Old stones' song: Use-wear experiments and analysis of the Oldowan quartz and quartzite assemblage from Kanjera South (Kenya)

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Abstract

Evidence of Oldowan tools by ~2.6 million years ago (Ma) may signal a major adaptive shift in hominin evolution. While tool-dependent butchery of large mammals was important by at least 2.0 Ma, the use of artifacts for tasks other than faunal processing has been difficult to diagnose. Here we report on use-wear analysis of ~2.0 Ma quartz and quartzite artifacts from Kanjera South, Kenya. A use-wear framework that links processing of specific organic materials and tool motions to their resultant use-wear patterns was developed in a suite of experiments. A blind test was then carried out to assess and improve the efficacy of this experimental use-wear framework, which was then applied to the analysis of 62 Oldowan artifacts from Kanjera South. Use-wear on a total of 23 artifact edges was attributed to the processing of specific materials. Use-wear on seven edges (30%) was attributed to animal tissue processing, corroborating zooarchaeological evidence for butchery at the site. Use-wear on sixteen edges (70%) was attributed to the processing of plant tissues, including wood, grit-covered plant tissues that we interpret as underground storage organs (USOs), and stems of grass or sedges. These results expand our knowledge of the suite of behaviors carried out in the vicinity of Kanjera South to include the processing of materials that would be "invisible" using standard archaeological methods. Wood cutting and scraping may represent the production and/or maintenance of wooden tools. Use-wear related to USO processing extends the archaeological evidence for hominin acquisition and consumption of this resource by over 1.5 Ma. Cutting of grasses, sedges or reeds may be related to a subsistence task (e.g., grass seed harvesting, cutting out papyrus culm for consumption) and/or a non-subsistence related task (e.g., production of "twine," simple carrying devices, or bedding). These results highlight the adaptive significance of lithic technology for hominins at Kanjera.

Keywords: Early Pleistocene archaeological sites, Oldowan artifact function, use-wear analysis, Kanjera South, East Africa

Introduction

The evaluation of traces produced on artifact surfaces through the working of different materials provides one of the few methods for assessing the range of activities carried out by ancient hominins, and contributes to reconstructions of hominin behavior. Here we analyse use-wear of the lithic industry from the Oldowan site of Kanjera South, southwestern Kenya (Plummer et al., 1999; 2009a,b; Braun et al., 2008; 2009a,b; Ferraro et al., 2013). This assemblage is particularly suited for use-wear analysis, as stone artifact surfaces have not undergone extensive post-depositional modification, and multiple raw materials preserve use-wear traces.

Use-wear analysis was first developed in Russia during the 1930s (Olausson, 1980), and following the English translation of Sergei Semenov's *Prehistoric Technology* (Semenov, 1964), interest in use-wear analysis in the international scientific community grew (Odell, 2004). Archaeologists initially had high expectations for the interpretative potential of this analysis, especially when applied to Paleolithic stone tools. However, its application proved difficult, due to an increased appreciation of the post-depositional modification of artifact edges (e.g., Plisson & Mauger, 1988) as well as considerable inter-observer variation in use-wear interpretation (Newcomer et al., 1986; Unrath et al., 1986). Although the degree of subjectivity involved is not necessarily greater than other commonly collected classes of archaeological data (e.g., zooarchaeological data) (Odell, 2004), some became skeptical of the application of use-wear analysis to stone artifact assemblages, especially in the deep past (Shea, 1987; Bamforth, 1988).

Recently, many analysts have implemented protocols that provide a more rigorous framework for assessing artifact function than had been common in the past (e.g., Lemorini et al., 2006; Claud, 2008; Rots, 2010). These protocols explicitly address concerns about post-depositional modification, and the linkage between a particular type of edge modification and the type of material being processed. They include the study of all artifacts in an assemblage to assess the impact of post-depositional processes on artifact edges, experiments to create a use-wear reference collection with the same raw materials being investigated archaeologically, the development of visualisation techniques that reduce the glare of highly reflective raw materials, and blind tests of the analyst interpreting use-wear. These protocols were followed here in the analysis of Oldowan quartz and quartzite artifacts from Kanjera South. There has also been an attempt to quantify use-wear, utilising technologies derived from the material sciences (e.g., Stemp and Stemp, 2003; Evans and Donahue, 2008; Stevens et al., 2010; Stemp and Chung, 2011; Evans and Macdonald, 2011). These approaches have had some success and may ultimately provide useful experimental protocols for use-wear analysts. While these have not yet developed into mature methodologies that can be applied to large artifact samples from archaeological sites, we hope to apply quantitative approaches to the use-wear on Kanjera artifacts in future.

Locality

The late Pliocene Oldowan occurrences at Kanjera South are found on the northern foothills of the Homa Mountain carbonatite complex, Homa Peninsula, southwestern Kenya (Fig. 1).

FIGURE 1 HERE

The Southern Member of the Kanjera Formation is comprised of six beds, from oldest to youngest KS-1 to KS-6 (Behrensmeyer et al., 1995; Plummer et al., 1999). Archaeological materials have been excavated from a ~ 3 metre sequence from the top of Bed KS-1 through Bed KS-3, and are the focus of current study. Lower KS-1 begins with the catastrophic flow of pyroclastic material from the Homa Mountain complex in the south towards the depocenter to the north in the Nyanza Rift graben. This part of the sequence exhibits little internal stratification and no pedogenic development. In contrast, the well-bedded, better sorted and pedogenically modified upper parts of KS-1 reflect the reworking of the original pyroclastic flows by ephemeral streams. This environmental setting continued in KS-2, with deposition by anastomosing channels with intermittent, diffuse, generally low energy flow, interrupted by several thin, diffuse conglomerate lenses representing short intervals of higher energy flow. Pedogenesis in KS-2 is better developed than in upper KS-1. KS-3 exhibits soft sediment deformation and preserves some channels, suggesting a transition to a wetter environment. Even so, the pedogenic features and palaeosol carbonates found in this unit demonstrate the existence of stable land surfaces. A lake transgression depositing KS-4 clays caps the archaeological sequence.

The presence of the Olduvai subchron (1.95-1.77 Ma) in Bed KS-5 overlying the archaeological levels, and the co-occurrence of the equid *Equus* sp., the suids *Metridiochoerus andrewsi* and *M. modestus*, and the proboscidean *Deinotherium* sp., indicate that the KS-1 to KS-3 archaeological occurrences date between approximately 2.3 Ma (the dispersal of *Equus* across Africa, and the first occurrence of *M. modestus*) and 1.95 Ma (the base of the Olduvai subchron) (Plummer et al., 1999). An age of ~ 2 Ma for the archaeological occurrences seems most likely, given the apparent rapidity of deposition. Hominins were the primary agent of accumulation of the archaeological material, barring materials deposited in the conglomerate lenses (Plummer et al., 1999; Ferraro et al., 2013). The majority of the *in situ* artifacts are from Excavation 1, a 169 m^2 area that has yielded 3663 fossils and 2883 artifacts lifted with three dimensional coordinates. The bulk of the artifacts are from KS-2, which accumulated rapidly, probably representing decades to centuries of deposition.

The lithic industry: raw material and technology

The heterogeneity of the geology on the Homa Peninsula and its environs (Saggerson, 1952; LeBas, 1977), in combination with hominin lithic preferences, has resulted in artifact assemblages with greater raw material diversity than those from other Oldowan sites (Braun et al., 2009a,b) (Table 1).

TABLE 1 HERE

Extensive raw material surveys have produced a comprehensive database of 315 separate lithologies available on and in the immediate vicinity of the Homa Peninsula (Braun et al., 2008). Lithologies incorporated in the technological system of Oldowan hominins at Kanjera South include a variety of igneous rocks (e.g., carbonatite, rhyolite, granite), sedimentary rocks (e.g., chert, limestone), metamorphic rocks (e.g., meta-quartzite), and metasomatised rocks (e.g., fenitised andesite) (LeBas, 1977; Plummer, 2004). Geochemical studies have isolated primary and secondary sources for the stone used in artifact manufacture (Braun et al., 2008). Examination of the raw materials of the clast populations on and off the Homa Peninsula demonstrates that 28% of the Kanjera South artifact sample was made with non-local raw materials, defined here as raw materials not found as outcrops on the Homa Peninsula or in conglomerates in the radial drainage system of the Homa Mountain carbonatite complex.

Geochemical analysis indicates that one of the raw materials under discussion here, banded quartzite, crops out in the Kisii highlands over 60 km away from the Homa Peninsula, and was available in stream and river conglomerates no closer than 10-13 km away from Kanjera South (Braun et al., 2008). Vein quartz is also not available in the immediate vicinity of Kanjera, and may ultimately derive from the Kisii Highlands, but its minimum transport distance is uncertain. The high proportion of raw materials coming from 10 or more kilometres away from the site is unique within the Oldowan; most Oldowan sites were formed on or near major raw material sources (Plummer, 2004; Harmand, 2007; Goldman-Neuman & Hovers, 2009; Rogers & Semaw, 2009). Technological analyses of the Kanjera South raw materials indicate that there was differential transport and curation of raw materials from outside the peninsula, with the majority of flakes of non-local material being derived from later stages of core reduction. Cores made from these "non-local" materials are relatively uncommon, and when they are found they are generally heavily reduced (Braun et al., 2009a,b).

The technology at Kanjera South provides some interesting insights into hominin behavior in the early Pleistocene. Although flakes and debris from flake production dominate the assemblage, core forms at Kanjera South are somewhat distinct from other Oldowan assemblages, and are focused on radial, discoidal, and polyhedral forms (Braun et al., 2009a,b). Large flakes are often re-utilised as cores (Fig. 2), and polyfacial forms are prevalent in some raw materials.

FIGURE 2 HERE

No single core production mode (Roche, 2000) dominates the assemblage. Curation beyond what is commonly associated with an Oldowan assemblage is evinced by relatively high proportions of core rejuvenation flakes and intentionally retouched flakes in "non-local" raw materials, where the retouch is unidirectional, continuous, and tends to be concentrated on one edge (Braun, 2006). The assemblage is characterized by technological diversity, with different raw materials displaying widely divergent technological strategies (Braun et al., 2009b; Braun & Plummer, 2013).

The quartzite materials exhibit two main schema of reduction. The first and most common scheme involves the use of relatively large flakes (>5 cm) as cores, where the ventral surface of the cores is used as a removal surface and the dorsal side of the original flake is used as a flaking surface (Braun et al., 2009b). The second reduction mode for quartzite, and the primary reduction mode for quartz, is similar to that described by de la Torre and Mora (2005) as bifacial abrupt, whereby a single removal surface is dominated by unipolar and bipolar removals that intersect at the center of mass of the core. There is a subsequent removal pattern that runs orthogonal to the main axis of flaking. The series of removals tends to be relatively short with few overlapping removals. The absence of a long series of removals as seen in other Oldowan contexts (e.g., Lokalalei 2C; Delagnes & Roche, 2005) may simply reflect the small size of the original cobbles (Fig. 2; Table 2). The presence of rounded river cortex on almost all of the cores indicates they were collected from a fluvial context.

TABLE 2 HERE

Materials & Methods

We followed a four step methodology in carrying out this analysis. The first step was the examination of the entire artifact sample from our excavations macroscopically and with a stereomicroscope. This allowed us to assess its suitability for use-wear analysis, and select the best preserved edges for investigation. Use-wear experiments with flakes made from the same raw materials used by the Kanjera hominins were then carried out to link specific use-wear features to tool motions and the materials being processed. Blind tests were then carried out to assess the efficacy of the use-wear framework, followed by analysis of the Oldowan artifacts themselves. These steps are considered in turn below.

Initial examination of archaeological materials

This study began when one of us (CL) evaluated the entire artifact sample from Kanjera South housed in the National Museums of Kenya (n=4474, of which 3954 are detached pieces) (Table 1) to assess the quality of edge preservation across raw materials, and the post-depositional processes impacting artifact surfaces. The Kanjera South assemblage is very well preserved and edges were rarely subject to the types of damage usually associated with rolling or fluvial action (Schick, 1987a; Braun, 2006). However, as has been noted in other use-wear studies in Africa (e.g., Keeley and Toth, 1981), some raw materials suffer light post-depositional chemical dissolution, which compromises their edge morphology. In the Kanjera South sample, artifacts made with carbonatite, limestone, microijolite, ijolite, phonolite, and to some extent fenetized andesite were effected by post-depositional chemical dissolution. Here we limit our analysis to the “detached piece” sample of quartz and quartzite, two raw materials that retain exceptionally well-preserved edges. Other raw materials (e.g. rhyolite, chert) have well-preserved edges, but we are still building a comparative database for their analysis. The Kanjera South sample totaled 248 quartzite artifacts, of which 222 were detached pieces, and 91 quartz artifacts, of which 77 were detached pieces. Artifacts were gently washed with warm water and soap, and then were washed for five minutes in demineralized water in an ultrasonic tank, after which they were air dried. Edges of these artifacts were inspected unassisted and using a stereomicroscope (SM Nikon objective 1X, oculars 10X, magnification zoom from 0.75X to 7.5X) in reflected light.

Three criteria were applied to select artifacts for use-wear analysis: completeness (artifacts without potentially functional edges were dropped from the analysis), surface preservation, and the presence of removals and/or rounding localized on the very edges of the artifacts, indicating ancient use. We are confident that edge modifications we have identified resulted from artifact use, rather than a post-depositional process. The main features that differentiate traces of use from post-depositional alterations are the combination of the trace attributes – the contact with the worked material produces specific combinations of attributes which rarely are replicated by postdepositional agents. As reference collections of experimental use-wear testify, traces of use are always distributed in a localized portion of the artifact, in close proximity to the edge.   Post-depositional marks, on the other hand, are often randomly spread over the lithic surface, including on raised or projecting areas of the artifact (Shea & Klenck, 1993). Taphonomic analysis of the Kanjera faunal assemblages (Ferraro et al., 2013; Parkinson, 2013) provides a further indication that postdepositional processes were unlikely to have been a significant contributor to the marks found on the artifacts. Only 8.8% (444/5021) of the fossils greater than 2 cm in length in the large faunal assemblage from Kanjera South preserved abrasion from trampling or sedimentary movement (Parkinson, 2013), and the faunal sample exhibits fine surface damage (e.g., tooth marks, cut marks, percussion pits and striae) that would have been obliterated if postdepositional processes had significantly impacted the assemblage (Ferraro et al., 2013). Moreover, quartz and quartzite are much harder materials than bone, and so would have been less affected than the bone by the minor amount of sedimentary abrasion to which the archaeological materials were subjected. Following these premises, every quartzite and quartz artifact with at least one potentially functional edge was carefully observed over its entire surface by eye and with a stereomicroscope, and items showing marks or abrasion patches randomly distributed both on and away from their edges were dropped from the analysis.

Artifacts with post-depositional surface alteration detectable with the naked eye or with the assistance of a reflected light stereomicroscope were also removed from the analysis. Three types of non-use related surface alteration were recognized individually or in combination on the same artifact: 1) generalized rounding of the surface, 2) edge crumbling, and 3) widespread glossy/bright appearance of the quartzite cement matrix. Generalized rounding and widespread glossy appearance are caused by sedimentary abrasion, either as a result of hydraulic transport prior to deposition, or sediment settling and pedogenic processes following deposition (Levi-Sala 1988; Plisson & Mauger, 1988). Post-depositional chemical alteration of artifacts may also result in a widespread glossy appearance (Plisson & Mauger, 1988; Stapert, 1976). Edge crumbling is caused by pressure, from trampling or sedimentary load, which results in micro-fracturing of the more fragile portions of the artifact edges (Flenniken & Haggarty, 1979; McBrearty et al., 1998).

The Kanjera quartz and quartzite artifacts are well preserved, with only a low percentage (less than 12%) exhibiting a rounded and/or glossy appearance. Thirty-five artifacts made of quartzite (16 % of the quartzite detached piece sample) and 27 artifacts made of quartz (35 % of the quartz detached piece sample) were selected for analysis. Their surfaces had a fresh appearance, had surface modifications exclusively associated with the functional zone of the artifact edge, and some showed localized edge-removals (12 quartzite, 6 quartz) and edge-rounding (18 quartzite, 2 quartz) suggestive of use (Fig. 3).

FIGURE 3 HERE

Reference Collections

Reference collections of quartz and quartzite flakes used to process a variety of materials in controlled experiments were necessary to interpret the use-wear on the Oldowan artifacts. These collections were derived from two sources; experiments carried out by CL with quartz and quartzite flakes in her laboratory, which she has been using to interpret use-wear on these raw materials from a variety of sites, and experiments conducted in East Africa to augment the existing collection (Table 3). Although the quartz and quartzite flakes in CL's reference collection come from different sources than the East African materials, their structure is similar to the structure of the Kenyan raw materials in terms of the size and morphology of the crystals and the amount of matrix.

TABLE 3 HERE

A total of 14 quartz and 70 quartzite flakes were used in 94 use-wear experiments to link specific types of edge modification to the processing of specific types of materials, and to specific processing tasks. Some flakes were used for several tasks, either using different edges for different tasks, or, less frequently, using the same edge. These latter samples allowed us to investigate edge modification caused by overlapping types of use-wear. Experiments were designed to replicate tasks potentially carried out by Oldowan hominins, including butchery (carcass skinning, cutting of meat alone, or meat with some contact with bone), bone working, hide scraping, working wood, cutting grass, and the processing of underground storage organs (USOs), in this case wild African tubers. The stone tool motions carried out while conducting these tasks were abrading, cutting and slicing, scraping, and engraving. These motions are commonly used with stone tools, and are defined following Keeley (1980).

CL performed a variety of processing experiments using 14 quartz and 35 quartzite flakes in her laboratory at the University of Rome (Table 3). Additional experiments were carried out in East Africa using thirty-five flakes of the same quartzite utilised by Oldowan hominins at Kanjera (Fig. 4; Table 3). This is a high-grade metaquartzite with interlocking microcrystralline quartz grains. The high maturity of the quartz grains is a result of their long entrainment as beach sand during Bukoban times (Huddleston, 1951). The bright vitreous luster and porphyroblastic texture distinguish it from lower grade metamorphic quartzites (Howard, 2005). The quartzite used in the experiments was collected from conglomerates in paleo-channels exposed in a modern quarry south of the Homa Mountain complex.

FIGURE 4 HERE

Nineteen quartzite flakes were used in skinning, defleshing, and disarticulation of two goats (*Capra hircus)* in Kenya by two members of the Samburu tribe with extensive butchery experience. Three quartzite flakes were used to cut stems of a coarse, wild grass on the Homa Peninsula, near the shore of Lake Victoria. Finally, thirteen quartzite flakes were used by ten adult women from the Hadza hunter-gatherer tribe in Tanzania to collect and process two species of wild tubers, //Ekwa (*Vigna frutescens*) and Shaehako (*Vigna macrorhyncha*). The Hadza routinely consume both tuber species and used the flakes to process the tubers in their usual manner. The stone flakes were used to: 1) cut portions of the tuber free from the segments remaining in the ground during extraction, 2) peel the tuber, or scrape the dirt and debris covering the outer peel of the tuber, and 3) section the tuber. The two species of tubers differ in their composition, processing, and consumption: //Ekwa tubers are most often roasted before eating, and a quid of indigestible fiber is spit out during consumption. Shaehako, which are less fibrous, are eaten raw or roasted and are consumed completely (no quid). Both raw and roasted tubers were cleaned in separate trials.

All experimental flakes were washed in three steps to remove residues of processed materials from their edges. They were washed first with water and soap, then in a chemical wash starting with a dilute 3% acetic acid (CH_3COOH) for fifteen minutes, and then a dilute 3% sodium hydroxide (NaOH) base for fifteen minutes, and finally a wash with de-mineralized water in an ultrasonic tank. Silicone (two components Provil Novo-Light Fast, Heraeus and two components Elite HD+ Light Body Fast Set) moulds of the used edges were made and observed under the microscope to detect use-wear, and define micro-wear attributes for diagnosing the materials being worked (Table 4). CL made observations of the moulds (negative replicas) rather than making casts (positive replicas) of each mould surface, as the same observations can be made either way. This protocol has the advantages of lowering laboratory expenses by eliminating the need for casting material, and also limits the loss of fine details that can occur when using casts. The use of moulds allowed observation without the high degree of glare common with quartz-rich raw materials.

TABLE 4 HERE

Blind Test

Few use-wear studies have been conducted on the raw materials analysed here (e.g., Sussman, 1985, 1988; Fullagar, 1986; Knutsson 1988; Pant, 1989; Knutsson & Lindé, 1990; Pignat & Plisson, 2000; Marquéz et al., 2001; Stemp et al., 2013). A blind test was carried out to assist in interpreting the materials being worked, and the motions or actions being carried out (e.g., cutting, scraping). Eight fresh flakes of the same Kenyan quartzite used by Kanjera hominins were used to a) butcher a goat limb, b) scrape the surface of a goat femur, c) skin and section two raw, dirt-covered sweet potatoes (*Ipomoea batatas*), d) skin and section a clean sweet potato, and e) cut and scrape relatively soft wood (ornamental cherry, *Prunus* sp.) and hard wood (black maple, *Acer nigrum*) branches in TP's laboratory at Queens College (Table 5).

TABLE 5 HERE

Two additional Kenyan quartzite flakes were used to cut North American grass (species unknown) in a field in southern New York. These ten flakes were then cleaned with soap and water, and transported to Italy for use-wear analysis. No information on the use or treatment of the flakes was provided to CL prior to use-wear analysis. These flakes were washed in CL's lab first with water and soap, then in a chemical wash starting with a dilute 3% acetic acid (CH_3COOH) for fifteen minutes, and then a dilute 3% sodium hydroxide (NaOH) base for fifteen minutes, and finally a wash with de-mineralized water in an ultrasonic tank. Results of the blind test were promising enough (see Results below) that the interpretation of the use-wear of the Kanjera Oldowan flakes was undertaken.

Macro- and micro-analysis of Kanjera artifacts

The reference samples and blind testing provided insight into how to interpret the use-wear preserved on the archaeological sample. Analysis of the macro-traces provided information about the potential activities being carried out (e.g., cutting, scraping, piercing, etc.) and general interpretation of the hardness of the worked material (see Tringham et al., 1974; Lemorini et al., 2006; Rots, 2010). The hardness categories used were soft (e.g., animal soft tissue [muscle, tendons, digestive tract, abdominal fat], herbaceous plants, some tubers), medium (e.g., wood, hide), and hard (e.g., animal hard tissue [bone, ivory, horn, teeth], and stone). Materials of intermediate hardness or resistance may result in use-wear traces that are intermediate between these categories (e.g., soft/medium or medium/hard). Microscopic analysis (examination of micro-edge rounding, polishes, abrasions, and striations) was conducted to provide a more detailed understanding of the activities carried out with the lithic artifacts, and to assist in the diagnosis of the material being processed (see Rots, 2010). A two-component silicone moulding material (Provil Novo Light Fast, Heraeus; Elite HD+ Light Body Fast Set) was used to make fine-grained moulds of the edges of these artifacts in Kenya. These negative casts were then analysed by CL at the Laboratory of Techno-Functional Analysis of the Museo delle Origini, Sapienza (University of Rome in Italy) under reflected light.

Most use-wear analysis is carried out with either scanning electron microscopy (SEM) or optical light microscopy, and the interpretation of the use-wear is dependent on the experience of the observer and his/her ability to interpret the generated images. These methods are complementary, and either can provide satisfactory results (Borel et al., in press). The SEM has the advantage of a wider depth of field, which can allow well-focused pictures and high resolution imaging. Scanning electron microscopes are also useful for the analysis of highly reflective raw materials (for a comprehensive description of the SEM approach and its potential see Knutsson 1988; Knutsson & Lindé 1990; Ollé & Vergès 2013). However, scanning electron microscopes are not as readily available as optical light microscopes, and are not transportable to the field. For this analysis, we used a metallographic microscope (Nikon Eclipse with 10X, 20X, and 50X objectives and 10X oculars) equipped with a reflected differential interference contrast (DIC), and a confocal system (Nikon Eclipse C1). The shallow depth of field in the optical light microscope renders relief well, and this method allows the easy identification of polish and striations (see Igreja, 2009 for a protocol similar to that used here). Other advantages of our analytical setup are that it allows fast positioning of the samples, and it removes the glare associated with quartz-rich lithologies (Sussman, 1985, 1988; Stemp et al., 2013). The metallographic microscope and DIC system permitted us to obtain optimal resolution at 100x and 200x magnification. The confocal system was added to the protocol when a magnification of 500x or more was needed. While our analytical setup plus silicone moulds are suitable for this analysis, there is no doubt that the combined use of multiple techniques may improve it in the future (Borel et al., in press).

Results

The development of the reference collection highlighted an important difference between use-wear distribution in microcrystalline (e.g., flint or chert) and hyaline (obsidian) raw materials, versus materials with internal structure or large grains (e.g., quartz and quartzite). The quartzite was composed almost entirely of silica, and was probably derived from a very mature quartz beach sand precursor lithology because of the lack of other minerals (Huddleston, 1951). During regional metamorphism of this quartzite there has been extensive dissolution and recrystallization of much of the original quartz such that the present lithology consists of residual quartz grains set in a fine-grained silica matrix. Use traces are very localised in quartz and quartzite, appearing on the face of a single quartz crystal or small clusters of crystals, and (on the quartzite) on small patches of silica matrix. In contrast, microcrystalline and glassy raw materials such as flint and obsidian have use-wear distributed extensively and more uniformly across much of the utilised artefact edge (Clemente Conte & Gibaja Bao, 2009).

Analysis of the experimental reference collections allowed CL to develop a set of micro-wear attributes for interpreting the use-wear of quartzite and quartz. Certain traits were identified as diagnostic depending on the location and substrate of the material where the trace was located. Traits on quartz crystals (in both quartz and quartzite), and the silica matrix surrounding the crystals in quartzite, were identified (Table 4). The extent of development of use-wear traces (e.g., slight or well-developed), the texture of the polish (smooth or rough), the topography of the polish (e.g., flat or domed), and the depth and shape of striae (e.g., striae that taper to a point versus striae that diverge in one direction [comet-tail]) were useful in diagnosing the hardness of the substance being worked. In some instances these traits could be used to make a more specific diagnosis of the material that was processed (Table 4; Fig. 5-7; Supplementary Fig. 1-3). The location and orientation of the micro-wear features were also useful in diagnosing tool motion (the actions being carried out with the stone tool) such as cutting or scraping.

FIGURES 5-7 HERE

Blind test

The results of the blind test broadly confirmed the utility of use-wear analysis for the interpretation of the function of quartzite artifacts. Traces of use-wear were found on 8 out of 10 flakes, with the used edge correctly identified in all eight cases. The hardness of the material being worked was correctly recognized in all eight cases where use-wear was identified (100% success rate). The actual material that was worked was correctly identified in five of the seven cases where a specific material was diagnosed (success rate of 71%). Discrimination between butchery, wood-working, and tuber processing was apparent from these results. The motion (e.g., cutting, scraping) was also correctly inferred in seven of the eight cases (success rate of 88%). Thus, the use-wear analysis of quartz-rich lithologies does provide useful information for interpreting artifact function. Our results fall at the high end of other published blind test results, which documented the direction of motion correctly 43-92% of the time, and the actual material being processed 16-79% of the time (Evans & Macdonald, 2011).

The blind test had some important implications for determination of quartz and quartzite artifact function. The diagnosis of USO/tuber processing was dependent on the tubers having adherent sediment. Peeling and sectioning the grit-covered sweet potatoes in the blind test produced recognizable, localized, and oriented scratches. This edge modification was very similar to the use-wear produced by Hadza women collecting and cleaning wild tubers in Tanzania (Fig. 6). Processing of the clean, soil-free sweet potato during the blind test did not produce these scratches. The weak use-wear that developed during clean sweet potato processing only allowed the detection of the hardness of the material being worked (i.e., soft; Flake B5, Table 5).

Incorrect functional interpretations were made in four of the eight flakes with interpretable use-wear. While both flakes used to butcher a goat limb (B6 and B7) were correctly interpreted as having been used to cut animal flesh, they also had functional areas on their artifact edges that were attributed to processing other materials, a medium-hard material (B6-hide?) and a soft material (B7-plants?). In addition to the functional areas on the artifact edge correctly diagnosed as having been used for wood-working, flakes B1 and B4 developed "gripping wear" from contact between the flake edge and the experimenter's hand during material processing. Gripping wear was attributed by the analyst (CL) to processing of soft material (animal tissue?) in B1, and a medium-hard material (hide?) in B4. Rots (2010) found that gripping and hafting traces were not uncommon in flint industries, and cautioned that analysts should look for them in use-wear studies. We thought the contact between the experimenter's hand and the artifact during processing would not create recognizable traces, particularly when using hard lithologies such as quartzite. However, the firm contact between the analysts' hands and the artifact edge during wood-working did lead to edge alteration, and interestingly enough this alteration was interpreted by CL as contact with animal tissue (muscle or hide). The results of the blind test suggest that gripping traces can develop relatively rapidly even in silica-rich raw materials. On more homogenous, microcrystalline, or glassy raw materials, such as flint and obsidian, use traces are generally distributed along the edge as a line or band, whereas gripping or hafting traces are recognized as localized wear spots (Rots, 2010). At this stage, it is not possible to distinguish gripping traces from use traces on tools made of quartz and quartzite, as in both cases wear is distributed over relatively small areas. However, gripping wear did not frequently develop, and most of the archaeological specimens show use-wear on only one edge (Table 6). It thus seems unlikely that gripping wear was an important source of error in the interpretation of the use-wear of the Oldowan artifacts reported below.

TABLE 6 HERE

A final interpretative insight resulted from the processing of two “soft” materials, grass and animal soft tissue. The wild grass cut in Kenya used for the reference sample was much more abrasive than the North American grass cut with flakes B9 and B10. The Kenyan grass caused a more a diagnostic pattern of use-wear to develop with fewer strokes than the less coarse North American grass. (Tables 3 and 5). In their use-wear experiments, Keeley and Toth (1981) also found that wild grasses from Koobi Fora, Kenya affected the flake edges much faster than temperate European grasses. The North American grass, which was probably not a good analogue for the coarser East African grass, caused shallow abrasions to develop that were confused with traces developed by cutting meat. Use-wear analysts working with other raw materials (e.g., flint, obsidian) have also had problems distinguishing herbaceous plant and meat use-wear, particularly if the activity was carried out for a short time, and the use-wear traces were not well developed (Gassin, 1996; van Gijn, 1989; Lemorini, 2000). Further experiments on wild grasses, reeds and sedges in Kenya are necessary to more properly assess the degree of overlap between the use-wear of soft plant and animal tissues, particularly when the traces are not very well developed.

In summary, the blind test provided insight into how the use-wear of quartz and quartzite Oldowan artifacts should be interpreted. The hardness or resistance of the worked material can be determined accurately. However, there may be some misattribution of wear when it is only weakly developed. Use-wear from wood-working and butchery was clearly identified, as was use-wear related to the processing of a grit-covered plant tissue, which we are interpreting as USO processing. Unlike the use-wear of other materials, the diagnosis of use-wear associated with processing of USOs is based both on the physical properties of the plant tissue, as well as the contact between sedimentary particles on the USO and a forcefully directed tool edge. Our overall conclusion is that quartzite and quartz use-wear can provide useful information on the function of Oldowan tools.

Kanjera South: quartzite artifact use-wear

Twenty-five of the 35 quartzite artifacts (69%) selected for analysis showed traces interpreted as use-wear (Table 6). Five artifacts showed no post-depositional alteration and the remaining 20 showed minimal alteration, having a diffuse matrix sheen that did not obscure the use-wear and probably resulted from post-depositional settling of the sediments and pedogenic processes. The morphological characters allowing the interpretation of the tool kinetics and the properties of the worked material were readily observable because of the excellent preservation of the artifact surfaces (Table 6). Cutting motion was recognized on eleven of 25 edges, and was linked to working soft animal tissue (n=3), wood (n= 2), abrasive herbaceous plants (e.g., grasses or sedges, n= 1), wood and herbaceous plants (n=1), USO processing (n=1), a soft material (n=1), a medium/hard material (n=1), and an indeterminate material (n=1). Scraping activities (9 of 25 edges) were related to wood-working (n=2), USO processing (n=2), and an indeterminate medium/hard material (n=5). Six “mixed” activities, represented by overlapping cutting and scraping, were linked to USO processing (n=3), wood and USOs (n=1), and animal soft tissue and bone (n=1).

Kanjera South: quartz artifact use-wear

Fourteen of 27 artifacts (52%) selected for analysis show traces interpreted as use-wear (Table 6). Quartz use-wear is more difficult to interpret than quartzite, as quartz lacks the interstitial silica matrix that develops characteristic use-wear traces in quartzite (Table 4). A variety of materials were cut, including animal soft tissue (n=1), a combination of wood and abrasive herbaceous plant (n=1), and indeterminate soft (n=1) and medium (n=1) materials. Three edges were used to scrape a medium material (n=2), and bone (n=1). Mixed actions of cutting and scraping were carried out working wood (n=2) and an indeterminate material (n=1). Soft animal tissue (n=1) and a soft material (n=1) were processed without an interpretable kinetic signal.

In summary, use-wear of 23 artifact edges was attributed to the processing of either plant (16 edges, 70%) or animal (7 edges, 30%) tissue (Fig. 8, Table 6). Whether this frequency is an accurate reflection of the time spent on different processing activities is not clear, as the analysed sample is a tiny proportion of the total number of edges in the archaeological assemblage. But the results suggest that plant processing was a significant component of the Oldowan hominin behavioral repertoire at Kanjera South.

FIGURE 8 HERE

Discussion

Interpretation of Oldowan hominin behavior tends to focus on stone tool production and transport (Schick, 1987b; Toth, 1987; Delagnes & Roche, 2005; Harmand, 2007; Braun et al. 2008; Rogers & Semaw, 2009; Goldman-Neuman & Hovers, 2012), and/or hominin strategies for large mammal acquisition and transport (Bunn & Kroll, 1986; Potts, 1991; Oliver, 1994; Blumenschine, 1995; Plummer, 2004; Domínguez-Rodrigo et al., 2007; Pante et al., 2012). Other aspects of hominin behavior are more difficult to assess, as they are not directly drawn from interpretations of physical remains at archaeological sites. The sorts of tools Oldowan hominins may have made from perishable materials are unknown, even though analogy with nonhuman primates and hunter-gatherers suggest they existed (Panger et al., 2003; Plummer, 2004). Stable isotopic composition of hominin enamel (Lee-Thorpe & Sponheimer, 2006; van de Merwe et al., 2008; Cerling et al., 2013; Sponheimer et al., 2013), hominin tooth microwear and topography (Ungar, 2012), analogy with living humans and non-human primates (Peters & O'Brien, 1981; O'Connell et al., 1999; Wrangham et al., 1999), actualistic studies of potential plant food availability from modern ecosystems (Sept, 1994; Peters &Vogel, 2005; Copeland, 2009), and mechanical properties of potential wild plant foods (Dominy et al., 2008) suggest that Oldowan hominins could have consumed a variety of plant foods, although the actual species of plants and types of plant products that were consumed are unknown. Social behaviors, such as the type of hominin mating systems, and the scale and extent of food-sharing, are also difficult to address with the paleoanthropological record (Swedell & Plummer, 2012). The use-wear analysis of Oldowan artifacts from Kanjera adds value to the zooarchaeological, lithic, and isotopic analyses being carried out at the site, by identifying suites of behaviors that would normally be invisible archaeologically, and by corroborating behaviors inferred through other analyses. Moreover, they illustrate the adaptive significance of lithic technology to 2 Ma Oldowan hominins on the Homa Peninsula. These issues are further noted below.

Subsistence at Kanjera South

Use-wear provides an independent method from zooarchaeology to assess subsistence activities at Kanjera. The salient, archaeologically observable food resource in the Oldowan diet is meat (here referring to all soft tissue within the body, e.g., muscle, viscera, brains, and marrow). Large mammal bones with stone tool-induced modification are coeval with the oldest archaeological traces at ~2.6 Ma, suggesting that butchery is a component of the Oldowan diet as soon as tools appear (de Heinzelin et al., 1999; Semaw et al., 2003). Butchery use-wear on Oldowan artifacts has been reported for ~ 1.78 Ma Oldowan artifacts from Aïn Hanech, Algeria (Sahnouni et al., 2013), and for Early Stone Age artifacts from Koobi Fora at ~ 1.5 Ma (Keeley & Toth, 1981). However, the frequency and intensity of late Pliocene hominin carnivory is unclear (Plummer, 2004). At Kanjera, stone artifacts and fauna are stratified through several metres of sediment, representing hundreds to thousands of years. Zooarchaeological analysis provides evidence of hominins having repeated access to largely complete size 1 and 2 bovid carcasses, as well as at least intermittent access to fleshy carcasses of larger animals (Ferraro et al., 2013; Parkinson, 2013). This provides the oldest evidence of sustained hominin involvement with carcasses, and indicates that by 2 Ma hominins at Kanjera South practiced persistent carnivory. Use-wear on both quartzite and quartz artifacts described here corroborates the use of artifacts for butchery (Fig. 8, Table 6).

Clear use-wear evidence for plant-processing complements the evidence for butchery. Plant foods are of critical importance to African tropical foragers, and it is likely that Oldowan hominins relied predominantly on plant foods as well (Lee, 1979; Peters and O'Brien, 1981; Peters, 1987; Rodman, 2002; Schoeninger et al., 2001; Sept, 1986; Stahl, 1984; Vincent, 1984). Wild plant foods commonly eaten by baboons, chimpanzees, and humans in Africa include fleshy fruits, flower buds, nuts, nut-like oil-seeds, seed pods, leaves, stems/pith, and terrestrial and aquatic USOs (Gaulin, 1979; Hladik and Chivers, 1994; Peters and O'Brien, 1981, 1994; Wrangham et al., 2009). USOs have figured prominently in models of hominin dietary evolution (Deacon, 1993; Stahl, 1984; Milton, 1999; O'Connell et al., 1999; Wrangham et al., 1999; Laden & Wrangham, 2005; Dominy et al., 2008; Wrangham et al., 2009; Lee-Thorp et al., 2012), either as critical fallback foods allowing survival in savanna ecosystems or as staple components of the hominin diet. Raw USOs are not only targeted by chimpanzees (Hernandez-Aguilar et al., 2007), but also may have been a significant component of the diet of *Australopithecus* spp., *Paranthropus boisei*, and *H. erectus sensu lato* (O'Connell et al., 1999; Laden & Wrangham, 2005; Dominy et al., 2008; Ungar, 2012). USOs, as a collected resource that can be bundled and transported, may also have played a key role in the evolution of central place foraging and provisioning (Isaac, 1978; Wrangham et al., 1999).

Despite the prominence of USOs in the discussions of hominin diets, there has been very little archaeological evidence supporting hominin acquisition and consumption of them. The use-wear reported here provides the oldest archaeological documentation of hominin processing of relatively soft, grit-covered plant materials, interpreted here as the signature of USO processing. Our results extend the evidence for USO processing by over 1.5 million years (Mercader et al., 2008). Whether these were USOs from C_3 plants, such as the tubers the Hadza consume, CAM plants, or C_4 plant parts such as sedge corms which frequently have a grit-covered tunic that needs to be removed (Dominy, 2012) is unknown.

Non-food processing activities

Wood cutting and scraping may have been an important activity, based on the number of edges interpreted to have been used on wood. It is possible that the wood use-wear reported here represents hominin extracting food, such as larvae, from recesses in tree trunks and limbs as seen in modern chimpanzees (Yamagiwa et al., 1988). However, we would expect the kinetics to better reflect gouging or boring activities if this were the case. It seems more likely that flakes of quartzite and quartz were used to cut and scrape wood in the production or maintenance of wooden tools. Our close living relatives (chimpanzees) commonly use wooden tools in extractive foraging, stripping branches of their leaves for use as probes, and in one population sharpening branches with their teeth to create a “spear” to kill bushbabies in holes in trees (Whiten et al., 1999; Preutz & Bertolani, 2007). It doesn’t seem like a major cognitive leap to envision hominins working branches into simple tools, particularly since the reduction of a quartzite core evinces a more sophisticated series of technological steps than cutting or sharpening a branch. If this interpretation is correct, documentation of wood-working at Kanjera South may provide the oldest evidence of two steps in the hominin use of tools to make tools– i.e., hammerstones to strike stone flakes that were then used to make wooden implements – a previously undocumented behavior in the early Oldowan record and among non-human primate tool users (McGrew, 1992; Davidson & McGrew, 2005; Carvalho et al., 2009; Carvalho & McGrew, 2012). What hominins were making with wood is unclear, but digging sticks for USO acquisition and hunting spears are both distinct possibilities, given the use-wear evidence for

USO processing, and zooarchaeological evidence for early access to size 1 and 2 bovid carcasses. Previous use-wear and phytolith analyses have suggested that later hominins (probably *H. erectus sensu lato*) made wooden tools between 1.4 to 1.7 Ma (Keeley and Toth, 1981; Domínguez-Rodrigo et al., 2001), and zooarchaeological evidence for early access to wildebeest-sized mammal carcasses at FLK Zinj, Olduvai Gorge, Tanzania, has been used to argue for the presence of wooden spears by ca. 1.8 Ma (Bunn & Pickering, 2010; Bunn & Gurtov, 2013). The results presented here may extend the evidence of wood-working to over 1.95 Ma (the base of the Olduvai subchron), and earlier than the oldest fossil possibly attributable to *H. erectus sensu lato* (occipital fragment KNM-ER 2598; 1.89 Ma) (Antón, 2003). It has been argued that the Kanjera artifacts were made by a species of *Homo* (Plummer, 2004; Plummer et al., 2009a), and their age at ~ 2 Ma may indicate that either very early *H. erectus* or a taxon that preceded it was making wooden tools.

This study extends the earliest evidence for herbaceous plant processing beyond ~ 1.5 Ma noted by Keeley and Toth (1981) who described polish related to grass or reed cutting. Some Kanjera artifacts also appear to have been used to cut highly siliceous plants, such as grasses, sedges, or reeds. Such vegetation would have been common in the vicinity of the site, which was formed in a C_4 plant-rich landscape near a lake margin (Plummer et al., 2009a, b). Whether herbaceous plants were cut as part of a subsistence activity (e.g., grass seed harvesting, cutting out papyrus culm for consumption) and/or a non-subsistence related task (e.g., production of “twine” or simple carrying devices, cutting of grass for bedding) is unclear.

The Technological System at Kanjera South

These results should be viewed within the broader context of the lithic and zooarchaeological analyses at Kanjera South. Studies of the stone tools and their sources indicates that the Kanjera artifacts were part of a technological system where hard, easily flaked raw materials not found on the Homa Peninsula were preferentially transported and curated relative to the artifacts made from locally available but generally softer rocks (Braun et al., 2008, 2009a, b). Edge durability experiments have demonstrated that harder raw materials such as quartzite maintain sharp edges far longer than many of the locally available raw materials (Braun et al., 2009a). For example, 500 strokes with a locally available limestone flake were unable to remove the skin from a single limb of a domestic goat, as the flake was effectively dulled after 200 strokes. In contrast, 500 strokes from a quartzite flake were able to remove the skin from four goat limbs without significant dulling of the tool edge (Braun et al., 2009a). A clast of quartzite or quartz would thus be much more effective than a limestone clast of equal size, as the former would dispense flakes with a much longer use-life, and hominins would not have to replenish their toolstone supply as frequently. The energetic investment in the transport of hard toolstone indicates that lithic technology was of great adaptive significance. This suggests that the processing of materials with stone tools was an important aspect of Oldowan hominin foraging ecology at Kanjera South. Foraging may not have been assisted by tool use, as in chimpanzees, but actually *tool-dependent* (Plummer, 2004).

Use-wear and zooarchaeological analyses provide insight into what these adaptively significant, tool-related tasks were. Artifacts were used in the processing of high quality foods, including animal tissue and USOs, which may have been a dietary staple or an important fallback food (Laden & Wrangham, 2005; Marlowe & Berbesque, 2009; Wrangham, 2009). Animal tissue and USOs are nutritionally complementary (Milton, 1999), and large carcasses, and some species of very fibrous, tough-skinned USOs (Vincent, 1984) would have been difficult, if not impossible, to process without stone tools. While roasting of USOs makes them easier to peel (Dominy et al., 2008), there is no evidence for hominin use of fire at Kanjera South, and we suspect if USOs were consumed they were being extracted from the ground, cleaned, and eaten raw.

In addition to their necessity for carcass and USO processing, stone tools may have played an important role in the acquisition of these resources. Hominin hunting of prey seems likely for size 1 and 2 antelopes at Kanjera South (Ferraro et al., 2013; Parkinson, 2013), and it seems credible that hominin hunting of size 1-3 antelopes occurred at ~ 1.8 Ma at FLK Zinj, Olduvai Gorge, Tanzania (Domínguez-Rodrigo et al., 2007; Bunn & Pickering, 2010; Bunn & Gurtov, 2013; but see Pante et al., 2012). It is highly unlikely that the relatively small cores and flakes used at Kanjera South (Braun, 2006) were used in hunting game or digging for USOs. The scraping and cutting of wood suggested by use-wear analysis may signal hominin fashioning of tools from perishable materials that were more appropriate for these tasks.

Animal tissue and USOs share other important characteristics; they are resources that require skill to acquire, and they can be obtained in packages large enough to satisfy the dietary needs of multiple individuals (Bunn & Kroll, 1986; O'Connell et al., 1999; Kaplan et al., 2000; Laden & Wrangham, 2005). Skill-based acquisition of foods that could be shared within a group, and be used to provision subadults who were unlikely to meet their own nutritional needs, may thus have been an important component of hominin socioecology at Kanjera South (Oliver, 1994; Kaplan et al., 2000; Aiello & Key, 2002; Schuppli et al., 2012; Swedell & Plummer, 2012; Crittenden et al., 2013).

Finally, while it is possible that the use-wear derives from activities that were carried out "on-site," or in the immediate vicinity of the Kanjera South locality, quartzite and possibly quartz were transported over 10 km to the site. It is therefore possible that some artifacts were used at multiple points across the landscape prior to discard. Certainly the finding that some artifacts have use-wear from processing more than one material supports the perspective that artifacts were used in more than one processing event.

The energetic investment in lithic technology, the possible use of lithics to make other tools, the use of tools to extract nutrient dense foods from their surroundings, and their likely ramifications for hominin socioecology all highlight the adaptive significance of lithic technology by 2 Ma at Kanjera South. Data presented here indicate that Oldowan hominin foraging for animal and plant tissues at Kanjera South was not just tool-assisted, but that tool-use was part of an embedded and broadly applied tool-dependent adaptation to life in a relatively open ecosystem within East Africa.

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Figure legends

Figure 1. Placement map showing the location of Kanjera in southwestern Kenya and of the Southern Exposures at Kanjera where the Oldowan occurrences are found. The composite stratigraphic log shows the basal three beds of the Southern Member (KS-1 to KS-3) and the

base of KS-4. Spatially associated artifacts and fossils are found as diffuse scatters and also in more vertically discrete concentrations from the top of KS-1 through KS-3, with KS-2 providing the bulk of the archaeological sample.

Figure 2. A representative sample of quartz and quartzite artifacts from the excavations at Kanjera South. (a) and (b) quartzite cores; (c) and (d) quartzite whole flakes; (e) quartz core and (f) quartz whole flake. Scale bars equal to 1 cm.

Figure 3. Use-related edge removals from (a) experimental quartzite flake used to scrape wood and (b) Oldowan flake #3051. Scale bars equal to 1 mm.

Figure 4. Representative images of experiments carried out to develop the use-wear reference collection. The experiments in these photos were conducted with the same quartzite used in Oldowan artifact manufacture at Kanjera. (a) cutting of coarse, wild grasses in Kenya; (b) wood-working; (c) goat butchery; (d) cutting, peeling, and slicing of wild //Ekwa and Shaehako tubers by Hadza women in Tanzania.

Figure 5. (a) Use-wear from wood-working on an experimental flake, showing rough and domed polish on the matrix; (b) Kanjera quartzite artifact # 592 with matrix showing rough and domed polish, attributed to wood-working; (c) crystal on the edge of an experimental flake used for wood-working; the development of polish on its surface gives it a characteristic domed topography; (d) Kanjera quartzite artifact # 10063 with a crystal showing the domed topography attributed to wood-working.

Figure 6. Use-wear developed on the edge of an experimental quartzite flake during the cutting, peeling and sectioning of wild tubers by a Hadza woman showing (a) deep, narrow, tapering striae on the face of a quartz crystal; (b) localized well developed abrasion on a crystal, and (c) widespread, flat, rough polish in closely packed patches on matrix.

Figure 7. (a) Kanjera quartzite artifact # 19149 with use-wear attributed to USO-working (red dots indicate use-wear location), including (b) matrix showing widespread, flat, rough polish in closely packed patches; (c) narrow, tapering striae on crystal, and (d) localized well-developed abrasions on crystal.

Figure 8. Use-wear results for quartz and quartzite Oldowan artifacts from Kanjera South.

Supplementary Data

Supplementary Figure 1. (a) Use-wear from butchery (contact with animal soft tissues) on an experimental flake, showing rough polish on the matrix; (b-c) use-wear from butchery on an experimental flake, showing crystals with widespread lightly developed abrasions.

Supplementary Figure 2. (a,b) Kanjera quartzite artifact # 14981 with crystals showing widespread lightly developed abrasions attributable to butchery.

Supplementary Figure 3. (a) Kanjera quartz artifact # 129 with red dots indicating use-wear location; (b) crystal on the edge of artifact #129 showing a “melting” appearance given by a well-developed pitted polish attributed to bone working; (c) use-wear from bone-working on an experimental flake, showing crystal with a “melting” appearance.

Table

	Flaked Piece	Pounded Piece	Snapped Flake	Split Flake	Whole Flake	Angular Fragment	Grand Total
Bukoban Basalt	10		15	6	66	34	131
Bukoban Felsite	26	1	25	22	127	89	290
Bukoban Quartzite	26		27	15	67	113	248
Chalcedony	1				4	2	7
Fenetized Nyanzian	226	1	144	106	527	781	1785
Homa Carbonatite	8		7	1	22	27	65
Homa Limestone	25		16	16	79	119	255
Homa Microijolite	6		3		7	13	29
Homa Phonolite	61		40	25	150	310	586
Ijolite	1		1			2	4
Kisingiri Melanephelinite	1				1	1	3
Nyanzian Chert	7		4	2	16	13	42
Nyanzian Rhyolite	22		29	17	94	137	299
Oyugis Granite	22		8	9	44	65	148
Quartz	14		4	5	28	40	91
Rawi Porcellainite	1		1		5	5	12
Sheared Rhyolite	0	0	0	0	2	0	2
Unknown	60	1	41	29	145	201	477
Grand Total	517	3	365	253	1384	1952	4474

Table 1. Typological and raw material composition of the Kanjera South Oldowan artefact assemblage from Beds KS-1 to KS-3, Excavations 1, 2, 5 and 6.

Raw Material	Typology	Average Length	Average Width	Average Thickness
Quartzite	Flaked Pieces (Cores)	46.8 (45.9)	36.0 (34.3)	25.1 (24.5)
	Detached Pieces (Whole Flakes)	33.5 (31.2)	28.1 (26.1)	17.4 (8.9)
Quartz	Flaked Pieces (Cores)	55.5 (60.4)	36.7 (37.8)	27.9 (22.5)
	Detached Pieces (Whole Flakes)	30.8 (30.6)	26.0 (26.9)	12.2 (8.4)

Table 2. Summary dimensions of the quartzite and quartz artefact samples from Kanjera South. Length, width and thickness of detached pieces are the three longest axes that are orthogonal to each other. All measures in mm, with median values in parentheses.

		Experiments Conducted in Cristina Lemorini's Laboratory								Experiments Conducted in East Africa					
		antler	*Bone*	*bone & hide*	*animal flesh*	*animal flesh & bone*	*hide*	*Wood*	*stone on stone*	*Goat skinning*	*Goat butchery*	*Shaehako tubers*	*//Ekwa tubers*	*Wild riparian grass*	*Total*
Motion	**Raw Material**														
abrading															
	Quartz								1						1
	Quartzite		2												2
	sub-total		*2*						*1*						*3*
Cutting															
	Quartz				1	3	7								11
	Quartzite	1	1		1	10	2	2		3	16			3	39
	sub-total	*1*	*1*		*2*	*13*	*9*	*2*		*3*	*16*			*3*	*50*
engraving															
	Quartz							1							1
	Quartzite	2	2					1							5
	sub-total	*2*	*2*					*2*							*6*
Scraping															
	Quartz	2						2							4
	Quartzite	1	3			1	3	8							16
	sub-total	*3*	*3*			*1*	*3*	*10*							*20*
cutting & scraping															
	Quartz														0
	Quartzite			1											1
	sub-total			*1*											*1*
cutting, peeling, sectioning															
	Quartz														*0*
	Quartzite											7*	6^		*13*
	sub-total											*7*	*6*		*13*
scraping & engraving															
	Quartz														0
	Quartzite							1							1
	sub-total							*1*							*1*
	Total	*6*	*8*	*1*	*2*	*14*	*12*	*15*	*1*	*3*	*16*	*7*	*6*	*3*	*94*

Table 3. The number of edges used in use-wear experiments conducted In CL's laboratory, and in East Africa, by motion and raw material. Experiments generally conducted for a minimum of 30 minutes. *Four Shaehako tubers were roasted, 3 were unroasted. ^Four //Ekwa tubers were roasted, 2 were unroasted.

Material Being Processed	Crystals (Quartz and Quartzite)	Cement Matrix (Quartzite)
Animal soft tissue	widespread lightly developed abrasion	rough polish
Fresh hide	widespread well developed abrasion	_
Bone	pitted melting polish & shallow narrow striae on domed (convex) topography	smooth, flat polish; striae have comet (divergent) tails
Herbaceous plants	localized well developed abrasion & deep, narrow striae	very localized, smooth, flat patches of polish
Tubers	localized well developed abrasion & deep, narrow, tapering striae	widespread, flat, rough polish in closely packed patches
Wood	polish on domed (convex) topography, with deep, narrow, tapering or corrugated striae	rough polish on domed (convex) topography

Table 4. Microwear attributes used to diagnose the material being worked with quartz and quartzite tools.

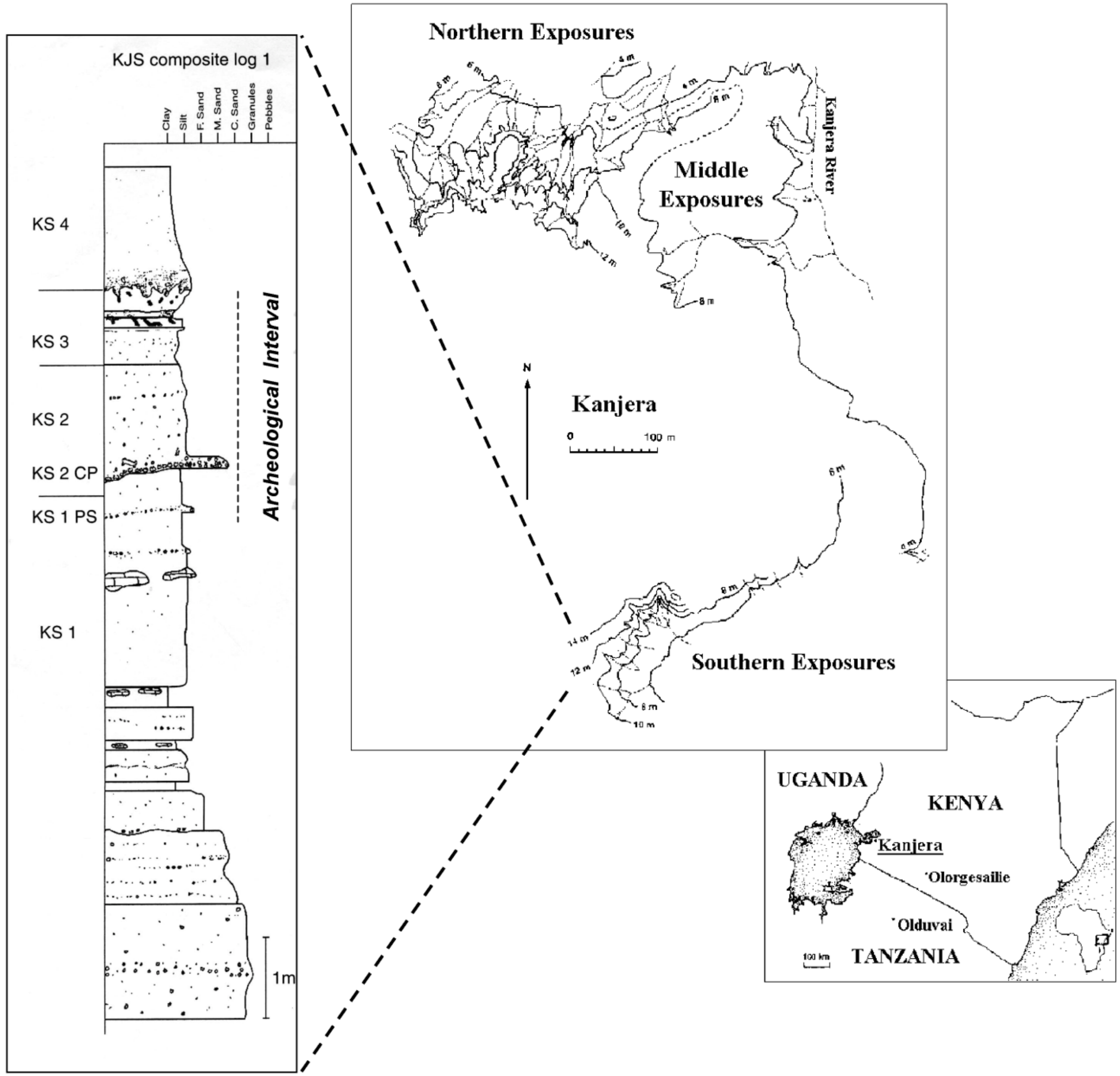
Flake number	Experimental protocol		Use-wear analysis			
	Material worked	**Activity carried out**	**Inferred material worked 1**	**Inferred activity carried out 1**	**Inferred material worked 2**	**Inferred activity carried out 2**
B1	Soft wood (ornamental cherry, *Prunus* sp.)	cutting (500 strokes)	Wood	cutting	soft material (animal tissue?) (gripping wear)	cutting
B2	Sweet potato (*Ipomoea batatas*) covered with fine sand	scraping off dirt (322 strokes) + Cutting (333 strokes)	*No use-wear detected*	n/a		
B3	Sweet potato covered with fine sand	scraping off dirt (350 strokes) + Cutting (459 strokes)	grit covered plant tissue/USO	cutting and scraping		
B4	Hard wood (black maple, *Acer nigrum)*	scraping (470 strokes)	wood	scraping	medium-hard material (hide?) (gripping wear)	scraping
B5	Clean sweet potato	scraping (486 strokes) + Cutting (120 strokes)	soft material	piercing		
B6	Goat (*Capra hircus*) limb	cutting off meat + hitting bone a few times (500 strokes)	animal Flesh	cutting	medium-hard material (hide?)	transverse motion
B7	Goat limb	cutting meat and piercing fascia sheets (350 strokes)	animal Flesh	piercing	soft material (plants?)	scraping
B8	Goat bone (femur)	bone scraping (400 strokes)	*no use-wear detected*	n/a		
B9	Fresh grass, field in southern NY	cutting (300strokes)	animal Flesh	cutting		
B10	Fresh grass, field in southern NY	cutting (500 strokes)	animal Flesh	cutting		

Table 5. Blind test experimental protocol and use-wear analysis results. Two results are given if more than one material is inferred to have been worked in the use-wear analysis.

Tool	Used edge	Raw Material	Techno-Type	Edge Angle	Action	Material
14216	1	Quartz	Split flake	65	cutting	animal flesh
10182	1	Quartz	Whole flake	71	cutting	indeterminate
11851	1	Quartz	Whole flake	54	cutting	indeterminate
11926	1	Quartz	Whole flake	90	cutting	medium material
14375	1	Quartz	Whole flake	50	cutting	soft material
4019	1	Quartz	Core	70	cutting	wood + herbaceous plants
5676	1	Quartz	Angular fragment	33	cutting & scraping	indeterminate
2121	1	Quartz	Whole flake	36	indeterminate	animal flesh
66	1	Quartz	Whole flake	55	indeterminate	soft material
10063	1	Quartz	Angular fragment	66	cutting & scraping	wood
12886	1	Quartz	Whole flake	32	cutting & scraping	wood
129	1	Quartz	Whole flake	84	scraping	bone
9681	1	Quartz	Whole flake	90	scraping	medium material
14375	2	Quartz	Whole flake	45	scraping	medium material
420	1	quarzite	Angular fragment	39	cutting	animal flesh
9854	1	quarzite	Angular fragment	66	cutting	animal flesh
14981	1	quarzite	Whole flake	63	cutting	animal flesh
5370	1	quarzite	Snapped flake	indeterminate	cutting	herbaceous plants
9160	1	quarzite	Whole flake	66	cutting	indeterminate
57	1	quarzite	Snapped flake	indeterminate	cutting	medium hard material
2090	1	quarzite	Whole flake	62	cutting	soft material
4764	1	quarzite	Whole flake	55	cutting	USOs
6151	1	quarzite	Whole flake	48	cutting	Wood
10052	1	quarzite	Split flake	53	cutting	Wood
12110	1	quarzite	Whole flake	69	cutting	wood + herbaceous plants
13201	1	quarzite	Whole flake	45	cutting & scraping	animal flesh & bone
16184	1	quarzite	Core	69	cutting & scraping	USOs
19149	1	quarzite	Whole flake	56	cutting & scraping	USOs
37	1	quarzite	Whole flake	indeterminate	cutting & scraping	USOs
6284	1	quarzite	Snapped flake	29	cutting & scraping	wood + USOs
142	1	quarzite	Whole flake	indeterminate	scraping	medium hard material
2053	1	quarzite	Whole flake	indeterminate	scraping	medium hard material
3051	1	quarzite	Whole flake	indeterminate	scraping	medium hard material
8556	1	quarzite	Angular fragment	88	scraping	medium hard material
9564	2	quarzite	Retouched flake	85	scraping	medium hard material
12189	1	quarzite	Angular fragment	indeterminate	scraping	USOs
24409	1	quarzite	Whole flake	56	scraping	USOs
9564	1	quarzite	Retouched flake	60	scraping	wood
592	1	quarzite	Whole flake	80	scraping	wood

Table 6. Kanjera South Oldowan use-wear sample, with interpretation.

Figure 1



KJS composite log 1
Clay
Silt
F. Sand
M. Sand
C. Sand
Granules
Pebbles
KS 4
KS 3
KS 2
KS 2 CP
KS 1 PS
KS 1
Archeological Interval
1m
Northern Exposures
Middle Exposures
Kanjera River
Kanjera
N
0
100 m
Southern Exposures
UGANDA
KENYA
Kanjera
Olorgesailie
Olduvai
TANZANIA
100 km

Figure 2

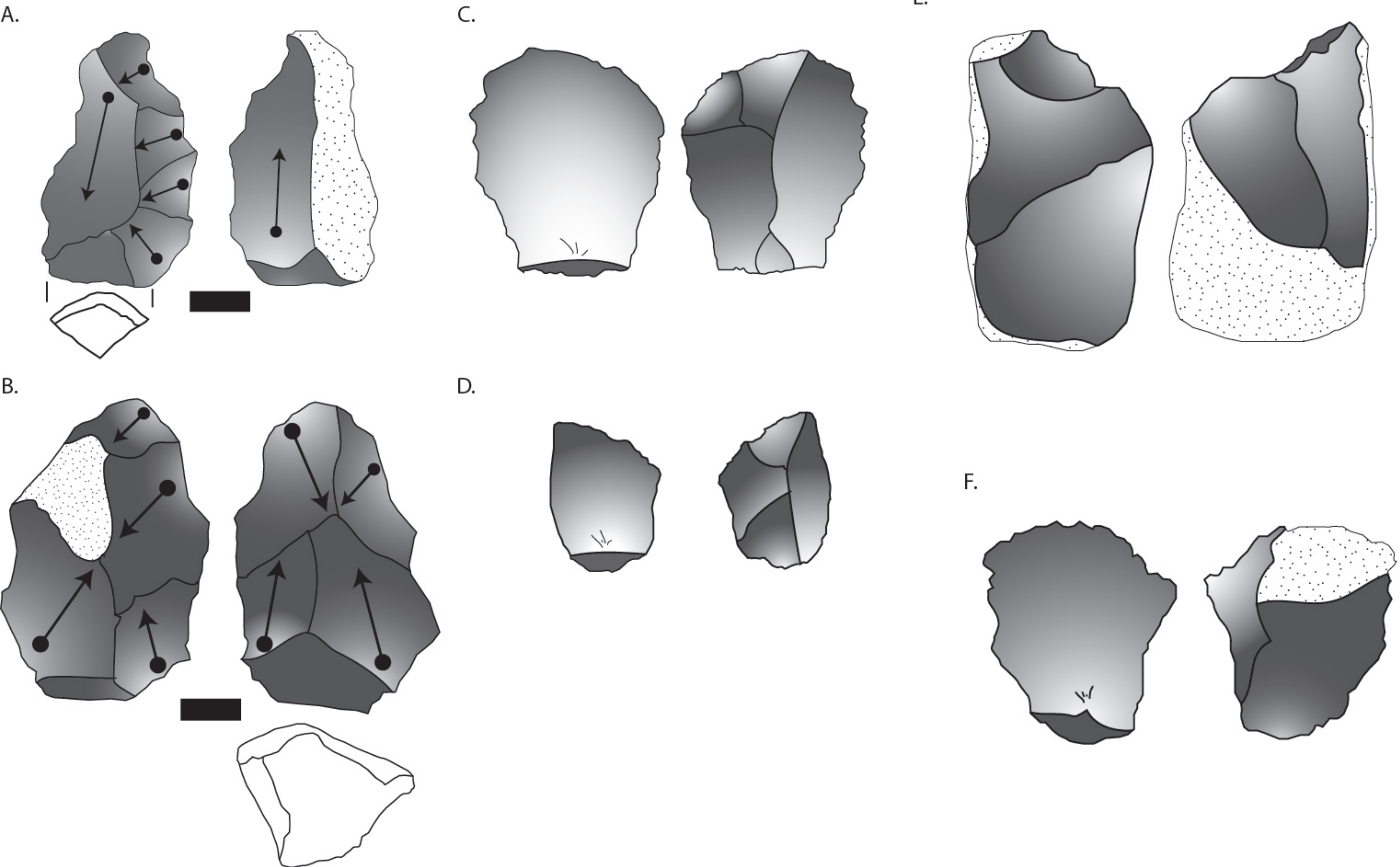
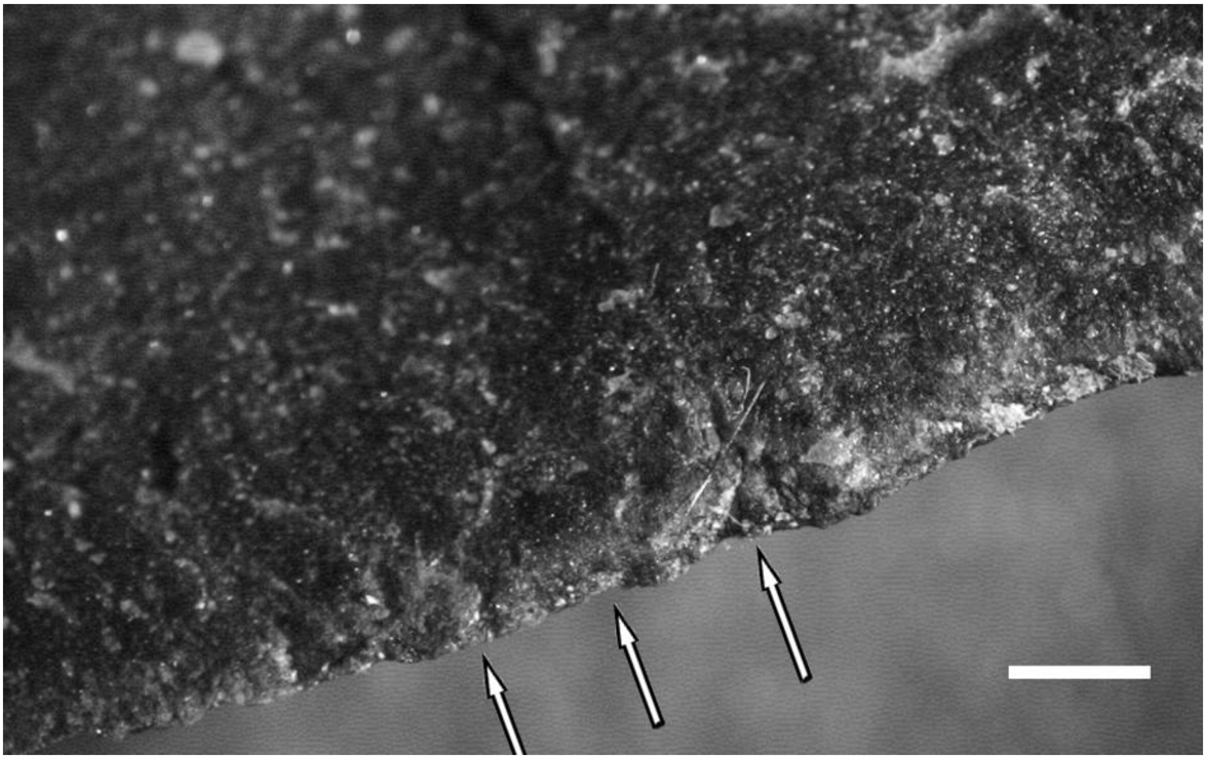
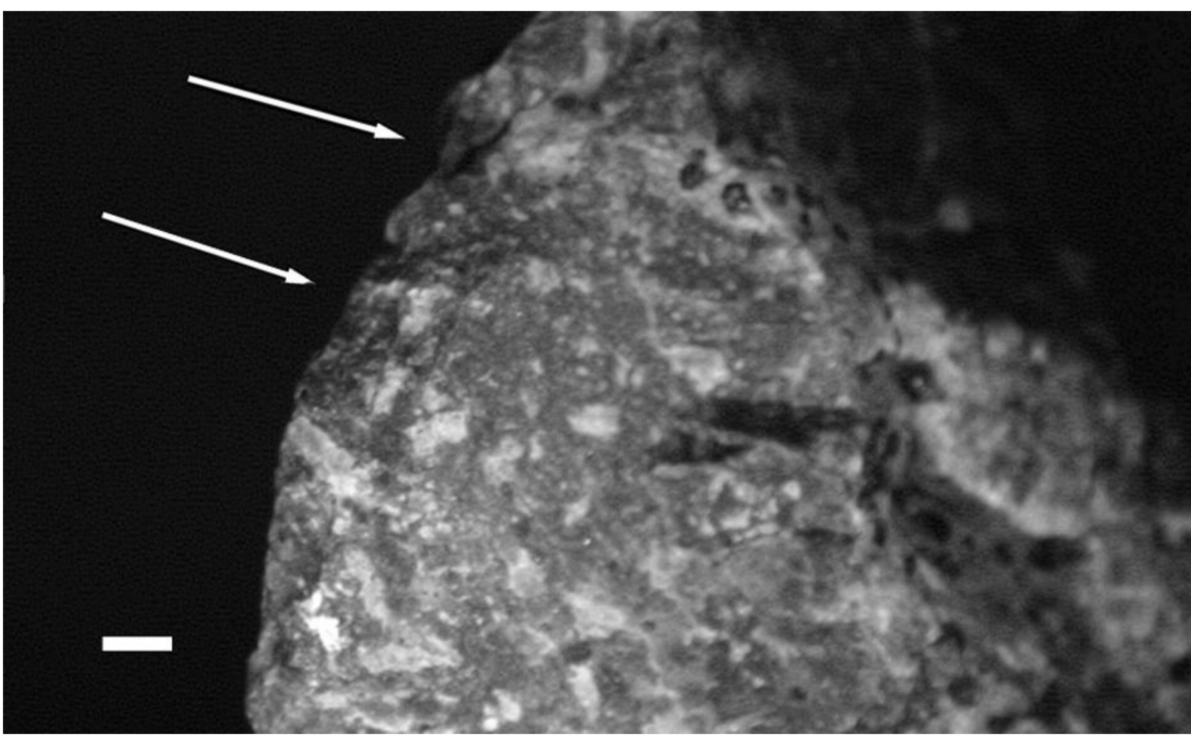


Figure 3



(a)



(b)

Figure 4

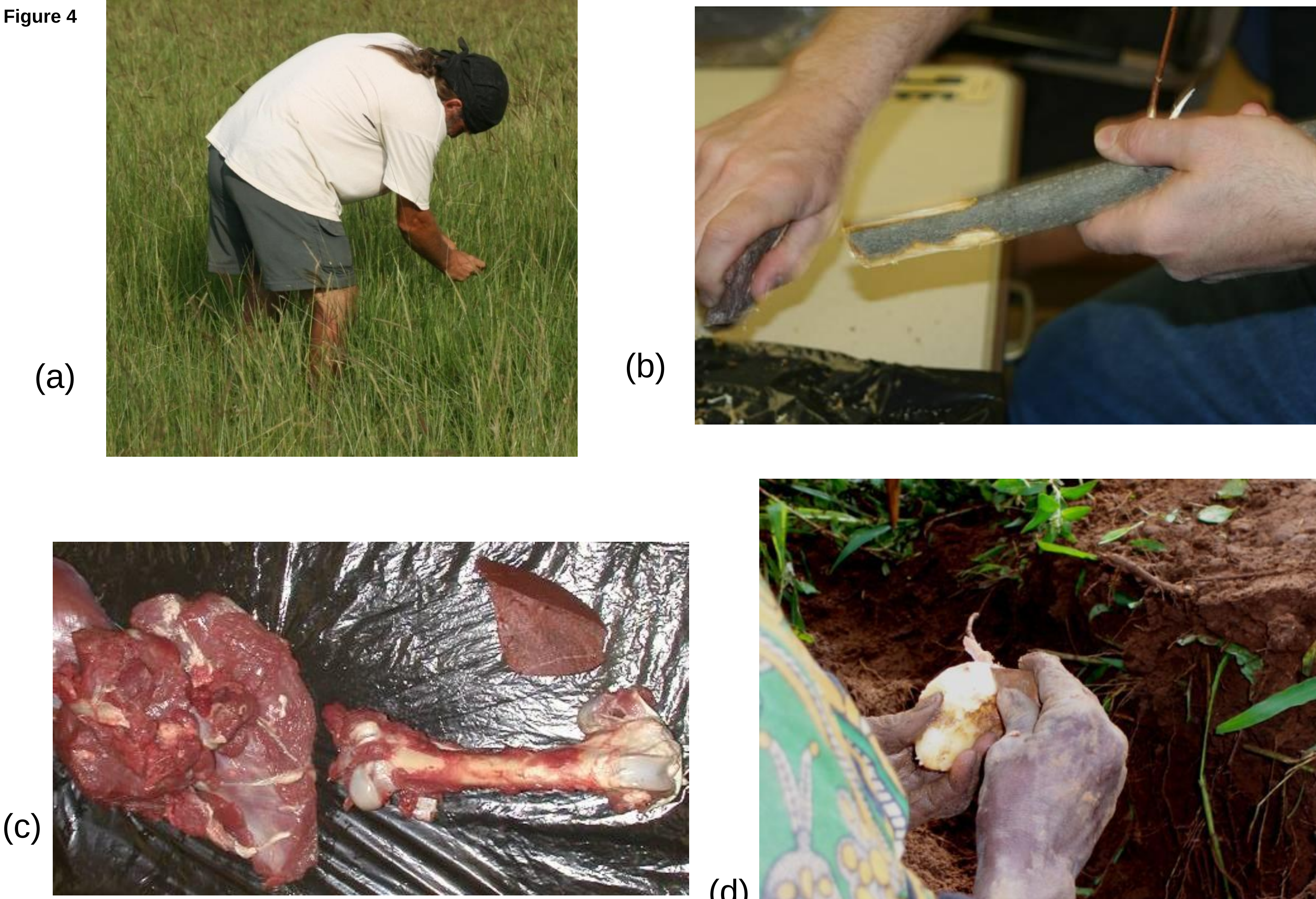


Figure 5

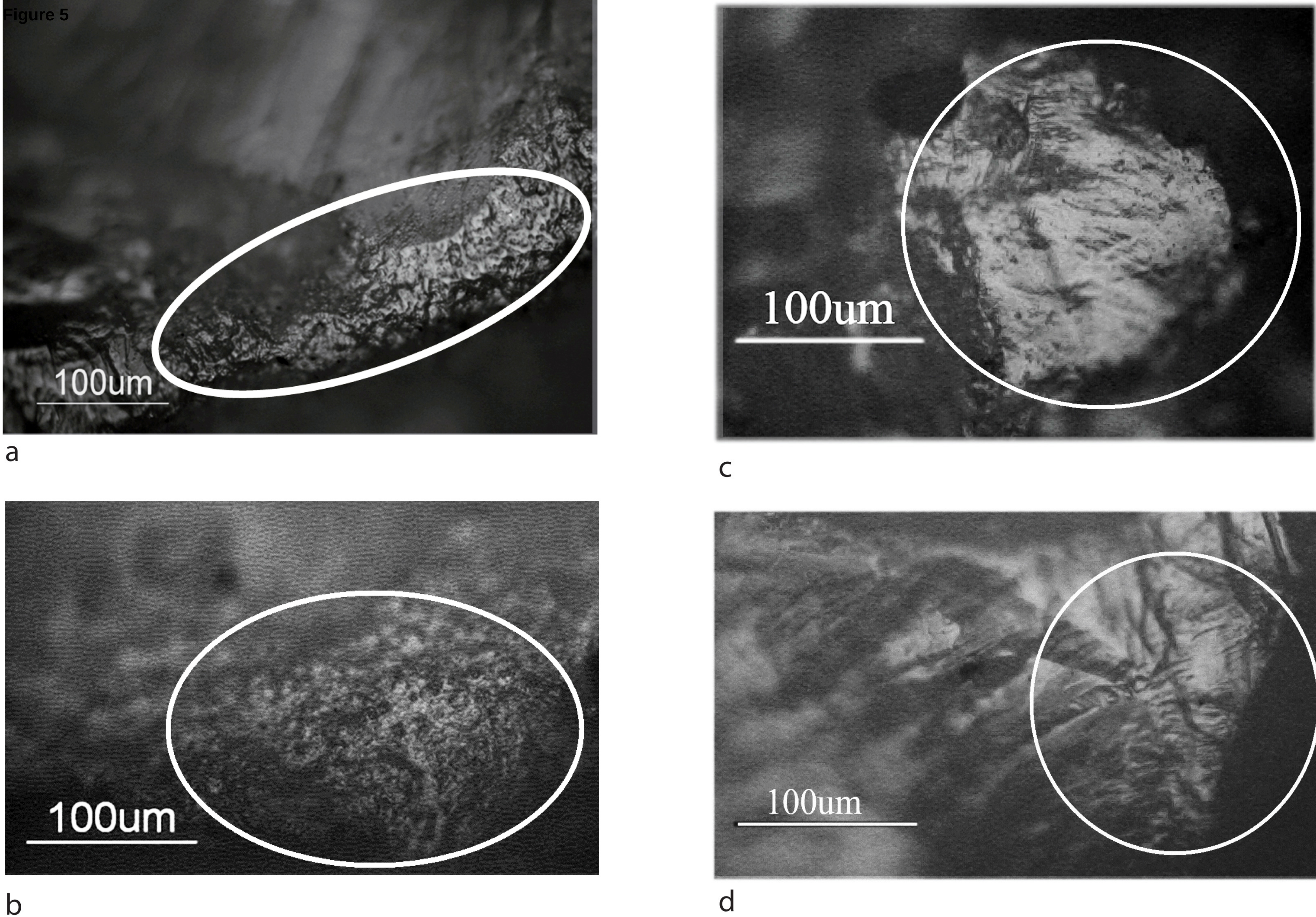
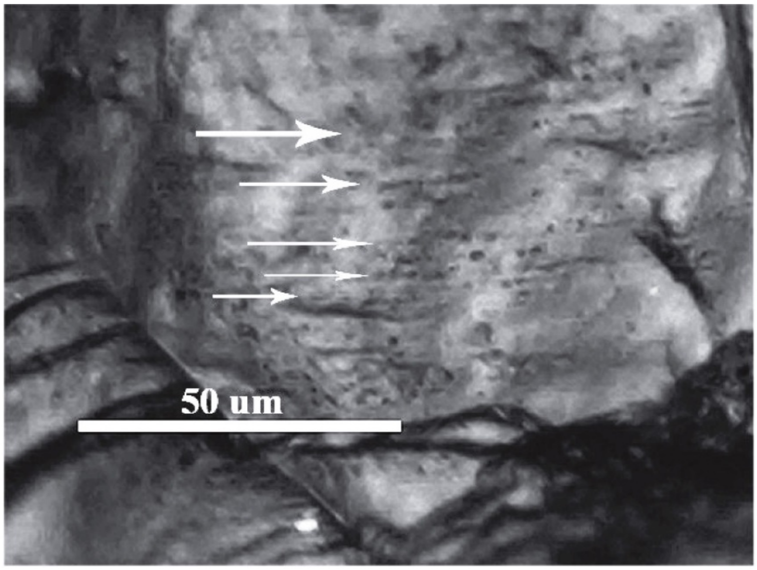
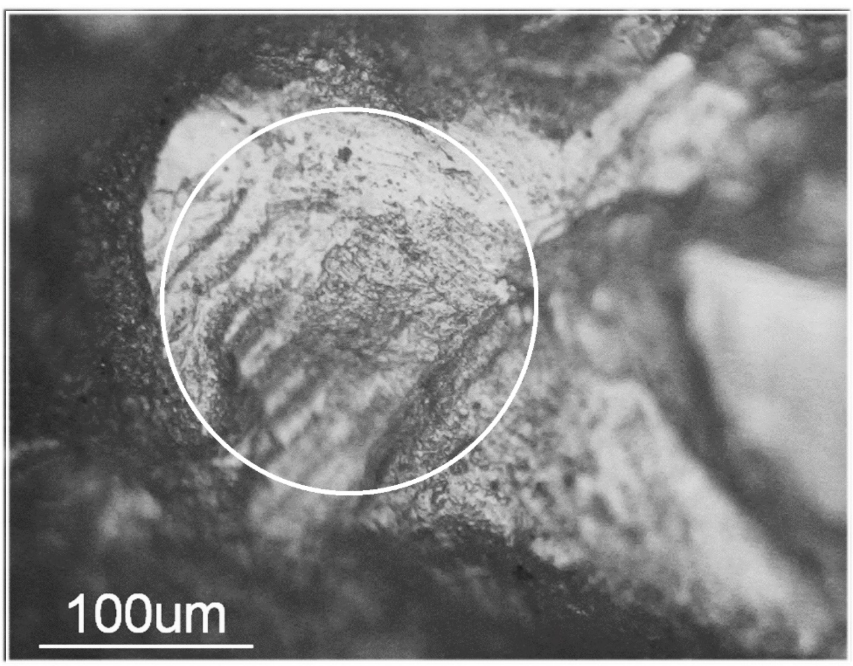


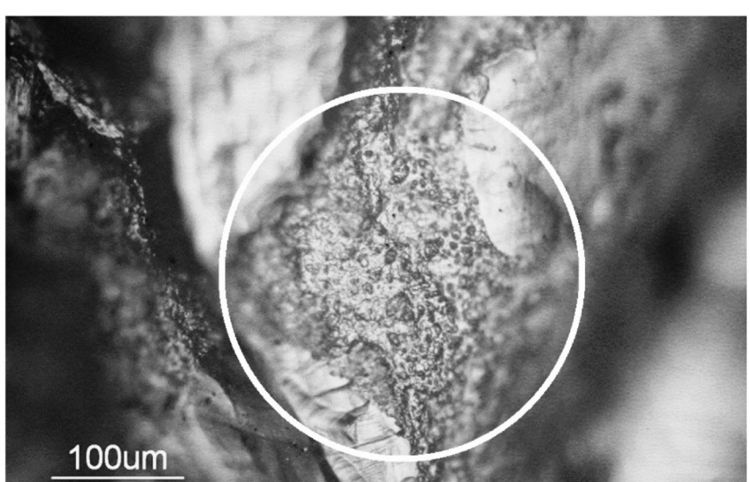
Figure 6



a



b



c

Figure 7

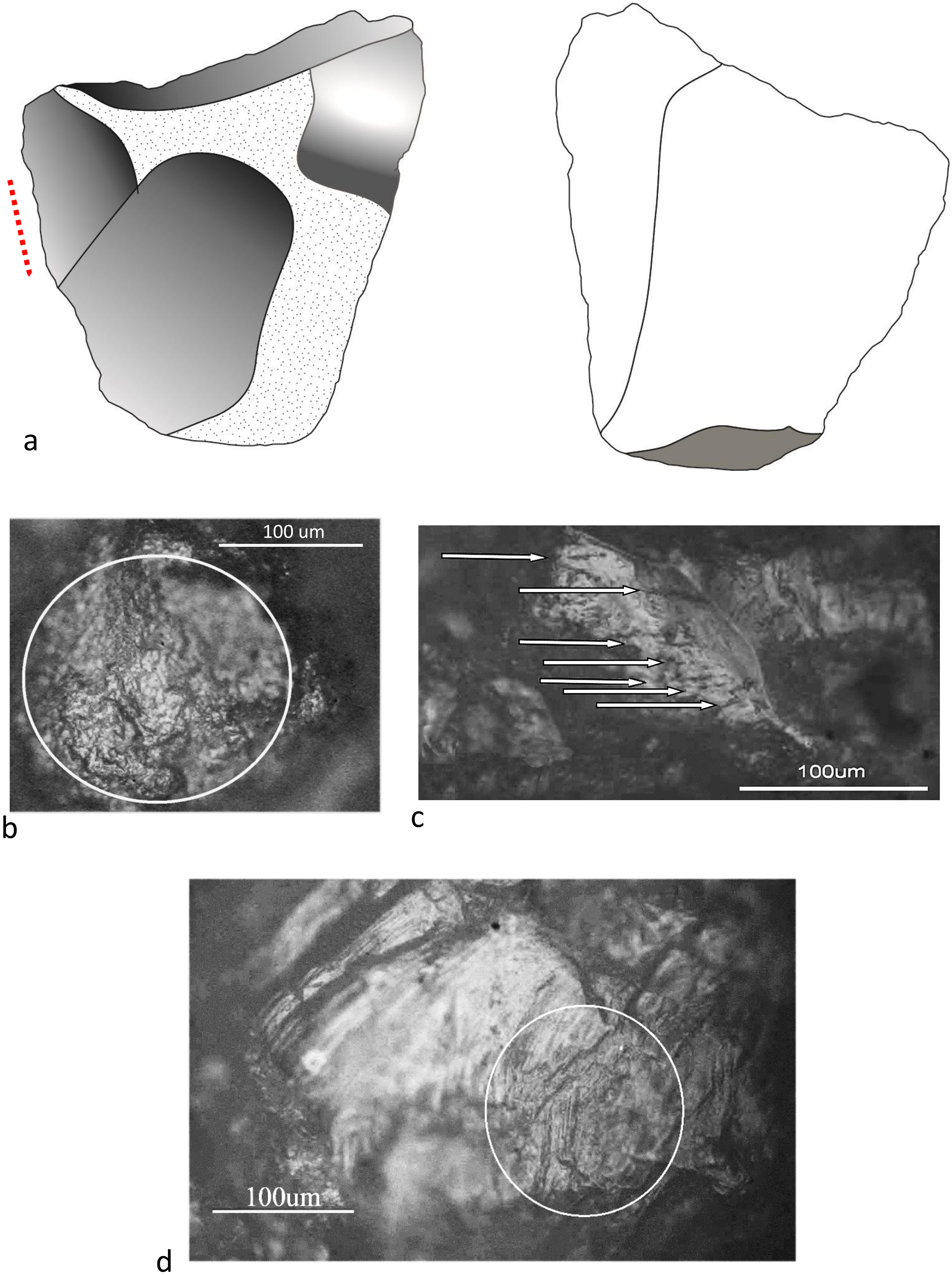
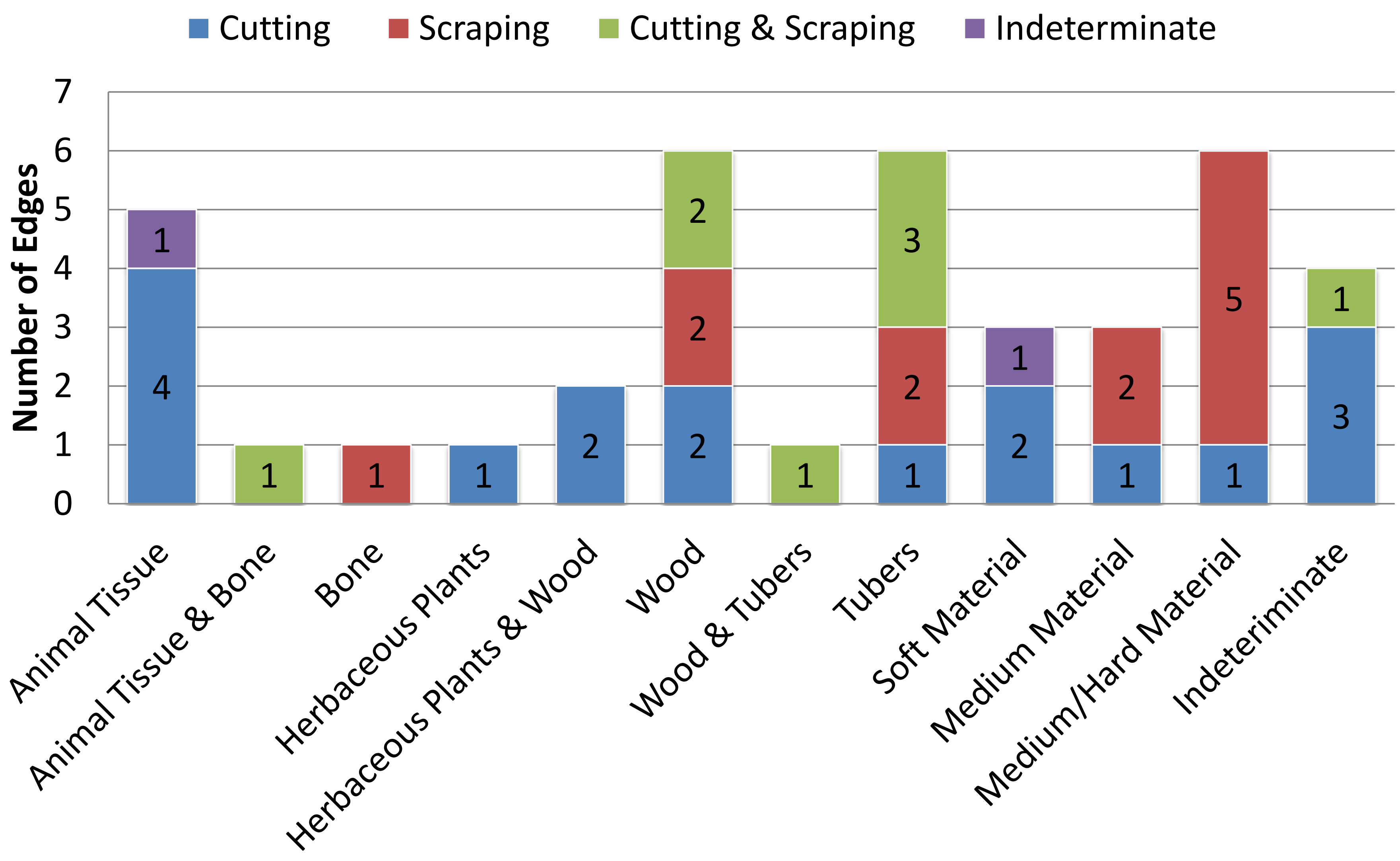


Figure 8



Cutting
Scraping
Cutting & Scraping
Indeterminate
Number of Edges
0
1
2
3
4
5
6
7
4
1
1
1
1
2
2
2
2
1
1
2
3
2
1
1
2
1
5
1
3
1
Animal Tissue
Animal Tissue & Bone
Bone
Herbaceous Plants
Herbaceous Plants & Wood
Wood
Wood & Tubers
Tubers
Soft Material
Medium Material
Medium/Hard Material
Indeteriminate

Supplementary Figure 1

Supplementary Figure 2

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Supplementary Figure 3

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