Archaeol Method Theory (2014) 21:781 823
DOI 10.1007s1081601391765

The Transition to the Acheulean in East Africa: an Assessment of Paradigms and Evidence from Olduvai Gorge (Tanzania)

Ignacio de la Torre Rafael Mora

Published online: 2 May 2013
Springer Scienceusiness Media ew ork 2013

Abstract The origin of the Acheulean constitutes a key aspect of current research in the archaeology of human evolution. Olduvai Gorge is one of the main sites in Africa in the study of the transition from the Oldowan to the Acheuleandue to both the uniqueness of its archaeological recordand the influence of early investigations at Olduvai on the development of Early Stone Age research. This paper reviews the impact of work at Olduvai in shaping a modern view of cultural evolution from the Oldowan to the Acheulean. It also evaluates the lithic assemblages ecavated by Mary eakey in Olduvai Middle and pper ed IIbased on a firsthand review of the collections. e conclude that prev ious paradigms used to eplain inter assemblage variability are not superseded as much as generally assumedand that a modern view of the origins of the Acheulean requires a reassessment of the cultural biologicaland paleoecological evidence at Olduvai and elsewhere in Africa.

Keywords Olduvai Gorge · Acheulean origins · Oldowan · Early Stone Age

Introduction

Current evidence points to Africa as the region where the Acheulean first emerged. The archaeological record in Konso (eyene et al. 2013)Olduvai (eakey 1971)Gona (uade et al. 2004)Koobi Fora (arris and Isaac 1976)est Turkana (epre et al. 2011)Sterkfontein (Kuman and Clarke 2000)and the Vaal River (Gibbon et al. 2009) among othersindicates that the earliest handaes appeared in the 1.76 1.4 myr time

I. de la Torre ( )
Institute of Archaeologyniversity College ondon
3134 Gordon Square C10Pondon K
email: i.torreucl.ac.uk

R. Mora
Centre d Estudis del Patrimoni Arqueologic de la Prehistoria. Facultat de letres
niversitatAutonoma de arcelona08193 ellaterra Spain

spanand rapidly dispersed across the ear East (arosef and GorenInbar 1993) and India (Pappu et al. 2011). hile refinement of the eact timing of Acheulean beginnings is still ongoingthere is general agreement that the Acheulean must have emerged from the previous Oldowana technology widely documented in East Africa.

Olduvai Gorge was the first archaeological sequence in East Africa where strati graphic succession from the Oldowan to the Acheulean was documented (eakey et al. 1931b). Etensive fieldwork since the 1930sthe quality and abundance of the archaeological recordand the long succession of welldated assemblageshave made Olduvai one of the main sequences of reference for the study of early stages of cultural evolution in Africa. The influence of research at Olduvai is not only empirically basedbut also theoreticalas many current paradigms are deeply rooted in models originally proposed by ouis eakey (1951) and then reformulated by Mary eakey (1971).

Debate over the interpretation of interassemblage variability and its bearing on cultural evolution at Olduvai Gorge has been ongoing for decades (e.g.Isaac 1971 ay 1976ower 1977Stiles 1979Davis 1980Gowlett 1988)and continues today (de la Torre and Mora 2005Semaw et al. 2009). In recent yearsculturehistory implications of Mary eakey s (1971) model have been substituted by ecologicalfunctional eplanations of interassemblage variability at the onset of the Acheuleanbut her terminology and data interpretation are still widely accepted. This paper reviews the history of ideas on the interpretation of cultural evolution and assemblage variability at Olduvai Gorgeand presents data on several Middle and pper ed II assemblages based on a direct revision of eakey s lithic collections. In doing soour aim is twofoldto point out pitfalls of past and current models eplaining variability at the beginning of the Acheuleanand to highlight the importance of sustaining hypotheses on a primary study of assemblages. Our results indicate that cultural and biological dualphyla paradigms such as the classic binomial equation Oldowan omo habilis and Acheulean omo erectus widely used to eplain interassemblage variabilityare yet to be superseded.

The Establishment of a Cultural Evolutionary Sequence at Olduvai Gorge

Despite a 3month field season in 1913Reck (1914) did not find any stone tools that could prove the presence of humans in Olduvai Gorge. ApparentlyReck was convinced that no lithic artefacts were present at the Gorgewhereas even before his first visit eakey was certain that he would eventually find specimens of the handae culture at Olduvaiwith the added advantage of finding this culture in association with a rich fauna (eakey 19513). Indeedon the very first day of his first epedition to Olduvai in 1931he found handaes in ed IV (eakey 1951). ithin a few daysunrolled coupes de poing (i.e.handaes) had been found in situ in various parts of the sequence and were compared to the Kenyan Chellean and Acheulean (eakey et al. 1931a).

y a couple of months later (eakey et al. 1931b)a preliminary cultural sequence of the Olduvai record had been established. This included a newly discovered industry first termed PreChellean (eakey et al. 1931b) and then formally named Oldowan (e.g.eakey 1936)as well as a long sequence of handaebearing assemblages.

Following the original proposal by Reck (1914)Olduvai deposits were divided into five beds by eakey et al. (1931a). ed Ithe lowest deposits in the seriescontained archaiclooking stone tools without handaes. These were followed by early Chellean tools at the bottom of ed IIabove which an advanced Chellean occurred. In ed III eakey et al. (1931b) reported artefacts regarded as transitional from the Chellean to the Acheuleanwhile the lower part of ed IV contained early Acheulean and ed V the socalled Kenya Aurignacian. To a great etentthis earliest description of the Olduvai archaeological seriesclaiming to have in beds s 1 to 4 the gradual evolution from a PreChellean type of culture to a developed Acheulean (eakey et al. 1931b1075)would prevail until today.

Subsequent field seasons at Olduvai in the 1930s led to refinements of the archaeo stratigraphic sequence (Table 1)in which a steady unilineal progression in the shaping of artefacts was portrayed (eakey 1936)Oldowan bifacial chopping tools at the top of Olduvai ed I led to Chellean archaic handaes. ikewisethe progressive improvement of handaes differentiated several phases within the Chelleanand then the Acheulean. eakey (1936) was careful to stress that the distinction between the Chellean and Acheulean was in some instances only a matter of classificatory convenienceand asserted that during the latter part of the Chellean both cultures were indistinguishable. The Acheulean stages 4 and 5 constituted the height of handae makingwhereas stage 6 was marked by the decadence (eakey s words) of this technologydue to the less sophisticated appearance of bifaces (Fig. 1).

Documentation of in situ material throughout the entire sequence of Olduvai led eakey (1951) to report that ed I had at least four levels with Oldowan stone tools none of them with handaes. The separation of five phases within the Chellean and siin the Acheulean was still sustainedbut instead of considering stages 1 5 in the Chellean and stages 1 6 in the Acheulean (eakey 1936)eakey (1951) proposed consecutive numeration of the entire archaeological sequenceperhaps to emphasize continuity of progressive evolution of cultures at Olduvai. Furthermoresuch cultural stages were now meticulously correlated with stratigraphic markers. Following Reck s (1914) original division of sedimentary bedseakey (1951) positioned stage 1 of the Chellean between the top of ed I and the bottom of ed IIand characterized this period by the crudeness of its handaes. The development of the Chellean would cover the whole of ed II andaccording to eakey s (1951) new evolutionary scheme (Table 1)the Acheulean per se began in stage 6 of the cultural sequence which corresponded to ed III deposits. Given that stage 9 handaes resembled those from stage 7eakey (1951117) asserted that stage 8 toolmakers did not evolve from stage 7but rather they represented an intrusive element at Olduvai. Thenthe Acheulean would continue evolving up to the top of ed IVwith the last phase of the Olduvai Acheuleanstage 11 (Table 1).

ouis eakey s (1951) model at Olduvai became a sequence of reference for cultural evolution during the Early Stone Age. The Olduvai record was unique in Africa due to the presence of stone tools in a diachronic sequenceoften in situ and associated with faunal remains. As summarized a little later (eakey 1954)Olduvai represented the gradual transition from the pebble tools of the Oldowan (ed I) to the first handaes of the Chellean (base of ed II)the discovery of soft hammer in the transition to the Acheulean (top of ed II)and the development of the Acheulean with cleavers bolasand carefully shaped bifaces in ed IV.

Table 1 The evolution of Early Stone Age cultures at Olduvai Gorge, according to Louis Leakey (1936, 1951)

Leakey 1936			Leakey 1951			
Stratigraphy	Culture	Stone tool features	Stratigraphy	Chelles\ Acheulean stage	Culture	Stone tool features
	Acheulean stage 6	Poorly made handaxes	Top of Bed IV	Stage 11	Acheulean	Small, crude and assymetrical handaxes
	Acheulean stage 5	Ovates and almond-shaped bifaces	Upper part of Bed IV	Stage 10	Acheulean	Most handaxes made on flakes. Predominance of soft hammer
	Acheulean stage 4	Very large and well-made handaxes		Stage 9	Acheulean	U-shaped cleavers and *bolas*. Great morphological and metrical variability of handaxes
	Acheulean stage 3	Ovate bifaces and U-shaped cleavers		Stage 8	Acheulean	Smaller bifaces and cleavers. "S twist" ovates. Cleavers are V-shaped rather than U-shaped
	Acheulean stage 2	Pointed elongated handaxes	Base of Bed IV	Stage 7	Acheulean	Common use of soft hammer and cleavers. Large and well-made bifaces
	Acheulean stage 1	First appearance of cleavers	Bed III	Stage 6	Acheulean	First in situ appearance of cleavers. More evolved bifaces
	Chellean stage 5	Symmetrically biconvex handaxes with entirely trimmed edges	3 m above stage 4	Stage 5	Chellean	Use of soft hammer. Bilaterally symmetrical handaxes with biconvex sections
	Chellean stage 4	Biconvex handaxe sections. Lower face of handaxes still flatter than upper sides	3 m below junction of Bed II and Bed II	Stage 4	Chellean	Handaxes with entirely trimmed edges
	Chellean stage 3	Thickness of upper side of handaxes less pronounced. More carefully trimmed handaxes	6 m above stage 2	Stage 3	Chellean	Large and thick handaxes with roughly triangular and oval shapes
	Chellean stage 2	More pointed and elongated handaxes	3–5 m above bottom of Bed II	Stage 2	Chellean	Large handaxes with thick butt-ends and flat lower sides
Lowest Bed II	Chellean stage 1	Crude handaxes	Top of Bed I–bottom of Bed II	Stage 1	Chellean	Crude handaxes

Table 1 (continued)

Leakey 1936			Leakey 1951			
Stratigraphy	Culture	Stone tool features	Stratigraphy	Chelles\ Acheulean stage	Culture	Stone tool features
Bed I	Oldowan or Pre-Chellean	Worked pebbles with unifacial and bifacial flaking	Bed I		Oldowan	Unifacial and bifacial choppers

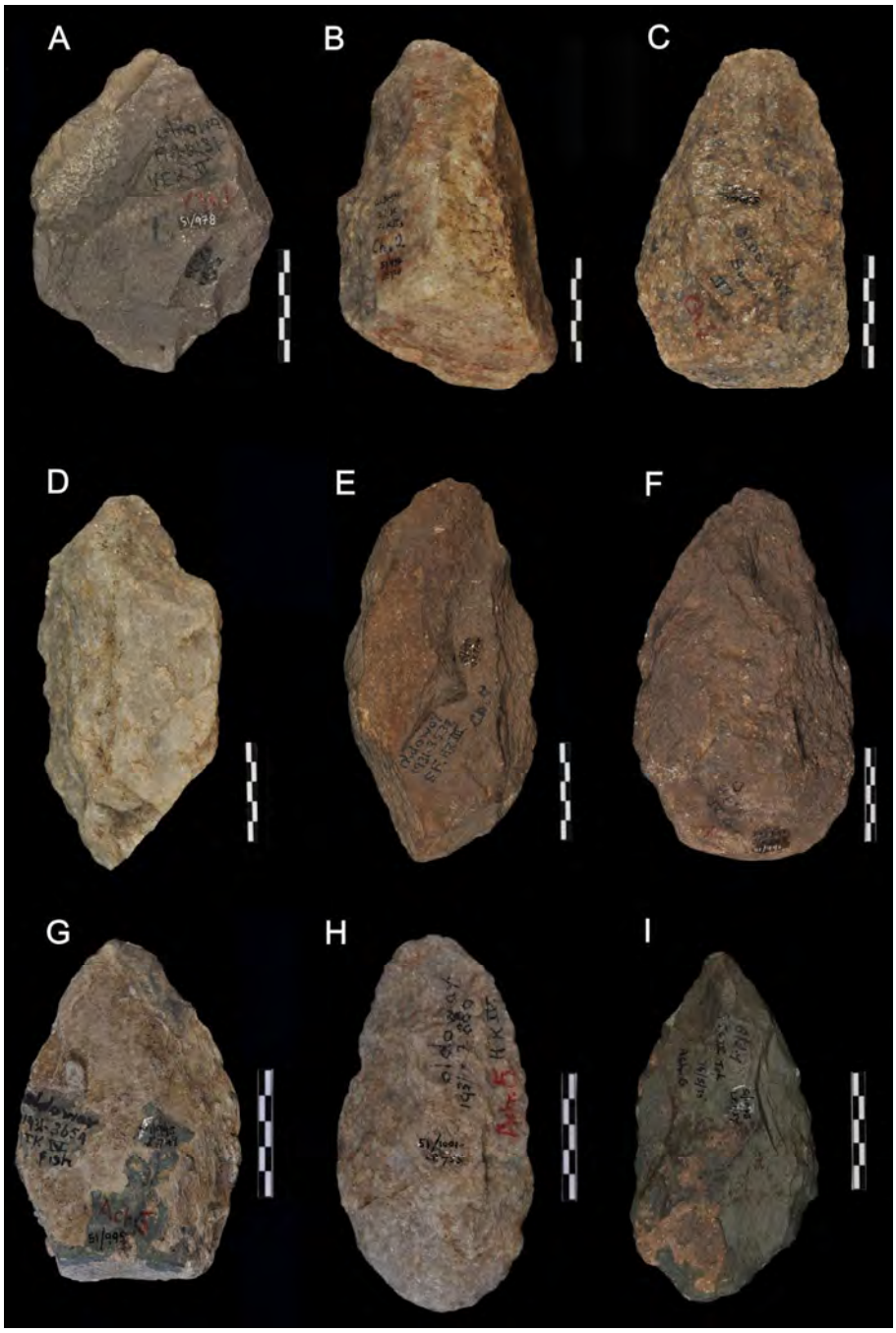


Fig. 1 Olduvai Gorge handaes attributed by ouis eakey to various stages of the ChellesAcheul culture. A Chellean 1VEK II Chellean 2FK II C Chellean 3Surface II D Chellean 4FK II E Chellean 5EFR III F Acheulean 2K IV low G Acheulean 3TK IV Fish Acheulean 5K IV I Acheulean 6GTC IV. All artefacts courtesy of CInstitute of Archaeology Collections

Cultural change was seen by ouis eakey (1936 1951 1954) as gradual and usually driven by local evolution of tool techniques within a unilineal sequence. This is interestingfor in those years unilineal evolutionary lines of Palaeolithic cultures paradigmatic of the de Mortillet s approachwere being substituted by reuil s models of parallel phyla. eakey (1936) contemplated the eistence of two cultural complees in Africathe ChelleanAcheulean (made by omo sapiens)and the Clactonianevalloisian tradition (attributed to the eanderthals). oweverhe be lieved that at Olduvai and in the whole of the Chellean Acheulean compleonly Middle Pleistocene . sapiens were involved. Thereforecultural evolution had to follow internal mechanisms of gradual change (eakey 1936). In the following years eakey (1951 1954) held to this model of local transitions and steady change at Olduvaialthough in some instances he did not rule out eternal influencesfor eample when proposing that stage 8 in the Olduvai sequence probably represents a migration into the area of a group of handae makers who had specialized in this particular direction elsewhere (eakey 1951118).

Fieldwork between 1931 and 1947 at Olduvai enabled eakey (1951) to construct the cultural evolutionary framework discussed above. Once the geological and archaeological sequence had been structuredeakey (1965) states that in 1951 a new phase of research began at the Gorgenow focused on the ecavation of socalled living floors of early handae man . etween 1951 and 1958the eakeys concen trated on ed IIessentially at K and SK (eakey 1958). hereas K had originally been positioned at the base of ed II and considered as Chellean stage 1 (eakey 1951 1958)new fieldwork suggested it was placed substantially higher up in ed II (eakey 1965). everthelessthe cultural sequence originally proposed by ouis eakey did not undergo substantial modificationsalthough it was epected that with a little luck the day will come when we shall be able to announce the discovery of wellpreserved remains of early handae man (eakey 195471). And indeedthat day came and heralded a new phase of research at Olduvaione that provided the basis for an alternative model of cultural evolution (eakey 1971).

The Classic Model of Early Stone Age Cultures in Olduvai

The discovery of inanthropus in 1959 boosted a new phase of investigation at Olduvai in which largescale ecavations took place in eds I and II. This archaeo logical researchnow led by Mary eakeyproved so fruitful that an entirely new hypothesis of cultural evolution at Olduvai would be proposed. Mary eakey s (1967 1971 1975) model was based on a finergrained record than previous attempts whereas ouis eakey s view was grounded on only a few dozen in situ artefacts in each stratigraphic interval (eakey 1936 1951 1954)Mary eakey (1967) stressed that her new model contemplated fullscale ecavations in four sites in ed I and nine in ed II.

hereas the interpretation of ed I remained largely unchanged (with all the assemblages attributed to the Oldowan)the ed II sequence would be (in the words of Mary eakey (1967417)) radically altered . ew work at sites discovered back in 1931 1932indicated that some localities originally thought to be in different stratigraphic levels were in fact in a similar position. That was particularly true of the

upper part of ed IIwhere the position of sites previously had been determined according to their stratigraphic distance from ed III. oweverthat assignment was based on the misidentification of red sediments as belonging to ed IIIwhile they were actually from ed II (eakey 1967).

The other main factor contributing to a maor reconsideration of the sedimentary sequence was the identification of a new stratigraphic markerthe Aeolian Tuff (then also called Tuff IIA)which was used to separate lowermost ed II from the rest of the upper sequence. ouis eakey (1965) had stressed thaton paleoenvironmental and paleontological groundsower ed II was more similar to ed I than to the rest of ed II. owMary eakey (1967) would also introduce cultural elementswhereas the former evolutionary model (eakey 1951) constrained the Oldowan to ed IM. eakey (1967) proposed that there was no cultural change in lower ed IIand sites in such stratigraphic position were nearly indistinguishable from the ed I Oldowan. Thereforeouis eakey s (1951) stage 1 of the Chellean was now subsumed into the classic Oldowanand the formerly named crude handaes typical of the Chellean stage 1 were reconsidered as one of the few indicators of internal evolution within the Oldowanand named as protobifaces (eakey 1967). In this new modelit would only be in Middle ed II that novel cultures emerged (eakey 1967).

ew ecavations in Middle and pper ed II had revealed an unepected cultural developmentmore compleand quite unlike the simple succession origi nally thought to have eisted ( )asthere now appears to be no progressive evolution from the Oldowan through the Chellean to the Acheulian (eakey 1967431). The key aspect of the new model was the reection of the unilineal traectory traced by . eakey (1951)based on slow and gradual cultural change. According to the new hypothesisduring Middle and pper ed II times there were two distinct but coeistent cultural elements (early Acheulean and Developed Oldowan)which had occasional contact with one another (eakey 1967). The Early Acheulean culture was characterized by the relative abundance of handaes and included EFRCKElephant Korongo (the three of them originally placed by . eakey in the Chellean stage 4) and some other unecavated sites formerly considered as Chellean stage 5. In contrastthe Developed Oldowan usually lacked handaes. The degree of cultural contact between the Acheulean and the Developed Oldowan was measured by a variable frequency of handaes in the latter assem blages but when they handaesare in etremely low numbers without any suggestions of local manufacturethey may well merely be obets trouvspicked by the makers of the developed Oldowan culture (eakey 1967432). Thereforeon the one hand there would be Developed Oldowan sites such as MKFCFC est (all in Middle ed II) and TK ower Floor (pper ed II)which due to the low (3 9) but still significant presence of handaesindicated some contact with Acheulean toolmakers. On the other handsites such as KE Sandy ConglomerateTK pper Floorand Kwhere handaes were absent or rare warranted no cultural contact between the Developed Oldowan and Acheulean makers.

In summarythe new model portrayed little evolutionary change in ed I and ower ed IIecept for the appearance of protobifaces in the higher Oldowan levelsand the increasing rarity of the socalled diminutive choppers. Following the paleoecological break marked by the Aeolian tuffM. eakey (1967441) proposed

that in Middle and pper ed IItwo cultural elements are represented: a develop ment of the Oldowanwhich is probably indigenousand a lower Acheulian which appears to be intrusive and to have reached the area at a lower Acheulian stage of development . This was a crucial statement in changing the perspective of the Olduvai sequencenot only were the Developed Oldowan and the Acheulean phylo genetically unrelatedbut these different cultural entities had shared the same territory during a considerable time period. ouis eakey s unilineal evolution of one single cultural thread throughout the Olduvai sequence was definitively superseded.

The introduction of biological parameters was another novelty of the new model and had great impact in later interpretations. As mentioned aboveearly views (e.g. eakey 1936) considered some kind of . sapiens as the author of the entire Chelles Acheul comple. Cultural variation was eplained by migrations of new groups into Olduvai (e.g.eakey 1951)but interassemblage variability was not attributed to different species. The phenomenal succession of human fossil discoveries at Olduvai since 1959howeverwould bring relationships between speciation and stonetool making into the limelight. This occurredfor eamplewith the taonomic and phylogenetic debate of . habilis and Paranthropus boisei and the authorship of the Oldowan at FK in(see review in de la Torre 2011a). It is therefore not unepected that M. eakey (1967) also speculated with possible links between hominins and different culturesand hypothesized that the Oldowan was made by . habilis and the Acheulean by . erectus .

The complete study of the eds I and II assemblages soon followed (eakey 1971)becoming probably the most influential monograph ever published on Early Stone Age research. Although with some modificationsM. eakey s (1971) monu mental work reaffirmed her preliminary model (eakey 1967). FirstlyOlduvai Gorge volume 3 (eakey 1971) consolidated eakey s (1966 1967) typology of Early Stone Age artefactsassociating specific tools with particular stratigraphic intervals and cultural periods. uantitative parameters became an essential part of the interpretationthe 1960 1963 ecavations provided a prodigious number of archaeological remains in each sitewhich enabled M. eakey to assess statistically interassemblage variability. This was probably the main reason for the different interpretations drawn by ouis and Mary eakey: the evolutionary sequence in the first model (eakey 1951) considered the earliest appearance of particular tools or techniques (bifacescleaverssoft hammeretc.)as the main proy for cultural changein contrastMary eakey s (1971) interpretations relied on the variable frequencies of typesand not on the presenceabsence of specific obects.

The cultural evolutionary model proposed in Olduvai Gorge volume 3 (eakey 1971) built on her earlier interpretation (eakey 1967). Thusall ed I and ower ed II assemblages were assigned to the Oldowan. According to eakey (1971)even the earliest Oldowan had a diversified tool kit characteristic of the whole period which contained various forms of chopperspolyhedronsdiscoidsscrapersburins and other heavy (i.e.larger than 50 mm) and light duty (smaller than 50 mm) tools. The socalled protobifaces were considered to be numerically rareand restricted to the time span between pper ed I and the Sandy Conglomerate in Middle ed II. InitiallyM. eakey (1967) only considered an undetermined Developed Oldowan in Middle and pper ed II. oweversubsequent full analysis of assemblages (eakey 1971) revealed two faciesthe Developed Oldowan A (DOA) and the Developed

Oldowan (DO). The DOA was characteristic of the Sandy Conglomerate in the lower part of Middle ed II (i.e.between Tuff IIA and II)and the DOwas located above Tuff II(in the upper part of Middle ed II)and in pper ed II. From this perspectivethe DOA (present at K levels 3 5 and in FK orth Sandy Conglomerate) showed continuity of typically Oldowan toolsalthough the frequency of spheroids and subspheroids increasedas did the number and variety of lightduty tools. The main difference between DOA and the DOsites was the presence of some handaes among the latteralthough the frequency of spheroids and subspheroids continued to increase with respect to earlier assemblagesas did the percentage of battered stone tools.

hile the DOA and DOpresented a clear stratigraphic (below and above Tuff IIrespectively) and typological (handae absence versus presence) dividedistinc tion between the DOand the Acheulean was more complicatedas both contained handaes and were potentially stratigraphically penecontemporary. eakey (1971) established percentage of bifaces as the key differentiating variablebifaces had to form over 40 50 of the tool types for an assemblage to be considered as Acheulean. ased on this and other proies such as the morphology and size of handaesit was argued that DOsites were convincingly separated from the Acheulean in Middle and pper ed II. In the new modelthe Middle ed II sequence would begin with Early Acheulean assemblages (mainly EFRbut also CK and Elephant K)followed by Developed Acheulean sites such as FC estMK Main Site and SKand TK and K in pper ed II (eakey 1971).

The absence of bifacial tools that could be considered as intermediate forms between protobifaces and Middle ed II handaesled to the hypothesis that the Acheulean culture was intrusive in Olduvairight after the deposition of Tuff II. Thereforein eakey s (1971) viewthe Developed Oldowan was an uninterrupted local continuation from the Oldowanin which the same tool forms persistwith the addition of some new elements and an increase in others that were rare in the Oldowan (page 269) whichwhen compared to the Acheulean seem to indicate that the two dissimilar industrial complees of Middle and pper ed II should be interpretedfor the presentas representing two distinct cultural traditionsperhaps made by two different groups of hominids (page 272). Given that there was convincing proof of the association of . habilis with Oldowan assemblages eakey (1971) corroborated her previous hypothesis (eakey 1967) about links between . habilis and the Developed Oldowanand the intrusive Acheulean with a new hominin species in Olduvai . erectus .

The essence of the model presented in Olduvai Gorge volume 3 remained unchanged in later publicationsalthough some minor modifications were added. eakey (1975) for instancedid not change her interpretation of the classic Oldowan recordbut reconsidered some of the evidence for later periods. Firstlythe DOA was said to appear not only in the lower part of Middle ed IIbut also in ower ed II at KE (eakey 1975483)this means that KE evel 2previously considered as indeterminate Oldowan (eakey 19713) or possible DOA (eakey 1971285)was now definitely classified as the latter. ith regards to more recent assemblageseakey (1975) was still confident that SKKand TK pper Floor were DOamong thesetool categories such as scrapersburinsawls outils caills and laterally trimmed flakes showed similar frequenciesand also contained low percentages (2 13) of poorly made

handaes. The status of TK ower Floor (TK F) and MK Main Site (MK MS) howeverwas unclearеakey (1971) had already commented on handae similarities between such assemblages and those of the Acheulean. Returning to the point again eakey (1975) considered that TK F and MK MS could possibly be classified as Acheulean. ater publications (e.g.eakey 1978) were more specific about this issue both MK MS and TK F contained abundant choppersspheroidsand small tools typical of the DO. oweverunlike the small and crude bifacial handaes from the DOin MK MS and TK F bifaces were large and boldly flaked typical of the Acheulean. Thereforeon the basis of bifaces these two sites could be considered as Acheuleanwhile based on the tool kit as a whole they fitted best with the DO(eakey 197813). Similar doubts were raised by eakey (1975) about FC estwhere handaes were also Acheuleanlikebut in which the low number of bifaces precluded further discussions on the assemblage s cultural status.

Setting aside minor readustmentsthe main innovation of eakey s (1975) con tribution was to etend her own hypothesis of cultural evolution to the top of the Olduvai deposits. etween 1968 and 1971she had resumed fieldwork at Olduvai now focusing on ecavations in eds III and IV. As a resultM. eakey (1975) stated that there were no grounds on which to propose a progressive refinement of handae techniques from ed II up to the top of the Acheulean sediments at Olduvaiin the Masek beds. This was a definitive rupture with the model of gradual and unilineal evolution once defended by . eakey (1951). Even more importantlyM. eakey (1975) suggested that the duration of the Oldowan tradition was much longer than had been thought previouslyin factthis tradition continued to ed IVwith what she now named the Developed Oldowan C (DOC). As with the DOthe DOC was characterized by low percentages of smallstepflakedand asymmetrical handaes together with high frequencies of lightduty tools. eakey (1975) still considered that the Developed Oldowan had evolved from the ed I Oldowanand had no evolu tionary relationship with the Acheulean. Although acknowledging that it is difficult to eplain why this tradition the Developed Oldowanshould have remained distinct from the Acheuleanwhich was contemporaneous from middle ed II onwardsand from which the concept of bifacial tools was almost certainly borrowed (eakey 1975485)she was firmly convinced of the separation between the two cultures and of their coeistence throughout the entire Olduvai sequence.

ith the refinement of her cultural evolutionary model (eakey 1975)Mary eakey closed this second period of research at Olduvai. The monograph of 1968 1971 ecavations at eds IIIand IV and Masek (eakey and Roe 1994) was belated and published in a different research contetwhich eplains the lesser impact of eakey and Roe s (1994) results when compared to the massive influence of earlier publications. ased on an unparalleled empirical recordMary eakey s ecavations at Olduvai eds I and II (eakey 1966 1967 1971 1975 1978) became the milestone for all subsequent investigations on the Early Stone Age (ESA). Although its influence has been well acknowledged at the empirical level (i.e.for the importancequalityand quantity of the Olduvai record)other elements should be remembered tooeakey s work had a profound impact on the way early stone tools were studiedthe perspectives by which industrial complees were definedand on understanding relationships between human species and cultural change. All this eplains whysoon after her model was formulated eakey s hypotheses began to be contested.

The Olduvai Cultural Sequence Reconsidered

Mary eakey s technological and stratigraphic characterization of the classic Oldowan is still widely accepted. In contrasther interpretation of the cultural sequence in Middle and pper ed II sparked a long debate from the startand even today (Semaw et al. 2009de la Torre and Mora 2005this paper) is an issue of discussion. Isaac (1974512) summarized the problem when stating that some favour the idea that each industrial pattern was the habitual product of a distinct cultural and ethnic groupwhi ch over hundreds of thousands of years propagated its traditions separately from the traditions of other cultural groups ( ). Others argue that recurrent differences in the need for certain artefact types could give rise to situations in which they were sometimes abundantsometimes rarethis has come to be known as the activityfacies eplanation of variability . Alternatives to Mary eakey s interpretation of interassemblage variability in Olduvai offered two main eplanationssome authors accepted the arguments proposed by eakey to distinguish between two cultures andor facies (e.g.Isaac 1969 1971 1972ay 1976ower 1977Davis 1980Roe 1994Callow 1994)although such variability is interpre ted differently. For others (Mason 1976ones 1994Stiles 1980Gowlett 1988de la Torre and Mora 2005 Semaw et al. 2009)interassemblage variability at Olduvai is not significant enough to ustify any distinction between sites (Table 2).

Isaac (1969) pioneered the proposal of alternative eplanations to eakey s inter pretationeven before the publication of Olduvai Gorge volume 3 (eakey 1971). Isaac (1969 1971)and then ay (1976)would draw attention to the fact that Acheulean sites seemed to be in riverine contetsas opposed to Developed Oldowan assemblages which apparently were situated closer to the Olduvai paleo lake margin. Functional hypotheses were not new to eplanations of interassemblage variability in the ESA (e.g.Clark 1959Kleindienst 1961Posnasky 1959). It is likely that eamples from other East African Acheulean sites with variable percent ages of handaes influenced Isaac s proposal that the DOat Olduvai could be a functional facies of the early Acheulean. This modelwhich can be termed as the ecological or functional hypothesis of the AcheuleanDeveloped Oldowan vari abilitysoon became popular and provided an environmental alternative to eakey s view of parallel cultural phyla. For Isaac (1969)the key innovation of the Acheulean was the production of large flakes as blanks for handaeswhich entailed the formulation of specific techniques distinctive from Oldowan knapping methods. Thereforevariability within Middle and pper ed II assemblages could be eplained either by functional parameters related to the need for large flakesor by the distance of settlements to the large cobbles from which such large flakes were obtained (Isaac 196916). As a third option to eakey s (1967 1971 1975) parallel cultural phyla and his own activity differences (Isaac 1969) hypothesesIsaac (1971) reminded that interassemblage variability could also be eplained by random change of cultural norms that issome recurrent varieties of industry may well result from independent repeated stochastic variation rather than from longterm persistence of a cultural phylum (Isaac 1971561).

In the wake of Isaac s observationsay (1976) confirmed that some patterning eisted in the sedimentary contets of the DOand early Acheulean siteswith the

Table 2 Main archaeological sites in Olduvai Gorge and their cultural attribution according to different authors

Stratigraphy		Site	Leakey 1951[a]	Leakey 1958	Leakey 1967	Leakey 1971	Leakey 1975	Stiles 1977	Davis 1980	De la Torre and Mora 2005	Semaw *et al.* 2009
Bed II	Upper	BK		CHEL. 1	DEVEL. OLD.	DOB	DOB		DOB2	ACH.	ACH.
		TK UF			DEVEL. OLD.	DOB	DOB	ACH.	DOB2	ACH.	ACH.
		TK LF	CHEL. 5		ACH.\DEVEL. OLD.	DOB	EARLY ACH.?	ACH.	DOB2	ACH.	ACH.
	Middle	SHK		CHEL. 2		DOB	DOB		DOB1		ACH.
		MNK MAIN SITE			ACH.\DEVEL. OLD.	DOB	EARLY ACH.?		DOB1		ACH.
		FC WEST			ACH.\DEVEL. OLD.	DOB	INDET	ACH.	DOB1	ACH.	ACH.
		EF-HR	CHEL. 4		LOWER ACH.	EARLY ACH.	EARLY ACH.	ACH.		ACH.	ACH.
		MNK SKULL SITE				OLD.	OLD.		OLD.		OLD.
		FLK NORTH SC				DOA	DOA		DOA	OLD.	OLD.
		HWK EAST SC			DEVEL. OLD.	DOA	DOA		DOA	OLD.	OLD.
	Lower	HWK EAST LEVEL 2	CHEL. 1		OLD.	INDET	OLD.		DOA		OLD.
Bed I	Upper	FLK NORTH LEVELS 1–6			OLD.	OLD.	OLD.		OLD.	OLD.	OLD.
	Middle	FLK ZINJ	OLD.		OLD.	OLD.	OLD.		OLD.	OLD.	OLD.
	Lower	FLK NN LEVELS 1–3	OLD.		OLD.	OLD.	OLD.		OLD.		OLD.
		DK			OLD.	OLD.	OLD.		OLD.	OLD.	OLD.

[a] Based on correlations between Louis Leakey (1951) and Mary Leakey (1967)

latter usually located inland (i.e.further than 1 km from the Olduvai paleolake)and the DOnormally within the lake margin. Thereforethis spatialpaleoenvironmental divide seemed to support the hypothesis that interassemblage variability could be due to functional factorsand was eplicitly linked by ay (199033) to Isaac s activity facies hypothesis.

Despite the originality of the ecological modelin subsequent years debate on the character of the Olduvai stone tools remained basically taonomic. ower (1977) was one of the few who directly studied Olduvai lithic collectionsalthough his reanalysis was limited to choppers from the Oldowan (DKFKFK inand FK orth) DOA (K East)DO(TK)and the early Acheulean (EFR). ower (1977) agreed that there were grounds on which to differentiate industriesbut based on the typometric features of choppers he concluded that there was cultural continuity. Thuswhereas Mary eakey (1967 1971) had portrayed the early Acheulean as intrusive in Olduvai and unrelated to the Developed Oldowanower (1977) proposed that there was a direct ascendant descendant relation between the twoand in fact suggested that the ower Acheulean should be included in the Oldowan Industrial Comple.

Stiles (1977) also studied the original assemblagesreviewing EFR and TK F as eamples of the early Acheuleanand TK F and FC est OF for the socalled DO. Stiles (1977) did not challenge eakey s (1971) typology and his analysis remained mainly morphometric. e concluded that some differences eisted between the two s ets of assemblageschoppers were more intensively worked in EFR and TK Fwhich also contained larger handaes and flakes with a higher number of dorsal scars. In contrastscrapers in TK F and FC est OF were larger and more heavily retouched. everthelessStiles (1977) multivariate analyses did not support significant differences in the percentage of tool types. In factStiles (1991) argued that eakey s (1971) arguments on the different proportions of tool types between the DOand the Acheulean were invalidated once eakey (1975) herself considered that TK F could be Acheuleanfor this assemblage had the larger frequency of lightduty tools (Stiles 1980 1991). On the other handStiles (1977) multivariate analysis suggested a dual pattern in handaeswith the larger Acheulean bifaces made on flakes as opposed to smaller handaes on blocks in the DO. These differences werenonethelessattribut ed to raw material constraintsStiles (1991) asserted that DOhandaes were made primarily on quartzwhereas those of the Acheulean were typically on lava. The unsuitability of quartz for the production of large flakesthereforewould eplain differences between the two types of handaes.

Of the sicriteria used by eakey t o differentiate the DOfrom the Acheulean (1 larger proportion and variety of lightduty tools in the DO 2 higher frequency of spheroidssubspheroidsand modified blocks in the DO3 larger handaes in the Acheulean4 more heterogeneity in size and form of DOhandaes5 handaes on flakes in the Acheulean versus bifaces on block in the DOand 6 inability of DOtoolmakers to produce large flakes)Stiles (1977 1980) considered that only two were validhandaes in TK F and EFR were indeed larger than in the other assemblagesand were usually made on big flakes. These differenceshoweveronly reflected the high variability among Acheulean assemblages and differential access to raw

materials. Following Mason s (1976) firm opposition to the DOtermStiles (1977 1980) proposed that the Olduvai Middle and pper ed II sites were all early Acheulean assemblages.

ones (1979 1994) focused on the study of ed IV rather than on earlier assem blagesbut his comprehensive eperimental program was also relevant for discus sions on the character of the Developed Oldowan and Acheulean. Firstlyhe agreed with eakey (1975) that no evolution from crude to refined handaes eisted from Middle ed II to ed IV and beyond (but see Roe 1994). everthelessones (1994) noticed a clear patterning between Developed Oldowan and Acheulean handaes. Focusing on the ed IV samplehe showed that DOC handaes were rarely on flakes (10 20)whereas flakes accounted for 70 90 of handae blanks in the Acheulean. Despite thisthe few DOC handaes on flakes were identical technolog ically to the Acheulean ones. The other main differenceaccording to oneswas that DOC handaes were more intensively shaped than those in Acheulean assemblages. ones (1994) favored a new interpretationdi fferences between the Developed Oldowan and Acheulean handaes could be eplained by intensity of reduction. andaes from the Developed Oldowanwith a greater number of scars and smaller in size than those of the Acheuleancoul d represent later stages of biface re sharpeningwhereas Acheulean handaes were in the initial stages of their functional life and hence markedly unformatted. ot surprisinglyones interpretation (based on his 1976 1983 eperimental knapping program) was proposed roughly at the same time as the very same reduction hypothesis was used to eplain Middle Palaeolithic tool types (Dibble 1984 1988) and variation of forms in the Oldowan (Toth 1982 1985 1987Potts 1991). According to ones (1994)the wider diversity of tool types in Developed Oldowan sites could be the result of a variety of functional activitieswhile the Acheulean assemblages represented discard areas produced by the same hominins.

Further studies discussing the Developed Oldowan Acheulean problem in Olduvai (e.g.Davis 1980Gowlett 1988Roe 1994Callow 1994) were based not on firsthand revisions of the actual collectionsbut on a reconsideration of published data. Despite thisconflicting interpretations arose. For eample Davis (1980) reached opposing conclusions to those of Stiles (1977)and supported the validity of eakey s original definitionsDavis (1980) criticized Stiles for not including the whole sample of DOsites in his analysisfor not taking the DOA into considerationand f or basing his entire analysis on only one type of artefacti.e.bifaces. y comparing statistical frequencies of tool types in DOA and DOsitesDavis (1980) found continuity between the DOA and the earlier DOassemblagesand a break between these and the pper ed II sites. According to his resultsthe DOMiddle ed II sites (FC est OFSKand MK Main Site) had more choppers and spheroidssubspheroids than the DOpper ed II assembla ges (TK FTK Fand K)whereas the latter contained higher frequencies of bifaces and small flake tools. Given the variable frequencies of tool types and the disparate paleoenvironmental location of sites (the maority of Middle ed II sites were said to be along the lake margin)Davis (1980) not only defended the validity of the Developed Oldowan as a distinctive industrybut proposed a division of the DOinto Developed Oldowan 1 and a later DO2.

Also using eakey s original dataGowlett s (1988) statistical analysis yielded some disparities between the DOand Acheulean handaesalthough he insisted that such morphometric dissimilarities in bifaces did not necessarily have to be interpreted as evidence of cultural differences. Roe (1994) and Callow (1994) considered both the ed II sites and the upper sequence of Olduvaiand found significant statistical differences in the metrics of handaes of DO DOC and Acheulean sites. This led them to support a separation between the Developed Oldowan and the Acheulean. Interestinglywhereas eakey (1971) had originally stated that one of the defining characteristics of the DOwas heterogeneity in handae morphometrics as opposed to the AcheuleanRoe (1994) proposed eactly the oppositehe suggested that Developed Oldowan handaes showed remarkable homogeneityin contrast to the higher variability of Acheulean bifaces. Callow (1994) stated that the contrast between the Acheulean and the Developed Oldowan bifaces was associated not only with sizebut also blankswith handaes on flakes in the Acheulean versus handaes on blocks in the Developed Oldowan. This latter differentiationalready emphasized by eakey (1975) and ones (1994)was considered by Callow as essential in order to differentiate the two industries.

ot surprisinglya unified perspective of the Developed OldowanAcheulean problem is lacking (Table 2). Furthermoreviews are not eempt from contradictions. hereas the original proposition moved from tooltype frequencies as the base for the DOAcheulean distinction (eakey 1971) to qualitative differences between handaes (eakey 1975)some of M. eakey s supporters used those percentages to defend the original classification (e.g.ower 1977) or even to further taonomic differentiation (Davis 1980). hile eakey (1971) proposed that DOhandaes showed heterometric shapes with respect to those of the Acheuleansupporters of the same differentiation of industries stated eactly the opposite (Roe 1994203). For some (e.g.Stiles 1980)DOand Acheulean handaes were too similar to use this kind of tool as the main differentiating element. For others (ones 1994Gowlett 1988Roe 1994)disparities found in bifaces were too significant to be ignored.

everthelessthese divergent viewpoints have some points in commonower (1977)Stiles (1980)and ones (1994) studies were based on published or indirect dataand their quantitative analyses closely followed eakey s typology. Problems of eakey s typology have been raised on a number of occasions (e.g.Isaac 1986Potts 1991)but classification of the actual Olduvai stone tools usually remained unchallengedand consequently occurred with frequencies of types in assemblages. Only recently have some authors (de la Torre and Mora 2005Semaw et al. 2009) begun to discuss the meaning of eakey s types and their implications for the understanding of interassemblage variability at Olduvaigiven the contradictory results of statistical analyses based on eakey s original classification of assemblages it may be argued that only direct revisions of the actual assemblages can shed some new light on the topic.

A Current View of the Developed Oldowan Acheulean at Olduvai Gorge

Recent contributions (de la Torre and Mora 2005Semaw et al. 2009) agree that Mary eakey s classic model of cultural evolution in Olduvai needs reconsiderationand

propose a more straightforward interpretation of the sequencewhere only the Oldowan and Acheulean technocomplees are recognized. According to that view transitional stages such as DOA and DOdo not eist. In this paperrelationships between the Oldowan and the socalled DOA will not be discussedas they are much more complethan de la Torre and Mora (2005) initially thoughtand require further investigation. Insteadwe will focus on the problem of the DOand Acheuleanfor which the theoretical grounds of Mary eakey s model will be contetualized in our restudy of the archaeological assemblages.

The Theoretical ackground of the Two Cultural Phyla

Mary eakey (1971) claimed to overcome ouis eakey s (1951) cultural evolution ary model on the grounds of her new fieldwork resultsand on a change of theoretical perspective. She recalled that when eakey (1951) published the first detailed description of the Olduvai cultural sequencethere was a general tendency to follow the late Abbreuil in subdividing the Acheulean and indeed the maority of Stone Age lithic industries into a whole series of evolutionary stages and phasesbasing the subdivisions largely on typologies of selected specimens and not on entire assem blages (eakey 1971262).

ith regards to the latter part of the above statementin the late 1950s early 1960s a new perspective favored ecavating large horizontal areas in order to epose living floors with large numbers of artefacts (Clark 1960Kleindienst 1961 1962owell and Clark 1964etc.). The 1960 1963 ecavations at Olduvai followed such a premise in which whole assemblages rather than individual obects were the main subect of study. Kleindienst s proposals had substantial influence on Mary eakey s own research designparticularly the adoption of a 40 (eakey 19712) or 50 (eakey 1971269) threshold of handaes for an Olduvai assemblage to be consid ered as Acheulean. Criticism of this proposition requires some clarificationfirstlyit was Kleindienst (196140) and not Kleindienst (1962) who proposed such a fre quencyMary eakey (1971) misquoted the referenceand following her many researchers did so tooincluding one of us (de la Torre 2011b). That is not irrelevant for Kleindienst (1961) was not suggesting that assemblages with less than 40 60 of bifaces should be considered as nonAcheuleanbut ust reporting that ate Acheulean sites normally had such percentagesand that variability could be eplained by site function. everthelessKleindienst (1962) firmly advocated that qualitative studies had to be replaced by quantitative analysiswhich wasin her view the only way to account for interassemblage variability. In thisMary eakey (1967 1971 1975) fully agreed with Kleindienstreplacing ouis eakey s (1951) former model (based on qualitative descriptions of handaes) by one where obect frequen cies determined cultural adscriptions. That probably eplains why earlier publications (eakey 1967 1971) relied so heavily on the variable percentages of retouched tools spheroidssubspheroidsand handaes to classify assemblages either as Oldowan Developed Oldowanor Acheulean. Of coursethis quantitative perspective was not eceptional in a scientific contet where the ordesian approachone based on cumulative frequencies of tool types (ordes 1961)ruled Palaeolithic research worldwideKleindienst and eakey only adapted the East African record to the internationally dominant paradigm.

Returning to Mary eakey s (1971262) quote aboveshe was implicitly stating that her hypothesis overcame theoretical problems of previous interpretations (e.g. eakey 1951) by superseding reuil s paradigms. oweverthat is debatablethere is no doubt that ouis eakey s model was heavily influenced by reuil s view of cultural change. onethelessin the particular case of Olduvai Gorgeouis eakey (e.g. 1951) depicted a gradual evolution of cultures with little eternal contact (see above). In factit could be argued that Mary eakey s model was nearer to reuil s paradigms than ouis eakey s (1951). reuilas Peyrony before himportrayed variation in terms of dual cultural phylaand applied such concept to the ower Palaeolithic to eplain differences between assemblages with and without handaes.

The issue of the Clactonian is essential hereand might help towards understand ing the roots of Mary eakey s Olduvai model. Formally defined by reuil (1932) the Clactonian was considered as a coreandflake industry by cultural groups who were different from those making handaes. Essential in reuil s original model is that the Clactonian was seen as contemporary to the Chelleanand both had a parallel evolutionwith the latter ultimately leading to the Acheuelan (reuil 1932). The earliest descriptions had already introduced another element in the modelthat of cultural contactby stating that the ClactononSea lithic artefacts contained some clumsy pointed formswhich might perhaps be considered as unsuccessful attempts to copy the Chellean implement (arren 1922598)and stressing the divergence of races and cultures which were living contemporaneously together (arren 1922 602). In ritainthis culture history approach prevailed until the 1970sand maintained a divide between the Acheulean and the Clactonian (hite 2000)under reuil s frameworkcultures could coeist and evolve in parallel without necessarily having to share evolutionary links. The influence of this dual cultural phyla model on Mary eakey s (1967 1971 1975) hypothesis for Olduvai is fairly obvious. In fact parallelisms can be traced back to the 1930swhen M. eakey herself conducted ecavations in a Clactonian site in ritainand eplicitly accepted the eistence of two contemporary Palaeolithic cultures (the Clactonian and Acheulean)considered to be the product of separate racial groups (Oakley and eakey 1937).

M. eakey s (1967 1971) hypothesis in Olduvai resembled closely the Clactonian modelfollowing almost every point made by reuil decades earlierthe Developed Oldowan (as the Clactonian) had an independent although parallel evolution to the Acheuleanbut which (at least in Olduvai) had no evolutionary links. As with the Clactoniancoeistence between the Acheulean and the Developed Oldowan would eventually lead to cultural contactsas reflected by the adoption of handaemaking by the latter. Mary eakey s model presented some novelties over former proposals firstthe rich human fossil record of Olduvai enabled the introduction of a biological divide between cultures. And secondlyinstead of using the fossil directeur ap proach (characteristic of the reuil and ouis eakey models)Mary eakey sustained her hypothesis in the differentiation of assemblages and cultures through tool type frequenciesin the same fashion as popularized by ordes.

According to hite (2000)a new period on Clactonian research began in ritain in the 1970swhen the new processual perspective overtook the culture history paradigm. Parallelism with the Olduvai case is again remarkableas many of the alternative perspectives on eakey s interpretation were clearly embedded in the ew

Archaeology paradigm (e.g.Isaac 1971Stiles 1977Toth 1982). oweverthe new theoretical perspective was not usually accompanied by a reconsideration of Mary eakey s typology. As argued elsewhere (de la Torre and Mora 2009)most revisions of the Olduvai stone tools in recent decades may have adopted alternative theoretical backgrounds and new research questionsbut few actually challenged Mary eakey s original lithic taonomy. That compliance has a great impact on the interpretation of assemblagesfor if a study is to follow eakey s classificationultimately it is bound to find the same tooltype variability. Such variability can then be eplained by cultural history reasonsecological vari ablesfunctional hypothesisetc.but is nonetheless grounded on the same interpretation of the material cultureand therefore needs to account for the interassemblage differences already identified by eakey. This circular process can only be avoided by critically reassessing eakey s typology as pioneered by Toth (1982)Isaac (1986)and Potts (1991)and lately updated by de la Torre and Mora (2005) and Semaw et al. (2009). The typology of Olduvai ed I and II assemblages was the third pillar of Mary eakey s modelalongside the quantitative approach and the culture history theoretical background. e have ust reviewed the latter twobut there is no point in criticizing alternative models to eakey sif they all are based on the acceptance of an interassemblage variability which is not necessarily warranted. First of alla reconsideration of the actual assemblages is required in order to ascertain whether or not such variability is visible in Middle and pper ed II.

The Middle and pper ed II ithic Assemblages

De la Torre and Mora (2005) presented a detailed report of the stone tools ecavated by Mary eakey in EFRFC est OFTK Fand TK Fplus some data on a sample from K. The present section is based on de la Torre and Mora (2005) for FC est OFTK Fand TK Fupdates the information available for EFR (only M. eakey s ecavations)and adds the study of further collections (i.e.the whole assemblage of SKAnneeand a sample from SK Main SiteChanneland MK MS)also based on a direct analysis of the eakeys (1971) original collec tions. De la Torre and Mora (2005) discussed each site assemblage separatelyand inferences were made regarding site formation processesintegrity of levelsand cultural adscription. Instead of adopting an individual approach to each sitethe updated dataset serves to consider on an interassemblage basis the key parameters traditionally used to distinguish the Acheulean from the Developed Oldowan.

The first question is whether there is significant interassemblage variability in the overall composition of tool categories at the Olduvai Middle and pper ed II sites. Although comparative statistics of tool types have been the focus of most previous works (e.g.Stiles 1977 1991Davis 1980)the present study is based on a techno logical breakdown of categories (Table 3) as defined by de la Torre and Mora (2005) rather than on eakey s typological classification. The most conspicuous association (i.e.proportional overrepresentation of cores in SK Anne) revealed by the ien test and correspondence analysis (Fig. 2) is probably meaninglessgiven that eakey (1971) eplicitly stated that not all the debitage had been collected in SK and K therefore leading to an overabundance of core forms. The same collecting bias may also eplain the proportionally high number of small retouched pieces in SK. Tests

Table 3 reakdown of stone tools from Olduvai Middle and pper ed II assemblages ecavated by eakey (1971) in Olduvaiaccording to our classification (see discussion of lithic categories in de la Torre and Mora 2005 and de la Torre 2011b)

	EFR		FC est OF		SK Annee		TK F		TK F	
Cores and test cores	35	9.2	43	6.4	98	24.1	10	2.4	24	1.4
CT and broken CTs	33	8.7	2	0.3	3	0.7	10	2.4	17	1.0
CT blanks	3	0.8			5	1.2				
Small retouched pieces	5	1.3	13	1.9	46	11.3	20	4.9	25	1.5
ammerstones	4	1.1	84	12.4	4	1.0	2	0.5	24	1.4
Flakes and flake fragments	300	78.9	494	73.2	229	56.4	338	82.2	1472	88.1
ammerstones with fractured angles			31	4.6	15	3.7	9	2.2	28	1.7
Anvils and broken anvils			8	1.2	5	1.2	18	4.4	33	2.0
Spheroids and subspheroids					1	0.2	4	1.0	48	2.9
Total	380	100.0	675	100.0	406	100.0	411	100.0	1671	100.0

epectedly highlight the large number of large cutting tools (CTs) in EFRbut this assemblage is not too different from TK and SK. In realitythe greatest disparity does not seem to occur between DOsites and EFRbut between FC est and all other sites. The overrepresentation of regular hammerstones (ien test) and hammerstones with fracture angles (correspondence analysis) at FC est OF may or may not have a functional meaningbut it is certainly difficult to draw cultural implications from this pattern.

eakey (1975) admitted the problems of using only tooltype frequencies to maintain her previous cultural classification (eakey 1967 1971)so she turned to

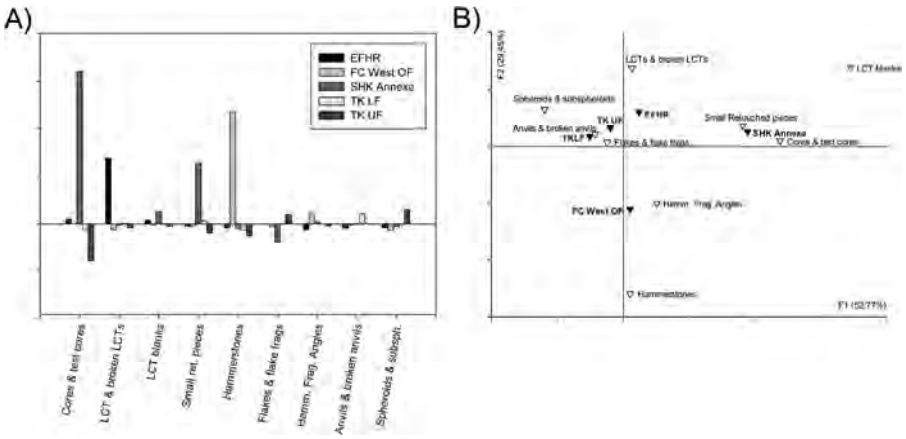


Fig. 2 a ien test and b correspondence analysis of the main technological categories in Olduvai Middle and pper ed II assemblages. The ien is a nonparametric Chi square test used to highlight significant differences in assemblage compositionand is based on the inertia of the correspondence analysis (see equations in Volle 198161 69aplace 1980). Correspondence analysis is a generalized principal component analysis used for the treatment of qualitative data (Abdi and illiams 2010)

qualitative differences in handaes as the main criterion on which to differentiate the DOfrom the Acheulean. Size and manufacturing techniques were the two main parameters involved. Following Isaac s (1969) ideas on the relevance of large flake production for the emergence of the Acheuleaneakey (1975485) argued that basicallythe factor that distinguishes the two traditions Acheulean and DOis an inability to detach large flakes in the Developed Oldowan . onethelessTable 4 shows that handaes on flakes are present in all DOsites. Indeedconsidering that we did not have access to the entire handae sample from some collections (SK ChannelK)it is likely that frequencies of handaes on flakes are even larger. arge flake production should not only be accounted for on the basis of handaesin SK Anneefor instancealthough the number of handaes is lowthere are several large (10 cm)nonretouched flakes clearly related to the CT chane opratoire (see Table 3). Similarly with Kwhere not only are very large (2 kg) flakes document edbut so are huge cores that evidence the production of CT blanks (Fig. 3). Thereforealthough EFR stands out for the overwhelming use of large flakes as blanks for CT shapinglarge flake production is present in every single assemblage studied here.

eakey (1971 1975) also asserted that DOhandaes were consistently smaller than Acheulean ones. Most authors (Davis 1980Stiles 1991Roe 1994) accepted such a suggestionsince they had used the classification and metrics originally proposed by eakey. Stiles (1991)for eampleproposed that the smaller size of DOhandaes was due to raw material constraintsas they were usually made on quartzitea rock from which it is more difficult to obtain large flakes. owever Table 4 shows no particular predominance of quartzite handaeswith the eception of TK F (which in any case is considered as Acheulean by eakey (1975)). Also eamples of the production of large quartzite flakes eist in nearly all Middle and pper ed II sites. Thereforeraw material constraints alone do not eplain the alleged size difference between Acheulean and DOhandaes.

ones (1994) eplained size variation by handae reduction stageAcheulean handaes would represent early phases of flakingwhereas those of the DOwere more heavily reduced forms. oweverour review of the materials suggests that only in K do handaes show consistently higher numbers of scars than in EFR (see de la Torre and Mora 2005). SKChannel (Fig. 4) may also contain more heavily reduced handaesbut with regard to the other assemblagesresharpening or long reduction sequences of faonnage are rare or absentCTs are usually poorly shaped and faonnage is normally limited to the shaping of the tip and edges. In fact intensity of faonnage is probably more related to blank type than to resharpening or long reduction sequencesSharon (2008) points out that large flake CTs world wide consistently show minimal trimming if a blank of appropriate size and shape is available. ava flakes at EFR or quartzite slabs in TKfor eamplewould provide such blanks which required minimal secondary retouch.

In our viewthe consistently smaller size of DOhandaes may be due to morphometric bias introduced by the socalled diminutive bifaces (eakey 1971) as discussed elsewhere (de la Torre and Mora 2005)some of those pieces could be broken handae tipswhile others are not even retouched. The problem with some of the former morphometric studies lies in the comparison of propercomplete handaes with items that were originally (eakey 1971) classified as suchbut

Table 4 Breakdown of large cutting tools by raw materials and blanks

	Raw material								Blank							
	Lava	%	QTZ	%	Gneiss	%	Total	%	Flake	%	Block\cobble	%	Indet	%	Total	%
BK	8	100.0					8	100.0	3	37.5	1	12.5	4	50.0	8	100.0
TK UF	9	52.9	8	47.1			17	100.0	3	17.6	4	23.53	10	58.8	17	100.0
TK LF	3	30.0	7	70.0			10	100.0	2	20.0	5	50	3	30.0	10	100.0
SHK Channel	12	66.7	5	27.8	1	5.6	18	100.0	7	38.9	2	11.11	9	50.0	18	100.0
SHK Annexe	2	66.7	1	33.3			3	100.0	1	33.3			2	66.7	3	100.0
FCWEST			2	100.0			2	100.0	1	50.0	1	50		0.0	2	100.0
EFHR	24	72.7	9	27.3			33	100.0	30	90.9	1	3.03	2	6.1	33	100.0

It includes complete and fractured LCTs. A sample only was studied for BK and SHK channel

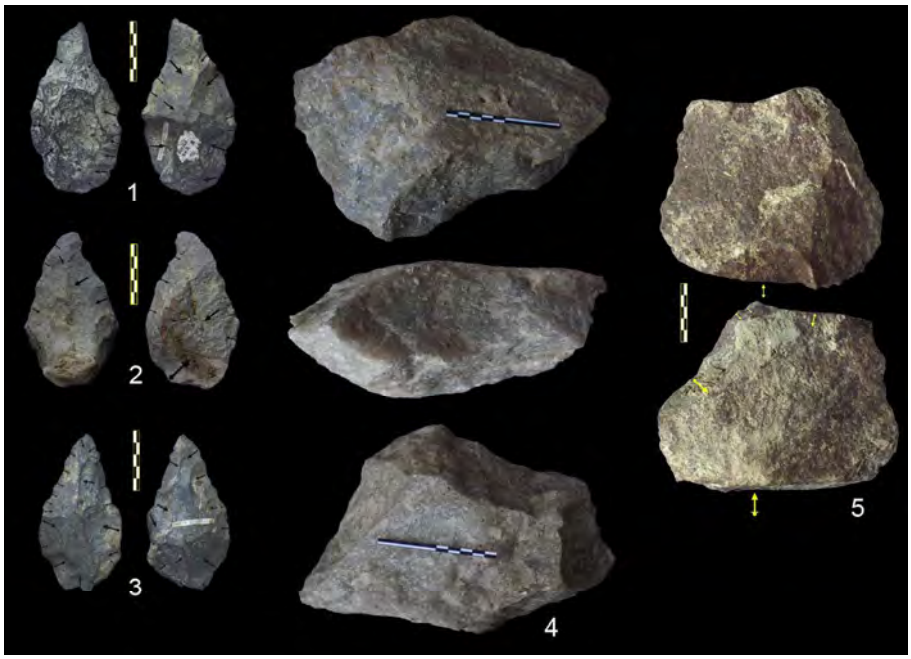


Fig. 3 Elements of the CT chane opratoire in K. 1 3 ifaces 4 CT core6.9 kg. 5 nretouched CT blank weighing over 2 kg

whose typological andor technological signatures can be reasonably challenged (de la Torre and Mora 2005)once the original assemblages are revisited (see Fig. 5). In factonce dubious pieces are removed from the Middle and pper ed II assemblagessize of handaes is very similar and no consistent morphometric differences are recorded (Table 5 and Fig. 6)as supported by the Kruskal allis test of average length (Chisquare5.366df6 p0.498) and weight (Chisquare6.464df6 p0.373) of the whole sample of handaes.

Once tooltype frequenciesthe inability to produce large flakes and the systematic smaller size of handaes in the DOare ruled out as valid criteria to differentiate these assemblages from the Acheuleanit remains now to discuss eakey s (1971 1975) proposition that DObifaces were cruder and poorly made. Although CTs from EFR have usually been considered as bifaces (e.g.eakey 1971Stiles 1991)in reality most handaes ecavated by eakey at that site are unifacially shaped large flakesin which retouch is unsystematicand is normally restricted to the edge of the piecewith noninvasive faonnage (and therefore no reduction of the central volume of artefacts)no bilateral symmetry and poor bifacial interaction (Fig. 7). As argued elsewhere (de la Torre and Mora 2005)most of those handaes fit best in the group of knives (sensu Kleindienst 1962) or other categories of crude CTs than within that of real bifaces. On the other handseveral sites attributed to the DOcontain handaes that can be considered as proper bifaces (Fig. 8)in SK Channelsome CTs show bifacial retouch all around the edgewith invasive scars from opposite directions that meet at the centrehence shaping the volume of artefacts (Fig. 4). The same applies to Kwhere several handaes show some bilateral and

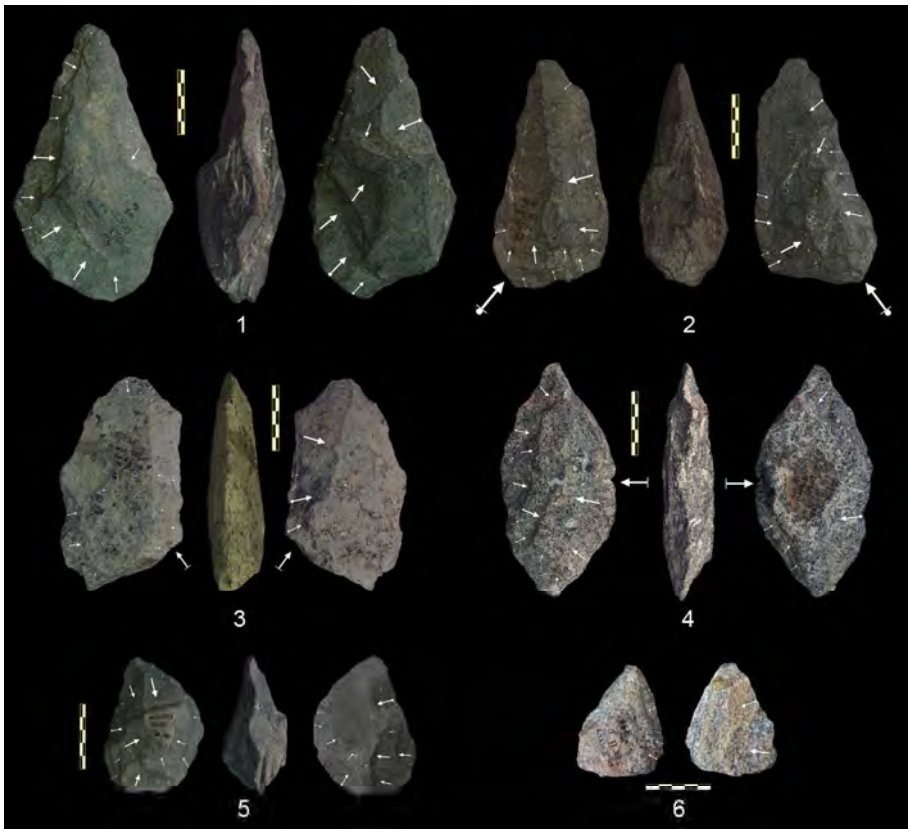


Fig. 4 CTs from SK Channel. 1 ava handae on an indeterminate blank. 2 5 ava handaes on flake. 6 Small gneiss handae on an indeterminate blank

biconvesymmetry (Fig. 3nos. 1 3). In briefthe term biface can be used accurately to describe a number of CTs from both K and SKChannel (with some eamples also at MK MS and TK)where there seems to be an attempt to obtain bilaterally and bifacially symmetrical handaes. These templateshoweverare absent in eakey s EFR collectionwhere faonnage is rareunsystematicand produces unstandardized forms. Thereforeif we were to assess the skill of Middle and pper ed II knappers in making real bifacesthe most unsuitable assemblage would be EF Rwhich is nonetheless the only one originally considered as Acheulean.

e suggest that a clearcut consistency in handaemaking is shared by all sites under studyproduction of large flakes as blanks for handaes predominate in some assemblages (e.g.EFR)while in others there is more frequent use of slabs (TK) or cobbles (K). The predominance of any particular blank is probably linked to raw material availabilityas Stiles (1977 1991) proposedbut the ability to produce large flakes and use them as handae blanks is present at all sites. Some handaes are more intensively reduced (e.g.some eamples from K and SKChannel) than others (EFRTK)as ones (1994) stressedbut the overall pattern is one where faonnage was unsystematic and barely modified the original shape of blanks. TK epitomizes the inconsistency of attempts to distinguish two cultural traditions where

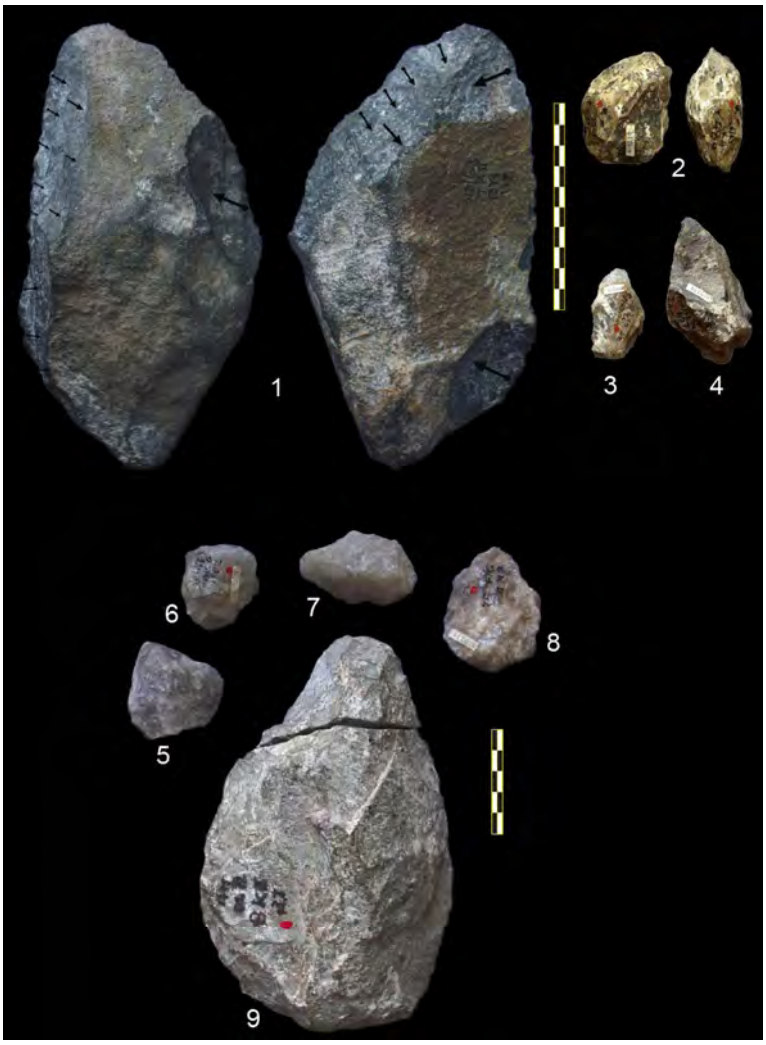


Fig. 5 1 ava handae compared to socalled diminutive handaes 2 4 from TK F. 2 and 3 are here interpreted as quartzite chunkswhereas 4 could be a fragment of a broken lava handae. 5 8 Alleged diminutive handaes on quartzite compared to a genuine lava handae (9) from K. 5 8 are considered here as irregular fragments with no shaping involved

there is only oneTK Freclassified as early Acheulean by eakey (1975)contains handaes which are virtually indistinguishable either in terms of the raw materials blanksor technologyfrom those at TK Fsupposedly DO(Fig. 9).

Although small debitage systems played no part in eakey s differentiation between the Acheulean and DOa comparison of cores and retouched tools may also contribute towards an assessment of interassemblage variability. eakey s (1971) typological classification of small retouched tools contains considerable inconsistencies (e.g. Torre and Mora 2009)and nearly all the small retouched pieces in Middle and pper ed II can be classified typologically either as sidescrapers or denticulates (de la Torre and Mora 2005). Table 6 and Fig. 10 show that EFR small retouched tools are

Table 5 Dimensions of CTs in the Middle and pper ed II sites (length measured following the typological ais)

Site		o.	Minimum	Maimum	Mean	Standard deviation
K	ength	8	90	190	142.75	30.222
	idth	8	58	110	78.13	16.208
	Thickness	8	29	68	39.75	12.937
	eight	8	157	1260	485.50	337.150
EFR	ength	32	103	235	146.69	27.691
	idth	32	62	110	84.06	12.725
	Thickness	32	27	63	43.78	8.151
	eight	32	306	1375	586.50	217.665
FCest	ength	2	92	120	106.00	19.799
	idth	2	63	105	84.00	29.698
	Thickness	2	32	60	46.00	19.799
	eight	2	225	1065	645.00	593.970
SKAnnee	ength	1	190	190	190.00	
	idth	1	117	117	117.00	
	Thickness	1	56	56	56.00	
	eight	1	1160	1160	1160.00	
SKChannel	ength	12	80	196	146.08	38.316
	idth	12	53	112	85.42	16.195
	Thickness	12	35	72	51.00	11.370
	eight	12	189	1228	686.67	327.385
TKF	ength	9	100	290	156.11	60.267
	idth	9	60	118	86.11	16.120
	Thickness	9	30	55	44.67	7.730
	eight	9	289	2230	844.44	604.792
TKF	ength	10	86	265	149.00	53.628
	idth	10	59	112	86.30	17.852
	Thickness	10	27	74	46.40	15.414
	eight	10	199	1788	831.10	585.038

Included here are only those considered as proper handaeswhich ecludes many of those originally classified (eakey 1971) as diminutive bifaces

significantly larger than those in the other assemblageswhich is also supported by Kruskal allis tests of mean weight and length (Chisquare22.764df4 p0.000 and Chisquare20.369df4 p0.000respectively) that indicate significant differ ences in the sample. onethelessthis trend can be attributed to the small sample from EFR (n5)and to constraints of classificationwhile the term CT is usually reserved for artefacts 10 cm (Kleindienst 1961 1962)at EFR there is a size continuum between handaes and smaller retouched pieces that makes it difficult to draw a line between the two categories. All the other assemblageshowevershow similar size dimensions and raw material proportionsirrespective of their original assignation to the DOor Acheulean (Tables 6 and 7and Fig. 10).

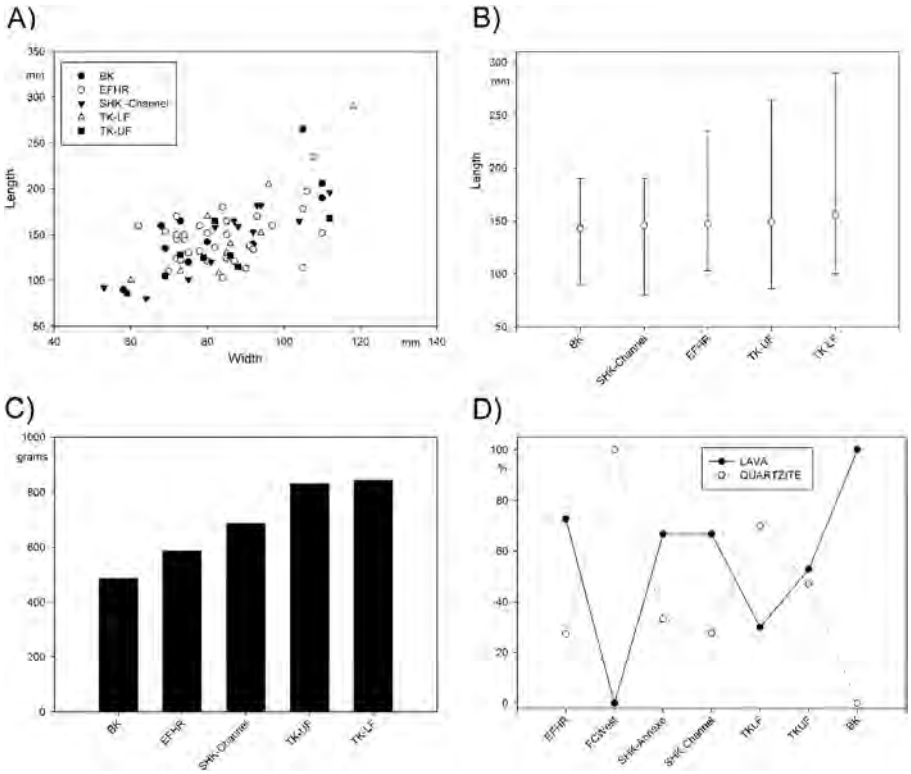


Fig. 6 Comparative features of Middle and pper ed II handaes. a ength and width (mm). b Average length (mm). c Mean weight (grams). d Distribution of main raw materials

ith regards to coresstructured methods of reduction (Fig. 11) are present in all Middle and pper ed II assemblages (de la Torre and Mora 2005)a pattern that has been considered a proy for the emergence of the Acheulean (de la Torre 2009 2011b). Table 8 and Fig. 12 show the main features of small debitage coreswhich can be used to discern possible technological clusters. The Kruskal allis tests of average length (Chisquare22.742df4 p0.000) and weight (Chisquare 13.241df4 p0.010) indicate that there is no homogeneity in core size across siteswith larger cores in TK F and EFR. onethelessother variables suggest a different clustering of assemblagesfor instancethe Chisquare test (df8 p0.025) indicates significant differences in the number of eploited core surfaces (see also Fig. 12f)but here EFRFC estand TK F show similar dynamics in contrast to the relative overabundance of multifacial cores at TK F and unifacial cores at SK Annee. Significant differences are also detected in raw material composition (Chi square: df8 p0.0001)which highlight the predominance of lava cores at EFR and FC estand of quartzite cores at SK Annee. Figure 12e indicates a smaller number of flake scars on the SK Annee cores and higher frequencies in TK F which is supported by the Chisquare test (df12 p0.017). Chi square tests of other variables from Fig. 12 such as core blanks (df12 p0.09) and corte(df12 p 0.05) do not reect the null hypothesisand hence no further differences are observed. Thereforeno clear patterning emerges from the interassemblage comparison of

Fig. 7 ava handaes from EFR

cores. In factwhen all attributes are considered together in the correspondence analysis (Fig. 12h)no obvious clustering occurs that could separate the alleged DOfrom Acheulean assemblages.

In summarycores and retouched pieces do not help distinguish the socalled DO sites from the Acheuleancuriously enoughthe category that was supposed to convey interassemblage differences (i.e.handaes) according to the typological approachhas been shown to yield no significant interassemblage size variability (see discussion above)whereas such variability is attested among cores and small retouched tools. oweverheterogeneity of the small debitage sample does not cluster the alleged DOsites in contrast to Acheulean onesbut rather shows random trends that cannot be attributed to any consistent dual pattern.

aving discarded several possible lines of evidence aimed at distinguishing the DOfrom the Acheuleanit seems that it all comes down to the variable frequencies of handaesEFR contains a substantial numberthe other sites yield lower percentages. The meaning of such dissimilar frequencies is more difficult to unravel although it seems plausible that relative numbers of handaes were a function of the activities carried out onsite. From the viewpoint of the formation of lithic assem blageshandae frequency can be related to the nature and stages of the chane opratoire represented at each site. At SK Annee and FC estfor instancelithic

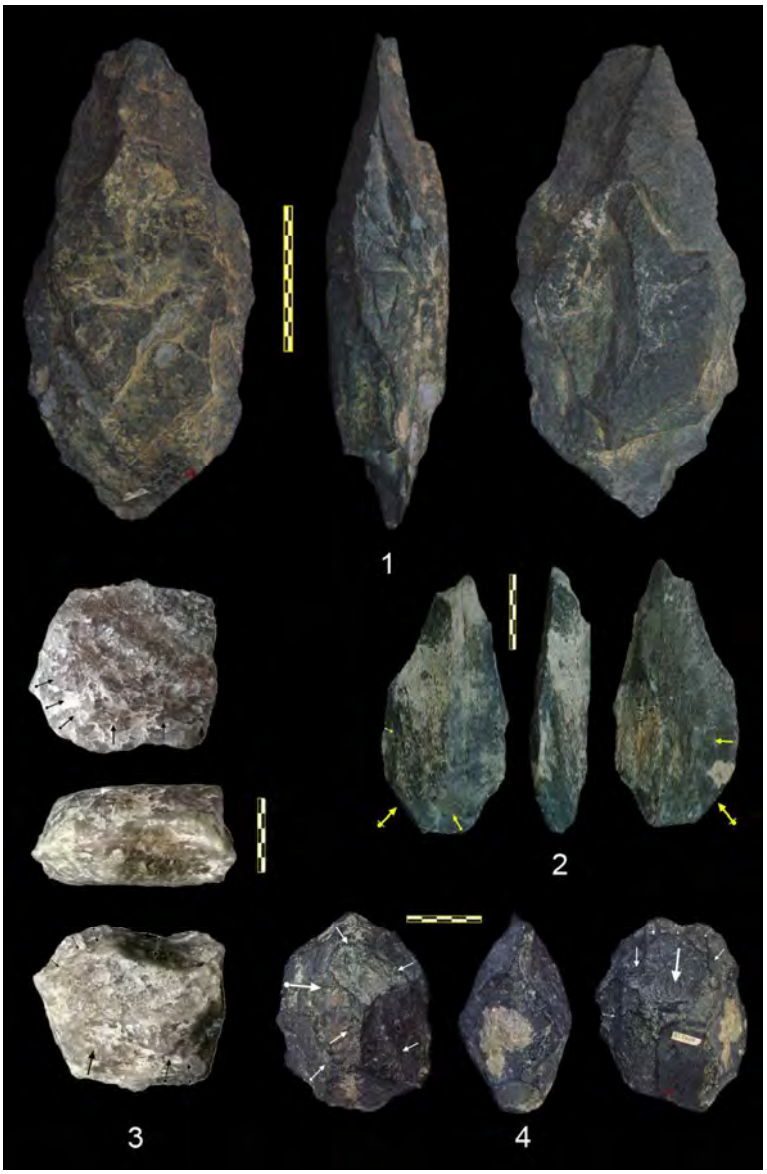
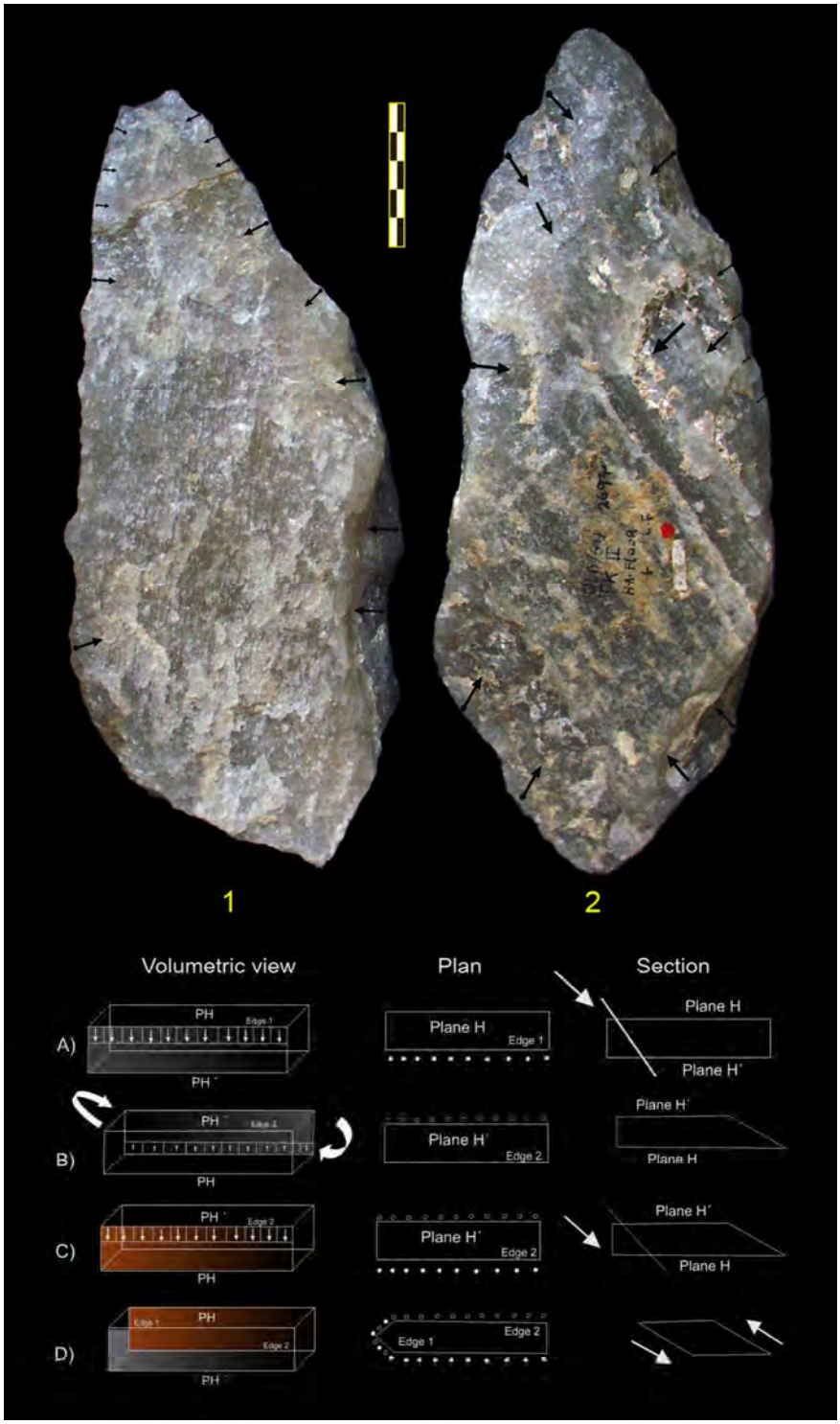


Fig. 8 1 and 4 ava handaes from MK Main Site. 2 one tool from FC site resembling CT technology. 3 roken quartzite handae from FC est

production was focused on the reduction of small debitage cores and flakeswhereas at EFR such production also included abundant CTs (Table 3). At EFRno large cores suitable for the production of CT flake blanks are documentedand therefore fragmentation of the chane opratoire between quarry and discard must have eisted. At TKmany CTs were made on quartzite blocks (Table 4)which could have been transported to the sites as unmodified blanks. Onsite handae shaping at TK could then eplain the significant numbers of flakes and the propor tionally lower frequencies of small cores with respect to other sites (Table 3).



◀Fig. 9 CTs from TK F (1) and TK F (2)almost identical morphologically and technologicallybut proposed by eakey (1975) as belonging to different lithic traditions (TK F to the Acheulean and TK F to the DO). Manufacturing techniques are remarkably alikefollowing a similar rhomboidal strategy to that described by arosef and GorenInbar (1993153) at beidiya. A The horizontal plane (P) serves as a striking platform for etractions on edge 1. The blank is turned over and C the opposite surface (P ′) is used as a striking platform to shape another edge of the blank (edge 2). D o bifacial interaction between surfaces P and P ′ occursand edges 1 and 2 remain unifacial with the ception of the tipwhere some bifacial shaping eists in order to create a point (see full description of this method in de la Torre and Mora 2005)

The points presented abovehowevershould be considered ust as a working hypothesis to eplain the documented interassemblage divergences in overall tool frequenciesan accurate reconstruction of the formation of lithic assemblages must be based on a proper understanding of Olduvai site contets (enitoCalvo and de la Torre 2011) and a more accurate estimate of timeaveraging processes (e.g.Stern 1994)both of which are still lacking.

If the above is based on the stone toolsare there other proies that may enable patterns to be discernedSystematic studies of eakey s Middle and pper ed II bone assemblages are not abundant and contribute little in addressing inter assemblage variabilityMonahan (1996) analyzed K and MK MSand Egeland (2007) KTKand FC est OF. oth authors stressed the relevance of carcass processing by humans at Kwhich Monahan (1996) etended to MK MSwhile Egeland (2007) highlighted the difficulty in determining human involvement in both

Table 6 Dimensions (millimeters and grams) of small retouched tools in the Middle and pper ed II sites

Site		Minimum	Maimum	Mean	Standard deviation
EFR	ength	80	99	88.75	7.974
	idth	61	74	68.75	5.737
4	Thickness	28	41	33.25	6.021
	eight	132	300	201.75	74.5313
FCest	ength	27	79	45.23	13.299
	idth	23	53	35.54	8.599
13	Thickness	14	38	18.62	6.104
	eight	14	140	45.38	32.875
SK Annee	ength	21	63	38.07	10.005
	idth	18	65	34.13	9.972
46	Thickness	7	37	15.37	5.389
	eight	5	116	27.326	22.1011
TK F	ength	25	93	51.3	17.945
	idth	24	85	45.2	16.913
20	Thickness	10	47	21.1	9.222
	eight	11	414	90.1	97.9237
TK F	ength	17	84	47.12	18.791
	idth	20	75	36.92	15.055
25	Thickness	10	25	15.88	4.157
	eight	7	212	62.84	66.227

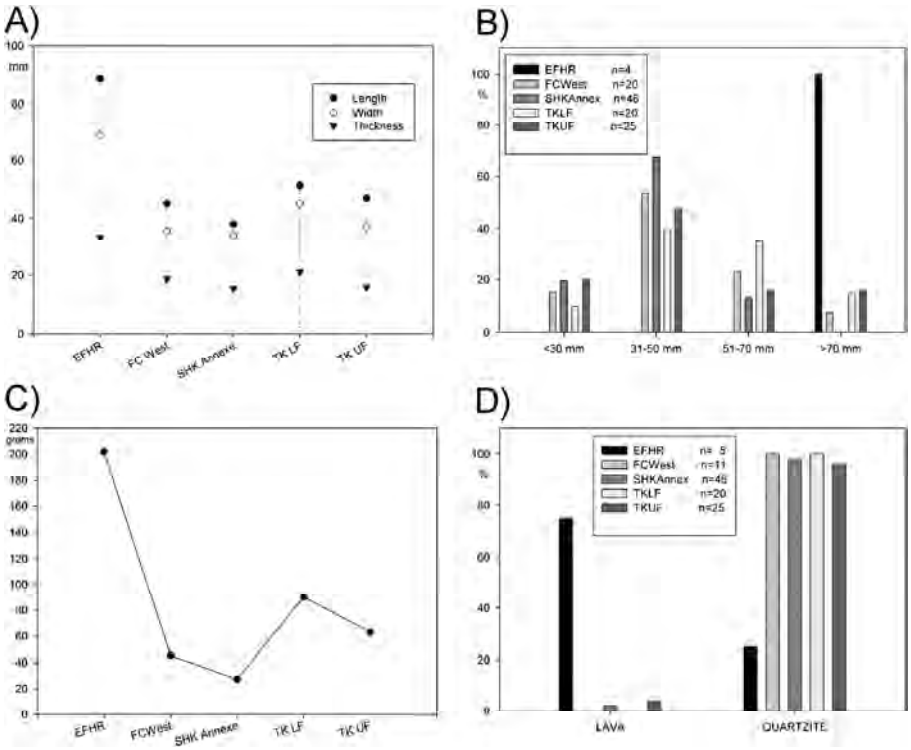


Fig. 10 Main attributes of small retouched tools. a Average dimensions. b ength ranges. c Average weight. d Raw materials

levels of TK and FC est OF. Thereforethere is very little zooarchaeological data available to sustain comparisons of subsistence strategies of Middle and pper ed II hominins.

The paleoecological setting of sites has also been used to discuss interassemblage variabilityleading to a popular hypothesis proposed to eplain differences between the DOand the Acheulean (ay 1976Isaac 1969 1971). Mary eakey was well aware of this ecological hypothesisbut she eplicitly ruled it out (eakey 1971272) asserting that no clear paleoecological differences were visible in the Middle and pper ed II record. Despite the appeal of this approach (Acheulean riverine environments distant from the Olduvai paleolakevs DOlakeshore settings)

Table 7 Percentage of cores and small retouched tools by raw ma terials (see absolute frequencies in Table 3) for those sites where the whole assemblage was studied

Site	Cores			Retouched	
	ava	uartzite	Gneiss	ava	uartzite
EFR	85.7	14.3	0	100	0
FCest	69.3	30.7	0	0	100
SK Annee	17.4	81.6	1	2.2	97.8
TK F	37.5	62.5	0	0	100
TK F	57.9	36.8	5.2	4	96

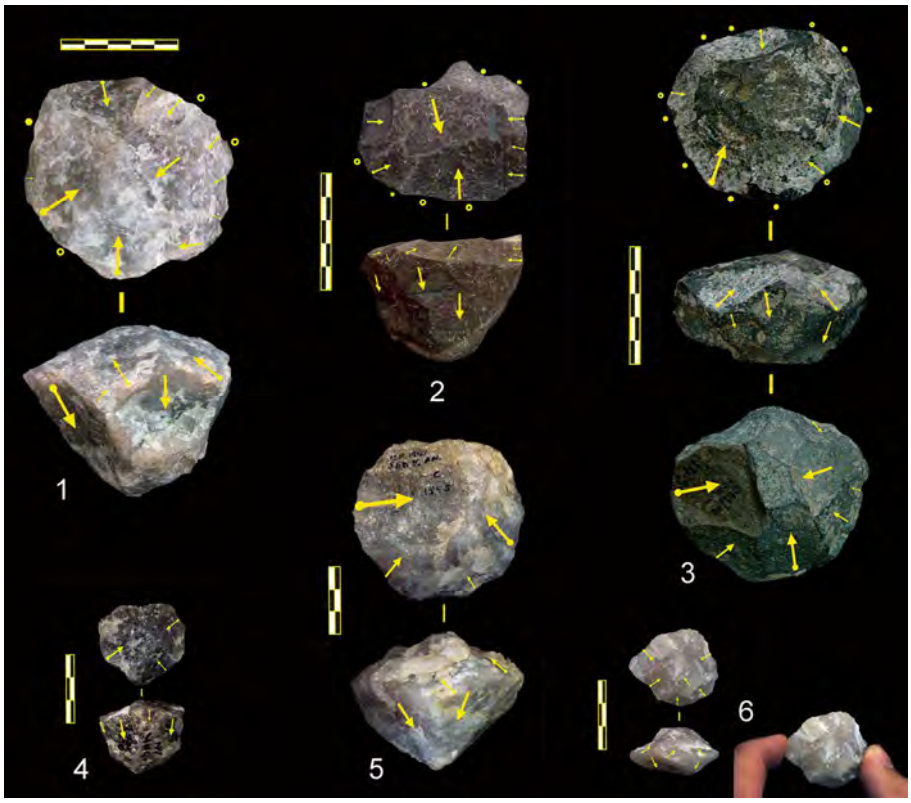


Fig. 11 ifacial centripetal cores from Middle and pper ed II assemblages. 1 and 3 MK Main Site. 2 EFR. 4 and 5 SK Annee. 6 TK F

which is still greatly favored in recent literaturewe agree with eakey that the hypothesis is not entirely grounded on the evidence currently available at Olduvai. Although eakey (1971124) reported the presence of a channel at EFRshe also stated that the archaeological level lay over clayswhich we assume should have formed on a lake floodplain or alike. uteven accepting ay s (1976) estimation of the 1 km distance from EFR to the lakethe TK evidence does not fit the model assuming that the lakeshore was more or less in the same location during the two occupations (and therefore TK was positioned within the lake floodplain)then we would have an Acheulean occupation (TK Faccording to eakey 1975) 1 km from the lake. ikewisethe SK Main Site contains socalled DOmaterials in channel environments (e.g.SKChannel)as do K and TK (eakey 1971166 173and 199). It is true that most supporters of the ecological hypothesis do not attribute cultural meaning but rather a functional one to the alleged interassemblage variability. owevereven if we were to assume such interassemblage variabilitythe evidence currently available does not support an ecological separation between handaerich assemblages and the othersif anythingit would be paleogeographical as the assemblages with lower handae frequencies are clustered in the Side Gorge.

To summarizeat present there are no solid arguments to support meaningful inter assemblage differences in the postTuff IIMiddle and pper ed II sequence

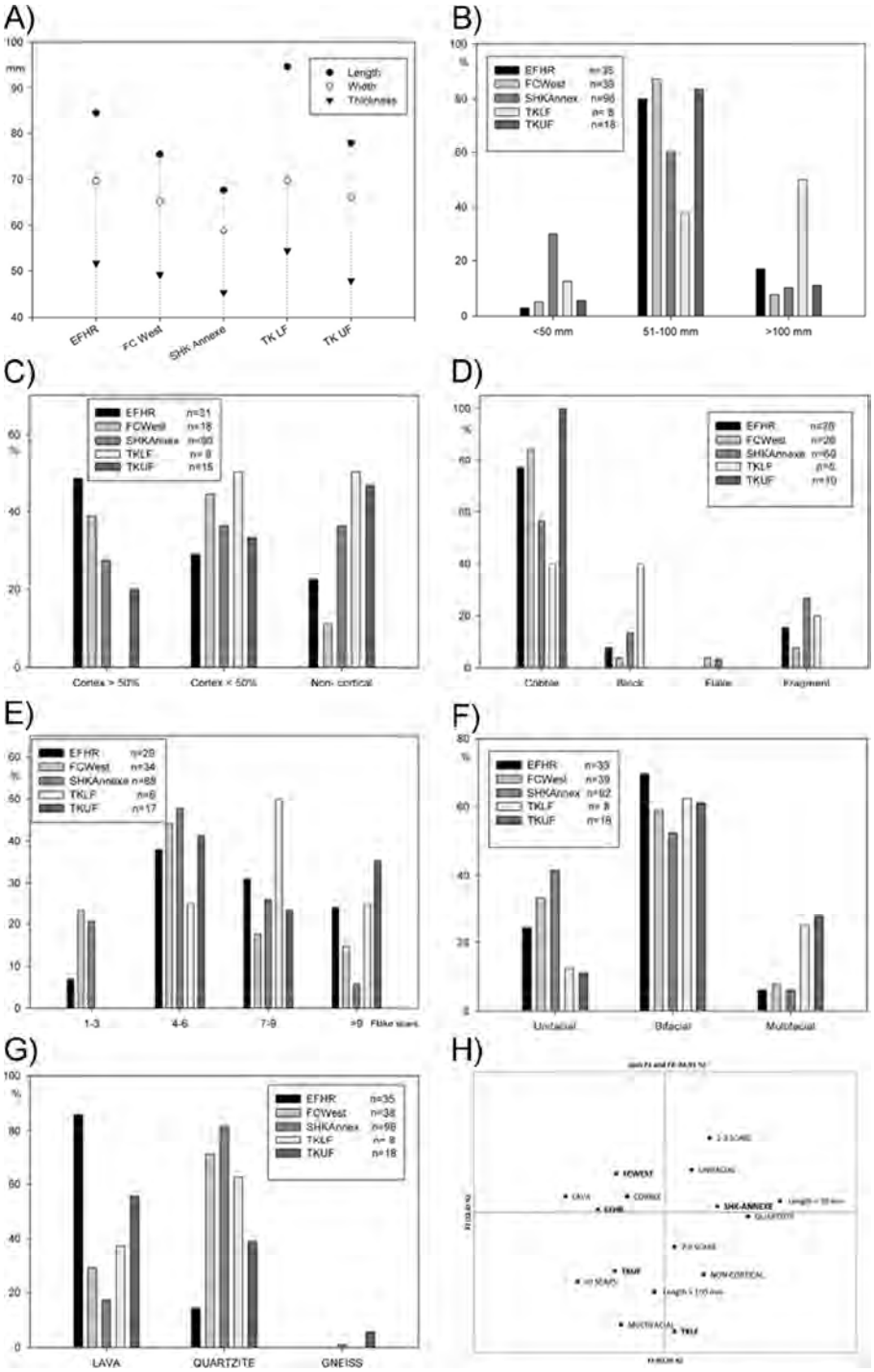
Table 8 Dimensions (millimeters and grams) of small debitage cores in the Middle and pper ed II sites

Site		Minimum	Maimum	Mean	Standard deviation
EFR	ength	47	118	84.72	16.583
	idth	26	100	69.66	16.046
32	Thickness	26	94	51.63	13.555
	eight	143	1153	449.7	265.2876
FCest	ength	47	125	75.42	18.011
	idth	35	118	65.18	19.871
43	Thickness	22	100	49.18	15.598
	eight	41	2049	387.92	378.117
SK Annee	ength	25	144	67.63	26.387
	idth	24	133	58.63	22.689
98	Thickness	20	108	45.31	18.384
	eight	15	2657	333.9	433.535
TK F	ength	50	160	94.63	35.42
	idth	47	97	69.75	20.155
10	Thickness	34	88	54.25	19.869
	eight	113	1186	544	431.054
TK F	ength	44	140	77.89	22.736
	idth	38	145	66.11	23.121
24	Thickness	26	68	47.89	11.172
	eight	47	1341	295.67	301.05

ecavated by eakey. This applies to the lithic collections (in which there is overall similarity of tool frequencies and shared technological skills)the faunal assemblages (where preservation and taphonomic issues make it difficult to make comparisons) and the paleoecological setting (for which the available data is limited and ambigu ous). As suchno culturalfunctionalor paleoecological eplanations eplain alone the variability of the Olduvai Middle and pper ed II sites whichaccording to the available evidenceshould be all considered within the same technocomple.

It has been argued that the mere presence of handaesregardless their frequency shall be considered as an indicative of the Acheulean character of the assemblages (Gowlett 1986de la Torre 2011b)although other technological features such as the sophistication of small debitage methods (de la Torre 2009) and the fragmentation of reduction sequences (de la Torre et al. 2008) can also be used to characterize early Acheulean technologies. On these groundsour analysis concludes that all the currently known Middle and pper ed II sites should be attributed to the Acheulean.

Fig. 12 Main features of small debitage cores (only those sites for which the whole assemblage was analyzed). a Average lengthwidthand thickness. b Core length ranges. c Amount of corteon cores. d Core blanks. e umber of flake scars on cores (scars per core averages: EFR7.66FC est5.79SK Annee5.73TK F9.00TK F8.82). f umber of flaked surfaces on cores. g Core raw materials. h Correspondence analysis of main features of cores b



Discussion

In the last few decadesthere has been growing consensus that the DOat Olduvai is only an activity facies of the Acheulean linked to functional andor paleocological factors. everthelessthe term Developed Oldowan is used profusely in current literatureeven though authors are cautious not to embrace eakey s dual phyla model. oweverit could be argued that we are still far from falsifying the dual phyla paradigmlet alone superseding it theoretically. eakey (1978) reminded us of the consistent (and on several occasions direct) association between Oldowan lithic artefacts and . habilis fossils at Olduvai. Stratigraphicallythe most recent . habilis (MK Skull Site) is found in a nonhandae contet. In contrastall . erectus fossils at Olduvai appear in handaebearing deposits. Thereforethe classic binomial equation Oldowan . habilis and Acheulean . erectus would workif one is to support that postTuff IIinterassemblage differences represent only activity related Acheulean variation. onethelesshow do we interpret cultural variability if biological diversity is empirically demonstratedIn that casea more cautious approach to straightforward functionalecological eplanations for cultural variation would have to be taken.

That is eactly what the paleoanthropological record seems to suggest at present an increasingly complescene of biological and archaeological diversity drawn from penecontemporary sequences such as the Turkana basinwhere . habilis seems to have coeisted with . erectus during a substantial time span (Spoor et al. 2007). The persistence of . habilis at Koobi Forain contets where both the Acheulean and . erectus eistetends the range of culturebiology possibilitiesfor eamplethat . habilis continued using an Oldowan technology after the emergence of the Acheulean and . erectus or that . habilis adopted the new technological innovations. These are only some of the options (which arbitrarily leave P. boisei aside of the discussion despite its presence in Oldowan and Acheulean contets)and are based on the working hypothesis that . erectus was responsible for Acheulean innovations fossils assigned to this species such as KMER 3733dated at 1.6 1.78 myrwere thought to predate the emergence of the Acheuleanbut new data from est Turkana (epre et al. 2011) and Konso (eyene et al. 2013) situates the earliest handaes ust around that time1.75 myr. Thisof coursedoes not eclude potential associations of . erectus with Oldowan assemblages as well.

Thusif the traditional Oldowan . habilis and Acheulean . erectus equation were applied to this increasingly complebiological and archaeological recordwe have to presume then that the dual phyla modelsupposedly supersededcould still be used to eplain interassemblage variability. In other wordsthere would be no grounds on which to rule out that a dual pattern of cultures and species applies to the Olduvai archaeological recordeactly as originally portrayed by eakey (1971 1975 1978). In such a casewe would be no closer to superseding dual phyla models than we were decades agodespite the overwhelming (and arguably untested) current preference for ecological and functional interpretations eplaining interassemblage variability at the onset of the Acheulean.

The documented coeistence between . habilis and . erectus is fascinating and raises the possibility for several different scenarios. One is the return to eakey s dual phyla of Oldowan . habilis and Acheulean . erectus to eplain the documented

interassemblage differences in the 1.8 1.4 myr interval in East Africa. oweverthis option raises many other questionsfor eampleif there were biological reasons (e.g.anatomical andor cogni tive constraints) that prevented . habilis from adopting an Acheulean technology. Another possibility would be that . habilis did adopt the technological innovations of the Acheulean. In this casehoweverwe would be no closer to identifying the reasons for the inconsistencies in the definition of the Developed Oldowan. Additionallythis would require engaging in discussions about acculturation as the cause of cultural change andor interassemblage variability whichas we will argue belowalso hinder research in other Palaeolithic contets such as the Chatelperronian.

early half a million years of coeistence (Spoor et al. 2007) also triggers questions regarding the niches eploited by these species. The paleobiology of early . erectus suggests that this hominin had larger home ranges than . habilis (e.g. Antn 2003)and the very fact that the two hominins remained sympatric for half a million yearswould probably require some kind of niche compartmentalization. oth factors could potentially account for ecological differences between the two speciesdictating different behavioral strategies that could in turn eplain variability in stone tool assemblages. Thereforein this scenario interassemblage variability could result from both biological differences between the two speciesbehavioral andor ecological constraints imposed by variations in the niches eploited by each species.

In the case of Olduvai Gorgeit is also possible that . habilis simply did not coeist with . erectus for a considerable period of time. owermost ed II assem blages are definitely Oldowan (eakey 1971de la Torre and Mora 2005 lumenschine et al. 2012) and human remains are attributed to . habilis in a time span (circa 1.75 myr) in which earliest Acheulean assemblages are documented in est Turkana (epre et al. 2011) and Konso (eyene et al. 2013). In contrastthe fossil record above Tuff IIat Olduvai is devoid thus far of . habilis remainsand it could therefore be argued that all the Middle and pper ed II assemblages were made by . erectus . Given that in this paper we have proposed that all postTuff II sites documented thus far belong to the Acheuleanembracing the Acheulean . erectus equation would then rule out any role by . habilis in the formation of the Middle and pper ed II assemblages.

nfortunatelythe low resolution of the available evidence currently precludes adequate testing of these possible scenarios. e have argued in this paper that this is not only due to the many empirical hindrances inherent to the coarsegrained nature of the Early Stone Age record (e.g.Stern 1994)but also our poor conceptualization of the fossil and archaeological evidencewhich is still deeply rooted in paradigms developed several decades ago.

Resilience of old paradigms is certainly not restricted to the emergence of the Acheuleanfor instancecurrent debate on the composition of Asian Middle Pleistocene assemblages still largely revolves around the frequency and morphology of handaes onlywhich are used to support (orton et al. 2006) or challenge (e.g. Petraglia and Shipton 2008) the nature of the Movius ine. Despite the totally different temporal and geographic contetsresemblance can also be identified between the theoretical framework of the Developed Oldowan (originally interpreted as a crude copy by . habilis of Acheulean technology developed by a new hominin

. erectus) and the Chatelperronian (considered by many as an attempt by eanderthals to reproduce Aurignacian technology developed by early modern humans). Curiously enoughinfluential views (e.g.Mellars 2005) support such an interpretation of the Chatelperronian (although see d Errico et al. 1998)despite the serious problems of fossil and stone tool associations (arosef and ordes 2010) while in East Africa (where . habilis and . erectus do seem to have coeisted for hundreds of thousands of years) functional interpretations of interassemblage vari ability are currently favored.

This poses an interesting paradothe more intensive fieldwork in Europe and the recognition of the unsuitability of ordes (1961) typology to measure cultural and functional interassemblage differences (e.g.Dibble 1988Delagnes et al. 2007) have led to the acknowledgement of problems surrounding functional interpretations of Mousterian variability as originally proposed by inford (1973). Thuscurrent Mousterian archaeologists are cautious when correlating lithic variability with spe cific activity facies. In contrastthe influence of the processual approach in East Africa has favored such activityfacies models for Early Stone Age assemblage variationdespite the deficient knowledge of archaeological and paleoecological contetsand the untested correlation between lithic variability and particular paleoenvironmental settings. In the meantimecultural contact between different hominin species dominates discussions over the Middle to pper Palaeolithic tran sition in Europe despite the problematic fossilindustry associations (arosef and ordes 2010)whereas today very few would defend the proposal that assimilation of a new technology by . habilis eplains the Developed Oldowandespite the increasing evidence of a long coeistence between . habilis and . erectus (Spoor et al. 2007).

In summaryit seems that theoretical and empirical problems still surround the debate over cultural evolution and interassemblage variability at Olduvai and else where. Given the increasingly more complescenario of hominin interactions in the 1.8 1.4 myr spanit should not be ruled out that assemblage variation actually reflects cultural andor biological differences in that particular time frame. onethelessit has also been argued here that the available evidence from Olduvai is too ambiguous to support either cultural or ecological eplanations of variability.

In realitya maor part of the problem surrounding the long debate over the DOand the Acheulean is that all comparisons have been based on contrasting EFR against the other Middle and pper ed II sites. Although EFR shares a technological back ground with the other assemblagesit seems to be an oddity in several aspectsincluding the overall predominance of lavagreater distance from the lakeand the abundance of handaes. The absence of assemblages like EFR higher up in the ed II sequence makes comparisons with the socalled DOsites difficult. The same applies to the etremely limited information currently available on subsistence strategies and the paleoecological contet of Middle and pper ed II siteswhich hinders the validity of the popular (but untested) ecologicalfunctional interpretations of the Developed OldowanAcheulean at Olduvai.

Our technological reassessment of eakey s collections indicates an overall similar ity of small debitage coresretouched toolsand CT faonnage techniques. The only main difference in the postTuff IIassemblages seems to be frequency of handaes between EFR and the other sites. ut apart from thatall the eakey assemblages can

confidently be attributed to the same technocomplethe Acheulean. oweverthat does not automatically preclude the eistence of interassemblage variation in the Olduvai recordor its eplanation by culturalbiologicalor paleoecological factors this paper simply underlines the point that the available data is insufficient to defend such variabilityand that only by etending the sample can this issue be addressed.

Conclusions

Olduvai Gorge has played a pivotal role in the shaping of our view of cultural evolution in the Early Stone Age. For two decadesouis eakey s (1951) gradualist model of the ChellesAcheul culture at Olduvai was the main conceptual and empirical framework used to understand the evolution of the Acheulean in East Africa. This gradual progression model of the Acheulean was refuted empirically by Mary eakey (1967)and the influence of the stochastic hypothesis (Isaac 1977) led to generalized reection of temporal trends in the refinement of early Acheulean handaes. ouis eakey s (1951) model was definitely superseded by the publication of Olduvai Gorge vol. 3 (eakey 1971)which became even more influential than the previous monograph. eakey (1971) proposed that the Oldowan led to the DOAand the latter to the DOdue to the influence of a new culture (the Acheulean) and hominin species (. erectus). hereas the attribution of the preTuff IIevidence to the Oldowan currently remains unchallenged (independent of the acceptance or not of the DOA)most later studies (e.g.ay 1976ones 1994) have favored a functional interpretation for the alleged variability in the Middle and pper ed II assemblages which for many is only a matter of variation within the Acheulean technocomple (Gowlett 1988Stiles 1980de la Torre and Mora 2005Semaw et al. 2009).

This paper has attempted to place the debate of cultural variation and evolution at Olduvai Gorge in a historical contetand to emphasize how far we still are from superseding earlier paradigms. It has been argued that even functional and paleoeco logical eplanations have a number of flawsstemming both from the uncritical acceptance of Mary eakey s original definitions and the very limited record avail able. e agree that the study of lithic interassemblage variability should not be an end in itself (Shea 2011)and evolutionary perspectives on stone tool analysis must consider the widest possible range of eplanations for cultural change (Kuhn 2004). ut a better knowledge of the organization of technology (elson 1991) and the role of cultural constraints (emonnier 1990) in the shaping of the Olduvai assemblages can only be achieved by combining these perspectives with a full understanding of the paleoecological and paleogeographical settingsas attempted in roughly contem porary contets (e.g.raun et al. 2008). Theoretical models such as those developed for the Oldowan (lumenschine and Peters 1998) would help identify priorities of research on the origins of the Acheulean in Olduvai. And all of this should be accompanied by substantial enlargement of the empirical dataset.

Apart from the broad perspective provided by ay (1976)we know very little about the paleoecological and stratigraphic contets of Middle and pper ed II sites. The same applies to subsistence activities (for which most of the available data refers only to one siteK (Monahan 1996Egeland 2007DominguezRodrigo et al. 2009)and to raw materials (Kyara 1999)for which a detailed mapping of available

sources is still missing. Even the chronology is uncertainEFR used to be considered as the earliest Acheulean occurrence in East Africa at around 1.5 myr (eakey 1971)but the discovery of new sites in Konso (Asfaw et al. 1992eyene et al. 2013)est Turkana (epre et al. 2011)and Gona (uade et al. 2004)along with the stratigraphic inconsistencies of the Middle ed II sites (see ay (1976) versus eakey (1971))and the problems of recent dating attempts (Manega 1993Tamrat et al. 1995)have relegated the Olduvai early Acheulean to the background. ew data on all these aspectsplus reconnaissance of the stratigraphic sequence in search of new sites in different stratigraphic and paleogeographic positionsis thus essential in order to eplore the nature of cultural change and ecological adaptations at Olduvai Gorge.

Acknowledgments Current research in Olduvai by OGAP (Olduvai Geochronology Archaeology Pro ect) is authorized by the Commission for Science and Technology (COSTEC) and the Department of AntiquitiesTanzania. Funding by the SF (CS0852292)ritish Academy (IP090186)and the Euro pean Research CouncilStarting Grants (283366)is gratefully acknowledged.

References

Abdi.illiams. . (2010). Correspondence Analysis. In . Salkind (Ed.) Encyclopedia of research design (pp. 267 278). Sage: Thousand Oaks.

AntnS. C. (2003). atural history of omo erectus . earbook of Physical Anthropology46 126 170.

Asfaw.eyene.SuwaG.alkerR. C.hiteT. D.oldeGabrielG.emaneT. (1992). The earliest Acheulean from KonsoGardula. ature360 732 735.

arosefO.ordes.G. (2010). ho were the makers of the Chtelperronian culture ournal of uman Evolution59 586 593.

arosefO.GorenInbar. (1993). The lithic assemblages of beidiya. A lower Palaeolithic site in the ordan Valley. Monographs of the Institute of Archaeology n34 . erusalem: uedem.

enitoCalvoA.de la TorreI. (2011). Analysis of orientation patterns in Olduvai ed I assemblages using GIS techniques: implications for site formation processes. ournal of uman Evolution61 50 60.

eyene.KatohS.oldeGabrielG.art. K.toK.SudoM.KondoM.yodoM.RenneP. R.SuwaG.Asfaw. (2013). The characteristics and chronology of the earliest Acheulean at Konso. Ethiopia: Proceedings of the ational Academy of Sciences.

inford. R. (1973). Interassemblage variability the Mousterian and the functional argument. In C. Renfrew (Ed.) The eplanation of culture change. Models in Prehistory (pp. 227 254). ondon: Duckworth.

lumenschineR. .PetersC. R. (1998). Archaeological predictions for hominid land use in the paleo Olduvai asinTanzaniaduring lowermost ed II times. ournal of uman Evolution34 565 607.

lumenschineR. .MasaoF. T.Stollhofen.StanistreetI. G.amfordM. K.AlbertR. M.au. K.PrassackK. A. (2012). andscape distribution of Oldowan stone artifact assemblages across the fault compartments of the eastern Olduvai ake asin during early lowermost ed II times. ournal of uman Evolution63 384 394.

ordesF. (1961). Typologie du Palolithique Ancien et Moyen . Paris: CRS Editions.

ower. R. F. (1977). Attributes of Oldowan and ower Acheulean tools: tradition and design in the Early ower Palaeolithic. The South African Archaeological ulletin32 113 126.

raunD. R.RogersM. .arris. . K.alkerS. . (2008). andscapescale variation in hominin tool use: evidence from the Developed Oldowan. ournal of uman Evolution55 1053 1063.

reuil. (1932). es industries clats du palolithique ancien1.e Clatonien. Prhistoire1 125 190.

CallowP. (1994). The Olduvai ifaces: Technology and Raw Materials. In M. D. eakey D. A. Roe (Eds.) Olduvai Gorge. Volume 5. Ecavations in beds IIIIV and the Masek beds1968 1971 (pp. 235 253). Cambridge: Cambridge niversity Press.

Clark. D. (1959). Ecavations at roken illorthern Rhodesia. ournal of the Royal Anthropological Institute of Great ritain and Ireland89 201 232.

Clark. D. (1960). uman ecology during Pleistocene and later times in Africa South of the Sahara. Current Anthropology1 307 324.

D ErricoF.ilho.ulienM.affierD.Pelegrin. (1998). eanderthal acculturation in estern EuropeA critical review of the evidence and its interpretation. Current Anthropology39 1 44.
DavisD. D. (1980). Further consideration of the developed Oldowan at Olduvai Gorge. Current Anthropology21 840 843.
de la TorreI. (2009). Technological Strategies in the ower Pleistocene at Penin(est of ake atron Tanzania). In K. Schick . Toth (Eds.) The cutting edge: new approaches to the archaeology of human origins (pp. 93 113). loomington: Stone Age Institute Press.
de la TorreI. (2011a). The origins of stone tool technology in Africa: a historical perspective. Philosophical Transactions of the Royal Society 366 1028 1037.
de la TorreI. (2011b). The Early Stone Age lithic assemblages of Gadeb (Ethiopia) and the developed Oldowanearly Acheulean in East Africa. ournal of uman Evolution60 768 812.
de la TorreI.MoraR. (2005). Technological Strategies in the ower Pleistocene at Olduvai eds I and II. iege: ERA112.
de la TorreI.MoraR. (2009). Remarks on the Current Theoretical and Methodological Approaches to the Study of Early Technological Strategies in Eastern Africa. In E. overs D. R. raun (Eds.) Interdisciplinary approaches to the Oldowan (pp. 15 24). Dordrecht: Springer.
de la TorreI.MoraR.MartnezMoreno. (2008). The early Acheulean in Penin(ake atron Tanzania). ournal of Anthropological Archaeology27 244 264.
DelagnesA.aubert.Meignen. (2007). es technocomplees du Palolithique moyen en Europe occidentale dans leur cadre diachronique et gographique. In . Vandermeersch . Maureille (Eds.) es andertaliensiologie et Cultures (pp. 213 229). Paris: d. du CTS.
Dibble. . (1984). Interpreting typological variation of Middle Paleolithic scrapers: functionstyleor sequence of reduction ournal of Field Archaeology11 431 436.
Dibble. . (1988). Typological Aspects of Reduction and Intensity of tilization of ithic Resources in the French Mousterian. In . . Dibble A. Montethite (Eds.) pper Pleistocene prehistory of estern Eurasia (pp. 181 197). Philadelphia: The niversity Museum.
DomnguezRodrigoM.MabullaA.unn. T.arbaR.DezMartnF.EgelandC. P.EsplezE. EgelandA.ravedra.SnchezP. (2009). nraveling hominin behavior at another anthropo genic site from Olduvai Gorge (Tanzania): new archaeological and taphonomic research at Kpper ed II. ournal of uman Evolution57 260 283.
EgelandC. P. (2007). ooarchaeological and taphonomic perspectives on hominid and carnivore in teractions at Olduvai GorgeTanzania. loomington: npublished PhDIndiana niversity.
GibbonR. .GrangerD. E.KumanK.PartridgeT. C. (2009). Early Acheulean technology in the Rietputs FormationSouth Africadated with cosmogenic nuclides. ournal of uman Evolution56 152 160.
Gowlett. A. . (1986). Culture and conceptualisation: The OldowanAcheulian gradient. In G. . ailey P. Callow (Eds.) Stone Age prehistory: studies in memory of Charles Mcurney (pp. 243 260). Cambridge: Cambridge niversity Press.
Gowlett. A. . (1988). A case of developed Oldowan in the Acheulean orld Archaeology20 13 26.
arris. . K.IsaacG. . (1976). The Karari industry: early Pleistocene archaeological evidence from the terrain east of ake TurkanaKenya. ature262 102 107.
ayR. . (1976). Geology of the Olduvai Gorge. erkeley: niversity of California Press.
ayR. . (1990). Olduvai Gorgea case history in the interpretation of hominid paleoenvironments in East Africa. In (. F. aporteEd.) Establishment of a Geologic Framework for Paleoanthropology. oulder: Geological Society of America242 23 37.
owellF. C.Clark. D. (1964). Acheulian unterGatherers of SubSaharan Africa. In F. C. owell F. ourlire (Eds.) African ecology and human evolution (pp. 458 533). ondon: Methuen.
IsaacG. . (1969). Studies of early culture in East Africa. orld Archaeology I1 28.
IsaacG. . (1971). The diet of early man: aspects of archaeological evidence from lower and middle Pleistocene sites in Africa. orld Archaeology2 278 299.
IsaacG. . (1972). Chronology and tempo of cultural change during the Pleistocene. In . . ishop . A. Miller (Eds.) Calibration of ominoid evolution. Recent advances in isotopic and other dating methods as applicable to the origin of man (pp. 381 417). Edinburgh: Scottish Academic Press.
IsaacG. . (1974). Stratigraphy and patterns of cultural change in the Middle Pleistocene. Current Anthropology15 508 514.
IsaacG. . (1977). Olorgesailie. Archeological studies of a Middle Pleistocene ake asin in Kenya . Chicago: niversity of Chicago Press.
IsaacG. . (1986). Foundation Stones: Early Artifacts as Indicators of Activities and Abilities. In G. . ailey P. Callow (Eds.) Stone Age Prehistory: Studies in Memory of Charles Mcurney (pp. 221 241). Cambridge: Cambridge niversity Press.

onesP. R. (1979). Effects of raw materials on biface manufacture. Science204 835 836.
onesP. R. (1994). Results of Eperimental ork in Relation to the Stone Industries of Olduvai Gorge. In M. D. eakey D. A. Roe (Eds.) Olduvai Gorge. Volume 5. Ecavations in eds IIIIVand the Masek eds1968 1971 (pp. 254 298). Cambridge: Cambridge niversity Press.
KleindienstM. R. (1961). Variability within the ate Acheulian assemblage in East Africa. The South African Archaeological ulletin V35 52.
KleindienstM. R. (1962). Component of the East African Acheulian Assemblage: An Analytic Approach. In G. Mortelmans . enquin (Eds.) Actes du IV Congrs Panafricain de Prhistoire et de lEtude du uaternaireeopoldville1959 (pp. 81 108). Tervuren: elgie AnnalenMuse Royal de l Afrique Centrale.
KuhnS. . (2004). Evolutionary perspectives on technology and technological change. orld Archaeology36 561 570.
KumanK.ClarkeR. . (2000). Stratigraphyartefact industries and hominid associations for SterkfonteinMember 5. ournal of uman Evolution38 827 847.
KyaraO. A. (1999). ithic Raw Materials and Their Implications on Assemblage Variation and ominid ehavior During ed IIOlduvai GorgeTanzania. ew runswick: npublished Ph.D. niversity of Rutgers.
aplaceG. (1980). e lien comme mesure de l information dans un tableau de contingence. Dialektik 1979 19801 15.
eakey. S. . (1936). Stone Age Africa. An outline of Prehistory in Africa. ondon: Oford niversity Press.
eakey. S. . (1951). Olduvai Gorge. A report on the evolution of the handae culture in eds I IV. Cambridge: Cambridge niversity Press.
eakey. S. . (1954). Olduvai Gorge. Scientific American190 66 71.
eakey. S. . (1958). Recent discoveries at Olduvai GorgeTanganyika. ature181 1099 1103.
eakey. S. . (1965). Olduvai Gorge 1951 61. Volume 1. A preliminary report on the geology and fauna. Cambridge: Cambridge niversity Press.
eakeyM. D. (1966). A review of the Oldowan culture from Olduvai GorgeTanzania. ature210 462 466.
eakeyM. D. (1967). Preliminary Survey of the Cultural Material from eds I and IIOlduvai Gorge Tanzania. In . . ishop . D. Clark (Eds.) ackground to evolution in Africa (pp. 417 446). Chicago: niversity of Chicago Press.
eakeyM. D. (1971). Olduvai Gorge. Vol 3. Ecavations in eds I and II1960 1963. Cambridge: Cambridge niversity Press.
eakeyM. D. (1975). Cultural Patterns in the Olduvai Sequence. In K. . utzer G. . Isaac (Eds.) After the Australopithecines. Stratigraphyecologyand cultural change in the Middle Pleistocene (pp. 477 493). Chicago: Mouton.
eakeyM. D. (1978). Olduvai Fossil ominids: Their Stratigraphic Positions and Associations. In C. olly (Ed.) Early ominids from Africa (pp. 3 16). ondon: G. Duckworth.
eakeyM. D.RoeD. A. (1994). Olduvai Gorge. Volume 5. Ecavations in eds IIIIVand the Masek eds1968 1971. Cambridge: Cambridge niversity Press.
eakey. S. .opwoodA. T.Reck. (1931a). Age of the Oldoway one edsTanganyika Territory. ature128 724.
eakey. S. .opwoodA. T.Reck. (1931b). ew yields from the Oldoway one eds Tanganyika Territory. ature128 1075.
emonnierP. (1990). Topsy turvy techniques. Remarks on the social representation of techniques. Archaeological Review from Cambridge9 27 37.
epreC. .Roche.KentD. V.armandS.uinnR. .rugal. P.TeierP. .enobleA. FeibelC. S. (2011). An earlier origin for the Acheulian. ature477 82 85.
ManegaP. C. (1993). GeochronologyGeochemistry and Isotopic Study of the PlioPleistocene ominid Sites and the gorongoro Volcanic ighland in orthern Tanzania. oulder: npublished Ph.D. niversity of Chicago.
MasonR. . (1976). The Earliest Artefact Assemblages in South Africa. In (. D. Clark G. . IsaacEd.) es plus anciennes industries en Afrique. nion Internationales des Sciences Prhistoriques et Protohistoriques9th Congrs. ice: ISPP140 156.
MellarsP. (2005). The impossible coincidence. A singlespecies model for the origins of modern human behavior in Europe. Evolutionary Anthropology14 12 27.
MonahanC. M. (1996). Variability in the foraging behavior of early omo: A taphonomic perspective from ed IIOlduvai GorgeTanzania. Madison: npublished PhDniversity of isconsinMadison.

elsonM. C. (1991). The Study of Technological Organization. In M. . Schiffer (Ed.) Archaeological method and theoryvol. 3 no. 1 (pp. 57 100). Tucson: niversity of Arizona Press.
ortonC. .aeK.arris. . K.ee. (2006). Middle Pleistocene handaes from the Korean Peninsula. ournal of uman Evolution51 527 536.
OakleyK. P.eakeyM. D. (1937). Report on ecavations at aywick SandsEsse(1934)with some observations on the Clactonian industryand on the fauna and geological significance of the Clacton Channel. Proceedings of the Prehistoric Society3 217 260.
PappuS.Gunnell.AkhileshK.raucherR.TaiebM.DemoryF.Thouveny. (2011). Early Pleistocene presence of Acheulian ominins in South India. Science331 1596 1599.
PetragliaM. D.ShiptonC. (2008). arge cutting tool variation west and east of the Movius ine. ournal of uman Evolution55 962 966.
PosnaskyM. (1959). A hope fountain site at OlorgesailieKenya Colony. The South African Archaeological ulletin IV83 89.
PottsR. (1991). hy the OldowanPlioPleistocene toolmaking and the transport of resources. ournal of Anthropological Research47 153 176.
uade.evin.SemawS.StoutD.RenneP.RogersM. .SimpsonS. (2004). Paleoenvironments of the earliest stone toolmakersGonaEthiopia. Geological Society of America ulletin116 1529 1544.
Reck. (1914). Erste Vorlufige Mitteilung ber den Fund eines fossilen Menschenskelets aus entral afrika. Sitzungsberichte der Gesellschaft aturforschender Freunde zu erlin3 81 95.
RoeD. A. (1994). A metrical analysis of selected sets of handaes and cleavers from Olduvai Gorge. In M. D. eakey D. A. Roe (Eds.) Olduvai Gorge. Volume 5. Ecavations in eds IIIIVand the Masek eds1968 1971 (pp. 146 234). Cambridge: Cambridge niversity Press.
SemawS.RogersM. .StoutD. (2009). The OldowanAcheulian Transition: Is there a Developed Oldowan Artifact TraditionIn M. Camps P. Chauhan (Eds.) Sourcebook of Paleolithic transi tions. Methodstheoriesand interpretations (pp. 173 193). ew ork: Springer.
SharonG. (2008). The impact of raw material on Acheulian large flake production. ournal of Archaeological Science35 1329 1344.
Shea. . (2011). Stone tool analysis and human origins research: some advice from uncle screwtape. Evolutionary Anthropology20 48 53.
SpoorF.eakeyM. G.GathogoP. .rownF. .AntnS. C.McDougallI.KiarieC.ManthiF. K.eakey. . (2007). Implications of new early omo fossils from Ilereteast of ake Turkana Kenya. ature448 688 691.
Stern. (1994). The implications of timeaveraging for reconstructing the landuse patterns of early tool using hominids. ournal of uman Evolution27 89 105.
StilesD. (1977). Acheulian and developed Oldowan. The meaning of variability in the Early Stone Age. Mila6 1 35.
StilesD. (1979). Early Acheulean and developed Oldowan. Current Anthropology20 126 129.
StilesD. (1980). Industrial Taonomy in the Early Stone Age of Africa. Anthropologie VIII189 207.
StilesD. (1991). Early hominid behaviour and culture tradition: raw material studies in ed IIOlduvai Gorge. African Archaeological Review9 1 19.
TamratE.Thouveny.TaiebM.Opdyke. D. (1995). Revised magnetostratigraphy of the Plio Pleistocene sedimentary sequence of the Olduvai Formation (Tanzania). Palaeogeography PalaeoclimatologyPalaeoecology114 273 283.
Toth. (1982). The Stone Technologies of Early ominids at Koobi ForaKenyaAn Eperimental Approach. npublished Ph. D.erkeleyniversity of California.
Toth. (1985). The Oldowan reassessed: a close look at Early Stone artifacts. ournal of Archaeological Science12 101 120.
Toth. (1987). ehavioral inferences from Early Stone artifact assemblages: an eperimental model. ournal of uman Evolution16 763 787.
VolleM. (1981). Analyse des Donnes. Paris: 2nd EditionEconomica.
arrenS. . (1922). The Mesvinian industry of ClactononSeaEsse. Proceedings of the Prehistoric Society of East Anglia3 597 602.
hiteM. . (2000). The Clactonian question: on the interpretation of CoreandFlake assemblages in the ritish ower Paleolithic. ournal of orld Prehistory14 1 63.