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4 **Old stones' song: Use-wear experiments and analysis of the Oldowan quartz**
5 **and quartzite assemblage from Kanjera South (Kenya)**
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8 Cristina Lemorini^a, Thomas W. Plummer^{b*}, David R. Braun^c, Alyssa N. Crittenden^d, Peter W.
9 Ditchfield^e, Laura C. Bishop^f, Fritz Hertel^g, James S. Oliver^f, Frank W. Marlowe^h, Margaret J.
10 Schoeningerⁱ, Richard Potts^{j,k}
11
12
13

14 ^a Dipartimento di Scienze dell' Antichità, Università di Roma "La Sapienza," P.le A. Moro 5,
15 00185 Rome, Italy, email: cristina.lemorini@uniroma1.it
16
17

18 ^bDepartment of Anthropology, Queens College & NYCEP, City University of New York,
19 Flushing, NY 11367, USA, email: thomas.plummer@qc.cuny.edu
20
21

22 ^cDepartment of Archaeology, University of Cape Town, Rondebosch 7701, South Africa
23 email: drbraun76@gmail.com
24
25

26 ^dDepartment of Anthropology, University of Nevada, Las Vegas, 4505 S. Maryland Pkwy, Las
27 Vegas, NV 89154-5003, USA, email: Alyssa.Crittenden@unlv.edu
28
29

30 ^eResearch Laboratory for Archaeology and the History of Art, University of Oxford, Oxford,
31 OX1 3QT UK, email: peter.ditchfield@rlaha.ox.ac.uk
32
33

34 ^fResearch Centre in Evolutionary Anthropology and Palaeoecology, School of Natural Sciences
35 and Psychology, Liverpool John Moores University, Byrom Street, Liverpool, L3 3AF, UK,
36 email: L.C.Bishop@ljmu.ac.uk
37 email: J.S.Oliver@2012.ljmu.ac.uk
38
39

40 ^gDepartment of Biology, California State University, Northridge, CA 91330-8303, USA,
41 e-mail: fritz.hertel@csun.edu
42
43

44 ^hDivision of Biological Anthropology, Department of Archaeology and Anthropology,
45 University of Cambridge, Pembroke Street, Cambridge, CB2 3QG, UK,
46 email: frank.marlowe@gmail.com
47
48

49 ⁱDepartment of Anthropology, University of California, San Diego, San Diego, CA, 92093, USA,
50 email: mjschoen@ucsd.edu
51
52

53 ^jHuman Origins Program, National Museum of Natural History, Smithsonian Institution,
54 Washington, D. C., 20013-7012, USA, email: POTTSR@si.edu
55
56

57 ^kPalaeontology Section, Earth Sciences Department, National Museums of Kenya, Box 40658,
58 Nairobi, Kenya
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61 *Corresponding author, office phone number (718) 997-5514 USA
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4 **Abstract**
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6 Evidence of Oldowan tools by ~2.6 million years ago (Ma) may signal a major adaptive shift in
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8 hominin evolution. While tool-dependent butchery of large mammals was important by at least
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10 2.0 Ma, the use of artifacts for tasks other than faunal processing has been difficult to diagnose.
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12 Here we report on use-wear analysis of ~2.0 Ma quartz and quartzite artifacts from Kanjera
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14 South, Kenya. A use-wear framework that links processing of specific organic materials and tool
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16 motions to their resultant use-wear patterns was developed in a suite of experiments. A blind test
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18 was then carried out to assess and improve the efficacy of this experimental use-wear
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20 framework, which was then applied to the analysis of 62 Oldowan artifacts from Kanjera South.
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22 Use-wear on a total of 23 artifact edges was attributed to the processing of specific materials.
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24 Use-wear on seven edges (30%) was attributed to animal tissue processing, corroborating
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26 zooarchaeological evidence for butchery at the site. Use-wear on sixteen edges (70%) was
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28 attributed to the processing of plant tissues, including wood, grit-covered plant tissues that we
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30 interpret as underground storage organs (USOs), and stems of grass or sedges. These results
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32 expand our knowledge of the suite of behaviors carried out in the vicinity of Kanjera South to
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34 include the processing of materials that would be “invisible” using standard archaeological
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36 methods. Wood cutting and scraping may represent the production and/or maintenance of
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38 wooden tools. Use-wear related to USO processing extends the archaeological evidence for
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40 hominin acquisition and consumption of this resource by over 1.5 Ma. Cutting of grasses, sedges
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42 or reeds may be related to a subsistence task (e.g., grass seed harvesting, cutting out papyrus
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44 culm for consumption) and/or a non-subsistence related task (e.g., production of “twine,” simple
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46 carrying devices, or bedding). These results highlight the adaptive significance of lithic
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48 technology for hominins at Kanjera.
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4 **Keywords:** Early Pleistocene archaeological sites, Oldowan artifact function, use-wear analysis,
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7 Kanjera South, East Africa
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10 11 12 13 14 **Introduction**

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16 The evaluation of traces produced on artifact surfaces through the working of different materials
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18 provides one of the few methods for assessing the range of activities carried out by ancient
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20 hominins, and contributes to reconstructions of hominin behavior. Here we analyse use-wear of
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22 the lithic industry from the Oldowan site of Kanjera South, southwestern Kenya (Plummer et al.,
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24 1999; 2009a,b; Braun et al., 2008; 2009a,b; Ferraro et al., 2013). This assemblage is particularly
25
26 suited for use-wear analysis, as stone artifact surfaces have not undergone extensive post-
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28 depositional modification, and multiple raw materials preserve use-wear traces.
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32 Use-wear analysis was first developed in Russia during the 1930s (Olausson, 1980), and
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34 following the English translation of Sergei Semenov's *Prehistoric Technology* (Semenov, 1964),
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36 interest in use-wear analysis in the international scientific community grew (Odell, 2004).
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40 Archaeologists initially had high expectations for the interpretative potential of this analysis,
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42 especially when applied to Paleolithic stone tools. However, its application proved difficult, due
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44 to an increased appreciation of the post-depositional modification of artifact edges (e.g., Plisson
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46 & Mauger, 1988) as well as considerable inter-observer variation in use-wear interpretation
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48 (Newcomer et al., 1986; Unrath et al., 1986). Although the degree of subjectivity involved is not
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50 necessarily greater than other commonly collected classes of archaeological data (e.g.,
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52 zooarchaeological data) (Odell, 2004), some became skeptical of the application of use-wear
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54 analysis to stone artifact assemblages, especially in the deep past (Shea, 1987; Bamforth, 1988).
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4 Recently, many analysts have implemented protocols that provide a more rigorous
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6 framework for assessing artifact function than had been common in the past (e.g., Lemorini et
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8 al., 2006; Claud, 2008; Rots, 2010). These protocols explicitly address concerns about post-
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10 depositional modification, and the linkage between a particular type of edge modification and the
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12 type of material being processed. They include the study of all artifacts in an assemblage to
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14 assess the impact of post-depositional processes on artifact edges, experiments to create a use-
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16 wear reference collection with the same raw materials being investigated archaeologically, the
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18 development of visualisation techniques that reduce the glare of highly reflective raw materials,
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20 and blind tests of the analyst interpreting use-wear. These protocols were followed here in the
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22 analysis of Oldowan quartz and quartzite artifacts from Kanjera South. There has also been an
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24 attempt to quantify use-wear, utilising technologies derived from the material sciences (e.g.,
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26 Stemp and Stemp, 2003; Evans and Donahue, 2008; Stevens et al., 2010; Stemp and Chung,
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28 2011; Evans and Macdonald, 2011). These approaches have had some success and may
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30 ultimately provide useful experimental protocols for use-wear analysts. While these have not
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32 yet developed into mature methodologies that can be applied to large artifact samples from
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34 archaeological sites, we hope to apply quantitative approaches to the use-wear on Kanjera
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36 artifacts in future.
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45 46 47 48 *Locality*

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

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36 The presence of the Olduvai subchron (1.95-1.77 Ma) in Bed KS-5 overlying the
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38 archaeological levels, and the co-occurrence of the equid *Equus* sp., the suids *Metridiochoerus*
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40 *andrewsi* and *M. modestus*, and the proboscidean *Deinotherium* sp., indicate that the KS-1 to KS-
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42 3 archaeological occurrences date between approximately 2.3 Ma (the dispersal of *Equus* across
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44 Africa, and the first occurrence of *M. modestus*) and 1.95 Ma (the base of the Olduvai subchron)
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46 (Plummer et al., 1999). An age of ~ 2 Ma for the archaeological occurrences seems most likely,
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48 given the apparent rapidity of deposition. Hominins were the primary agent of accumulation of
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4 the archaeological material, barring materials deposited in the conglomerate lenses (Plummer et
5 al., 1999; Ferraro et al., 2013). The majority of the *in situ* artifacts are from Excavation 1, a 169
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7 m² area that has yielded 3663 fossils and 2883 artifacts lifted with three dimensional coordinates.
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11 The bulk of the artifacts are from KS-2, which accumulated rapidly, probably representing
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13 decades to centuries of deposition.
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19 *The lithic industry: raw material and technology*
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22 The heterogeneity of the geology on the Homa Peninsula and its environs (Saggerson, 1952;
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24 LeBas, 1977), in combination with hominin lithic preferences, has resulted in artifact
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26 assemblages with greater raw material diversity than those from other Oldowan sites (Braun et
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28 al., 2009a,b) (Table 1).
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32 **TABLE 1 HERE**
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34 Extensive raw material surveys have produced a comprehensive database of 315 separate
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36 lithologies available on and in the immediate vicinity of the Homa Peninsula (Braun et al., 2008).
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39 Lithologies incorporated in the technological system of Oldowan hominins at Kanjera South
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41 include a variety of igneous rocks (e.g., carbonatite, rhyolite, granite), sedimentary rocks (e.g.,
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43 chert, limestone), metamorphic rocks (e.g., meta-quartzite), and metasomatised rocks (e.g.,
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45 fenitised andesite) (LeBas, 1977; Plummer, 2004). Geochemical studies have isolated primary
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47 and secondary sources for the stone used in artifact manufacture (Braun et al., 2008).
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51 Examination of the raw materials of the clast populations on and off the Homa Peninsula
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53 demonstrates that 28% of the Kanjera South artifact sample was made with non-local raw
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55 materials, defined here as raw materials not found as outcrops on the Homa Peninsula or in
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57 conglomerates in the radial drainage system of the Homa Mountain carbonatite complex.
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4 Geochemical analysis indicates that one of the raw materials under discussion here, banded
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6 quartzite, crops out in the Kisii highlands over 60 km away from the Homa Peninsula, and was
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8 available in stream and river conglomerates no closer than 10-13 km away from Kanjera South
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10 (Braun et al., 2008). Vein quartz is also not available in the immediate vicinity of Kanjera, and
11
12 may ultimately derive from the Kisii Highlands, but its minimum transport distance is uncertain.
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14 The high proportion of raw materials coming from 10 or more kilometres away from the site is
15
16 unique within the Oldowan; most Oldowan sites were formed on or near major raw material
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18 sources (Plummer, 2004; Harmand, 2007; Goldman-Neuman & Hovers, 2009; Rogers & Semaw,
19
20 2009). Technological analyses of the Kanjera South raw materials indicate that there was
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22 differential transport and curation of raw materials from outside the peninsula, with the majority
23
24 of flakes of non-local material being derived from later stages of core reduction. Cores made
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26 from these “non-local” materials are relatively uncommon, and when they are found they are
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28 generally heavily reduced (Braun et al., 2009a,b).
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36 The technology at Kanjera South provides some interesting insights into hominin
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38 behavior in the early Pleistocene. Although flakes and debris from flake production dominate the
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40 assemblage, core forms at Kanjera South are somewhat distinct from other Oldowan
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42 assemblages, and are focused on radial, discoidal, and polyhedral forms (Braun et al., 2009a,b).
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44 Large flakes are often re-utilised as cores (Fig. 2), and polyfacial forms are prevalent in some
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46 raw materials.
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50 ***FIGURE 2 HERE***

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53 No single core production mode (Roche, 2000) dominates the assemblage. Curation beyond
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55 what is commonly associated with an Oldowan assemblage is evinced by relatively high
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57 proportions of core rejuvenation flakes and intentionally retouched flakes in “non-local” raw
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4 materials, where the retouch is unidirectional, continuous, and tends to be concentrated on one
5 edge (Braun, 2006). The assemblage is characterized by technological diversity, with different
6 raw materials displaying widely divergent technological strategies (Braun et al., 2009b; Braun &
7 Plummer, 2013).
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14 The quartzite materials exhibit two main schema of reduction. The first and most
15 common scheme involves the use of relatively large flakes (>5 cm) as cores, where the ventral
16 surface of the cores is used as a removal surface and the dorsal side of the original flake is used
17 as a flaking surface (Braun et al., 2009b). The second reduction mode for quartzite, and the
18 primary reduction mode for quartz, is similar to that described by de la Torre and Mora (2005) as
19 bifacial abrupt, whereby a single removal surface is dominated by unipolar and bipolar removals
20 that intersect at the center of mass of the core. There is a subsequent removal pattern that runs
21 orthogonal to the main axis of flaking. The series of removals tends to be relatively short with
22 few overlapping removals. The absence of a long series of removals as seen in other Oldowan
23 contexts (e.g., Lokalalei 2C; Delagnes & Roche, 2005) may simply reflect the small size of the
24 original cobbles (Fig. 2; Table 2). The presence of rounded river cortex on almost all of the cores
25 indicates they were collected from a fluvial context.
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43 ***TABLE 2 HERE***
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48 **Materials & Methods**

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50 We followed a four step methodology in carrying out this analysis. The first step was the
51 examination of the entire artifact sample from our excavations macroscopically and with a
52 stereomicroscope. This allowed us to assess its suitability for use-wear analysis, and select the
53 best preserved edges for investigation. Use-wear experiments with flakes made from the same
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4 raw materials used by the Kanjera hominins were then carried out to link specific use-wear
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6 features to tool motions and the materials being processed. Blind tests were then carried out to
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8 assess the efficacy of the use-wear framework, followed by analysis of the Oldowan artifacts
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10 themselves. These steps are considered in turn below.
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16 *Initial examination of archaeological materials*
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19 This study began when one of us (CL) evaluated the entire artifact sample from Kanjera South
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21 housed in the National Museums of Kenya (n=4474, of which 3954 are detached pieces) (Table
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23 1) to assess the quality of edge preservation across raw materials, and the post-depositional
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25 processes impacting artifact surfaces. The Kanjera South assemblage is very well preserved and
26
27 edges were rarely subject to the types of damage usually associated with rolling or fluvial action
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29 (Schick, 1987a; Braun, 2006). However, as has been noted in other use-wear studies in Africa
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31 (e.g., Keeley and Toth, 1981), some raw materials suffer light post-depositional chemical
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33 dissolution, which compromises their edge morphology. In the Kanjera South sample, artifacts
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35 made with carbonatite, limestone, microijolite, ijolite, phonolite, and to some extent fenitized
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37 andesite were effected by post-depositional chemical dissolution. Here we limit our analysis to
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39 the “detached piece” sample of quartz and quartzite, two raw materials that retain exceptionally
40
41 well-preserved edges. Other raw materials (e.g. rhyolite, chert) have well-preserved edges, but
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43 we are still building a comparative database for their analysis. The Kanjera South sample totaled
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45 248 quartzite artifacts, of which 222 were detached pieces, and 91 quartz artifacts, of which 77
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47 were detached pieces. Artifacts were gently washed with warm water and soap, and then were
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49 washed for five minutes in demineralized water in an ultrasonic tank, after which they were air
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4 dried. Edges of these artifacts were inspected unassisted and using a stereomicroscope (SM
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6 Nikon objective 1X, oculars 10X, magnification zoom from 0.75X to 7.5X) in reflected light.
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9 Three criteria were applied to select artifacts for use-wear analysis: completeness
10 (artifacts without potentially functional edges were dropped from the analysis), surface
11 preservation, and the presence of removals and/or rounding localized on the very edges of the
12 artifacts, indicating ancient use. We are confident that edge modifications we have identified
13 resulted from artifact use, rather than a post-depositional process. The main features that
14 differentiate traces of use from post-depositional alterations are the combination of the trace
15 attributes – the contact with the worked material produces specific combinations of attributes
16 which rarely are replicated by postdepositional agents. As reference collections of experimental
17 use-wear testify, traces of use are always distributed in a localized portion of the artifact, in close
18 proximity to the edge. Post-depositional marks, on the other hand, are often randomly spread
19 over the lithic surface, including on raised or projecting areas of the artifact (Shea & Klenck,
20 1993). Taphonomic analysis of the Kanjera faunal assemblages (Ferraro et al., 2013; Parkinson,
21 2013) provides a further indication that postdepositional processes were unlikely to have been a
22 significant contributor to the marks found on the artifacts. Only 8.8% (444/5021) of the fossils
23 greater than 2 cm in length in the large faunal assemblage from Kanjera South preserved
24 abrasion from trampling or sedimentary movement (Parkinson, 2013), and the faunal sample
25 exhibits fine surface damage (e.g., tooth marks, cut marks, percussion pits and striae) that would
26 have been obliterated if postdepositional processes had significantly impacted the assemblage
27 (Ferraro et al., 2013). Moreover, quartz and quartzite are much harder materials than bone, and
28 so would have been less affected than the bone by the minor amount of sedimentary abrasion to
29 which the archaeological materials were subjected. Following these premises, every quartzite
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4 and quartz artifact with at least one potentially functional edge was carefully observed over its
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6 entire surface by eye and with a stereomicroscope, and items showing marks or abrasion patches
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8 randomly distributed both on and away from their edges were dropped from the analysis.
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11 Artifacts with post-depositional surface alteration detectable with the naked eye or with
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13 the assistance of a reflected light stereomicroscope were also removed from the analysis. Three
14
15 types of non-use related surface alteration were recognized individually or in combination on the
16
17 same artifact: 1) generalized rounding of the surface, 2) edge crumbling, and 3) widespread
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19 glossy/bright appearance of the quartzite cement matrix. Generalized rounding and widespread
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21 glossy appearance are caused by sedimentary abrasion, either as a result of hydraulic transport
22
23 prior to deposition, or sediment settling and pedogenic processes following deposition (Levi-Sala
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25 1988; Plisson & Mauger, 1988). Post-depositional chemical alteration of artifacts may also
26
27 result in a widespread glossy appearance (Plisson & Mauger, 1988; Stapert, 1976). Edge
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29 crumbling is caused by pressure, from trampling or sedimentary load, which results in micro-
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31 fracturing of the more fragile portions of the artifact edges (Flenniken & Haggarty, 1979;
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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

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4 *Reference Collections*
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7 Reference collections of quartz and quartzite flakes used to process a variety of materials
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9 in controlled experiments were necessary to interpret the use-wear on the Oldowan artifacts.
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11 These collections were derived from two sources; experiments carried out by CL with quartz and
12
13 quartzite flakes in her laboratory, which she has been using to interpret use-wear on these raw
14
15 materials from a variety of sites, and experiments conducted in East Africa to augment the
16
17 existing collection (Table 3). Although the quartz and quartzite flakes in CL's reference
18
19 collection come from different sources than the East African materials, their structure is similar
20
21 to the structure of the Kenyan raw materials in terms of the size and morphology of the crystals
22
23 and the amount of matrix.
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28 ***TABLE 3 HERE***
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31 A total of 14 quartz and 70 quartzite flakes were used in 94 use-wear experiments to link specific
32
33 types of edge modification to the processing of specific types of materials, and to specific
34
35 processing tasks. Some flakes were used for several tasks, either using different edges for
36
37 different tasks, or, less frequently, using the same edge. These latter samples allowed us to
38
39 investigate edge modification caused by overlapping types of use-wear. Experiments were
40
41 designed to replicate tasks potentially carried out by Oldowan hominins, including butchery
42
43 (carcass skinning, cutting of meat alone, or meat with some contact with bone), bone working,
44
45 hide scraping, working wood, cutting grass, and the processing of underground storage organs
46
47 (USOs), in this case wild African tubers. The stone tool motions carried out while conducting
48
49 these tasks were abrading, cutting and slicing, scraping, and engraving. These motions are
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51 commonly used with stone tools, and are defined following Keeley (1980).
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58 CL performed a variety of processing experiments using 14 quartz and 35 quartzite flakes
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4 in her laboratory at the University of Rome (Table 3). Additional experiments were carried out in
5
6 East Africa using thirty-five flakes of the same quartzite utilised by Oldowan hominins at
7
8 Kanjera (Fig. 4; Table 3). This is a high-grade metaquartzite with interlocking microcrystalline
9
10 quartz grains. The high maturity of the quartz grains is a result of their long entrainment as beach
11
12 sand during Bukoban times (Huddleston, 1951). The bright vitreous luster and porphyroblastic
13
14 texture distinguish it from lower grade metamorphic quartzites (Howard, 2005). The quartzite
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16 used in the experiments was collected from conglomerates in paleo-channels exposed in a
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18 modern quarry south of the Homa Mountain complex.
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27 **FIGURE 4 HERE**
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29 Nineteen quartzite flakes were used in skinning, defleshing, and disarticulation of two goats
30
31 (*Capra hircus*) in Kenya by two members of the Samburu tribe with extensive butchery
32
33 experience. Three quartzite flakes were used to cut stems of a coarse, wild grass on the Homa
34
35 Peninsula, near the shore of Lake Victoria. Finally, thirteen quartzite flakes were used by ten
36
37 adult women from the Hadza hunter-gatherer tribe in Tanzania to collect and process two species
38
39 of wild tubers, //Ekwa (*Vigna frutescens*) and Shaehako (*Vigna macrorhyncha*). The Hadza
40
41 routinely consume both tuber species and used the flakes to process the tubers in their usual
42
43 manner. The stone flakes were used to: 1) cut portions of the tuber free from the segments
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45 remaining in the ground during extraction, 2) peel the tuber, or scrape the dirt and debris
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47 covering the outer peel of the tuber, and 3) section the tuber. The two species of tubers differ in
48
49 their composition, processing, and consumption: //Ekwa tubers are most often roasted before
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51 eating, and a quid of indigestible fiber is spit out during consumption. Shaehako, which are less
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4 fibrous, are eaten raw or roasted and are consumed completely (no quid). Both raw and roasted
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6 tubers were cleaned in separate trials.
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9 All experimental flakes were washed in three steps to remove residues of processed
10 materials from their edges. They were washed first with water and soap, then in a chemical wash
11 starting with a dilute 3% acetic acid (CH₃COOH) for fifteen minutes, and then a dilute 3%
12 sodium hydroxide (NaOH) base for fifteen minutes, and finally a wash with de-mineralized
13 water in an ultrasonic tank. Silicone (two components Provil Novo-Light Fast, Heraeus and two
14 components Elite HD+ Light Body Fast Set) moulds of the used edges were made and observed
15 under the microscope to detect use-wear, and define micro-wear attributes for diagnosing the
16 materials being worked (Table 4). CL made observations of the moulds (negative replicas)
17 rather than making casts (positive replicas) of each mould surface, as the same observations can
18 be made either way. This protocol has the advantages of lowering laboratory expenses by
19 eliminating the need for casting material, and also limits the loss of fine details that can occur
20 when using casts. The use of moulds allowed observation without the high degree of glare
21 common with quartz-rich raw materials.
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40 **TABLE 4 HERE**

41 *Blind Test*

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43 Few use-wear studies have been conducted on the raw materials analysed here (e.g., Sussman,
44 1985, 1988; Fullagar, 1986; Knutsson 1988; Pant, 1989; Knutsson & Lindé, 1990; Pignat &
45 Plisson, 2000; Marquéz et al., 2001; Stemp et al., 2013). A blind test was carried out to assist in
46 interpreting the materials being worked, and the motions or actions being carried out (e.g.,
47 cutting, scraping). Eight fresh flakes of the same Kenyan quartzite used by Kanjera hominins
48 were used to a) butcher a goat limb, b) scrape the surface of a goat femur, c) skin and section two
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4 raw, dirt-covered sweet potatoes (*Ipomoea batatas*), d) skin and section a clean sweet potato, and
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6 e) cut and scrape relatively soft wood (ornamental cherry, *Prunus* sp.) and hard wood (black
7
8 maple, *Acer nigrum*) branches in TP's laboratory at Queens College (Table 5).
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11 **TABLE 5 HERE**
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14 Two additional Kenyan quartzite flakes were used to cut North American grass (species
15
16 unknown) in a field in southern New York. These ten flakes were then cleaned with soap and
17
18 water, and transported to Italy for use-wear analysis. No information on the use or treatment of
19
20 the flakes was provided to CL prior to use-wear analysis. These flakes were washed in CL's lab
21
22 first with water and soap, then in a chemical wash starting with a dilute 3% acetic acid
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24 (CH_3COOH) for fifteen minutes, and then a dilute 3% sodium hydroxide (NaOH) base for fifteen
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26 minutes, and finally a wash with de-mineralized water in an ultrasonic tank. Results of the blind
27
28 test were promising enough (see Results below) that the interpretation of the use-wear of the
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30 Kanjera Oldowan flakes was undertaken.
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38 *Macro- and micro-analysis of Kanjera artifacts*
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41 The reference samples and blind testing provided insight into how to interpret the use-wear
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43 preserved on the archaeological sample. Analysis of the macro-traces provided information
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45 about the potential activities being carried out (e.g., cutting, scraping, piercing, etc.) and general
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47 interpretation of the hardness of the worked material (see Tringham et al., 1974; Lemorini et al.,
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49 2006; Rots, 2010). The hardness categories used were soft (e.g., animal soft tissue [muscle,
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51 tendons, digestive tract, abdominal fat], herbaceous plants, some tubers), medium (e.g., wood,
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53 hide), and hard (e.g., animal hard tissue [bone, ivory, horn, teeth], and stone). Materials of
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55 intermediate hardness or resistance may result in use-wear traces that are intermediate between
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4 these categories (e.g., soft/medium or medium/hard). Microscopic analysis (examination of
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6 micro-edge rounding, polishes, abrasions, and striations) was conducted to provide a more
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8 detailed understanding of the activities carried out with the lithic artifacts, and to assist in the
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10 diagnosis of the material being processed (see Rots, 2010). A two-component silicone moulding
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12 material (Provil Novo Light Fast, Heraeus; Elite HD+ Light Body Fast Set) was used to make
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14 fine-grained moulds of the edges of these artifacts in Kenya. These negative casts were then
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16 analysed by CL at the Laboratory of Techno-Functional Analysis of the Museo delle Origini,
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18 Sapienza (University of Rome in Italy) under reflected light.
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24 Most use-wear analysis is carried out with either scanning electron microscopy (SEM) or
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26 optical light microscopy, and the interpretation of the use-wear is dependent on the experience of
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28 the observer and his/her ability to interpret the generated images. These methods are
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30 complementary, and either can provide satisfactory results (Borel et al., in press). The SEM has
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32 the advantage of a wider depth of field, which can allow well-focused pictures and high
33
34 resolution imaging. Scanning electron microscopes are also useful for the analysis of highly
35
36 reflective raw materials (for a comprehensive description of the SEM approach and its potential
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38 see Knutsson 1988; Knutsson & Lindé 1990; Ollé & Vergès 2013). However, scanning electron
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40 microscopes are not as readily available as optical light microscopes, and are not transportable to
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42 the field. For this analysis, we used a metallographic microscope (Nikon Eclipse with 10X, 20X,
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44 and 50X objectives and 10X oculars) equipped with a reflected differential interference contrast
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46 (DIC), and a confocal system (Nikon Eclipse C1). The shallow depth of field in the optical light
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48 microscope renders relief well, and this method allows the easy identification of polish and
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50 striations (see Igreja, 2009 for a protocol similar to that used here). Other advantages of our
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52 analytical setup are that it allows fast positioning of the samples, and it removes the glare
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4 associated with quartz-rich lithologies (Sussman, 1985, 1988; Stemp et al., 2013). The
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6 metallographic microscope and DIC system permitted us to obtain optimal resolution at 100x
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8 and 200x magnification. The confocal system was added to the protocol when a magnification of
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10 500x or more was needed. While our analytical setup plus silicone moulds are suitable for this
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12 analysis, there is no doubt that the combined use of multiple techniques may improve it in the
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14 future (Borel et al., in press).
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21 **Results**

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23 The development of the reference collection highlighted an important difference between
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25 use-wear distribution in microcrystalline (e.g., flint or chert) and hyaline (obsidian) raw
26
27 materials, versus materials with internal structure or large grains (e.g., quartz and quartzite). The
28
29 quartzite was composed almost entirely of silica, and was probably derived from a very mature
30
31 quartz beach sand precursor lithology because of the lack of other minerals (Huddleston, 1951).
32
33 During regional metamorphism of this quartzite there has been extensive dissolution and
34
35 recrystallization of much of the original quartz such that the present lithology consists of residual
36
37 quartz grains set in a fine-grained silica matrix. Use traces are very localised in quartz and
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39 quartzite, appearing on the face of a single quartz crystal or small clusters of crystals, and (on the
40
41 quartzite) on small patches of silica matrix. In contrast, microcrystalline and glassy raw
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43 materials such as flint and obsidian have use-wear distributed extensively and more uniformly
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45 across much of the utilised artefact edge (Clemente Conte & Gibaja Bao, 2009).
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53 Analysis of the experimental reference collections allowed CL to develop a set of micro-
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55 wear attributes for interpreting the use-wear of quartzite and quartz. Certain traits were
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57 identified as diagnostic depending on the location and substrate of the material where the trace
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4 was located. Traits on quartz crystals (in both quartz and quartzite), and the silica matrix
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6 surrounding the crystals in quartzite, were identified (Table 4). The extent of development of
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8 use-wear traces (e.g., slight or well-developed), the texture of the polish (smooth or rough), the
9
10 topography of the polish (e.g., flat or domed), and the depth and shape of striae (e.g., striae that
11
12 taper to a point versus striae that diverge in one direction [comet-tail]) were useful in diagnosing
13
14 the hardness of the substance being worked. In some instances these traits could be used to make
15
16 a more specific diagnosis of the material that was processed (Table 4; Fig. 5-7; Supplementary
17
18 Fig. 1-3). The location and orientation of the micro-wear features were also useful in diagnosing
19
20 tool motion (the actions being carried out with the stone tool) such as cutting or scraping.
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26 ***FIGURES 5-7 HERE***

27 *Blind test*

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31 The results of the blind test broadly confirmed the utility of use-wear analysis for the
32
33 interpretation of the function of quartzite artifacts. Traces of use-wear were found on 8 out of 10
34
35 flakes, with the used edge correctly identified in all eight cases. The hardness of the material
36
37 being worked was correctly recognized in all eight cases where use-wear was identified (100%
38
39 success rate). The actual material that was worked was correctly identified in five of the seven
40
41 cases where a specific material was diagnosed (success rate of 71%). Discrimination between
42
43 butchery, wood-working, and tuber processing was apparent from these results. The motion
44
45 (e.g., cutting, scraping) was also correctly inferred in seven of the eight cases (success rate of
46
47 88%). Thus, the use-wear analysis of quartz-rich lithologies does provide useful information for
48
49 interpreting artifact function. Our results fall at the high end of other published blind test results,
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51 which documented the direction of motion correctly 43-92% of the time, and the actual material
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53 being processed 16-79% of the time (Evans & Macdonald, 2011).
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4 The blind test had some important implications for determination of quartz and quartzite
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6 artifact function. The diagnosis of USO/tuber processing was dependent on the tubers having
7
8 adherent sediment. Peeling and sectioning the grit-covered sweet potatoes in the blind test
9
10 produced recognizable, localized, and oriented scratches. This edge modification was very
11
12 similar to the use-wear produced by Hadza women collecting and cleaning wild tubers in
13
14 Tanzania (Fig. 6). Processing of the clean, soil-free sweet potato during the blind test did not
15
16 produce these scratches. The weak use-wear that developed during clean sweet potato processing
17
18 only allowed the detection of the hardness of the material being worked (i.e., soft; Flake B5,
19
20 Table 5).
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26 Incorrect functional interpretations were made in four of the eight flakes with
27
28 interpretable use-wear. While both flakes used to butcher a goat limb (B6 and B7) were
29
30 correctly interpreted as having been used to cut animal flesh, they also had functional areas on
31
32 their artifact edges that were attributed to processing other materials, a medium-hard material
33
34 (B6-hide?) and a soft material (B7-plants?). In addition to the functional areas on the artifact
35
36 edge correctly diagnosed as having been used for wood-working, flakes B1 and B4 developed
37
38 “gripping wear” from contact between the flake edge and the experimenter’s hand during
39
40 material processing. Gripping wear was attributed by the analyst (CL) to processing of soft
41
42 material (animal tissue?) in B1, and a medium-hard material (hide?) in B4. Rots (2010) found
43
44 that gripping and hafting traces were not uncommon in flint industries, and cautioned that
45
46 analysts should look for them in use-wear studies. We thought the contact between the
47
48 experimenter’s hand and the artifact during processing would not create recognizable traces,
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50 particularly when using hard lithologies such as quartzite. However, the firm contact between
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52 the analysts’ hands and the artifact edge during wood-working did lead to edge alteration, and
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4 interestingly enough this alteration was interpreted by CL as contact with animal tissue (muscle
5 or hide). The results of the blind test suggest that gripping traces can develop relatively rapidly
6 even in silica-rich raw materials. On more homogenous, microcrystalline, or glassy raw
7 materials, such as flint and obsidian, use traces are generally distributed along the edge as a line
8 or band, whereas gripping or hafting traces are recognized as localized wear spots (Rots, 2010).
9 At this stage, it is not possible to distinguish gripping traces from use traces on tools made of
10 quartz and quartzite, as in both cases wear is distributed over relatively small areas. However,
11 gripping wear did not frequently develop, and most of the archaeological specimens show use-
12 wear on only one edge (Table 6). It thus seems unlikely that gripping wear was an important
13 source of error in the interpretation of the use-wear of the Oldowan artifacts reported below.

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28 ***TABLE 6 HERE***

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31 A final interpretative insight resulted from the processing of two “soft” materials, grass
32 and animal soft tissue. The wild grass cut in Kenya used for the reference sample was much
33 more abrasive than the North American grass cut with flakes B9 and B10. The Kenyan grass
34 caused a more a diagnostic pattern of use-wear to develop with fewer strokes than the less coarse
35 North American grass. (Tables 3 and 5). In their use-wear experiments, Keeley and Toth (1981)
36 also found that wild grasses from Koobi Fora, Kenya affected the flake edges much faster than
37 temperate European grasses. The North American grass, which was probably not a good
38 analogue for the coarser East African grass, caused shallow abrasions to develop that were
39 confused with traces developed by cutting meat. Use-wear analysts working with other raw
40 materials (e.g., flint, obsidian) have also had problems distinguishing herbaceous plant and meat
41 use-wear, particularly if the activity was carried out for a short time, and the use-wear traces
42 were not well developed (Gassin, 1996; van Gijn, 1989; Lemorini, 2000). Further experiments
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4 on wild grasses, reeds and sedges in Kenya are necessary to more properly assess the degree of
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6 overlap between the use-wear of soft plant and animal tissues, particularly when the traces are
7
8 not very well developed.
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11 In summary, the blind test provided insight into how the use-wear of quartz and quartzite
12
13 Oldowan artifacts should be interpreted. The hardness or resistance of the worked material can
14
15 be determined accurately. However, there may be some misattribution of wear when it is only
16
17 weakly developed. Use-wear from wood-working and butchery was clearly identified, as was
18
19 use-wear related to the processing of a grit-covered plant tissue, which we are interpreting as
20
21 USO processing. Unlike the use-wear of other materials, the diagnosis of use-wear associated
22
23 with processing of USOs is based both on the physical properties of the plant tissue, as well as
24
25 the contact between sedimentary particles on the USO and a forcefully directed tool edge. Our
26
27 overall conclusion is that quartzite and quartz use-wear can provide useful information on the
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29 function of Oldowan tools.
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38 *Kanjera South: quartzite artifact use-wear*

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40 Twenty-five of the 35 quartzite artifacts (69%) selected for analysis showed traces interpreted as
41
42 use-wear (Table 6). Five artifacts showed no post-depositional alteration and the remaining 20
43
44 showed minimal alteration, having a diffuse matrix sheen that did not obscure the use-wear and
45
46 probably resulted from post-depositional settling of the sediments and pedogenic processes. The
47
48 morphological characters allowing the interpretation of the tool kinetics and the properties of the
49
50 worked material were readily observable because of the excellent preservation of the artifact
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52 surfaces (Table 6). Cutting motion was recognized on eleven of 25 edges, and was linked to
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54 working soft animal tissue (n=3), wood (n= 2), abrasive herbaceous plants (e.g., grasses or
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4 sedges, n= 1), wood and herbaceous plants (n=1), USO processing (n=1), a soft material (n=1), a
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6 medium/hard material (n=1), and an indeterminate material (n=1). Scraping activities (9 of 25
7
8 edges) were related to wood-working (n=2), USO processing (n=2), and an indeterminate
9
10 medium/hard material (n=5). Six “mixed” activities, represented by overlapping cutting and
11
12 scraping, were linked to USO processing (n=3), wood and USOs (n=1), and animal soft tissue
13
14 and bone (n=1).
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21 *Kanjera South: quartz artifact use-wear*
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23 Fourteen of 27 artifacts (52%) selected for analysis show traces interpreted as use-wear (Table
24
25 6). Quartz use-wear is more difficult to interpret than quartzite, as quartz lacks the interstitial
26
27 silica matrix that develops characteristic use-wear traces in quartzite (Table 4). A variety of
28
29 materials were cut, including animal soft tissue (n=1), a combination of wood and abrasive
30
31 herbaceous plant (n=1), and indeterminate soft (n=1) and medium (n=1) materials. Three edges
32
33 were used to scrape a medium material (n=2), and bone (n=1). Mixed actions of cutting and
34
35 scraping were carried out working wood (n=2) and an indeterminate material (n=1). Soft animal
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37 tissue (n=1) and a soft material (n=1) were processed without an interpretable kinetic signal.
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43 In summary, use-wear of 23 artifact edges was attributed to the processing of either plant
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45 (16 edges, 70%) or animal (7 edges, 30%) tissue (Fig. 8, Table 6). Whether this frequency is an
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47 accurate reflection of the time spent on different processing activities is not clear, as the analysed
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49 sample is a tiny proportion of the total number of edges in the archaeological assemblage. But
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51 the results suggest that plant processing was a significant component of the Oldowan hominin
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53 behavioral repertoire at Kanjera South.
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57 ***FIGURE 8 HERE***
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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

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4 normally be invisible archaeologically, and by corroborating behaviors inferred through other
5 analyses. Moreover, they illustrate the adaptive significance of lithic technology to 2 Ma
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7 Oldowan hominins on the Homa Peninsula. These issues are further noted below.
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10 11 12 13 14 *Subsistence at Kanjera South*

15 Use-wear provides an independent method from zooarchaeology to assess subsistence activities
16 at Kanjera. The salient, archaeologically observable food resource in the Oldowan diet is meat
17 (here referring to all soft tissue within the body, e.g., muscle, viscera, brains, and marrow). Large
18 mammal bones with stone tool-induced modification are coeval with the oldest archaeological
19 traces at ~2.6 Ma, suggesting that butchery is a component of the Oldowan diet as soon as tools
20 appear (de Heinzelin et al., 1999; Semaw et al., 2003). Butchery use-wear on Oldowan artifacts
21 has been reported for ~ 1.78 Ma Oldowan artifacts from Ain Hanech, Algeria (Sahnouni et al.,
22 2013), and for Early Stone Age artifacts from Koobi Fora at ~ 1.5 Ma (Keeley & Toth, 1981).
23 However, the frequency and intensity of late Pliocene hominin carnivory is unclear (Plummer,
24 2004). At Kanjera, stone artifacts and fauna are stratified through several metres of sediment,
25 representing hundreds to thousands of years. Zooarchaeological analysis provides evidence of
26 hominins having repeated access to largely complete size 1 and 2 bovid carcasses, as well as at
27 least intermittent access to fleshy carcasses of larger animals (Ferraro et al., 2013; Parkinson,
28 2013). This provides the oldest evidence of sustained hominin involvement with carcasses, and
29 indicates that by 2 Ma hominins at Kanjera South practiced persistent carnivory. Use-wear on
30 both quartzite and quartz artifacts described here corroborates the use of artifacts for butchery
31 (Fig. 8, Table 6).
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4 Clear use-wear evidence for plant-processing complements the evidence for butchery.
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6 Plant foods are of critical importance to African tropical foragers, and it is likely that Oldowan
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8 hominins relied predominantly on plant foods as well (Lee, 1979; Peters and O'Brien, 1981;
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10 Peters, 1987; Rodman, 2002; Schoeninger et al., 2001; Sept, 1986; Stahl, 1984; Vincent, 1984).
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13 Wild plant foods commonly eaten by baboons, chimpanzees, and humans in Africa include
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16 fleshy fruits, flower buds, nuts, nut-like oil-seeds, seed pods, leaves, stems/pith, and terrestrial
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18 and aquatic USOs (Gaulin, 1979; Hladik and Chivers, 1994; Peters and O'Brien, 1981, 1994;
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21 Wrangham et al., 2009). USOs have figured prominently in models of hominin dietary evolution
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24 (Deacon, 1993; Stahl, 1984; Milton, 1999; O'Connell et al., 1999; Wrangham et al., 1999; Laden
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26 & Wrangham, 2005; Dominy et al., 2008; Wrangham et al., 2009; Lee-Thorp et al., 2012), either
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28 as critical fallback foods allowing survival in savanna ecosystems or as staple components of the
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31 hominin diet. Raw USOs are not only targeted by chimpanzees (Hernandez-Aguilar et al.,
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34 2007), but also may have been a significant component of the diet of *Australopithecus* spp.,
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37 *Paranthropus boisei*, and *H. erectus sensu lato* (O'Connell et al., 1999; Laden & Wrangham,
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40 2005; Dominy et al., 2008; Ungar, 2012). USOs, as a collected resource that can be bundled and
41
42 transported, may also have played a key role in the evolution of central place foraging and
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44 provisioning (Isaac, 1978; Wrangham et al., 1999).

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46 Despite the prominence of USOs in the discussions of hominin diets, there has been very
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48 little archaeological evidence supporting hominin acquisition and consumption of them. The
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50 use-wear reported here provides the oldest archaeological documentation of hominin processing
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52 of relatively soft, grit-covered plant materials, interpreted here as the signature of USO
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54 processing. Our results extend the evidence for USO processing by over 1.5 million years
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57 (Mercader et al., 2008). Whether these were USOs from C₃ plants, such as the tubers the Hadza
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4 consume, CAM plants, or C₄ plant parts such as sedge corms which frequently have a grit-
5 covered tunic that needs to be removed (Dominy, 2012) is unknown.
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11 *Non-food processing activities*
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14 Wood cutting and scraping may have been an important activity, based on the number of edges
15 interpreted to have been used on wood. It is possible that the wood use-wear reported here
16 represents hominin extracting food, such as larvae, from recesses in tree trunks and limbs as seen
17 in modern chimpanzees (Yamagiwa et al., 1988). However, we would expect the kinetics to
18 better reflect gouging or boring activities if this were the case. It seems more likely that flakes of
19 quartzite and quartz were used to cut and scrape wood in the production or maintenance of
20 wooden tools. Our close living relatives (chimpanzees) commonly use wooden tools in
21 extractive foraging, stripping branches of their leaves for use as probes, and in one population
22 sharpening branches with their teeth to create a “spear” to kill bushbabies in holes in trees
23 (Whiten et al., 1999; Preutz & Bertolani, 2007). It doesn’t seem like a major cognitive leap to
24 envision hominins working branches into simple tools, particularly since the reduction of a
25 quartzite core evinces a more sophisticated series of technological steps than cutting or
26 sharpening a branch. If this interpretation is correct, documentation of wood-working at Kanjera
27 South may provide the oldest evidence of two steps in the hominin use of tools to make tools—
28 i.e., hammerstones to strike stone flakes that were then used to make wooden implements – a
29 previously undocumented behavior in the early Oldowan record and among non-human primate
30 tool users (McGrew, 1992; Davidson & McGrew, 2005; Carvalho et al., 2009; Carvalho &
31 McGrew, 2012). What hominins were making with wood is unclear, but digging sticks for USO
32 acquisition and hunting spears are both distinct possibilities, given the use-wear evidence for
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4 USO processing, and zooarchaeological evidence for early access to size 1 and 2 bovid
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6 carcasses. Previous use-wear and phytolith analyses have suggested that later hominins
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8 (probably *H. erectus sensu lato*) made wooden tools between 1.4 to 1.7 Ma (Keeley and Toth,
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10 1981; Domínguez-Rodrigo et al., 2001), and zooarchaeological evidence for early access to
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12 wildebeest-sized mammal carcasses at FLK Zinj, Olduvai Gorge, Tanzania, has been used to
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14 argue for the presence of wooden spears by ca. 1.8 Ma (Bunn & Pickering, 2010; Bunn &
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16 Gurtov, 2013). The results presented here may extend the evidence of wood-working to over
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18 1.95 Ma (the base of the Olduvai subchron), and earlier than the oldest fossil possibly
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20 attributable to *H. erectus sensu lato* (occipital fragment KNM-ER 2598; 1.89 Ma) (Antón, 2003).
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22 It has been argued that the Kanjera artifacts were made by a species of *Homo* (Plummer, 2004;
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24 Plummer et al., 2009a), and their age at ~ 2 Ma may indicate that either very early *H. erectus* or a
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26 taxon that preceded it was making wooden tools.
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33 This study extends the earliest evidence for herbaceous plant processing beyond ~ 1.5 Ma
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35 noted by Keeley and Toth (1981) who described polish related to grass or reed cutting. Some
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37 Kanjera artifacts also appear to have been used to cut highly siliceous plants, such as grasses,
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39 sedges, or reeds. Such vegetation would have been common in the vicinity of the site, which
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41 was formed in a C₄ plant-rich landscape near a lake margin (Plummer et al., 2009a, b). Whether
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43 herbaceous plants were cut as part of a subsistence activity (e.g., grass seed harvesting, cutting
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45 out papyrus culm for consumption) and/or a non-subsistence related task (e.g., production of
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47 “twine” or simple carrying devices, cutting of grass for bedding) is unclear.
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55 *The Technological System at Kanjera South*
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4 These results should be viewed within the broader context of the lithic and
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7 zooarchaeological analyses at Kanjera South. Studies of the stone tools and their sources
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9 indicates that the Kanjera artifacts were part of a technological system where hard, easily flaked
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11 raw materials not found on the Homa Peninsula were preferentially transported and curated
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13 relative to the artifacts made from locally available but generally softer rocks (Braun et al., 2008,
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15 2009a, b). Edge durability experiments have demonstrated that harder raw materials such as
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17 quartzite maintain sharp edges far longer than many of the locally available raw materials (Braun
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19 et al., 2009a). For example, 500 strokes with a locally available limestone flake were unable to
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21 remove the skin from a single limb of a domestic goat, as the flake was effectively dulled after
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23 200 strokes. In contrast, 500 strokes from a quartzite flake were able to remove the skin from
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25 four goat limbs without significant dulling of the tool edge (Braun et al., 2009a). A clast of
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27 quartzite or quartz would thus be much more effective than a limestone clast of equal size, as the
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29 former would dispense flakes with a much longer use-life, and hominins would not have to
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31 replenish their toolstone supply as frequently. The energetic investment in the transport of hard
32
33 toolstone indicates that lithic technology was of great adaptive significance. This suggests that
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35 the processing of materials with stone tools was an important aspect of Oldowan hominin
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37 foraging ecology at Kanjera South. Foraging may not have been assisted by tool use, as in
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39 chimpanzees, but actually *tool-dependent* (Plummer, 2004).
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48 Use-wear and zooarchaeological analyses provide insight into what these adaptively
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50 significant, tool-related tasks were. Artifacts were used in the processing of high quality foods,
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52 including animal tissue and USOs, which may have been a dietary staple or an important fallback
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54 food (Laden & Wrangham, 2005; Marlowe & Berbesque, 2009; Wrangham, 2009). Animal
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56 tissue and USOs are nutritionally complementary (Milton, 1999), and large carcasses, and some
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4 species of very fibrous, tough-skinned USOs (Vincent, 1984) would have been difficult, if not
5 impossible, to process without stone tools. While roasting of USOs makes them easier to peel
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7 (Dominy et al., 2008), there is no evidence for hominin use of fire at Kanjera South, and we
8
9 suspect if USOs were consumed they were being extracted from the ground, cleaned, and eaten
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14 raw.

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16 In addition to their necessity for carcass and USO processing, stone tools may have
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18 played an important role in the acquisition of these resources. Hominin hunting of prey seems
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20 likely for size 1 and 2 antelopes at Kanjera South (Ferraro et al., 2013; Parkinson, 2013), and it
21
22 seems credible that hominin hunting of size 1-3 antelopes occurred at ~ 1.8 Ma at FLK Zinj,
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24 Olduvai Gorge, Tanzania (Domínguez-Rodrigo et al., 2007; Bunn & Pickering, 2010; Bunn &
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26 Gurtov, 2013; but see Pante et al., 2012). It is highly unlikely that the relatively small cores and
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28 flakes used at Kanjera South (Braun, 2006) were used in hunting game or digging for USOs.
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31 The scraping and cutting of wood suggested by use-wear analysis may signal hominin fashioning
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33 of tools from perishable materials that were more appropriate for these tasks.
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39 Animal tissue and USOs share other important characteristics; they are resources that
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41 require skill to acquire, and they can be obtained in packages large enough to satisfy the dietary
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43 needs of multiple individuals (Bunn & Kroll, 1986; O'Connell et al., 1999; Kaplan et al., 2000;
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45 Laden & Wrangham, 2005). Skill-based acquisition of foods that could be shared within a
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47 group, and be used to provision subadults who were unlikely to meet their own nutritional needs,
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49 may thus have been an important component of hominin socioecology at Kanjera South (Oliver,
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51 1994; Kaplan et al., 2000; Aiello & Key, 2002; Schuppli et al., 2012; Swedell & Plummer, 2012;
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53 Crittenden et al., 2013).
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4 Finally, while it is possible that the use-wear derives from activities that were carried out
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6 “on-site,” or in the immediate vicinity of the Kanjera South locality, quartzite and possibly
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8 quartz were transported over 10 km to the site. It is therefore possible that some artifacts were
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10 used at multiple points across the landscape prior to discard. Certainly the finding that some
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12 artifacts have use-wear from processing more than one material supports the perspective that
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14 artifacts were used in more than one processing event.
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19 The energetic investment in lithic technology, the possible use of lithics to make other
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21 tools, the use of tools to extract nutrient dense foods from their surroundings, and their likely
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23 ramifications for hominin socioecology all highlight the adaptive significance of lithic
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25 technology by 2 Ma at Kanjera South. Data presented here indicate that Oldowan hominin
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27 foraging for animal and plant tissues at Kanjera South was not just tool-assisted, but that tool-use
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29 was part of an embedded and broadly applied tool-dependent adaptation to life in a relatively
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31 open ecosystem within East Africa.
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41
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19 **References**

20
21
22

23 Antón, S.C., 2003. Natural history of *Homo erectus*. Yrbk. Phys. Anthropol. 46, 126–170.

24
25
26
27
28 Aiello L.C., Key, C., 2002. Energetic consequences of being a *Homo erectus* female. Am. J.
29
30 Hum. Biol. 14, 551–565.
31
32
33
34
35

36 Bamforth, D.B., 1988. Investigating microwear polishes with blind tests: the Institute Results in
37
38 context. J. Archaeol. Sci. 15, 11-23.
39
40
41
42

43 Behrensmeyer A.K., Potts, R., Plummer, T., Tauxe. L., Opdyke, N., Jorstad, T., 1995. The
44
45 Pleistocene locality of Kanjera, Western Kenya: stratigraphy, chronology and
46
47 paleoenvironments. J. Hum. Evol. 29, 247–274.
48
49
50
51
52

53 Blumenschine, R. J., 1995. Percussion marks, tooth marks, and experimental determinations of
54
55 the timing of hominid and carnivore access to long bones at FLK *Zinjanthropus*, Olduvai Gorge,
56
57 Tanzania. J. Hum. Evol. 29, 21–51.
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7 Borel, A., Ollé, A., Vergès, J.M., Sala, R. in press. Scanning electron and optical light
8
9 microscopy: two complementary approaches for the understanding and interpretation of usewear
10
11 and residues on stone tools. *J. Archaeol. Sci.*, <http://dx.doi.org/10.1016/j.jas.2013.06.031>.
12
13

14
15
16 Braun, D. R., 2006. The ecology of Oldowan technology: perspectives from Kanjera South and
17
18 Koobi Fora. Ph.D. Dissertation, Rutgers University.
19
20

21
22
23 Braun, D. R., Plummer, T. W., 2013. Oldowan technology at Kanjera South: technological
24
25 diversity on the Homa Peninsula. In: Sahnouni, M. (Ed) *Africa: Cradle of Humanity: Recent*
26
27 *Discoveries*, CNRPAH, Algeria, pp. 131-145.
28
29

30
31
32
33 Braun, D. R., Plummer, T. W., Ditchfield, P., Ferraro, J. V., Maina, D., Bishop, L. C., Potts, R.
34
35 2008. Oldowan behavior and raw material transport: perspectives from the Kanjera Formation.
36
37 *J. Archaeol. Sci.* 35, 2329–2345.
38
39

40
41
42
43 Braun, D.R., Plummer, T.W., Ferraro, J.V., Ditchfield, P., Bishop, L.C., 2009a. Raw material
44
45 quality and Oldowan hominin toolstone preferences: evidence from Kanjera South, Kenya. *J.*
46
47 *Archaeol. Sci.* 36, 1605-1614.
48
49

50
51
52
53 Braun, D., Plummer, T. W., Ditchfield, P., Bishop, L.C., Ferraro, J.V. 2009b. Oldowan
54
55 technology and raw material variability at Kanjera South, Kenya. In Hovers, E., Braun, D.R.
56
57 (Eds.) *Interdisciplinary Approaches to the Oldowan*, Springer, New York, pp. 99-110.
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7 Bunn, H.T., Kroll, E.M., 1986. Systematic butchery by Plio-Pleistocene hominids at Olduvai
8
9 Gorge, Tanzania. *Curr. Anthropol.* 27, 431-452.

10
11
12
13
14 Bunn, H.T., Pickering, T.R., 2010. Bovid mortality profiles in paleoecological context falsify
15
16 hypotheses of endurance running-hunting and passive scavenging by early Pleistocene
17
18 hominins. *Quat. Res.*, 74, 395-404.

19
20
21
22
23 Bunn, H.T., Gurtov, A.N. in press. Prey mortality profiles indicate that Early Pleistocene *Homo*
24
25 at Olduvai was an ambush predator. *Quaternary International*.

26
27
28
29
30
31 Carvalho, S., Biro, D., McGrew, W.C. & Matsuzawa, T. 2009. Tool-composite reuse in wild
32
33 chimpanzees (*Pan troglodytes*): archaeologically invisible steps in the technological evolution of
34
35 early hominins? *Animal Cognition* 12, 103-114.

36
37
38
39
40
41 Carvalho, S., McGrew, W. C. 2012. The origins of the Oldowan: Why chimpanzees (*Pan*
42
43 *troglodytes*) still are good models for technological evolution in Africa. In Domínguez-Rodrigo,
44
45 M. (Ed.) *Stone Tools and Fossil Bones: Debates in the Archaeology of Human Origins*,
46
47 Cambridge University Press, Cambridge, pp. 201-221.

48
49
50
51
52
53 Cerling, T.E., Manthi, F.K., Mbua, E.N., Leakey, L.N., Leakey, M.G., Leakey, R.E., Brown,
54
55 F.H., Grine, F.E., Hart, J.A. Kalemeg, P., Roche, H., Uno, K.T., Wood, B.A., 2013. Stable
56
57
58
59
60
61
62
63
64
65

1
2
3
4 isotope-based diet reconstructions of Turkana Basin hominins. *Proc. Natl. Acad. Sci.* 110,
5
6 10501–10506.
7
8
9

10
11 Claud, E., 2008. Le statut fonctionnel des bifaces au Paléolithique moyen récent dans le Sud-
12
13 Ouest de la France. Étude tracéologique intégrée des outillages des sites de La Graulet, La Conne
14
15 de Bergerac, Combe Brune 2, Fonseigner et Chez-Pinaud / Jonzac. Ph.D. Dissertation, Université
16
17 de Bordeaux 1.
18
19
20
21
22

23
24 Clemente Conte, I., Gibaja Bao, J., 2009. Formation of use-wear traces in non-flint rocks: the
25
26 case of quartzite and rhyolite. Differences and similarities. *BAR (I.S.)* 1939, 93-98.
27
28
29
30

31
32 Copeland, S.R. 2009. Potential hominin plant foods in northern Tanzania: semi-arid savannas
33
34 versus savanna chimpanzee sites. *J. Hum. Evol.* 57, 365–378.
35
36
37

38
39 Crittenden, A.N., Conklin-Brittain, N.L., Zes, D.A., Schoeninger, M.J., Marlowe, F.W. 2013.
40
41 *Evol. Hum. Behav.* 34, 299-304.
42
43
44

45
46 Davidson, I. & McGrew, W.C. 2005. Stone tools and the uniqueness of human culture. *J. Roy.*
47
48 *Anthropol. Inst.* 11, 793-817.
49
50
51

52
53 Deacon, H. 1993. Planting an idea: an archaeology of Stone Age gatherers in South Africa. *S.*
54
55 *Afr. Archaeol. Bull.*48, 86-93.
56
57
58
59
60
61
62
63
64
65

1
2
3
4 de Heinzelin , J., Clark, J.D., White, T., Hart, W., Renne P., WoldeGabriel G., Beyene, Y., Vrba.
5
6
7 E. 1999. Environment and behavior of 2.5-million-year-old Bouri hominids. *Science* 284, 625–
8
9 629.

10
11
12
13
14 Delagnes, A., Roche, H., 2005. Late Pliocene hominid knapping skills: the case of Lokalalei 2C,
15
16 West Turkana, Kenya. *J. Hum. Evol.* 48, 435-472.

17
18
19
20
21 de la Torre, I., Mora, R. 2005. Technological Strategies in the Lower Pleistocene at Olduvai
22
23 Beds I and II. *Liege: ERAUL* 112.

24
25
26
27
28 Domínguez-Rodrigo, M., Serrallonga, J., Juan-Tresserras, J., Alcalá, L., & Luque, L.
29
30 (2001). Woodworking activities by early humans: a plant residue analysis on Acheulian stone
31
32 tools from Peninj (Tanzania). *J. Hum. Evol.*, 40, 289–299.

33
34
35
36
37
38 Domínguez-Rodrigo, M., Barba, R., Egeland, C., 2007. Deconstructing Olduvai: a Taphonomic
39
40 Study of the Bed I Sites. Dordrecht, Springer.

41
42
43
44
45 Dominy, N., J., Vogel, E., R., Yeakel, J. D., Constantino, P., Lucas, P. W. 2008. Mechanical
46
47 properties of plant underground storage organs and implications for dietary models of early
48
49 hominins. *Evol. Biol.* 35, 159–175.

50
51
52
53
54
55 Dominy, N.J., 2012. Hominins living on the sedge. *Proc. Nat. Acad. Sci.* 109, 20171-72.
56
57
58
59
60
61
62
63
64
65

1
2
3
4 Evans, A. A., Donahue, R. E., 2008. Laser scanning confocal microscopy: a potential technique
5
6 for the study of lithic microwear. *J. Archaeol. Sci.* 35, 2223-2230.
7
8

9
10
11 Evans, A. A., McDonnald, D., 2011. Using metrology in early prehistoric stone tool research:
12
13 further work and a brief instrumental comparison. *Scanning* 33, 294-303.
14
15
16

17
18 Ferraro, J.V., Plummer, T.W., Pobiner, B.L., Oliver, J.S, Bishop, L.C., Braun, D.R., Ditchfield,
19
20 P. W., Seaman, J.W. III, Binetti, K.M., Seaman, J.W. Jr., Hertel, F., Potts, R. 2013. Earliest
21
22 archaeological evidence of persistent hominin carnivory. *PLoS ONE* 8(4): e62174.
23
24
25

26
27
28 Flenniken, J.J., Haggarty, J.C., 1979. Trampling as an agency in the formation of edge damage:
29
30 an experiment in lithic technology. *Northwest Anthropological Research Notes* 13, 208-214.
31
32
33

34
35 Fullagar, R.L.K. 1986. Use-wear on quartz. In Ward, G. (Ed.) *Archaeology at ANZAAS*.
36
37 Australian Institute of Aboriginal Studies, Canberra, pp. 191-197.
38
39
40

41
42 Gassin, B., 1996. Évolution socio-économique dans le Chasséen de la grotte de l'Église
43
44 supérieure (Var) : apport de l'analyse fonctionnelle des industries lithiques, CRA-Monographies
45
46 17, Paris.
47
48
49

50
51
52
53 Gaulin, S. 1979. A Jarman/Bell model of primate feeding niches. *Hum. Ecol.* 7, 1–19.
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4 Goldman-Neuman, T., Hovers, E., 2009. Methodological considerations in the study of Oldowan
5 raw material selectivity: insights from A.L. 894 (Hadar, Ethiopia). In: Hovers, E., Braun, D.R.
6
7 (Eds.), *Interdisciplinary Approaches to the Oldowan*. Springer, New York, pp. 71-84.
8
9

10
11
12
13
14 Goldman-Neuman, T., Hovers E., 2012. Raw material selectivity in late Pliocene Oldowan sites
15 in the Makaamitalu Basin, Hadar, Ethiopia. *J. Hum. Evol.* 62, 353-366.
16
17
18
19

20
21 Harmand, S., 2007. Economic behaviors and cognitive capacities of early hominins between 2.34
22 Ma and 0.70 Ma in West Turkana, Kenya. *Mitteilungen der Gesellschaft für Urgeschichte* 16,
23 11-23.
24
25
26
27

28
29
30
31 Hernandez-Aguilar, R.A., Moore, J., Pickering, T.R., 2007. Savanna chimpanzees use tools to
32 harvest the underground storage organs of plants. *PNAS* 104, 19210-19213.
33
34
35
36

37
38 Hladik, C.M., Chivers, D.J., 1994. Foods and the digestive system. In: Chivers, D.J., Langer, P.,
39 (Eds.), *The Digestive System in Mammals: Food, Form and Function*. Cambridge University
40 Press, Cambridge, pp. 65–73.
41
42
43
44

45
46
47
48 Howard, J.L., 2005. The quartzite problem revisited. *J. Geol.* 113, 707-713.
49
50

51
52
53 Huddleston, A., 1951. *Geology of the Kisii District*. Report No. 18, Geol. Surv. Kenya ,
54 Government Printer, Nairobi.
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4 Igreja, M., 2009. Use-wear analysis of non-flint stone tools using DIC microscopy and resin
5 casts: a simple and effective technique, in Recent functional studies on non flint stone tools :
6 methodological improvements and archaeological inferences. Proceedings of the workshop, 23-
7 25 May 2008, Lisbon (Padrão dos Descobrimentos).
8
9

10
11
12
13
14
15
16 Isaac, G.L., 1978. The food-sharing behavior of protohuman hominids. *Sci. Amer.* 238, 90-
17 108.
18
19

20
21
22
23 Kaplan, H., Hill, K., Lancaster, J., Hurtado, M., 2000. A theory of human life history evolution:
24 diet, intelligence, and longevity. *Evol. Anthropol.* 9, 156–185.
25
26
27

28
29
30
31 Keeley, L. H., 1980. *Experimental Determination of Stone Tool Uses: A Microwear Analysis.*
32 The University of Chicago Press, Chicago.
33
34

35
36
37
38 Keeley, L.H., Toth, N., 1981. Microwear polishes on early stone tools from Koobi Fora, Kenya.
39 *Nature* 293, 464-465.
40
41

42
43
44
45 Knutsson, K., 1988. *Patterns of Tool Use. Scanning Electron Microscopy of Experimental*
46 *Quartz Tools.* AUN 10, Uppsala.
47
48

49
50
51
52 Knutsson, K., Lindé, K. (1990). Post-depositional alterations or wear marks on quartz tools,
53 preliminary observations on an experiment with aeolian abrasion. In Séronie-Vivien, M.R.,
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4 Lenoir, M. (Eds.) Cahiers du Quaternaire, vol. 17, Le silex de sa genèse à l'outil. Actes du V^o
5 Colloque International sur le silex. Éditions du C.N.R.S., Paris, pp. 607-618.
6
7
8
9

10
11 Laden, G., Wrangham, R.W., 2005. The rise of the hominids as an adaptive shift in fallback
12 foods: plant underground storage organs (USOs) and australopith origins. *J. Hum. Evol.* 49, 482–
13 498.
14
15
16
17
18
19
20

21 Le Bas, M.J., 1977. Carbonatite-Nephelinite Volcanism. John Wiley & Sons, New York.
22
23
24
25

26 Lee, R.B., 1979. *The !Kung San: Men, Women, and Work in a Foraging Society* Cambridge
27 University Press, New York.
28
29
30
31
32

33 Lee-Thorp, J., Likius, A., Mackaye, H. T., Vignaud, P., Sponheimer, M., Brunet, M., 2012.
34 Isotopic evidence for an early shift to C4 resources by Pliocene hominins in Chad. *Proc. Natl.*
35 *Acad. Sci.* 109, 20369–20372.
36
37
38
39
40
41
42

43 Lee-Thorp, J., Sponheimer, M., 2006. Contributions of biogeochemistry to understanding
44 hominin dietary ecology, *Yearb. Phys. Anthropol.* 49, 131–148.
45
46
47
48
49

50 Lemorini, C., 2000. *Reconnaître des Tactiques d'Exploitation du Milieu au Paléolithique*
51 *Moyen. La Contribution de l'Analyse Fonctionnelle.* BAR (I.S.) 858.
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4 Lemorini, C., Stiner, M.C., Gopher, A., Shmelmitz, R., Barkai, R., 2006. Use-wear analysis of an
5
6 Amudian laminar assemblage from the Acheuleo-Yabrudian of Qesem Cave, Israel. *J. Archaeol.*
7
8
9 *Sci.* 33, 921-934.
10

11
12
13
14 Levi-Sala, I., 1988. Processes of polish formation on flint tool surface. *BAR (I.S.)* 411, 83-97.
15
16
17

18
19 Marlowe, F.W., Berbesque, J.C., 2009. Tubers as fallback foods and their impact on Hadza
20
21 hunter-gatherers. *Am. J. Phys. Anthropol.* 140, 751-758.
22
23

24
25
26 Márquez, B., Ollé, A., Sala, R., Vergès, J.M. 2001. Perspectives méthodologiques de l'analyse
27
28 fonctionnelle des ensembles lithiques du Pléistocène inférieur et moyen d'Atapuerca (Burgos,
29
30 Espagne). *L'Anthropologie* 105, 281-299.
31
32

33
34
35
36 McBrearty, S., Bishop, L., Plummer, T. W., Dewar, R., Conard, N., 1998. Tools underfoot:
37
38 human trampling as an agent of lithic artifact edge modification. *Amer. Antiq.* 63, 108-129.
39
40

41
42
43 McGrew, W.C. 1992. *Chimpanzee Material Culture: Implications for Human Evolution.*
44
45 Cambridge University Press, Cambridge.
46
47

48
49
50 Mercader, J., Bennett, T., Raja, M., 2008. Middle Stone Age starch acquisition in the Niassa
51
52 Rift, Mozambique. 2008. *Quat. Res.* 70, 283–300.
53
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4 Milton, K., 1999. A hypothesis to explain the role of meat-eating in human evolution. *Evol.*
5
6 *Anthropol.* 8, 11–21.

7
8
9
10
11 Newcomer, M., Grace, R., Unger-Hamilton, R., 1986. Investigating microwear polishes with
12
13 blind test. *J. Archaeol. Sci.* 13, 203-217.

14
15
16
17
18 O’Connell, J.F., Hawkes, K., Blurton Jones, N.G., 1999. Grandmothering and the evolution of
19
20 *Homo erectus*. *J Hum Evol* 36, 461–485.

21
22
23
24
25
26 Odell, G.H., 2004. *Lithic analysis*. Kluwer Academic, New York.

27
28
29
30
31 Olausson, D. S., 1980. Starting from scratch: The history of edge wear research from 1838-1978.
32
33 *Newsletter of Lithic Technology* 9, 48-60.

34
35
36
37
38 Oliver, J.S., 1994. Estimates of hominid and carnivore involvement in the FLK *Zinjanthropus*
39
40 fossil assemblage: some socioecological implications. *J. Hum. Evol.* 27, 267–294.

41
42
43
44
45 Ollé, A., Vergès, J.M. in press. The use of sequential experiments and SEM in documenting
46
47 stone tool microwear, *J. Archaeo. Sci.*, <http://dx.doi.org/10.1016/j.jas.2013.10.028>

48
49
50
51
52
53 Panger, M.A., Brooks, A., Richmond, B., Wood, B., 2002. Older than the Oldowan? Rethinking
54
55 the emergence of hominin tool use. *Evol. Anthropol.* 11, 235–245.

1
2
3
4 Pant, R. K. 1989. Étude microscopique des traces d'utilisation sur les outils de quartz de la
5
6 Grotte de l'Arago, Tautavel, France. *L'Anthropologie* 93, 689-704.
7
8
9

10
11 Pante, M.C., Blumenschine, R.J., Capaldo, S.D., Scott, R.S. 2012. Validation of bone
12
13 surface modification models for inferring hominin and carnivore feeding interactions,
14
15 with reapplication to FLK 22, Olduvai Gorge, Tanzania. *J. Hum. Evol.* 63, 395-407.
16
17
18
19
20

21 Parkinson, J. 2013. A GIS Image Analysis Approach to Documenting Oldowan Hominin
22
23 Carcass Acquisition: Evidence from Kanjera South, FLK Zinj, and Neotaphonomic Models of
24
25 Carnivore Bone Destruction. Ph.D. Dissertation, City University of New York.
26
27
28
29
30

31 Peters, C.R., 1987. Nut-like oil seeds: food for monkeys, chimpanzees, humans, and probably
32
33 ape-men. *Am. J. Phys. Anthropol.* 73, 333–363.
34
35
36
37

38 Peters, C.R., O'Brien, E.M., 1981. The early hominid plant-food niche: insights from an analysis
39
40 of plant exploitation by *Homo*, *Pan*, and *Papio* in eastern and southern Africa. *Curr. Anthropol.*
41
42 22, 127–140.
43
44
45
46
47

48 Peters, C.R., O'Brien, E.M., 1994. Potential hominid plant foods from woody species in semiarid
49
50 versus sub-humid subtropical Africa. In Chivers, D.J., Langer, P. (Eds.) *The Digestive System*
51
52 in Mammals: Food, Form and Function, Cambridge University Press, Cambridge, pp. 166–192.
53
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4 Peters, C.R., Vogel, J.C., 2005. Africa's wild C₄ plant foods and possible early hominid diets. J.
5
6 Hum. Evol. 48, 219-236.
7
8

9
10
11 Pignat, G., Plisson, H. 2000. Le quartz, pour quel usage ? l'outillage mésolithique de Vionnaz
12
13 (Suisse) et l'apport de la tracéologie. In: P. Crotti, P. (Ed.) MESO'97, CAR, Lausanne, 65-87.
14
15

16
17
18 Plisson, H., Mauger, M., 1988. Chemical and mechanical alteration of microwear polishes: an
19
20 experimental approach. Helinium XXVIII/1, 3-16.
21
22

23
24
25
26 Plummer TW, Bishop LC, Ditchfield P, and Hicks J. 1999. Research on Late Pliocene Oldowan
27
28 Sites at Kanjera South, Kenya. J. Hum. Evol. 36, 151-170.
29
30

31
32
33 Plummer TW. 2004. Flaked stones and old bones: biological and cultural evolution at the dawn
34
35 of technology. Yearb.Phys. Anthropol. 47, 118-164.
36
37

38
39
40 Plummer T.W., Ditchfield, P.W., Bishop, L.C., Kingston, J.D., Ferraro, J.V., Braun, D. Hertel,
41
42 F., Potts, R. 2009a. Oldest evidence of toolmaking hominins in a grassland-dominated
43
44 ecosystem. PLoS ONE 4(9): e7199, 1-8.
45
46
47

48
49
50 Plummer, T.W., Bishop, L.C., Ditchfield, P.W., Ferraro, J.V., Kingston, J.D., Hertel, F., Braun,
51
52 D.R. 2009b. The environmental context of Oldowan hominin activities at Kanjera South, Kenya,
53
54 In Hovers, E., Braun, D.R. (Eds.) Interdisciplinary Approaches to the Oldowan, Springer, New
55
56 York, pp.149-160.
57
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7 Potts, R. 1991. Why the Oldowan? Plio-Pleistocene toolmaking and the transport of resources. J.
8
9 Anthropol. Res. 47, 153–176.
10

11
12
13
14 Pruetz, J. D., Bertolani, P. 2007. Savanna Chimpanzees, *Pan troglodytes verus*, hunt with tools,
15
16 Curr. Biol. 17, 1–6.
17
18
19
20

21 Roche, H. 2000. Variability of Pliocene lithic productions in East Africa. Acta Anthropol. Sin.
22
23 19, 98–103.
24
25
26
27

28 Rodman, P.S. 2002. Plants of the apes: is there a hominoid model for the origins of the hominid
29
30 diet? In: Ungar, P., Teaford, M.F. (Eds.) Human Diet, Bergin and Garvey, Westport, CT, pp. 76–
31
32 109.
33
34
35
36
37

38 Rogers, M.J., Semaw, S. (2009). Something from nothing: the appearance and context of the
39
40 earliest archaeological record. In Camps, M., Chauhan, P. (Eds.) Sourcebook of Paleolithic
41
42 Transitions, Springer, New York, pp. 155-171.
43
44
45
46
47

48 Rots, V., 2010. Prehension and Hafting Traces on Flint Tools: A Methodology, Leuven
49
50 University Press, Leuven.
51
52
53
54

55 Saggerson, E. P., 1952. Geology of the Kisumu District. Geol. Surv. Kenya, Report 21, 86pp.
56
57
58
59
60
61
62
63
64
65

1
2
3
4 Sahnouni, M., Rosell, J., van der Made, J., Vergès, J.M., Ollé, A., Kandi, N., Harichane, Z.,
5
6
7 Derradji, A., Medig, M., 2013. The first evidence of cut marks and usewear traces from the Plio-
8
9 Pleistocene locality of El-Kherba (Ain Hanech), Algeria: implications for early hominin
10
11 subsistence activities circa 1.8 Ma. *J. Hum. Evol.* 64, 137-150.
12
13
14

15
16 Schick, K.D. 1987a. Experimentally derived criteria for assessing hydrologic disturbance of
17
18 archaeological sites.” In: Nash, D.T., Petraglia, M.D. (Eds.), *Natural Formation*
19
20 *Processes and the Archaeological Record*. BAR International Series 352, 86-107.
21
22
23

24
25
26 Schick, K.D. 1987b. Modeling the formation of early stone age artifact concentrations. *J. Hum.*
27
28 *Evol.* 16, 789–808.
29
30
31

32
33 Schuppli, C., Isler, K., van Schaik, C. P., 2012. How to explain the unusually late age at skill
34
35 competence among humans. *J. Hum. Evol.*, 63, 843–850.
36
37
38

39
40 Schoeninger, M.J., Bunn, H.T., Murray, S., Marlett, J.A. 2001. Composition of tubers used by
41
42 Hadza foragers of Tanzania. *J. Food Composition Anal.* 14, 15–25.
43
44
45

46
47
48 Semaw, S., Rogers, M.J., Quade, J., Renne, P., Butler. R., Domínguez-Rodrigo, M., Stout, D.,
49
50
51 Hart, W, Pickering, T., Simpson, S. 2003. 2.6-Million-year-old stone tools and associated bones
52
53 from OGS-6 and OGS-7, Gona, Afar, Ethiopia. *J. Hum. Evol.* 45, 169-177.
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4 Semenov, S.A., 1964. Prehistoric Technology; an Experimental Study of the Oldest Tools and
5
6 Artefacts from Traces of Manufacture and Wear [by] S.A. Semenov. Translated and with a Pref.
7
8 by M.W. Thompson, Cory. Adams & Mackay, London.
9

10
11
12
13
14 Sept, J. M. 1986. Plant foods and early hominids at site FxJj 50, Koobi Fora, Kenya. *J. Hum.*
15
16 *Evol.* 15, 751–770.
17
18

19
20
21 Sept, J.M. 1994. Beyond bones: archaeological sites, early hominid subsistence, and the costs
22
23 and benefits of exploiting wild plant foods in east African riverine landscapes. *J. Hum. Evol.* 27,
24
25 295–320.
26
27

28
29
30
31 Shea, J.J., 1987. On accuracy and relevance in lithic use-wear studies. *Lithic Technology* 16,
32
33 44-50.
34
35

36
37
38 Shea, J.J., Klenck, J.D. 1993. An experimental investigation of the effects of trampling on the
39
40 results of lithic microwear analysis. *J. Archaeol. Sci.* 20, 175-194
41
42

43
44
45 Sponheimer, M., Alemseged, Z., Cerling, T.E., Grine, F.E., Kimbel, W.H., Leakey, M.G., Lee-
46
47 Thorp, J.A., Manthi, F.K., Reed, K.E., Wood, B.A., Wynn, J.G., 2013. Isotopic evidence of early
48
49 hominin diets. *Proc. Natl. Acad. Sci.* 110, 10513–10518.
50
51

52
53
54
55 Stahl, A.B. 1984. Hominid dietary selection before fire. *Curr. Anthropol.* 25, 151–168.
56
57
58
59
60
61
62
63
64
65

1
2
3
4 Stapert, D., 1976. Some natural surface modifications on flint in the Netherlands. *Palaeohistoria*
5
6 18, 8-41.
7
8
9

10
11 Stemp, W.J., Chung, S., 2011. Discrimination of surface wear on obsidian tools using LSCM
12 and RelA: pilot study results (area-scale analysis of obsidian tool surfaces). Special Issue on
13
14 Diverse Applications of Surface Metrology II 33 (5), 279–293.
15
16
17
18
19
20

21 Stemp, W.J., Lerner, H.J., Kristant, E.H. 2013. Quantifying microwear on experimental
22
23 Mistassini quartzite scrapers: Preliminary results of exploratory research using LSCM and scale-
24
25 sensitive fractal analysis. *Scanning* 35, 28-39.
26
27
28
29
30

31 Stemp, J., Stemp, M., 2003. Documenting stages of polish development on experimental stone
32
33 tools: surface characterization by fractal geometry using UBM laser profilometry. *J. Archaeol.*
34
35 *Sci.* 30, 287-296.
36
37
38
39
40

41 Stevens, N.E., Harro, D.R., Hickli, A., 2010. Practical quantitative lithic use-wear analysis using
42
43 multiple classifiers. *J. Archaeol. Sci.* 37, 2671-2678.
44
45
46
47

48 Sussman, C., 1985. Microwear on quartz: fact or fiction? *World Archaeol.* 17, 101-111.
49
50
51
52

53 Sussman, C. 1988. A microscopic analysis of use-wear polish formation on experimental quartz
54
55 tools. Oxford: John and Erika Hedges Ltd. (B.A.R. International Series, 395).
56
57
58
59
60
61
62
63
64
65

1
2
3
4 Swedell, L. & T. W. Plummer (2012). A papionin multi-level society as a model for early
5
6 hominin evolution. *Inter. J. Primatol.* 33, 1165-1193.
7
8

9
10
11 Toth, N. 1987. Behavioral inferences from Early Stone Age archaeological assemblages: an
12
13 experimental model. *J. Hum. Evol.* 16, 763–787.
14
15

16
17
18 Tringham, R., Cooper, G., Odell, G.H., Voytek B., Whitman A., 1974. Experimentation in the
19
20 formation of edge damage: a new approach to lithic analysis, *J. Archaeol. Sci.* 1, 171-196.
21
22

23
24
25 Ungar, P. S. 2012. Dental evidence for the reconstruction of diet in African early *Homo*. *Curr.*
26
27 *Anthro.* 53, S318-S329.
28
29

30
31
32 Unrath, G., Owen, L. R., van Gijn, A., Moss, E. H., Plisson, H., Vaughan, P., 1986. An
33
34 evaluation of use-wear studies on stone tools. In: Owen, L.R., Unrath, G. (Eds.), *Technical*
35
36 *Aspects of Microwear Studies on Stone Tools*, International Union for Quaternary Research.
37
38 Commission for the Paleocology of Early Man News of INQUA, 1984.
39
40
41
42
43

44
45 van der Merwe, N.J., Masao, F.T., Bamford, M.K., 2008. Isotopic evidence for contrasting diets
46
47 of early hominins *Homo habilis* and *Australopithecus boisei* of Tanzania. *S. Afr. J. Sci.* 104,
48
49 153-155.
50
51

52
53
54 Van Gijn, A.L., 1989. The wear and tear of flint principles of functional analysis applied to
55
56 Dutch Neolithic assemblages. *Analecta Praehistorica Leidensia* 22, Leiden.
57
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7 Vincent ,A., 1984. Plant foods in savanna environments: a preliminary report of tubers eaten by
8
9 the Hadza of northern Tanzania. *World Archaeol.* 17, 132–142.
10

11
12
13
14 Whiten, A., Goodall, J., McGrew, W.C., Nishida, T., Reynolds, V., Sugiyama, Y., Tutin, C.E.G.,
15
16 Wrangham, R.W., Boesch 1999. Cultures in chimpanzees. *Nature* 399, 682-685.
17
18

19
20
21 Wrangham, R., 2009. *Catching Fire: How Cooking Made Us Human.* Basic Books, New York.
22
23

24
25
26 Wrangham, R., Holland Jones, J., Laden, G., Pilbeam, D., & Conklin-Brittain, N. L. (1999). The
27
28 raw and the stolen: Cooking and the ecology of human origins. *Curr. Anthro.*, 40, 567–594.
29
30

31
32
33 Wrangham, R., Cheney, D., Seyfarth, R., & Sarmiento, E. 2009. Shallow-water habitats as
34
35 sources of fallback foods for hominins. *Am. J. Phys. Anthro.*, 140, 630–642.
36
37

38
39
40 Yamagiwa, J., Yumoto, T., Ndunda, M., Maruhashi, T., 1988. Evidence of tool-use by
41
42 chimpanzees (*Pan troglodytes schweinfurthii*) for digging out a bee-nest in the Kahuzi-Biega
43
44 National Park, Zaire. *Primates* 29, 405-411.
45
46
47

48 49 50 **Figure legends**

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53 Figure 1. Placement map showing the location of Kanjera in southwestern Kenya and of the
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55 Southern Exposures at Kanjera where the Oldowan occurrences are found. The composite
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57 stratigraphic log shows the basal three beds of the Southern Member (KS-1 to KS-3) and the
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4 base of KS-4. Spatially associated artifacts and fossils are found as diffuse scatters and also in
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6 more vertically discrete concentrations from the top of KS-1 through KS-3, with KS-2 providing
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8 the bulk of the archaeological sample.
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14 Figure 2. A representative sample of quartz and quartzite artifacts from the excavations at
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16 Kanjera South. (a) and (b) quartzite cores; (c) and (d) quartzite whole flakes; (e) quartz core and
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18 (f) quartz whole flake. Scale bars equal to 1 cm.
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24 Figure 3. Use-related edge removals from (a) experimental quartzite flake used to scrape wood
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26 and (b) Oldowan flake #3051. Scale bars equal to 1 mm.
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31 Figure 4. Representative images of experiments carried out to develop the use-wear reference
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33 collection. The experiments in these photos were conducted with the same quartzite used in
34
35 Oldowan artifact manufacture at Kanjera. (a) cutting of coarse, wild grasses in Kenya; (b)
36
37 wood-working; (c) goat butchery; (d) cutting, peeling, and slicing of wild //Ekwa and Shaehako
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39 tubers by Hadza women in Tanzania.
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45 Figure 5. (a) Use-wear from wood-working on an experimental flake, showing rough and domed
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47 polish on the matrix; (b) Kanjera quartzite artifact # 592 with matrix showing rough and domed
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49 polish, attributed to wood-working; (c) crystal on the edge of an experimental flake used for
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51 wood-working; the development of polish on its surface gives it a characteristic domed
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53 topography; (d) Kanjera quartzite artifact # 10063 with a crystal showing the domed topography
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55 attributed to wood-working.
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4 Figure 6. Use-wear developed on the edge of an experimental quartzite flake during the cutting,
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6 peeling and sectioning of wild tubers by a Hadza woman showing (a) deep, narrow, tapering
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8 striae on the face of a quartz crystal; (b) localized well developed abrasion on a crystal, and (c)
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10 widespread, flat, rough polish in closely packed patches on matrix.
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16 Figure 7. (a) Kanjera quartzite artifact # 19149 with use-wear attributed to USO-working (red
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18 dots indicate use-wear location), including (b) matrix showing widespread, flat, rough polish in
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20 closely packed patches; (c) narrow, tapering striae on crystal, and (d) localized well-developed
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22 abrasions on crystal.
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28 Figure 8. Use-wear results for quartz and quartzite Oldowan artifacts from Kanjera South.
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36 **Supplementary Data**

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41 Supplementary Figure 1. (a) Use-wear from butchery (contact with animal soft tissues) on an
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43 experimental flake, showing rough polish on the matrix; (b-c) use-wear from butchery on an
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45 experimental flake, showing crystals with widespread lightly developed abrasions.
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51 Supplementary Figure 2. (a,b) Kanjera quartzite artifact # 14981 with crystals showing
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53 widespread lightly developed abrasions attributable to butchery.
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4 Supplementary Figure 3. (a) Kanjera quartz artifact # 129 with red dots indicating use-wear
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6 location; (b) crystal on the edge of artifact #129 showing a “melting” appearance given by a
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8 well-developed pitted polish attributed to bone working; (c) use-wear from bone-working on an
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10 experimental flake, showing crystal with a “melting” appearance.
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	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
Fenitized 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 Porcellanite	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															
		<i>abrading</i>								1						1
		Quartz														
		Quartzite		2												2
	<i>sub-total</i>		2												3	
<i>Cutting</i>	Quartz				1	3	7								11	
	Quartzite	1	1		1	10	2	2		3	16			3	39	
	<i>sub-total</i>	1	1		2	13	9	2		3	16			3	50	
	<i>engraving</i>	Quartz							1						1	
	Quartzite	2	2						1					5		
	<i>sub-total</i>	2	2						2					6		
<i>Scraping</i>	Quartz	2						2							4	
	Quartzite	1	3			1	3	8							16	
	<i>sub-total</i>	3	3			1	3	10							20	
	<i>cutting & scraping</i>	Quartz													0	
	Quartzite			1										1		
	<i>sub-total</i>			1										1		
<i>cutting, peeling, sectioning</i>	Quartz														0	
	Quartzite										7*	6^		13		
	<i>sub-total</i>										7	6		13		
	<i>scraping & engraving</i>	Quartz													0	
	Quartzite							1						1		
	<i>sub-total</i>							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, <i>Prunus</i> sp.)	cutting (500 strokes)	Wood	cutting	soft material (animal tissue?) (gripping wear)	cutting
B2	Sweet potato (<i>Ipomoea batatas</i>) covered with fine sand	scraping off dirt (322 strokes) + Cutting (333 strokes)	<i>No use-wear detected</i>	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, <i>Acer nigrum</i>)	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 (<i>Capra hircus</i>) 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)	<i>no use-wear detected</i>	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	quartzite	Angular fragment	39	cutting	animal flesh
9854	1	quartzite	Angular fragment	66	cutting	animal flesh
14981	1	quartzite	Whole flake	63	cutting	animal flesh
5370	1	quartzite	Snapped flake	indeterminate	cutting	herbaceous plants
9160	1	quartzite	Whole flake	66	cutting	indeterminate
57	1	quartzite	Snapped flake	indeterminate	cutting	medium hard material
2090	1	quartzite	Whole flake	62	cutting	soft material
4764	1	quartzite	Whole flake	55	cutting	USOs
6151	1	quartzite	Whole flake	48	cutting	Wood
10052	1	quartzite	Split flake	53	cutting	Wood
12110	1	quartzite	Whole flake	69	cutting	wood + herbaceous plants
13201	1	quartzite	Whole flake	45	cutting & scraping	animal flesh & bone
16184	1	quartzite	Core	69	cutting & scraping	USOs
19149	1	quartzite	Whole flake	56	cutting & scraping	USOs
37	1	quartzite	Whole flake	indeterminate	cutting & scraping	USOs
6284	1	quartzite	Snapped flake	29	cutting & scraping	wood + USOs
142	1	quartzite	Whole flake	indeterminate	scraping	medium hard material
2053	1	quartzite	Whole flake	indeterminate	scraping	medium hard material
3051	1	quartzite	Whole flake	indeterminate	scraping	medium hard material
8556	1	quartzite	Angular fragment	88	scraping	medium hard material
9564	2	quartzite	Retouched flake	85	scraping	medium hard material
12189	1	quartzite	Angular fragment	indeterminate	scraping	USOs
24409	1	quartzite	Whole flake	56	scraping	USOs
9564	1	quartzite	Retouched flake	60	scraping	wood
592	1	quartzite	Whole flake	80	scraping	wood

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

Figure 1

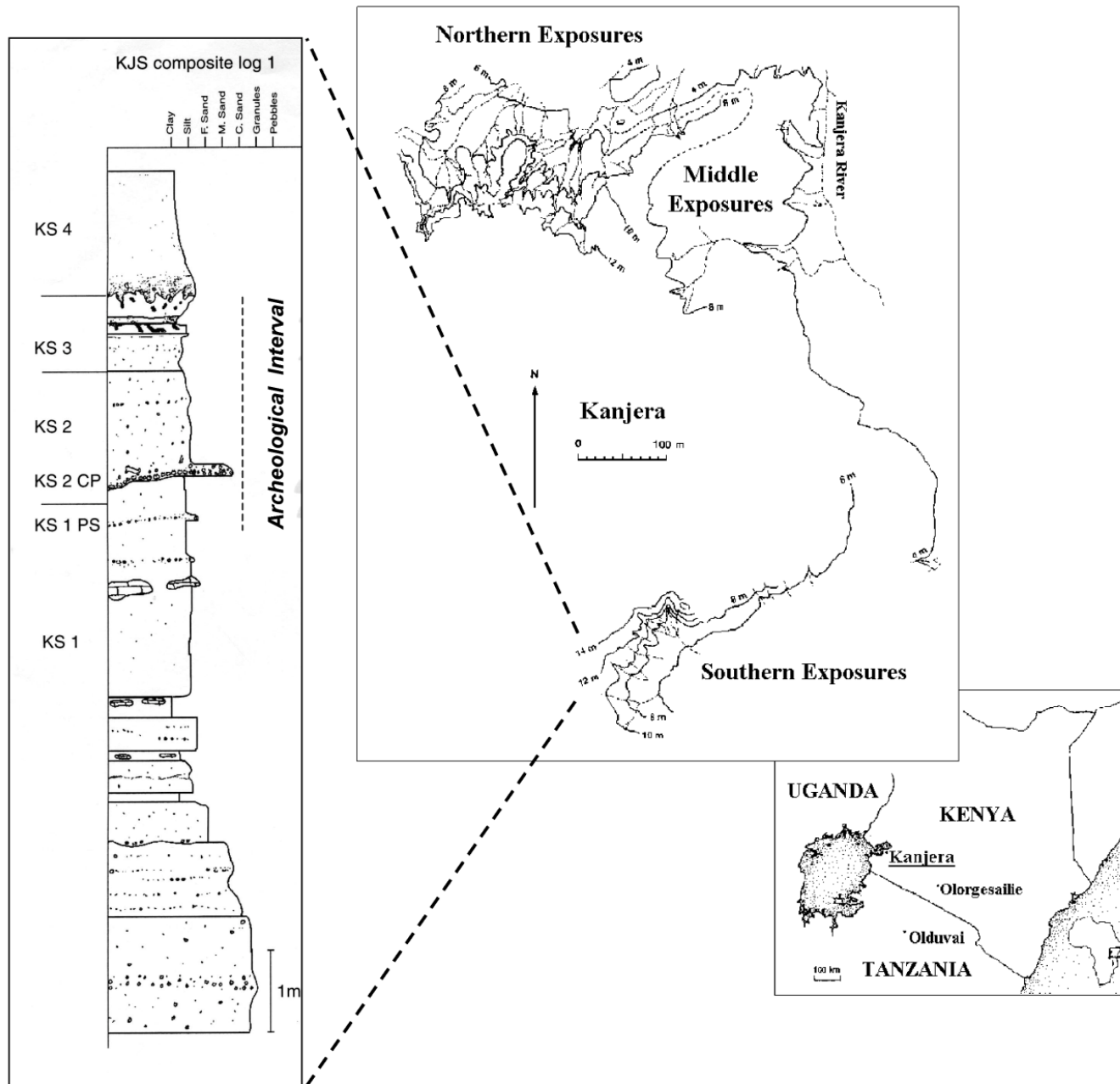
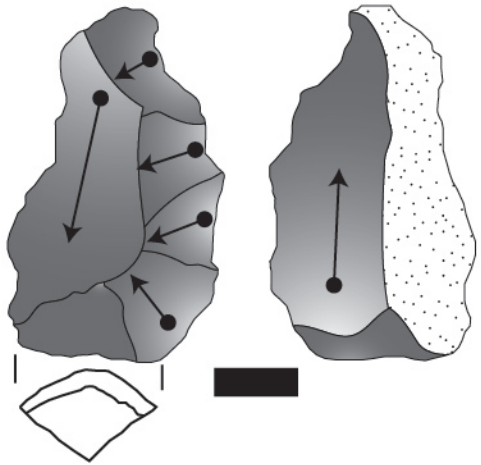
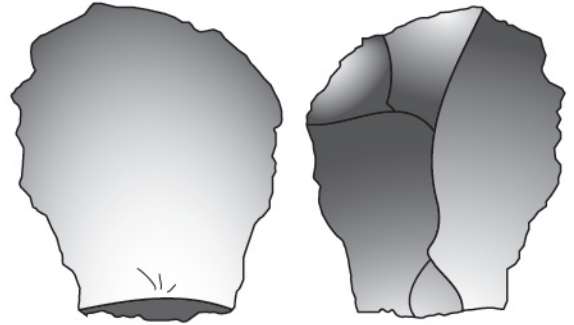


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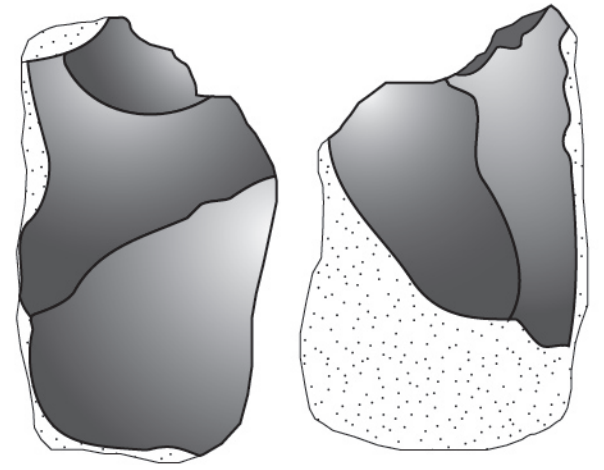
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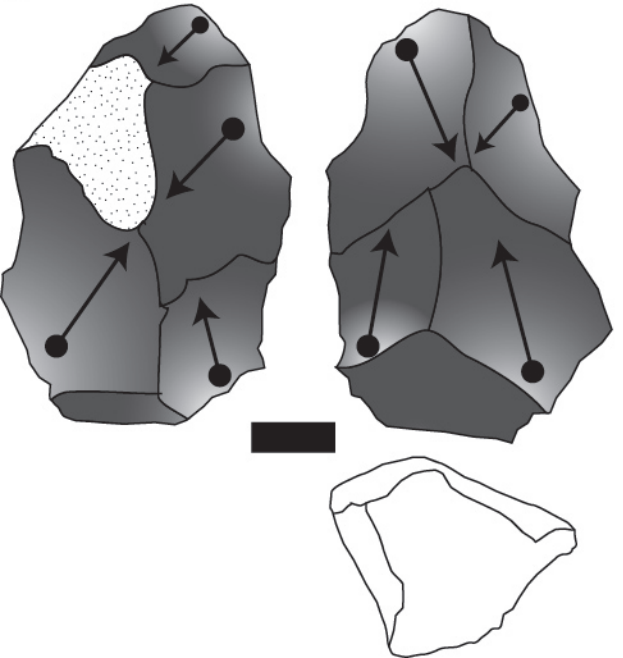
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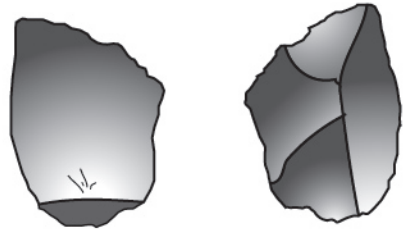
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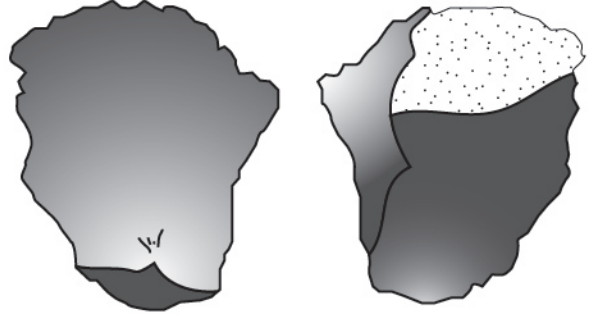
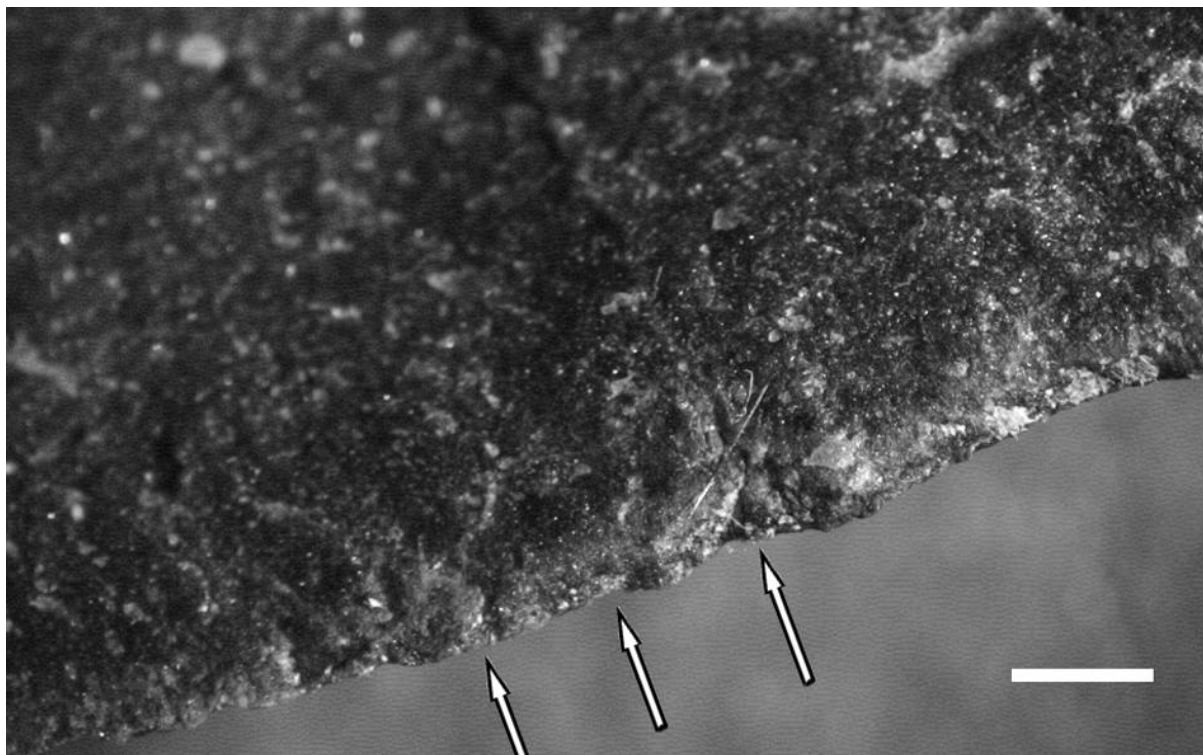
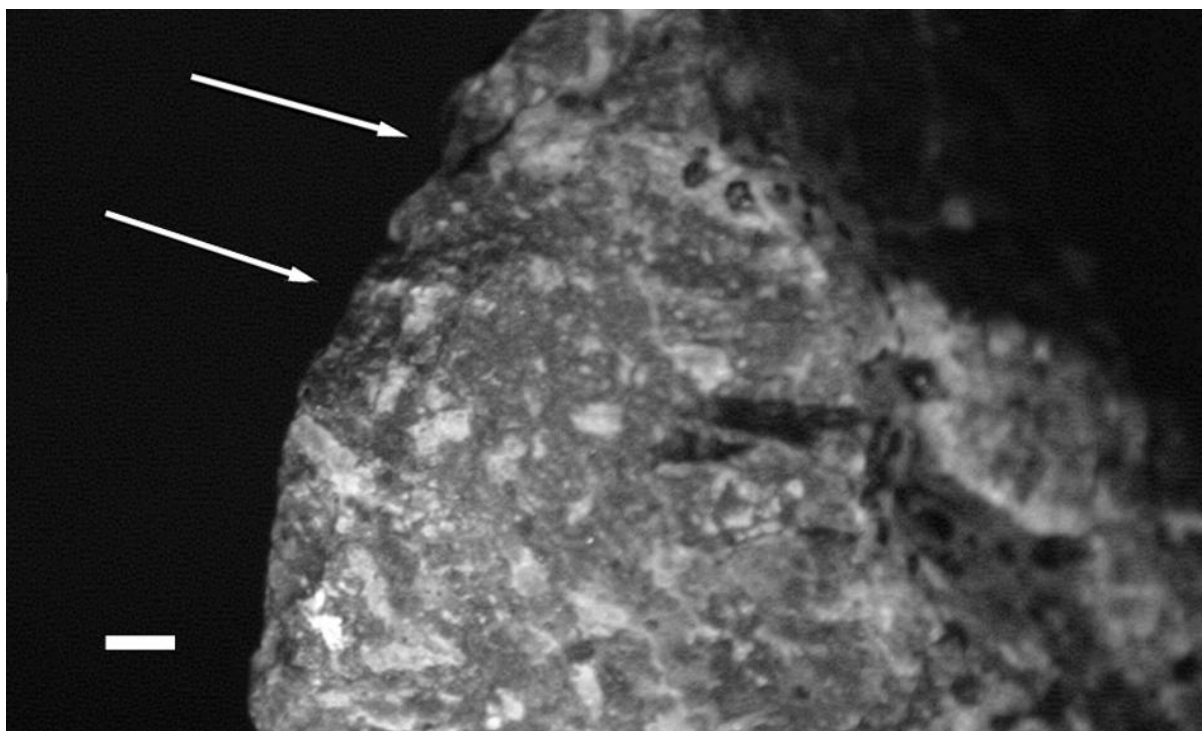


Figure 3



(a)



(b)

Figure 4

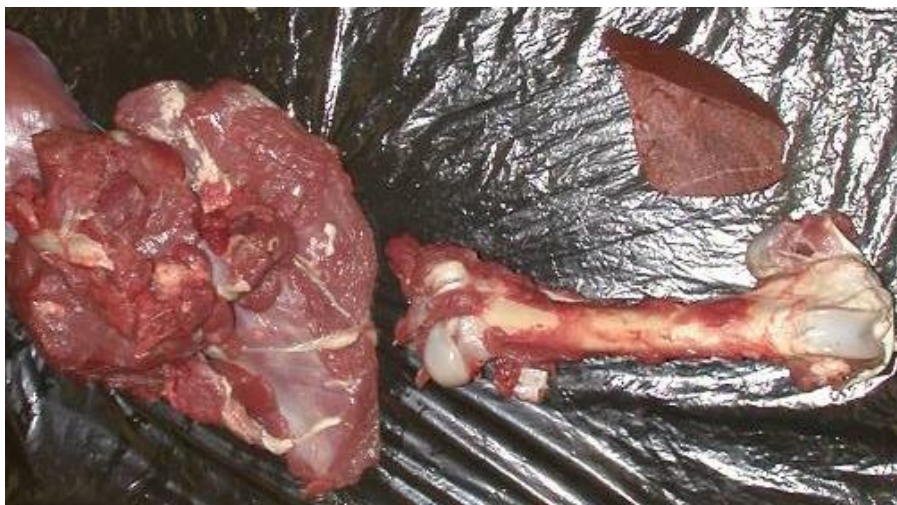
(a)



(b)



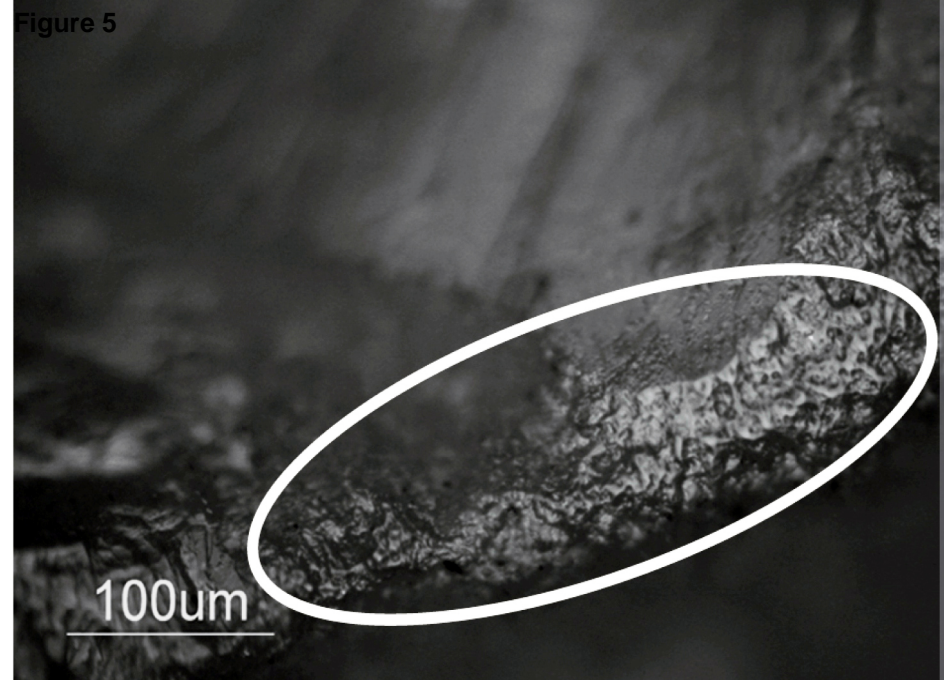
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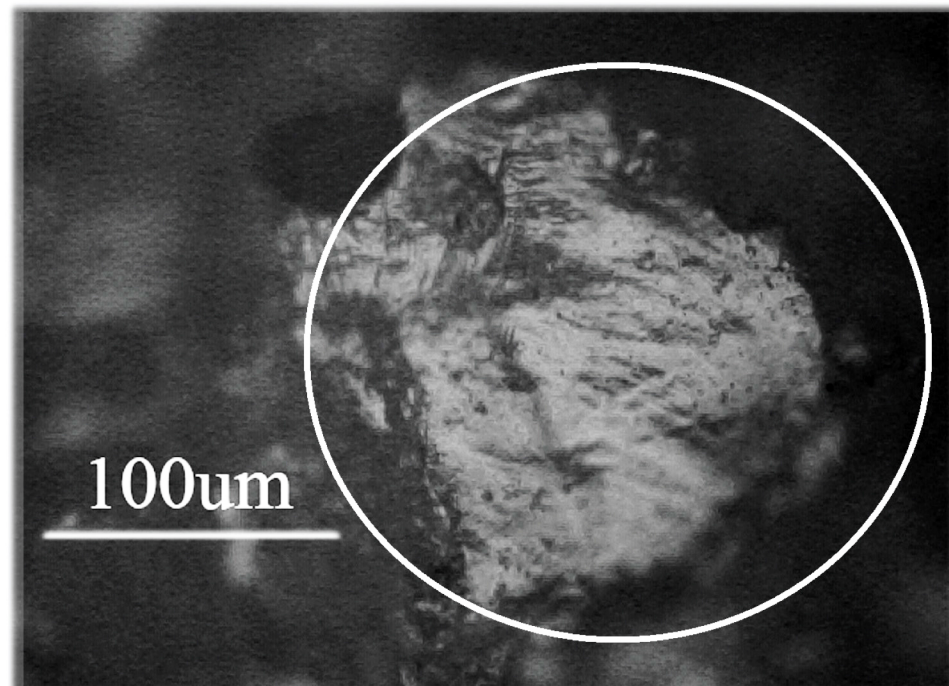
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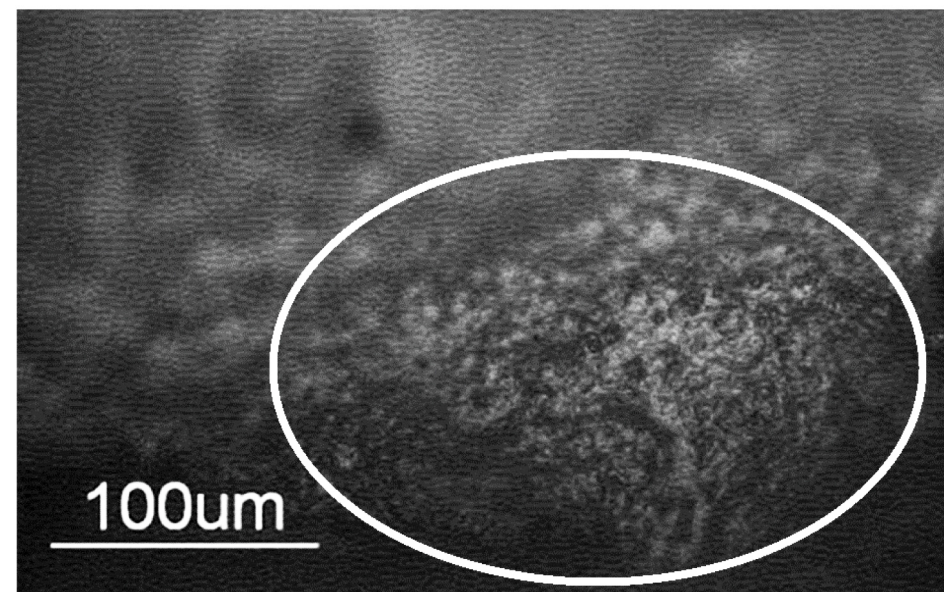
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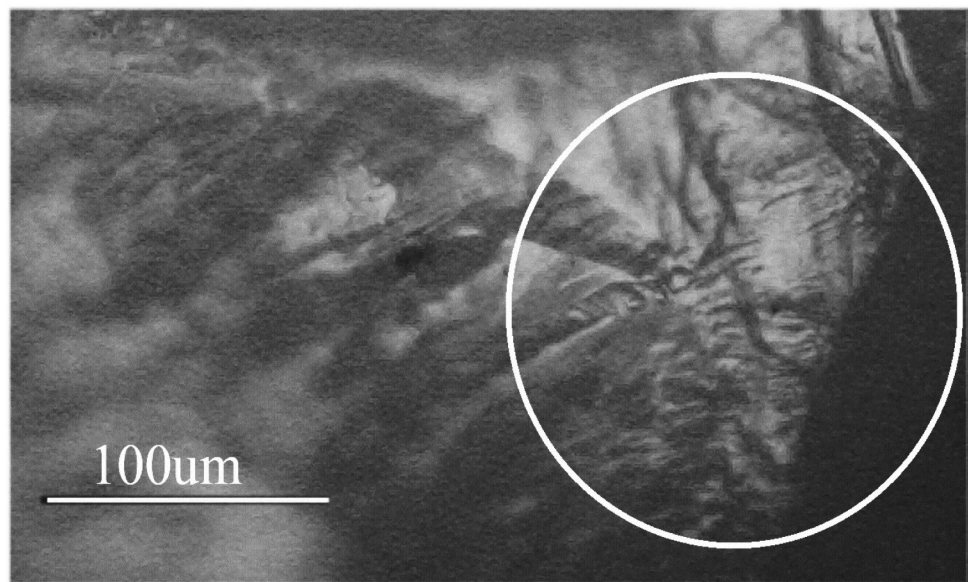
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c

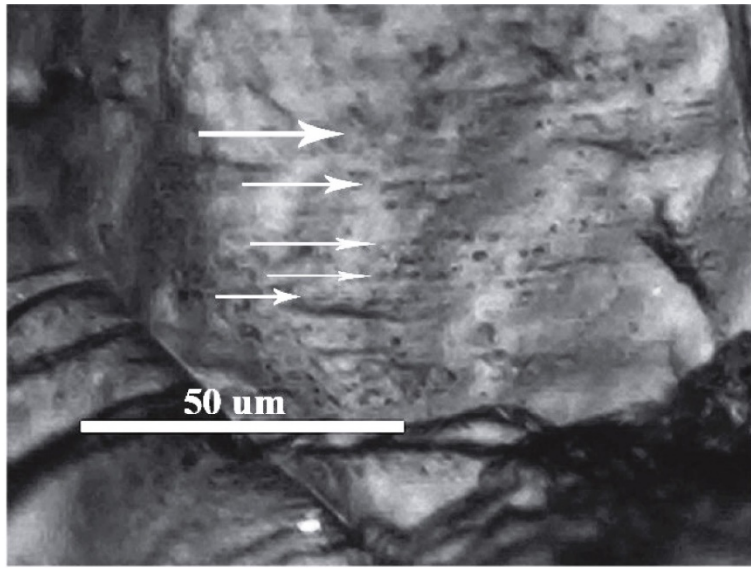


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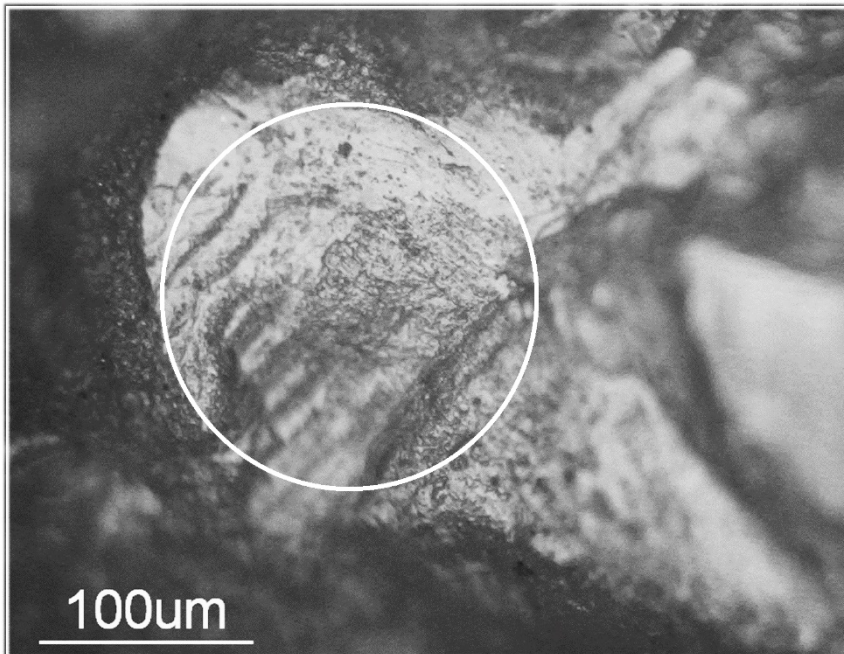


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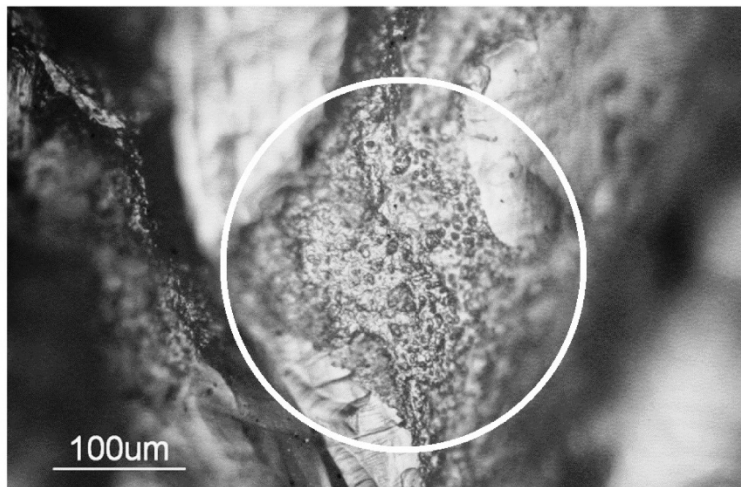
Figure 6



a

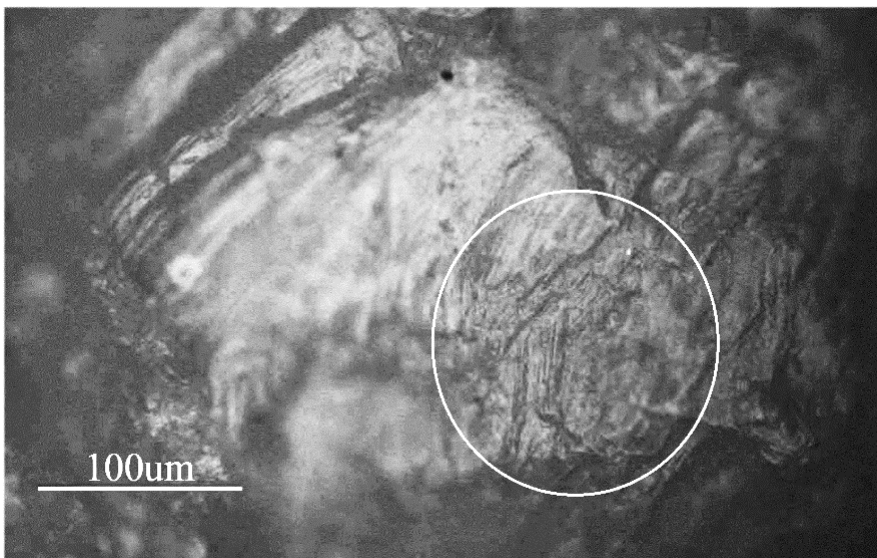
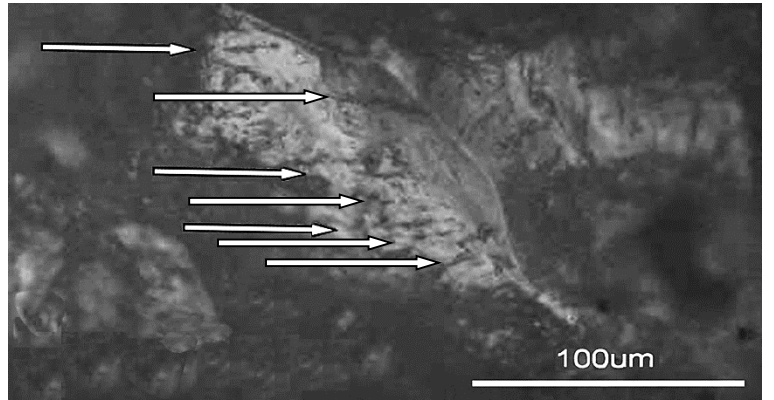
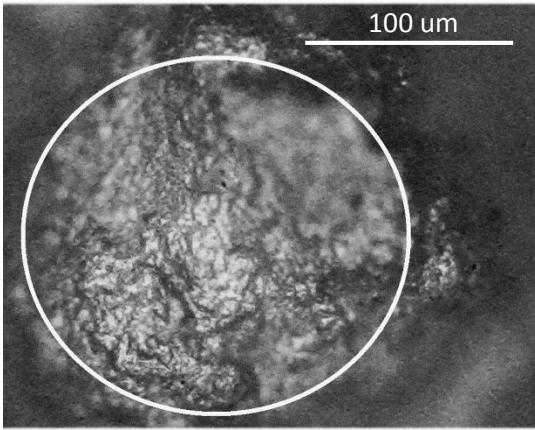
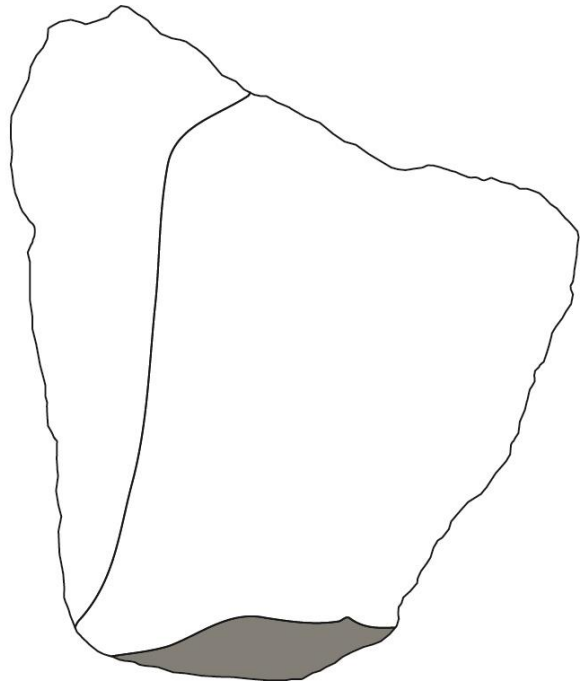
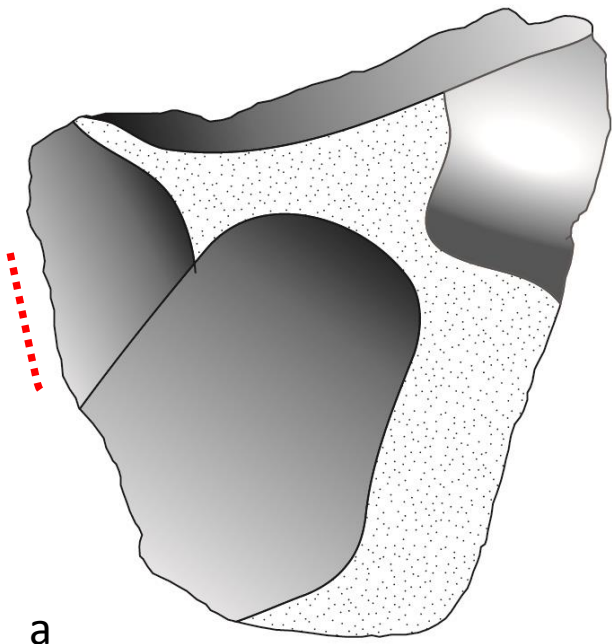


b



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Figure 7

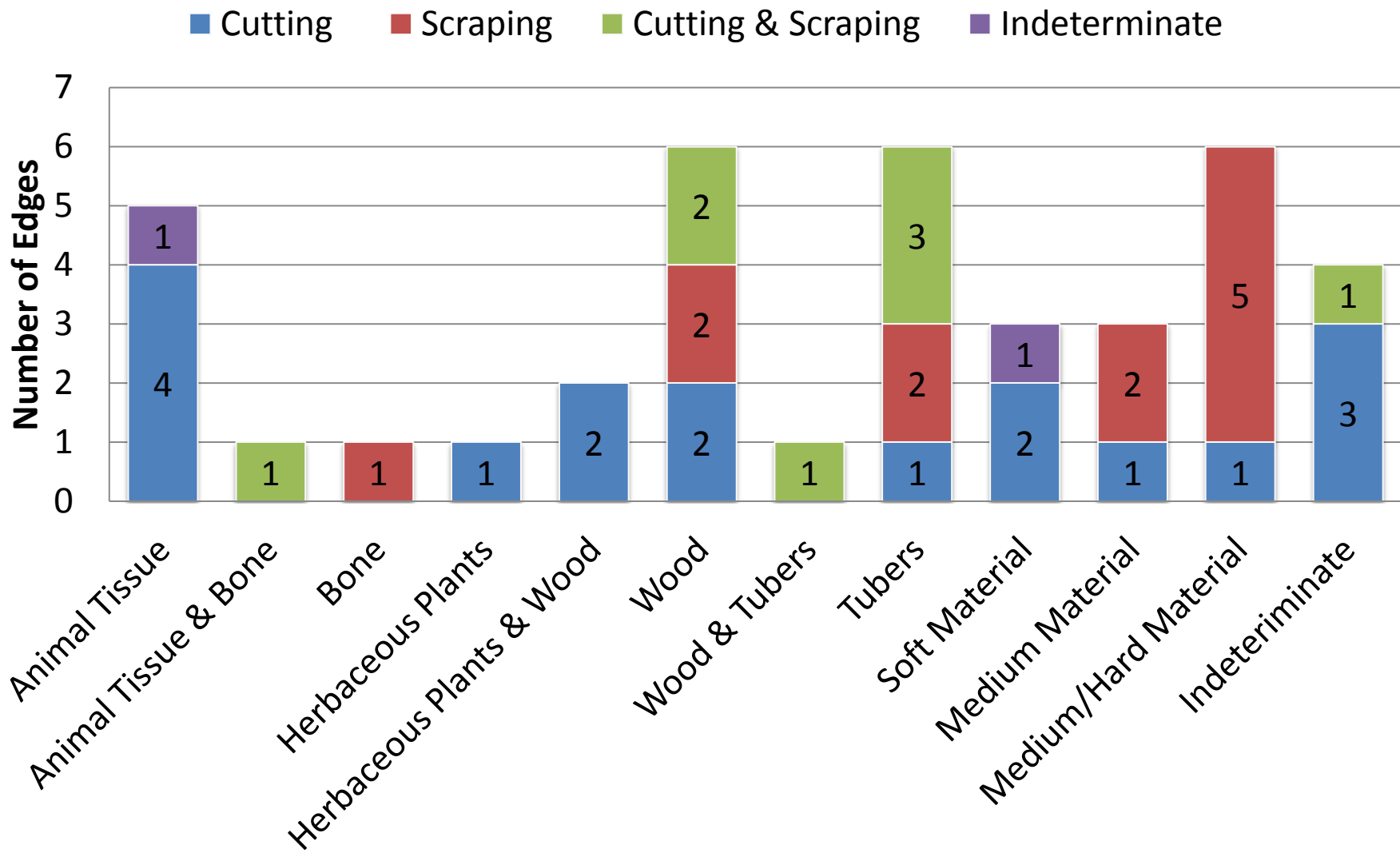


b

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d

Figure 8



Supplementary Figure 1

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Supplementary Figure 2

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Supplementary Figure 3

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