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Pounding tools in HWK EE and EF-HR (Olduvai Gorge, Tanzania): percussive activities in the Oldowan - Acheulean transition

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Abstract

In this paper, we present pounded objects from excavations at HWK EE and EF-HR, which are studied from macro and microscopic perspectives. Analysis of HWK EE revealed one of the largest collections of percussive objects from Olduvai Gorge, while excavations at EF-HR have allowed us to recover a much wider collection of percussive tools than previously recorded. Differences are observed between the two localities: at the Acheulean site of EF-HR, percussive tools were predominantly used in the production of flakes and large cutting tools (LCTs). At the Oldowan site of HWK EE, the tool repertoire probably related to a wider range of activities, including bone breaking and bipolar knapping. Comparison of these two assemblages, potentially produced by different hominin species, helps provide a wider picture of pounding activities during the Oldowan - Acheulean transition at Olduvai Gorge.

Keywords

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1. Introduction

Interest in determining the function of percussive tools began early in African Stone Age studies, as illustrated by debate on the use of so-called ‘bolas’ and spheroids (Gobert, 1910; Leakey, 1931; 1950; Clark, 1955; Leakey, 1971; Schick and Toth, 1994; Willoughby, 1985). Since then, researchers have included pounding tools in their technological analyses of Early Stone Age assemblages documented across the East African Rift valley (e.g. Leakey, 1971; Isaac, 1997; Piperno et al., 2004; Chavaillon, 2004; Delagnes and Roche, 2005; Mora and de la Torre, 2005). More recent research has developed techniques to differentiate marks caused by natural agents from use-wear traces produced during percussive activities (Caruana et al., 2014). This has been accompanied by the development of more quantitative approaches to the study of wear traces on pounding tools (de la Torre et al., 2013; Caruana et al., 2014; Benito-Calvo et al., 2015).

Functional analysis through microscopic studies has been extensively used to assess activities on Palaeolithic sites. Despite the limited number of use-wear analyses conducted specifically on Early Stone Age (ESA) assemblages to study the function of flakes (e.g. Keeley and Toth, 1981; Sussman, 1987), new investigations have shown that hominins manufactured and used stone tools to consumed not only meat but also a variety of plants (Lemorini et al., 2014; Melamed et al., 2016), emphasizing the diversity of hominin diet. It has been hypothesized that during the ESA hominins used percussive tools to process nuts (Goren-Inbar et al., 2002; 2014; 2015), as well as plants and meat (e.g. Willoughby, 1985; de la Torre et al., 2013). Taphonomic studies have shown that hominins broke bones to access marrow (Bunn, 1981; Blumenschine and Selvaggio, 1988; Pobiner, 2007; Pobiner et al., 2008; Ferraro et al., 2013). Others have noted the benefits of pounding food in the absence of fire (Carmody and Wrangham, 2009), and the importance of consuming nuts, fruits and tubers as a source of nutrients (Peters, 1987). Primatological studies show that nuts, processed through pounding activities, represent an important source of food for West African chimpanzees (Yamakoshi, 1998), and ethnographic studies indicate the importance of percussive activities among hunter-gatherers (Murray et al., 2001).

In her seminal publication on Olduvai Gorge Mary Leakey (1971) described a series of objects under the category of ‘utilised material’, which grouped tools bearing percussive traces such as anvils and hammerstones. Subsequent re-analysis of Olduvai lithic assemblages emphasized the importance of these objects during Bed I and II times (Mora and de la Torre, 2005). Others have examined the function of pounding tools from Olduvai Gorge through experimental programmes (e.g. de la Torre et al., 2013; Sánchez-Yustos et al., 2015), began to apply microscopic analyses to the study of archaeological pounding tools (Arroyo and de la Torre, 2016), and compared them with chimpanzee nut cracking stone tools (Arroyo et al., 2016). The next step in percussive tool research is to expand these new protocols on experimental objects, and use such framework to undertake functional analysis of archaeological assemblages.

In this paper, we present a comprehensive study of percussive objects excavated by the Olduvai Geochronology Archaeology Project (OGAP) in the HWK EE and EF-HR localities. HWK EE, a late Oldowan site, was originally excavated by Mary Leakey after she had prepared her 1971 monograph, and the assemblage remained unpublished (Pante and de la Torre, submitted). Renewed excavations at this locality by OGAP have produced a detailed record of the stratigraphic sequence, in the transition from Lower to Middle Bed II (around 1.7 Ma), and revealed one of the largest Oldowan collection of stone tools and fossil assemblages (de la Torre et al., submitted ‘a’).

The Acheulean site of EF-HR was discovered in 1931, and is a well-known locality on the north side of the Gorge, about 1.2 km from the Third Fault (Leakey, 1971). The age of EF-HR was previously estimated at 1.6-1.5 Ma (Manega, 1993), although recent work by

OGAP has refined its stratigraphic position, and located this site above Tuff IIC and therefore within Upper Bed II (de la Torre et al, submitted ‘b’; McHenry, submitted).

In this study, we present a systematic technological and microscopic analysis of a large sample of percussive tools from HWK EE and EF-HR, and compare them with results from other Beds I and II pounding tools (Arroyo and de la Torre, 2016), as well as experimental tools made from Olduvai quartzite (de la Torre et al., 2013; Arroyo et al., 2016).

Overall, our aim is to discuss differences on the type of pounding tools across the Oldowan-Acheulean transition at Olduvai Gorge, thus contributing to a better understanding of variations in technological and functional patterns.

This study is the first systematic functional analysis of complete assemblages of percussive tools from late Oldowan and Acheulean sites. In addition to shed new light on hominin tool use and subsistence strategies, and complement the technological analysis of the lithic assemblages (de la Torre and Mora, submitted ‘a’ and ‘b’), our use-wear contribution aims to serve as a reference for the identification of pounding tools in other African ESA sites, and set the foundations for a better understanding of their function.

2. Materials and methods

2.1 The percussive assemblages from HWK EE and EF-HR

The HWK EE percussive collection presented here (T1-Main Trench and satellite trenches [T27, T28 and T29]) consists of 349 pounded objects (representing 1.93% of the stone tool assemblage [*n*= 18,107] collected from the four trenches) (de la Torre et al., submitted ‘a’). As such, HWK EE has one of the largest concentrations of percussive tools in Bed I and Bed II localities (Table 1). Complete objects form 59.3% (*n*= 207) of the studied assemblage, 35.2% (*n*= 123) are fractured percussive tools, and 5.4% (*n*= 19) are hammerstone flakes/ fragments. Most percussive objects (*n*= 293 [84%]) were recovered from the T1-Main Trench, 3.7% (*n*= 13) from Trench 27, 6% (*n*= 21) from Trench 28, and 6.3% (*n*= 22) from Trench 29 (see details in de la Torre et al., submitted ‘a’).

Insert Table 1

Percussive tools from HWK EE are most abundant in archaeological layers within the Lower Augitic Sandstone (LAS) (*n*= 283 [81.1%]) and the Lemuta member (LEM) (*n*= 58 [16.6%]). A few isolated percussive pieces (*n*= 8 [2.3%]) were recovered from the upper interval, Tuff IIB zone (descriptions in de la Torre et al., submitted ‘a’) (SOM 1-A).

Leakey (1971) only refers to the presence of 4 hammerstones and 10 utilised cobbles at EF-HR. Renewed excavations at this locality by OGAP unearthed 50 percussive objects (Table 1), most from levels L2 (*n*= 44) and L1 (*n*= 3) in the T2-Main Trench, and three from trench T12. 50% (*n*= 25) of EF-HR pounding tools were found in a sandy context, 28% (*n*= 14) on clay, 20% (*n*= 10) on gravel, and just one object (2%) came from within the clay (see stratigraphic details in de la Torre et al., submitted ‘b’) (SOM 1-B).

Conservation of percussive tools shows differences according to raw material. Generally, quartzite pounding tools are well preserved; there is a low incidence of surface abrasion, with a few examples at HWK EE (*n*= 4) having scattered, abraded zones (except for one which has concentrated areas of abrasion). On the other hand, lava objects from both sites (although particularly EF-HR) show variable degrees of weathering, i.e. post-depositional chemical alterations (e.g. van Gijn, 1990; Asryan et al., 2017). Under the binocular microscope, grains of these altered tools appear rounded and have a slight sheen. At EF-HR there are examples of tools affected by grain rounding (*n*= 13), exfoliation (*n*= 2) and surface cracks (*n*= 8).

2.2 Methods

2.2.1 Macroscopic analysis

Pounded tools were grouped into two main categories, namely active and passive elements, following Chavaillon's (1979) terminology. Techno-typological classification is based on Leakey (1971) and Mora and de la Torre (2005), and a brief description of each technological category is given in Table 2. Also recorded were general features such as battered areas, number of working surfaces and fractures. Raw material classification is based on McHenry and de la Torre (submitted).

Insert Table 2

In addition to the qualitative analysis of all percussive tools, in the case of subspheroids and hammerstones with fracture angles (HFA) we also performed statistical tests to characterise and compare their shape. This aims to shed light on the long-standing discussion on whether or not the spherical form of subshperoids is intentional (e.g. Schick and Toth, 1994; Texier and Roche, 1995). To avoid the bias introduced by raw material and blank variability, all HFA and subspheroids selected for statistical analysis are of the same raw material (i.e. quartzite). Shape analysis was undertaken using orthogonal digital images of subspheroids and HFA and processed with ImageJ (Rasband, 1997), following protocols similar to Tanabata et al. (2012). General morphological parameters (i.e. tool area and perimeter) were calculated, as well as various shape descriptors used in particle analysis, such as aspect ratio (which measures the proportional relationship between length and width), solidity (which measures the overall concavity of the shape), roundness and circularity (both parameters used to calculate the closest fit of tool shape to a circle, which is represented by a value of one) (Olson, 2011). Image J was also employed to obtain additional quantitative data, and to calculate the area of battered marks and depressions.

To determine the possible function of different percussive tools, we used an experimental reference collection of Olduvai objects used by modern humans (de la Torre et al., 2013) and captive chimpanzees (Arroyo et al., 2016). Quantitative data collected during the macroscopic analysis was processed using PAST (Hammer et al., 2001) and SPSS packages.

2.2.2 Microscopic analysis

All percussive objects were inspected to assess their suitability for microscopic analysis. Microscopic analysis was undertaken primarily on quartzite percussion objects (*n*= 38) because their state of conservation was better than tools of other raw materials. However, volcanic (*n*= 10) and gneiss (*n*= 1) pieces were also selected. Prior to analysis, all objects were gently cleaned with water to eliminate dust and superficial sediment.

We followed a low magnification approach (Semenov, 1964; Tringham et al., 1974; Odell, 1979), using a binocular microscope (Leica S8APO with a magnification range between 1x and 8x, equipped with 10x ocular lenses, fiber optic illumination and a digital camera EC3). This conforms with procedures used on pounding and grinding tools from later prehistoric periods (e.g. Adams, 1993; 2002; Adams et al., 2009; Dubreuil, 2001; 2004; Hamon, 2008), as well as on ESA flakes (e.g. Lemorini et al., 2014). The same methodology has also been applied to analysis of archaeological pounding tools from Olduvai Beds I and II (Arroyo and de la Torre, 2016) and experimental anvils (de la Torre et al., 2013), and aids the characterization of use-wear traces on medium-to-large size objects which cannot be studied using a high magnification approach with scanning electron microscopes (SEM).

We focused on identifying and describing percussive traces which could have been produced through a tribological mechanism of fatigue wear (Kato, 2002) (e.g. pits, micro-fractures, crystal/grain crushing, impact points and micro-fractures), or due to a process of abrasive wear, e.g. linear traces, polish (Adams et al., 2009) and abrasion (Keeley, 1980).

3. Results

3.1 Techno-typological analysis

HWK EE has a greater variety of percussive tools than EF-HR (Table 1); active elements are dominated by knapping hammerstones and fractured hammerstones (*n*= 242), with a significant presence of hammerstones with fracture angles (HFA) (*n*= 19), hammerstones with active edges (HAE) (*n*= 20) and subspheroids (*n*= 12). Passive elements are represented by passive hammerstones with friction marks (PHFM) (*n*= 2) and anvils (*n*= 9), the latter having the largest mean dimensions (Table 3 and Figure 1). There are also pitted stones (*n*= 19) which could have been used as passive or active elements. We have not identified clear passive elements in EF-HR, and the percussive assemblage is dominated by knapping hammerstones and fractured hammerstones (*n*= 38), followed by HFA (*n*= 7), HAE (*n*= 3), and pitted stones (*n*= 2) (Table 3 and Figure 1).

Insert Figure 1

Normality tests, run for each technological category to allow statistical comparison of both assemblages, show that artefact samples do not all have a normal distribution in length and weight parameters ($p< 0.05$). Non-parametric Mann-Whitney U tests for the percussive assemblages from HWK EE and EF-HR show significant differences in length ($z= -5.970$, p (2-tailed)< 0.05) and weight ($z= -6.190$, p (2-tailed)< 0.05). These statistical results, illustrated in Figure 2A, show that the EF-HR percussive objects tend to have higher mean dimensions than those from HWK EE.

Insert Table 3

Insert Figure 2

At HWK EE, 30.3% (*n*= 100) of percussive objects are on quartzite, with basalt trachyte/trachyandesite, and phonolite having similar percentages (23.9%, 22.1% and 22.7% respectively) (see Table 4). Basalt (38%) and trachyte/trachyandesite (24%) are the predominant raw materials at EF-HR, followed by phonolite (22.0%), quartzite (14.0%) and gneiss (2.0%). The Chi square test indicates no significant overall differences in raw material per site (χ^2= 7.562, df= 3, *p*= 0.056), although when adjusted residual values are considered, HWK EE shows a higher frequency of quartzite percussive tools. While preferential use of cobbles as blanks is indicated at both sites, blocks are also well represented at HWK EE (Table 5).

Insert Table 4

Insert Table 5

3.1.1 Active elements

Knapping hammerstones

Knapping hammerstones (including fractured knapping hammerstones) are the most common pounding tool of all percussive objects at both EF-HR (76% *n*= 38) and HWK EE (71.4% *n*= 242) (Table 1), and are primarily on cobble blanks (*n*= 90 [75.6%] at HWK EE; *n*= 23 [76.7%] at EF-HR), most often trachyte/trachyandesite and basalts (Table 4). Although the HWK EE knapping hammerstones do not follow a normal distribution in length and weight (Shapiro-Wilk test, *p*< 0.05), the Mann-Whitney U non-parametric test revealed significant differences in length, width and weight (*p* (2-tailed)< 0.05 on the three variables), with a group of EF-HR hammerstones having larger dimensions (Figure 2C).

Despite size differences, all knapping hammerstones display similar use-wear patterns characterized by concentrated battered marks formed by superimposed impacts, located at least at one end of the blank, as well as impact points scattered across the surfaces.

In general, percussive traces are invasive, indicating use in a high intensity activity and contact with hard material. The HWK EE knapping hammerstones usually have one working zone, with percussive traces on small areas of their surface, although rare pieces display several working zones (Figure 3A). The EF-HR knapping hammerstones show a greater degree of use and have multiple zones with battering marks covering large portions of the surface, suggesting deliberate re-orientation of the tool during use in search of convex areas (Figure 3B).

Insert Figure 3

Hammerstones with an active edge (HAE)

The Mann-Whitney U test reveals no significant differences in length between the three HAE at EF-HR and the twenty at HWK EE (z= -.594; p (2-tailed)= 0.552); width (z= -.927; p (2-tailed)= 0.927) and weight (z= -.091; p (2-tailed)= 0.927) (Figure 2D).

The HAE from EF-HR are on lava (basalt [n= 1] and phonolite [n= 2]) cobbles; at HWK EE, six are on blocks and five on cobbles, while blanks for the remaining nine pieces are indeterminate. At both sites, these objects bear percussive marks on one or two angular areas, opposite an unmodified natural surface (Figure 4). Although use-wear distribution is similar, there are differences between HAE on lava and those on quartzite. Lava HAE from both sites show intense damage on one working zone (Figure 4B and SOM 2), characterized by invasive battering marks and the presence of multiple step and hinge fractures with no preferential orientation. In contrast, quartzite HAE (present only at HWK EE) have superficial percussive marks formed by repetitive impact points along one edge (Figure 4A).

Insert Figure 4

Subspheroids

Subspheroids were identified solely at HWK EE (n= 12 [3.6%]) (Figure 5), but the original blank could be determined only in two (one cobble and one block, both quartzite). In size, they are similar to the knapping hammerstones from the site (Table 3), but the Mann-Whitney U test indicates significant differences in length (z= -2.678; p (2-tailed)= 0.007), but not weight (z= -1.025; p (2-tailed) = 0.305). Most subspheroids (n= 9) have several working zones with isolated battered areas and impact points scattered across both flaked zones and edges.

Six subspheroids are multifacial cores, dominated by secant scars flaked from multiple knapping platforms. Battering marks on these objects are located mainly on ridges, and some impact points are visible inside flake scars. The latter suggests that flaking took place before the tools were used in percussive activities (Figure 6A). It was not possible to determine the sequential use of blanks for the remaining subspheroids (n= 6) as no overlapping occurs between percussive traces and flake scars (Figure 6B).

Insert Figure 5

Insert Figure 6

Hammerstones with fracture angles (HFA)

5.8% (n= 19) of the HWK EE pounded tools and 14% (n= 7) at EF-HR, were classified as HFA (*sensu* Mora and de la Torre, 2005). HFA are larger at EF-HR than HWK EE, with significant differences in length and weight (T-test, $p< 0.05$). The EF-HR tools are on basalt (n= 4), phonolite (n= 1), trachyte/trachyandesite (n= 1) and quartzite (n= 1) cobbles, bearing battered areas associated with multidirectional, non-invasive, step fractures. Those at HWK EE were mainly on cobbles (*n*= 13), mostly basalt (*n*= 8), followed by quartzite (*n*= 6), trachyte/trachyandesite (*n*= 3) and phonolite (*n*= 2). They show similar percussive patterns to those from EF-HR, with lava HFA bearing more intense fracturing of the active surface than their quartzite counterparts.

HFA show no clear signs of flaking, and damage is related primarily with percussive motions. All display battering scattered across the surface, located mainly in distal and convex zones, covering small areas, and occasionally associated with macrofractures having semicircular, wide and short morphologies. The morphometric and shape characteristics of HFA (Table 6) show no significant differences in area and perimeter (Kruskal-Wallis test, $p > 0.05$) when compared to subspheroids. The Kruskal-Wallis non-parametric test shows no significant differences in roundness ($p = 0.212$), solidity ($p = 0.077$) and aspect ratio ($p = 0.212$) between subspheroids and HFA.

Insert Table 6

3.1.2. Active/ passive elements: pitted stones

The pitted stones from HWK EE (*n*= 19) are on lava cobbles (basalt [42.1%], phonolite [36.8%], trachyte/trachyandesite [15.8%] and pumice [5.3%]), while those at EF-HR (*n*= 2) are on basalt cobbles (Table 4 and 5). The EF-HR pitted stones have higher mean dimensions and weight than the HWK EE pieces (Table 3 and Figure 2F).

Pitted stones usually have a single working zone on one face of the cobble, although some of the HWK EE specimens (*n*= 5) show several working zones located on the horizontal plane and on the convex ends of blanks. The main macroscopic use-wear feature is a depression which tends to be circular and/or oval in morphology (Figure 7). One example from HWK EE shows a depression on one horizontal plane in addition to battering marks on the proximal zone of the right lateral plane, a large step fracture, and two possible flake scars (Figure 7C and SOM 4). Such multiuse of a pitted stone was also identified on a second object, in which the exploitation surface is opposite the location of the depression (SOM 4).

Analysis of six pitted stones from HWK EE provided a mean area fur such pits of 6.83 cm^2 (SD= 3.00 cm^2). Depression profiles are mainly concave, but there are examples (such as tool HWKEE L6-981) with angular profiles (SOM 3). The inner areas of depressions in some pitted stones (e.g. HWKEE L1-2735 and HWKEE L6-981, SOM 3) have a uniform, polished surface, but in general surfaces tend to be irregular.

Insert Figure 7

3.1.3 Passive elements (anvils)

This group includes nine percussive objects from HWK EE, whose mean dimensions are larger than the active elements (Table 3). They are all on tabular quartzite blocks and have one or two working zones on the horizontal plane. Three anvils show small battered areas covering less than 5% of the surface. On two of these anvils, an additional battered area is located on a transversal plane; as the anvils could not have been stationary due to their lack of stability, these tools may also have used as active elements.

Impact points tend to be either scattered across the horizontal plane (Figure 8A) or in the contact between the horizontal and lateral planes (Figure 8B). Occasionally (*n*= 4), these impacts are associated with unidirectional, superimposed macro-fractures, normally wide and short in morphology, with step terminations located on one edge and associated with battering marks (Figure 8C). Included in the passive element group, are two lava PHFM (passive hammerstones with friction marks) from HWK EE, on which traces are related to a friction motion producing an abraded surface.

Insert Figure 8

3.1.4. Utilised material and other tools with percussive marks

At HWK EE, 2.1% (*n*= 7) of percussive objects were classified as utilised materials other than the categories described above; all are on quartzite tabular blocks and have at least one possible working zone on a horizontal plane, on which there are superficial wear traces characterised by isolated and scattered impact points. The absence of fractures or battered areas of utilised materials hinders their categorisation within any of the previous percussive groups.

Included in the two assemblages analysed here are some flakes (EF-HR: 0.38%; HWK EE: 5.56% of total flakes), flake fragments (EF-HR: 1.47%; HWK EE: 3.80% of total flake fragments), cores (EF-HR: 20.14%; HWK EE: 23.46% of total cores) and chunks (EF-HR: 0.83%; HWK EE: 14.21% of total chunks), with percussive marks on their surfaces (Table 7). Battering marks could have been produced on these detached pieces either by a non-knapping percussive task, or during core flaking. *Écaillé* marks were also found on cores, flakes, flake fragments and chunks (Table 7).

Battering marks on cores are normally located on the side opposite the flaking surface. In these cases, use of the blank as a pounding tool seems to have occurred first, as otherwise the knapping edge would have hindered manipulation of the blank during battering.

Insert Table 7

3.2 Microwear analysis

Forty-nine percussive objects from HWK EE (*n*= 42) and EF-HR (*n*= 7) were selected for microscopic characterization of percussive traces. The objects analysed include anvils (*n*= 7), knapping hammerstones/fractured hammerstones (*n*= 12), HAE (*n*= 8), HFA (*n*= 6), subspheroids (*n*= 11) and core-hammerstones (*n*= 3). They are on various raw materials (HWK EE: quartzite: *n*= 35; basalt: *n*= 2; phonolite: *n*= 2; pumice: *n*= 1; trachyte/trachyandesite: *n*= 2; EF-HR: basalt: *n*= 1; trachyte/trachyandesite: *n*= 2; gneiss: *n*= 1; quartzite: *n*= 3) (Table 8).

Table 9 summarizes microscopic percussive traces identified on pounding tools from both sites. 70.4% of the EF-HR tools studied and 85.7% of HWK EE pieces show crystal and grain crushing on their surfaces, frequently associated with micro-fractures and having a stepped morphology (present on 15 percussive tools, 30.6%). A few percussive tools (*n*= 18 [36.7%]) also bear irregular micro-fractures, and some pieces (*n*= 4 [8.2%]) have a combination of both types of micro-fractures, caused by the detachment of small crystal/grain fragments.

Insert Table 8

Insert Table 9

Microscopic percussive traces are associated with a fatigue wear mechanism (*sensu* Adams et al., 2009) produced by a thrusting percussion motion. As no major differences were found between HWK EE and EF-HR on pits, micro-fractures, impacts and crushing (Mann-Whitney U, *p*> 0.05), results of both sites are based on the general classification of objects (passive vs active elements). Only one tool from HWK EE showed traces that can be linked to an abrasive wear mechanism.

Crystal crushing, with its frosted appearance (*sensu* Adams et al., 2009) and scattered impact points of irregular/circular morphology, were common on anvils (Figure 8A-2), and superficially affect the grain structure of blanks. Crushed areas (Figure 8C-2) are mainly associated with micro-fractures of irregular (*n*= 4) or stepped (*n*= 1) morphology (Figure 8A-1). Only one anvil displays an intense battered area associated with the development of pits and detachment of small crystal fragments. The horizontal plane of another anvil shows a cluster of parallel, linear traces, 'U'-shaped in section whose maximum length is 20-30 mm (Figure 9A-1). The high incidence and length of these linear traces suggest a sliding movement against a hard material.

Of the nineteen pitted stones analysed macroscopically, two whose surfaces were the best preserved, were selected for microscopic study. In both cases, use-wear patterns of depressions are similar; surfaces are affected by a process of grain fracturing and detachment associated with grain crushing (Figure 7B). The lack of linear traces can be related to the absence of sliding movements during use, and the formation of depressions are the result of thrusting percussion.

Insert Figure 9

Linear traces are absent in all analysed active elements. Impact points (*n*= 36) and crushed areas (*n*= 34) are the most common percussive traces (Figure 10). Pits show an angular /concave morphology and diameter <1 mm, and were identified mainly on knapping hammerstones (*n*= 4) and subspheroids (*n*= 3) from HWK EE. These pits identified in subspheroids and hammerstones can be linked with an intense use, as indicated by the greater occurrence of percussive traces on blanks. Micro-fractures on tools (*n*= 34), common on the battered areas of active elements, are generally stepped in morphology (*n*= 18).

Some quartzite tools (one subspheroid, four knapping hammerstones and two HAE) with percussive traces located on angular areas, show the development of slight rounding and compression of the edge caused by micro-fracturing of crystals (Figure 9B). These micro-fractures diverge in opposite directions and progressively break the active edge causing it to become blunt. The process is more superficial on the HAE specimens due to the low incidence of percussive traces, while on knapping hammerstones the degree of roundness in battered areas is more evident.

Insert Figure 10

4. Discussion

4.1 Percussive activities at HWK EE and EF-HR

Pounded tools involved in flaking activities

Differences are observed between the knapping hammerstones from HWK EE and EF-HR; the earlier assemblage (HWK EE) displays a relatively homogenous size distribution, while at EF-HR it is possible to distinguish a second group of hammerstones larger than 10 cm, which often bear a higher incidence of traces on the surface.

This size variation of knapping hammerstones is connected with the *chaîne opératoire* at each site. At EF-HR, the production of large flakes and LCTs (de la Torre and Mora, submitted 'b') requires larger hammerstones. In contrast, the selection of cobbles for use as hammerstones in HWK EE is adapted to a *chaîne opératoire* of small debitage (de la Torre and Mora, submitted 'a'). The presence of cores with percussive marks (Table 7) highlights the multi-functionality of these tools. Thus, in both Oldowan and Acheulean assemblages analysed, re-utilisation of objects as battering and flaking tools seems to be a common practise.

Flaking activities are predominant at both sites, and include bipolar knapping as well as freehand flaking (de la Torre and Mora, submitted ‘a’ and ‘b’). The bipolar technique is more common at HWK EE, where 74 bipolar cores (8.0% of all cores from the T1-Main Trench, T27, T28 and T29 trenches) were identified, while at EF-HR (T2-Min Trench and T12) 5.2% of cores (*n*= 9) were bipolar (Table 7).

Pitted stones were described previously at Olduvai, primarily from Beds III and IV (Leakey and Roe, 1994), and more rarely from Beds I and II (Leakey, 1971). These objects have been linked to bipolar knapping (Jones, 1994), and experimental work has shown that cobbles used as passive and active elements can develop depressions on their surfaces (Le Brun-Ricalens et al., 1989; Jones, 1994; Roda et al., 2012). It was not possible to assess with confidence whether the pitted stones from HWK EE and EF-HR were used as active or passive elements, as most were of a size suitable for both motions. Whichever the case, most of the HWK EE and EF-HR pitted stones can be considered as part of a bipolar *chaîne opératoire*, due to the characteristics of depressions which have developed through a process of repetitive impact in which the surface is fractured, producing the detachment of small fragments, and progressively forms a depression with an irregular internal surface. These features, as well as the presence of bipolar cores and *pieces esquilles* in the lithic assemblages, suggest that most pitted stones from HWK EE and EF-HR were involved in bipolar knapping activities.

Experimental bipolar anvils of Olduvai quartzite usually do not develop depressions, and they show instead large and clustered crushed areas (de la Torre et al., 2013). Such wear patterns have not been identified conclusively on any of the analysed percussive tools, suggesting that both HWK EE and EF-HR hominins chose preferentially lava cobbles as anvils (i.e. some of the pitted stones) to be used on bipolar knapping activities.

Bone breaking and processing of organic materials

Bone breaking is well documented in Olduvai Gorge fossil assemblages (e.g. Blumenschine and Selvaggio, 1988; Blumenschine, 1995). Bone specimens with percussive traces and notches have been identified at both EF-HR (de la Torre et al., submitted ‘b’) and, particularly, at HWK EE, where incidence of percussive marks on fossils suggests hominins broke limb bones to access the marrow (Pante et al., submitted). In this regard, it has been suggested elsewhere (Mora and de la Torre, 2005) that anvils (which were identified only at HWK EE), and probably other tools such as HFA, could have been involved in bone breaking.

Experiments have shown that bone marrow extraction is an activity during which the use-wear formation process is very slow, and other percussive activities (such as nut cracking or plant pounding) can produce similar use-wear patterns (de la Torre et al., 2013; Sánchez Yustos et al., 2015). Experimental anvils occasionally have fragments detached, and bear scattered impacts produced by missed blows, microscopic abrasions (made by the movement of the bone across their surface), and small removals along the edges (de la Torre et al., 2013, Benito-Calvo et al., in press). Hammerstones used to break bones show grain and crystal crushing on their surfaces, with sporadic detachment of small fragments and grains. Damage becomes more intense on those hammerstones used for longer period (Benito-Calvo et al., in press). Micro 3D techniques have shown that use-wear marks on tools used for breaking bones are mainly recognised at a microscopic level, rather than macroscopically. This is because bones absorb force transmitted by the hammer, which is thus barely transferred to the anvil. Therefore, bone-breaking tools may go undetected in the archaeological record unless a microscopic approach is adopted (Benito-Calvo et al., in press).

Meat and plant processing, particularly underground storage organs (USOs), have been identified in the ESA record through functional analysis on flakes (e.g. Lemorini et al., 2014). In HWK EE, the presence of cut marks on fossils indicates that hominin accessed carcasses (Pante et al., submitted), and in EF-HR the same pattern probably applies (de la Torre et al., submitted ‘b’). However, the identification of these activities through the analysis of archaeological pounding tools is uncertain. Experimental anvils used to process tubers and tenderize meat show impact points and crushed areas scattered across the anvil surfaces (de la Torre et al., 2013).

Nut-cracking activities are known in the ESA (Goren-Inbar et al., 2002; 2014; 2015), but its identification is generally elusive in most of the archaeological record. Experimental anvils used for nut cracking by humans show a very low degree of surface modification, with only few isolated impact points and shallow abrasions identified microscopically (de la Torre et al., 2013). Experimental anvils of Olduvai quartzite used by chimpanzees *(Pan troglodytes*) in nut cracking (Arroyo et al., 2016) also show a low degree of modification, with occasional detachment of fragments from tools’ edges. Use-wear marks in active and passive elements are characterised by small crushed areas and impact points located mainly on peripheral areas of the working surfaces. This use-wear pattern has been interpreted as the result of the contact between the active and the passive elements (Arroyo et al., 2016). Overall, quartzite nut cracking tools used by captive chimpanzees show similar use-wear traces (small area of coverage, similar distribution patterns) to anvils used for plant processing or bone breaking (Arroyo et al., 2016). Such similarities of use-wear patterns on tools involved in different tasks are connected with the adoption of a thrusting percussion motion in all these tasks, and the resistant properties of quartzite, and therefore contribute to further complicate the functional attribution of EF-HR and HWK EE pounding tools.

As a whole, wear formation on pounding tools used to process organic materials is dependent on the length of the activity, the hardness of the material process, and the intensity of the contact between the active and the passive elements. This latter process (i.e. contact between the hammer and the anvil) is responsible for most of wear traces observed on the experimental tools. Only microscopic abrasions identified on some anvils used to break bones and crack nuts are the result of a friction motion against the materials during the activity. In addition, similarities on use-wear patterns on tools employed on different activities are caused by to the use of similar kinetic motions.

Reconstructing percussive activities by hominins: a comparison of experimental and archaeological pounding tools

It is relevant to acknowledge that a correlation of bone breaking or plant processing with a particular type of pounding tool is uncertain. However some patterns can be recognised on both the archaeological and the experimental assemblages.

Quartzite HAE and utilised materials from HWK EE with low intensity wear traces implying contact with a medium-low resistant material can be added to anvils as tools potentially used for processing bones and/or other organic materials. This is suggested by microscopic analysis which revealed use-wear traces such as impacts, step fractures or pits associated with a thrusting percussion motion, and having similar morphologies to those traces seen on experimental tools (de la Torre et al., 2013; Arroyo et al., 2016). Further similarities are evident on other anvils from Bed I and II Leakey's assemblages, which show working surfaces are dominated by scattered impact points, stepped fractures, abrasions, and crushed crystals (Arroyo and de la Torre, 2016). Such consistent use-wear patterns on the anvils help to speculate on their potential use on similar activities across Beds I and II.

HFA have been recognised in other ESA sites such as Gadeb (de la Torre, 2011), Garba IVD (Gallotti, 2013) and Gesher Benot Ya'aqov (Alperson-Afil and Goren-Inbar, 2016). All of them are very similar despite their chronological and geographic variability. Assessing their function is problematic as experimental active pounding elements do not display similar use-wear patterns as those seen on archaeological pieces. The latter show intense percussive traces and have multiple fractures indicating potential involvement in heavy duty tasks in which they were in contact with high resistant materials.

The presence of subspheroids/spheroids in HWK EE is a further difference with EF-HR, where there are none. Leakey (1971) noted that the presence of these tools increased in Middle and Upper Bed II, and considered them to be the benchmark of the Developed Oldowan. Morphological characteristics of subspheroids/spheroids have been widely discussed in the literature, with some supporting a preconceived spherical shape (Texier and Roche, 1995), while others have considered their final shape as the result of intense use (e.g. Schick and Toth, 1994). Subspheroids/spheriods have been interpreted as throwing implements (Leakey, 1931; 1950; Clark, 1955; Leakey, 1971; Wilson et al., 2016), knapping hammerstones (Willoughby, 1987; Schick and Toth, 1994), cores with subsequent battering (Mora and de la Torre, 2005), and active elements for the processing of plants (Willoughby, 1985; Sánchez Yustos et al., 2015). At HWK EE, flaking scars clearly link subspheroids with knapping activities (Figure 6B), while the superficial incidence of percussive marks (Figure 6A) suggests additional use in non-invasive activities (e.g. contact with materials of medium-low resistance, or limited use).

All things considered, use-wear patterns on pounded tool from HWK EE and EF-HR suggest that hominins primarily used them in a direct percussion motion. Percussive tools involved on knapping activities (hammerstones, pitted stones and some re-used cores) are predominant on both sites. The low incidence of use-wear traces on tool types such as HAE, anvils and subspheroids, reinforce their use on non-flaking activities to process medium-soft materials which included limb bones, but probably plants and/or nuts as well. In this regard, while acquisition of meat is often invoked as the main objective of Plio-Pleistocene subsistence strategies (e.g., Plummer, 2004), the limited number of studies on use wear analysis (e.g. Keeley and Toth, 1981; Sussman, 1987; Lemorini et al., 2014) are pointing to other functions for the early stone tools, and a wide breadth of the hominin diet. Nevertheless, establishing which specific organic materials beside bones were processed through pounding activities at Olduvai Gorge will require further research, and the aid of other techniques such as residue analysis.

4.2 The HWK EE and EF-HR percussive assemblages in the wider context

Absolute frequencies of pounding tools from Olduvai Middle and Upper Bed II assemblages (Table 10) indicate variable proportions, irrespective of whether they are Acheulean or Oldowan. Figure 11 suggests association of some sites with particular tool types, such as hammerstones at HWK EE (Leakey and OGAP), EF-HR and FC West, or spheroids/subspheroids at BK and HWK E.

Insert Table 10

Insert Figure 11

Overall, there seems to be no dichotomy at Olduvai between the Acheulean and Oldowan on the frequencies of pounding tools. Rather than cultural, differences must be function-related, and therefore each locality should be considered individually. There is a greater variety of pounding tools (e.g. HAE) which might have not been used for stone knapping activities at HWK EE, while at EF-HR percussive tools related to flake and LCT production predominate. In other Acheulean localities such as TK, there is a large collection of percussive objects with anvils and spheroids/subspheroids (Leakey, 1971; de la Torre and Mora, 2005), although recent excavations have documented lower frequencies of both types of percussive tools (Santonja et al., 2014). Pounding tools have also been recognised in other East African ESA sites of a similar chronological range as EF-HR and HWK EE. Such is the case at Koobi Fora (Isaac, 1997), Garba IV (Gallotti, 2013), and Gadeb 2E (de la Torre, 2011) among others, although percussive objects rarely represent more than 5% of the entire lithic assemblages.

5. Conclusions

Recent excavations at EF-HR and HWK EE produced a large collection of tools involved in percussive activities which have been macro- and microscopically analysed in this paper. We have shown that hominins adjusted selection of hammerstones according to different knapping activities, with the larger hammerstones used at EF-HR related primarily to the production of large cutting tools. Documentation of hammerstones reused as cores, subspheroids resulting from a combination of flaking and battering tasks, and pitted stones with occasional flaking scars, reinforce the poly-functional nature of Early Stone Age tools.

The results presented in this paper highlight the importance of applying use wear analysis to percussive tools as means to interpret hominin subsistence activities. Our microscopic analysis shows variability in the intensity of use that could be linked to the processing of different materials. The larger collection and variety of pounding tools found at HWK EE reveals a wider range of activities, probably involved in bone breaking, bipolar knapping and possibly the processing of other organic materials, while at EF-HR the focus is primarily focused on the production of stone tools. The data presented here suggests inter-assemblage variability in pounding assemblages, a variability that includes the existence of specific points in the landscape which early humans dedicated to particular tasks.

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Figure 8. Use-wear patterns in HWK EE anvils: A) T29L52-83 bears impact points on the central area of the horizontal plane. 1.-Impact point associated with an irregular micro-fracture (40x, scale 700 µm); 2.-Cicular impact point (40x, scale 700 µm). B) Artefact T29L51-264 shows a small crushed area located on the edge. C) Anvil T28L40-1 with stepped edge fractures. 1.-Detail of crystal fracture (10x, scale 3 mm); 2.-Crystal crushing

(10x, scale 3 mm).

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Figure 10. Microwear traces of a Trachyte/trachyandesite hammerstone (EF-HR L2-1145) from EF-HR bearing grain crushing (1. 30x, scale 1 mm; 2. 50x, scale 800 µm) and impact points (3. 20x, scale 2 mm). Yellow arrows refer to battered scars.

Figure 11. Correspondence factorial analysis (CFA) of percussive tools per Middle/Upper Bed II sites (see details in Table 9). Sph/Sub-sph: spheroids and subspheroids. SHK have been excluded as Mary Leakey did not collect any hammerstones.

Supplementary Online Material

SOM 1. Absolute and relative frequencies of percussive objects across different stratigraphic intervals at HWK EE (A), and the geological context of pounded tools from EF-HR (B).

SOM 2. 3D model of the HAE from Figure 4B.

SOM 3. 3D model of a pitted stone (HWKEE L6-981) with a single angular depression and polished inner surface.

SOM 4. 3D models of the pitted stone from Figure 7B and object T29L50-89. Both objects are poly-functional tools, as they show battering marks and flaking scars.

Tables

Table 1

	EF-HR		HWK EE	
	N	**%**	**N**	**%**
Battered fragments	0	0	19	5.4
Fractured knapping hammerstones	8	16.0	123	35.2
Knapping hammerstones	30	60.0	119	34.1
Hammerstones with active edge	3	6.0	20	5.7
Hammerstones with fracture angles	7	14.0	19	5.4
Subspheroids	0	0.0	12	3.4
Utilised material	0	0.0	7	2.0
Pitted stones	2	4.0	19	5.4
Passive hammer with friction marks	0	0.0	2	0.6
Anvils	0	0.0	9	2.6
Total	**50**	**100**	**349**	**100**

Table 2

Function	Technological category	Abbreviation	Characteristics	Reference
Active elements	Knapping hammerstone		Concentrated battered areas and impact points located on convex surfaces, occasionally linked to fractures with an oval/circular morphology	Leakey, 1971
	Hammerstone with fracture angles	HFA	Battered areas associated to multiple angular and dihedral fractures, with no directionality of the detachments, and opposed to an unmodified surface	Mora and de la Torre, 2005
	Hammerstone with active edge	HAE	Battering on a natural angular surface associated to multiple non-invasive fractures	This work
	Spheroids/subspheroid		Tools with a spherical shape, faceted scars and battered areas or impact points located mainly on the ridges	Leakey, 1971
	Utilised material		Isolated impact marks scattered across the surfaces of the blank an a superficial incidence	This work
Active/passive elements	Pitted Stone		Oblong/oval depressions on one or more surfaces of the artefact	Leakey, 1994
Passive elements	Anvil		Cuboid blocks or cobblestones with 90^o edges bearing percussive marks and plunging scars	Leakey, 1971
	Passive hammer with friction marks	PHFM	Tools whose working areas show traces produced by a friction motion	This work

Table 3

		EF-HR					**HWK EE**				
		N	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**	**N**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Fractured hammerstones	Length	8	102	43	80,4	19,0	123	103	15	68,3	16,5
	Width		80	37	61,3	15,6		85	10	54,8	13,8
	Thickness		77	23	45,0	16,4		72	7	41,4	12,2
	Weight		790,0	67,1	301,3	227,1		867,2	10,0	222,0	141,1
Hammerstones with active edge	Length	3	123	66	88,7	30,2	20	140	68	88,1	15,7
	Width		93	62	73,7	16,9		95	47	72,2	13,4
	Thickness		64	52	58,0	6,0		88	27	59,5	14,6
	Weight		876,7	337,9	536,0	296,4		1481,2	237,4	558,6	314,3
Hammerstones with fracture angles	Length	7	129	67	98,9	21,4	19	111	41	78,3	21,0
	Width		108	52	84,3	20,4		91	33	65,5	18,1
	Thickness		97	46	66,7	17,7		77	24	55,8	15,6
	Weight		1704,2	321,7	879,4	536,1		985,1	41,1	466,9	293,5
Pitted stones	Length	2	134	93	113,5	29,0	19	112	63	86,3	12,8
	Width		95	90	92,5	3,5		98	45	68,8	14,1
	Thickness		84	65	74,5	13,4		90	33	51,4	16,0
	Weight		1646,9	656,5	1151,7	700,3		1803,6	175,3	505,5	450,2
PHFM	Length	0					2	74	60	67,0	9,9
	Width							58	49	53,5	6,4
	Thickness							38	35	36,5	2,1
	Weight							212,9	139,0	176,0	52,3
Knapping hammerstones	Length	30	135	52	96,0	20,8	119	141	31	75,4	16,0
	Width		122	34	81,8	20,8		99	30	60,7	12,9
	Thickness		98	13	60,9	17,2		79	0	47,3	11,8
	Weight		2239,1	22,0	703,9	468,1		1450,9	38,0	328,9	202,0
Subspheroids	Length	0					12	95	39	62,8	15,4
	Width							82	29	56,0	14,0
	Thickness							75	24	51,4	13,8
	Weight							783,5	38,1	285,1	206,2
Utilised material	Length	0					7	88	66	74,7	8,1
	Width							63	53	58,6	3,5
	Thickness							57	34	43,1	9,7
	Weight							378,1	158,1	251,7	75,6
Anvils	Length	0					9	127	76	96,2	14,9
	Width							108	58	77,3	18,3
	Thickness							80	40	54,8	11,7
	Weight							918,5	311,8	588,4	231,0

Table 4

		EF-HR		HWK EE	
		N	**%**	**N**	**%**
Fractured knapping hammerstones	Basalt	1	12.5	23	18.7
	Quartzite	3	37.5	29	23.6
	Phonolite	2	25.0	47	38.2
	Indet. lava	0	0.0	1	0.8
	Trachyte	2	25.0	23	18.7
Hammerstones with active edge	Basalt	0	0.0	1	5.0
	Quartzite	1	33.3	10	50.0
	Phonolite	2	66.7	2	10.0
	Pumice	0	0.0	1	5.0
	Trachyte	0	0.0	6	30.0
Hammerstones with fracture angles	Basalt	4	57.1	8	42.1
	Quartzite	1	14.3	6	31.6
	Phonolite	1	14.3	2	10.5
	Trachyte	1	14.3	3	15.8
Pitted stones	Basalt	2	100.0	8	42.1
	Phonolite	0	0.0	7	36.8
	Pumice	0	0.0	1	5.3
	Trachyte	0	0.0	3	15.8
PHFM	Phonolite	0	0.0	1	50.0
	Trachyte	0	0.0	1	50.0
Knapping hammerstones	Basalt	12	40.0	39	32.8
	Quartzite	2	6.7	27	22.7
	Phonolite	6	20.0	16	13.4
	Gneiss	1	3.3	0	0.0
	Trachyte	9	30.0	37	31.1
Subspheroids	Quartzite	0	0.0	12	100.0
Utilised material	Quartzite	0	0.0	7	100.0
Anvils	Quartzite	0	0.0	9	100.0

Table 5

		EF-HR		**HWK EE**	
		N	**%**	**N**	**%**
Fractured knapping hammerstones	Indet.	8	100.0	123	100.0
Hammerstones with active edge	Block	0	0.0	6	30.0
	Cobble	3	100.0	5	25.0
	Indet.	0	0.0	9	45.0
Hammerstones with fracture angles	Cobble	7	100.0	13	68.4
	Indet.	0	0.0	6	31.6
Pitted stones	Cobble	2	100.0	15	78.9
	Indet.	0	0.0	4	21.1
PHFM	Cobble	0	0.0	1	50.0
	Indet.	0	0.0	1	50.0
Knapping hammerstones	Block	0	0.0	5	4.2
	Cobble	23	76.7	90	75.6
	Fragment	1	3.3	0	0.0
	Indet.	6	20.0	24	20.2
Subspheroids	Block	0	0.0	1	8.3
	Cobble	0	0.0	1	8.3
	Indet.	0	0.0	10	83.3
Utilised material	Block	0	0.0	4	57.1
	Cobble	0	0.0	1	14.3
	Indet.	0	0.0	2	28.6
Anvils	Block	0	0.0	5	55.6
	Indet.	0	0.0	4	44.4

Table 6

ID	Category	Blank	Area (mm^2)	Perimeter (mm)	Shape descriptors			
					Circularity	**Aspect Ratio (AR)**	**Roundness**	**Solidity**
L6-1692	HFA	Indet	1712.49	165.527	0.785	1.041	0.96	0.973
L2-712	HFA	Indet	1492.53	159.276	0.739	1.204	0.831	0.975
T27L31-55	HFA	Indet	2963.83	225.664	0.731	1.189	0.841	0.968
L1E-168	HFA	Indet	2023.67	172.481	0.855	1.018	0.983	0.985
LCHA-518	HFA	Cobble	1553.84	151.318	0.853	1.049	0.953	0.986
L6-837	Subspheroid	Block	5780.81	302.705	0.793	1.169	0.855	0.972
LCHA-1050	Subspheroid	Indet	3659.66	230.895	0.863	1.069	0.935	0.988
L1E-152	Subspheroid	Indet	3943.83	248.412	0.803	1.168	0.856	0.978
L10-2495	Subspheroid	Indet	3128.27	220.42	0.809	1.092	0.916	0.973
L6-951	Subspheroid	Indet	2754.34	205.24	0.822	1.153	0.867	0.984
L1-2540	Subspheroid	Indet	2488.26	195.084	0.822	1.211	0.826	0.982
LCHA-1081	Subspheroid	Indet	2038.66	177.781	0.811	1.135	0.881	0.972
L6-1044	Subspheroid	Cobble	2019.42	172.878	0.849	1.037	0.965	0.983
L10-1421	Subspheroid	Indet	2196.56	182.052	0.833	1.093	0.915	0.978
T29L50-96	Subspheroid	Indet	1215.77	136.613	0.819	1.078	0.928	0.975
L2-530	Subspheroid	Indet	707.49	103.612	0.828	1.307	0.765	0.979
T27L30-7	Subspheroid	Indet	1762.5	163.511	0.828	1.083	0.923	0.984

Table 7

Total		EF-HR		HWK EE	
		N Objects with battering	**%**	**N Objects with battering**	**%**
Cores EF-HR (n= 139) HWK EE (n= 925)	Bipolar Cores	9	6,47	74	8,00
	Cores with *écaillés*	7	5,04	58	6,27
	Cores with percussive marks	28	20,14	217	23,46
Flakes EF-HR (n= 524) HWK EE (n= 1368)	Flakes with *écaillés*	6	1,15	81	5,92
	Flakes with percussive marks	2	0,38	76	5,56
Flake fragments EF-HR (n= 884) HWK EE (n= 3081)	Flake fragments with *écaillés*	2	0,23	46	1,49
	Flake fragments with percussive marks	13	1,47	117	3,80
Angular fragments EF-HR (n= 121) HWK EE (n= 964)	Angular fragments with *écaillés*	0	0,00	4	0,41
	Angular fragments with percussive marks	1	0,83	137	14,21

Table 8

	HWK EE					**EF-HR**			
	Qtz	Ba	Ph	Pu	T/Tr	Qtz	Gn	T/Tr	**Total objects analysed**
Fractured hammestone	0	0	1	0	0	0	0	0	**1**
Knapping hammerstones	6	1	0	0	0	0	1	3	**11**
HAE	5	0	1	0	1	1	0	0	**8**
HFA	4	0	0	0	1	1	0	0	**6**
Core-hammerstones	2	0	0	0	0	1	0	0	**3**
Subspheroids	11	0	0	0	0	0	0	0	**11**
Pitted Stones	0	1	0	1	0	0	0	0	**2**
Anvils	7	0	0	0	0	0	0	0	**7**
Total	**35**	**2**	**2**	**1**	**2**	**3**	**1**	**3**	**49**

Table 9

		Linear Traces				**Polish/abrasion**				**Pits**				**Micro-fractures**				**Impact points**				**Crushing**			
		Absent		Present		Absent		Present		Absent		Present		Absent		Present		Absent		Present		Absent		Present	
	Total objects analysed	N	Column %	N	Column %	N	Column %	N	Column %	N	Column %	N	Column %	N	Column %	N	Column %	N	Column %	N	Column %	N	Column %	N	Column %
Fractured hammestone	1	1	2.1	0	0.0	1	2.2	0	0.0	1	2.7	0	0.0	1	10.0	0	0.0	1	16.7	0	0.0	1	12.5	0	0.0
Knapping hammerstones	11	11	22.9	0	0.0	8	17.8	3	75.0	7	18.9	4	33.3	2	20.0	9	23.1	3	50.0	8	18.6	4	50.0	7	17.1
HAE	8	8	16.7	0	0.0	8	17.8	0	0.0	7	18.9	1	8.3	2	20.0	6	15.4	2	33.3	6	14.0	2	25.0	6	14.6
HFA	6	6	12.5	0	0.0	6	13.3	0	0.0	4	10.8	2	16.7	0	0.0	6	15.4	0	0.0	6	14.0	1	12.5	5	12.2
Core-hammerstones	3	3	6.3	0	0.0	3	6.7	0	0.0	2	5.4	1	8.3	0	0.0	3	7.7	0	0.0	3	7.0	0	0.0	3	7.3
Subspheroids	11	11	22.9	0	0.0	11	24.4	0	0.0	8	21.6	3	25.0	3	30.0	8	20.5	0	0.0	11	25.6	0	0.0	11	26.8
Pitted Stones	2	2	4.2	0	0.0	2	4.4	0	0.0	2	5.4	0	0.0	0	0.0	2	5.1	0	0.0	2	4.7	0	0.0	2	4.9
Anvils	7	6	12.5	1	100.0	6	13.3	1	25.0	6	16.2	1	8.3	2	20.0	5	12.8	0	0.0	7	16.3	0	0.0	7	17.1

Table 10

	Culture	Stratigraphic position	Hammerstones, HAE and HFA	Spheroids/ subspheroids	Anvils and PHFM	Pitted stones	Utilised material/ modified battered nodules and blocks	Total	Reference
HWK E (Levels 3, 4, 5)	Oldowan	Middle Bed II	23	114	19	0	202	358	Leakey, 1971
HWK EE (OGAP)	Oldowan	Middle Bed II	281	12	11	19	7	330	This work
HWK EE (Leakey)	Oldowan	Middle Bed II	70	7	1	3	8**	89	Pante and de la Torre, this volume
FLK N Sandy Conglomerate	Oldowan	Middle Bed II	35	47	2	0	0	84	de la Torre and Mora, 2005
MNK Skull	Oldowan	Middle Bed II	15	6	3	0	54	78	Leakey, 1971
FC West	Acheulean	Middle Bed II	115	0	8	0	0	123	de la Torre and Mora, 2005
MNK Main	Acheulean	Middle Bed II	64	159	24	0	199	446	Leakey, 1971
EF-HR	Acheulean	Upper Bed II	48	0	0	2	0	50	This work
SHK	Acheulean	Upper Bed II	*	318	26	0	115	459	Leakey, 1971
BK	Acheulean	Upper Bed II	43	446	23	0	394	906	Leakey, 1971
TK	Acheulean	Upper Bed II	63	52	51	0	0	166	de la Torre and Mora, 2005

Figure 1

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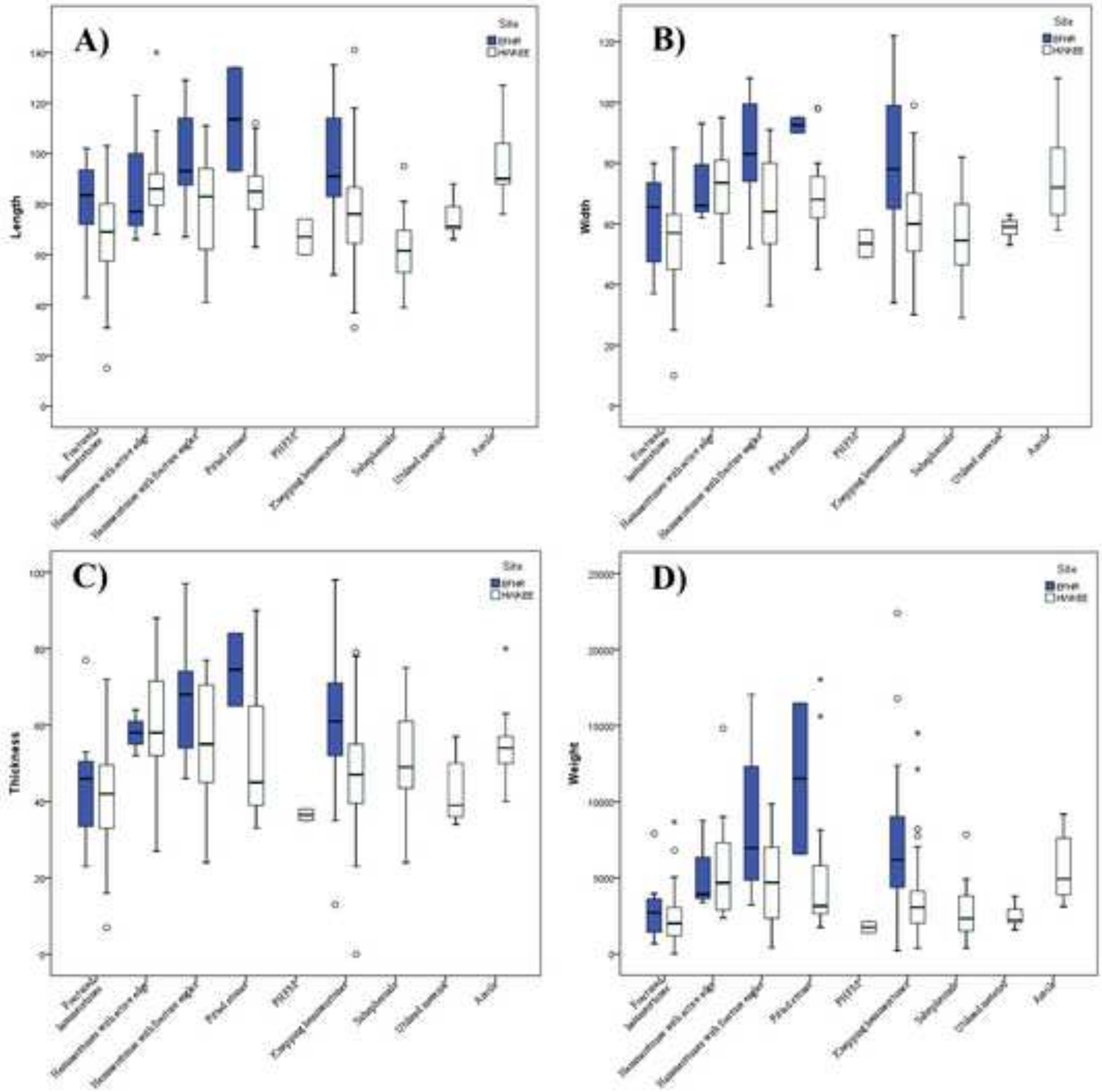

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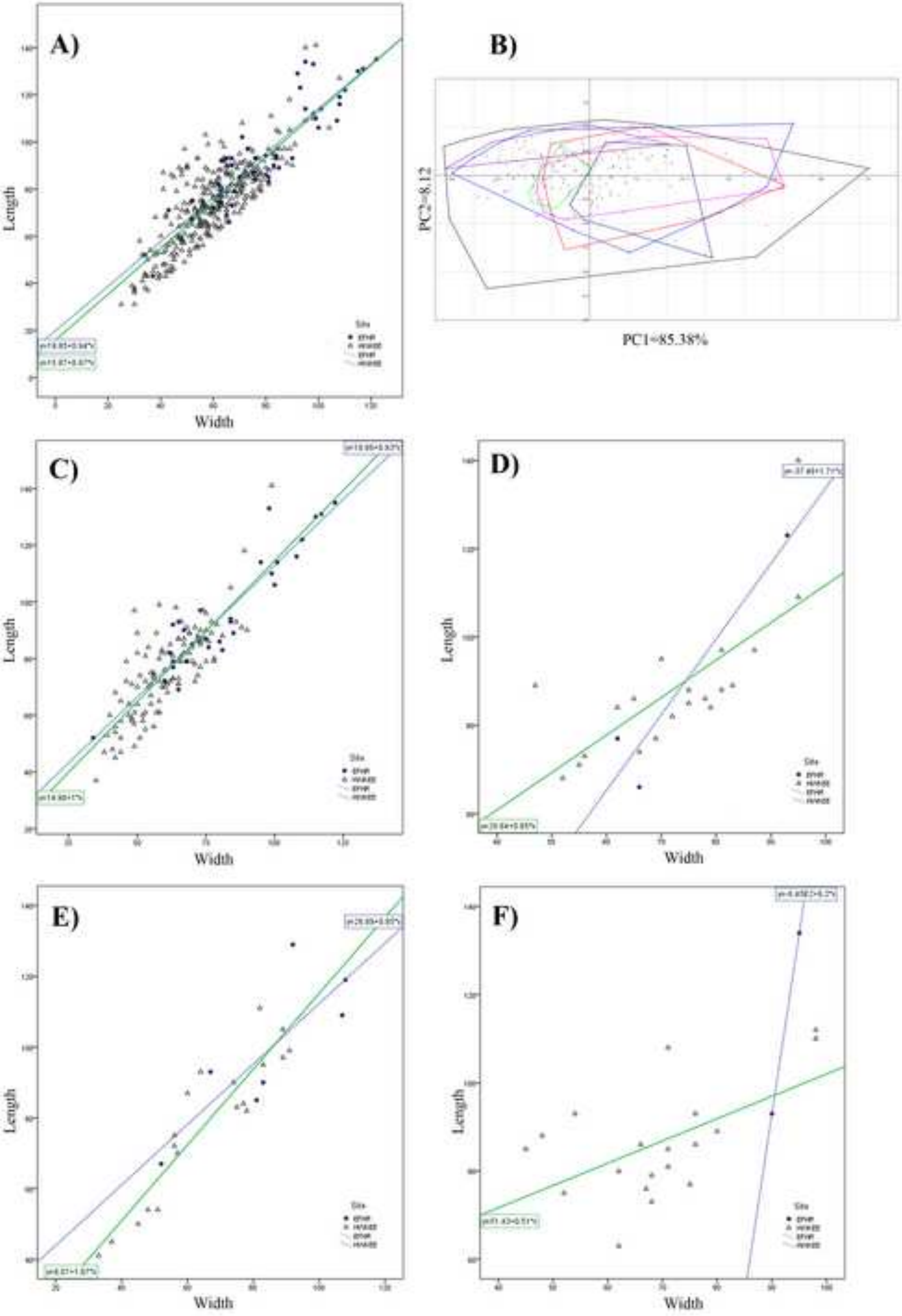

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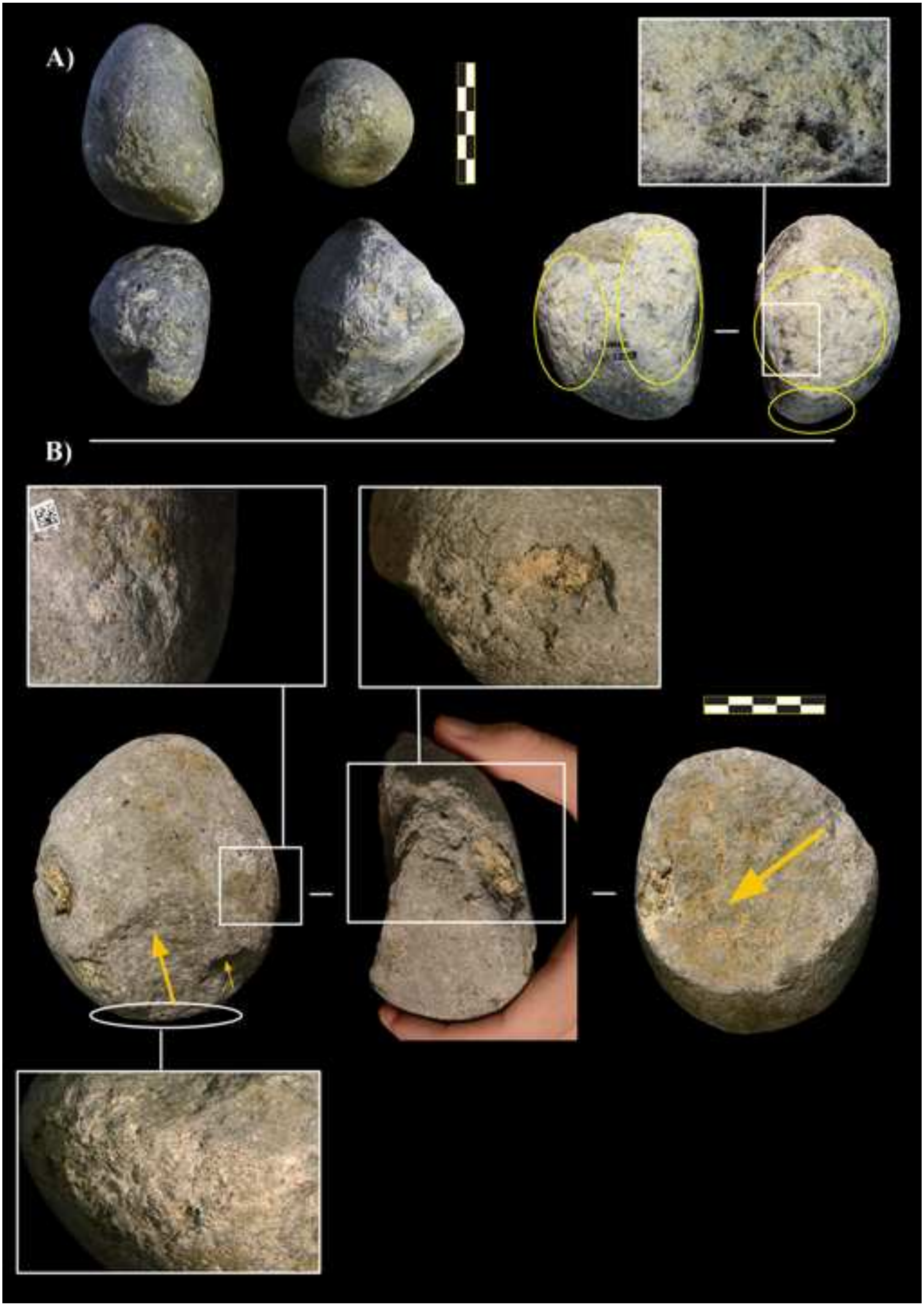

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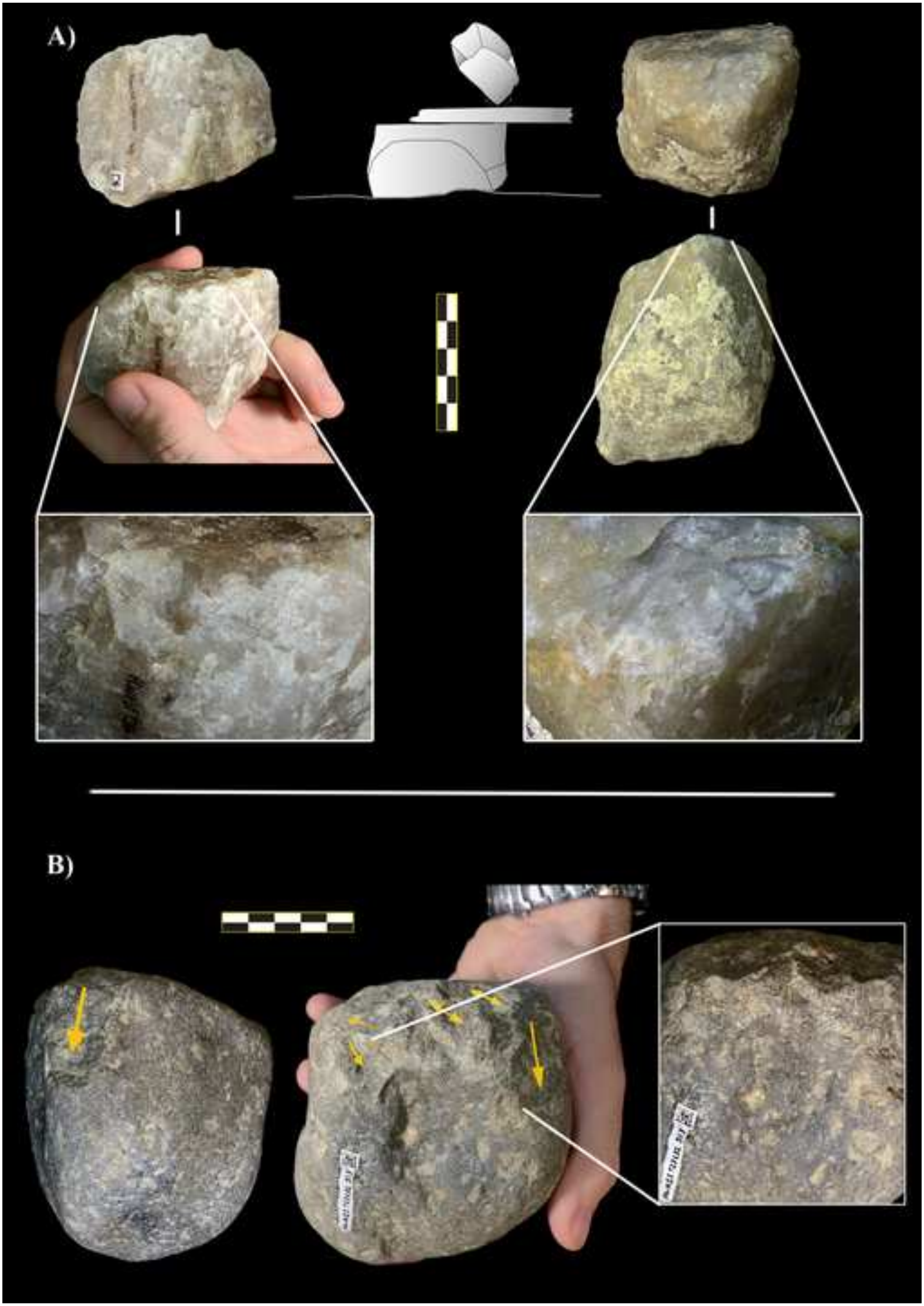

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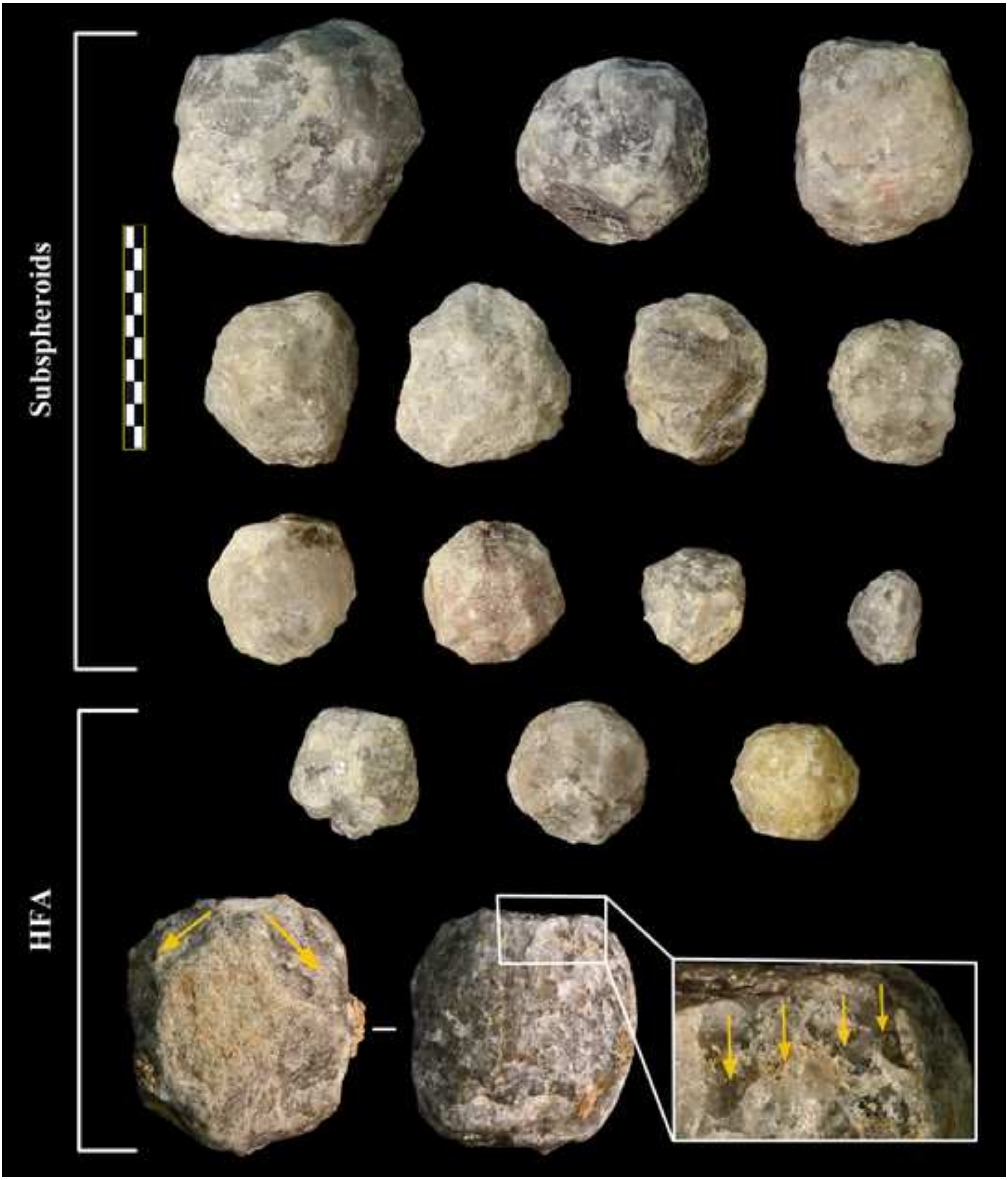

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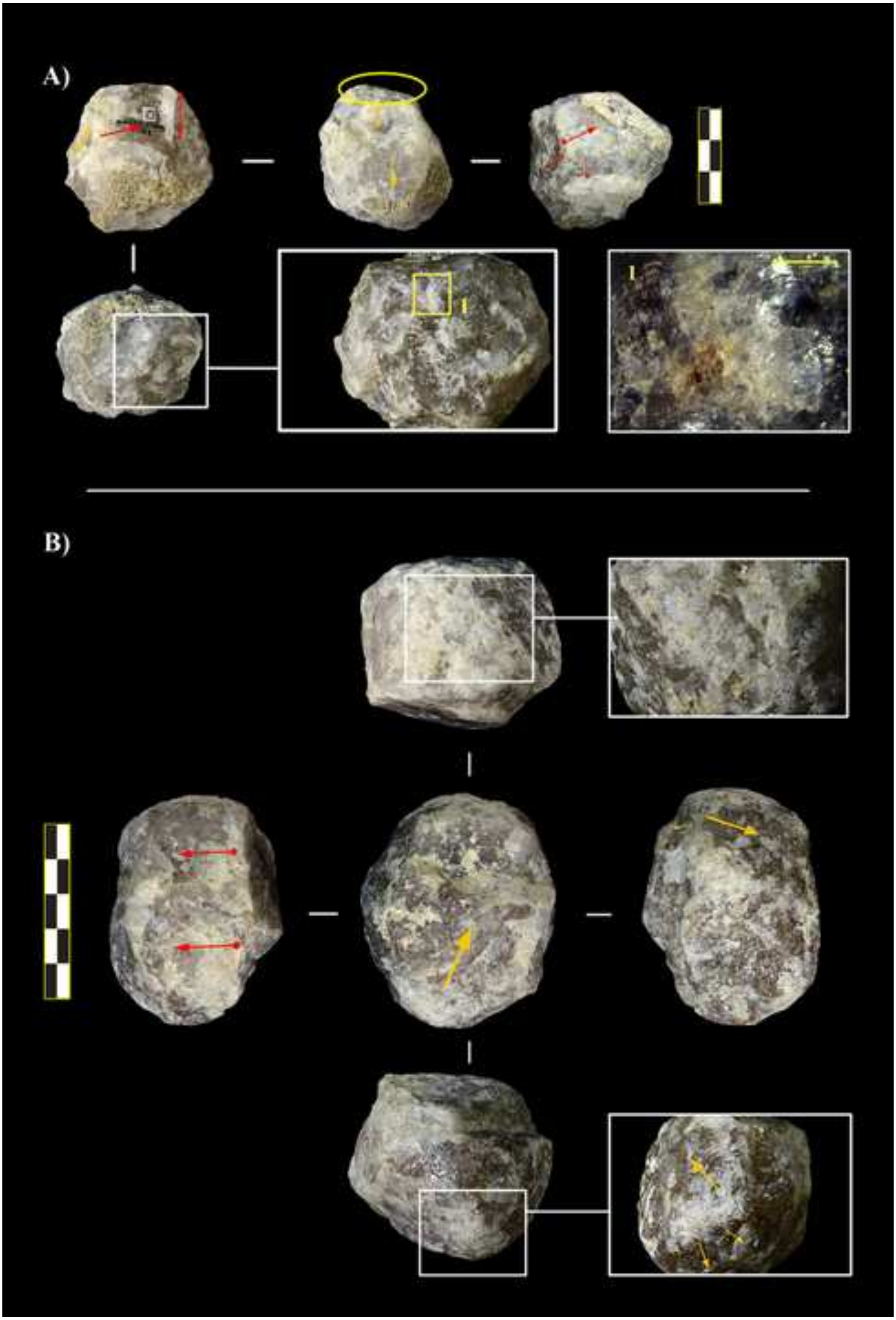

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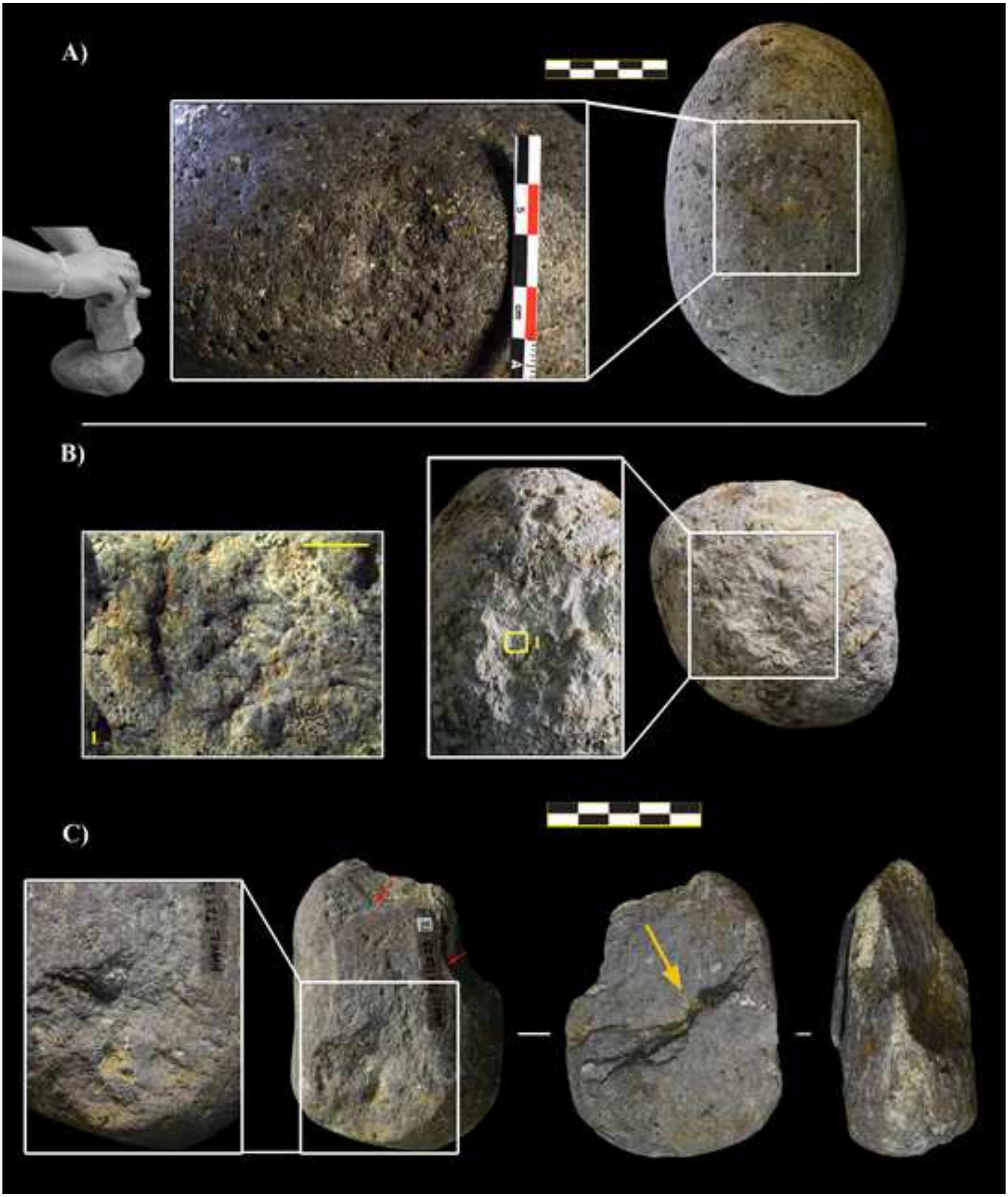

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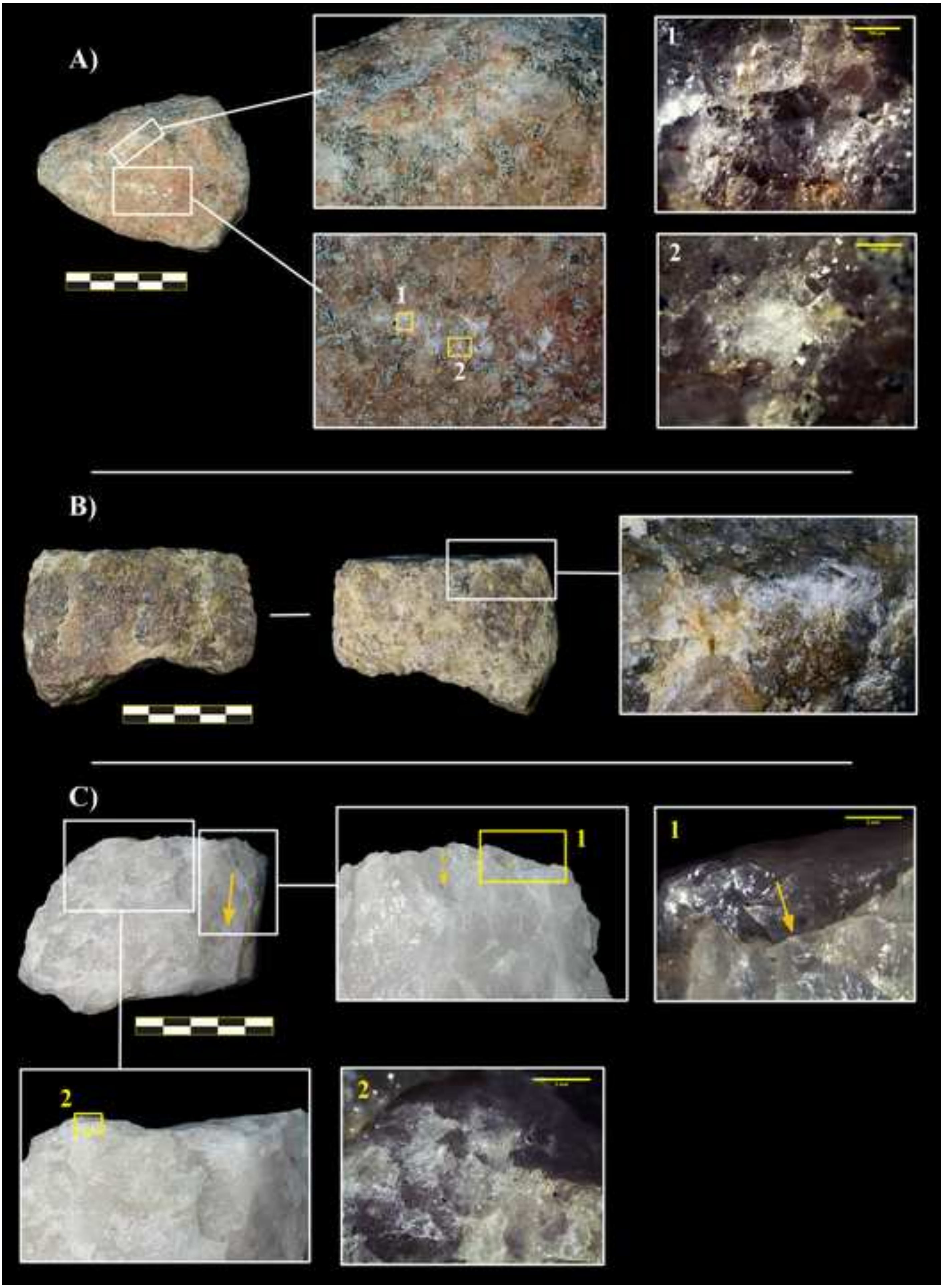

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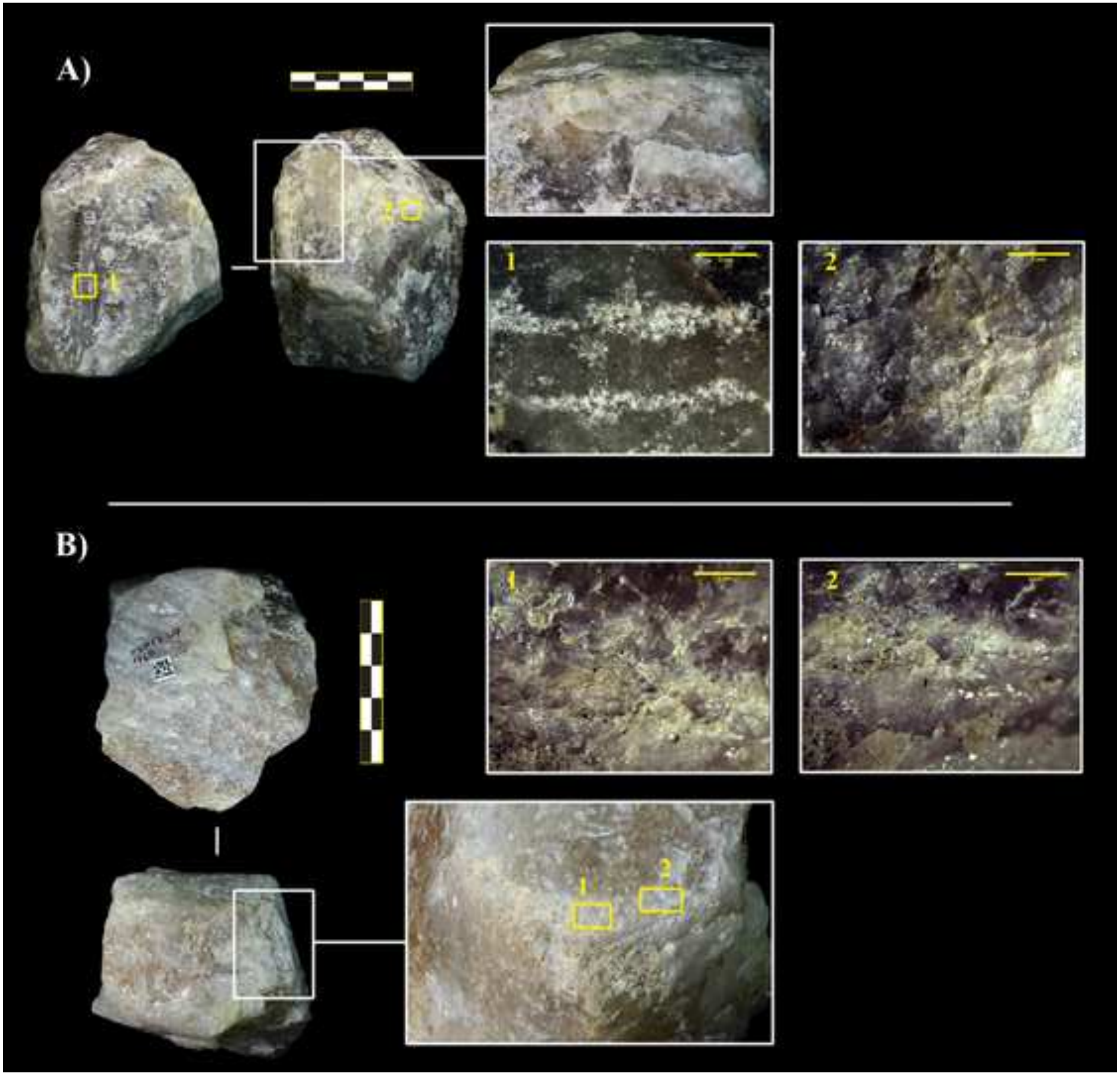

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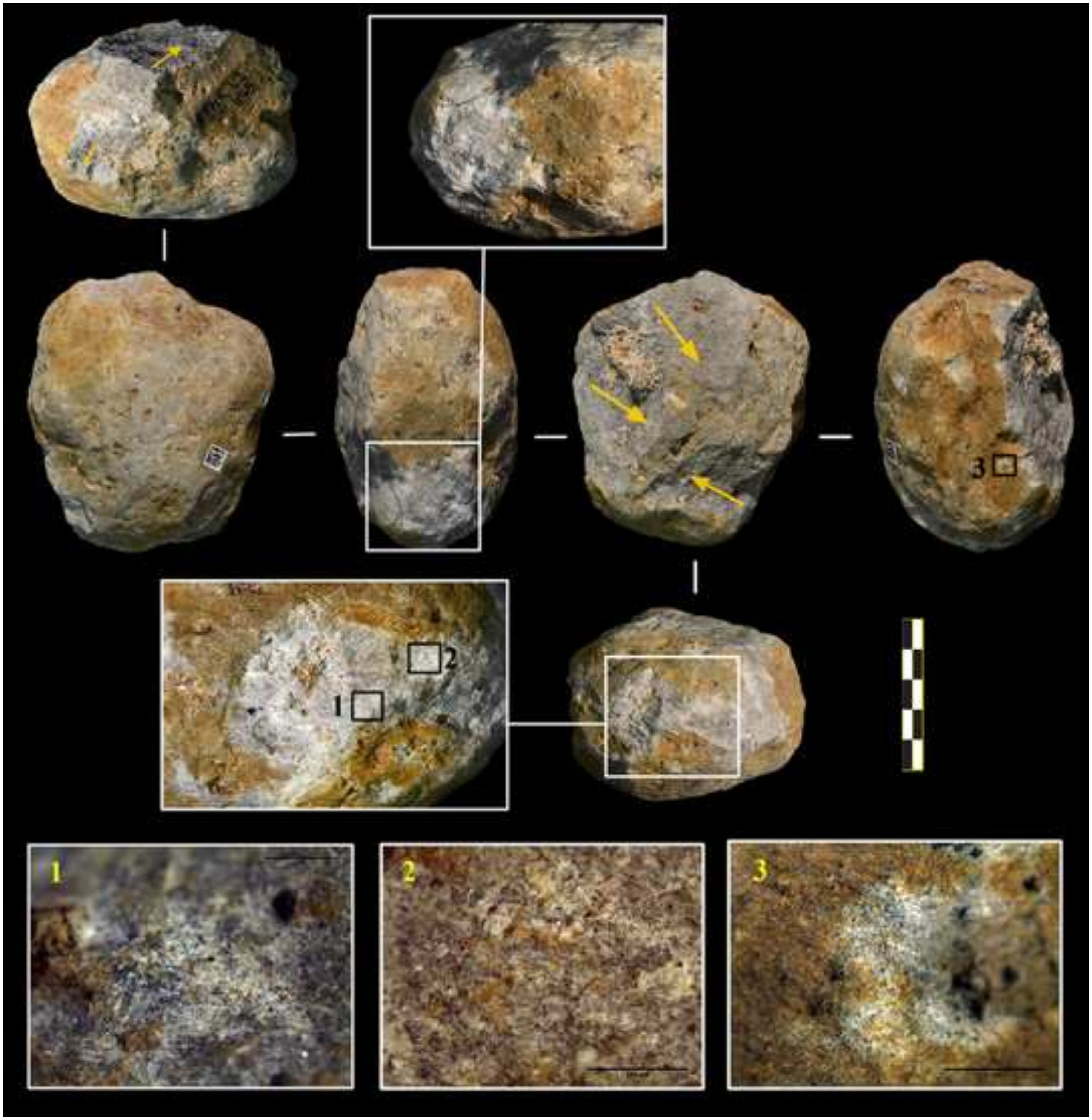
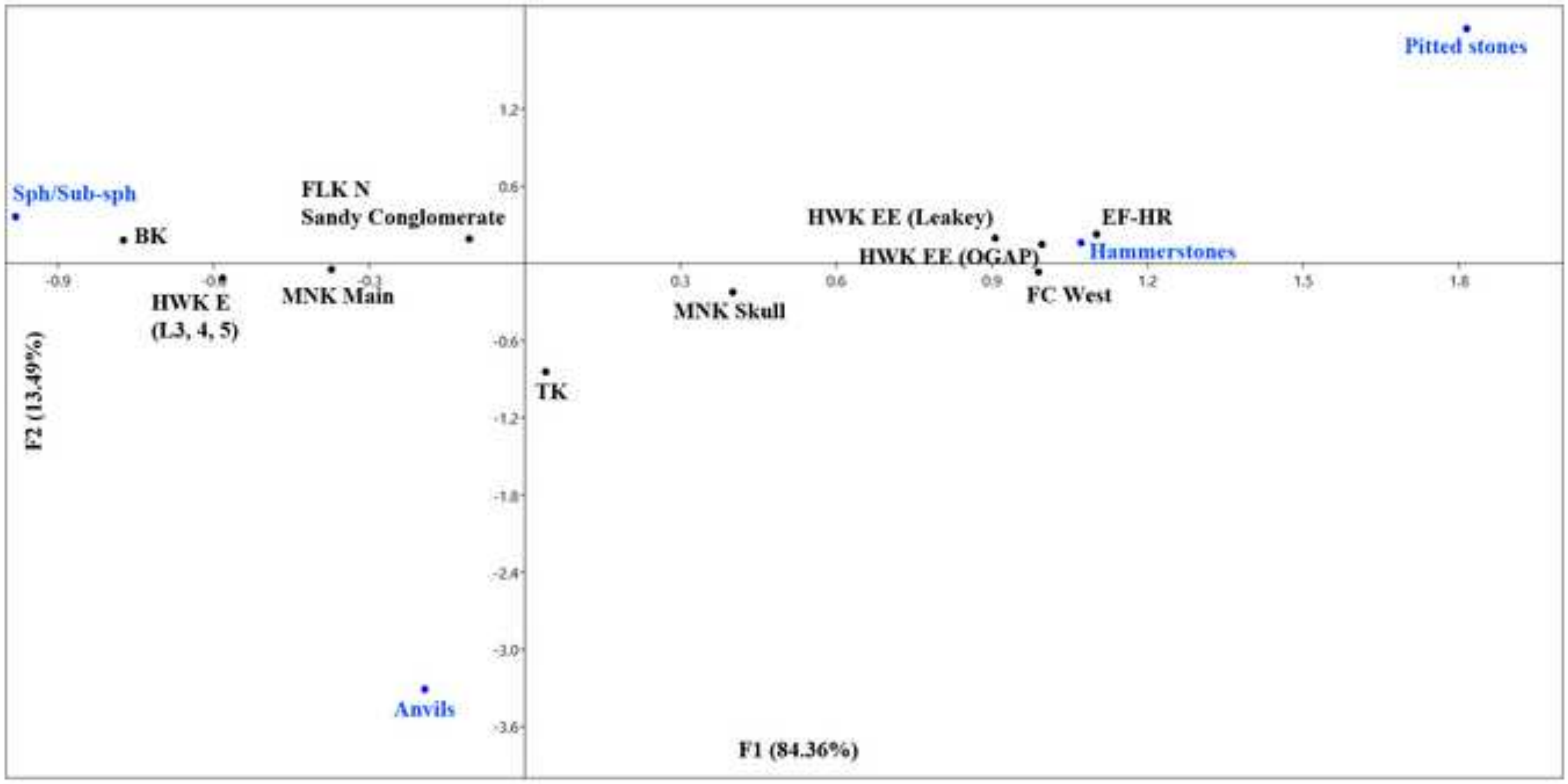


Figure 11


Pitted stones
1.2
Sph/Sub-sph
FLK N
Sandy Conglomerate
0.6
HWK EE (Leakey)
EF-HR
BK
HWK EE (OGAP)
Hammerstones
-0.9
-0.6
-0.3
0.3
0.6
0.9
1.2
1.5
1.8
HWK E
(L3, 4, 5)
MNK Main
MNK Skull
FC West
-0.6
F2 (13.49%)
TK
-1.2
-1.8
-2.4
-3.0
Anvils
-3.6
F1 (84.36%)

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4