flake	1	0.1			1			1	0			
	Other retouched flake	12	0.9	2	2	8	1	1	4	3	1	1	1
	Foliate point fragment	9	0.7	2	3	4	2	1	3	0	3		
	Handaxe	1	0.1			1			1	0			
	Retouched tool subtotal	64 (1)	4.7	10	22	32	9	12	26	4	10	2	1
Total													
	n	7737 (100)		1235	5184	1317	86	100	583	169	142	189	90
	% without debris		100	18	47	35	6	7	43	12	10	14	7

Note: IOCCS = indeterminate/other cryptocrystalline silicate.

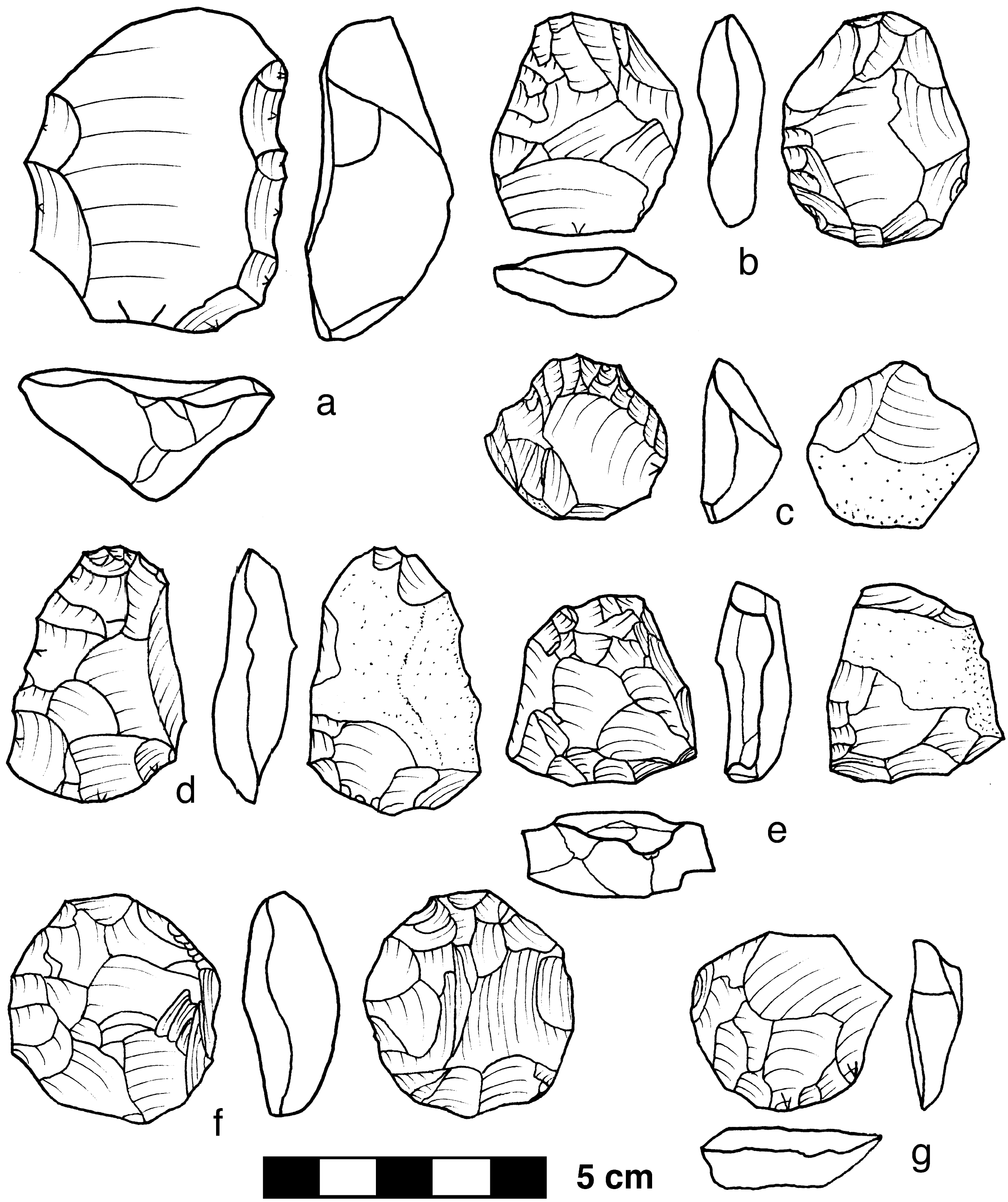

Fig. 11. Cores from AHS: (a) Levallois core with overshot flake scar, (b) Levallois core with truncated flake scar, (c) Levallois core, (d, e) Levallois cores with bidirectional-opposed preparation, (f, g) discoidal cores.

AHS core subassemblage. Of the 572 whole flakes from AHS, 341 (60%) were sufficiently well preserved for the full set of technological measurements to be made on them (see also Table 7).

There are 64 retouched artifacts in the AHS assemblages (Figs. 13 and 14). The most common retouched tool types are sidescrapers and "other retouched flakes." There are more retouched tools and a greater variety of retouched tool types in AHS Levels 6–8 than in Levels 1–5. This probably reflects differences in sample size. A small number of foliate point fragments and bifacially retouched tools were recovered from AHS. The presence of foliate points at AHS is important because it indicates that these artifacts were in use from the beginning of the Kibish sequence. This being said, the foliate-point fragments from AHS are not precisely the same small, symmetrical pieces seen in Member III assemblages and surface collections and in later east African MSA contexts elsewhere (e.g., Gademotta, Porc Epic; see discussion below). Larger excavated samples from AHS and other Kibish Member I contexts are needed to shed light on the variability of foliate points and other bifacially

Table 7
Descriptive statistics for variables measured (in mm) on cores, whole flakes, and retouched flake tools from AHS

Artifact category	Statistics	Length	Width	Thickness	Striking platform width	Striking platform thickness
Cores						
	Mean	39	33	14		
	Standard deviation	6	5	5		
	Range	32–56	24–46	4–30		
	Count	18	18	18		
Whole flakes						
	Mean	30	25	5	18	4
	Standard deviation	11	9	3	8	2
	Range	13–86	12–71	2–18	4–52	1–16
	Count	341	341	341	341	341
Retouched flake tools						
	Mean	34	30	9	24	6
	Standard deviation	11	8	5	11	2
	Range	18–59	13–52	2–36	8–47	4–12
	Count	54	54	54	23	23

Note: For cores, length, width, and thickness are morphological; for whole flakes and retouched flake tools, length, width, and thickness are technological (see Appendix).

flaked artifacts. Descriptive statistics for measurements of retouched tools from AHS are also presented in Table 7.

No hammerstones were recovered from AHS. A small pellet of red ochre (AHS #2100) was recovered from AHS Level 6. There is no obvious sign of abrasion or modification on its surface. It is not beyond the realm of possibility that this “ochre” is merely a decomposing fragment of the red shale that is common in the AHS lithic assemblage.

No refitting constellations have been identified at AHS. This is not because they are absent, but rather a reflection of limited time in the field and opportunities for laboratory work in Addis Ababa during the 2003 season. During the course of excavation and surface collection, clusters of stone tools of the same raw material type were noted on the surface and in both the AHS 1–5 and AHS 6–8 subassemblages. These observations suggest that future studies of the AHS assemblage will probably reveal refitting constellations.

AHS faunal evidence

Identified nonhuman vertebrate faunal remains from AHS include those of *Hippopotamus amphibius*, *Crocodylus niloticus*, *Giraffa* spp., and *Litocranius* cf. *L. walleri*. These fossils and other faunal remains from AHS are described by Assefa et al. (2008).

Interpretation of AHS

The AHS occurrence is a multicomponent site. If the contents of our trenches are representative of the site as a whole, there appear to have been at least two major phases of occupation. These resulted in dense concentrations of artifacts in Levels 4 and 6. The only human remains from this site are two conjoining tibial fragments from the surface and Level 6. There do not appear to be marked technological or typological contrasts between the Level 1–4 and Level 6–8 lithic assemblages. The abundant debris, cortical flakes, and non-Levallois debitage in the AHS assemblages suggest that a considerable amount of stone tool production occurred at this locality, possibly as the result of repeated, sustained occupations. Following this logic, AHS Levels 4 and 6 seem likely to have been more substantial occupations than either KHS Level 3 or BNS Level 3.

The Bird’s Nest Site (BNS)

The BNS was discovered by Z. Assefa in 2002, during a canvass of the environs of the Omo II/PHS locality. It is located at 424 m above sea level on the southern side of the Omo River at N 5° 24.462′, E 35° 53.975′ (UTM 36 N E 0821360/N 0598499). The site is a promontory comprising a series of two small hills, each of which sits on top of a plateau of the uppermost level of Kibish Member II (Fig. 15).

The first and southernmost hill (BNS East) is about 2 m above the surrounding floodplain, and the second hill (BNS Main) is about 3 m above the floodplain. Both are arrayed in a line extending southeast from a much taller set of hills composed mainly of Member III sediments. The bulk of archaeological residues derive from the saddle north of BNS Main (where the eponymous bird’s nest was also located) on the disconformity separating uppermost Member II from lowermost Member III. The areas to the west and east of BNS are relatively flat alluvial floodplains, all meandering eastward towards the Omo River.

Excavation of BNS

The datum for BNS is located about 8 m north of the northernmost excavation square (on the slope of a large hill) and about 4 m above the surface of the site. The site was excavated using hand tools. Bumi workmen from Kibish and policemen from the Kibish Police Post assisted in screening (50-mm mesh). Excavation of BNS began in 2002 with a trench (S1) running 5 m west–east (Fig. 16). This trench was extended southward underneath BNS Main following a thin deposit of the sole artifact-bearing level, Level 3. The rows adjacent to E1 were gridded and systematically surface-collected. At the same time, a small test trench was excavated into BNS East. While this trench confirmed that Level 3 extended this far across the site, it also yielded only one artifact and no fossils, suggesting that the high density of archaeological remains did not continue in this direction. In 2003, the excavation was extended south around the periphery of the BNS Main hill where substantial numbers of artifacts were eroding from Level 3. During the course of this excavation we recovered numerous stone tools, bone fragments, and reddish patches suggesting combustion features. The latter were also typically associated with fragments of ostrich eggshell. We also made extensive surface collections in several of the steep erosional gullies flanking BNS. About half of the BNS Main hill was left undisturbed—an unintentional witness baulk—when an aborted cattle raid and ensuing gunfire interrupted excavations, which required us to close excavations at the site several days ahead of schedule.

The stratigraphy of the BNS encapsulates the transition between Kibish Members II and III. This stratigraphy is summarized in Table 8 and a profile is shown in Fig. 17. The principal archaeological level of BNS, BNS Level 3 (hereafter BNS L3), is directly superposed on the

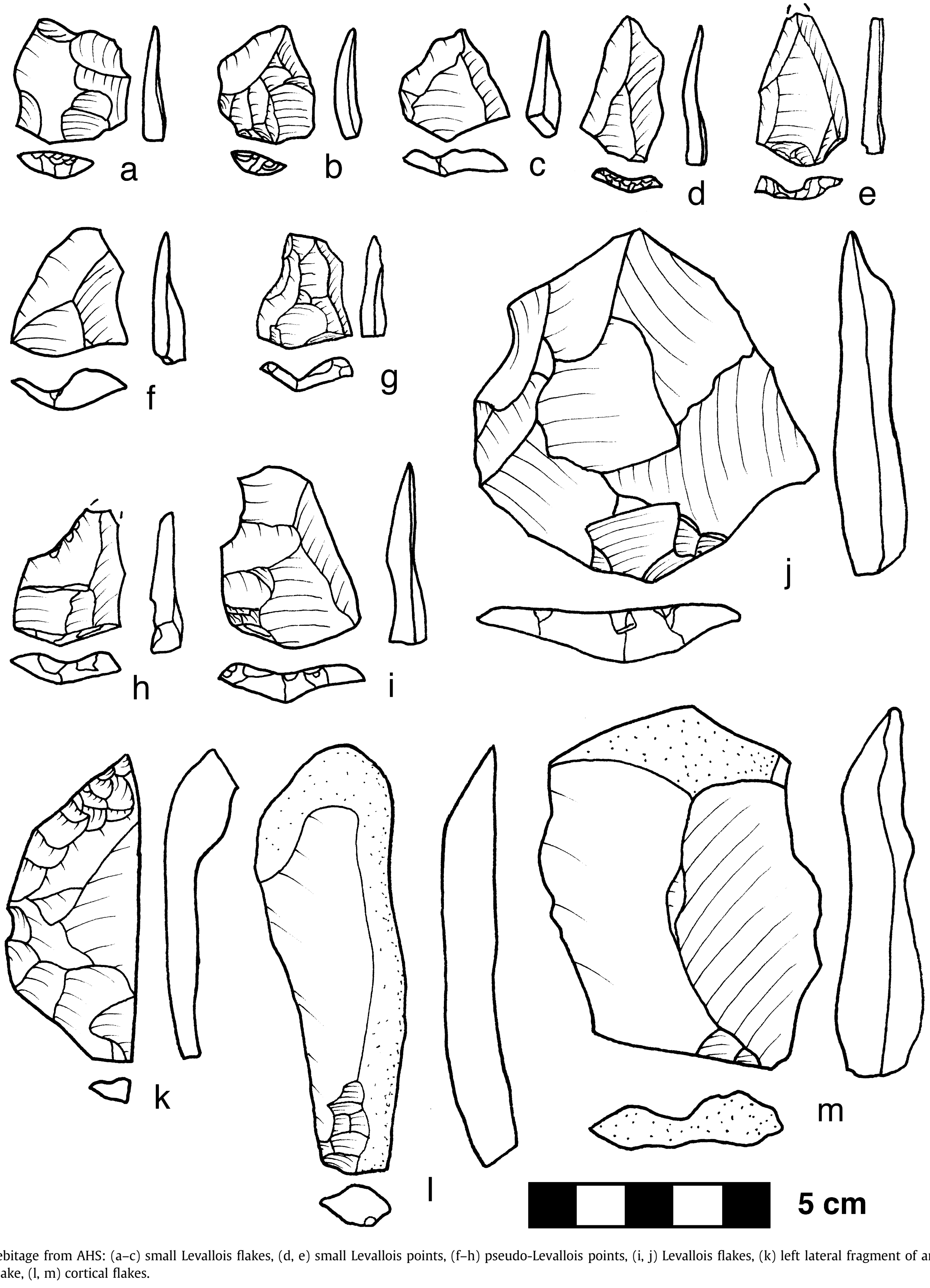

Fig. 12. Debitage from AHS: (a–c) small Levallois flakes, (d, e) small Levallois points, (f–h) pseudo-Levallois points, (i, j) Levallois flakes, (k) left lateral fragment of an overshot Levallois flake, (l, m) cortical flakes.

erosional disconformity at the top of Member II. Level 3 of BNS is a sand and silt deposit approximately 10 cm thick throughout its exposure. This level appears thicker towards the southern part of the site and thinner to the east and west. A massive silt deposit, the lowermost part of Member III, with its distinct, dark-brown anoxic stratum, directly overlies Level 3. The undated Member II tuff is visible 1.35 m below BNS L3. The Member III tuff, which is located at higher elevations than BNS L3, though not present in the

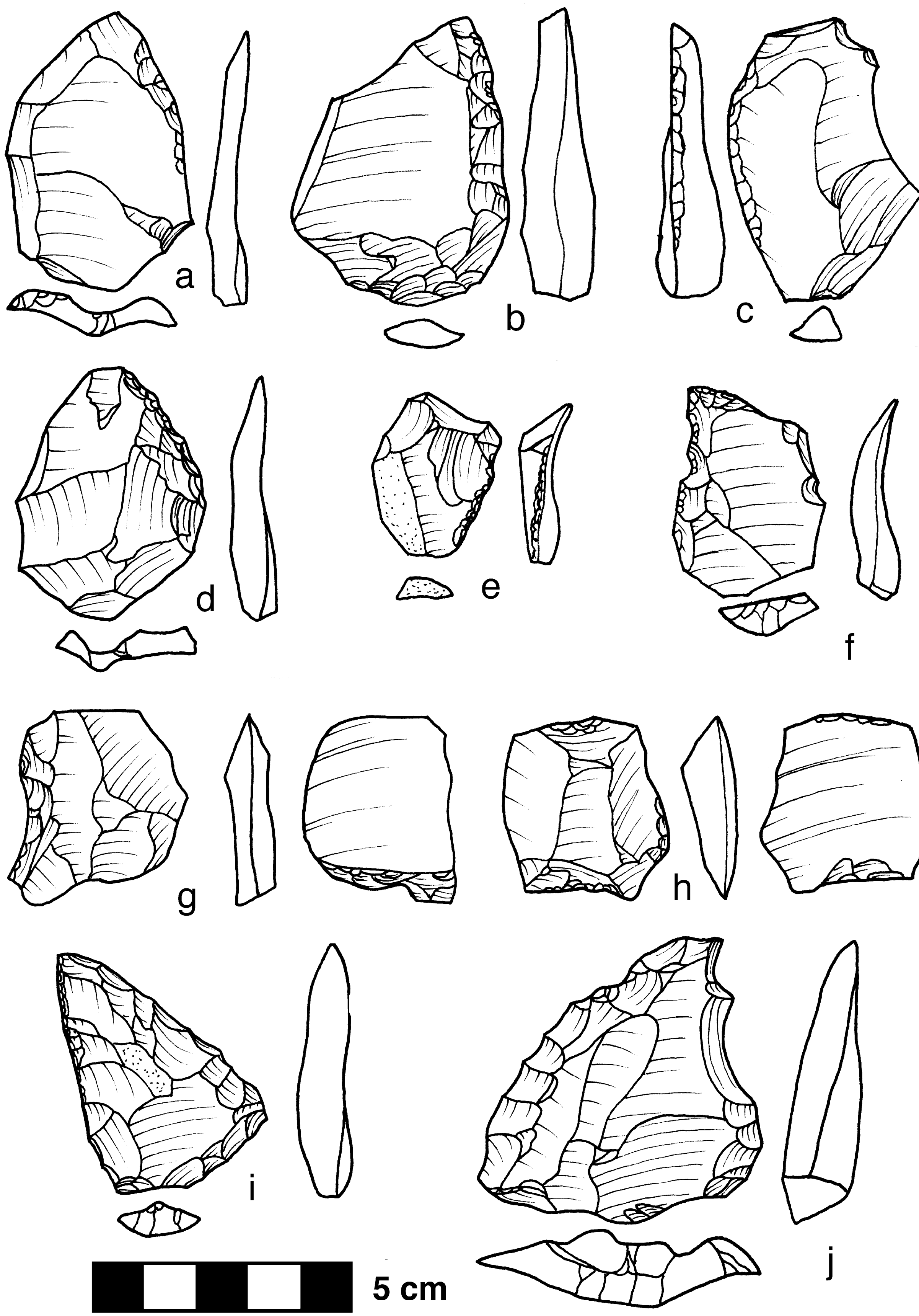

Fig. 13. Retouched tools from AHS—unifacially retouched tools: (a) retouched Levallois point, (b–e) scrapers, (f) awl/perforator, (g, h) truncations, (i, j) transverse/convergent scrapers.

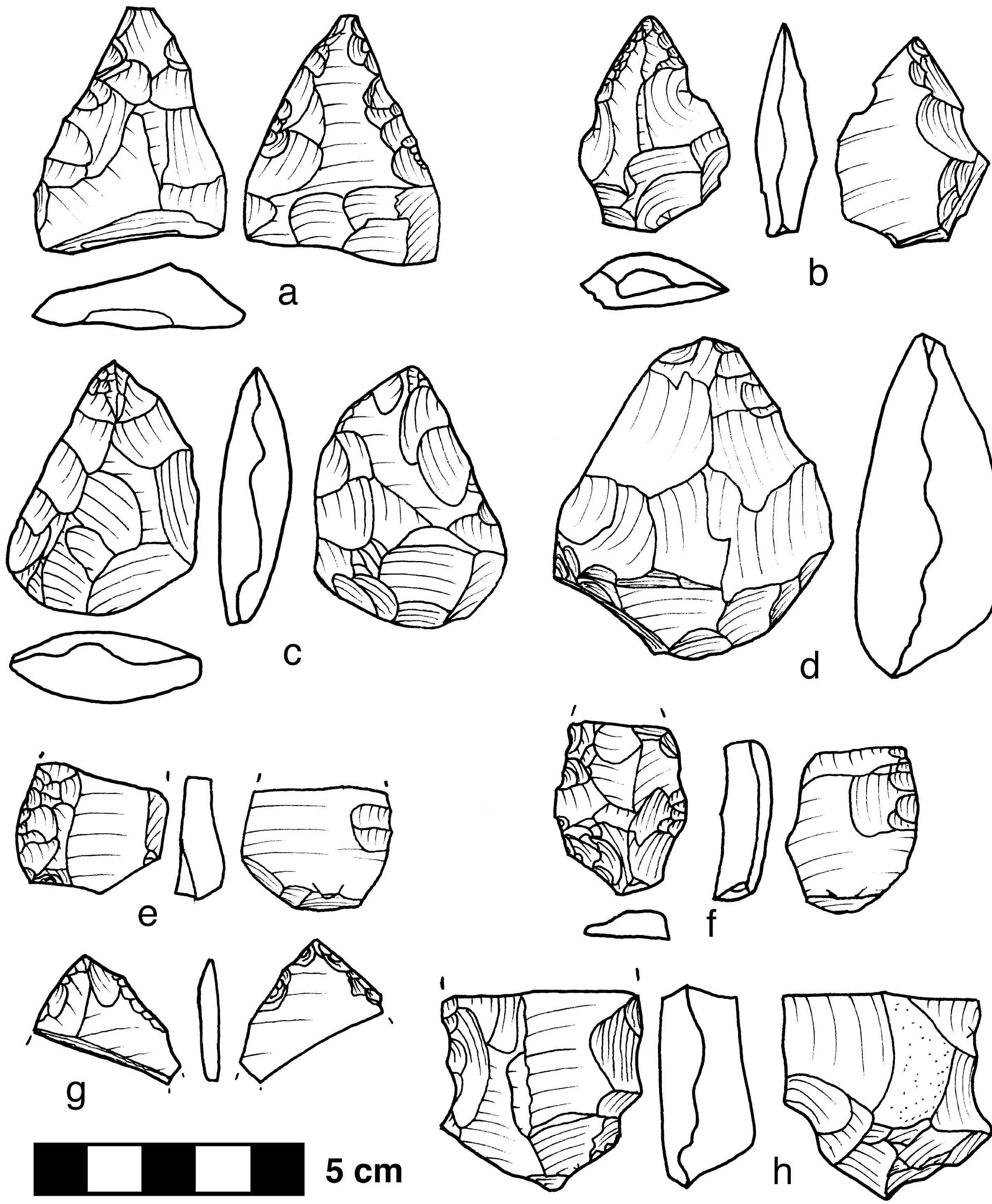

Fig. 14. Retouched tools from AHS—bifacially retouched tools: (a) tip of biface, (b) point on flake with bifacial and unifacial retouch on opposite lateral edges, (c) foliate point, (d) handaxe, (e, f) proximal flake fragments with bifacial retouch on one edge, (g) distal flake fragment with bifacial retouch, (h) *possible* basal fragment of biface.

immediate site environs, is dated to 104 ± 1 ka (McDougall et al., 2005). This date provides a minimum age for BNS.

BNS lithic assemblage

Table 9 summarizes the contents of the BHS lithic assemblage in terms of provenience, artifact categories, and raw materials. There are four main subassemblages from BNS. Level 3 of BNS includes all artifacts recovered in situ in Level 3, the surface collection from adjacent squares, and the single artifact from the BNS East test trench. A second subassemblage (BNS Area <50 m) comprises artifacts collected 1–50 m from the edge of the BNS areas of excavation and systematic surface collection. These artifacts, for the most part, come from steep erosional gullies leading directly away from the BNS (<10 m away) and from exposures of BNS L3 near the base of the large hill to the north of the site (most less than 20 m away). A third subassemblage (BNS Area 50–100 m) includes four artifacts found 50–100 m distant (though mostly closer to

Fig. 15. BNS (view south) at the end of 2003 excavations (J. Shea photo).

50–75 m) on relatively level surfaces of alluvial fans trailing away from the gullies flanking the excavation site.

Lithic raw materials in the BNS assemblage are dominated by fine-grained and highly siliceous rocks, mostly chert, but with significant components of jasper and chalcedony. Rhyolite is also prominently represented.

The main difference among these samples is that debris is more prominent in the BNS L3 assemblage than it is in the surface-collected assemblages. Otherwise, the proportions of cores, debitage, and retouched tools do not differ significantly between the BNS L3 and BNS Area <50 m samples.

Seventy-four cores and core fragments were recovered from BNS (Figs. 18–20). Asymmetrical discoids are the most common core type at BNS by a considerable margin, accounting for about half of the cores. Levallois flake cores and core fragments (mostly fragments of asymmetrical discoids) are also present in significant numbers. Table 10 presents descriptive statistics for the metric variables measured on the BNS cores.

Excluding debris ($n = 999$), there are 820 flakes and flake fragments in the BNS debitage sample (Fig. 21). Fully 34% of the flakes from BNS are cobble fragments, initial cortical flakes, or residual cortical flakes, again (as at AHS) suggesting a nearby raw material source and/or transport of minimally modified clasts. As was also seen at AHS, Levallois flakes and pseudo-Levallois points are prominent components of the whole, noncortical flake subassemblage. Table 10 also presents descriptive statistics for the technological variables measured on the BNS debitage.

The BNS assemblage contains 30 retouched tools (Fig. 22). Foliate point fragments are the most numerous retouched tool category, but at least half of these artifacts are from surface contexts. Various forms of scrapers account for about 27% of the retouched tools. Bipolar flakes and backed knives (both of which are included here among retouched tools) present something of a problem. The damage on the bipolar flakes bears more than a passing resemblance to use-related microfracturing rather than retouch. Similarly, the "backing" on the BNS backed knives is not consistent in its distribution or morphology. The artifacts in these two tool categories may well be the results of either use rather than deliberate shaping. Only four of the 30 retouched tools from BNS retain enough of their original flake surfaces to allow measurement of the flake dimensions (see also Table 10). One foliate point and four foliate point fragments from BNS were also measured, but

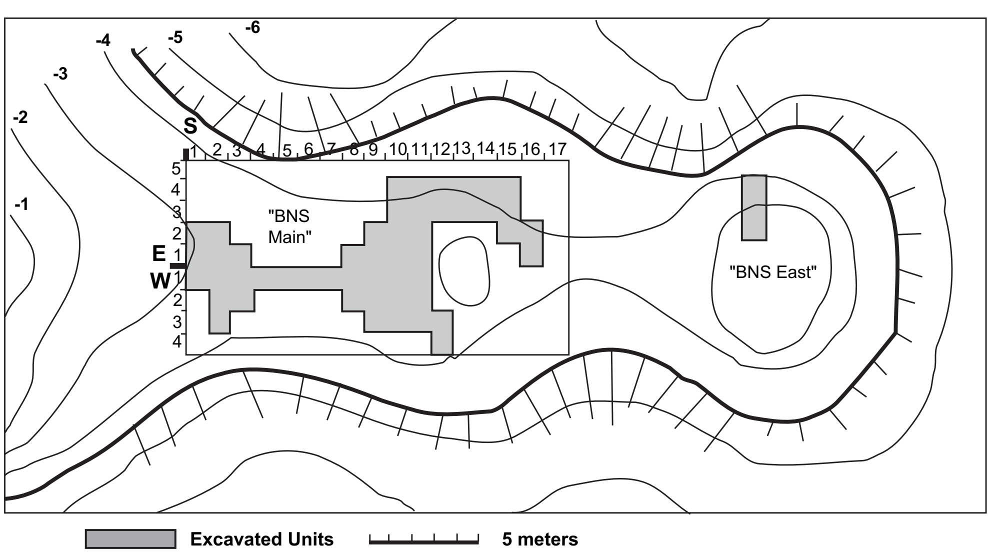

Fig. 16. Plan of BNS excavations.

Table 8
BNS stratigraphy

Level	Matrix and approximate elevation below datum at SW corner of N1/E1	Lithics	Fossils
1	Gray clay with two prominent dark-brown bands separated by a light-brown clay band with orange ferruginous deposits (<3.75 m). This is the lowermost Member III.	Absent	Absent
2	Dark-brown silt (−3.75–3.82 m). Thickness varies widely between 2 and 10 cm across the site.	Present?	Absent
3	Light-gray-tan sand with rounded sandstone concretions at the base (−3.82–3.92 m). Thickness wedges from 10 to 5 cm to the north.	Present	Present
4	Gray laminated clays (−3.92–5.00 m). This is the eroded uppermost part of Member II.	Absent	Absent

these were measured using different criteria (i.e., maximum length, maximum width, maximum thickness) (see also Table 10).

Twenty-four refitting constellations were identified among the BNS assemblage (see Sisk and Shea, 2008). Of these constellations, only five are conjoins (broken flakes). The rest are refits or mixed sets of technological refits and conjoins. Among the refits, the majority (16, or 84%) result from either core preparation, core exploitation, or both. Core rejuvenation is represented by only three constellations. Like the refitting constellations at KHS, refitting sets that contain cortical flakes usually feature unilinear flake removals, while those involving cores and/or refitting sets of noncortical flakes tend to feature radial/centripetal core surface preparation. This evidence reinforces the picture of a technological strategy that changes dynamically along the course of core reduction, switching from unilinear to radial/centripetal core-surface preparation along with diminution in core size.

BNS faunal evidence

The faunal remains from BNS and the gullies flanking it that could be identified to taxon include those of *Hippopotamus*, *Phacochoerus africanus*, *Thronomys gregorianus*, and various Bovini. A fuller discussion of these remains is presented by Assefa et al. (2008). Numerous fragments of ostrich eggshell were excavated from Level 3 in squares S15/E3 and S16/E3. The sediments around these eggshells were reddened, possibly from fire, but no macroscopic carbon fragments were observed.

Interpretation of BNS

The BNS occurrence appears to be a site consisting of many small occupation units. There is no clear evidence for structures or features, but rather only evidence for the production of flakes from pebble cores. A minimalist interpretation would view BNS as a fortuitously preserved part of the landscape in which flintknapping occurred on a semiregular basis immediately preceding the massive flooding that marked the deposition of basal Member III.

Isolated surface finds in Members I–III

Many isolated finds of stone tools were made on eroding surfaces of Members I–III during our investigations in the Kibish Formation and by the 1967 Kenyan expedition (Figs. 23–25). Surface finds were not collected systematically, and they are thus not strictly comparable in statistical terms with the excavated assemblages. There are some clear differences between the surface-collected artifacts and the excavated assemblages that may be archaeologically significant. Among the surface finds, there are many large pointed artifacts, Levallois points, foliate bifacial points, lanceolate bifaces, handaxes, and "heavy duty" core-tools, such as core-axes and picks. Few such tools occur in the excavated assemblages.

One possible explanation for these differences is that they reflect an unconscious collection bias on our part, our eyes naturally being attracted to large symmetrical artifacts. Archaeological surface collections in many parts of the world are affected by similar kinds of collection biases, and we cannot reject this explanation.

A second possibility is that some of these surface finds may be redeposited from older sediments. This is unlikely. If it were true, one would expect these tools to exhibit surfaces abraded from fluvial transport. It is not the case that the surface-collected artifacts as a group are disproportionately heavily weathered. Basalt artifacts are more weathered that nonbasalt artifacts, and this difference is also seen in the excavated assemblages. The nonbasalt surface finds are not, as a group, more heavily weathered than artifacts of the same raw materials recovered by excavation.

A third possibility is that these artifacts reflect different patterns of artifact discard behavior than those involved in the accumulation of the dense artifact "patches" on which our excavations focused. There is no reason to assume that the Kibish MSA humans had a single unvarying technological strategy whose lithic "signature" remained the same throughout their annual round and across the Lower Omo Valley paleolandscape. Further investigations of the lithic "scatter between the patches" in the Kibish Formation are needed to test this hypothesis.

Overview of the Omo Kibish MSA

This section presents an overview of the Kibish Middle Stone Age assemblages in strategic perspective. That is, it attempts to relate the tabulations of artifact frequencies in the foregoing sections to variation in technological strategies.

Lithic raw material economy

The most likely sources of the lithic raw materials in the Omo Kibish MSA assemblages are gravel deposits in Kibish Formation Member I. This inference is supported by the high proportions of cortical flakes and debris in all of the MSA assemblages and by our

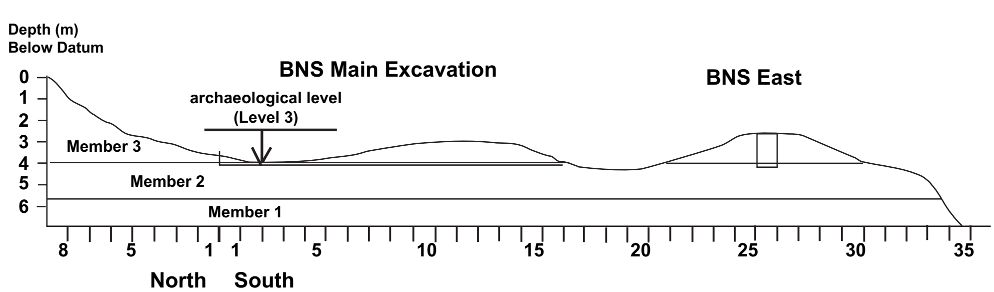

Fig. 17. Profile of BNS.

Table 9
Summary of BNS assemblages: Artifacts by proveniences and rock types

Tool group	Tool type	*n* (subtotal %)	% without debris	Provenience			Raw material							
				BNS L3	BNS <50 m	BNS >50 m	Jasper	Chalcedony	Chert	IOCCS	Shale	Rhyolite	Basalt	Ind. volc.
Core														
	Bifacial chopper	5	0.5	2	3				2			3		
	Partial discoid	4	0.4	1	3		1	1			1	1		
	Polyhedron	1	0.1		1							1		
	Asymmetrical discoid	37	4.0	20	17		7	9	15	1		5		
	Levallois flake core	8	0.9	3	5		2		6					
	Core on flake	2	0.2	2					1		1			
	Other core type	2	0.2	2			1	1						
	Core fragment	15	1.6	11	4		2	2	7			2	1	1
	Core subtotal	74 (3.8)	8.0	41	33		13	13	31	1	2	12	1	1
Flake														
	01. Cobble fragment	61	6.6	39	22		7	14	17	2		12	3	6
	02. Initial cortical flake	101	10.9	59	41	1	14	17	34	7	1	17	9	2
	03. Residual cortical flake	122	13.2	74	48		15	21	46	3	1	23	8	5
	04. Levallois flake	30	3.2	18	12		3	4	11	1		4	2	5
	05. Levallois blade	1	0.1	1					1					
	06. Levallois point	2	0.2		2				1				1	
	07. Atypical Levallois flake	1	0.1	1					1					
	09. Atypical Levallois point	1	0.1	1					1					
	10. Pseudo-Levallois point	19	2.1	9	10		3		11			3	2	
	11. Kombewa flake	1	0.1	1					1					
	12. Blade	3	0.3	2	1				2			1		
	13. Noncortical flake	112	12.1	76	35	1	9	18	43	5	2	23	8	4
	14. Biface-thinning flake	2	0.2	1	1				1			1		
	15. Core-trimming element	60	6.5	39	21		11	3	24	1		11	9	1
	16. Flake fragment, proximal	84	9.1	40	44		13	5	33	5		20	7	1
	17. Flake fragment, other	204	22.1	118	86		25	20	58	11	2	46	31	11
	18. Blocky fragment	16	1.7	9	7		2	3	8			1		2
	Flake subtotal	820 (42.6)	88.6	488	330	2	102	105	293	35	6	162	80	37
Debris														
	19. Debris	999 (51.9)		952	47		104	201	524	35	15	61	53	6
Hammerstone														
	02. Hammerstone fragment	1	0.1	1									1	
	Hammerstone subtotal	1 (0.1)	0.1	1									1	
Retouched tool														
	02. Sidescraper	4	0.4	2	2			2	1			1		
	03. Double scraper	2	0.2	2					2					
	04. Convergent sidescraper	1	0.1		1		1							
	05. Transverse scraper	1	0.1	1			1							
	07. Backed knife	6	0.6	1	5				5				1	
	10. Bipolar flake	6	0.6	3	3				4			2		
	11. Other retouched flake	2	0.2		2				1	1				
	12. Foliate point	1	0.1	1					1					
	12. Foliate point fragment	7	0.8	3	2	2	2	1	1	2		1		
	Retouched tool subtotal	30 (1.6)	3.2	13	15	2	4	3	15	3		4	1	
Total		1924 (100.0)		1495	425	4	223	322	863	74	23	239	136	44
Column total														
	Column total without debris		100.0	58.7	40.9	0.4	12.9	13.1	36.6	4.2	0.9	19.2	9.0	4.1

Note: IOCCS = indeterminate/other cryptocrystalline silicate, Ind. volc. = indeterminate volcanic.

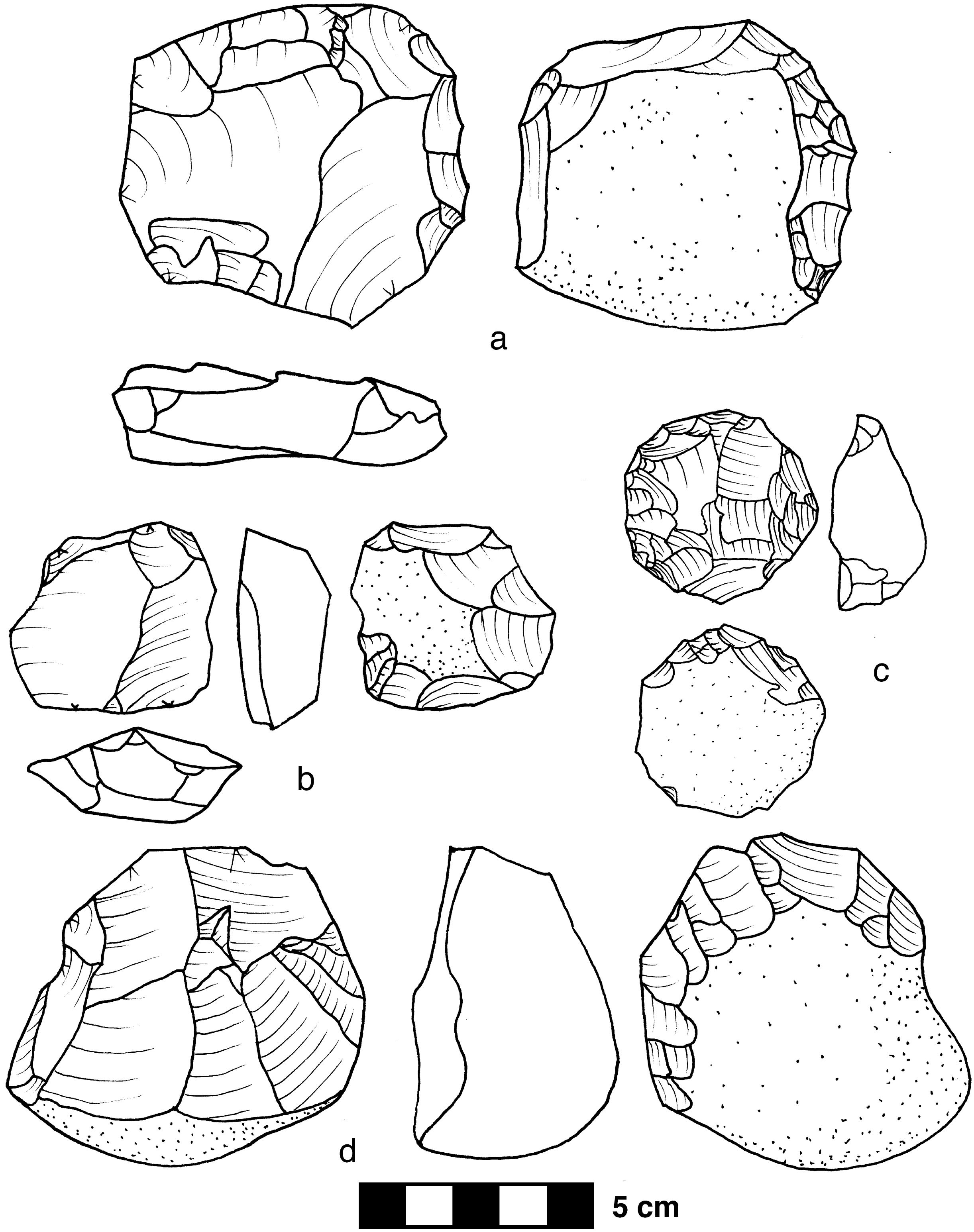

Fig. 18. Large cores from BNS: (a–c) Levallois cores, (d) pebble-core (bifacial chopper).

surveys of raw materials in contemporary exposures of gravel deposits in Kibish Member I. The overwhelming majority of pebbles and cobbles in these gravels are basalt and rhyolite. Most of these rocks possess poor conchoidal fracture properties, owing to large crystal sizes, but fine-grained rhyolite and basalt can be found with little difficulty. Rocks with high silica content and good conchoidal fracture properties, such as jasper, chalcedony, and chert, are present in abundance in all contemporary exposures of Kibish Formation gravels. The main difference between these high-quality raw materials and the coarse-grained volcanics in Kibish Member I gravel deposits is that the high-quality rocks are generally available in smaller clast sizes. The only raw material observed in the

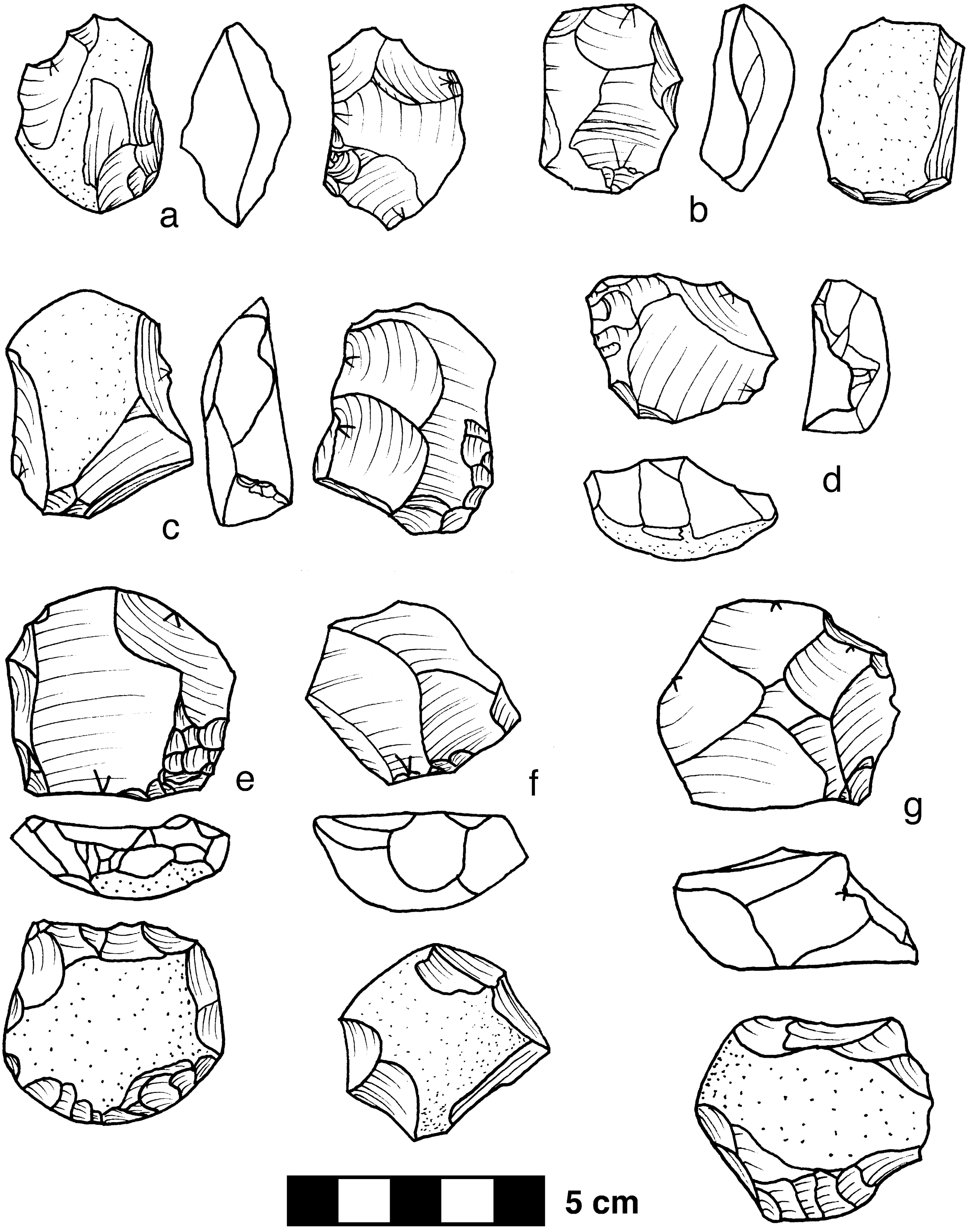

Fig. 19. Medium-sized cores from BNS: (a) partial discoid, (b) Levallois core, (c) Kombewa core on cortical flake fragment, (d) asymmetrical discoid, (e) Levallois core, (f, g) discoidal cores.

archaeological assemblages but not in the gravel exposures was the opal silica seen at KHS and AHS.

Percentages of cores, whole flakes (all flakes minus non-proximal flake fragments and debris), and retouched tools from each site made of different rock types are presented in Table 11. In terms of raw counts of different rock types, chert is the most popular raw material in each of the assemblages. The next most common raw material varies from site to site, but all of the major tool categories in all of the sites present the same basic pattern. The overwhelming majority of artifacts listed (60–95% per assemblage) are made of high-quality lithic raw materials (jasper, chalcedony, chert, and other cryptocrystalline silicates), while

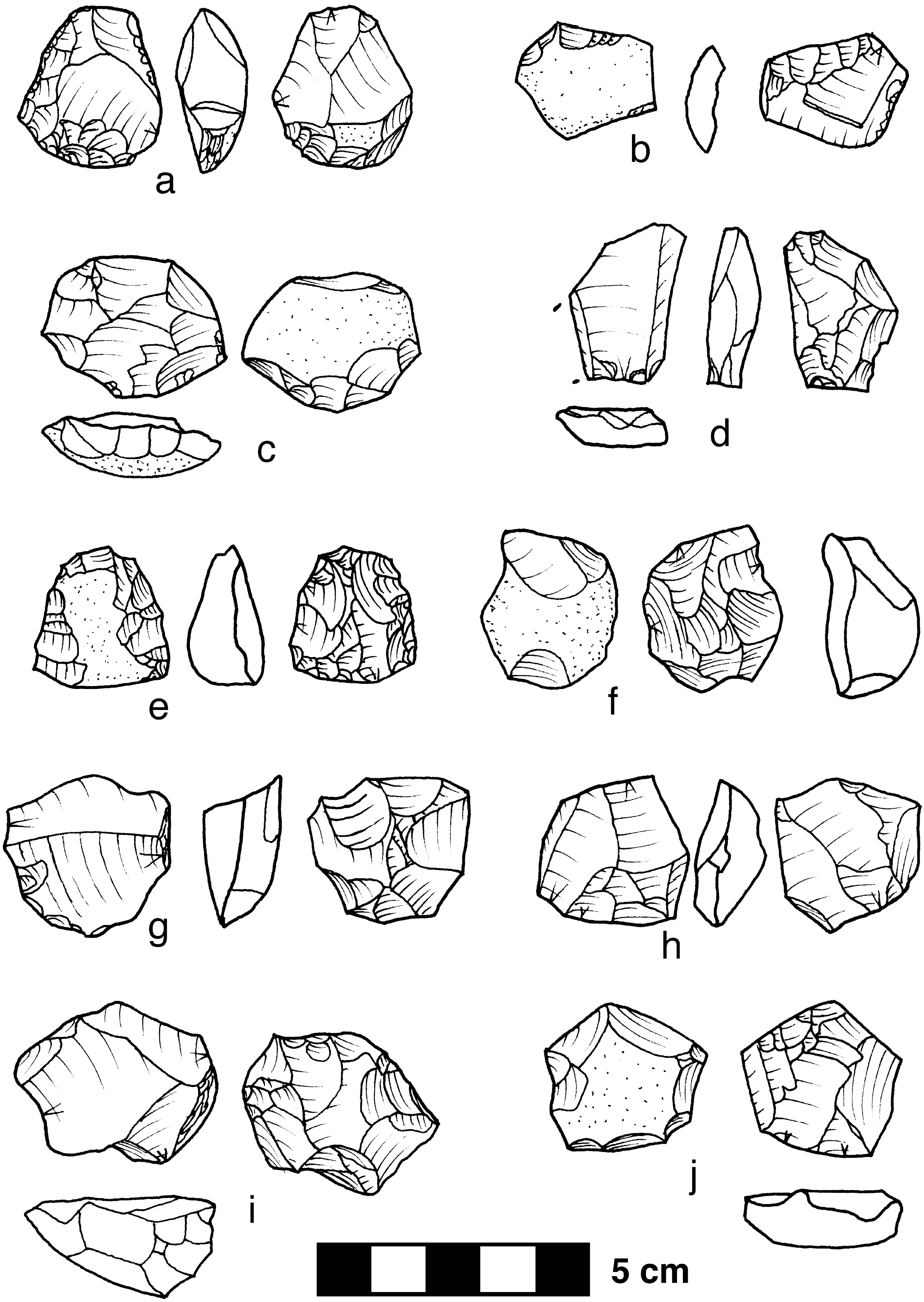

Fig. 20. Small cores from BNS: (a) asymmetrical discoid, (b) core-on-flake, (c) asymmetrical discoid, (d) fragment of core-on-flake, (e, f) asymmetrical discoid, (g) split core (partial discoid), (h) discoidal core, (i) Levallois point core, (j) asymmetrical discoid.

Table 10
Descriptive statistics for variables measured (in mm) on cores, whole flakes, and retouched flake tools from BNS

Artifact category	Statistics	Length	Width	Thickness	Striking platform width	Striking platform thickness
Cores						
	Mean	42	34	18		
	Standard Deviation	11	10	7		
	Range	28–74	18–63	7–40		
	Count	34	34	34		
Whole flakes						
	Mean	32	26	7	17	5
	Standard Deviation	11	9	3	8	3
	Range	3–95	9–54	2–23	2–40	1–25
	Count	139	139	139	139	139
Retouched flake tools						
	Mean	32	27	11	16	4
	Standard Deviation	14	8	4	n.a.	n.a.
	Range	20–47	18–38	6–16	16	4
	Count	4	4	4	1	1

Note: For cores, length, width, and thickness are morphological; for whole flakes and retouched flake tools, length, width, and thickness are technological (see Appendix).

a minority (5–40% per assemblage) are made of low-quality raw materials (shale, rhyolite, basalt, and other volcanics) (Table 12). These proportions of high- vs. low-quality raw materials are very nearly the opposite of these rocks' representation in Kibish Formation gravels. From this difference, one can conclude the Kibish MSA humans exercised a high degree of selectivity in raw-material choice. However, a very different pattern appears when one examines the intensity to which raw materials of differing quality were reduced. Low-quality raw materials exhibit consistently higher ratios of "whole flakes" (complete flakes and proximal flake fragments) to cores than do high-quality rock types in each of the Kibish assemblages (Table 12).

One further aspect of raw material choice requires comment. Fairly consistently among all three assemblages, the most heavily modified artifacts (cores, retouched tools) and many of the smallest flakes are of rocks with a red color (usually jasper, chert, and shale). Inasmuch as these are also high-quality raw materials, this seeming emphasis on the reduction of red clasts may simply be a coincidence. On the other hand, there are well-documented patterns of symbolic behavior, usually involving red mineral pigments in Africa and elsewhere (Wreschner, 1980; Barham, 2002; Henshilwood and Marean, 2003; Hovers et al., 2003). A cultural preference for red raw materials might explain the intense reduction of otherwise rather poor-quality shale at AHS. Testing the hypothesis of a possible color preference in Kibish MSA raw material economy requires further study.

Core technology

The percentages of cores, flakes, and retouched tools (excluding debris) for KHS, AHS, and BNS are presented in Table 13. Overall, the most common core types are asymmetrical discoids and Levallois cores. Together, these core types account for 69% of all of the whole cores in the Kibish MSA assemblages. Most of the other morphological core types are each represented by only a few specimens, and thus little more can be inferred from their statistical variation.

The highly contingent classification of core types in Table 13 in some ways obscures more basic technological variation. Regrouping these morphological core types into pebble cores, formal cores, cores-on-flakes, and "other" cores/core fragments, we can shed light on technological variability among the Kibish MSA assemblages.

"Pebble cores" are those cores whose overall shape reflects their origin as a clast (either a pebble or a cobble). This category subsumes choppers, core-scrapers, discoids, and polyhedrons. In structural terms, the planes formed by the striking platform and flake release surfaces are largely interchangeable. Consequently, the size and shape of flakes detached from these cores are largely determined by the original configuration of the raw material and by the effects of greater or lesser, usually expedient, reduction (Toth, 1985). Increased production of such expedient cores has been linked by Parry and Kelly (1987) to increased sedentism, and by Kuhn (1995) to technological strategies emphasizing the provisioning of places in bulk with raw materials.

"Formal cores" are those cores whose overall shape reflects the imposition and maintenance of a hierarchy of striking platform and flake release surfaces. This category subsumes Levallois cores and asymmetrical discoids. Maintaining a particular flake release surface results in flakes with particular, predictable morphologies, usually ones that either optimize potential cutting edge (per unit of core mass) or, failing this, ones that maintain the distal and lateral convexities of the flake release surface (Boëda et al., 1990; Sandgathe, 2004). Including asymmetrical discoids among such cores, as is done here, reflects the observation that these cores exhibit a clear hierarchy of striking platform and flake release surfaces. Parry and Kelly (1987) argued that the increased production of formal cores reflects an accommodation to high residential mobility, or, as Kuhn (1995) puts it, a strategy emphasizing "provisioning people" with raw materials in efficiently transportable forms.

Whether "cores-on-flakes" ought to be treated as a subset of formal cores or as a category in their own right is debatable. They have much in common with pebble cores in that their shape largely reflects their appearance at the point they were co-opted for use as a source of flakes. On the other hand, the cores-on-flakes in Kibish MSA assemblages clearly have a hierarchy of flake release surfaces (usually the former flake ventral surface) and striking platform surfaces (usually a truncation or steep retouch on the flake's dorsal surface). They differ from other formal core types only in that the shape of the flakes detached from their flake release surface is usually predetermined by preexisting dorsal scar ridges or the bulbar convexity, rather than by previous flake removals.

Table 13 also presents the core component of the Kibish MSA assemblages in terms of this simplified core classification. Formal cores outnumber pebble cores in all of the assemblages except AHS Levels 1–5. They predominate only in the BNS assemblage. The final shape of a core at discard can reflect many factors, but if we follow the models of Parry and Kelly (1987) and Kuhn (1995; see also Wallace and Shea, 2006), then one could infer that the predominance of formal cores in the Kibish MSA may reflect overall high levels of residential mobility. Obviously, additional samples and further independent measures of mobility pattern variation are needed to test this hypothesis.

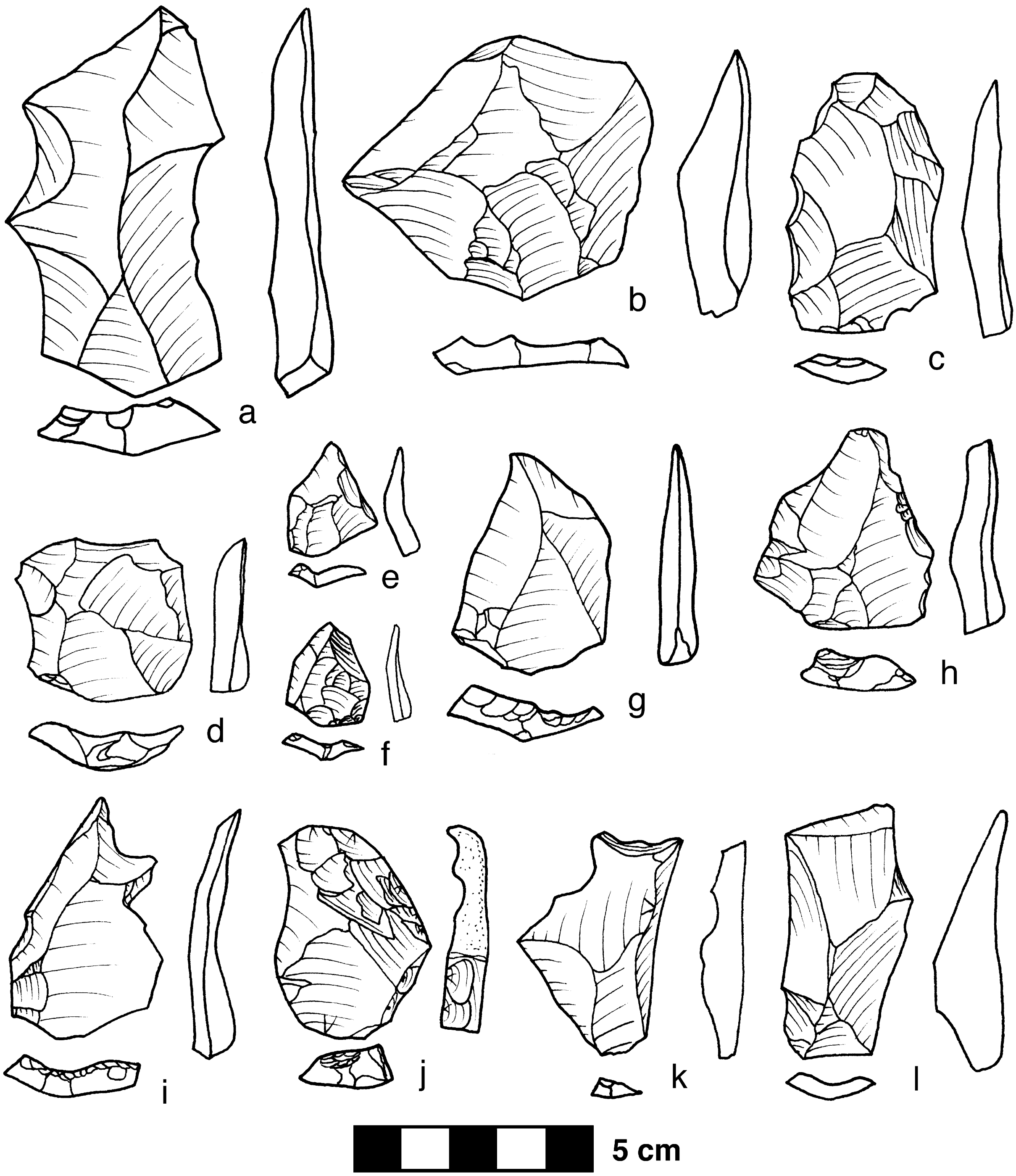

Fig. 21. Debitage from BNS: (a–d) Levallois flakes, (e–i) Levallois points, (j, k) core-trimming flakes, (l) noncortical flake.

One of the most striking features of the Kibish MSA assemblages is the small size of the cores, particularly the "formal" cores (Table 14; Fig. 26). More than 85% of the cores from our sites are less than 50 cm^3. The overall mean core volume for the three assemblages is 25 cm^3. The cores from KHS appear to be larger on average than those from AHS and BNS, but this reflects the skewing effect of two very large cores from KHS (both from the 1967 Kenyan collection). Removing these cores from consideration drops the mean core volume at KHS to 11 cm^3. At first glance, these cores' small size suggests more intense reduction than seen in other east African MSA assemblages featuring larger cores; but the small size of the Kibish MSA cores almost certainly reflects their origin as relatively small clasts. Despite the remarkable nature of the small cores from the Kibish MSA, it is not the case that core reduction intensity is uniformly high. Ratios of flakes to cores vary widely among the Kibish MSA assemblages. At AHS, Levels 1–5 (47:1) and Levels 6–8 (32:1) appear to have been the focus of considerably greater knapping activity than either KHS (5:1) or BNS (9:1).

Debitage technology

Table 15 presents the frequencies of different debitage types for KHS, AHS, and BNS. In all of these assemblages, nonproximal flake fragments are the most common debitage category, followed by

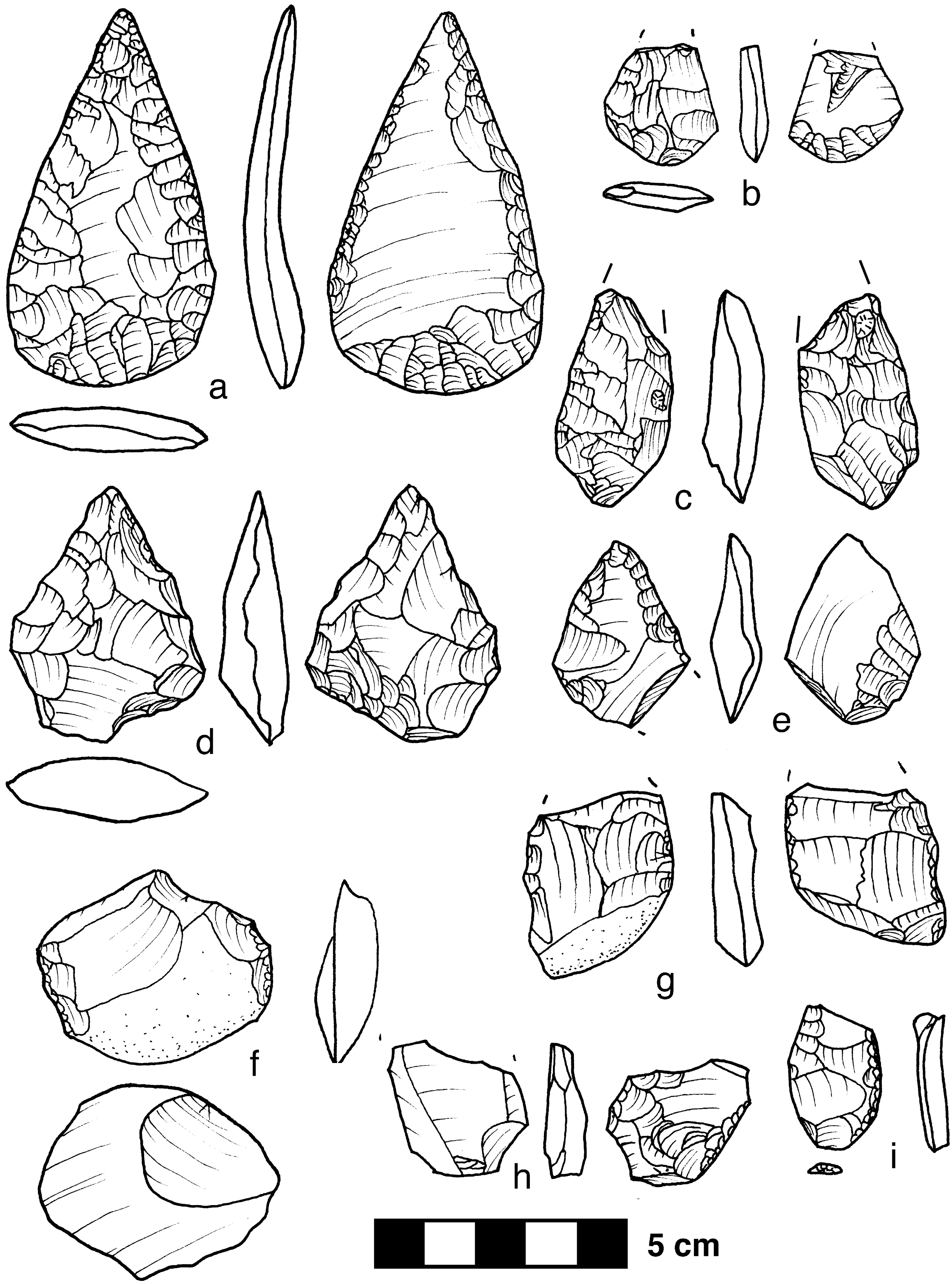

Fig. 22. Retouched tools from BNS: (a) foliate point, (b) proximal fragment of foliate point with possible impact fractures, (c) foliate point with distal breakage and subsequent retouch, (d) foliate point, (e) foliate point on flake, (f), double scraper, (g) proximal fragment of foliate point, (h) proximal flake fragment with ventral retouch, (i) double scraper.

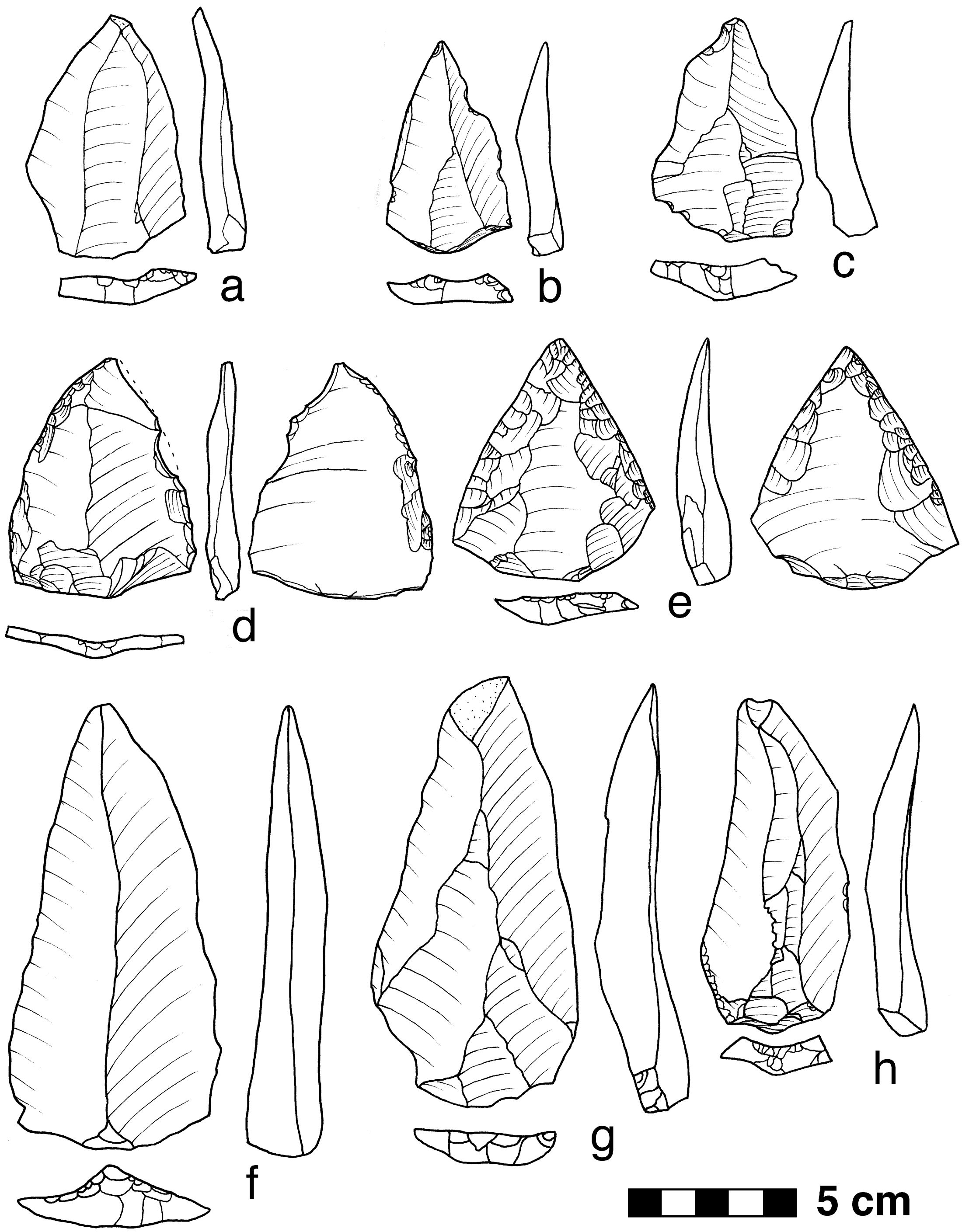

Fig. 23. Selected isolated surface finds from the Kibish Formation Members 1 and 3—Levallois points/triangular flakes: (a–c) Levallois points, (d, e) retouched Levallois points, (f–h) elongated Levallois points. (Note: e is from the Omo 1967 Collections in National Museums of Kenya.)

proximal flake fragments and various cortical flakes. Levallois debitage and pseudo-Levallois points constitute a significant minority of the flakes from each site. The prominence and consistency with which these debitage types occur in the Kibish MSA assemblages suggests a pattern of core reduction that, following decortication, probably alternated between recurrent radial/centripetal flake removals (which create pseudo-Levallois points) and large preferential flake removals (which create both "typical" and "atypical" Levallois debitage).

As with morphological core types, such a highly contingent classification of debitage as presented in Table 15 obscures basic patterns of technological variation. Following the method of Geneste (1985), these debitage types can be grouped together into flakes originating in the same kind of technical operation. These operations and their associated debitage types are initial core preparation (cobble fragments, initial and residual and cortical flakes), core exploitation/reduction (Levallois debitage, Kombewa flakes, blades, other noncortical flakes, and proximal flake fragments), and core rejuvenation (core-trimming elements). Debris and nonproximal flake fragments are not included in this tabulation, because they can occur in any of these technological operations. (Biface-thinning flakes could reflect either core exploitation

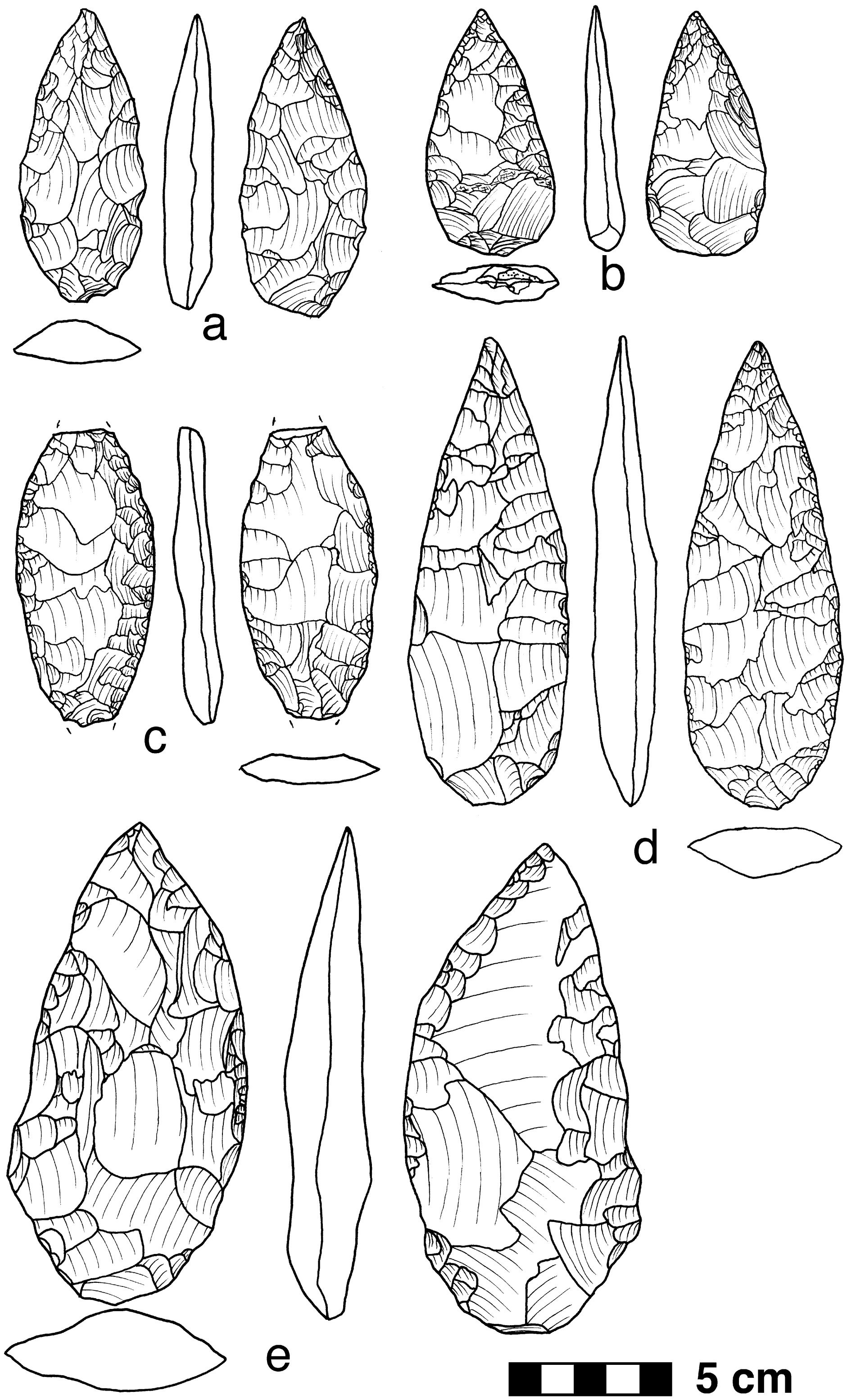

Fig. 24. Surface finds from the Kibish Formation Members 1 and 3—pointed bifaces: (a–c) foliate points, (d) lanceolate point, (e) elongated handaxe. (Note: b and c are from the Omo 1967 Collections in National Museums of Kenya.)

or core rejuvenation, depending on their size; but they are so few in number in the Kibish assemblages that placing them in either category makes no difference in the resulting statistics.) Table 15 also presents the debitage for KHS, AHS, and BNS reorganized in terms of these three technical operations. Kamoya's Hominid Site and BNS exhibit nearly identical patterns of technological variation, about even percentages (40–50%) of flakes referable to core preparation and core exploitation. The AHS assemblages exhibit considerably greater proportions of core exploitation flakes (71–84%) compared to core preparation (16–24%). Core rejuvenation accounts for a small percentage (1–10%) of the flakes in any of the assemblages. This latter pattern may reflect the fact that many of

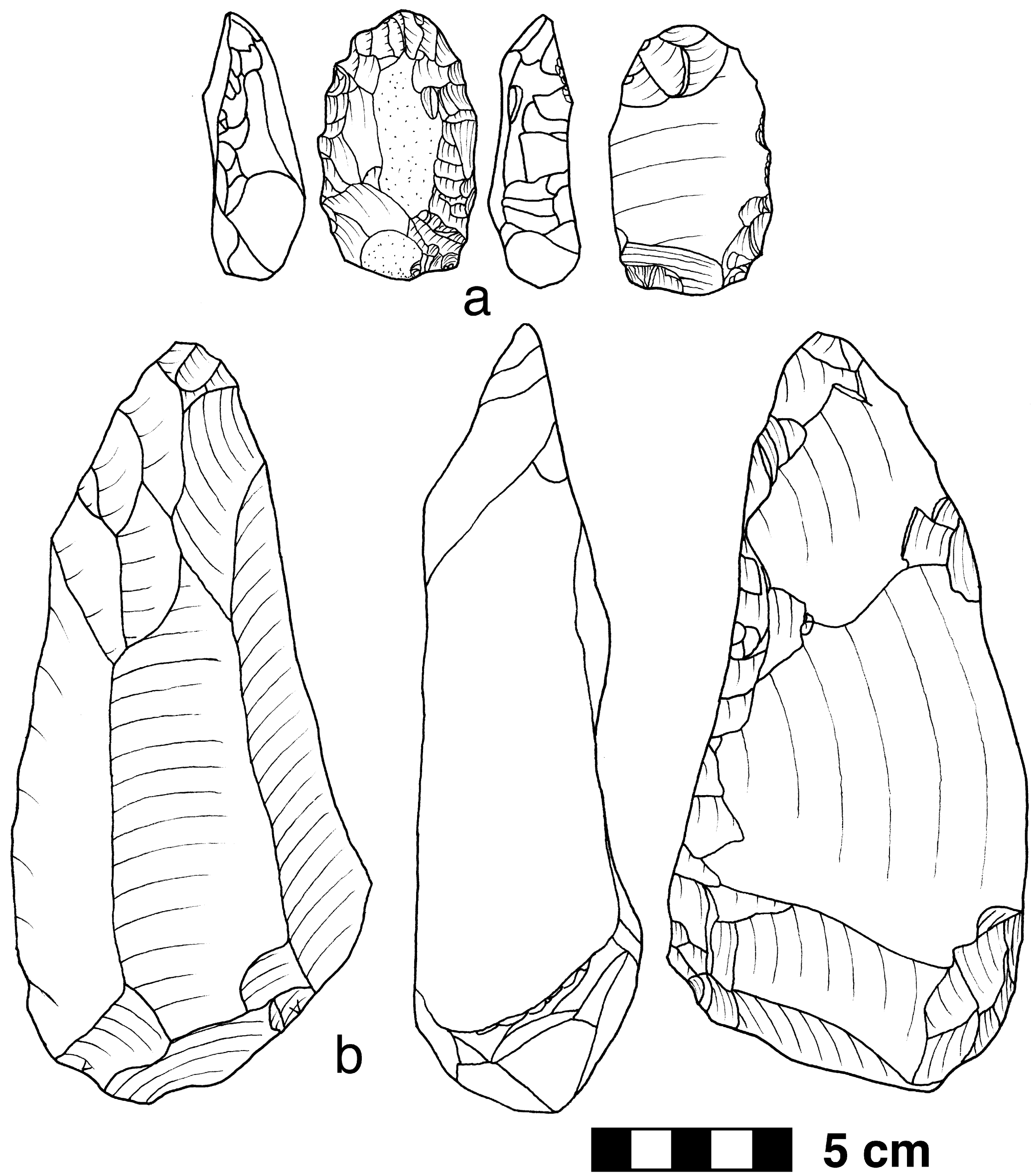

Fig. 25. Surface finds from the Kibish Formation Members I and III—core-axes and picks: (a) core-axe, (b) pick. (Note: b is from the Omo 1967 Collections in National Museums of Kenya.)

Table 11
Percentages of different raw materials in major tool categories for KHS, AHS, and BNS

	High-quality raw materials					Low-quality raw materials					
Sample	Jasper	Chalcedony	Chert	IOCCS	Subtotal	Shale	Rhyolite	Basalt	Indet. volcanic	Subtotal	Row total (n)
KHS cores	42	17	25	0	83	4	4	8	0	17	24
KHS flakes	26	19	25	4	75	7	2	11	6	25	106
KHS rettls	10	0	30	0	40	20	20	5	15	60	20
KHS total	27	16	26	3	71	8	5	10	6	29	150
AHS cores	17	14	37	14	83	11	3	3	0	17	35
AHS flakes	6	7	44	12	69	10	14	8	0	31	810
AHS rettls	14	19	41	6	80	16	3	2	0	20	64
AHS total	7	8	44	11	70	10	13	7	0	30	909
BNS cores	18	18	42	1	78	3	16	1	1	22	74
BNS flakes	13	14	38	4	68	1	19	8	4	32	616
BNS rettls	13	10	50	10	83	0	13	3	0	17	30
BNS total	13	14	39	4	70	1	18	7	4	30	720

Note: IOCCS = indeterminate/other cryptocrystalline silicate; rettls = retouched tools.

Table 12
High- vs. low-quality raw material use in the Kibish MSA assemblages

Site assemblage	Tool group	High-quality raw material	Low-quality raw material
KHS			
	Whole flakes and proximal fragments	79	27
	Cores	20	4
	Flakes/cores	4	7
AHS			
	Whole flakes and proximal fragments	556	254
	Cores	29	6
	Flakes/cores	19	42
BNS			
	Whole flakes and proximal fragments	421	195
	Cores	58	16
	Flakes/cores	7	12

Note: High-quality raw material = jasper, chalcedony, chert, IOCCS (indeterminate/other cryptocrystalline silicate); low-quality raw material = rhyolite, basalt, indeterminate volcanic.

the Kibish MSA cores start their "use-lives" as small clasts that present little "payoff" (i.e., few useful flakes) for efforts to rejuvenate them.

The efficiency of flake production is an important dimension of lithic technological organization. Leroi-Gourhan (1964) originally proposed that the yield of cutting edge per unit of lithic raw material increased steadily over the course of the Paleolithic. As much as 90,000 years may separate the Kibish Member I sites—KHS and AHS (ca. 195 ka)—from BNS (ca. 104 ka). Comparing measurements of flake production efficiency may shed light on diachronic trends in the Kibish MSA technological strategies. Flake production efficiency can be estimated for the Kibish MSA assemblages by comparing the values of two ratios calculated from flake measurements, flake surface area/flake thickness ratio (FSA/T) and the striking platform width/striking platform thickness ratio (SPW/T) (Dibble, 1997). The ratio FSA/T expresses the horizontal extent of a flake relative to its thickness as follows:

$$(\text{technological length} \times \text{midpoint width})/\text{midpoint thickness}.$$

All other things being equal, a flake with a higher FSA/T value is one that has more successfully recovered potential cutting edge from

Table 13
Core type variation in the Kibish MSA assemblages

Core type	KHS (*n*)	AHS 1–5 (*n*)	AHS 6–8 (*n*)	BNS (*n*)
Unifacial chopper	1			
Bifacial chopper	2			5
Partial discoid				4
Discoid		2		
Core scraper	1		4	
Polyhedron	1			1
Asymmetrical discoid	1	1	4	37
Levallois core	10		3	8
Core on flake				2
Other core type	2		1	2
Core fragment	6		7	15
Total	24	3	19	74
Pebble cores	5	2	4	9
Formal cores	11	1	7	45
Cores on flakes	0	0	0	2
Other core types	2	0	1	2
Formal cores/pebble cores	2.2	0.5	1.8	5.0

Table 14
Variation in core volume (cm^3) for technological core types in the Kibish MSA assemblages

Core type	Mean	Median	SD	*n*
Pebble cores	117.2	34.6	195.1	12
Formal cores	20.8	14.8	16.13	45
Core-on-flakes	9.5	8.0	4.4	3
Other	16.9	16.9	14.7	2

a core than one with a lower FSA/T value. Thus, FSA/T serves as a measure of the success of flake production.

The ratio SPW/T expresses the lateral extent of a striking platform relative to the distance between the point of fracture initiation and the dorsal surface of the flake using the following formula:

$$\text{striking platform width}/\text{striking platform thickness}.$$

Controlled experiments show that striking platform thickness has a significant effect on the size of hard-hammer flakes (Pelcin, 1997; Shott et al., 2000). Striking platform width has relatively little effect on flake size. Because relatively wider platforms remove portions of core surface that could theoretically be used as platforms for additional flake removals, flakes with higher SPW/T ratios are more "costly" per unit of potential utility (FSA/T) than flakes with lower SPW/T ratios. Table 16 presents summary statistics of FSA/T and SPW/T variation for the Omo Kibish assemblages. These data were calculated on whole flakes longer than 30 mm in each Kibish MSA assemblage. The values of SPW/T do not differ significantly among the KHS, AHS, and BNS assemblages (ANOVA, $F = 1.24$, $p = 0.29$), but the values of FSA/T do (ANOVA, $F = 5.81$, $p = 0.003$). Contrasts between FSA/T values of BNS on the one hand and a "pooled" sample of the two Member I assemblages (AHS and KHS) are even more significant (ANOVA, $F = 9.41$, $p = 0.002$). The BNS assemblage exhibits essentially the same values for the "cost" of lithic production as the KHS and AHS assemblages but lower values for the "benefit"—cutting edge per unit of stone. These data suggest that there was no overall increase in flake production efficiency in the MSA of the Kibish Formation between 195 ka and 104 ka.

Retouched tool technology

Retouched tools are a minor component of the Kibish MSA assemblages, accounting for slightly more than 4% of all nondebris artifacts recovered from KHS, AHS, and BNS. The most common retouched tool types are simple sidescrapers, followed by foliate points and foliate point fragments (Table 17). If one were to treat the various scraper types together with notches and denticulates as a single larger "unifacially retouched flake" category, this would account for nearly half (43%) of the retouched tools from the Kibish MSA assemblages.

Retouched tools of the same morphological tool type can differ in the extent to which they are retouched. A rough estimate of retouch extent can be made by counting the number of eight polar coordinates about the tool's circumference that were retouched and calculating the corresponding percentage of the tool's circumference. Table 17 also presents a summary of the polar-coordinate counts for the different retouched tool types in the Kibish MSA assemblages. Retouched flake tools in the Kibish MSA assemblages are not extensively retouched. The mean values for the sum of polar coordinates differ among the Kibish MSA assemblages: KHS = 3, AHS = 4 (for both Levels 1–5 and Levels = 6–8), and BNS = 5. By this measure, retouch is somewhat more extensive at BNS than in the other assemblages. Only 32 (43%) of the retouched tools from Kibish MSA assemblages are retouched on more than half of their circumference. To the extent retouch can be

Table 15
Debitage type variation in the Kibish MSA assemblages

Flake types	KHS		AHS 1–5		AHS 6–8		BNS	
	n	%	*n*	%	*n*	%	*n*	%
Cobble fragment	3	2.1			14	2.3	61	7.4
Initial cortical flake	19	13.0	8	3.6	35	5.8	101	12.3
Residual cortical flake	25	17.1	13	5.8	41	6.8	122	14.9
Levallois flake	10	6.8	7	3.1	15	2.5	30	3.7
Levallois blade	2	1.4					1	0.1
Levallois point			1	0.4	6	1.0	2	0.2
Atypical Levallois flake					2	0.3	1	0.1
Atypical Levallois blade					1	0.2		0.0
Atypical Levallois point					1	0.2	1	0.1
Pseudo-Levallois point	5	3.4	10	4.4	17	2.8	19	2.3
Kombewa flake			1	0.4	1	0.2	1	0.1
Blade					1	0.2	3	0.4
Noncortical flake	13	8.9	48	21.3	114	18.9	112	13.7
Biface-thinning flake					1	0.2	2	0.2
Core-trimming element	6	4.1	1	0.4	19	3.2	60	7.3
Flake fragment, proximal	22	15.1	46	20.4	104	17.3	84	10.2
Flake fragment, other	40	27.4	85	37.8	221	36.7	204	24.9
Blocky fragment	1	0.7	5	2.2	9	1.5	16	2.0
Flakes subtotal	146	100.0	225	100.00	602	100.0	820	100.0
Technical operation								
Core preparation 1–3	47	45	21	16	90	24	284	47
Core exploitation 4–14, 16	52	50	113	84	263	71	256	43
Core rejuvenation 15	6	6	1	1	19	5	60	10
Subtotal	105	100	135	100	372	100	600	100

equated with either tool modification for use or resharpening during use, this evidence suggests that neither of these factors played a major role in the technological strategies of the Kibish MSA humans.

Comparing the FSA/T values for the measured flakes to those of retouched flake tools from the same assemblage provides a second, independent measure of retouch intensity (Table 18). The greater the difference, the more intensively the retouched flakes, as a group, have been retouched. The mean FSA/T values for retouched flake tools are in each case significantly ($p < 0.05$) smaller than those for the unretouched flakes in the same assemblages. This, not surprisingly, suggests that retouched flake tools possessed relatively less potential utility when they were discarded than unretouched flakes in the same assemblage.

A discussion of retouched tools is an appropriate place to comment on possible evidence for hafting among the Kibish assemblages. Ambrose (2001) argued that hafting technology was an emergent feature of the African MSA (see also Leakey, 1954: 60; Clark, 1988: 298). The tangs on North African Aterian points, backing of geometric microliths in the South African Howiesons Poort Industry, and bifacial points from various South African Still Bay assemblages point unambiguously to MSA hafting technology (Clark, 1988: 298; Shea, 1997; Lombard, 2005; Minichillo, 2005). Probably the strongest evidence for hafting in the Kibish assemblages consists of two points from BNS (Fig. 22a,b) that have had their bulbar eminence removed by invasive retouch. Such retouch might have made it easier to insert these points into slotted handles. Stone tools do not have to be retouched in order to be hafted, but hafting creates incentives for standardized tool designs (Keeley, 1982). The Kibish evidence does not contraindicate the presence of hafting technology. Rather, the scarcity of clear hafting-related modifications among the Kibish MSA stone tools could signal that hafting was not a sufficiently regular component of the Kibish humans' technological strategy for it to have encouraged the production of standardized tool forms.

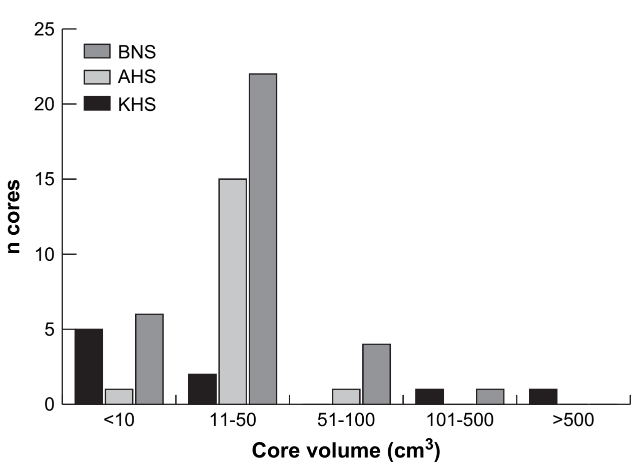

Fig. 26. Histogram of core volume.

Overview of the Kibish MSA industry

The principal shared features of the Omo Kibish MSA assemblages include the following characteristics:

(1) Stone tools are made from pebble- and cobble-sized clasts procured from (probably local) gravel deposits.

Table 16
FSA/T and SPW/T variation in the Kibish MSA assemblages

Ratio	Site	KHS	AHS	BNS
FSA/T				
	Mean	171.4	201.0	159.6
	SD	109.0	98.2	54.3
SPW/T				
	Mean	3.4	4.1	3.9
	SD	1.5	2.1	1.8
n		22	144	76

Table 17
Retouched tool type variation in the Kibish MSA assemblages

	KHS	AHS	BNS	Total
Retouched tool type				
Point/triangular flake	1	2		3
Sidescraper	4	13	4	21
Double scraper		5	2	7
Convergent sidescraper	1		1	2
Transverse scraper		6	1	7
Awl	1	4		5
Backed knife	3	2	6	11
Notch	1	3		4
Denticulate	4	6		10
Bipolar flake		1	6	7
Other retouched flake	4	12	2	18
Foliate point fragment		9	8	17
Handaxe	1	1		2
Column total	20	64	30	114
Circumference retouched				
13%	2	2		4
25%	7	11	1	19
38%		3		3
50%	1	14	1	16
63%		5	3	8
75%	1	9	3	13
88%		3		3
100%	1	6	1	8
Mean	3	4	5	4

(2) Clasts composed of high-quality (i.e., fine-grained, homogeneous, and highly siliceous) rocks, such as chert, jasper, and chalcedony, are more heavily reduced than those of lower-quality rocks, such as shale, rhyolite, and basalt.
(3) Core surface preparation is primarily unidirectional-parallel during decortication, changing to primarily discoidal and radial/centripetal in later phases of core exploitation.
(4) The final forms of cores are predominantly formal (i.e., Levallois cores or asymmetrical discoids). This evidence could indicate a technological strategy responding to the need for standardized tool forms in the context of high residential mobility (Parry and Kelly, 1987).
(5) Relatively little effort was expended on core rejuvenation, possibly because of small initial raw material size. Many "core-trimming elements" are actually plunging flakes that might more appropriately be called "core-terminating elements."
(6) A preponderance of small cores suggests relatively high thresholds for core discard. This could equally well reflect either small initial raw material size or intense curation of cores by transport, or both.
(7) Large numbers of cortical flakes among all assemblages suggest that core preparation occurred on site. Whether this was near or far from the point of raw material procurement remains unknown.
(8) Among debitage products referable to core exploitation, Levallois flakes and pseudo-Levallois points are especially common.
(9) Refitting sets of artifacts typically reflect core preparation, core exploitation, core rejuvenation, or pairs of these three technological operations (mostly preparation and exploitation). No refitting sets feature evidence for all three technological operations. This segmentation of lithic reduction sequences is consistent with inferred patterns of high residential mobility and the curation of cores by transport.
(10) Quantitative measures of flake production efficiency (i.e., FSA/T and SPW/T) have relatively low values, suggesting little effort was made to either conserve core utility or to optimize the recovery of cutting edge (Shea et al., 2007).
(11) Unifacially retouched flakes (scrapers, notches, denticulates) dominate the retouched tool population.
(12) Bifacially retouched tools (foliate points, lanceolates, and handaxes) are rare, mainly found as either isolated surface finds or fragmentary artifacts in excavated assemblages.
(13) Prismatic blades and so-called "Upper Paleolithic/Later Stone Age" retouched tool types (endscrapers, backed knives, and burins) are rare and backed pieces/geometric microliths are absent.
(14) Retouched tools occur in a wide range of sizes without apparent morphological standardization.
(15) Larger core-tools, such as handaxes, picks, and core-axes, are present, but they are rare in excavated assemblages. They are more prominent as isolated surface finds.

Table 18
Mean FSA/T values for unretouched flakes and retouched flake tools in the Kibish MSA assemblages

	KHS	AHS	BNS	Grand total
Unretouched flakes	171.0	201.0	159.0	185.3
Retouched flake tools	165.3	138.2	60.0	134.4
Difference	5.7	62.8	99.0	50.9

Although the particular manifestations of these characteristics vary among the Kibish MSA assemblages, they are sufficiently consistent to reinforce a picture of overall technological and typological unity. It therefore seems convenient to refer to these assemblages collectively as a technological single entity, the *Kibish Industry*. Several lines of evidence point towards the Kibish Industry reflecting a technological strategy responding to the needs of high residential mobility. On the other hand, tools modified for hafting and bifacially retouched tools, which are often linked to theoretical models of high-mobility technological strategies are conspicuously rare. That the Kibish MSA does not fit one or another of the archaeological theoretical archetypes of either high or low mobility is not altogether surprising. The actual technological strategies of the Omo Kibish humans were probably compromises between contradictory imperatives of mobility and sedentism, curation and expedience, functional and cultural factors, and other situational variables that we can only dimly view in a small number of archaeological assemblages.

Comparison with other east African MSA assemblages

It is not easy to place the Kibish Industry in the larger MSA of eastern Africa. Unlike northern Africa and southern Africa, whose MSA records preserve regional horizon-wide turnovers in named industries, the MSA of eastern Africa instead features a complex mosaic of local industries and industrial sequences (Clark, 1988). There is no single overarching regional culture-historical framework for the eastern African MSA. Situating the Kibish MSA in its regional context therefore requires site-by-site comparisons between the Kibish Industry and MSA sites in Ethiopia, Kenya, and adjacent countries (Fig. 27).

The nearest and best-dated MSA contexts are those from the Gademotta and Kulkuletti site complex (Wendorf and Schild, 1974). Gademotta and Kulkuletti are open-air sites (really elongated trenches cutting across numerous individual MSA levels) on the slopes above the western shore of Lake Ziway, in the Central Rift Valley of Ethiopia. Radiopotassium dates of 140 ka to 230 ka have been obtained for early MSA contexts at Gademotta (Wendorf et al., 1975). The principal source of raw materials at these sites is a series of nearby obsidian flows. The Gademotta/Kulkuletti assemblages have several obvious points of similarity with the Kibish Industry. Heavy cutting tools (i.e., handaxes, lanceolates) are rare, and there

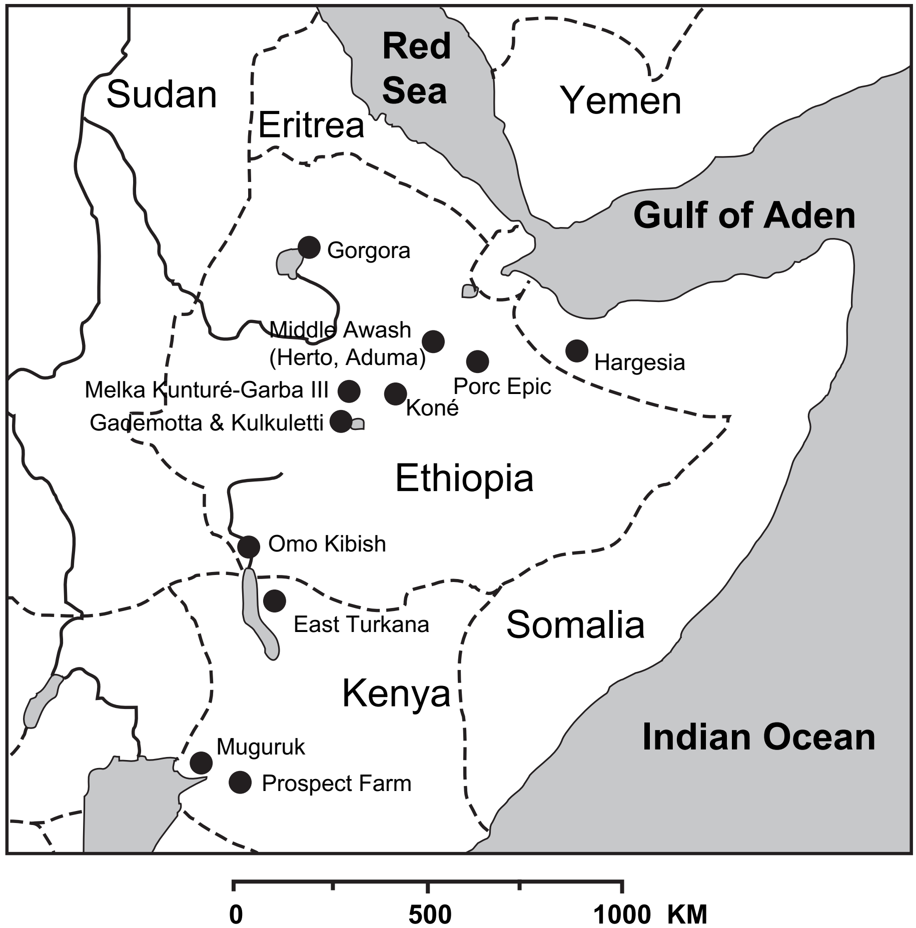

Fig. 27. Map of east Africa showing location of MSA sites discussed in the text.

are both large and small Levallois cores and flakes. The main points of difference appear to revolve around points, both retouched triangular flakes (retouched Levallois points, Mousterian points, convergent sidescrapers) and foliate points. These tools are more prominent components of the Gademotta/Kulkuletti assemblages than they are in the Kibish Industry. The technique of resharpening the distal tips of points through the use of tranchet and burin blows—clearly apparent at Gademotta/Kulkuletti (Wendorf and Schild, 1993)—is not present among the Kibish assemblages.

The Middle Awash Valley in northeastern Ethiopia also has an archaeological record of roughly the same age and with many parallels to the Kibish Industry. Clark et al. (2003) recently described lithic assemblages associated with early *H. sapiens* fossils in the Upper Herto Member, Bouri Formation. These assemblages date to 154–160 ka and are composed of tools from controlled surface collections and excavations. The most obvious points of similarity with the Kibish Industry are the presence of handaxes and picks as well as a prominent Levallois component, the latter with common radial/centripetal preparation. Similarities with the Kibish Industry are stronger still for assemblages of the Aduma Industry, found in the Ardu Beds, several kilometers north of Herto in the Middle Awash Valley (Yellen et al., 2005). The Aduma Industry assemblages from Ardu B date to around 90 ka on the basis of U-series and optically stimulated luminescence (OSL) dates. They possess many of the same features as the Upper Herto assemblages (large cutting tools, prominent Levallois core-reduction technology). They also feature retouched triangular points, foliate bifacial points and small, asymmetrical discoidal cores and Levallois cores like those seen in the Kibish assemblages. The few clear differences between the Aduma and Kibish industries probably reflect raw-material variation. Large clasts of volcanic rock and obsidian are readily available at Aduma but rare in the Kibish Formation.

Porc Epic Cave is a third dated Ethiopian site with parallels to Omo Kibish. Porc Epic is located near Dire Dawa (southern Afar Rift). Obsidian hydration dates the MSA levels of this site to at least 60–77 ka (Breuil et al., 1951; Clark et al., 1984). Assefa (2002) described the zooarchaeological assemblage, while Pleurdeau (2003, 2005) described the Porc Epic MSA lithic assemblage. This assemblage features a prominent Levallois component (42% of cores) and a rich series of retouched triangular flakes and foliate points. Some of these points have close counterparts among the Kibish Industry, though these are mainly surface finds. Burins are common at Porc Epic, though the burin/tranchet technique seen at Gademotta/Kulkuletti does not appear to have been used to resharpen point tips there. Heavy bifacial cutting tools are rare. The backed pieces (*piéce a dos abbatu*) reported by Pleurdeau have no exact parallel among the backed knives from Kibish. Like Gademotta/Kulkuletti, large triangular Levallois flakes appear to have been selected for use as blanks for the production of foliate points. Such a mode of selection is not clear among the Kibish assemblages, owing mainly to small sample size.

Taken together, the evidence from Omo Kibish, Gademotta/Kulkuletti, the Middle Awash, and Porc Epic suggest the possibility of early *H. sapiens* populations practicing relatively similar technological strategies throughout a considerable part of southern and central Ethiopia between 80 ka and 200 ka. There are additional undated sites from Ethiopia and adjacent countries that hint at more widespread “connections” among northeast African MSA industries, but their uncertain geochronology limits what one can infer from comparisons.

In geographic terms, the nearest MSA sites to Omo Kibish are six MSA localities from East Turkana reported by Kelly and Harris (1992; Kelly, 1996). Like the Kibish assemblages, the East Turkana MSA assemblages represent a mix of high- and low-quality materials, with an emphasis on the reduction of the former. Small Levallois cores and retouched triangular flakes are present, but foliate bifaces appear to be absent. Some of the similarities between the East Turkana MSA assemblages and those from Omo Kibish reflect the common use of small pebbles in both areas. The kinds of large cutting tools (picks, handaxes, lanceolates) occasionally seen in Omo Kibish are not reported from the East Turkana sites.

Koné is an open-air workshop site located inside a caldera in the southwest corner of the Afar Rift (Kurashina, 1978). The site is undated, but its lithic assemblage is reported to be techno-typologically similar to that of Gademotta/Kulkuletti (Clark, 1988: 260). Levallois points were a significant focus of tool production at Koné. Koné and the Kibish sites share rare evidence of bifacial retouch on flakes and foliate bifaces. Their most important point of similarity is the use of truncated flakes as cores and, on the basis of tools illustrated by Clark (1988: 259), the production of asymmetrical discoids. The complex Nubian-technique of Levallois point production seen at Koné is not seen among the Kibish assemblages.

Gorgora Rockshelter is located on the northern shore of Lake Tana. This site, which was excavated in the 1940s (Moysey, 1943), contains a 2 m-deep sequence of MSA assemblages. Many of the “waste flakes” from this site contain a facetted striking platform, suggesting a significant Levallois component. Bifacial foliates are prominent among the retouched tool component (Leakey, 1943). Of these points, many of the shorter ones appear similar to those from the Kibish Industry. Backed pieces like those from Porc Epic were also recovered from Gorgora, but the relatively uncontrolled nature of the excavations at this site leaves doubt about their association with the other MSA artifacts.

The site of Garba III at Melka Kunturé contains MSA assemblages in alluvial sediments of uncertain age. The earliest of these assemblages feature small triangular and cordiform handaxes and foliate bifaces. As in the Kibish assemblages, endscrapers and burins are rare, and Levallois flakes represent a small proportion of all debitage (Hours, 1976).

The Muguruk in western Kenya preserves a sequence of assemblages spanning the Sangoan-Lupemban/MSA transition (McBrearty, 1981). The assemblages from Muguruk are organized into an earlier Ojolla Industry and a later Pundo Makwar Industry. The Ojolla Industry differs significantly from the Kibish Industry in retaining a prominent heavy bifacial cutting tool component and relatively rare Levallois debitage. The Pundo Makwar Industry shares many of the same key features as the Kibish Industry. These features include a prominent Levallois debitage component, relatively few biface-thinning flakes, small foliate bifaces, and predominantly radial/centripetal core preparation.

Small foliate points and convergently retouched triangular flakes such as those seen among the Kibish assemblages also have parallels among the obsidian artifacts from Prospect Farm in western Kenya (Anthony, 1978). The numerous thinned and elongated foliate bifaces found primarily on the surface and eroding from the top of Kibish Member III have obvious points of similarity with artifacts from Hargesia, Somalia (Clark, 1954), and, indeed with similar Lupemban artifacts from contexts throughout equatorial Africa. At this juncture, however, the relatively rudimentary state of lithic typology for the MSA in eastern Africa makes further evaluation of these similarities problematical.

The Kibish Industry and most of the east African MSA assemblages described above share the following key features:

(1) Large core-tools (handaxes, picks, core-axes, and lanceolates) are present but relatively rare. Such symmetrical bifaces tend to be relatively small and triangular, ovate, or cordiform in shape.
(2) Levallois debitage is present in all assemblages. Radial/centripetal Levallois core-preparation seems to have been a common technique, but most estimates are based on counts of cores rather than analysis of scar patterns on the dorsal surfaces of flakes.
(3) Discoidal core reduction is also present in most assemblages.
(4) Foliate bifacial points are present in many assemblages, although their frequency varies.
(5) There is little evidence for the systematic production of geometric backed pieces. Such backed pieces are known from sites not much further south than those discussed here, including Mumba Cave in Tanzania (Mehlman, 1989) and Enkape Ya Muto in the southern Kenya (Ambrose, 2002).

The MSA assemblages from Omo Kibish Members I–III appear to be a local variant of a larger, as yet unnamed, east African MSA industrial complex (Brandt, 1986; Clark, 1988). There appear to be strong typological similarities among east African MSA assemblages spanning the period from ca. 140–230 ka (at Omo Kibish Member I and Gademotta/Kulkuletti) to at least ca. 80–100 ka (at Omo Kibish Member III, Aduma Ardu B, and Porc Epic). Such similarities could indicate a significant degree of cultural continuity and perhaps demographic stability in this region. Although one is rightly skeptical about equating similarities among stone tool industries with biological continuities among their makers (Clark and Riel-Salvatore, 2005), there are reasons apart from those involving assumptions about the sources of lithic industrial variation that suggest that there may have been such continuity.

High topographic relief insulates eastern Africa (or rather, microregions within eastern Africa) from wide climate change to a somewhat greater degree than northern or southern Africa (Hamilton, 1982; Littmann, 1989). During arid phases of the middle–late Pleistocene climate, such topographic variation may have created hospitable refugia for human populations within eastern Africa (Brandt, 2006). The Red Sea coast of Eritrea, for example, featured freshwater “oases” at times of lowered sea level and inland desertification (Faure et al., 2002; Bruggemann et al., 2004). The woodlands lining the Omo River may have been a similar such refugium during arid periods, though probably more episodically than for prolonged periods. Techno-typological continuities among east African MSA assemblages may reflect the isolation, persistence, and periodic dispersals of early *H. sapiens* populations within this region. This hypothesis clearly needs further substantiation from paleoclimatic studies within east Africa and from more detailed analysis of east African MSA assemblages, as well as concerted efforts to date more of them. If this hypothesis is supported by research, increased understanding of the sources of behavioral variability reflected in the east African MSA will shed considerable light on the origin and initial adaptive radiation of *H. sapiens*.

Conclusions

Since the discovery of the Omo Kibish fossils more than thirty years ago, little has been known about their archaeological associations. This paper has reported what we have recently learned about the archaeological context of these fossils. There remains much more that can be done in the Lower Omo Valley, both in terms of geochronology, fossil prospection, and archaeology, but for the present, the paleoanthropological evidence from the Omo Kibish formation contributes to research on the origins of *H. sapiens* in Africa.

The Omo Kibish fossils and their archaeological associations suggest that skeletally modern-looking *H. sapiens* were present in eastern Africa by at least 195 ka. We do not know if our species emerged in this region from local precursors or if it is descended from populations who migrated from elsewhere (Bräuer, 1992). The retention of archaic morphology among the Herto fossil sample and Omo II suggests such a local origin (White et al., 2003). One could also cite techno-typological continuities in this region across the Acheulean MSA "transition" as further support for such a regional-continuity hypothesis (Brandt, 1986; McBrearty, 2003). Typological similarities between the Kibish Industry, the Aduma Industry, and other dated MSA assemblages from Ethiopia, Sudan, Somalia, and Kenya suggest that the MSA of eastern Africa shows a mosaic pattern of variation through time and space. This mosaic pattern contrasts with the kinds of sharp breaks and horizon-wide transformations of the MSA record elsewhere in Africa (Clark, 1984, 1988). Whether this mosaic pattern of industrial variability in eastern Africa is real, and perhaps a reflection of evolutionarily stable adaptations among early populations of *H. sapiens,* or if it is instead an illusion created by a relatively coarse-grained archaeological record, can only be revealed by further research.

It is tempting to close this paper with an assessment of what the MSA evidence suggests about the "behavioral modernity" of the Omo Kibish humans. It is a temptation worth resisting. The criteria for recognizing behavioral modernity in the archaeological record are in one way or another ultimately derived from what are perceived as the emergent behavioral features of the European Upper Paleolithic (McBrearty and Brooks, 2000; Henshilwood and Marean, 2003). The use of these traits reflects three historically contingent facts: (1) the behaviors in question are associated with the first *H. sapiens* populations in Europe; (2) Paleolithic archaeology began earlier in Europe than in other parts of the Old World; (3) the European Paleolithic record was used (and continues to be used) as a model for Paleolithic cultural succession in other regions. Thus, the "standard" for human behavioral modernity is what *H. sapiens* populations were doing when they dispersed into Europe after 45 ka. It should surprise no one that African MSA humans come up short in an assessment of their modernity that cross-cuts significant evolutionary time and space. The MSA Africans weren't Upper Paleolithic Europeans. Socrates would rate poorly compared to the dimmest twenty-first-century college student if the standards for "behavioral modernity" were recently derived features of North American material culture. Such comparisons move us very little towards understanding behavioral differences among prehistoric humans if we do not have robust models for the cognitive, social, and ecological sources of their strategic variability.

Paleoanthropological research at Omo Kibish—as well as elsewhere in Africa and the Near East—is making it increasingly clear that there was a long period, perhaps 200–40 ka, during which the residues of *H. sapiens* adaptive strategies differed significantly from those of humans who lived after this period. The nature of contrasting patterns of human behavior before and after ca. 40 ka is one of the most intensely researched and debated topics in Paleolithic archaeology (Klein, 1992, 2000; McBrearty and Brooks, 2000; Bar-Yosef, 2002; Henshilwood and Marean, 2003; Mellars, 2006; Stiner and Kuhn, 2006; Zilhão, 2006). Far less research has been directed at human behavioral variability before the so-called "human revolution" of 50–30 ka. Understanding what these earlier Middle Paleolithic/Middle Stone Age *H. sapiens* populations were doing between 250 ka and 50 ka, as well as the nature and stability of their adaptations, will only advance to the degree that we also understand the sources of their strategic ecological and behavioral variability.

Improved knowledge about the archaeological contexts for early human fossils is an important step towards such an improved understanding of the behavioral variability of early *H. sapiens*. It is simply not credible to try to assess the behavioral variability of human populations distributed on a continental scale over hundreds of thousands of years with evidence from one site, or even a small number of sites in the same region. We need far more well-dated and well-documented archaeological sites than are presently available to even begin to frame the broad outlines of such an assessment.

For nearly thirty years, there was little that could be said with confidence about either the age or the behavior of the Omo Kibish humans. We now know they lived around 195 ka and that their adaptations were similar to those of roughly contemporaneous humans living in at least the northern part of eastern Africa at 250–50 ka. Recent studies of genetic and linguistic variation increasingly point to this part of Africa as a likely region for the origin and initial dispersal of our species (Lahr and Foley, 1994; Tishkoff and Verrelli, 2003). There is much to be gained by improved understanding of these fossils' archaeological and geological contexts. It is hoped that the archaeological research in the Lower Omo Valley Kibish Formation reported here will inspire others to carry out similar research on archaeological contexts of the many other early *H. sapiens* fossils about which we currently know so little.

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Appendix. Lithic analysis framework

There is no single standardized typology for the east African MSA comparable to that used in Europe, western Asia, and North Africa (i.e., Bordes, 1961; Geneste, 1985; Debénath and Dibble, 1994). This appendix describes the classifications and measurements used in the analysis of the Omo Kibish MSA assemblages. The artifact-types and measurements recorded by this study are "standard" ones in broad use among Paleolithic researchers.

Raw materials

Raw material color/texture was recorded for all artifacts except the debris from AHS (a decision reflecting limited time and lab space). All identifications were made by the author based on visual inspection. The following list summarizes the major rock types:

Jasper—fine-grained, brightly lustrous, usually bright red or bright yellow.

Chalcedony—white or pale yellow with varying degrees of translucency.
Chert—generally highly siliceous, but opaque. Color varies widely across a spectrum from green to tan to light brown and dark brown. (One particular variety of dark-brown chert may be fossil wood, but petrographic study would be needed to confirm this identification.)
Shale—generally pink, dark green, or black, with a matte luster. (The pink shale is noticeably less siliceous than the others and may instead actually be some kind of silicified mudstone.)
Rhyolite—widely variable in color (mostly shades of gray) with wide variation in the visibility of flow-banding and phenocrysts. Rhyolites used for stone tool production are significantly more fine-grained and less phenocrystic than the more common rhyolites in the Kibish Member I gravels.
Basalt—mostly nonvesicular and either dark gray or green in color. Again, this contrasts with the more common coarse-grained and vesicular basalts in local gravel deposits.
Indeterminate/other cryptocrystalline silicate—this category includes rare pieces of quartz, quartzite, opal silica, and a small number of indeterminate raw materials.
Indeterminate volcanic—this category encompasses a small number of rock types that were clearly volcanic in nature but not conclusively identifiable as rhyolite or basalt.

In addition to these basic rock type identifications, each rock was also characterized by an assessment of its color and texture. Unfortunately, color/texture proved so widely variable for each rock type that paired rock-type and color/texture values resulted in hundreds of raw material taxa. In the interest of brevity only rock type identifications are discussed in this report.

Artifact classification

Flaked stone artifacts were divided into five main artifact categories, cores, debitage (flakes), debris, retouched tools, and hammerstones. More specific classifications and measurements differed among these artifact categories. Each is discussed below. All artifact measurements were made in millimeters using digital calipers. Classifications and measurements were recorded by hand in the field and later transcribed into an electronic database. Representative samples of artifacts were sketched in the field by the author. A selection of these sketches, inked by the author, accompanies this report.

Cores/flaked pieces

Cores include most of the artifacts from which flakes longer than 1 cm have been struck. (Handaxes, foliate points, and other large cutting tools were treated as retouched tools. See discussion below.) Cores from the Kibish MSA assemblages were classified in terms of the following artifact-types:

Unifacial chopper—a pebble core that has a single continuous series of flake scars aligned in the same direction along one portion of its circumference.
Bifacial chopper—a pebble core that has two series of continuous flake scars detached on opposite faces of the same portion of its circumference, but not for more than 50% of its circumference.
Partial discoid—a pebble core that has bifacial flake scars on more than 50% of its circumference.
Discoid—a pebble core, roughly circular in planform aspect and lenticular cross section, whose entire circumference has bifacial flake scars, but whose flake scars do not extend past the midpoint of the core.
Core scraper—essentially a discoid with one flat, noncortical surface and another highly convex surface covered by flake scars.
Polyhedron—a pebble core with more than one discrete series of bifacial and/or unifacial flake scars.
Asymmetrical discoid—a core on which invasive flake removals are predominantly on one side and platform preparation flake scars are on the other. Flake scars on the former surface do not generally extend beyond the midpoint of the core surface. Usually, there is a residual cortical surface at the center of the less invasively flaked surface. Yellen et al. (2005) coined the term “Aduma cores” for similar artifacts from the Middle Awash Valley.
Levallois core—cores with a hierarchy of flake removal surfaces, a flake removal surface on which flake scars extend past the midpoint of the core, and a platform preparation surface with less invasive flake scars.
Core-on-flake—a flake that has a flake detachment scar longer than 30 mm somewhere on its surface and no other sign of edge-modification or retouch.
Other core type—this category encompasses cores that do not fit into one of the above categories (e.g., pebbles with a single flake removal, prismatic blade cores). (Note: Handaxes in the Kibish assemblages are treated as retouched tools.)
Core fragment—fragment of a pebble, flake, or angular rock fragment with visible flake scars greater than 20 mm, but for which no precise typological assignment could be made.

The principal measurements made on cores included the following:

Length—the core’s longest dimension.
Width—the longest dimension perpendicular to length.
Thickness—the distance between the upper and lower surfaces of the core measured at the intersection of length and width and perpendicular to the plane defined by the length and width dimensions.

Debitage/unretouched flakes and flake fragments

Debitage includes all unretouched flakes and flake fragments larger than 1 cm. The debitage types recognized by this study include the following:

Cobble fragment—hemispherical fragment of a cobble or pebble split by a shear fracture.
*Initial cortical flak*e—flake with more than half of its dorsal surface covered by cortex.
Residual cortical flake—flake with less than half of its dorsal surface covered by cortex.
Levallois flake—symmetrical, noncortical flake with facetted and projecting striking platform.
Levallois blade—symmetrical, noncortical blade (an elongated rectangular flake) with facetted and projecting striking platform.
Levallois point—symmetrical, noncortical triangular flake with facetted and projecting striking platform.
Atypical Levallois flake—asymmetrical, noncortical, or partly cortical flake with facetted and projecting striking platform.
Atypical Levallois blade—asymmetrical, noncortical, or partly cortical blade with facetted and projecting striking platform.
Atypical Levallois point—asymmetrical, noncortical, or partly cortical triangular flake with facetted and projecting striking platform.
Pseudo-Levallois point—triangular or trapezoidal flake with facetted striking platform and whose technological and morphological long axes diverge from each other.

Kombewa flake—a flake whose dorsal surface preserves the former ventral bulbar surface of the flake/core from which it was struck.
Prismatic blade—flakes whose length is at least twice that of their width, which feature parallel lateral edges and distal–proximally aligned dorsal flake scars.
Noncortical flake—any non-Levallois, noncortical flake longer than 30 mm in any dimension and not subsumed by other debitage types.
Biface-thinning flake—a flake with a facetted striking platform, low external platform-dorsal surface angle, and multidirectional flake scars on its dorsal surface.
Core-trimming element—flakes whose lateral or distal edges contain substantial amounts of residual core edge (i.e., for more than one third of the flake's circumference).
Flake fragment, proximal—incomplete flake retaining the striking platform and bulbar eminence.
Flake fragment, other—incomplete flake lacking the striking platform and/or bulbar eminence. More specific notations about the kind of flake fragment (distal, medial, lateral, etc.) were noted in cataloging Kibish MSA artifacts, but this aspect of flake-fragment variation is not explored in this analysis.
Blocky fragment—angular flake fragment that cannot be definitively assigned to a flake fragment subtype.

Five metric variables were measured on all whole flakes longer than 30 mm. These measurements, based on definitions in Dibble (1997), were selected because they can be related to cost/benefit models of lithic production strategies (see text).

Values for the following variables were measured on all whole flakes from the Kibish MSA assemblages longer than 30 mm:

Technological length—the distance from the point of percussion on the flake striking platform to the most distant point on the distal end of the flake perpendicular to the plane of striking-platform width.
Midpoint width—flake width measured perpendicularly to technological length at the midpoint of technological length.
Midpoint thickness—the distance between the dorsal and ventral surfaces at the midpoint of technological length.
Striking platform Width—the distance between the two most lateral points on the striking platform.
Striking platform thickness—the distance between the point of percussion and the nearest point on the opposite edge of the striking platform.

Debris/small debitage

Debris included flakes or flake fragments smaller than 30 mm in any dimension. When time allowed (i.e., at KHS and BNS), debris was cataloged as either "cortical" or "noncortical."

Retouched tools

Retouched tools from the Kibish MSA assemblages were classified in terms of the following numbered types:

Point—triangular flake with retouch restricted to its distolateral edges (e.g., Mousterian point, retouched Levallois point).
Sidescraper—flake with invasive retouch along one lateral edge.
Double scraper—flake with invasive retouch along both lateral edges and whose edges do not converge to a point at the distal end of the flake.
Convergent sidescraper—flake with invasive retouch along both lateral edges and whose edges converge symmetrically to a point at the distal end of the flake.
Transverse scraper—flake with invasive retouch on its distal edge.
Awl—flake with sharp projection formed by two sets of concave flake removals.
Backed knife—blade or elongated flake with steep/noninvasive retouch along only one of its lateral edges.
Notch—flake with either a single or a small cluster of flake removals creating a marked concavity on its edge.
Denticulate—flake with a series of deep concavities along its edge.
Bipolar flake—a flake with symmetrical patterns of crushing and/or invasive flake scars on opposite sides of the circumference. (Sometimes called *outils écaillées* or "scaled pieces"; the retouch on these tools is more likely use-related damage, possibly arising from the use of the tool as a wedge.)
Other retouched flake—retouched flake not subsumed by the other categories.
Foliate point—bifacially flaked artifact with convergent lateral edges that is less than 10 cm in length. Fragments of foliate points were differentiated from whole pieces.
Handaxe—bifacially flaked artifact with outwardly curving lateral edges and a convergent distal tip that is greater than 10 cm in length. Further typological notes (following conventions in Debénath and Dibble (1994) were made among "comments" in the artifact catalog.
Lanceolate biface—elongated bifacially flaked artifact with parallel–convergent lateral edges that is less than 10 cm in length.

This retouched tool typology originally included contingencies for burins and truncated flakes, but none of these artifacts were recovered by our excavations.

Including handaxes among the retouched tools was an arbitrary decision, as the larger ones certainly could have functioned as cores (i.e., as sources of useable flakes). Most of the handaxes from the Kibish Formation are relatively small, thin, and feature straight lateral edges and shallow flake scars on their surfaces. These properties suggest that knapping activities associated with them at the time they were discarded were more directed at shaping and maintaining the edges of these tools as functional cutting edges than it was towards large flake production.

The distinctions among foliate points, lanceolates, and handaxes were also arbitrary. Were this typology to be redesigned, it would have treated the bifacially retouched artifacts as a single category of artifacts separately from retouched flakes, and it would have characterized them in terms of metric criteria such as length and cross-sectional area.

Measurements of the retouched tools are largely the same as those made for debitage (i.e., length, width, thickness, platform width, platform thickness).

The extent of retouch on each tool was measured by placing the artifact on an eight-point polar-coordinate grid and recording the number of whole segments of the tool's circumference that intersected with retouched edges.

Hammerstones/pounded pieces

Pebbles/cobbles with discrete patches of pitting and crushing of the sort resulting from hard-hammer percussion were identified as hammerstones. Hammerstones were classified as either whole or fragmentary, and their length, width, and thickness were measured in the same way as for cores. Cores with signs of percussion damage on them were classified as cores, but a note reporting their visible damage was made in the "comments" section of the catalog.

Refitting

Numerous refitting constellations were found in the KHS and BNS assemblages (see Sisk and Shea, 2008). The catalog number and provenience of each artifact in these constellations was recorded. The component artifacts were drawn/photographed in both separate and conjoined/refitted positions. Each set of artifacts was recorded as either comprising refits (artifacts divided by conchoidal fracture), conjoins (artifacts broken by nonconchoidal fracture), or a combination of both. Refitting sets were further classified in terms of the kind of technological operation from which they represented, as follows:

Core preparation—refitting sets of cortical flakes with either cortical or plain striking platforms.
Core exploitation—refitting sets of partly cortical and/or noncortical flakes with noncortical striking platforms, or either such flakes refitting to a core.
Core rejuvenation/termination—flakes whose lateral or distal edges preserve residual striking platforms and/or "plunging"/overshot flakes that refit to a core.

Refitting sets that combined two of these kinds of technological operations were classified as resulting from core preparation/exploitation or core exploitation/rejuvenation. These are, admittedly, somewhat subjectively assessed analytical units, but there is precedent for their use (Geneste, 1989; Cziesla, 1990).

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