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New methodological and technological approaches to the Oldowan and Acheulian archaeology of Olduvai Gorge (Tanzania) – introduction

MANUEL DOMÍNGUEZ-RODRIGO, ENRIQUE BAQUEDANO, AUDAX MABULLA, FERNANDO DIEZ-MARTÍN, CHARLES EGELAND AND MANUEL SANTONJA

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For many years, Olduvai Gorge was home to Africa's oldest flake-and-core (i.e. 'Oldowan') and Acheulian industries. Largely for this reason, the Gorge's numerous archaeological localities have played a critical historical role in the definition of these lithic technologies (Kleindienst 1962, 1973; L. Leakey 1936, 1951; M. D. Leakey 1971). While subsequent research has uncovered earlier examples of both Oldowan and Acheulian artefacts throughout Africa, Olduvai continues to yield significant insight into the lives and minds of early human ancestors, including numerous anthropogenic Oldowan faunas (this volume; Domínguez-Rodrigo *et al.* 2017), one of the oldest Acheulian records, containing the oldest, most symmetrical handaxe found to date (Diez-Martín *et al.* 2015), and early evidence for megafaunal exploitation (Domínguez-Rodrigo *et al.* 2014a, b; Organista *et al.* 2015). For these reasons, Olduvai's Oldowan and Acheulian archaeological records keep providing exceptional windows into the lives and minds of early human ancestors.

The number, extent and spatial resolution of the excavations in Beds I and II at Olduvai now enable detailed questions to be asked about site formation and hominin behaviour from both inter- and intra-site perspectives. Although some have argued that Olduvai Bed I and II sites were heavily impacted by fluvial postdepositional processes (e.g., de la Torre *et al.* 2017), such claims are geoarchaeologically naive and taphonomically unsupported.This volume highlights the use of new analytical approaches to the documentation of the creation and use of Oldowan and Acheulean stone tools and the spatial distribution of archaeological materials. The use of these methods emphasizes and provides insights into the complexities of Oldowan and Acheulian cultures. Ultimately, the papers in this volume reveal novel interpretations of the behaviours of Oldowan and Acheulian hominins living within the Olduvai Basin during Bed I and II times.

Previous work by The Olduvai Paleoanthropology and Paleoecology Project (TOPPP) emphasized the palaeoecological context of the most well-known Bed I and Bed II sites (special volumes of Quaternary Research (2010) and Quaternary International (2014)). The present volume works within this palaeoecological framework to focus on site-specific patterns of hominin behaviour. In doing so, the papers analyse the functional association of stone tools and fossil bones, the variability and technological complexities of the lithic assemblages, and provide a comparative framework to understand the differences and similarities identified in the Oldowan and Acheulian records. Before we fully synthesize the importance of these studies, it is important to stress that what is understood as 'Oldowan' (more specifically, the 'Developed Oldowan' as applied to the Bed II archaeological record) and 'Acheulian' is a contested ground. We, thus, offer a critical review both of how these industrial complexes are currently defined and how they differ from each other typologically (the prime focus of most comparative analyses) and beyond.

What's in the name? The Developed Oldowan-Acheulian dichotomy

M. D. Leakey (1971) observed that the transition from Bed I to Bed II times saw changes both in the frequencies of various tool types and, critically, the appearance of bifacial tools. For this reason, she identified a dual 'tradition' during Bed II composed of Developed Oldowan and Acheulian assemblages. While critics of this dual tradition perspective argue that no such distinction exists (e.g. Semaw *et al.* 2009; de la Torre & Mora 2013), this assertion is based on equally valid, but very different, criteria from those originally used by M. D. Leakey (1971) to classify the Bed II assemblages. The rejection of Leakey's dual tradition model, then, has occurred despite the fact that her typological arguments remain unchallenged. Leakey's criteria to differentiate the Developed Oldowan from the Acheulian rested on the following premises:

- Assemblage classification is made largely on typological grounds, with flaked artefacts as the basis for tool classification. Bed I Oldowan sites are dominated by choppers, whereas Bed II Developed Oldowan sites are dominated by spheroids, subspheroids, modified battered nodules and blocks, and retouched flakes. For M. D. Leakey (1976: p. 443), this typological difference 'reflects an important change in the tool

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requirements' of hominins, thus placing an emphasis on tool function and, indirectly, on the range of activities performed at sites.

- Acheulian sites were identified as assemblages where bifaces constituted >40% of all flaked artefacts. Although bifaces occur in most Middle and Upper Bed II sites, the simple presence/absence of bifaces seemed unreasonable to Leakey because using a marginally represented (i.e. index fossil) artefact type muted the representativeness of the predominant elements of any given assemblage (M. D. Leakey 1976). Functionally, a site where the bulk of artefacts are Oldowan choppers and flakes and bifaces are comparatively underrepresented cannot be compared to a site where bifaces are predominant.
- Technological differences between Acheulian and Developed Oldowan bifaces. The former are bigger, fall into a more restrictive size range and show a lower frequency of trimming flake scars.
- An element that critics of the Acheulian-Developed Oldowan dichotomy tend to forget is that M. D. Leakey (1976) stressed that this division was applicable only to the Olduvai Bed I and Bed II sites. After a review of sites that also contained bifaces and were considered contemporaneous with Olduvai Bed II, she argued further that 'it is doubtful whether any comparable assemblages exist' elsewhere (1976: p. 450). Only the South African Transvaal caves showed some similarities to the Developed Oldowan from Olduvai.

Initially, M. D. Leakey had divided the Developed Oldowan (DO) into several types. The DOA assemblages were characterized by the presence of choppers, spheroids, subspheroids and protobifaces. The DOB added small bifaces to this tool kit, a smaller number of crude bifaces and also a small group of light-duty tools (M. D. Leakey 1971: p. 4–8).

The coexistence in Middle Bed II of assemblages placed in the two technological categories identified by Leakey gave rise to decades of debate. Some scholars have considered DO to be a transitional phase between the Oldowan and the Acheulean (i.e. Clark 1970; Chavaillon *et al.* 1979; Clark & Kurashina 1979; Bar-Yosef 1994; Klein 1999; Semaw *et al.* 2009). Others have linked the differences between the two categories to different uses of the knapped raw materials (Stiles 1979), to different states of tool reduction or mobility patterns (Jones 1994), to environmental factors (Hay 1976, 1990; Isaac 1984) or to site functionality (Gowlett 1986). More recent studies that focus on Olduvai (de la Torre & Mora 2005) or that also take into account other parts of the African continent (Semaw *et al.* 2009; Diez Martín & Eren 2012; Sahnouni *et al.* 2013) agree in considering the DOB and the Acheulian to be equivalent, arguing that their obvious contemporaneous existence at Olduvai is reason enough to drop the idea that the DOB was a transitional phase.

Critics of the Acheulian-Developed Oldowan dichotomy tend to replace typology with technology. The 'know-how' criterion based on the inferred intellectual sophistication of the bifacial handaxe has forced a return to L. Leakey's (1951) conceptual approach in which the handaxe, as an index fossil, defined the presence of the Acheulian. However, this creates a blurred boundary as to when an assemblage can be classified as Acheulian. If the presence of one biface amongst thousands of 'Oldowan' artefacts is enough to qualify it as Acheulian, the next inferential step is that the indirect presence of a biface (in the form of a biface flake or a negative scar of a large flake from a core) would also qualify it as Acheulian. This creates ontological problems because an assemblage could be classified not only by the presence of a marginal element, but also by an indirect (and subjective) marker of its purported presence in that same assemblage.

M. D. Leakey's definition of the Acheulian, in which bifaces dominate the 'tool' set, has also been questioned because of the arbitrary use of biface percentages. This criticism is more understandable. Boundaries of this kind, whether based on percentages or other factors, produce artificial divisions – a tool assemblage consisting of 30% bifaces could be as Acheulian as another one with 60% bifaces. The main problem with this criterion is that no specific threshold has been demonstrated to effectively discriminate sites. Again, Leakey's approach emphasizes industry type and site functionality. While we agree, then, that her 40% threshold is to some extent arbitrary and thus marginalizes assemblages where this index is slightly lower or higher, we concur with the spirit of this approach: namely, assemblage functionality, as reflected by the predominant artefact types, is critical to understanding site functionality and, thus, the difference between Oldowan and Acheulian. Some have argued, in fact, that if Acheulian and Oldowan sites were functionally distinct, these distinctions may be reflected in their palaeogeographical/palaeoecological contexts (Hay 1976).

Handaxe size, in addition to their proportional representation, may also be relevant given experimental evidence that large handaxes are less effective than small handaxes as butchery tools (Galán & Domínguez-Rodrigo 2014).

The question thus remains: can we effectively and consistently discriminate between Acheulian and Developed Oldowan sites using Leakey's original criteria or any of the critics' alternative technological suggestions? The waters become even murkier here, as it is unclear whether archaeologists from different schools of thought even refer to the same thing when invoking the term 'Acheulian'. To complicate matters further, Acheulian and Oldowan assemblages, at least defined on strictly typological grounds, can be interstratified at the same sites (Diez-Martín *et al.* 2015).

Palaeogeography and palaeoecology of Oldowan and Acheulian sites

Determining the palaeoecological setting of sites is crucial to understanding hominin adaptive and behavioural patterns. Hay (1976) created a palaeogeographical framework at Olduvai based on the location of sites relative to inferred minimum shorelines. Based on this, he defined two palaeogeographical locations: lake-margin sites (an area between the shoreline and a maximum of 1 km from the shoreline) and inland sites (any areas >1 km away from the lake shoreline). By this method, Hay classified 38 sites as lake-margin and 18 as inland. He stressed that 'nine out of ten Acheulian sites are inland. ... and seven of the Oldowan B sites are lake-margin. . .The correlation between industry and paleogeography is close' (Hay 1976: p. 114).

Domínguez-Rodrigo *et al.* (2005, 2014a, b) built upon this approach by stressing that local ecology (i.e. an ecotone), itself partly determined by palaeogeography, is critical to establishing the functionality of a site and thus, explaining the properties of its lithic assemblage. There remains some confusion about the veracity of Hay's original palaeogeographical patterns and the distinction between broad palaeogeographical settings and local habitats. For instance, de la Torre (2016) questions the association of Acheulian sites with inland settings, arguing, in contrast that several are in fact found in 'lake-margin/alluvial fan' settings. However, this is based not on Hay's original palaeogeographical scheme but on his geological facies classification, the latter of which says little about the immediate ecological context of a site. A lake-margin/alluvial fan can encompass a variety of ecotones with diverse lithologies and divergent patterns of resource distribution. Thus, de la Torre's (2016) characterization of the Acheulian sites ER-HR and CK as 'lake-margin/alluvial fan' sites overlooks the fact that, when viewed contextually and in reference to their local habitat, both sites are located within an alluvial fan that formed at the bottom of the highland slope, where the lake did not in fact reach (Hay 1976). The palaeogeographical context of these sites, then, is fluvial. The utilization of broad labels like 'lake-margin/alluvial fan' thus produces very little information about a site's palaeoecological context.

The strong association of handaxe sites with fluvial contexts is borne out by the fact that all the Bed II sites with such lithic assemblages (e.g. FLK West, BK, TK, EF-HR) are situated near river systems, which influences their local palaeoecology, and, according to Hay's palaeogeographical definition, are situated inland. During uppermost Bed II times, in fact, no clear evidence of a lake exists, which again indicates that the Acheulian artefacts from TK (and the handful from BK) are not linked to activities performed by the lake margin. This contrasts with the Bed I record, where most sites on the eastern side of the lake are linked strictly to lake-margin environments even if some are near fluvial inputs (e.g. PTK, DS). What is more, Oldowan sites both during Bed I and II times tend to be lake-margin locales both palaeogeographically and palaeoecologically.

These associations all strongly suggest that palaeoecological context played an important role in the emergence of Acheulian tool kits in the palaeo-Olduvai Basin.

The hard evidence of the earliest Acheulian chronology

The earliest stages of the African Acheulian are currently being investigated by five research teams. A team led by Harmand and Roche have reported on the oldest Acheulian site in the West Turkana area at Kokiselei 4 (Lepre *et al.* 2011). The site has been dated to 1.76 Ma and possibly older based on regional correlation and sedimentation rates (Lepre *et al.* 2011). No technological analysis of this assemblage has yet been published, but the Kokiselei Acheulian large cutting tools (LCT) are relatively crudely shaped.

Beyene *et al.* (2013) have long been conducting research at the site of Konso-Gardula in South Ethiopia, where they have documented an Acheulian archaeological record that stretches half a million years and includes one of the oldest such assemblages known. The age of the oldest Acheulian site at Konso-Gardula (KGA6-A1) is bracketed by two tuffs (1.74–1.66 Ma). Its stratigraphical position between these tuffs suggests the assemblage is probably 1.7 Ma in age. Based on their discovery of rudimentary LCTs in the oldest periods of the Konso-Gardula Acheulian and far more elaborate handaxes in later periods (*c.* 1.2–1 Ma), Beyene and colleagues argue that the Acheulian evolved towards the production of fully refined handaxes by the end of the early Pleistocene.

At Melka Kunture in Ethiopia, Mussi's team is also conducting work on the Acheulian (Gallotti *et al.* 2014; Mussi *et al.* 2014). Thus far none of the Acheulian sites at this locality is older than 1.5 Ma, which is also true of the Acheulian sites under the investigation of the Olduvai Geochronology and Acheulean Paleoanthropology Project (OGAPP; de la Torre & Mora 2013). While OGAPP has neither discovered new sites nor pushed back the age of the Acheulian at Olduvai, several summaries on the evolution of the Acheulian have emerged as part of this project (de la Torre & Mora 2013; de la Torre 2016).

The work of TOPPP has contributed two findings that are relevant to the origins of the Acheulian. The first is the discovery of Olduvai's earliest Acheulian site, FLK West, which directly overlies a volcanic tuff dated to *c.* 1.7 Ma and is located below a capping tuff dated to 1.66 Ma (Diez-Martín *et al.* 2015). FLK West can thus be added to the short list of Acheulian sites that date to 1.7 Ma and one of the two sites (together with KG) associated with secure maximum and minimum ages. The second is the co-occurrence at FLK West of very rudimentary LCTs in the same horizon with fairly

elaborate bifacially shaped handaxes, which demonstrates that by 1.7 Ma, at least at Olduvai, hominins possessed the technical skills to produce complex Acheulian artefacts previously known to exist only in contexts younger than 1.2 Ma.

Site functionality of Acheulian and Oldowan sites

Evidence for carcass butchery (including megafaunal exploitation) during Bed II times has been found at FLK West, SHK and BK, all of whose lithic assemblages are dominated typologically by Oldowan tools (LCTs and handaxes are marginally represented) (Domínguez-Rodrigo *et al.* 2014a, b; Organista *et al.* 2015). No taphonomic evidence of butchery, however, has been documented for the Acheulian dominated assemblages of EF-HR and TK (Egeland & Domínguez-Rodrigo 2008; Yravedra *et al.* 2016). Pene-contemporaneous sites across the FLK West palaeolandscape like HWK and HWKE, both characterized as Developed Oldowan, have not yielded unambiguous evidence of butchery (Egeland & Domínguez-Rodrigo 2008; Yravedra *et al.* 2017a). A similar situation has been identified at MNK and FC West, both, typologically, Developed Oldowan assemblages. This lends credence to M. D. Leakey's (1971) original typological approach, which emphasized functional differences between both types of industrial assemblages.

Contributions of the present volume to the Oldowan-Acheulian debate

More than 50 years after the discovery and excavation of the Zinj Floor by Mary Leakey, TOPPP has uncovered several new, and very dense, Oldowan sites in Bed I. One of these sites, David's Site (DS), is the most spatially extensive early Pleistocene Oldowan site known to date. This volume introduces new simulation techniques that predicted the density of materials in the unexcavated portions of this extraordinary open-air site. Through a combination of spatial regression and algorithms that model cluster and scatter patterns within large, excavated areas, predictions of material location were generated for, and then tested on, subsequently excavated areas. The resulting predictions reproduced with high resolution the observed frequencies of materials that were later uncovered from the modelled areas (correlations between prediction and observation were >0.9). This method promises to aid the analysis of spatial distributions both on and off site (Domínguez-Rodrigo *et al.* 2017).

The earliest Acheulian from Olduvai is now known to date to at least 1.7 Ma at FLK West (Diez-Martín *et al.* 2015). It is at FLK West, too, that a clear association between Acheulian tools and animal butchery is documented. The taphonomic analysis of the assemblage shows that a variety of carcasses, from small- to large-sized animals, were butchered at the site throughout the entire Oldowan-Acheulian sequence (Yravedra *et al.* 2017a). A geometric morphometric study of a sample of cutmarks shows that LCTs were not in fact involved in the butchery process. A similar method is applied to the cutmarked bone assemblage from BK (Yravedra *et al.* 2017b). Typologically Oldowan, BK preserves evidence for the butchery of dozens of animals, including several megafaunal taxa (*Pelorovis*, *Syncerus*, *Sivatherium*, *Elephas*). Using a sample of experimentally produced cutmarks and a novel combination of photogrammetric and geometric morphometric approaches, a majority of the BK marks could be assigned objectively to the edges of the unretouched quartzite flakes so common in the BK lithic assemblage. Such morphometric approaches have the potential to differentiate the raw material and the tool type responsible for the production of butchery marks.

The site of SHK (1.5 Ma), because it is situated chronologically during a time with many typologically Oldowan sites with technologically Acheulian tools, merits special attention. On-going excavations confirm that SHK Main and the SHK Annexe, traditionally considered to be distinct sites, in fact lie upon the same palaeosurface. Because the two concentrations lie ~100 m apart, this (now) single site displays a spatial extent that is unprecedented at this time. Technically, it is one single site, whose extension is unprecedented and presents some of the complexities of the 1.5 Ma archaeological record. At this time, some sites at Olduvai are several times bigger and denser in remains compared to the Oldowan sites from Bed I. In the framework of our efforts to better understand the SHK complex, we present the results of our investigation in the new area known as SHK Extension, excavated between SHK Main and SHK Annex (Diez-Martín *et al.* 2017). The main archaeological patch unearthed in this site is synchronous with SHK Main site and both areas provide a remarkable opportunity to understand hominin behaviour in this fluvial environment from a landscape-orientated perspective. Through the implementation of archaeo-stratigraphical, taphonomic, technological and lithic refitting analyses we have been able to undertake a high-resolution evaluation of the spatial component of the archaeological aggregate of SHK Extension and to explore more in-depth the issue of inter-assemblage variability at a local scale. Understanding the mechanisms that drive inter-assemblage variability at both local and regional scales is crucial for our current interpretation of the Developed Oldowan/Acheulean gradient in Bed II times. The work by Sánchez-Yustos *et al.* (2017) deals with this same issue in a broader context and from an alternative perspective. Through the study and comparison of the flake production processes observed in the SHK lithic assemblage and the later BK assemblage, it aims at providing empirical data (based on both diacritical and technological approaches) on the diversity and variability of core reduction strategies in these two Developed Oldowan sites. This work explores, thus, the Developed Oldowan/

Acheulean interface using alternative technological markers to the more traditionally orientated study of LCTs, concluding that the Developed Oldowan in Bed II exhibits more conceptual and technological complexity than the Oldowan in Bed I.

Acheulian site functionality is addressed at the most impressive Acheulian site in Bed II: TK. TK is the largest excavation of an Acheulian site at Olduvai Gorge. This has resulted in large industrial assemblages (Santonja *et al.* 2017). Dozens of bifaces were studied at TKLF within a technoeconomic and technological framework (Santonja *et al.* 2017). Here, the study of the lithic assemblage of a new Acheulian level, TKSF (Rubio-Jara *et al.* 2017), very close stratigraphically and temporarily to TKLF, is presented. The differences between these Acheulean floors (TKLF and TKSF) allow the authors to suggest that the possible explanation of Acheulean variability is due to the different activities and patterns of behaviour carried out by hominins. Therefore, the importance of conducting extensive archaeological excavations to understand sites as functional areas is stressed.

These new methodological approaches to the study of technology and spatial analysis are complemented by residue analyses. Mercader *et al.* (2017) introduce here a new referential protocol to identify the severity of contamination of starch microresidues in archaeological sediments and materials. This study is, in fact, the first to systematically study the impact of modern starches from surface and buried soils, windborne dispersal, human motion, excavation techniques and toolkits, and field attire on the quality of archaeological starch samples. This study also demonstrates the various diagenetic changes, including cavitation, fissuring, disruption and gelatinization that buried starch granules experience even in a relatively short amount of time. Mercader *et al.* (2017) illustrate how lithic samples excavated under standard field conditions can be contaminated, and that when a sample is compromised during excavation, it may be impossible to distinguish between target and introduced starches.

Together, these new methods and protocols reveal a wealth of information about the oldest archaeological record at Olduvai, and we hope that the studies published in this issue shed further light on the Developed Oldowan/Acheulian debate, the functionality of early sites, and spatio-temporal variability in African hominin behaviour during the first million years of the archaeological record.

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Manuel Domínguez-Rodrigo (m.dominguez.rodrigo@gmail.com) and Enrique Baquedano, Institute of Evolution in Africa (IDEA), Covarrubias 36, Madrid 28010, Spain; Manuel Domínguez-Rodrigo, Complutense University, Madrid 28040, Spain; Manuel Domínguez-Rodrigo, Royal Complutense College at Harvard, 26 Trowbridge Street, Cambridge, MA 02138, USA; Enrique Baquedano, Museo Arqueológico Regional Plaza de las Bernardas, Alcalá de Henares, Madrid, Spain; Audax Mabulla, Paleontology and Archaeology Unit, National Museums of Tanzania, Dar es Salaam, Tanzania; Fernando Diez-Martín, Department of Prehistory and Archaeology, University of Valladolid, Pza. del Campus, s/n, Valladolid 47011, Spain; Charles Egeland, Department of Anthropology, University of North Carolina at Greensboro, Greensboro, NC, USA; Manuel Santonja, CENIEH, Paseo de Atapuerca s/n, Burgos, Spain; *received 23rd April 2017, accepted 14th June 2017.*