Research

The origins of stone tool technology in Africa: a historical perspective

Ignacio de la Torre*

Institute of Archaeology, University College London, 31–34 Gordon Square, London WC1H 0PY, UK

The search for the earliest stone tools is a topic that has received much attention in studies on the archaeology of human origins. New evidence could position the oldest traces of stone tool-use before 3.39 Myr, substantially earlier than previously documented. Nonetheless, the first unmistakable evidence of tool-making dates to 2.6 Ma, the period in which Oldowan assemblages first appear in the East African record. However, this is not an unchangeable time boundary, and considerations about the tempo and modo of tool-making emergence have varied through time. This paper summarizes the history of research on the origins of stone knapping in Africa and places the current evidence in a historical perspective.

Keywords: stone tools; Oldowan; Africa; early Pleistocene; archaeology of human origins; history of palaeoanthropology

1. INTRODUCTION

The quest for the earliest evidence of culture is one of the main fields of research in human evolutionary studies and has occupied many scholars since the beginning of the discipline. During the last decade, there has been widespread consensus regarding 2.5–2.6 Myr—the age of the oldest Oldowan assemblages in Gona [1]—as the time period in which the earliest signs of human culture are traceable in the archaeological record. However, this chronological rubicon has changed during the two centuries of investigations on the archaeology of human origins. Indeed, the 2.5–2.6 Myr time barrier, in recent years considered as a consolidated threshold for the emergence of lithic technology, has just been shattered with new discoveries in Dikika, which if confirmed could push back the empirical evidence for stone tool use to before 3.39 Ma [2].

Given that a number of recent studies review the state of the art in Oldowan research and the origins of stone tool technology according to current archaeological evidence [3–6], this paper adopts an alternative perspective, giving a double meaning to ‘culture evolves’ by examining not only the empirical record for the dawn of technology in Africa, but also the origins and evolution of ideas about this subject. The ‘year zero’ for the earliest cultural evidence, explanatory models for the emergence of technology and the possible makers of the first stone tools have varied substantially throughout the history of the discipline, according to theories and paradigms dominant in each research period. This paper will consider the evolution of such ideas and place the current view of Oldowan technology in a historical perspective.

2. EARLY PERSPECTIVES ON THE ORIGINS OF STONE TOOL TECHNOLOGY

It was only at the end of the seventeenth century that stone tools ceased to be included within the general category of fossils and began to be considered as humanly made [7]. During the eighteenth and nineteenth centuries, lithic artefacts were classified and systematized into successive cultural phases, leading to highly influential models such as those developed by Thomsen and Boucher de Perthes, still used today as the basics of cultural classification in prehistory. The search for the earliest stone tools became a popular field of research from the beginning, and polemics soon arose; the question of the Eolithic came up in the 1860s, when Bourgeois announced the presence of flint tools in the Oligocene deposits of Thenay in France. Since then, alleged discoveries claimed the existence of ‘Tertiary man’ assemblages older than those of the Palaeolithic, made by humans living in a period—the Eolithic—in which stones were crudely worked or not knapped but used in their natural form. At the beginning of the twentieth century, Boule [8] attempted to demonstrate the dubious nature of the Eolithic industries claimed to have been discovered in Europe. However, despite the efforts of influential researchers (e.g. [8]), the Eolithic issue continued to be the subject of great controversies. Piltdown Man, for example, provided key support for the Eolith hypothesis until the 1940s and 1950s [9,10], for it was assumed that, although Eolithic stones alone could be considered as natural, their association with a human fossil demonstrated their archaeological nature; in a tautological paradox, the dubious Piltdown Man provided support for the alleged stone tools it was associated with (and vice versa), and hence was used to prove the existence of the Eolithic culture in Europe.

In the meantime, researchers in Africa had started to develop the first cultural sequences, initially based

*i.torre@ucl.ac.uk

One contribution of 26 to a Discussion Meeting Issue ‘Culture evolves’.

Figure 1. Key East African sites cited in the text.

on European referential frameworks. Leaving aside the polemic Eolithic, the Chellean was considered in Europe as the earliest handaxe culture, followed by the Acheulean, and then the Middle and Upper Palaeolithic. Although no absolute chronologies were available, Goodwin & Van Riet Lowe [11] proposed the Stellenbosch industry as the oldest in the African continent, which was paralleled to the European Chellean. However, new fieldwork led to the recognition of a culture even older than the Chellean, the Oldowan, named after the then-called Oldoway Gorge. In his first visit to the gorge in 1931, Louis Leakey discovered in the lower part of the sequence stone tools that seemed to exist before the emergence of handaxes and the Chellean. The first news of this novel industry was published in *Nature* on 26 December of that year [12], although the term Oldowan was still not employed (table 1). A little later, a conference was organized in Cambridge by the Royal Anthropological Institute to discuss Leakey's [25] discoveries. At this meeting, Leakey reported the existence of a pebble industry in Oldoway Bed I, older than the Chellean from Bed II and the Acheulean from Bed III. Illustrous convenors, such as Gordon Childe, Burke, Bate and Smith Woodward, accepted that in Oldoway there was a gradual evolution from the pebble industry to handaxe cultures, and concluded that 'there is no reason to doubt that the series from East Africa is of at least equal antiquity with the European, and it may even begin somewhat earlier' [25, p. 67]. Although the term 'Oldowan' had not yet appeared in the proceedings of the Cambridge conference [25], this meeting was essential for the acceptance of such a culture [26].

Immediately afterwards, one of the earliest descriptions noted that 'the principal tool of the Oldowan

Table 1. Some of the major events in the history of early stone tools in Africa.

major events	references
2009 cutmarked bones in Dikika reported to be older than 3.39 Myr	[2]
1999 sophisticated reduction sequences reported at Lokalalei 2C	[13]
1997 earliest stone tools dated at 2.5 Ma in Gona	[14]
1973 first archaeological discoveries in Hadar	[15]
1971 publication of excavations in Olduvai Beds I and II	[16]
1969 first lithics discovered in Omo	[17,18]
1961 radiometric dating of the Oldowan at Olduvai	[19]
1960 discovery of <i>Homo habilis</i> , considered the first Oldowan toolmaker	[20]
1959 discovery of <i>Zinjanthropus boisei</i> associated with Oldowan tools	[21]
1934 formal description of the Oldowan	[22,23]
1931 Louis Leakey reports 'pre-Chellean' artefacts in Olduvai	[12]
1913 Hans Reck reports fossiliferous beds in Olduvai	[24]

culture is of very simple form. A rolled pebble or a nodule of chert, or a rough lump of almost any kind of rock is trimmed very roughly along one edge or side, so as to produce a jagged cutting edge' [22, p. 144], and a formal definition would follow, asserting that 'The Oldowan culture comprises a series of artefacts which are made either from water-worn pebbles or from lumps of rock. The piece of material to be made into a tool was then trimmed very roughly by striking off flakes in two directions so that the line of

intersection of these flake scars gave a jagged cutting edge along one side of the pebble or lump of rock' [23, p. 40].

The Oldowan was not automatically accepted by all researchers as evidence of the earliest human culture in Africa. In 1919, Wayland had discovered another lithic industry, in the stone assemblages collected from the terraces of the Kafu River in Uganda. This culture, named Kafuan, consisted of fractured cobbles which were very archaic looking [27]. Although the characterization of the Kafuan and its sub-stages was based on dubious criteria such as the roundness or the elongation of pieces collected from river terraces with high-energy deposits [26], the fact remains that the term Kafuan became established in the archaeological literature of the 1930s–1950s (e.g. [28,29]). Indeed, Leakey [23] even commented that he would have preferred to consider the assemblages of the lower beds at Olduvai as Developed Kafuan, but did not do so because Wayland argued that the Olduvai collections were more advanced than the most developed Kafuan culture. Curiously, Leakey's renowned prescient skills failed for once when, referring to the Kafuan, he asserted that 'there is not really any justification for giving a separate culture name to the last stage of the 'pebble culture', and eventually the name 'Oldowan' will probably be dropped' [23, p. 40]. Eventually, it was the other way around, and by the end of the 1950s the Kafuan had almost disappeared from the literature; in a remarkably similar trajectory as the Eolith in Europe [9], cumulative evidence led to the conclusion that the alleged assemblages from the higher terraces of African rivers were mere natural rocks [30,31]. Tacitly, the Kafuan had ceased to exist.

Nonetheless, the Oldowan was not yet considered by all researchers as the earliest evidence of culture, and in the 1950s a new contender appeared. In the post-World War II scientific environment nearly all the academic community had accepted that the South African australopithecines were bipedal and somehow related to humans. In this context, it was suggested that australopithecine fossils were associated with cultural remains, the so-called osteodontokeratic industry [32]. Based on the Makapansgat assemblages, Dart proposed that australopithecines employed bones, teeth and horn in a variety of subsistence activities that included the killing and processing of animal carcasses.

Decades later, Brain [33] demonstrated that the australopithecines were the hunted rather than the hunters, whose remains had been accumulated alongside those of other animals by predators transporting carcasses to trees. Subsequently, the osteodontokeratic industry as defined by Dart [32] was largely discredited. Nevertheless, recent studies have provided new insights into the possible use of bone tools by South African australopithecines [34], which to some extent have revived credibility for Dart's original osteodontokeratic proposal.

3. OLDUVAI AS A SEQUENCE OF REFERENCE

With the settling of the Kafuan controversy [30,31] and the ruling out of stratigraphic relationships

between human fossils and lithic assemblages in the South African caves [35,36], by the end of the 1950s there seemed to be consensus on the absence of links between australopithecines and stone tools. However, the 1959 discovery of the *Zinjanthropus* (now *Paranthropus*) *boisei* skull, spatially associated with a large lithic assemblage, sparked new controversies; according to Louis Leakey, the fact that the FLK Zinj site was located in the lower part of the Olduvai sequence proved the connection between the Oldowan culture and *Zinjanthropus boisei*.

Leakey's purpose was anything but innocuous, and it resembles Dart's attempts to provide South African australopithecines with some human traits by granting them the capacity for making the Osteodontokeratic culture. Leakey's consideration of the *boisei* skull as a new genus found considerable opposition, as many believed *boisei* could fit better within the South African genus *Paranthropus* named by Broom [37]—see review by Wood & Constantino [38]. However, Leakey [39] alleged that *Zinjanthropus* was ancestral to modern humans, the 'proof' being that *boisei* was a tool-maker; once again, cultural traits were used to justify phylogenetic links. Using a type of tautological reasoning, Leakey argued that the South African *Paranthropus* and *Australopithecus* were not 'real humans', for they did not make artefacts, whereas *Zinjanthropus* knapped stone tools and, therefore, was a human ancestor.

Despite controversies, the Oldowan was becoming central in the debate about the earliest cultural evidence in Africa. In fact, stone tools had adopted a pivotal role in explanatory mechanisms of human evolution. For example, Washburn [40] assumed that the adoption of bipedalism was directly related to tool-use. Along similar lines, Robinson [41] linked tool-making, brain size increase and bipedalism, although he rejected the idea that australopithecines—among which he included *Australopithecus*, *Paranthropus* and *Zinjanthropus*—made stone tools. Interestingly, Robinson [35,41] distinguished between tool-use, which he accepted for australopithecines, and tool-making, exclusive to the genus *Homo*.

In this context, Olduvai (figure 1) soon produced a new controversy with the discovery of *Homo habilis* [20]. More gracile and morphologically similar to humans than *Zinjanthropus boisei*, the very definition of *Homo habilis*, 'handy man', entailed that this hominin was seen as the author of the Oldowan. In a U-turn of earlier arguments, *Zinjanthropus boisei* became the prey of *Homo habilis* rather than the maker of the Oldowan tools [20]. It should be kept in mind that the anatomical arguments used by Leakey *et al.* [20] to include *habilis* within the genus *Homo* were highly controversial (see [42]), so once again cultural traits were tautologically employed to help justify taxonomic classifications; in this new reading of the evidence, the fact that *habilis* made stone tools 'proved' that it belonged to the genus *Homo* [20].

The paradigm change caused by discoveries in Olduvai (table 1) was also prompted by the radically new chronological framework developed for early archaeological assemblages; at the onset of the

1960s, most of the 'pre-Acheulean' evidence available corresponded to surface artefacts collected in river terraces all across Africa, plus some sparse archaeological remains from the South African caves. On the basis of the Pluvial theory originally proposed by Wayland (e.g. [27]), it was thought that the oldest stone tools corresponded to the end of the so-called First Pluvial or beginning of the Second Pluvial, no earlier than half a million years ago. However, the K/Ar dating of Olduvai Bed I [19] revolutionized temporal scales of human evolution; now shown to be older than 1.7 Myr, FLK Zinj placed stone tool-making more than 1 Myr earlier than had previously been considered.

In sum, by the mid-1960s, research on the earliest human cultures in Africa had undergone dramatic changes; it was now understood that typological sequences established in fluvial terraces across the entire continent had no chronological reliability and were of no use in differentiating techno-cultural stages. Furthermore, the inability to link the fossil-rich caves of South Africa with reliable radiometric and archaeological contexts made it difficult to use those sequences as a comparative reference. In contrast, Olduvai in East Africa yielded fluvio-lacustrine deposits with *in situ* assemblages, associations between stone tools and human fossils, and a reliable radiometric sequence. Consequently, by the mid-1960s there was consensus that the earliest cultural evidence was at least 1.8 Myr old, corresponded to the Oldowan (a culture defined three decades earlier), and had probably been made by hominins like the *Homo habilis* discovered in Olduvai Bed I.

4. THE ESTABLISHMENT OF THE MODERN CHRONO-STRATIGRAPHIC FRAMEWORK

Success of fieldwork in Olduvai encouraged further research projects in East Africa, which in turn led to the discovery of new fossiliferous sequences throughout the Rift Valley. Two of the areas found during the late 1960s to early 1970s, Hadar and Koobi Fora (figure 1), became particularly significant. The controversy over the dating of the Kay Behrensmeyer Site (KBS) industry—the oldest stone tools at Koobi Fora—(see summary in Brown [43]), resembled earlier attempts to link taxonomic classifications and archaeological contexts. Given the similarities between the Olduvai Bed I assemblages and the KBS industry [44], the original date for the Koobi Fora assemblages of 2.6 Myr was claimed to demonstrate an early emergence of the genus *Homo* which, by default, was assumed to be responsible for the stone tools. However, cumulative radiometric [45] and biostratigraphic [46] evidence eventually proved the original dating of the KBS tuff to be wrong, and the Koobi Fora archaeological sites were firmly established at around 1.8 Myr, the same age as the Olduvai Bed I assemblages.

In the case of Hadar, the paramount palaeontological implications of *Australopithecus afarensis* [47] have sometimes overshadowed the pivotal role this discovery also had in changing views about the relationship between tool-making and human evolution. As mentioned above, during the 1960s many considered

that there was a close link between encephalization, adoption of bipedalism and emergence of stone tool-making [40,41,48]. However, the discovery of *Australopithecus afarensis*, a small-brained hominin dated to approximately 3.2 Myr, established a gap of almost 1.5 Myr between the oldest lithic assemblages in Olduvai and the earliest evidence of bipedalism in Hadar. Hence, *Australopithecus afarensis* proved that there was no cause-effect relationship between the emergence of bipedalism and stone tool-making; in a pendulum swing that revived pre-World War II paradigms [49], australopithecines were once again considered as little more than specialized apes. Therefore, it can be argued that, owing to the discoveries in Hadar and the ever-expanding chronological gap between the earliest hominins and the oldest stone tools, the 1970s and 1980s witnessed the separation of paradigms ruling human palaeontology and those related to the archaeology of human origins; cultural domains had ceased to be considered as a pivotal evolutionary mechanism driving the emergence of hominins.

Nonetheless, despite the increasing divergence between human palaeontology and archaeology, the Oldowan was firmly established as a term defining the earliest traces of human culture. The publication of excavations in Olduvai Beds I and II [16] provided a solid chrono-stratigraphic background and an unparalleled archaeological dataset, which became the empirical and methodological frame of reference for the rest of the Oldowan sequences in Africa [50]. By the 1970s, nearly all the scientific community agreed that the earliest evidence of culture was to be found in Africa, especially in the area of the Rift Valley. Continued fieldwork led to the discovery of even older assemblages than those in Olduvai and Koobi Fora; in Omo (figure 1), lithic assemblages were discovered in the Shungura Formation [17,18]. With a provisional age of 2.04 Myr—subsequently pushed back to 2.34 Myr [51]—the Omo sites provided some of the earliest evidence for stone tool-making. Also in the 1970s, early stone tools were reported in Gona/Hadar [15], for which a similar age to Omo was suggested. However, owing to the absence of precise radiometric and stratigraphic contexts for the Gona/Hadar material, Omo had the most reliable evidence for the earliest human culture during the 1970s and the 1980s.

Over the last two decades, there has been an exponential increase in evidence for early technologies; in the Gona area (figure 1), recent fieldwork dated *in situ* assemblages to 2.5–2.6 Myr [14], making them the earliest stone tools yet known. Slightly younger are other lithic assemblages recently discovered in Hadar [52] and West Turkana [13], positioned in the same age interval as the Omo archaeological sites, at approximately 2.3 Myr. In short, the current archaeological record includes a number of well-dated lithic assemblages, which confirm that by 2.5 Myr stone tools were regularly made by some hominins. Given that the oldest fossils of early *Homo* [52,53] are bracketed in the same age interval as the earliest stone tools, a common view has related the speciation event leading to the origins of *Homo* with the

emergence of stone tools, whereas australopithecines usually have been depicted as lacking stone tool-making abilities. The increasingly larger gap between the earliest hominins—now dated at 6–7 Myr [54]—and the approximately 2.5 Myr date of the earliest stone tools [14], has maintained the rejection of causal connections between early phases of hominin evolution and the emergence of stone tool-making. Nonetheless, there have been new attempts to link phylogenetic relationships with cultural evidence, such as in the case of *Australopithecus garhi* [55], for which an ancestral relation to *Homo* is proposed not only by chronological and anatomical similarities but also by its association with cut-marked bones [56].

The scenario is becoming increasingly complex; during the last two decades there has been agreement in positioning the earliest archaeological evidence at 2.5–2.6 Myr, and relating the appearance of stone tool-making to climatic changes, emergence of new hominin species and dietary shifts. Nonetheless, the recent discovery of cut-marked fossils in Dikika that could be older than 3.39 Myr [2], in a context where only *Australopithecus afarensis* may have existed, could force a reconsideration of some of the explanatory models traditionally proposed to explain the origins of stone tool-making.

5. CHANGING PERSPECTIVES ON THE OLDOWAN

All modern conceptions of the earliest stone tools are based on the Oldowan technology and the monumental work of Leakey [16] in Olduvai. Nevertheless, views of the Oldowan have changed over the last few decades, due not only to empirical evidence available at the time, but also influenced by shifting dominant theories [50]. The chronological, stratigraphic and archaeological framework established by Leakey [16] was fundamentally typological and deeply rooted in the historical–cultural approach developed in Europe by Bordes [50]. From this perspective, the Oldowan and its variants were characterized by variable percentages of lithic types such as choppers, polyhedrons, discoids, different retouched types and others [16]. Inter-assembly comparisons were based on tool-type frequencies, which were believed to have chrono-stratigraphic and cultural implications.

The advent of processualism in archaeology greatly influenced Oldowan studies (e.g. [57], N. Toth 1982, unpublished PhD thesis). This approach focused on function rather than typology of stone tools. Following a remarkably similar pattern as occurred in Middle Palaeolithic research [58], Oldowan morphological variability was considered to be the result of artefact reduction intensity, not the product of culturally designed shapes [57,59]. In this perspective, the basic objective of Oldowan technology was the production of flakes (which in previous typological studies were considered as mere by-products), whereas core forms would vary according to cost–benefit strategies of raw material transport and use.

In recent years, integrative perspectives have been pursued and modern technological studies aim to combine processual views with the *chaîne*

*opératoire*¹ approach [5,50]. The importance of the study of reduction methods in the Oldowan is increasingly recognized and discussion of the technical abilities of early knappers is a key issue in Oldowan research. However, views on this topic have also changed through time, heavily influenced by their historical context.

Until the mid-1990s, it can be argued that the trend was to emphasize the archaism of earliest industries. Chavaillon [17], for example, coined the term ‘Shungura facies’ to describe the Omo assemblages, which, being considerably older than those at Olduvai and Koobi Fora, were thought to be also technologically more archaic. In a similar vein, Roche [61] proposed that assemblages older than 2 Myr were made by hominins who did not control the basics of stone tool knapping and displayed poor technological skills. At that time, the term ‘Pre-Oldowan’ was frequently used to refer to assemblages older than those from Koobi Fora and Olduvai. Thus, it was proposed that assemblages earlier than 2 Myr were characterized by low density accumulations and poor management of lithic resources [62]. The term ‘Nachukui industry’ was coined for the West Turkana assemblages which, alongside the Shungura Facies [17], would constitute the Omo Industrial Complex [62]. In this context, the simplicity of early lithic technologies was emphasized, and it was proposed that the Oldowan as a whole showed the same level of skills as displayed by extant apes [63].

It is likely that the very limited evidence available in the 1970s and 1980s, alongside the unimpressive lithics of Omo and the reported simplicity of Lokalalei 1 in West Turkana, contributed to shape an ‘ape’s view’ of the earliest industries. It could be argued, however, that such a perspective was also yet another expression of the dominant paradigm in Palaeolithic archaeology that, led by Binford [64,65], emphasized the behavioural archaism of pre-modern humans. In response to this view, the last two decades have witnessed a steady paradigmatic change, through which the behavioural sophistication of pre-*sapiens* humans has become increasingly acknowledged [66]. New archaeological evidence in Middle and Lower Palaeolithic research has undoubtedly contributed to this changing view of previous interpretations, but it is also likely that the same record is now being considered from a different perspective.

Oldowan research exemplifies this theoretical shift, in which the discovery breakthroughs at Gona [14] and Lokalalei 2C [13] have been pivotal in shaping modern views about early technologies. The 2.6–2.5 Myr Gona assemblages [14] demonstrate that early knappers understood and controlled the principles of conchoidal fracture, i.e. they knew that certain rocks can be broken according to the direction and intensity of the force transmitted. Gona knappers applied this knowledge to successfully obtain series of flakes from cores exploited through a panoply of methods [67] on rocks that were preferentially selected from raw material sources [68]. This required complex grip coordination and developed perceptual abilities [69], probably beyond the range of skills displayed by extant apes [4,6]. Along the same lines, the

approximately 2.3 Myr site of Lokalalei 2C in West Turkana [13] has provided stunning evidence regarding the skills of early knappers; as at Gona, cobbles were preferentially selected from raw material sources and transported to the site [70]. Some of the conjoined sets account for more than 50 flakes [71], demonstrating that stone toolmakers were capable of systematically reducing cores. The Lokalalei 2C assemblage indicates knappers' ability to adapt to technical problems arising during the reduction sequence, displaying not only sophisticated know-how, but also considerable motor skills [71].

Preliminary data from pene-contemporary sites in Hadar [72] and reassessment of some of the Omo assemblages [73] also suggest that by 2.3 Myr hominins had already mastered the principles ruling stone knapping. Therefore, recent research on early technologies tends to emphasize the complexity of the first lithic assemblages, contradicting previous views on the alleged simplicity of the early Oldowan. Nonetheless, this new scenario prompts further questions on the evolutionary significance of the origins of stone tool-making, especially with regard to two issues: the processes that led to the emergence of stone knapping, and the evolutionary relationships between the earliest industries and the post-2 Myr Oldowan assemblages.

With respect to the evolutionary processes resulting in the emergence of the earliest archaeological sites, there was some perplexity when Gona showed that the first stone tools already demonstrated correct understanding of knapping principles [14,74]. A gradualist evolutionary perspective expected that the earliest archaeological assemblages would represent poor attempts to obtain stone tools. However, the evidence from Gona and then Lokalalei 2C has provoked a reconsideration of this view; some now suggest that the emergence of stone tool production could have been an abrupt event slightly earlier than 2.6 Myr [74], whereas others have proposed the existence of an older than 2.5 Myr pre-archaeological phase, during which hominins experimented with stone tool manufacture [75]. According to the latter view, if in the period before 2.5 Myr knappers did not accumulate lithics at particular spots in the landscape, such behavioural patterns would not lead to the formation of sites, and therefore the earliest stone tools would be archaeologically invisible [59]. Interestingly, in the current paradigmatic cycle where alternative evolutionary mechanisms such as punctuated equilibrium and saltation have also become influential in archaeology (e.g. [66]), the 'pre-Gona' experimental stone tool-making hypothesis is still preferred by many, despite this theory of gradualist acquisition of technology advocating a pre-archaeological stage which is, by its own definition, empirically non-testable. In this context, studies combining primatological and archaeological evidence in order to trace the evolutionary origins of technology have proliferated [76,77], although the limits of such comparisons have also been stated [4,6].

Modern hypotheses will also have to accommodate the new evidence from Dikika; according to the discoverers [2], cut-marks on the pre-3.39 Myr bones

could have been inflicted by naturally sharp-edged stone tools and not necessarily by intentionally knapped flakes. From this perspective, the 2.6 Myr sites at Gona remain the earliest documented evidence of intentional flaking. Nonetheless, now discoverers of the Dikika fossils claim that hominins were using sharp-edged tools 800 000 years earlier than at Gona. If confirmed, this proposal would provide new evidence to support the existence of a long process of experimentation with stone tool-making and/or use before hominins had mastered the principles of knapping by 2.6 Myr. Furthermore, it suggests that different hominin species could have been involved in that process.

Lastly, present evidence about the earliest Oldowan also prompts discussions on technological and cultural links between the earliest industries and the post-2 Myr Oldowan assemblages. There is now debate on the validity of considering the Oldowan as a single techno-complex during the approximately 1 Myr span from Gona to the emergence of the Acheulean around 1.7–1.6 Ma. With the demonstration of the technological sophistication of the earliest industries [13,14], some authors prefer to include all the pre-Acheulean evidence within the Oldowan [74], whereas others propose a chronological meaning for the term 'Pre-Oldowan', reserved for sites older than 2 Myr [78]. Technological variability of the earliest sites has been the subject of recent debates [67,73], but a systematic comparison with post-2 Myr Oldowan assemblages remains to be undertaken. Nonetheless, whereas two decades ago it was common to associate earlier sites with a more archaic technology, at present one could be tempted to do the reverse; Gona [67] and Lokalalei 2C [71] show more intense reduction sequences and more precise knapping skills than, for example, the classic Oldowan sequences at Olduvai Bed I [16,79], which is more than 500 000 years younger. Accordingly, it is difficult to trace temporal trends within the Oldowan, and even more complicated to propose evolutionary progression.

This paper assumes that a techno-complex is a group of cultures that share similar general traits but different specific types according to variable ecological and cultural features [80]. From this perspective and considering the current available evidence, it can be argued that the Oldowan techno-complex, based on the production of flakes through a variety of non-prepared methods of core reduction, shows significant inter-assemblage variability, conditioned by ecological, temporal and cultural parameters, and which most probably involved several species of hominins. Perhaps due to the unspecific traits defining the Oldowan as a technology, the mechanisms which lead to the emergence 1.7–1.6 Ma of a new techno-complex, the Acheulean, are still unclear.

6. A CURRENT VIEW OF THE EARLIEST STONE TOOL-MAKING

Current evidence could place the earliest use of stone tools in the Pliocene, at before 3.39 Ma [2]. This suggests that stone tool use has deep roots in our evolutionary lineage [75,77], and could have played an instrumental role during some stages of human

evolution. The oldest lithic assemblages discovered so far are substantially younger, with the earliest evidence at Gona dated at 2.6 Myr [1]. The Gona stone tools are followed by approximately 2.3 Myr lithic assemblages in West Turkana [78], Omo [17,18] and Hadar [52]. Close to 2 Myr Oldowan assemblages are also documented in Kanjera [81], Koobi Fora [82] and Fejej [83], followed by the classic sequences at Olduvai [16], Koobi Fora [84] and others.

The earliest evidence of stone tool use and/or making seem to show spatial and chronological patterning; geographically (figure 1), the oldest archaeological traces are limited to the northern part of the East African Rift Valley, with Bouri, Gona and arguably Dikika yielding evidence of tool use before 2.4 Myr. By approximately 2.3 Myr, tool-making is also evidenced in the Lake Turkana basin (Omo, West Turkana), and by 2 Ma it had extended further to the south in the Lake Victoria region (e.g. Kanjera). The post-2 Myr Oldowan spread across the Rift Valley, eventually reaching South [85] and North Africa [86], and beyond [87].

All the earliest assemblages seem to share a number of features; Gona [14,67], Hadar [72], Lokalalei 2C [71], Kanjera [81] and some of the Omo sites [73] indicate that early knappers controlled the mechanisms of conchoidal fracture and the basic principles of stone knapping. With regard to assemblage composition, all these sites show similar percentages in which cores and flakes predominate, standardized forms are absent and retouched tools are not abundant. Recurrent reduction of the same exploitation surfaces of cores is well attested, although there is substantial inter-assemblage variation regarding the use of unifacial, bifacial and multi-facial methods. Core striking platforms are usually unprepared and rejuvenation products aimed to reactive flaking, although sometimes documented (e.g. Lokalalei 2C), are not abundant; once knapping surfaces lose the necessary convexities, cores are discarded. Raw material selectivity has been reported in most of the early sites [68,70,81,88], and it is likely that raw material factors played a major role in the length of reduction sequences; the quality, large size and abundance of cobbles in areas such as Gona [68], West Turkana [70] and Hadar [88] could have facilitated long sequences of core exploitation, whereas the smaller size of raw materials available in Omo [73] and Kanjera [81] conditioned the number of flaking series. In short, the earliest assemblages show a well-reasoned technological process which began with the preferential selection of suitable raw materials, continued with an understanding of the volumetric concepts required to exploit such raw materials and a successful application of that know-how in the reduction of cores, followed by an optimal production of flakes.

7. CONCLUSION

At present, and coinciding with the first centenary of the scientific discovery of Olduvai Gorge by Kattwinkel in 1911, there is a considerable wealth of empirical data on the Oldowan and the origins of

stone tool technology in Africa. There is also enough temporal distance to consider advances of the discipline from a historical perspective. This paper has attempted to integrate both aspects, placing the current view of the Oldowan on historiographic grounds. Here, it has been argued that an early phase of research covered investigations until the late 1950s, which were characterized by poor stratigraphic control of assemblages and the absence of absolute dates for the early stone tools [11,23,27,29]. The cascade of findings [19–21] in Olduvai Gorge since 1959 provided the Oldowan with a well-established stratigraphic sequence that pushed back stone tool-making to approximately 2 Myr, and sparked further discoveries in Africa, especially in the Rift Valley. Whereas in the 1960s it was common to associate hominin origins with stone tool-making [40,41], the modern research period that began in the 1970s demonstrated that the first stages of hominization underwent an independent process that started much earlier than the Oldowan. During the 1970s and 1980s, the limited empirical evidence and the influence of the ‘Binfordian’ paradigm [64,65] led to the portrayal of the Oldowan as a very simple and archaic technology, not too different from that displayed by extant apes [63]. Nevertheless, in the last 20 years this perspective has changed, owing in part to new discoveries [13,14], but also influenced by a new theoretical environment which emphasizes the complexity of early human behaviour (see a summary in Whiten *et al.* [89]).

Today, earliest Oldowan assemblages are seen as indicative of the sophistication of the technology of early knappers. However, it is important to stress that this interpretation is rooted in contemporary paradigms and biased by the record currently available. The aim of this paper has been to emphasize how variable perspectives are, especially when considered in their historical context. When Louis Leakey first reported the existence of an early industry in Olduvai, the conception of early technologies was very different from that of the present day. But there is no need to go back to 1931; only 1 year ago, the earliest evidence of stone tool use was 2.6 Myr. Now, this has been pushed back to 800 000 years earlier. As such, there is little doubt that new surprises await us in our future search for the earliest stone tools.

I wish to thank Norah Moloney, Chris Stringer, Andrew Whiten and two anonymous reviewers for their comments on earlier drafts of this paper.

ENDNOTE

¹See description of *chaîne opératoire* in the glossary to Goren-Inbar [60] in this issue.

REFERENCES

- 1 Semaw, S. *et al.* 2003 2.6-Million-year-old stone tools and associated bones from OGS-6 and OGS-7, Gona, Afar, Ethiopia. *J. Hum. Evol.* **45**, 169–177. (doi:10.1016/S0047-2484(03)00093-9)
- 2 McPherron, S. P., Alemseged, Z., Marean, C. W., Wynn, J. G., Reed, D., Geraads, D., Bobe, R. & Béarat, H. A. 2010 Evidence for stone-tool-assisted consumption of

- animal tissues before 3.39 million years ago at Dikika, Ethiopia. *Nature* **466**, 857–860. (doi:10.1038/nature09248)
- 3 Schick, K. & Toth, N. 2006 An Overview of the Oldowan industrial complex: the sites and the nature of their evidence. In *The Oldowan: case studies into the earliest Stone Age* (eds N. Toth & K. Schick), pp. 3–42. Gosport, IN: Stone Age Institute.
 - 4 Toth, N. & Schick, K. 2009 The Oldowan: the tool making of early hominins and chimpanzees compared. *Annu. Rev. Anthropol.* **38**, 289–305. (doi:10.1146/annurev-anthro-091908-164521)
 - 5 Hovers, E. & Braun, D. R. (eds) 2009 *Interdisciplinary approaches to the Oldowan*. Dordrecht, The Netherlands: Springer.
 - 6 Torre, I. de la 2010 Insights on the technical competence of the early Oldowan. In *Stone tools and the evolution of human cognition* (eds A. Nowell & I. Davidson), pp. 45–65. Boulder, CO: University Press of Colorado.
 - 7 Grayson, D. K. 1983 *The establishment of human antiquity*. New York, NY: Academic Press.
 - 8 Boule, M. 1905 L'origine des éolithes. *L'Anthropologie* **16**, 257–267.
 - 9 Grayson, D. K. 1986 Eoliths, archaeological ambiguity, and the generation of 'middle-range' research. In *American archaeology past and future: a celebration of the Society for American Archaeology 1935–1985* (eds D. J. Meltzer, D. D. Fowler & J. A. Sabloff), pp. 77–133. Washington, DC: Smithsonian Institution Press.
 - 10 McNabb, J. 2006 The lying stones of Sussex: an investigation into the role of the flint tools in the development of the Piltdown forgery. *Archaeol. J.* **163**, 1–41.
 - 11 Goodwin, A. J. H. & Van Riet Lowe, C. 1929 *The Stone Age cultures of South Africa*. Edinburgh: Annals of the South African Museum, n° XXVII.
 - 12 Leakey, L. S. B., Hopwood, A. T. & Reck, H. 1931 New yields from the Oldoway bone beds, Tanganyika territory. *Nature* **128**, 1075. (doi:10.1038/1281075a0)
 - 13 Roche, H., Delagnes, A., Brugal, J.-P., Feibel, C., Kibunjia, M., Mourre, V. & Texier, J. 1999 Early hominid stone tool production and technical skill 2.34 Myr ago in West Turkana, Kenya. *Nature* **399**, 57–60. (doi:10.1038/19959)
 - 14 Semaw, S., Renne, P., Harris, J. W. K., Feibel, C. S., Bernor, R. L., Fesseha, N. & Mowbray, K. 1997 2.5-million-year-old stone tool from Gona, Ethiopia. *Nature* **385**, 333–336. (doi:10.1038/385333a0)
 - 15 Corvinus, G. K. 1976 Prehistoric exploration at Hadar, Ethiopia. *Nature* **261**, 571–572. (doi:10.1038/261571a0)
 - 16 Leakey, M. D. 1971 *Olduvai Gorge: volume 3, excavations in Beds I and II, 1960–1963*. Cambridge, UK: Cambridge University Press.
 - 17 Chavaillon, J. 1976 Evidence for the technical practices of early Pleistocene Hominids, Shungura Formation, Lower Omo Valley, Ethiopia. In *Earliest man and environments in the Lake Rudolf Basin* (eds Y. Coppens, F. C. Howell, G. L. Isaac & R. E. F. Leakey), pp. 565–573. Chicago, IL: University of Chicago Press.
 - 18 Merrick, H. V., de Heinzelin, J., Haesaerts, P. & Howell, F. C. 1973 Archaeological occurrences of early Pleistocene Age from the Shungura Formation, Lower Omo Valley, Ethiopia. *Nature* **242**, 572–575. (doi:10.1038/242572a0)
 - 19 Leakey, L. S. B., Evernden, J. F. & Curtis, G. H. 1961 The age of Bed I, Olduvai Gorge, Tanganyika. *Nature* **191**, 478–479. (doi:10.1038/191478a0)
 - 20 Leakey, L. S. B., Tobias, P. V. & Napier, J. R. 1964 A new species of the genus *Homo* from Olduvai Gorge. *Nature* **202**, 5–7. (doi:10.1038/202005a0)
 - 21 Leakey, L. S. B. 1959 A new fossil skull from Olduvai. *Nature* **184**, 491–493. (doi:10.1038/184491a0)
 - 22 Leakey, L. S. B. 1934 The sequence of Stone Age cultures in east Africa. In *Essays presented to CG Seligman* (eds E. E. Evans-Pritchard, R. Firth, B. Malinowski & I. Schapera), pp. 143–146. London, UK: Kegan Paul, Trench, Trubner & Co. Limited.
 - 23 Leakey, L. S. B. 1936 *Stone Age Africa. An outline of prehistory in Africa*. London, UK: Oxford University Press.
 - 24 Reck, H. 1914 Erste Vorläufige Mitteilung über den Fund eines fossilen Menschen skelets aus Zentral-afrika. *Sitzungsberichte der Gesellschaft naturforschender Freunde* **3**, 81–95.
 - 25 Woodward, A. S. *et al.* 1933 Early humans remains in east Africa. *MAN* **33**, 65–68.
 - 26 O'Brien, T. P. 1939 *The prehistory of the Uganda protectorate*. Cambridge, UK: Cambridge University Press.
 - 27 Wayland, E. J. 1937 The Stone Age cultures of Uganda. *MAN* **67**, 55–56.
 - 28 Van Riet Lowe, C. 1953 The Kafuan culture in South Africa. *S. Afr. Archaeol. Bull.* **8**, 27–31. (doi:10.2307/3887461)
 - 29 Brain, C. K., Van Riet Lowe, C. & Dart, R. A. 1955 Kafuan Stone Artefacts in the post-Australopithecine breccia at Makapansgat. *Nature* **175**, 16–18. (doi:10.1038/175262b0)
 - 30 Clark, J. D. 1958 The natural fracture of pebbles from the Bakota Gorge, Northern Rhodesia, and its bearing on the Kafuan Industries of Africa. *Proc. Prehistoric Soc.* **24**, 64–77.
 - 31 Bishop, W. W. 1959 Kafu stratigraphy and Kafuan artifacts. *S. Afr. J. Sci.* **55**, 117–121.
 - 32 Dart, R. A. 1957 The Makapansgat Australopithecine Osteodontokeratic culture. In *Third Pan-African congress on prehistory, Livingstone 1955* (ed. J. D. Clark), pp. 161–171. London, UK: Chatto & Windus.
 - 33 Brain, C. K. 1981 *The Hunters or the hunted? An introduction to African cave taphonomy*. Chicago, IL: The University of Chicago Press.
 - 34 d'Errico, F. & Backwell, L. R. 2003 Possible evidence of bone tool shaping by Swartkrans early hominids. *J. Archaeol. Sci.* **30**, 1559–1576. (doi:10.1016/S0305-4403(03)00052-9)
 - 35 Robinson, J. T. 1961 The australopithecines and their bearing on the origin of man and of stone tool-making. *S. Afr. J. Sci.* **57**, 3–13.
 - 36 Mason, R. J. 1961 Australopithecus and the beginning of the Stone Age in South Africa. *S. Afr. Archaeol. Bull.* **16**, 8–14. (doi:10.2307/3887412)
 - 37 Broom, R. 1938 The pleistocene anthropoid apes of South Africa. *Nature* **142**, 377–379. (doi:10.1038/142377a0)
 - 38 Wood, B. & Constantino, P. 2007 *Paranthropus boisei*: fifty years of evidence and analysis. *Yearbook Phys. Anthropol.* **50**, 106–132. (doi:10.1002/ajpa.20732)
 - 39 Leakey, L. S. B. 1961 Africa's contribution to the evolution of man. *S. Afr. Archaeol. Bull.* **16**, 3–7. (doi:10.2307/3887411)
 - 40 Washburn, S. L. 1960 Tools and human evolution. *Sci. Am.* **203**, 63–75. (doi:10.1038/scientificamerican0960-62)
 - 41 Robinson, J. T. 1964 Adaptive radiation in the Australopithecines and the origin of man. In *African ecology and human evolution* (eds F. C. Howell & F. Bourlière), pp. 385–416. London, UK: Methuen & Co. Limited.
 - 42 Wood, B. & Collard, M. 1999 The changing face of genus *Homo*. *Evol. Anthropol.* **8**, 195–207. (doi:10.1002/(SICI)1520-6505(1999)8:6<195::AID-EVAN1>3.0.CO;2-2)
 - 43 Brown, F. H. 1994 Development of Pliocene and Pleistocene chronology of the Turkana basin, east Africa, and its relation to other sites. In *Integrative paths to the past paleoanthropological advances in honor of F Clark Howell* (eds R. S. Corruccini & R. L. Ciochon), pp. 285–312. New Jersey, NJ: Prentice Hall.

- 44 Leakey, M. D. 1970 Early artifacts from the Koobi Fora area. *Nature* **226**, 228–230. (doi:10.1038/226228a0)
- 45 McDougall, I., Maier, R., Sutherland-Hawkes, P. & Gleadow, A. J. W. 1980 K/Ar age estimate for the KBS tuff, east Turkana, Kenya. *Nature* **284**, 230–234. (doi:10.1038/284230a0)
- 46 Howell, F. C. 1972 Pliocene/Pleistocene *Hominidae* in Eastern Africa: absolute and relative ages. In *Calibration of hominoid evolution recent advances in isotopic and other dating methods as applicable to the origin of man* (eds W. W. Bishop & J. A. Miller), pp. 331–368. Edinburgh, TX: Scottish Academic Press.
- 47 Johanson, D., White, T. D. & Coppens, Y. 1978 A new species of the genus *Australopithecus* (primates: hominidae) from the Pliocene of Eastern Africa. *Kirtlandia* **28**, 1–14.
- 48 Le Gros Clark, W. 1967 *Man-apes or ape-men? The story of discoveries in Africa*. New York, NY: Holdt, Rinehart and Winston, Inc.
- 49 Cartmill, M., Pilbeam, D. & Isaac, G. L. 1986 One hundred years of paleoanthropology. *Am. Sci.* **74**, 410–420.
- 50 Torre, I. de la & Mora, R. 2009 Remarks on the current theoretical and methodological approaches to the study of early technological strategies in Eastern Africa. In *Interdisciplinary approaches to the Oldowan* (eds E. Hovers & D. R. Braun), pp. 15–24. Dordrecht, The Netherlands: Springer.
- 51 Howell, F. C., Haesaerts, P. & de Heinzelin, J. 1987 Depositional environments, archeological occurrences and hominids from members E and F of the Shungura Formation (Omo basin, Ethiopia). *J. Hum. Evol.* **16**, 665–700. (doi:10.1016/0047-2484(87)90019-4)
- 52 Kimbel, W. H. *et al.* 1996 Late Pliocene *Homo* and Oldowan tools from the Hadar formation (Kada Hadar member), Ethiopia. *J. Hum. Evol.* **31**, 549–561. (doi:10.1006/jhev.1996.0079)
- 53 Schrenk, F., Bromage, T. G., Betzler, C. G., Ring, U. & Juwayeyi, Y. M. 1993 Oldest *Homo* and Pliocene biogeography of the Malawi Rift. *Nature* **365**, 833–836. (doi:10.1038/365833a0)
- 54 Brunet, M. *et al.* 2002 A new hominid from the Upper Miocene of Chad, Central Africa. *Nature* **418**, 145–151. (doi:10.1038/nature00879)
- 55 Asfaw, B., White, T., Lovejoy, O., Latimer, B., Simpson, S. & Suwa, G. 1999 *Australopithecus garhi*: a new species of early hominid from Ethiopia. *Science* **284**, 629–635. (doi:10.1126/science.284.5414.629)
- 56 Heinzelin, J. d., Clark, J. D., White, T., Hart, W., Renne, P., WoldeGabriel, G., Beyene, Y. & Vrba, E. 1999 Environment and behavior of 2.5-million-year-old Bouri hominids. *Science* **284**, 625–629. (doi:10.1126/science.284.5414.625)
- 57 Isaac, G. L. 1986 Foundation stones: early artifacts as indicators of activities and abilities. In *Stone Age prehistory: studies in memory of Charles McBurney* (eds G. N. Bailey & P. Callow), pp. 221–241. Cambridge, UK: Cambridge University Press.
- 58 Dibble, H. L. 1987 The interpretation of Middle Paleolithic scraper morphology. *Am. Antiquity* **52**, 109–117. (doi:10.2307/281062)
- 59 Potts, R. 1991 Why the Oldowan? Plio-pleistocene tool-making and the transport of resources. *J. Anthropol. Res.* **47**, 153–176.
- 60 Goren-Inbar, N. 2011 Culture and cognition in the Acheulian industry: a case study from Gesher Benot Ya'akov. *Phil. Trans. R. Soc. B* **366**, 1038–1049. (doi:10.1098/rstb.2010.0365)
- 61 Roche, H. 1989 Technological evolution in Early hominids. *Ossa* **14**, 97–98.
- 62 Kibunjia, M. 1994 Pliocene archaeological occurrences in the Lake Turkana Basin, Kenya. *J. Hum. Evol.* **27**, 157–171. (doi:10.1006/jhev.1994.1040)
- 63 Wynn, T. & McGrew, W. C. 1989 An ape's view of the Oldowan. *MAN New Ser.* **24**, 383–398.
- 64 Binford, L. R. 1981 *Bones: ancient men and modern myths*. New York, NY: Academic Press.
- 65 Binford, L. R. 1985 Human ancestors: changing views of their behavior. *J. Anthropol. Archaeol.* **4**, 292–327. (doi:10.1016/0278-4165(85)90009-1)
- 66 d'Errico, F. & Stringer, C. B. 2011 Evolution, revolution or saltation scenario for the emergence of modern cultures? *Phil. Trans. R. Soc. B* **366**, 1060–1069. (doi:10.1098/rstb.2010.0340)
- 67 Stout, D., Semaw, S., Rogers, M. J. & Cauche, D. 2010 Technological variation in the earliest Oldowan from Gona, Afar, Ethiopia. *J. Hum. Evol.* **58**, 474–491. (doi:10.1016/j.jhev.2010.02.005)
- 68 Stout, D., Quade, J., Semaw, S., Rogers, M. J. & Levin, N. E. 2005 Raw material selectivity of the earliest stone tool-makers at Gona, Afar, Ethiopia. *J. Hum. Evol.* **48**, 365–380. (doi:10.1016/j.jhev.2004.10.006)
- 69 Stout, D. 2011 Stone toolmaking and the evolution of human culture and cognition. *Phil. Trans. R. Soc. B* **366**, 1050–1059. (doi:10.1098/rstb.2010.0369)
- 70 Harmand, S. 2009 Variability in raw material selectivity at the late Pliocene sites of Lokalalei, West Turkana, Kenya. In *Interdisciplinary approaches to the Oldowan* (eds E. Hovers & D. R. Braun), pp. 85–97. Dordrecht, The Netherlands: Springer.
- 71 Delagnes, A. & Roche, H. 2005 Late Pliocene hominid knapping skills: the case of Lokalalei 2C, West Turkana, Kenya. *J. Hum. Evol.* **48**, 435–472. (doi:10.1016/j.jhev.2004.12.005)
- 72 Hovers, E. 2001 Stone knapping in the Late Pliocene in Hadar, Ethiopia. In *Knapping stone. A uniquely hominid behaviour? International workshop*, 21–24 November. Pont-à-Mousson, Abstracts, pp. 11–12.
- 73 Torre, I. de la 2004 Omo revisited: evaluating the technological skills of Pliocene hominids. *Curr. Anthropol.* **45**, 439–465. (doi:10.1086/422079)
- 74 Rogers, M. J. & Semaw, S. 2009 From nothing to something: the appearance and context of the earliest archaeological record. In *Sourcebook of paleolithic transitions methods, theories, and interpretations* (eds M. Camps & P. Chauhan), pp. 155–171. New York, NY: Springer.
- 75 Panger, M. A., Brooks, A. S., Richmond, B. G. & Wood, B. 2002 Older than the Oldowan? Rethinking the emergence of hominin tool use. *Evol. Anthropol.* **11**, 235–245. (doi:10.1002/evan.10094)
- 76 Whiten, A., Schick, K. & Toth, N. 2009 The evolution and cultural transmission of percussive technology: integrating evidence from palaeoanthropology and primatology. *J. Hum. Evol.* **57**, 420–435. (doi:10.1016/j.jhev.2008.12.010)
- 77 Haslam, M. *et al.* 2009 Primate archaeology. *Nature* **460**, 339–344. (doi:10.1038/nature08188)
- 78 Roche, H., Brugal, J.-P., Delagnes, A., Feibel, C., Harmand, S., Kibunjia, M., Prat, S. & Texier, J. 2003 Les sites archéologiques plio-pléistocènes de la formation de Nachukui, Ouest-Turkana, Kenya: bilan synthétique 1997–2001. *Comptes Rendus Palevol.* **2**, 663–673. (doi:10.1016/j.crpv.2003.06.001)
- 79 Torre, I. de la & Mora, R. 2005 *Technological strategies in the lower Pleistocene at Olduvai Beds I & II*. Liege: ERAUL 112.
- 80 Clarke, D. L. 1968 *Analytical archaeology*. London, UK: Methuen.
- 81 Braun, D. R., Plummer, T., Ditchfield, P., Bishop, L. C. & Ferraro, J. V. 2009 Oldowan technology and raw material variability at Kanjera South. In *Interdisciplinary approaches to*

- the Oldowan* (eds E. Hovers & D. R. Braun), pp. 99–110. Dordrecht, The Netherlands: Springer.
- 82 Braun, D. R., Harris, J. W. K., Levin, N. E., McCoy, J. T., Herries, A. I. R., Bamford, M. K., Bishop, L. C., Richmond, B. G. & Kibunjia, M. 2010 Early hominin diet included diverse terrestrial and aquatic animals 1.95 Ma in East Turkana, Kenya. *Proc. Natl Acad. Sci. USA* **107**, 10 002–10 007. (doi:10.1073/pnas.1002181107)
 - 83 de Lumley, H. & Beyene, Y. (dirs) 2004 *Les sites préhistoriques de la région de Fejej, Sud-Omo, Ethiopie, dans leur contexte stratigraphique et paléontologique*. Paris: Editions Recherches sur les Civilisations (dirs).
 - 84 Isaac, G. L. & Isaac, B. (eds) 1997 *Koobi Fora research project, volume 5: Plio-Pleistocene archaeology*. Oxford, UK: Oxford University Press.
 - 85 Kuman, K. & Field, A. S. 2009 The Oldowan industry from Sterkfontein caves, South Africa. In *The cutting edge: new approaches to the archaeology of human origins* (eds K. Schick & N. Toth), pp. 151–169. Bloomington: Stone Age Institute Press.
 - 86 Sahnouni, M. 1998 *The lower Paleolithic of the Maghreb: excavations and analyses at Ain Hanech, Algeria*. Oxford, UK: BAR International Series 689.
 - 87 Gabunia, L., Antón, S. C., Lordkipanidze, D., Vekua, A., Justus, A. & Swisher III, C. C. 2001 Dmanisi and dispersal. *Evol. Anthropol.* **10**, 158–170. (doi:10.1002/evan.1030)
 - 88 Goldman-Neuman, T. & Hovers, E. 2009 Methodological considerations in the study of Oldowan raw material selectivity: insights from A.L. 894 (Hadar, Ethiopia). In *Interdisciplinary approaches to the Oldowan* (eds E. Hovers & D. R. Braun), pp. 71–84. Dordrecht, The Netherlands: Springer.
 - 89 Whiten, A., Hinde, R. A., Laland, K. N. & Stringer, C. B. 2011 Culture evolves. *Phil. Trans. R. Soc. B* **366**, 938–948. (doi:10.1098/rstb.2010.0372)