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Assessing functionality during the early Acheulean in level TKSF at Thiongo Korongo site (Olduvai Gorge, Tanzania)

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Abstract

To understand the identity of the early Acheulean, it is necessary to discriminate between the variables that influenced the selection of technological strategies. Functionality of the archaeological sites is crucial in assessing the manufacturing strategies of lithic tools. To achieve this goal, analysis of the post-depositional processes must be evaluated. When bone remains have been preserved, anthropic animal processing can be identified through zooarchaeological and taphonomic analyses, and the spatial relationships among all the components can also be assessed, especially when bone surface is not sufficiently preserved.

There are two levels present at Thiongo Korongo, ~1.3 Ma, TKLF and TKSF. These are in autochthonous position with no significant temporal diachrony but with substantial technological differences in the manufacturing of the lithic tools, which enables the analysis of the influence of human activities on technological behaviour. In order to evaluate this issue at TKSF, we present lithic, faunal, taphonomic, fabric, and spatial analyses.

An assemblage of megaherbivores, among which *Sivatherium* is outstanding, dominate the TKSF faunal remains. Cortical preservation is poor; there is no intervention of carnivores, the rate of green fractures is low, and a few cut marks on size 5 and 3b animals were identified. Hence, apparently human intervention on the fauna was not intensive. Spatial and geostatistical analyses hints of a specific area where megaherbivores were processed by humans. Through wear use and biomarker analyses on stone tools, we are currently trying to understand the activities that were carried out in the remaining paleosurface.

At paleosurface TKLF, the main anthropogenic input could be related to activities other than animal resource exploitation, in which large handaxes were necessary. Without the assessment of site functionality and chronological context, this data could have lead to the differences observed at TKLF and TKSF being attributed to different Acheulean stages.

Key words

Early Stone Age, Spatial Analysis, Acheulean Site Function, Lithic Technology, Faunal Analysis, Taphonomy.

1. Introduction

In the last two decades, information related to the emergence of the Acheulean has increased substantially. The current geochronological framework places the onset of the Acheulean in East Africa around 1.7/1.6 Ma at Kokiselei 4 at West Turkana, KGA6-A1 and KGA4-A2 at Konso, FLK West at Olduvai Gorge, BSN-12 and OGS-12 at Gona and Garba IVD at Melka Kunture (Quade et al., 2004; Beyene et al., 2013; Gallotti, 2013; Diez-Martín et al., 2015; Gallotti and Mussi, 2018a). Apart from those, there are not many sites with this technocomplex older than 1.2 Ma: KGA10-A11, KGA7-A1, A2, A3, KGA12-A1 at Konso (Beyene et al., 2013), BSN-12 at Gona (Quade et al., 2004), perhaps Gadeb 2 and 8 (Kurashina, 1978; Clark and Kurashina, 1979; de la Torre, 2011), Okote Member at Koobi Fora (Brown and McDougall, 2011), Nyabusosi 18 (Texier, 1995; 2005),Type Section Complex, Lepolosi, and Noolchalai at Peninj (1.5-1.4 Ma according Isaac and Curtis, 1974; Domínguez-Rodrigo et al., 2009 or 1.2/1.1 Ma according Deino et al., 2006), and Bed II at Olduvai Gorge, with the largest cluster composed of EF-HR, SHK, BK, FC West OF, and TK (Leakey, 1971; de la Torre et al., 2018; Santonja et al., 2014; Domínguez-Rodrigo et al., 2013; Diez-Martín et al., 2014). In the Eastern African sequences, there is a gap in the Acheulean archaeological record between ~1.2 and 1 Ma (Hay, 1994; Roche et al., 2003; Quade et al., 2008; Beyene et al., 2013; Clark and Kurashina, 1979), which allows us to distinguish chronologically the groups of Acheulean sites dated between 1.7 and 1.2 Ma from the later ones.

Knowledge of the Acheulean Technocomplex comes mainly from the technological analysis of the lithic industry (Gallotti, 2013; Diez-Martín et al., 2015; Beyene et al., 2013; Quade et al., 2004; de la Torre, 2011; Texier, 1995; Diez-Martín et al., 2018; Leakey, 1971; de la Torre et al.,2018; Santonja et al., 2014; 2018; Domínguez-Rodrigo et al., 2013; Diez-Martín et al., 2014; Rubio-Jara et al., 2017). Differences in the manufacturing strategies of lithic tools have been established between the Acheulean sites older than 1.2 Ma abaddend the younger ones (de la Torre and Mora, 2005; Sharon, 2007; 2010; Stout, 2011; Diez-Martín and Eren, 2012; Beyene et al., 2013; Sahnouni et al., 2013; Gallotti, 2013; Gallotti and Mussi, 2017, 2018a; Texier, 2018), perhaps not taking into consideration other variables that may influence those strategies, such as cultural traditions, quality and availability of raw material, functionality, etc.

Among these variables, functionality of the archaeological sites is determinant (Presnyakova et al., 2018), although this has been very rarely tackled, partly because most of these sites are more or less affected by hydraulic transport (Domínguez-Rodrigo et al., 2009; Gibbon et al., 2009; Diez-Martín and Eren, 2012; Gallotti, 2013; Diez-Martín et al., 2014; Uribelarrea et al., 2017; de la Torre et al., 2018; Semaw et al., 2018).

Functional analysis must be based on the analysis of the post-depositional processes that form the archaeological assemblages (Diez-Martín and Eren, 2012), particularly in the early Acheulean sites, as many of them are found in alluvial environments, in which taphonomic processes have rarely been taken into consideration (Petraglia and Potts, 1994). In those cases where bone remains are present, the zooarchaeological and taphonomic analyses enable the identification of anthropic activities related to animal processing, however preservation of the bones is not always ideal for an adequate analysis of bone surface modifications. Thus, in order to establish relationships between lithic industry and fauna, or among other elements, after

the analysis of completeness of the archaeological level, the spatial relationships among all the components must be assessed. The associations in the graphic display of spatial analyses are more complex and subtle than what can be visually inferred. Spatial statistical tests have been developed within the fields of earth sciences, health, and economy, and have become essential for the study of spatial distribution in archaeology (Baddeley et al., 2015; Bivand, 2010; Dorman, 2014; Pebesma, 2004; Roger et al., 2013). The analysis of spatial distribution has a great potential to reach conclusions regarding social behaviour, based on the bones and lithic tools abandoned by the hominins. Thus, research on etnoarchaeological, social behaviour and spatial distribution experienced a great surge in the late 70's and 80's of the 20th century (Binford, 1978; Hodder and Orton, 1976, Yellen, 1977). Over 25 years after the first works with statistical application to spatial analysis (Whallon, 1973, Whallon, 1974), there are more powerful statistical tools used in spatial analyses that can be applied to archaeology (Bivand, 2010; Dray et al., 2012; Pebesma, 2004; Roger et al., 2013). These analyses allows the objective determination of the presence and degree of spatial interdependences among the different elements of the archaeological record (Domínguez-Rodríguez and Cobo, 2017).

As has been pointed out, the highest concentration of early Acheulean sites has been recorded in Bed II at Olduvai Gorge (Leakey, 1971; Santonja et al., 2014; Diez-Martín et al., 2009, 2014, 2015; Sánchez-Yustos et al., 2016; Rubio-Jara et al., 2017; de la Torre et al., 2018), and the time span between 1.69 Ma y 1.34 Ma encompasses the whole chronological frame of the early Acheulean. Such characteristics allow the analysis of the variability of this technocomplex during its early stages in a confined geographical frame, with similar availability of lithic raw materials.

At Thiongo Korongo (TK), ~1.3 Ma, one of the highest concentrations of Acheulean lithic tools of the early Acheulean has been preserved (Leakey, 1971; Santonja et al., 2014) in autochthonous position, together with a large number of bones (Yravedra et al., 2016). The remains are allocated mainly on two stratigraphically close paleosurfaces, named TK Lower Floor (TKLF) and TK *Sivatherium* Floor (TKSF). Substantial technological differences can be distinguished in the manufacturing of the lithic tools (Rubio-Jara et al., 2017), which enables the analysis of the influence of the human occupations' functionality on the technological strategies implemented in the manufacturing of lithic tools during the early Acheulean.

In order to evaluate the effects of the functionality of the sites on the technological strategies for the first time, this paper presents the zooarchaeological and taphonomic study of the bone remains and stone tools recorded in the 45.3 m^2 excavated of the TKSF, the geoarchaeological analysis of this level; its depositional patterns and degree of disturbance, the analysis of the spatial integrity, the spatial distribution of faunal and lithic remains, as well as the statistical spatial analysis with the aim of objectively determining whether or not spatial interdependences of different types of archaeological remains exist, and how this dependence is expressed by clusters or regularity (Domínguez-Rodrigo and Cobo-Sánchez, 2017).

2. Thiongo Korongo Site and TKSF level

TK is located 2 km east of the junction of the Main and Side Gorges at Olduvai, Tanzania (**Fig. 1a**). From a stratigraphic point of view, it is located in Upper Bed II, nearby and adjacent to Bed III. It can be related to Tuff IID, and dated by $^{40}Ar/^{39}Ar$ to 1.353±0.035 Ma (Domínguez-Rodrigo et al., 2013).

The site was identified in 1931 by L. Leakey (Leakey, 1951), although not excavated until 1963 (Leakey, 1971), when M. Leakey dug two areas: Trench I, of 46.4 m^2, and Trench II, of 40.5 m^2, four meters apart. An approximately five-meter-thick stratigraphic sequence consisting of levels of tuff, clays, and calcareous crusts was described (Hay, 1976). Two main archaeological levels were identified: TK Lower Floor (TKLF) and TK Upper Floor (TKUF), which were considered true clay surfaces characterized by large industrial assemblages and a smaller amount of faunal remains. TKLF was interpreted as Acheulean, and TKUF as Developed Oldowan B (Leakey, 1975: 484, 1976: 31, 1978). From then on, TK played a decisive role in the debate about the relationship between the Oldowan and Acheulean (Bower, 1977; Stiles, 1977, 1979; Willoughby, 1987; Sahnouni, 1991; Ludwig and Harris, 1998; Kimura, 2002). Later research came to the conclusion that both industrial assemblages were technologically similar and could be ascribed to the Acheulean technocomplex (de la Torre, 2004; de la Torre and Mora, 2005).

In 2010, in the framework of The Olduvai Paleoanthropology and Paleoecology Project (TOPPP), a new research phase that is still ongoing commenced. The stratigraphic section established by our field work, combined with the sections referred to by M. Leakey (1971: 172-174), has allowed the reinterpretation of the stratigraphy of the site (Santonja et al., 2014), to verify that it is more complex than was previously thought (Rubio-Jara et al., 2017), and to correct mistakes made in previous interpretations, particularly related to TKUF which was mixed up with TKLF (Santonja et al., 2014; 2018). A new archaeological floor placed between TKLF and TKUF, named TK *Sivatherium* Floor (TKSF), unrecorded in M. Leakey and R. Hay's stratigraphic sequence (Leakey 1971: 172 ff), has been identified and 45.3 m^2 have been excavated.

The technological and techno-economic study of the *chaîne opératoire* phases identified in TKSF (Rubio-Jara et al., 2017) reveal that this new archaeological unit shows strong differences with the lithic industry and faunal remains of TKLF (Santonja et al., 2014; 2018; Yravedra et al., 2016). Both levels are clearly Acheulean, and are located stratigraphically very close to each other (between 21 and 42 cm), with no significant temporal diachrony (Rubio-Jara et al., 2017). This suggests that their technical and typological differences in the context of the variability of the Acheulean assemblages are mainly due to functionality criteria.

2.1. Geological context

Beds II, III, and IV of the Olduvai sequences, according to the stratigraphic nomenclature of Hay (1976), are displayed in the TK sedimentary outcrops. The maximum thickness recorded is about 8.90 m, of which 7.25 m are Bed II, 1.25 m Bed III , and 0.40 m Bed IV. Our fieldwork in the northwest part of TK carried out between 2014 and 2015 is represented to the stratigraphic section of **Fig. 1b** (Rubio-Jara et al., 2017), and must be added to the previous stratigraphic column (Santonja et al., 2014) and the sections documented by M. Leakey (1971: 172-174).

The TKSF occupation floor is located some 20-30 cm over the TKLF occupation floor. TKSF is exposed over a paleosurface composed of two sedimentary facies associated with a 40 cm thick loamy sand channel with tabular cross-stratification, internal structures, and NW-SE flow (**Fig. 1b**). Judging by the narrow and shallow nature of this channel, it was seasonal and short-lived, and had a low transport capacity. The base of these channel facies lie, depending on the

sector, over a pale yellow sandy loam tuff or a thin carbonate level. Both facies represent a very shallow lake environment. A 14 cm thick deposit of pale brown clay can be distinguished to the top of the channel facies and in the south side of the excavated area. This is interpreted as a decantation facies related to the loamy sand overbank placed in a stratigraphically lower position. On the other hand the TKSF occupation floor is covered by a horizon of white pale yellow sandy clay tuff about 25-52 cm thick, with very low erosive capacity. The uppermost part of the stratigraphic section consists of a pale yellow clay loam tuff 2-32 cm thick, truncated at the top by a cut and a fill and eroded by a new light grey clay tuff horizon which shows a marked erosive scar over the lower tuff. Several recent rills, fossilized colluvium, and soils end the section.

2.2. General Characteristics of the Lithic Industry present in the TKSF

A total of 1,161 lithic items were recovered from the 45.3 m^2 excavated at TKSF (**Fig. 2a and 2b**). This amounts to a density of 12.1 pieces per m^2 excluding shatter, and 5.3 kg m^2 of weight including it (Rubio-Jara et al., 2017). The different items have been distinguished according to the type of raw material employed **(Table 1)**, and it was found that 91% are made of quartzite, which came from the Naibor Soit Ndogo inselberg. At the time the site was formed, the base of the hill would have been about 750 m away (Santonja et al., 2014). Naibor quarzite (NQ) is a metamorphic rock composed almost entirely of quartz (98%) and has a schistose texture, which provides it with a very different knapping response compared to other fine-grained quartzites present at Olduvai (Jones, 1994). A total of eight percent of the items are "volcanic rocks" (VR) –phonolites, nephelinite, trachyte, and basalt- which come from the formations of the Olmoti, Ngorongoro, Sadiman, and Lemagrut volcanoes (Hay, 1976; Jones, 1994; Kyara, 1999: 14). These volcanic rocks could have been obtained from nearby streambeds. The remaining one percent of the items are made on vesicular lava, non-Naibor quartzite (nNQ), metamorphic rocks, and gneiss. The known gneiss outcrops are located 11 km west of TK, at Kelogi Hill (Hay, 1976; Kyara, 1999).

NQ and VR are the only raw materials in which all the phases of the *chaînes opératoires* are represented, and the handaxes are shaped. Knapping activities at the TKSF site are focused on producing flakes from cores, occasionally reshaping them by retouch, as well as the shaping of handaxes from slabs, cobbles, and even large flakes. Direct freehand percussion (FHP) exploitation schemes have been identified on blanks obtained from these two rock types. Bipolar percussion (BP) was observed almost exclusively on NQ.

Over half of all the VR items are cobbles (55.4%) and were used as hammerstones. This shows the importance of percussion activities and the versatility of these blanks, which were also exploited as cores.

All the identified exploitation systems are recorded in both NQ and VR in TKSF. Almost two thirds of the cores were exploited according to unsophisticated operative schemes: single surfaces with monopolar or bipolar removals, multipolar and bifacial cores. However, the existence of a peripheral unipolar system in 16.3% of the cores is noteworthy (similar to the Quina production concept documented in Europe, Turq, 2000: 316). This was also recorded at TKLF (Santonja et al., 2014). Discoid productions schemes, which are the most complex ones, are highly represented (22.4%).

The FHP exploitation method clearly prevailed over BP (60.4% and 39.6% respectively). The transfer of percussion methods has been documented, so in the 41.7% of the cores exploited by BP display FHP, and in 9.1% of the ones exploited by FHP display BP. This flexibility between techniques has also been confirmed among different categories of the *chaîne opératoire*, thus half of the polyhedral cores show marks on several ridges that suggest that they were used as hammerstones, and cores made on slabs by FHP were also used as anvils.

A total of 341 flakes were identified, most made of NQ (94.1%) and the rest (5.9%) made from VR blanks. Ten percent of the NQ flakes and none of the VR examples are more than 100 mm long, some of NQ reaching up to 160 mm. The size of the largest NQ flakes fall within the range of the Large Cutting Tool (LCT) category. On the other hand, 6.5% of all flakes show debitage and cortical backs, and most show a long active cutting edge, as well as use retouch and extensive removals. Obtaining long active cutting edges must therefore have been a primary goal in their preparation. The presence in TKSF of two VR flakes with extensive cortex, together with 2.2 flakes per core and only five undifferentiated products, suggests that exploitation of VR cores began outside the site or in a different sector of TKSF. However, the proportions of those three categories are more consistent on NQ; 5.1 flakes per core and about 9.6 undifferentiated products per core suggest that blanks of NQ would have been carried out and knapped on site. Consequently, at TKSF we identify an economy of production that differs for VR and NQ (Rubio-Jara et al., 2017).

Production of retouched tools was not the main objective at the TKSF, as only nine retouched items were documented: four scrapers, two denticulates, one notched tool, and two backed knives.

The *façonnage* phase consists of 53 items that represent 9.6% of the lithic assemblage (excluding undifferentiated products). Most of them (37 pieces) are handaxes. Eight trihedral picks, four cleavers, and four large shaped flakes and slabs have also been recorded, despite the difficulty of detaching large flakes on NQ. Whole pieces, tips and preforms (specimens in an intermediate phase of shaping) have been identified among the handaxes. Three of the NQ handaxes and three of the VR handaxes were made on flakes. The bilateral shaping of the NQ specimens is generally bifacial, and tends to be invasive. The cutting edge that covers the tool dominates the whole perimeter up to the tip, shaping the potentially sharp and active edges all around the tool. The reduction method used on the silhouettes produce pointed, oval, and transverse-edge handaxes. The presence of NQ handaxe preforms and points suggests that such tools were shaped and used on this level, and that they could have been used for a long time, as they were rejuvenated by lateral and distal sharpening removals (Rubio-Jara et al., 2017; Fig 5 and 7). The trihedral picks, which are slightly smaller than the NQ handaxes, are made on NQ slabs, and in half of them unifacial reduction is dominant. All cleavers are made on NQ flakes (types 0, I, and II of Tixier, 1956), except for an atypical one made on a NQ slab. Finally, the large scrapers and shaped slabs are usually over 10 cm long, and tend to be shaped to a tip, or create cutting edges on opposite backs that form a techno-functional unit suitable for gripping.

There is a large number (611 items) of undifferentiated products or shatter (debris, chunks, and angular fragments of NQ slabs). They constitute more than half (52.6%) of the TKSF

assemblage, of which 99% are on NQ and only 1% on VR (Rubio-Jara et al., 2017). The high occurrence of shatter may be produced mainly during all the phases of knapping on NQ slabs, although the possibility of it resulting from percussion activities that involved NQ anvils or hammerstones cannot be ruled out (Diez-Martín et al., 2011; Sánchez-Yustos et al., 2012; de la Torre and Mora, 2013).

3. Method and sample

3.1. Data acquisition and management

The topography of TKSF, the stratigraphic data, and the archaeological materials were recorded by a Leica Total Station TS02. All the information was managed using Microsoft Access and Microsoft Excel, and was processed with ArcGis®. The coordinates of faunal and lithic items were registered with a variable number of points according to their size and shape: small items with an undefined axis were recorded as a single point; small items with a silhouette suggestive of orientation were recorded with two points on the long axis; the rest of the items were identified with a number of points ranging from 3 to 43. The maps were drawn with ArcGis® software from the topographic data and the resulting polygon - in shape files .shp – was highly accurate. The orientation and slope of the items could be recorded more accurately and quickly by this method than by freehand drawing on graph paper.

3.2. Faunal analysis

Taxonomic identifications were carried out using comparative material, backed up with osteological atlases and references (Barone, 1976; Gentry and Gentry, 1978, 1978a; Pales and Lambert, 1971). However, in cases where such determination was not possible, fragments were attributed to animal weight/size classes following Bunn (1982), where “small” refers to Bunn’s (1982) sizes 1 (animals <50kg, such as Thompson's gazelles) and 2 (50 - 250kg, such as warthogs), “medium” to size 3a (250 - 500kg, such as gnus) and 3b (500 - 700kg, such as zebras), and “large” to sizes 4 (750 - 2000kg, such as elands or buffaloes), 5 (2000 - 6000kg, such as rhinoceros), and 6 (>6000kg, such as elephants).

Faunal remains were quantified by NISP and MNI. NISP determination follows the protocol described in Yravedra and Domínguez-Rodrigo (2009). MNI estimates considered element size and ontogenetic age (Brain, 1969). Skeletal part profiles were organized into four different anatomical regions: cranial (i.e., horn, cranium, mandible, and teeth), axial (vertebrae, ribs, pelvis, and scapula, according to Yravedra and Domínguez-Rodrigo, 2009), upper appendicular limbs (humerus, radius, ulna, femur, patella, and tibia), and lower appendicular limbs (metapodial, carpals, tarsals, phalanges and sesamoids).

Pursuant to Yravedra et al (2016), several procedures were followed to reconstruct site formation processes, assess site integrity, and evaluate the contribution of various biogenic agents to the faunal assemblage. The impact of water activity was estimated based on fragment size distributions and the presence of abrasion, polishing, and carbonates.

The analysis of animal sizes was carried out at three levels. First, all fragments were subjected to size-sorting. With regard to bone fragmentation indices, bones were separated into several categories according to their maximum length: <20mm, 21-40mm, 41-60mm, 61-80mm, 81-100mm, and >101mm. At a second level, only long bone fragments were considered, as

cancellous axial bones undergo different fragmentation patterns than do denser limb bones (Domínguez-Rodrigo and Martínez-Navarro, 2012). Based on the idea that anthropogenic bone concentrations yield greater fragmentation than those created by carnivore, the amount of preserved shaft circumference is also considered. Bunn (1982) proposed three categories for shaft circumference where (1) stands for shaft circumference <50%; (2) covers the >50% range; and (3) the shaft circumference is complete (100%). At a third level, according to Villa and Mahieu's (1991) classification, dry and green breakage was analysed and only those long bone fragments showing green breakage were considered. This distinction is important, as diagenetic (dry) breakage is relatively common in the assemblage, and thus the specimen size distribution could be quite different from the original deposit.

Weathering stages were also observed following Behrensmeyer (1978) to estimate exposure time. A spatial analysis of bones with evidence of abrasion-polish, carbonate encrustation, trampling-microabrasion, and biochemical marks was carried out to evaluate whether taphonomic phenomena were focused on specific areas. Bone surface modifications such as cut, percussion and tooth marks were systematically examined with 10X-20X hand lenses and indirect lighting (Blumenschine, 1988, 1995). The diagnostic criteria defined by Bunn (1982) and Domínguez-Rodrigo et al. (2009) guided the identification of cut marks, which have been clearly identified as straight continuous grooves , with V section and microstriation, as opposed to trampling marks, which are shallow, discontinuous grooves with open sections, often associated with microabrasiones. . Tooth marks were analysed following Blumenschine (1988, 1995). Finally, the identification of percussion marks was based on Blumenschine and Selvaggio (1988), Capaldo and Blumenschine (1994), and Blumenschine (1995). Those tend to be irregular circular marks with irregularities inside, different to carnivorous pits, which usually show a flat bottom.

3.3. Lithic taphonomy

The analysis of the surfaces of the lithic tools allows the identification of a number of post-depositional alterations, particularly when the whole lithic assemblage is affected (Harding et al., 1987; Petraglia and Potts, 1994; Dibble et al., 1997; Hosfield and Chambers, 2003; Hosfield, 2011). Thus, breakage patterns, rounding, patina development, heat alterations, and trampling analyses have been carried out (Shea, 1999; Hiscock, 2002; Burroni et al., 2002; Villa and Courtin, 1983; Glauberman and Thorson, 2012). Due to the particular characteristics of TKSF tools, roundness and breaking patterns have been analysed at TKSF.

The most common alterations among the lithic industry are rounding, abrasion, chipping, and pseudo-retouch (Petraglia and Potts, 1994; Shea, 1999; Bustos-Pérez et al., 2019). The establishment of the degree of rounding is usually done macroscopically (Petraglia and Potts, 1994, Panera and Rubio-Jara, 1996; Shea, 1999), although some protocols have been implemented in order to identify it microscopically (Shackley, 1974; Bustos-Pérez et al., 2019). Following an initial visual inspection of the TKSF lithic industry, and having observed a low rounding index in the sample, microscopic analysis was deemed necessary. Basic roundness categories were established: null, light, intense, and indeterminate (Panera and Rubio-Jara, 1996). Chipping and pseudo-retouch have been identified and described according to intensity.

Broken artefacts also provide information regarding the taphonomic history of the lithic assemblage. A high number of fractured pieces may suggest intense post-depositional processes (Andrefsky, 2005). A lithic piece can get fractured during production or use, or due to post-depositional processes (Hiscock, 2002). The mechanical particularities of NQ (Jones, 1994; Santonja et al., 2014; Bello-Alonso et al., submitted) often contribute to breaking during the knapping process, particularly during the final stages of handaxe production (Herzlinger et al., 2015). On the other hand, consumption of lithic tools has been verified in TKSF, and under that activity fractures occasionally occurred (e.g. handaxe broken tips; Rubio-Jara et al., 2017). Fracture analysis has been limited to flakes, taking into consideration the probabilities of fracture during the knapping process.

3.4. Spatial and geostatistical analyses

3.4.1. Orientation and fabric analyses

Orientation and fabric analysis are suitable methods to assess the sedimentary and natural post-depositional disturbance of archaeological assemblages (Schick, 1986; Bertran and Texier, 1995; Lenoble and Bertran, 2004; Domínguez-Rodrigo et al., 2012; Cobo-Sánchez et al., 2014; Domínguez-Rodrigo et al., 2014; García-Moreno et al., 2016).

The data used to test orientation and fabric (trend and dip) were obtained with a specific software GIS process. The trend was calculated with two different processes: minimum bounding rectangle of a polygon (MBR) and polygon main angle (PMA), methods which have already been used in similar archaeological contexts (Domínguez-Rodrigo et al., 2012;; Cobo-Sánchez et al., 2014; Domínguez-Rodrigo et al., 2014).

The items taken into account for this analysis are those >50 mm with an elongation index (i.e. = length/width) >1.6. The orientation data was evaluated with the Rayleigh and Kuiper tests to differentiate uniform (isotropic) from non-uniform (anisotropic) distributions (Fisher, 1993; Lenoble and Bertran, 2004).

In fabric analysis, the criteria are the same as in orientation analysis and we calculated some fabric indexes (eigenvectors, eigenvalues, K and C ratios, Vollmer´s fabric indexes) and produced various graphs (stereographic projections, Woodcock and Vollmer diagrams) (Fisher, 1993; Lenoble and Bertran, 2004; McPherron, 2005).

3.4.2. Density and distribution pattern analyses

Density and distribution pattern analyses were calculated with ArcMap® geo-statistic tools. The assemblage density was calculated through the kernel density method (Silverman, 2018), the clustering degree through Nearest Neighbour and Getis General Ord G statistical methods (Boots and Getis, 1988; Getis and Ord, 1992), and their spatial interrelations using K means, as well as HotSpot methods (Getis and Ord, 1992). All methods are commonly used in spatial analyses of Palaeolithic sites with contrasted and robust results (Romagnoli and Vaquero, 2016; Giusti et al., 2018).

3.4.3. Spatial point patterns

The point pattern from the archaeological level was examined to ascertain whether it was a complete spatial random (CSR) process. Homogeneous CSR (i.e., homogeneous Poisson) point patterns are characterized by being homogeneous (points lack spatial preference and they occur proportionally in any given area according to their dimensions) and by points being

spatially independent. A homogeneous Poisson distribution is a uniform distribution. An inhomogeneous Poisson distribution is a spatially-dependent intensity pattern. An inhomogeneous Poisson pattern can be CSR if point patterns show a Poisson probability distribution and if points are independent. A point pattern is stationary if point statistical properties do not depend on location. This pattern is also defined as isotropic if the statistical properties do not depend on the shifting or rotation of the window. CSR Poisson processes are both stationary and isotropic. Inhomogeneity may create spatially-varying intensity patterns, which should not be mistaken with clustering. In the former, points preserve their independence. In the latter, there is spatial dependence among points.

It is very common to use Ripley´s K-function, but this method is very sensitive to the spatial variation of intensity, leading to false clustering interpretations. For this reason, we carried out tests to assess whether the TK spatial pattern was a CSR Poisson process. For this purpose, we used quadrat counting (chi-squared) test of homogeneity by dividing the spatial window in square meter subunits. The quadrat test was used via Monte Carlo simulations (n=500). The result was obtained by averaging all simulations. Due to limitations of the quadrat test (Baddeley et al., 2015), we complemented it with a Diggle-Cressie-Loosmore-Ford (DCLF) test. The DCLF test was carried out also with Monte Carlo simulations (n=99) and averaged results. An extension of this test was also used, based on the simulation (n=19) of random inhomogeneous Poisson processes with intensity derived by using the leave-one-out kernel smoother method. We combined the use of the DCLF test with the inhomogeneous version of the L-function (see below), using a global envelope. The archaeological spatial pattern was compared to the resulting model.

A non-parametric method of kernel maps was also used to produce graphic smoothing estimations of intensity. Kernel band width selection was made using automatic algorithms that minimize error measurements. Diggle´s correction is commonly used to minimize the edge effect, but it assumes a Cox clustering process (Baddeley et al., 2015), which in the present case is inadequate. For this reason, we selected a likelihood cross-validation algorithm that assumes an inhomogeneous process as shown by homogeneity tests. Sometimes, fixed smoothing band widths fail to capture abrupt changes in local intensity. For this reason, adaptive estimators of intensity based on Dirichlet-Voronoi estimation of density are better able to capture the subtleties of local variation since the resulting bandwidths are local instead of the same for the whole window. The algorithm also enables averaging multiple computations across the window. The adaptive density kernels allowed more precise spatial delineation of regions within the area that were more intensely inhomogenous. Here, a tessellation of the intensity estimate based on a 10% fraction of the data points was used. Monte Carlo simulations (n=30) were used to derive the final pattern.

The K-function measures the cumulative average number of points falling within a certain radius of any given data point. This estimation is corrected for window-edge effects and modified according to intensity. However, given that the K-function assumes a homogeneus point process, more robust modified versions of this test exist. One of them is the L function, which can adapt a centred version of the K-function, and which applies a square root transformation of the Poisson K-function. This stabilizes the variance. Here, we used an inhomogeneous version of the L-function. Confidence intervals apply to these functions. Acceptance intervals for a CSR hypothesis using 5% significance levels were also used in our

analyses, by using confidence envelopes resulting from Monte Carlo bootstrap simulations. Corrections for edge effect, border effect, isotropy, and translation were applied. Global envelopes were selected because they include the most extreme deviations from the theoretical functions.

Clustering was approached through Clark-Evans tests using Monte Carlo simulations (n=300). This test produces R values from 0 (confirmation of the null hypothesis of CSR) to 1 (maximum cluster). However, this test assumes homogeneity and can be biased in inhomogeneous point processes. As a complement, the Hopkins-Skellam test was also used, because it is less sensitive than the Clark-Evans test to inhomogeneity (Baddeley et al., 2015). This test produces a value of A which indicates a random pattern (A=1), clustering (A<1), and regularity (A>1).

The TK archaeological sample was also analyzed as a multitype pattern to detect spatial co-dependence between lithic and bone remains. For this purpose, an inhomogeneous cross-type L-function was used. The L_{ij} indicates the association between both types of materials. If the data line is outside the confidence envelope, then both types of materials are spatially dependent. This can be expressed as being clustered (the probability of $_i$ points being within the distance of any specific radius of $_j$ points is higher than the benchmark value) or regularly spaced (the probability of i points being within the distance of any specific radius of $_j$ points is lower than the benchmark value). This type of analysis is displayed in a bivariable quadruple graph. The diagonal graphs (upper left and lower right) indicate the inhomogeneous L_{ii} distribution. The off-diagonal graphs (upper right and lower left) indicate the inhomogeneous L_{ij} association type. Global 95% confidence envelopes were used.

As a support to this approach, random labelling was also used via the J function. As explained in (Domínguez-Rodrigo et al., 2017), Fi(r) is the empty-space function for type i points. Gij(r) is the nearest neighbour function measuring distances from points i to j. If points of type i and j are independent, then Gij(r)=Fj(r). The Jij function is the result of 1-Gij(r)/1-Fj(r). Random labelling is a stochastic method randomly allocating labels to points. This is carried out via permutation tests involving Monte Carlo methods, which randomly label the original points (Baddeley et al., 2015). For envelope-based tests, “dot” functions are the most adequate. These functions evaluate distances from points i to any type of point. It is used to assess the dependence of one type of point to the rest of the point process. This procedure is most efficient in stationary processes and its selection here as a supplement to the inhomogeneous K function is just to balance the different selection of variance by stationary and non-stationary methods. Confidence envelopes were selected via resampling (n=50) Monte Carlo methods.

4. Results

4.1. Faunal analysis

The taxonomic study reveals TKSF preserved a macrovertebrate accumulation, among which megaherbivores are common, as several bones of *Sivatherium,* elephant, and buffalo are represented (**Fig. 2c**). Other animals of medium size are also represented, such as zebra, wildebeest, and *Metridiochoerus* (**Table 2**). Species of smaller sizes that could not be

taxonomically identified have been assembled in different categories according to their size (**Table 2**).

Among those of medium size, size 3b animals stand out. Despite relatively low NISP values, virtually all anatomical sections are represented (**Table 3**). Axial elements stand out amongst the larger animals –sizes 4 and 5- due to the high number of ribs and vertebrae (**Table 3-4**). Representation of axial and appendicular elements of *Sivatherium,* and dental fragments together with lower appendicular elements (i.e., metapodials) of hippopotamus, are also well-represented after detailed analysis of these two animals, which are the best represented **(Table 4)**. Nevertheless, axial bones are dominant amongst indeterminate bones of animals ascribed to sizes 4 and 5.

In relation to bone alteration patterns, it has been stated that 70.87% of the remains show poor preservation of the cortical surfaces, which has hindered observation of some bone alterations. Only 16.83% of the sample is well preserved and 12.30% is moderately well-preserved. Despite this data, polishing and abrasion has been identified in 81.35% of the sample, which together with the high percentage of remains with concretions (72.03%) suggests that the bones were exposed to hydric alterations for a prolonged time period However, the nature of these alterations are shown as polishing and abrasion rather than rolling, as less than 5% of bones show evidence of intense rolling **(Table 6)**. The high presence of polished and abraded bones, together with the scarcity of rounded bones suggest the existence of water flows on site, although these were low energy. The small particles transported by the streams probably gave place to abrasion and polishing, and although they were not strong enough as to move the bones of macromammals, they could have displaced those of microvertebrates, which are not found in TKSF. Thus, streams only acted as a modification agent, as has been experimentally recorded by Thompson et al. (2011).

Only 9% of the analysed remains are affected by weathering and this only to a low degree, suggesting that they were not at the mercy of the elements for long. Besides, biochemical alterations are not substantial (5.79%), and trampling affected just 15.11% of the bones. Finally, alterations due to carnivores such as tooth marks or furrowing on the epiphyses, which would suggest access to carcasses prior to sedimentation, have not been observed. The combination of these elements points to fast burial processes.

Fragmentation patterns show low incidence. More than 50% of the remains are over 4 cm in size, and several long bones of large animals such as *Sivatherium* and buffalo have been recorded. Furthermore, it has been observed that 65% of long bones have a diaphysis circumference percentage higher than 50% (**Table 5**), and more than 69% of the remains show diagenetic dry fractures (**Table 5**). Fractures with straight and mixed angles, close to 90º, have been observed among these remains, as well as several fragments with transverse and longitudinal transverse fractures. With regard to the bones with green fracture, 71,4% show oblique planes, and 28.6% longitudinal plane with oblique angles.

The poor state of preservation, together with alterations such as abrasion and calcareous concretions, hides the identification of anthropogenic alterations on bone surfaces (**Fig. 2d**). Despite these determining factors, three cut marks could be identified on a large animal (size 5) rib fragment, another one on a 3b size hartebeest pelvis, and a further one on a 3b size

ungulate metapodial. In this last specimen, however, marks are affected by polishing and abrasion **(Fig. 3).** Finally, two impact flakes have been observed on a size 5 animal rib and on a small size animal (size 2) diaphysis.

4.2. Lithic taphonomy

Crust which formed due to precipitation of calcium carbonate is present on 48.83 % of the lithic pieces (567), and 16.10% (187) of pieces had sediment adhered to the surface. Nevertheless, the degree of rounding could be analysed on the whole lithic series of TKSF (1,154 items). Only 4.9% show light rounding and 1.1% intense roundness on the edges (**Table 7**). A third (51) of the pieces with some degree of rounding are shorter than 4 cm, and could have been added by the sandy clay tuff that overlies the TKSF surface. This also suggests that 12 pieces between 4 and 10 cm long, and especially six pieces between 10 cm and 16 cm, including a NQ and a VR handaxes, as well as a VR hammerstone, could be old pieces recycled by hominins. Regarding raw materials, NQ show percentages slightly higher than VR (5% and 3.3% respectively), although this could be due to a lower representation of pieces shorter than 4 cm among the VR.

Over half (176; 51.6%) of the 341 flakes recorded at TKSF do not have fractures. Many of the broken pieces (137; 40.2% of the whole), show small fractures that have not substantially affected the original dimensions of the pieces, making the interpretation of the dorsal faces possible (Rubio-Jara et al., 2017). Only 28 flakes (8.2 % of the whole) show substantial fractures. On the other hand, the flakes are rarely affected by pseudo-retouch. This has only been identified on three NQ pieces between 80 to 119 mm long and on a single VR piece.

4.3. Orientation and fabric analysis

Similar orientation patterns are evident for both artefacts and faunal remains in the TKSF level (**Table 9**). The length of the mean vector, concentration, circular variance, and standard deviation have analogous values, consistent with characteristics of isotropic populations (**Table 9, Fig. 4**). Furthermore, Rayleigh and Kuiper´s tests results are consistent with an isotropic distribution of the lithic industry ($Z = 1.488$, $p = 0.226$ and $V = 1.408$, $p = > 0.15$ by MBR and $Z = 1.996$, $p = 0.136$ and $V = 1.682$, $p = 0.10 > p > 0.05$ by PMA) and faunal remains ($Z = 2.531$, $p = 0.08$ and $V = 1.438$, $p = > 0.15$ by MBR and $Z = 2.402$, $p = 0.091$ and $V = 1.485$, $p = > 0.15$ by PMA).

The absence of items (such as natural clasts) susceptible to fabric analyses in this level, other than artifacts and faunal remains, hinders the interpretation of the fabric results as a whole. Some small differences are detected among the lithic industry and faunal fabric patterns. The lithic industry is characterized by a lower girdle (girdle with cluster) degree than faunal remains (**Table. 8, Fig. 5**), and a higher K index value in MBG ($K = 0.66$) than faunal remains ($K = 0.16$). Likewise, the Vollmer´s index values and F or CGI indexes also reinforce these small differences in the fabric pattern (**Table. 8, Fig. 5**). Also, the eigenvalues of the lithic industry show a more girdle fabric pattern ($S1 = S2 >> S3$) than faunal remains, which show more lineal features ($S1 >> S2 = S3$). Regardless, the stereogram plots show that both assemblages have an isotropic feature (**Fig. 6**).

4.4. Spatial analysis

4.4.1. Density remains

The density and clustering analysis of the TKSF assemblage shows a significant degree of density and clustering (**Table. 9; Fig. 7a**). Merging together all assemblages there are 27.82 items/m^2, with the nearest neighbour index (R = 0.87 *p* = 0.000) and Getis-Ord General G index (G = 0.00 *p* = 0.000) coincident with a large degree of clustering (**Table. 9**).

The lithic industry shows a larger density value (21.08 items/m^2) than bones (6.02 items/m^2), but the degree of clustering is similarly high for both types of items and of similar value. The Getis-Ord General G index is also similar and shows higher cluster values for the lithic industry than for the faunal remains (**Table. 9; Fig. 7b-c**).

As can be observed in the density maps, the largest concentrations of lithic and bones do not overlap (**Fig. 7b-c**). However, in the south-eastern area of the excavation surface, a large concentration of lithics close to the main accumulation of long bones is visible. The faunal concentration produces a conspicuous semi-circular shape that surrounds the centre and largest accumulation of lithic implements. The largest accumulation of bones defines an external position with regard to this accumulation of artefacts (**Fig. 7b-c**).

The density and clustering analyses applied to the main techno-typological categories show the highest densities for shatter and flakes (10.79 and 6.80 items/m^2, respectively), as well as the highest degree of cluster (**Table 10**). Cobbles, percussion material, and LCTs show lower densities, with values around 1 item/m^2. Also, the degree of clustering and the neighbouring index are also substantially lower, both of which show a random or dispersed pattern (**Table 10**). In the density maps, it can be observed that cobbles, percussion materials, cores, and LCTs are located near the largest accumulation of faunal remains (**Fig. 8**). This situation seems to define a specific area of activity in the vicinity of the main faunal accumulation, which is suggestive of hominin activity.

4.4.2. Distribution pattern

The results of the distribution pattern analysis at TKSF show a specific association related to the density features mentioned above. Groups of K means occur in large numbers and define some specific concentrations of large faunal remains and artifacts with geo-statistical significance (**Fig.9**). The Cluster Outliers and Hot Spots maps similarly show a more patterned distribution with local concentrations (**Fig. 10-11**).

4.4.3. Spatial point patterns

The quadrat chi-square test showed that bones (X2=334.30; p=0.0195) and lithics (X2=454.76; p=0.0198) at TKSF were distributed in a significantly different manner from a stationary pattern. The DCLF test showed that the distribution of bones (u=108704; p=0.01) and lithics (u=24015; p= 0.01) followed an inhomogeneous pattern. This is also evidenced when comparing inhomogeneous Poisson simulation to the TKSF bone and lithic spatial patterns (**Fig. 12**). When using the homogeneous version of the L-function, one gets the impression that both lithics and bones show a clustering trend (**Fig. 13A, 13B**). However, when using the inhomogeneous L-function, it can be clearly noticed that lithics and bones follow a fairly inhomogeneous pattern (**Fig. 13C, 13D**). The point pattern of the bones shows a trend towards

clustering after a radius of 1500 mm, which indicates that in a radius of 1500 mm of any randomly chosen bone, other bones tend to cluster instead of using complete spatial randomness, and that lithics are more scattered than bones. This can be clearly observed in the kernel density maps of bones and lithics (**Fig. 14**). Bones show a more concentrated pattern, with one hot spot area, as shown by the adaptive density map, situated more distally than the hotter zone of lithic concentration (**Fig. 14**). Although there is an overlap of high intensity areas, showing co-dependence of spatial marks (i.e. bones and lithics) (see below), the different location of the hot spots indicates that this co-dependence is not very strong, as suggested by the random labelling J-dot function (**Fig. 15**).

Clark-Evans tests show that bones (R=0.85; p=0.006) and lithics (R=0.86; p=0.005) are clustered, which suggests inter-point dependence in their spatial distribution. However, this is the artificial result of the test, which is dependent on the homogeneity of the point process. Given that the TKSF pattern is inhomogeneous, a Hopkins-Skellam test on bones (A=0.20; p=<0.000) and lithics (A=0.13; p=<0.000) shows that clustering is not documented and that the data fit an inhomogeneous Poisson pattern well.

Cross-type analysis shows a trend towards slight clustering in bones starting at a distance of one meter from any random point and an increasing trend of slight and progressive clustering in lithics starting at radii of half a meter from any random point. The off-diagonal L_{ij} graphs indicate an increasing co-dependence in the form of clustering of lithic and bones after a radius of 20 cm of any random point (**Fig. 16**). This suggests that a) the deposition of bones and stone tools are spatially dependent, b) this spatial dependence has been maintained despite postdepositional biostratinomic taphonomic processes and, c) such a spatial co-dependence indicates a functional link between stone tools and bones during site formation. This pattern is even more nuanced, however, because two distinctive activity areas are documented for lithics and bones, both of which could have been created through the independent or combined action of either post-depositional processes and/or activities that required tools for tasks other than carcass butchery (**Fig. 14 C, D**). This is further supported by the random labelling method, which shows that if this spatial co-dependence can be observed, it is not as strong as to be spatially concurrent, which would be the case if random labelling displayed the TKSF point process outside the boundaries of the confidence interval for a random distribution (**Fig. 15**).

5. Discussion

Knowledge of the Acheulean in East Africa has developed substantially in the last decades. (Kuman and Clarke, 2000; Quade et al., 2004; Texier, 2005; Kuman, 2007; Beyene et al., 2013; Gallotti, 2013; Brown and McDougall, 2011; de la Torre, 2011; Domínguez-Rodrigo et al., 2013; Diez-Martín et al., 2014; Gibbon et al., 2014; Santonja et al., 2014; Diez-Martín et al., 2015; de la Torre et al., 2018; Gallotti and Mussi, 2018). A difference between the sites older than 1.2 Ma and those younger than 1 Ma has been proposed based on analyses of the technological strategies implemented on the manufacturing of lithic tools (de la Torre and Mora, 2005; Sharon, 2007; 2010; Stout, 2011; Diez-Martín and Eren, 2012; Beyene et al., 2013; Sahnouni et al., 2013; Gallotti, 2013; Gallotti and Mussi, 2017; 2018; Texier, 2018). Thus, sites older than 1.2 Ma are considered as early Acheulean. Our proposal is to use this appelation with a chronological sense, considering new data from FLK West ~1.69 Ma (Diez-Martín et al., 2015)

and TK~1.33 Ma (Satonja et al. 2014; 2018; Rubio-Jara et al. 2017), where complex processes in handaxe configuration have been described. In order to understand the identity of the first Acheulean sites, the variables that have influenced the selection of those strategies must be discriminated, and the functionality of the sites must be seen as a determinant conditioner of this process (Presnyakova et al., 2018).

A good deal of early Acheulean sites are either located in fluvial environments or have suffered other important post-depositional processes (Domínguez-Rodrigo et al., 2009; Gibbon et al., 2009; Gallotti, 2013; Diez-Martín et al., 2014; Uribelarrea et al., 2017; de la Torre et al., 2018; Semaw et al., 2018), which will have an influence on the analysis of these sites' functionality. Because the spatial relationships of the different elements of the archaeological assemblage are not significantly altered, the association of these elements must be analysed, particularly in the cases in which the remains are so badly preserved that taphonomic analyses cannot be carried out.

The densest known concentration of early Acheulean sites has been recorded in Bed II at Olduvai Gorge (Leakey, 1971; Santonja et al., 2014; Diez-Martín et al., 2009; 2014; 2015; Sánchez-Yustos et al., 2016; Rubio-Jara et al., 2017; de la Torre et al., 2018). Among the Olduvai early Acheulean sites, the particular features of the lithic assemblages and sedimentary environments identified in TK offer great potential for analysing the influence of functionality on the variability of the technological strategies during the early Acheulean stages. Two Acheulean paleosurfaces were identified at TK, TKLF and TKSF, with no significant temporal diachrony, although with substantial differences between their archaeological assemblages (Rubio-Jara et al., 2017).

The analysis of the lithic industry has shown higher density in TKLF than in TKSF (38.4 and 12.1 items per m^2 respectively). It has allowed the discernment of a differentiated economy of tool manufacturing: at TKLF, debitage of NQ and VR was transformed on site, whereas in TKSF only the NQ cores were knapped, and VR cores were flaked, at least in part, outside the site. Bipolar and freehand percussion are better represented in TKSF than in TKLF, and opportunistically exploited cores are more frequent in TKLF. Discoid and bifacial discoid cores dominate in TKSF, whereas flakes with rectangular formats prevail in TKSF. However, the greatest differences have been observed among the handaxes: 85 pieces in TKLF and 53 items in TKSF (Rubio-Jara et al. 2017; Santonja et al. 2018). In TKSF items heavier than 1 kg and longer than 19 cm are rare, whereas in TKLF items >19 cm and, on occasion, as heavy as 3 kg, were dominant. In the TKLF pieces, the functional area is concentrated on the apical third and they have backs on the base or on the edges. However, in TKSF, the whole perimeter is the cutting edge, and points and edges are more rejuvenated in TKSF than in TKLF.

From the point of view of lithic taphonomy, the degree of rounding at TKSF is very low and affects mainly pieces shorter than 4 cm, which were possibly redeposited by the sandy clay tuff that overlies this surface. However, six pieces between 10 and 16 cm that show some rounding, including two handaxes and a VR hammerstone, could have been recycled by hominins for later use from other deposits. The high flake fracture indexes are consistent with the knapping of NQ, which breaks easily, and therefore cannot be blamed on substantial post-depositional processes, as is suggested by the low number of flakes with pseudo-retouch. Nevertheless, a certain degree of trampling cannot be ruled out.

The faunal analysis of TKLF reveals a high MNI (i.e. 47), in which suids, antilopines and especially equids and alcelaphines dominate, and tragelaphines, bovines, reduncines, hippos, and crocodiles are present in lower frequencies (Hill, 1983; Egeland, 2008; Egeland and Domínguez-Rodrigo, 2008; Yravedra et al., 2016). Only 248 pieces, 23% of the whole, show good preservation. The presence of green fractures (in 99 pieces) in small and medium-sized animal, a single percussion mark (on a tibial shaft from a medium-sized one), one boring in a hippopotamus jaw (Hill, 1983), and a few tooth marks (4), indicate hominin and, to a lesser extent, carnivore activity (Yravedra et al., 2016). The analysis of the bones' cortical surfaces points to prolonged subaerial exposure and the influence of overland water flow and other erosive agents before being buried (Yravedra et al., 2016).

This scene is quite different to that observed in TKSF, where almost a third of the bone remains in which sizes were identified belong to species between 750 kg and 2,000 kg, and more than another third were species heavier than 2,000 kg. Some remains of elephant and buffalo have been identified, although *Sivatherium* and hippopotamus are dominant. Substantial differences are identified according to the elements represented: whereas in *Sivatherium* axial and appendicular elements dominate, dental fragments, lower appendicular bones and metapodials are most common for hippos, which suggests that these mega herbivores where fully represented on site. The low frequency of small and medium-sized mammals does not allow the establishment of conclusions regarding representation profiles. Despite evidence of concretion and altered cortical surfaces on 68% of the remains, five anthropogenic bones have been recorded: cut marks were observed on a size 5 animal rib and also on two size 3b bones. Two impact flakes were observed as well, one of them also on a size 5 animal rib. Weathering, trampling, and biochemical alterations suggest rapid burial.

Taphonomic analysis of the lithic industry and the faunal remains of TKSF is compatible with the absence of post-depositional processes that could have substantially modified the original spatial relationships of lithic pieces and bones. In addition, the lithic industry and faunal remains show orientation patterns consistent with an isotropic distribution. With regard to fabric analysis, the lithic industry shows a more girdle fabric, while bones display a more linear fabric pattern. However, the stereogram plots show that both assemblages have an isotropic feature, and the afformentioned differences can be related to the large metric differences between the lithics and faunal remains, where the presence of many large bones can be a problem in establishing solid comparisons between both assemblages.

Therefore, TKSF relates to a paleosurface in which the archaeological assemblage is found in an autochthonus position with no significant spatial modifications and that was subject to a relatively fast burial process that allows the analysis of its functionality. Site functionality is in fact being explored through biomarker analysis and use-wear analysis of the entire assemblages of knapped lithic pieces-a first for an Acheulean site- (Bello-Alonso et al., 2016, 2018). The faunal remains indicate an assemblage of megaherbivores, among which are several complete *Sivatherium* bones. No evidence for carnivore modification is present and very few bones are green-broken. Consequently, it seems that human intervention on the fauna was not intensive, although it has been confirmed by the presence of cut marks on size 5 and 3b animals. However, considering that in more than two thirds of the faunal remains cortical analysis could not be carried out, geo-statistical analysis has been implemented in order to establish dependency relationships between the fauna and lithic industry.

719 The spatial pattern analyses show a significant density and clustering degree; however, the
720 lithic industry displays larger density values and higher cluster values than bones. In relation to
721 techno-typological categories, shatter and flakes show the highest densities and cluster
722 degrees. The largest concentrations of lithics and bones do not overlap; nevertheless, the main
723 accumulation of long bones occurs in the south-eastern area, where a semi-circular shape of
724 long bones surrounding the central and largest accumulation of knapped stones is displayed.
725 Most of the *Sivatherium* bones and other remains with sizes compatible with this animal are
726 also in this area. Furthermore, in this sector, the density maps show clusters of percussion
727 elements, cobbles that could also have been used as hammerstones, and LCTs. In addition, two
728 of the three bones with percussion marks and one of the three bones with cut marks, as well
729 as several others with green fractures, were identified in this area.

730 According to spatial point patterns analyses, point statistical properties of the TKSF bones and
731 lithics do not depend on location, follow a spatially dependent pattern, and lithics are more
732 scattered than bones. This suggests the presence of one hot spot area. The cross-type analysis
733 suggests that the deposition of bones and stones are spatially-dependent, which indicates a
734 functional link between them during site formation. However the random labelling method
735 shows that this co-dependence is not as strong as to be spatially concurrent, because of post-
736 depositional processes and/or stone tools being used in activities other than carcass butchery.
737 As the taphonomic analysis of lithics and bones rules out the first scenario, the results suggest
738 the second is more probable.

739 ## 6. Conclusions

740 In order to understand the identity of the early Acheulean, it is necessary to discriminate
741 between the variables that influenced the selection of technological strategies, and here
742 functionality is a determinant conditioner. To reach this goal, first of all, it is necessary to
743 analyze the spatial relationships of the different elements of the archaeological assemblage
744 and the associations among these elements.

745 As TK two main paleosurfaces, TKLF and TKSF, have no significant temporal diachrony but
746 there are substantial differences between their archaeological assemblages. The TK site thus
747 offers much potential to assess the influence of functionality in the variability of the
748 technological strategies during the early Acheulean.

749 In this paper we have assessed functionality at TKSF through lithic, faunal, taphonomic, and
750 spatial analyses. Taphonomic data, orientation patterns, and fabric analyses rule out significant
751 post-depositional processes that could have modified the spatial relationships between lithics
752 and faunal remains. TKSF relates to a paleosurface in which the archaeological assemblage is
753 found in autochthonous position and experienced a relatively rapid process of burial that
754 allows the analysis of its functionality. In the absence of the results of wear use and biomarker
755 analyses, among others, human activities on macromammals have been evaluated with the
756 available data.

757 The bone remains seem to indicate an assemblage of megaherbivors, among which are several
758 complete *Sivatherium* bones. No evidence for carnivore intervention was found, green
759 fractures are rare, and only a few cut marks on size 5 and 3b animals have been identified.
760 Hence, it seems that human intervention on the fauna was not intensive, although it should be

taken into consideration that more than two thirds of the bones show poor cortical preservation.

Spatial and geostatistical analyses suggest a functional link between the lithics and bones during site formation, but this co-dependence is not as strong as to be spatially concurrent, as stone tools were used in more activities other than carcass butchery. Most of the *Sivatherium* bones were located in the south-eastern spot of the excavated area, where a semi-circular shape of long bones surrounding the central and largest accumulation of knapped stones was displayed, with clusters of percussion elements, cobbles, and LCTs, as well as bones with percussion and cut marks and green fractures.

Therefore, in the TKSF analysed paleosurface, activities related to megaherbivore processing were carried out, mainly in the south-eastern area, where the main accumulation of long bones were located, especially *Sivatherium*, together with clusters of percussion elements, cobbles, and LCTs, and most of the bones showed percussion, cut marks, and green fractures. The wide dispersion of flakes and shatter indicates that other human activities unrelated to the processing of animals were also carried out on this surface. We are currently trying to understand such activities through use-wear and biomarker analyses on stone tools.

The TKLF paleosurface, only 20-40 cm below TKSF, shows a very different scenario; as it took much longer to be buried, the find density of the lithic industry is considerably higher, and the preservation of the bone surface is poorer. The large taxonomic diversity, with no cut marks and only one percussion mark, can be interpreted as the result of natural processes, so the main anthropogenic input could be related to other resources where large handaxes were necessary. The technological and techno-economic study reveals strong differences between the lithic industry in TKLF and TKSF, especially among the handaxe configuration. Without assessment of site functionality and chronological context, this data could have led to the differences observed at TKLF and TKSF being assigned to different Acheulean stages.

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Chaîne opératoire phases at TKSF		Unworked items			Used, retouched, or shaped items			Total		
		a	b	c	a	b	c	a	b	c
0.	Procurement phase		24	7	4	27	3	4	51	10
1.1.	First reduction phase	29	1		3	1		32	2	
1.2.	Full reduction phase	257	16		11	1		268	17	
1.3.	Full reduction phase (backed products)	11			10	1		21	1	
1.4.	Cores	61	7		21	2		82	9	
	Subtotal of production phase	358	24		45	5		403	29	
2. *Façonnage* and retouched items on natural blank										
2.1.	Handaxes, preforms and fragments				30	7		30	7	
2.2.	Trihedral picks				8			8		
2.3.	Cleavers				4			4		
2.4.	Large scrapers & retouched slabs				4			4		
	Subtotal of façonnage phase				46	7		46	7	
3.	Shatter	605	5	1				605	5	1
	Total	**963**	**53**	**8**	**95**	**39**	**3**	**1058**	**92**	**11**
Total: **1161** pieces										

Table 1. *Chaîne opératoire* phases identified at TKSF. a. Naibor quartzite, b. Volcanic rocks, c. and other rocks; 0. Procurement phase includes cobbles, hammerstone detachments (basalt fragments with no percussion platform nor bulb produced by a hammerstone), cobbles with pits, and slabs with percussion marks; 1.1. First reduction phase produces highly cortical flakes (>90% cortex), cortical flakes (50-90% cortex), and cortical flake fragments when the flakes have small fractures which do not prevent determination of the cortex percentage. 1.2. Full reduction phase produces ordinary products: flakes with cortex removed (<10% cortex), partly cortical flakes (10-50% cortex), flake fragments with cortex removed and Janus flakes. 1.3. Full reduction phase produces backed items: flakes and flake fragments with debitage back or cortical back. 1.4. Cores (on slab, cobble, flake, or undetermined blank); 2. Façonnage phase; 3. Shatter or undifferentiated products. They are by-products of the *chaîne opératoire* but are not specific to any particular phase, and can be originated by both bipolar and freehand knapping. Shatter includes debris (produced during knapping and does not present a defined butt or bulb), chunks (core waste that display removal traces but cannot be assigned to any category of cores) and angular fragments (usually polyhedral, of any size, and produced during the knapping of NQ slabs, as it generates a large number of uncontrolled fractures).

	NISP	MNI
Elephas sp	4	1
Hippopotamus sp	19	1
Sivatherium	12	1
Syncerus sp.	3	1
Alcelaphini 3b	3	1
Equus oldowayensis	6	1
Metridiochoerus sp.	3	1
Suidae size 3	1	
Suidae size 2	2	
Indet size 1	5	
Indet size 2	13	
Indet size 3	14	
Indet size 3a	7	
Indet size 3b	17	
Indet size 4	38	
Indet size 5	50	
Indet size 6	1	
Indet	140	
Total	338	7

Table 2. NISP and MNI of the animals identified taxonomically classified by size and weight in TKSF.

Animal Size:	1		2		3		3a		3b		4		5		6	
	NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP
Skull	1	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Teeth	-	-	1	7.14	2	13.33	3	33.33	8	28.57	3	7.5	8	9.88	-	-
Mandible	-	-	-	-	1	6.67	-	-	1	3.57	-	-	-	-	-	-
Rib	1	25	4	28.57	1	6.67	-	-	4	14.29	10	25	21	25.93	1	20
Vertebrae	-	-	-	-	1	6.67	-	-	1	3.57	3	7.5	12	14.81	-	-
Scapulae	-	-	-	-	-	-	-	-	1	3.57	1	2.5	3	3.7	-	-
Pelvis	-	-	-	-	-	-	-	-	2	7.14	1	2.5	6	7.41	-	-
Humerus	-	-	-	-	-	-	-	-	-	-	-	-	4	4.94	-	-
Radius	-	-	1	7.14	-	-	-	-	-	-	-	-	-	-	-	-
Ulna	-	-	-	-	-	-	-	-	1	3.57	-	-	-	-	-	-
Femur	-	-	-	-	-	-	1	11.11	1	3.57	-	-	3	3.7	-	-
Tibiae	-	-	-	-	2	13.33	-	-	1	3.57	1	2.5	2	2.47	-	-
Metacarpal	-	-	-	-	-	-	-	-	1	3.57	-	-	1	1.23	-	-
Metatarsal	-	-	2	14.29	-	-	1	11.11	-	-	1	2.5	3	3.7	-	-
Metapodial	-	-	1	7.14	-	-	1	11.11	3	10.71	1	2.5	2	2.47	-	-
Carpal	-	-	1	7.14	1	6.67	1	11.11	1	3.57	-	-	4	4.94	2	40
Tarsal	-	-	-	-	-	-	1	11.11	1	3.57	-	-	4	4.94	-	-
Phalange	1	-	1	7.14	-	-	-	-	-	-	1	2.5	1	1.23	-	-
Indet.	1	-	3	21.43	7	46.67	1	11.11	2	7.14	18	45	7	8.64	2	40
Total	4		14		15		9		28		40		81		5	

Table 3. TKSF Skeletal part profiles according NISP and %NISP.

	Sivatherium sp		*Hippopotamus* sp		*Syncerus* sp.		Indet size 4		Indet size 5	
	NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP	NISP	%NISP
Teeth	-	-	6	31.58	2	66.67	2	5.41	2	4
Vertebrae	4	33.33	2	10.53	-	-	2	5.41	7	14
Ribs	-	-	-	-	-	-	10	27.03	21	42
Scapulae	2	16.67	-	-	1	33.33	-	-	1	2
Coxal	1	8.33	1	5.26	-	-	1	2.7	3	6
Femur	1	8.33	-	-	-	-	-	-	2	4
Humerus	1	8.33	-	-	-	-	-	-	3	6
Tibia	2	16.67	-	-	-	-	1	2.7	-	-
Carpal / Tarsals	1	8.33	4	21.05	-	-	-	-	3	6
Metapodial	-	-	5	26.32	-	-	2	5.41	1	2
Phalange	-	-	1	5.26	-	-	-	-	-	-
Indeterminate	-	-	-	-	-	-	19	51.35	7	14

Table 4. TKSF NISP values of large animals of size groups 4 and 5.

	Fracture		Green fracture Planes		Circunference Degree		
	Green	Dry	Oblique	Longitudinal	I	C	O
Shaft	7 (30.43%)	16 (69.57%)	5 (71,4%)	2(28,6%)	8 (34.78%)	4 (17.39%)	11 (47.83%)

Table 5. Fracture types according to Villa and Mahieu (1991) regarding dry and green fractures, fracture planes for green fractures, and circumference degree of the diaphysis according to Bunn (1982), where I: <50%, C: >50% and O: complete circumference.

	NISP	Cut Marks	Percussion marks	Tooth Marks	Polishing and Abrasion	Carbonate-concretion	Trampling	Biochemical	Weathering	Poor preservation
NISP	326	3			265	235	47	19	29	231
%					81.3	72	14.4	5.8	8.6	70.86

Table 6. TKSF. Alterations recorded at TKSF.

Rounding	QN	VR	Other	Total
Fresh	989	86	10	1086
Light	53	3		55
Intense	11	2		13
Indeterminate	4	2	1	7
Total	1057	93	11	1161

Table 7. Rounding of the lithic industry: NQ, Naibor Quartzite; VR, Volcanic Rocks.

	Assemblage	n	Mean Vector (μ)	Length of Mean Vector (r)	Concentration	Circular Variance	Circular Standard Deviation	Rayleigh Test (Z)	Rayleigh Test (p)	Kuiper's Test (Uniform. V)	Kuiper's Test (p)
MBR	Industry	183	47.793°	0.09	0.181	0.455	62.842°	1.488	0.226	1.408	> 0.15
	Fauna	115	25.012°	0.132	0.266	0.434	57.679°	1.996	0.136	1.682	0.10 > p > 0.05
PMA	Industry	183	126.53°	0.118	0.237	0.441	59.273°	2.531	0.08	1.438	> 0.15
	Fauna	115	154.667°	0.145	0.292	0.428	56.347°	2.402	0.091	1.485	> 0.15

Table 8. The results of the main orientation analysis and of the Rayleigh and Kuiper's tests on the uniformity of all assemblages of TKSF.

Assemblage		Woodcock´s index		Eigenvectors and Eigenvalues						Vollmer´s index			Benn´s index			
	n	K	C	V1	V2	V3	S1	S2	S3	Cluster	Girdle	Uniform	IS	EL	F	CGI
Industry MBG	183	0.66	1.04	268/51/31.157	13/12/59.989	112/37/90.854	0.317	0.275	0.215	0.169	0.304	0.527	0.677	0.134	0.781	0.556
Industry PMA	183	0.54	1.03	270/50/31.768	165/12/62.159	65/37/89.074	0.276	0.324	0.211	0.147	0.332	0.521	0.765	-0.176	0.650	0.443
Fauna MBG	115	0.16	1.95	275/67/8.3783	44/15/44.772	139/17/58.849	0.374	0.365	0.188	0.126	0.650	0.224	0.502	0.025	0.515	0.194
Fauna PMA	115	0.16	1.97	259/67/8.2736	136/13/44.722	42/19/59.005	0.370	0.363	0.188	0.128	0.651	0.222	0.509	0.019	0.519	0.197

Table 9. Fabric index of the TKSF archaeological remains.

Assemblage		Density		Nearest Neighbor index				Getis-Ord General G index			
	n	m^2	density / m^2	R	Z	*p*	Result	G	Z	*p*	Result
Total	1341	48.2	27.82	0.87	-8.65	0.000	Cluster	0.00	5.67	0.000	High-Cluster
Industry	1051	48.2	21.80	0.89	-5.80	0.000	Cluster	0.00	4.86	0.000	High-Cluster
Fauna	290	48.2	6.02	0.80	-5.51	0.000	Cluster	0.00	-5.21	0.000	Low-cluster
Flakes	328	48.2	6.80	0.91	-2.84	0.004	Cluster	0.00	4.49	0.00	High-Cluster
Shatter	520	48.2	10.79	0.84	-6.67	0.000	Cluster	0.00	4.90	0.000	High-Cluster
Cores	31	48.2	0.64	0.93	-1.14	0.251	Random	0.00	2.50	0.012	High-Cluster
LCT	48	48.2	1.00	0.93	-0.92	0.353	Random	0.00	1.04	0.295	Random
Cobble	52	48.2	1.08	1.13	1.92	0.053	Dispersed	0.16	-0.52	0.602	Random
Percussion materials	12	48.2	0.25	1.2	1.38	0.16	Random	0.00	1.04	0.298	Random

Table 10. Density and clustering values of the TKSF archaeological remains.

Captions

Fig. 1. A. Location of Thiongo Korongo (TK) at Olduvai Gorge (modified after Hay 1976); Location of TK in a lateral gully; Positions of the trenches excavated by M. Leakey (1963) and the sectors excavated by TOPPP (2010–2015), showing the areas occupied by the TKLF and the TKSF. B. Stratigraphical section showing the horizons excavated at TKSF.

Fig. 2. A, Lithic industry and faunal remains distribution; B, lithic industry distribution; C, faunal remains distribution; D

distribution map of faunal remains with cut marks, percussions marks, and green fractures.

Fig. 3. Cut marks at TKSF. TK'2014, nº 8263: Animal size 5 rib; TK'2015, nº 8599: Size 3b metapodial.

Fig. 4. TKSF: Rose diagrams of the studied assemblages

Fig. 5. TKSF: Woodcock´s diagram (upper) and Vollmer´s diagram (below) (adapted from Lenoble, et al., 2008).

Fig. 6. TKSF: Stereographic projection of the main studied assemblages.

Fig. 7. TKSF. Kernel density maps: A) all assemblage; B) lithic industry; C) faunal remains.

Fig. 8. TKSF. Kernel density maps by lithic industry techno-typological categories: A) Percussion elements; B) cobbles; C) shatter; D) cores; E) flakes; F) LCTs.

Fig. 9. TKSF. K-means groups maps: A) all assemblage; B) lithic industry; C) faunal remains.

Fig. 10. TKSF. Cluster outlie maps: A) all assemblage; B) lithic industry; C) faunal remains.

Fig. 11. TKSF. Optimized hotspot: A) all assemblage; B) lithic industry; C) faunal remains.

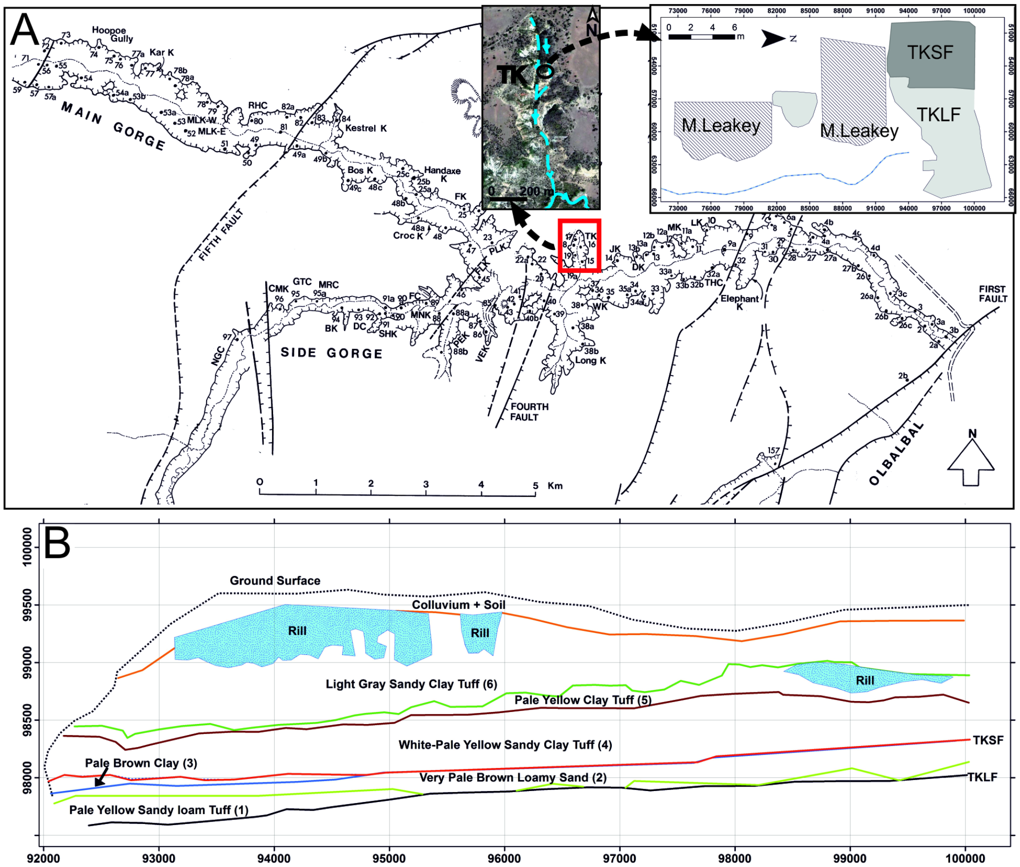
Figure 12. Besag´s inhomogeneous L-function applied to simulate a random inhomogeneous Poisson process (red dotted line), whose 95% confidence interval is shown as a gray global envelope. The TK bone and lithic data fall within the margins of the confidence envelope, showing that they are two inhomogeneous Poisson processes.

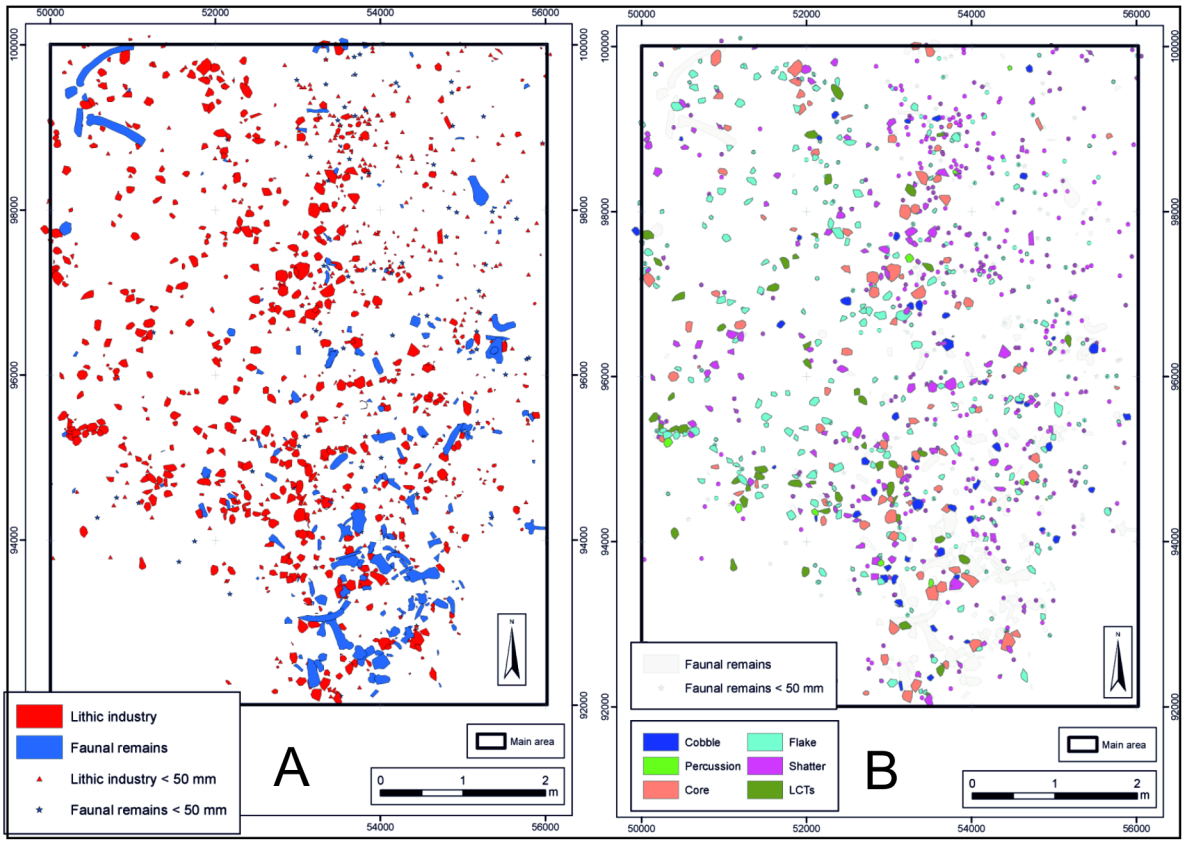
Figure 13. Besag´s L-function test applied with a homogeneous (A-B) and an inhomogeneous (C-D) Poisson process for lithics (A-D) and bones (B-D). A confidence global envelope is displayed together with the theoretical Poisson process (red dotted line).

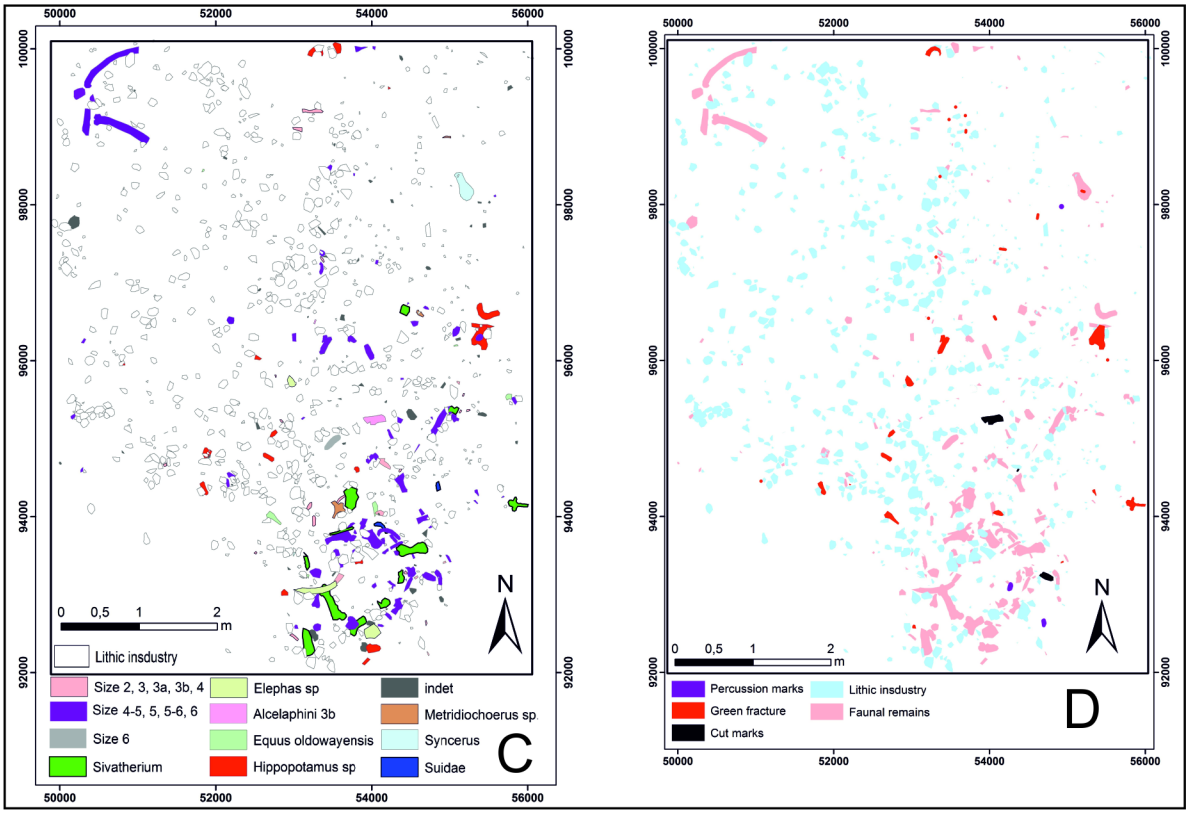
Figure 14. Kernel maps showing the distribution of lithics (A-C) and bones (B-D). Maps A and B were obtained using likelihood cross-validation. Maps C and D were obtained using adaptive intensity, based on Dirichlet-Voronoi estimation of density.

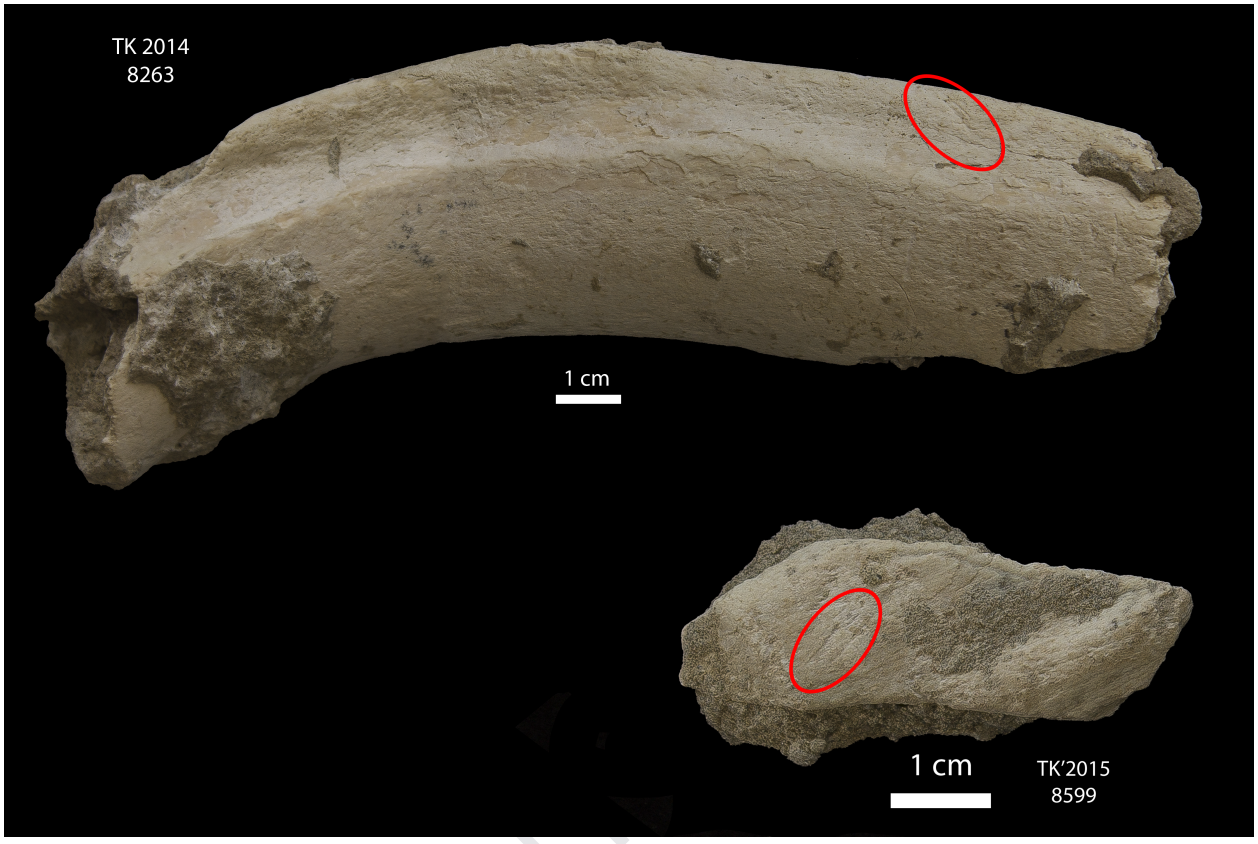
Figure 15. Random labelling using the J function. The TK bone-lithic point process shows random distribution within the confidence envelope indicating no strong co-dependence of fauna with lithics.

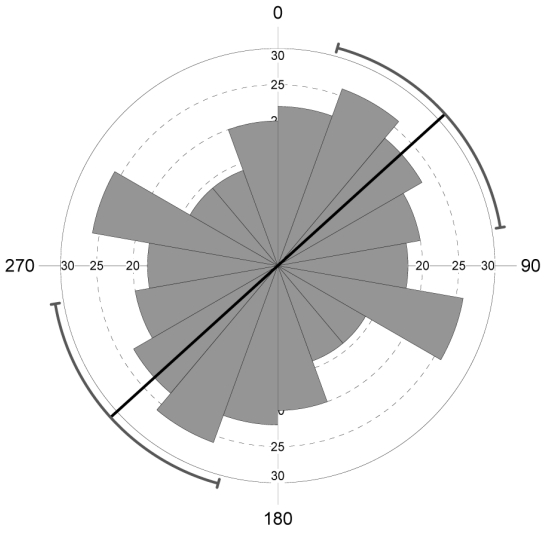
Figure 16. Cross- type analysis, using the inhomogeneous Besag´s L-function. Fauna (f) and lithics (l) show local minor clustering (diagonal) and their interaction (off-diagonal) shows spatial clustering co-dependence.


A
B
MAIN GORGE
SIDE GORGE
FIFTH FAULT
FOURTH FAULT
FIRST FAULT
OLBALBAL
TK
TKSF
TKLF
M.Leakey
Ground Surface
Colluvium + Soil
Rill
Light Gray Sandy Clay Tuff (6)
Pale Yellow Clay Tuff (5)
White-Pale Yellow Sandy Clay Tuff (4)
Pale Brown Clay (3)
Very Pale Brown Loamy Sand (2)
Pale Yellow Sandy loam Tuff (1)

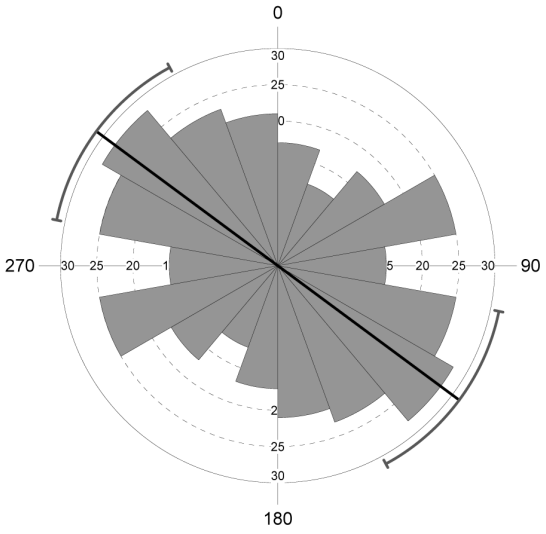

Lithic industry
Faunal remains
Lithic industry < 50 mm
Faunal remains < 50 mm
A
Main area
0 1 2 m
Faunal remains
Faunal remains < 50 mm
Cobble
Flake
Percussion
Shatter
Core
LCTs
B
Main area
0 1 2 m


0 0,5 1 2 m
Lithic insdustry
Size 2, 3, 3a, 3b, 4
Size 4-5, 5, 5-6, 6
Size 6
Sivatherium
Elephas sp
Alcelaphini 3b
Equus oldowayensis
Hippopotamus sp
indet
Metridiochoerus sp.
Syncerus
Suidae
C
N
0 0,5 1 2 m
Percussion marks
Green fracture
Cut marks
Lithic insdustry
Faunal remains
D
N

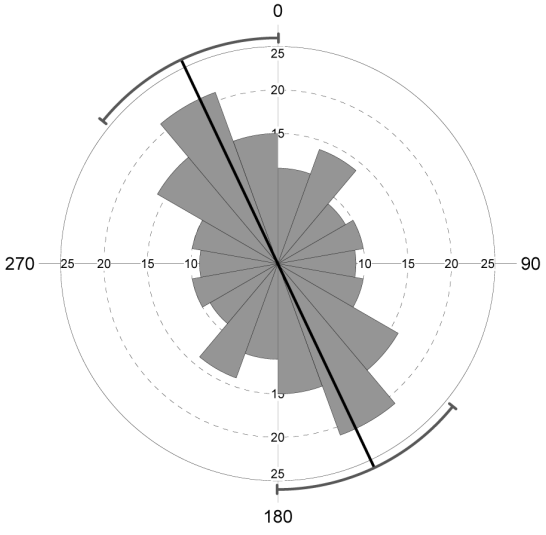




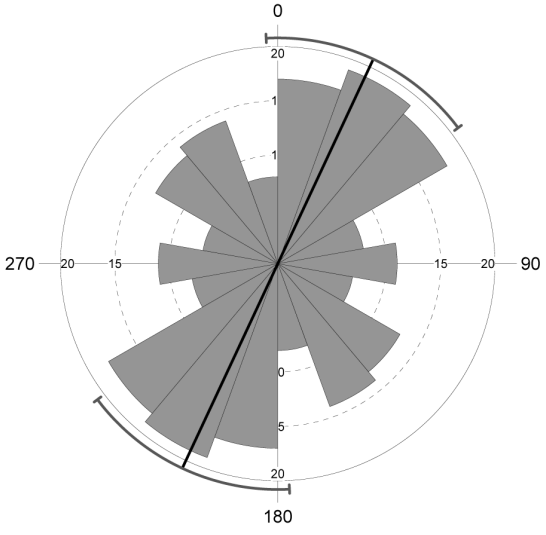
Lithic industry MBR



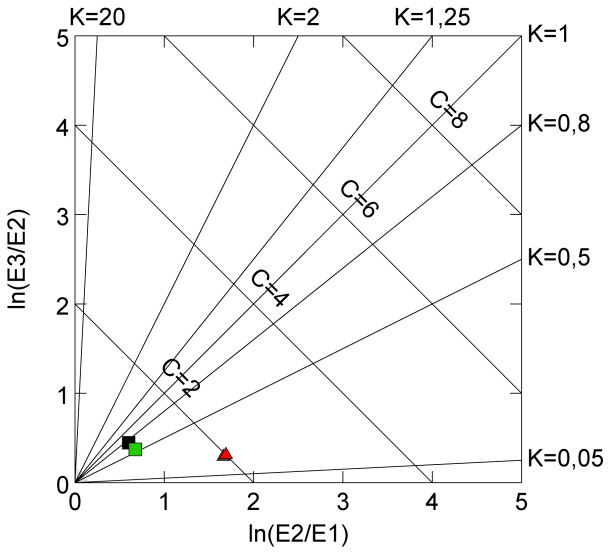
Lithic industry PMA

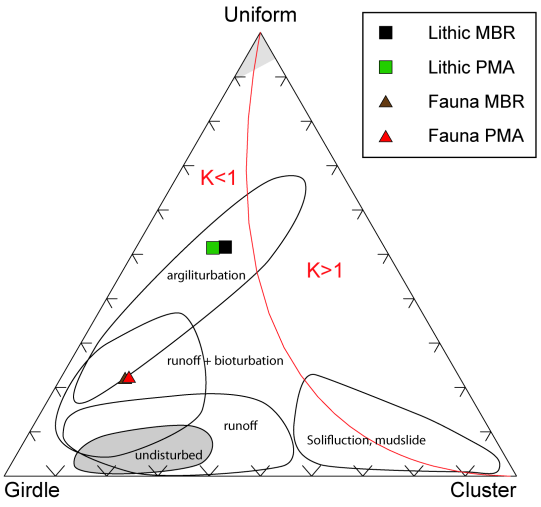


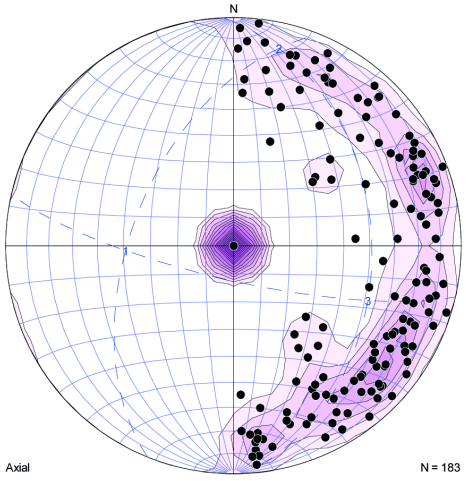
Faunal remains MBR



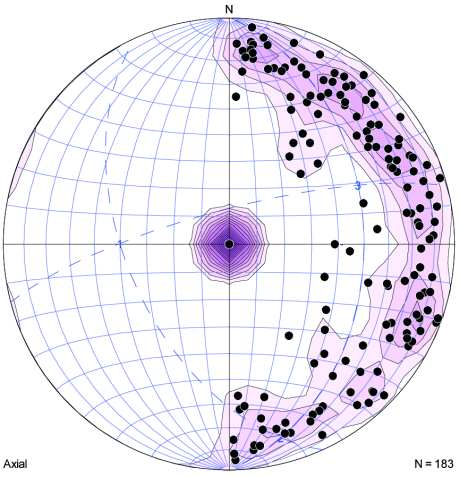
Faunal remains PMA



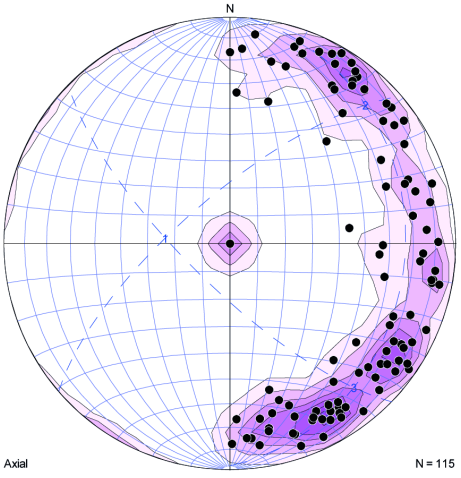




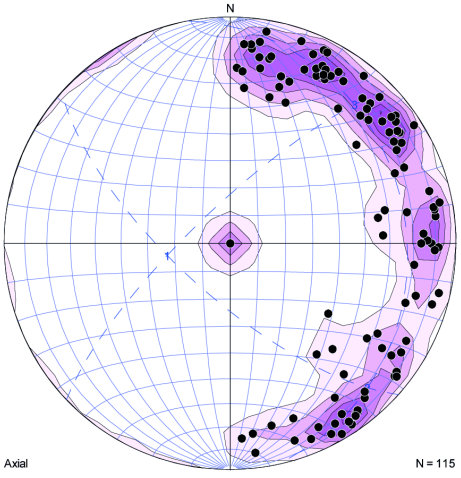
Lithic industry MBR



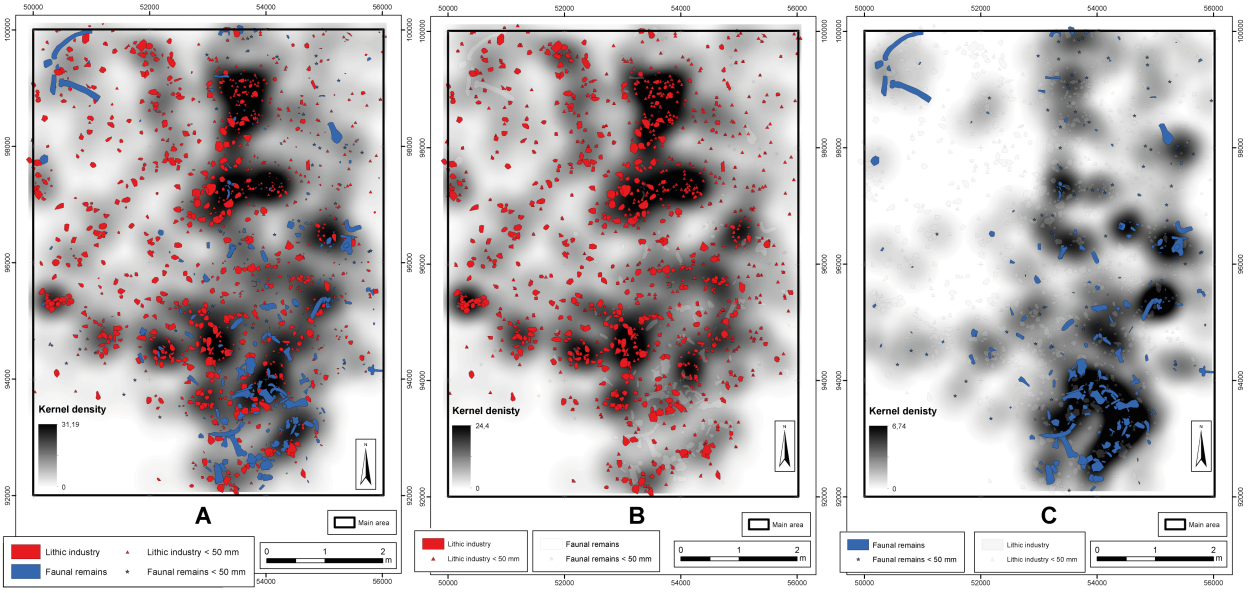
Lithic industry PMA

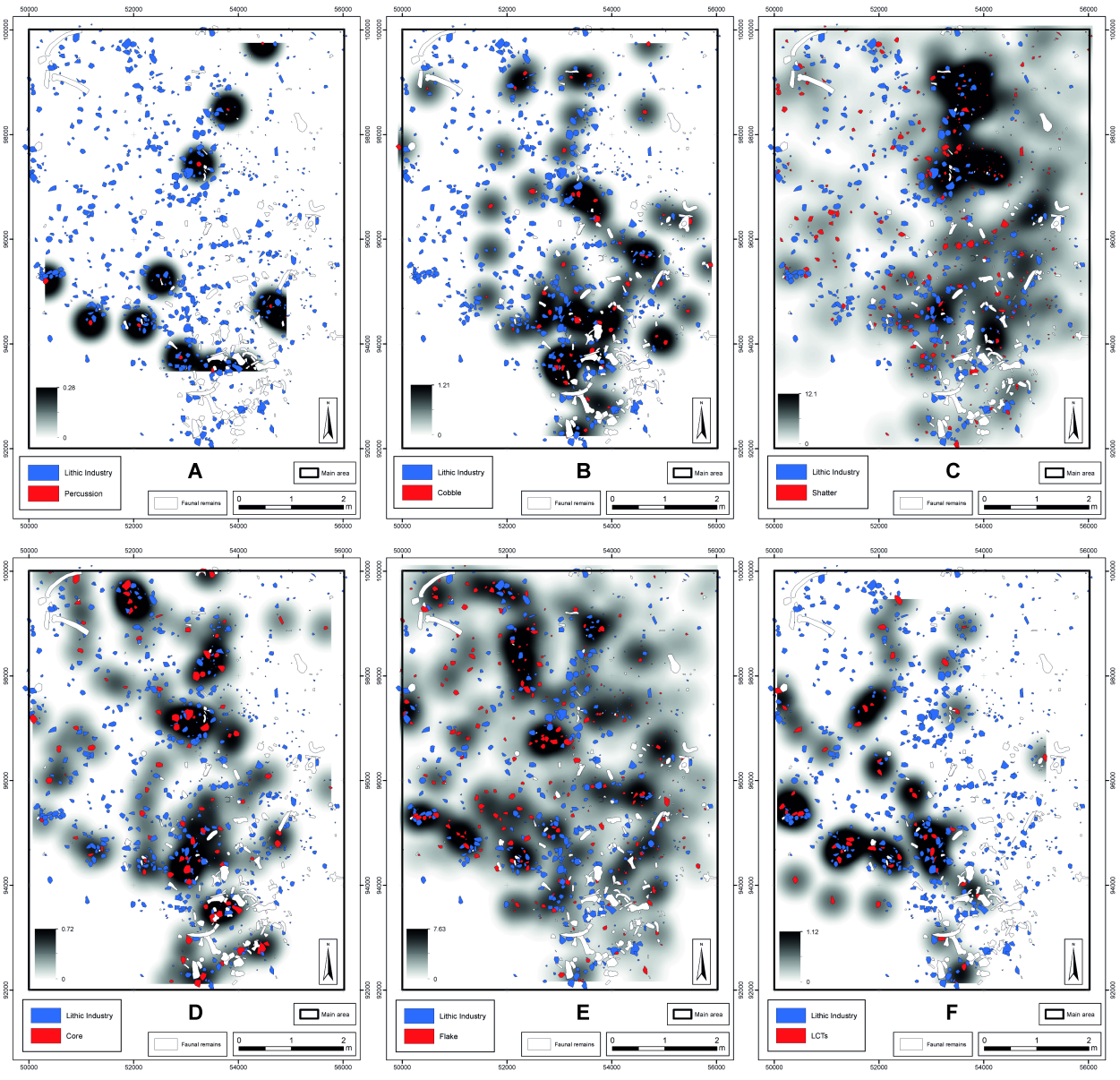


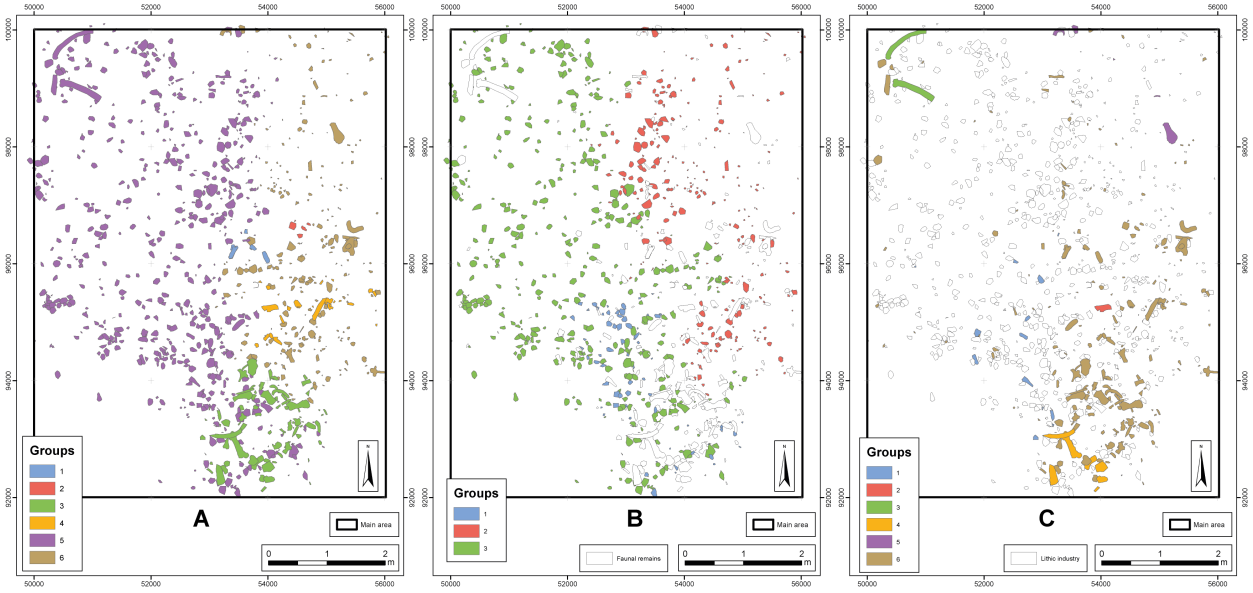
Faunal remains MBR

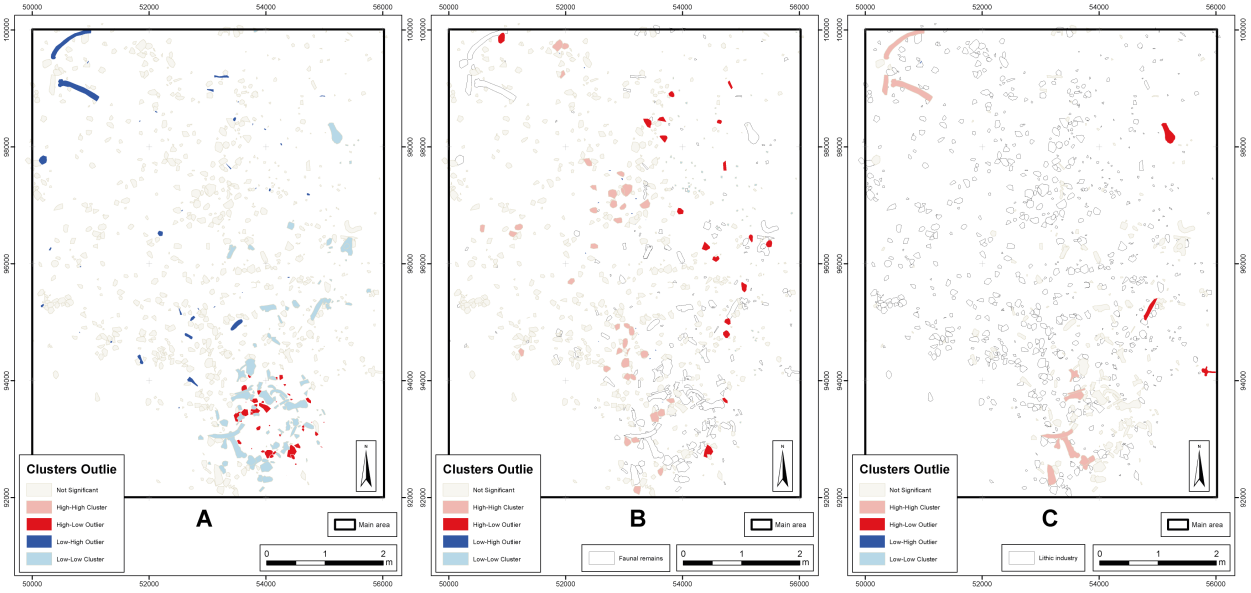


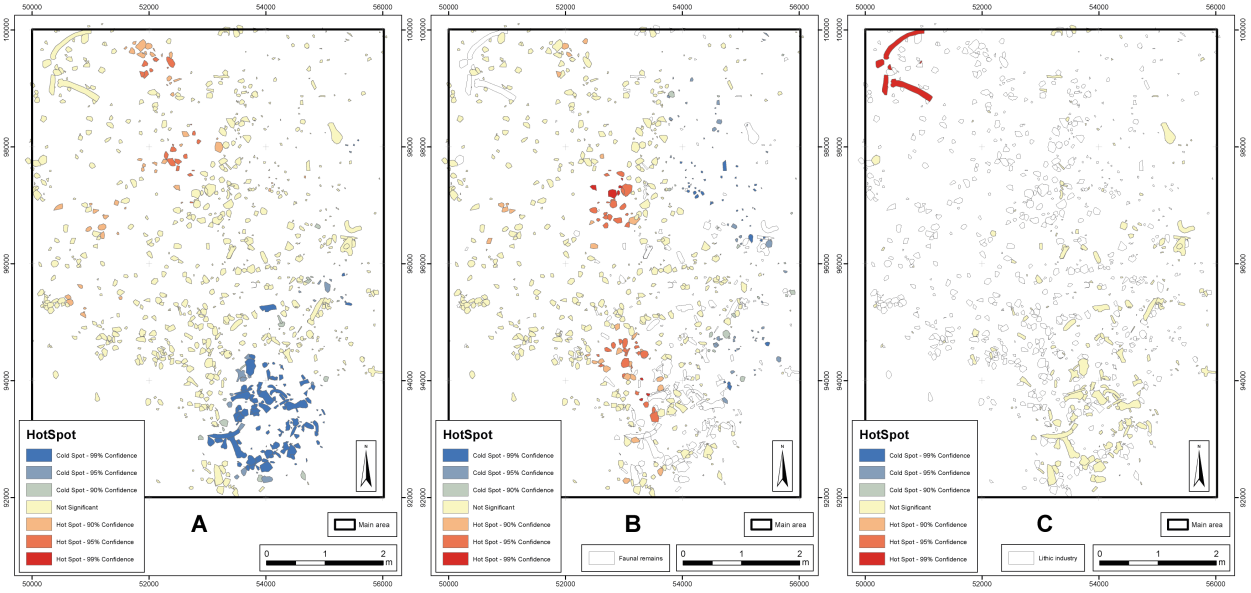
Faunal remains PMA

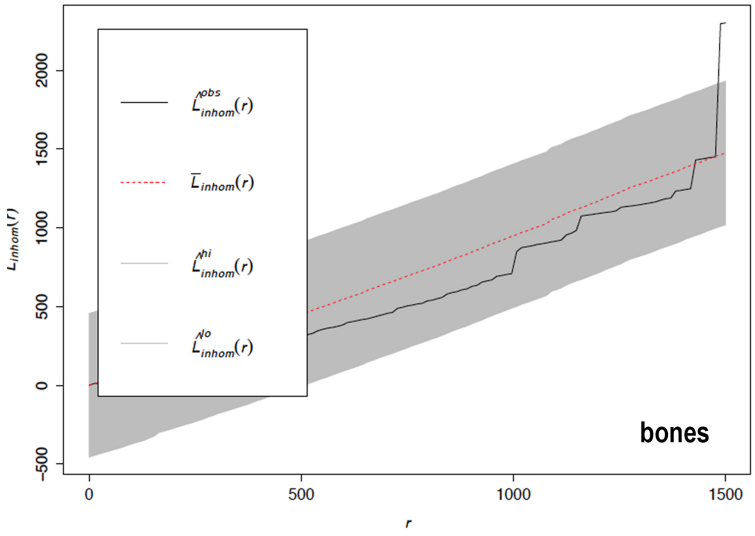


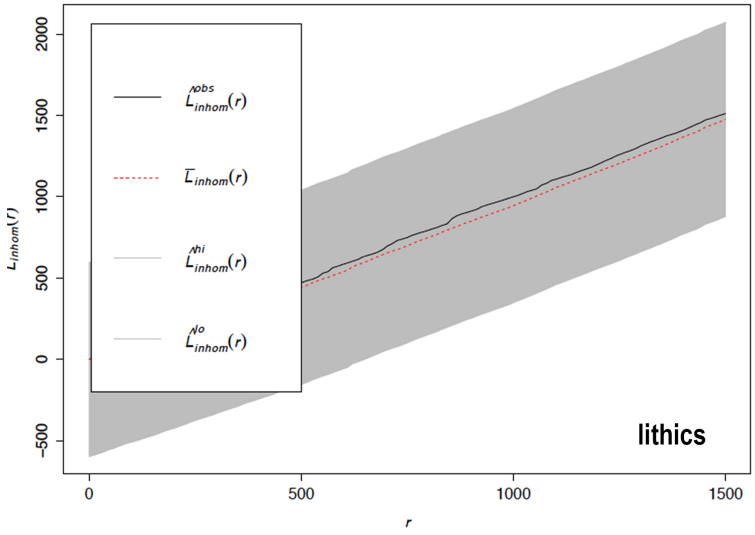

A
Lithic Industry
Percussion
B
Lithic Industry
Cobble
C
Lithic Industry
Shatter
D
Lithic Industry
Core
E
Lithic Industry
Flake
F
Lithic Industry
LCTs
Main area
Faunal remains
0 1 2 m

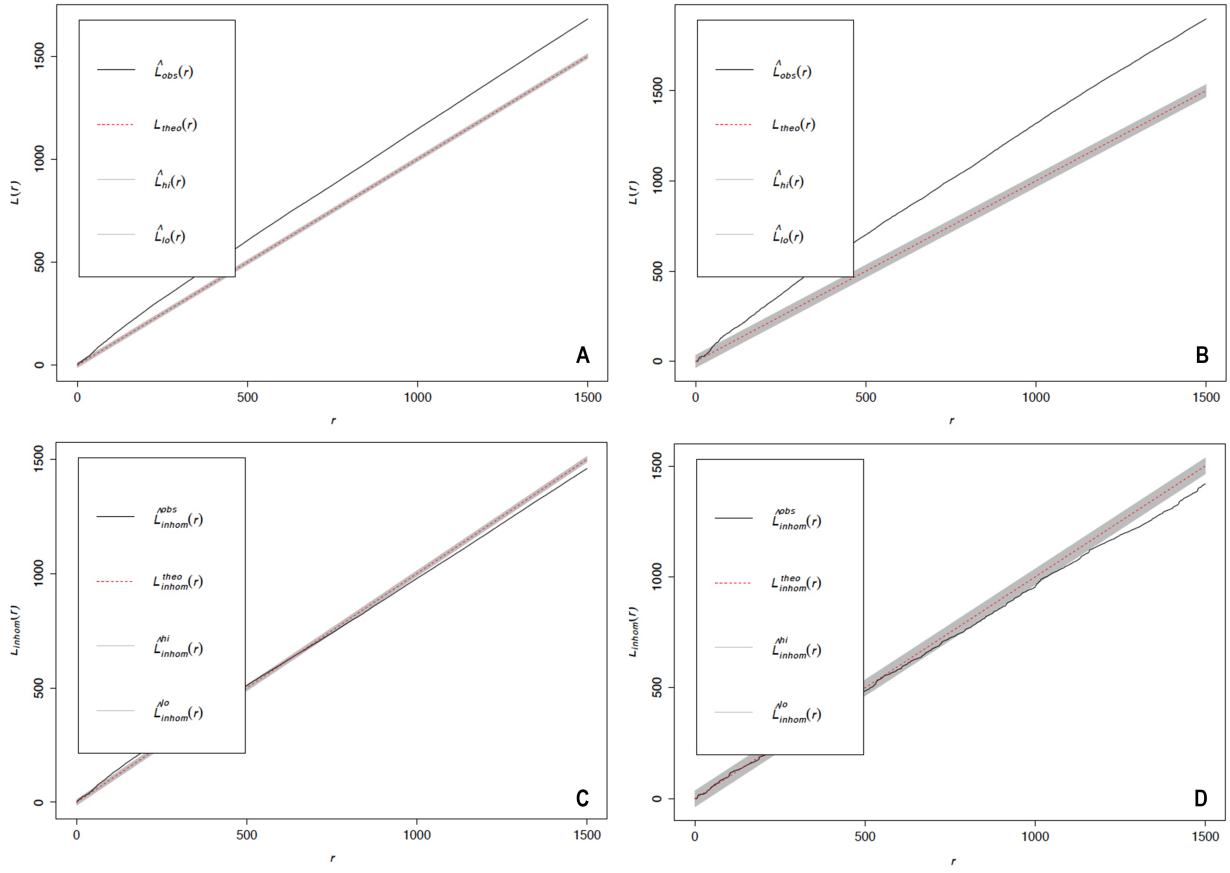


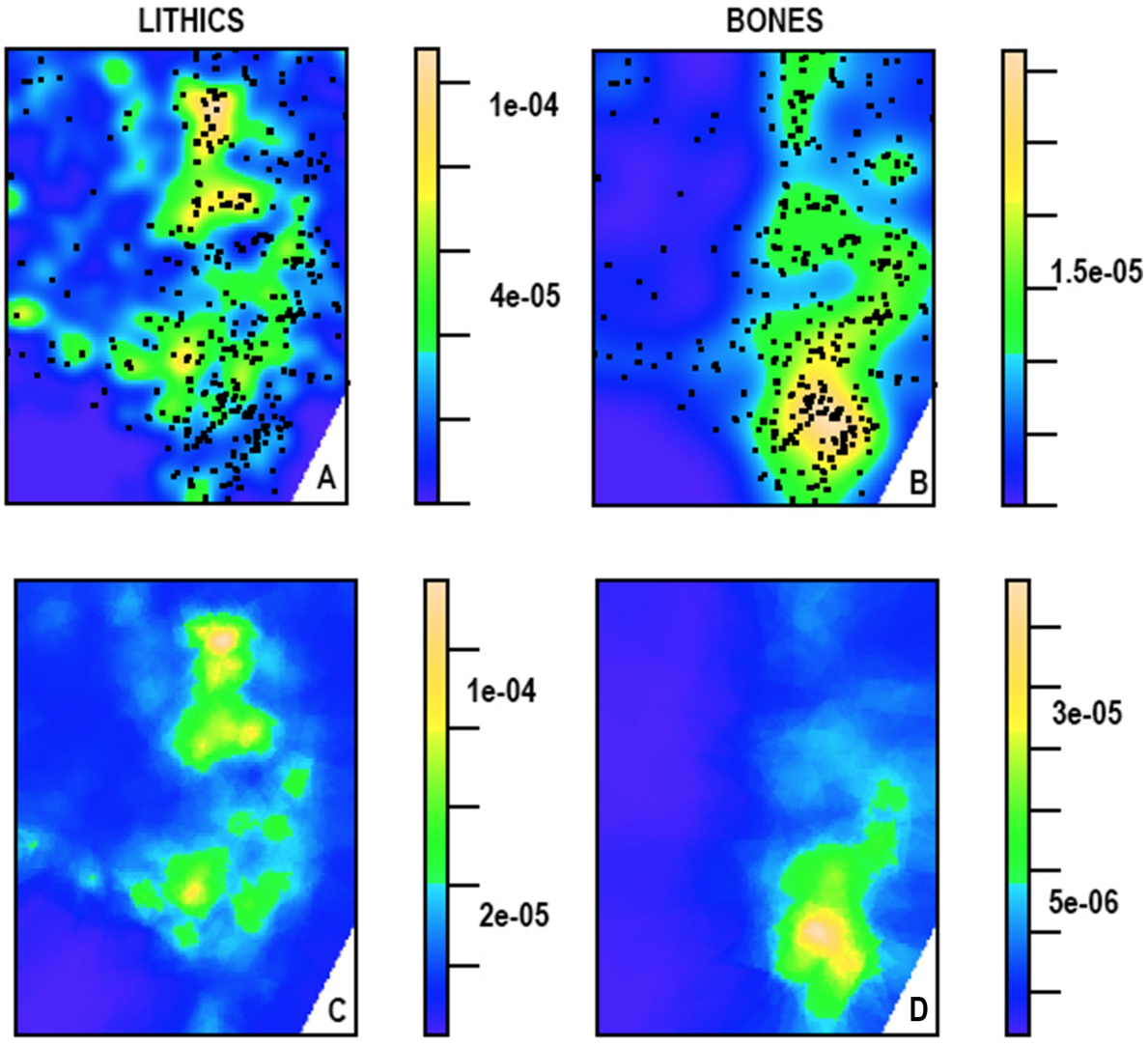


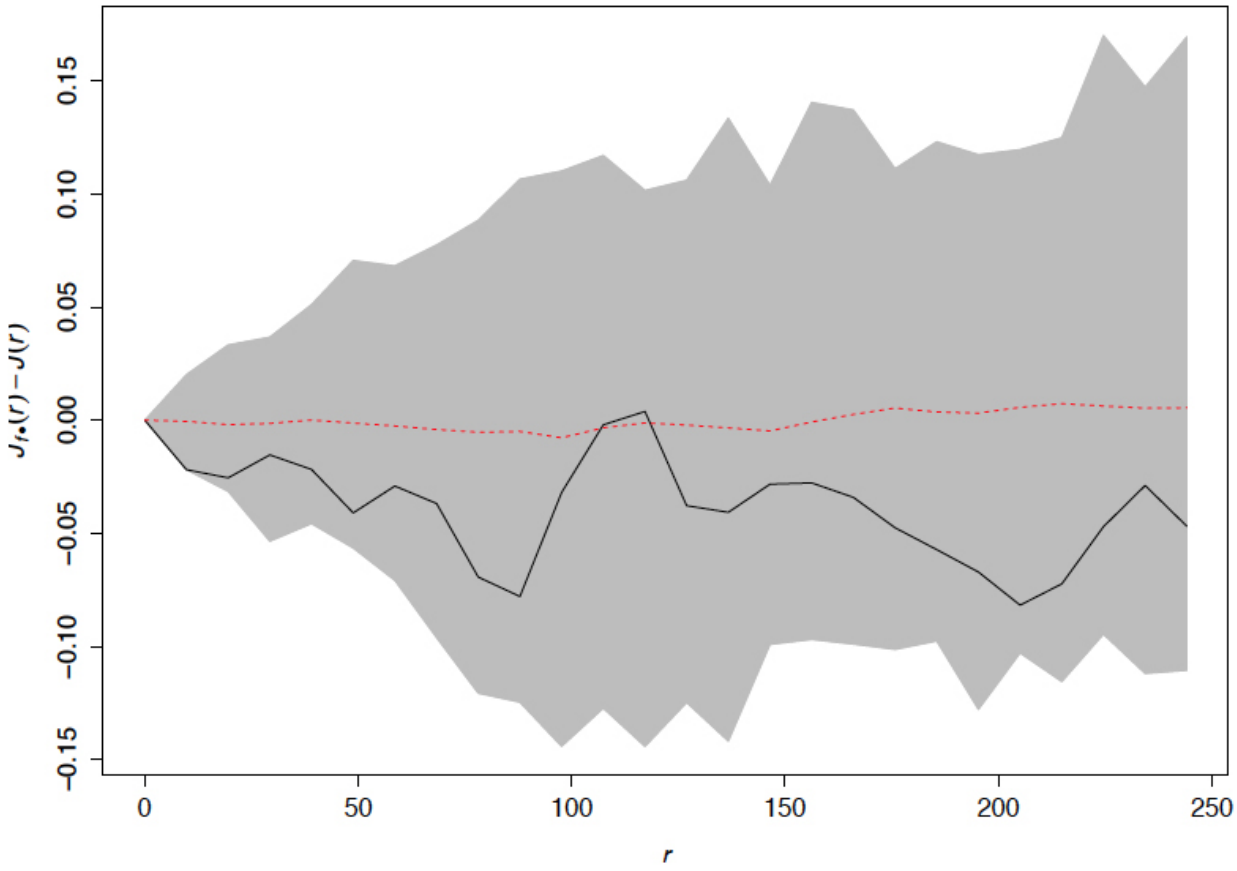


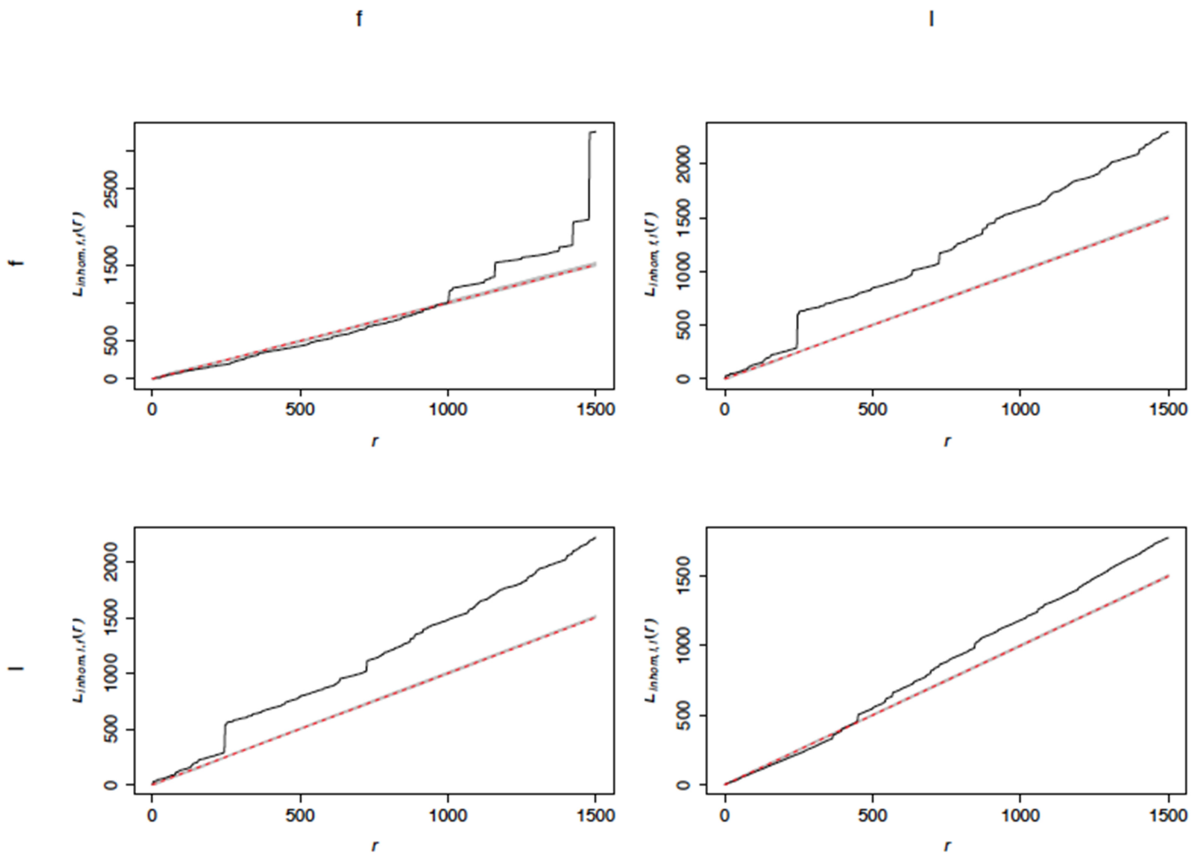

$\hat{L}^{obs}_{inhom}(r)$
$\bar{L}_{inhom}(r)$
$\hat{L}^{hi}_{inhom}(r)$
$\hat{L}^{lo}_{inhom}(r)$
bones
$L_{inhom}(r)$
r


$\hat{L}^{obs}_{inhom}(r)$
$\bar{L}_{inhom}(r)$
$\hat{L}^{hi}_{inhom}(r)$
$\hat{L}^{lo}_{inhom}(r)$
lithics
$L_{inhom}(r)$
r


$\hat{L}_{obs}(r)$
$L_{theo}(r)$
$\hat{L}_{hi}(r)$
$\hat{L}_{lo}(r)$
L(r)
r
0
500
1000
1500
A
B
$\hat{L}^{obs}_{inhom}(r)$
$L^{theo}_{inhom}(r)$
$\hat{L}^{hi}_{inhom}(r)$
$\hat{L}^{lo}_{inhom}(r)$
$L_{inhom}(r)$
C
D


LITHICS
BONES
1e-04
4e-05
1.5e-05
A
B
1e-04
2e-05
3e-05
5e-06
C
D





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We the authors declare that the manuscript entitled “Assessing functionality during the early Acheulean in level TKSF at Thiongo Korongo site (Olduvai Gorge, Tanzania)” has not any conflict of interest.

Sincerely,

Joaquín Panera
On behalf of all authors