Assessing the function of pounding tools in the Early Stone Age: A microscopic approach to the analysis of percussive artefacts from Beds I and II, Olduvai Gorge (Tanzania)

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Abstract

This study explores the function of quartzite pounding tools from Olduvai Gorge (Tanzania) using microscopic and use wear spatial distribution analysis. A selection of pounding tools from several Bed I and II assemblages excavated by Mary Leakey (1971) were studied under low magnification (<100x), and the microscopic traces developed on their surfaces are described. Experimental data and results obtained from analysis of the archaeological material are compared in order to assess activities in which pounding tools could have been involved. Results show that experimental anvils used for meat processing, nut cracking and/or bone breaking have similar wear patterns as those observed on archaeological percussive artefacts. This is the first time that a microscopic analysis is applied to Early Stone Age pounding artefacts from Olduvai Beds I and II, and this paper highlights the importance that percussive activities played during the Early Pleistocene, suggesting a wider range of activities in addition to knapping and butchering.

Keywords

Olduvai Gorge; battering activities; pounding tools; use wear analysis; Early Stone Age

1. Introduction

The use of pounding tools has been widely documented in the ethnographic record (i.e. Boshier, 1965; Maguire, 1965; Gould et al., 1971; Lee and DeVore, 1976; Yellen, 1977; Salazar et al., 2012) as well as in late Prehistory periods (i.e. Dodd, 1979; Adams, 1988; de Beaune, 1993; Adams et al., 2009; Dubreuil et al., 2015). Ethological research has shown that many non-human primate species habitually use stone tools for a variety of food-processing activities. For example, West African chimpanzees (*Pan troglodytes*) (i.e. Sugiyama and Koman, 1979; Sugiyama, 1997; Carvalho et al., 2007; 2008; Matsuzawa et al., 1999; Matsuzawa, 2011; Struhsaker and Hunkeler, 1971; Boesch and Boesch, 1983; Boesch-Achermann and Boesch, 1993) and Brazilian capuchin monkeys (*Sapajus libidinosus*) (i.e. Visalberghi et al., 2009; Fragaszy et al., 2004; Ferreira et al., 2010) use hammerstones and anvils to crack nuts, and Thai long-tailed macaques (*Macaca fascicularis*) (Malaivijitnound et al., 2007; Gumert et al., 2009; Gumert and Malaivijitnond, 2013; Haslam et al., 2013) use different types of hammers to process gastropods and crabs.

Recent years have witnessed an advancement in the study of percussive tools, especially those of the Early Stone Age (ESA). Interest increased in particular when researchers began to consider the mechanics of pounding as a key factor and potential previous stage leading to the emergence of knapping (De Beaune, 2000; 2004), and there has also growing interest in the analysis of wear patterns present on the pounding tools themselves (i.e. de la Torre et al., 2013; Caruana et al., 2014). Pounding tools have been recovered from Early Stone Age sites such as Koobi Fora (Isaac, 1997; Caruana et al., 2014), Melka Kunturé (Piperno et al., 2004; Chavaillon, 2004; Gallotti, 2013), Lokalalei 2C (Delagnes and Roche, 2005), Gesher Benot Ya'aqov (Goren-Inbar et al., 2002; 2014; 2015; Alperson-Afil and Goren-Inbar, 2016) and Olduvai Gorge (Leakey, 1971).

The Early Stone Age record in Olduvai Gorge, ranging from >1.8 to c. 0.5 my, is one of the best known in Africa. Lithic assemblages from different sites excavated by Mary Leakey in Beds I and II (Leakey, 1971) have been analysed by a number of researchers (e.g. Potts, 1982; Kimura, 1999; 2002; Ludwig, 1999; de la Torre and Mora, 2005), providing a substantial body of knowledge about hominin knapping skills and strategies. Some of this research focused on percussive tools and their role in assemblages and showed that ESA hominin activities focused not only on flake production, but also included the use of unshaped rocks probably involved in different pounding activities (e.g. Mora and de la Torre, 2005).

Further evidence for percussive activities in the ESA is preserved in fossil assemblages, the analysis of which showed bones that had been intentionally fractured by placing them on an anvil and hitting them with a hammerstone (Blumenschine and Selvaggio, 1988; Blumenschine, 1995). Such evidence supports the hypothesis that some percussive tools found at Olduvai could have been used to break bones in order to extract marrow (Mora and de la Torre, 2005). To test this hypothesis, and check whether other materials might have been processed with anvils and other battered stone tools, recent experimental programmes have developed a comparative framework to interpret archaeological material (de la Torre et al., 2013; Sánchez Yustos et al., 2015). Experimental results show that at macro- and microscopic levels different pounding tasks such as bipolar knapping, bone breaking, meat tenderizing, plant processing and nut cracking leave distinctive patterns of percussive marks on passive quartzite anvils (de la Torre et al., 2013), while other works have discussed the functionality of spheroids and subspheroids (Sánchez Yustos et al., 2015)

Having highlighted the importance of percussive tool use in the ESA record from Olduvai Gorge (Mora and de la Torre, 2005), and developed an experimental framework (de la Torre et al, 2013), the next step is to apply such analytical protocols to archaeological assemblages, and compare results with the experimental outcomes. This paper, which includes the first microscopic and use wear spatial distribution studies of archaeological pounded pieces from some of the classic assemblages excavated by Mary Leakey (1971) in Olduvai Beds I and II, contributes to the discussion of battered artefacts in the Early Stone Age. Furthermore, it demonstrates the relevance of percussive activities in human evolution through the application of new analytical methods to the study of Palaeolithic pounded tools.

2. Methods and materials

2.1 Methods

Use wear analysis is recognised as a valuable tool that can be employed to assess the use and function of stone tools. Despite development of the discipline since the 60s, it has rarely been applied to the African ESA. Use-wear studies have been conducted on African Lower Pleistocene as assemblages from Koobi Fora (Keeley and Toth, 1981), Kanjera (Lemorini et al., 2014), Ain Hanech (Sahnouni and Heinzelin, 1998; Vergés, 2003; Sahnouni et al., 2013), and Olduvai (Sussman, 1987), but all have focused on analysis of flakes using both high and low magnification approaches.

In this paper, we use a multi-scale approach (Grace, 1990) to analyse pounding tools from Olduvai Gorge that includes an analysis of morphological traces of use-wear using low power microscopy. As shown elsewhere (de la Torre et al., 2013), a low magnification approach (<100x) offers good results when analysing large percussive tools. In investigating the presence of percussive damage similar to those found on the experimental assemblage (de la Torre et al., 2013), this study analyses not only macroscopically visible damage patterns, but also areas where no damage was observable.

The analysis of artefacts was conducted at the National Museum of Tanzania (Dar es Salaam), using a fibre optic illumination trinocular microscope GX-XTL with a magnification range between 0.7x and 4.5x and a 10x eyepiece, allowing a final magnification of 45x. All photographs were taken with a Nikon D90 DLSR camera attached to the microscope and Nikon Camera Control Pro software.

In addition, and following the protocols established elsewhere (de la Torre et al., 2013; Benito-Calvo et al., 2015), a use wear spatial distribution analysis has been conducted using GIS to assess and quantify the degree of working surface modification in the pounded artefacts.

2.2 General characteristics of the lithic assemblage

Tools were selected from those assemblages excavated by Mary Leakey (1971) in Olduvai Beds I and II where a considerable number of percussive tools had previously been documented (Mora and de la Torre, 2005). On the basis of context and conditions of conservation/preservation, seven pounding tools from five different sites (BK, FC West, TK, SHK and FLK North Level 6) were selected for microscopic analysis (Figure 1). These sites span Bed I (FLK North Level 6), through Middle Bed II (FC West and SHK) to Upper Bed II (TK and BK) (Leakey, 1971; Hay, 1976).

Insert Figure 1.

The artefacts analysed here are on tabular quartzite blocks from Naibor Soit, a Precambrian inselberg located about 3.5 km from the confluence of the Main and Side Gorge, and within a 5 km radius of the main archaeological sites (Hay, 1976). Morphologically, the Naibor Soit quartzite is a coarse-grained crystalline rock, composed primarily of quartz and mica (Hay, 1976). In the source area, quartzite is available in different forms, from small, flat and portable blocks scattered across the Naibor Soit hills, to large fixed boulders (Jones, 1994).

3. Results

3.1 Techno-typological analysis

From a general perspective, and despite the variety of sites from which the tools were selected, the pounding tools analysed here are all morphologically similar, and conform to Leakey's (1971) original description of anvils. They have similar morphological characteristics (i.e. cuboid shapes), with mean dimensions of 123.6 x 95.9 x 72.4 mm and a mean weight of 1332.4 gr (see details in Table 1).

Insert Table 1.

The pounding tools showed macroscopic impact marks scattered along one or two horizontal planes on which percussive activity occurred. Occasionally, small battering areas were identified on contact zones between the horizontal and transversal planes (Figure 2). One anvil (FLK N 1/6 10290) showed a large battered area with an elongated morphology on one lateral plane. This area measures 3.13 cm^2, and which crystals appear heavily crushed, suggesting additional use as an active element; this is due to the morphological characteristics of the pounding marks and because they are located in a zone on the blank that would not have the stability required for being used as passive element. In addition, two artefacts originally classified by Leakey (1971) as anvils (TK II 2060 and SHK 2152), have a series of non-invasive, superimposed, contiguous stepped scars, wide and short in morphology, removed from the main horizontal plane at a 90º angle, and associated with impact points or superficial battered areas that tend to be distributed along the edge. These traces resemble fracture patterns described by Alimen (1963) as characteristic of anvils.

In summary, all percussive traces on the tools analysed are concentrated on peripheral areas, close to the edges or contact areas between two planes. Macroscopically, the central zones of blanks show no large areas with traces of use, and only a few isolated impact points. Therefore, their general morphological characteristics and percussive traces, along with the absence of large battered areas on surfaces, match with use-wear patterns documented on experimental anvils (see de la Torre et al., 2013), and thus suggest their possible use as passive elements.

Insert Figure 2

3.2 Use wear analysis

Table 2 summarizes the type of wear patterns identified on each tool analysed. All artefacts bear impact marks scattered across the horizontal plane as well as concentrated on small battering areas. These impact marks are circular, with fractured crystals at their central point (Figure 3 A-2, Figure 4 B-1). Small areas were identified that have repetitive impacts associated with the development of crushing (Figure 3 A-1 and B-1). In these areas, where the surface tends to have a frosted appearance (Adams, 2002; Adams et al., 2009) (Figure 4 A-2 and 3), repetitive impacts caused crushing and fracturing of crystals and removed small fragments producing step fractures (Figure 3 B-2), whose negatives occasionally show characteristics of conchoidal fracture produced by direct impact.

Moreover, most percussive tools analysed (n=4) have microfractures which are angular in shape ('V' fractures) and located mainly on the edges of the tool (Figure 3 B-3). Such fractures do not appear along the entire perimeter of the tool, but are associated normally with small battered areas, while the remaining edge is unmodified.

Insert Table 2

The percussive marks described above (impacts, crushing, angular microfractures and step fractures) are due to the tribological mechanisms of fatigue wear (Adams et al., 2009) produced by a thrusting percussion motion. Keeping in mind that all tools analysed are interpreted as having been used as passive elements (based on characteristics of the marks with impact points, areas of crystal crushing and edge fractures), the wear formation could be related to sporadic contact with the active element during use.

Insert Figure 3

Insert Figure 4

Furthermore, on some tools (e.g. TKII-2060 and FLKNI-8282), we have identified percussive marks on two opposed horizontal planes. Previous macroscopic analysis of the anvils suggests that damage on one face relates to marks produced by contact with the ground (Mora and de la Torre, 2005). However, from a microscopic perspective, similarities in the morphology of marks and their distribution, lead us to suggest that both horizontal planes were used and, either the blanks were occasionally flipped during a single task, or both faces were used on multiple occasions. Additionally, the size of blanks indicates that occasionally they could have been used as active elements, such as in the case of tool FLK N l/6 10290 (Figure 3 B), on which a battered area was identified at the intersection between the transversal and sagittal planes.

Five of the seven pounding tools have abrasions (sensu Keeley, 1980; Sussman, 1988) with the same morphology as those on experimental quartzite anvils described by de la Torre et al. (2013). Sussman's (1988) study on use wear formation on quartz tools described a similar type of wear and linked it with erosional processes caused by friction between two objects resulting in a rough surface. Abrasions on the anvils analysed in the present study have the same rough appearance as described by Sussman (1988), having a morphology that tends to be elongated, with no preferential orientation, located close to the edges (no pounding tools show abrasion on the central areas of their surfaces) (Figure 3 A-3), and a loosely, scattered distribution. Sometimes these abrasions are associated with crushed and microfractured areas (Figure 3 A-1) and, more specifically, they tend to be located on top of areas with crushing, suggesting that formation of abrasion occurred after the other wear traces.

3.3 Use wear spatial distribution analysis

All the analysed artefacts have a similar morphology and no significat size differences (Kruskal-Wallis test $p>0.05$ for length, width and weight), with similar areas (mean of 82.4 cm^2 and SD=20.0 cm^2) and perimeters (mean of 35.0 cm, SD=5.0 cm). Three of these pounding tools show clear macroscopic damage, allowing a more detailed and quantitative analysis of the spatial distribution of battering (see results in Table 3).

The BK-1 artefact possesses the greatest percentage of working surface damage (PA=9.05%) and the largest individual use wear mark (LUW), which covers 3.48% of the total surface. Artefacts FLKN-10290 and SHK-2152 show similar ratios, with PA < 0.4% and LUW < 0.20% (Table 3); these differences are potentially associated to greater use in the case of BK-1. Despite these variations, the three artefacts show a low density of wear traces (D<0.15%). Morphologically, macroscopic wear traces in all tools are relatively small (mean area=0.26 cm^2 and mean perimeter=1.7 cm), with a more uniform shape in tools FLKN-10290 (MNSH=1.19), and SHK-2152 (MNSH=1.19), and elongated in the case of tool BK-1 (MNSH=1.27).

The GIS analysis shows that wear traces are dispersed in tools FLKN-10290 and SHK-2152 (Ellipse elongation>2.2), whilst are more concentrated in BK-1 (Ellipse elongation=1.33). Despite these differences, use wear marks are located close to the edges in all three tools. In this case, the DAC index (distance to the centre of tool) yields high values (mean DAC>3 cm in all cases), while the DAE index (distance to the edge of the tool) shows a mean value of <1.3 cm (Table 3 and Figure 5).

Insert Table 3

Insert Figure 5

4. Discussion: assessing the function of percussive elements through comparison of archaeological and experimental data

In order to reconstruct activities that hominins might have undertaken during the ESA in Olduvai Beds I and II, we can use direct comparison between the results presented here and those obtained through our experimental programme (de la Torre et al., 2013).

The main characteristic shared by all pounding tools presented here is their low degree of damage and the location of wear on peripheral areas of working surfaces. Microscopic analysis indicates the presence of different traces such as crushing, microfractures and abrasions. De la Torre et al. (2013) showed that activities such as bone breaking and nut cracking occasionally produce microscopic abrasions on surfaces resulting from the friction produced between the anvil and element processed.

In the archaeological pieces studied here, the location of abrasions near the edge and occasionally associated with crushed areas suggests that, in fact, abrasion development is the result of contact between the artefact and some kind of organic material, as will be discussed below. Although the possibility that some abrasions were caused by post-depositional and transport/manipulation processes cannot be ruled out entirely, impact marks, areas of crushing and various fractures identified on pounding tool are certainly linked to use of blanks, as they show no evidence that could suggest a more recent origin (e.g. changes in patina).

The spatial distribution of marks in the pounding tools from Olduvai Gorge shows similarities with experimental anvils used for nut-cracking (de la Torre et al., 2013: 326). In both instances, PA and D indexes (PA<0.50%; D<0.15%) reflect the low density of macroscopic wear traces on the working surfaces. When the comparison is extended to the rest of the experimental results by de la Torre et al. (2013), further similarities are evident for anvils used on bone breaking, meat and plant processing, all showing low density of marks. In addition, experimental nut-cracking, meat tenderizing and bone breaking yield wear traces located very close to the edges of the working surface (see details in de la Torre et al., 2013: Table 6), with a standard deviation ellipse elongation showing similar values to those identified in the archaeological assemblage (Figure 6). In summary, our analysis of the use wear spatial distribution in pounding tools from Olduvai Gorge suggests similarities with patterns observed in experimental anvils used to process bone, meat and nut materials, with both assemblages sharing a low degree of modification in the working surfaces with percussive traces, an off-centre and scattered distribution of marks.

Figure 6

In our nut cracking experiments (de la Torre et al., 2013), anvils tend to show impact marks on peripheral areas, close to the edge, formed as a result of occasional contact between hammerstone and anvil, but there were no traces of the formation of depressions. During bone breaking and bone dismembering, sporadic edge fracture occurred, and some isolated impact points produced by missed blows were identified. Activities such as meat tenderizing and plant pounding tend to leave similar wear patterns on anvils, for example numerous superficial battering areas and clusters of impact points scattered across the working surface; one experimental anvil used to process meat shows a similar wear pattern to that seen on archaeological anvils such as SHK-2152 (Figure 7A). Finally, anvils involved in bipolar knapping activities bear the most intense wear marks consisting of large areas of battering and crushing that tend to be clustered in a central location (de la Torre et al., 2013). These results support those by Jones (1994) on the replication of pitted stones from Olduvai Beds III and IV, which he suggested were used in bipolar knapping activities.

Our analysis and comparison of both the experimental and archaeological assemblages from Beds I and II suggest that bipolar knapping was not the activity performed, as none of the Olduvai anvils analysed show heavy damage on their surfaces. Meat tenderizing and plant processing also tend to leave conspicuous percussive marks, recognisable macroscopically by clusters of impacts scattered across the active surface and very little edge damage is formed primarily by contact between the hammer and the anvil.

In contrast, there are two activities, namely nut cracking and bone breaking, in which similar wear patterns were recognised on both archaeological and experimental passive elements, with impact points, micro- and macro-fracturing of edges, and very few percussive marks in central areas. During processing, nuts and bones are normally placed in central areas of anvils, and therefore tend to absorb energy transmitted by the hammerstone. As a result, there is a lack of wear traces on these central areas, as the hardness and density of quartzite prevents formation of visible wear traces produced by pressure forces, while the weaker areas of edges tend to fracture more easily. Consequently, as can be seen in Figure 7B, use wear formation processes on the Olduvai pounding tools can be explained as the result of the pressure of force applied when hitting a bone placed close to the edge of the artefact, as well as by impacts from possibly too forceful and missed hits. If these pounding tools were used to process nuts, the presence of wear on the edge can be related to contact between the two percussive objects. In the case of nut-cracking activities, Gesher Benot Ya'aqov anvils show depressions on their horizontal surfaces (Goren-Inbar et al., 2002), which are abset in the pounding tools from Olduvai Gorge presented in this work. Olduvai Gorge quartzite is a non-maleable rock in which the wear formation process involves microfracturing and crushing of crystals. In contraste, the pitted stones from Gesher Benot Ya'aqov are made on basalt and limestone where wear formation processes are different from quartzite, and so, the same actitity could produce disparatet wear patterns.

Apart from nut cracking and bone breaking, another possibility (not experimentally tested yet), is that damage could be produced by hitting the bone directly against the edge of the artefact, using the same motion as in the so-called anvil-chipping technique (Shen and Wang, 2000).

Insert Figure 7

Although the patterns and characteristics of wear traces observed in the Olduvai pounding tools match with a passive function (following Chavaillon's 1979 terminology) as identified on the experimental material (de la Torre et al., 2013), it must be acknowledged that their identification as anvils requires further support. It has been long recognised (e.g. de Beaune, 1993; de Beaune, 2000; Donnart et al., 2009) that pounding tools may have been used in multiple activities, and their function as passive or active elements alternated. Most certainly, this may have been the case for many of the Olduvai percussive tools, as discussed above for artefact FLK N l/6 10290. Nevertheless, we have adopted a conservative approach when describing functionality of the artefacts analysed here, their morphology and size hints to a passive role for most of them, and tends to support Leakey's (1971) original classification of such pieces as anvils.

5. Conclusions

Before the current study, pounding tools from Olduvai Gorge had been described in detail from a macroscopic perspective (Leakey, 1971; Jones, 1994; Mora and de la Torre, 2005), with some experimental programmes attempting to identify activities that could have been undertaken with those tools (de la Torre et al, 2013; Sanchez Yustos et al, 2015). This paper represents the first attempt to describe microscopic use wear in Early Stone Age pounded tools and analysed the spatial distribution of the macroscopic traces, for which artefacts from some emblematic assemblages excavated by Mary Leakey (1971) in Olduvai Beds I and II were selected. This work has tested positively the potential of use-wear analysis on quartzite tools, encouraging the application of microscopic and use wear spatial distribution analysis to larger samples of Early Stone Age pounding artefacts.

Our results are thus a first step towards understanding formation processes of use wear from various pounding activities where there is an absence of grinding and friction movements and the primary motion is thrusting percussion. On the archaeological pounding tools analysed from Olduvai Beds I and II, traces of impacts, microfractures, crushed areas and abrasions were recognised, distributed primarily on peripheral areas of the working surfaces. Comparison of the characteristics of these percussive artefacts with results from the experimental programme indicate two activities (nut cracking and bone breaking) that show similar wear patterns in both assemblages, results that are consistent with the quantitative data obtained from GIS analysis. Thus, our microscopic analysis of a selection of pounding tools from Olduvai Gorge indicates that they were indeed involved in percussive activities different from stone tool knapping and butchering, thus contributing to extend the range of early hominin activities at Olduvai Gorge.

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