1. Survey methodology

General survey for fossils and archaeology in the Dikika Research Project area has been on-going since 1999 and has included some limited collection of interesting, representative or rare fossils and some archaeological collection at specific sites. In 2009 a more systematic collection strategy, which we call Level 2 survey, was initiated in several areas including Andedo where locality DIK-55 is located.

In Level 2 survey, a collection area typically corresponds to a stratigraphically well constrained and spatially limited geographic feature such as a small erosional gully. Before any collection, the limits of the area are flagged, and then a team moves across the area for a period of one hour flagging all fossils that they observe. Each of these flagged specimens is then assessed, and if it meets the collection criteria its location is recorded with a GPS and it is given a unique catalogue number.

The criteria for Level 2 survey mean collecting the following: all identifiable cranio-dental elements (including all greater than half teeth except elephant tusks), all horn cores, all greater than half astragali, and all long bones with an articular surface (calcanei, metapodials, humeri, ulnae, radii, scapulae, femora, tibiae, fibulae) except for hippos and elephants. Additionally, all clearly associated specimens with one of the above skeletal elements are collected. Furthermore all primates, carnivores and micromammals are collected. Fossils too large to transport, such as hippopotamus and elephant fossils, meeting these criteria are recorded but not collected. Additionally, in each collection locality all crocodile teeth and all significant fish and crocodile cranial parts are collected (crocodile teeth are collected in bulk and not piece-provenienced with GPS). The first occurrence of fish, turtle, crocodile, other reptiles, and invertebrates are also collected. A list of fossil specimens from Level 2 survey of DIK-55 and surrounding localities is provided below.

Archaeological survey is also conducted in each of these localities, and stone artefacts are recorded with the GPS. A basic technological and typological description is entered into the database at the find location. Whether an artefact is collected or not depends on its find context; however, no stone artefacts have been identified from DIK-55 and surrounding localities.

The two bones with stone tool modifications (DIK-55-2 and DIK-55-3) reported here were discovered in the course of doing Level 2 survey in the Andedo area. Neither bone fits the Level 2 collection criteria; however, they were recognized in the field as having marks that could represent stone tool modifications and were therefore collected for further study. Surrounding localities (see list below) were also revisited and each bone not collected previously was re-examined. In the course of this work one additional bone (DIK-41-164) was identified from a separate locality. A fourth bone (DIK-41-133) from this same locality met the Level 2 criteria for collection and was identified as having possible stone tool marks during field faunal analysis. The primary criterion for identifying these bones as potentially cutmarked was the presence of straight, sometimes multiple parallel, v-shaped grooves. All four of these bones were transported to Arizona State University for further analysis.

2. Faunal list

Supplementary Table 1 presents the faunal list for locality DIK-55 and surrounding localities (DIK-41, 42, 43, 44, 48, 54, and 59) from the same stratigraphic interval. Note that DIK-55 itself contained only two specimens, a Giraffidae radius and metapodial, that met our collection criteria (see above). The numbers in brackets represent the number of catalogued specimens from these localities. Additionally these localities combined included unidentified Chelonia, squamates, crocodiles, and Aves.

PRIMATES
- **Cercopithecidae**
  - Cercopithecidae indet. (5)

RODENTIA
- **Hystricidae**
  - *Hystrix* sp. (2)

CARNIVORA
- **Hyaenidae**
  - Hyaenidae gen. and sp. indet. (3)
- **Mustelidae**
  - *Enhydriodon* sp. (3)

PROBOSCIDEA
- **Elephantidae** (9)
  - *Elephas* cf. *recki*
  - ? *Loxodonta adaurora*

PERISSODACTYLA
- **Rhinocerotidae**
  - *Ceratotherium* cf. *mauritanicum* (3)
- **Equidae**
  - *Hipparion* sp. (23)

CETARTIODACTYLA
- **Hippopotamidae**
  - cf. *'Trilobophorus' afarensis* (55)
- **Suidae** (55 including 21 post-cranials not identified to genus, but mostly *Notochoerus* and *Nyanzachoerus*)
  - *Nyanzachoerus kanamensis* (7)
  - *Notochoerus euilus* (11)
  - *Kolpochoerus* cf. *afarensis* (16)
- **Giraffidae** (10)

Giraffa cf. *jumae* (5?)
Giraffa cf. *stillei* (5?)
Bovidae (85 including 9 unidentified post-cranials, mostly of *Aepyceros*)
Tragelaphus cf. *nakuae* (7)
Ugandax coryndonae (39)
'Praedamalis' deturi (2)
Aepyceros sp. (21)
Alcelaphini indet. (7)

Supplementary Table 1. Faunal list for DIK-55 and surrounding localities.

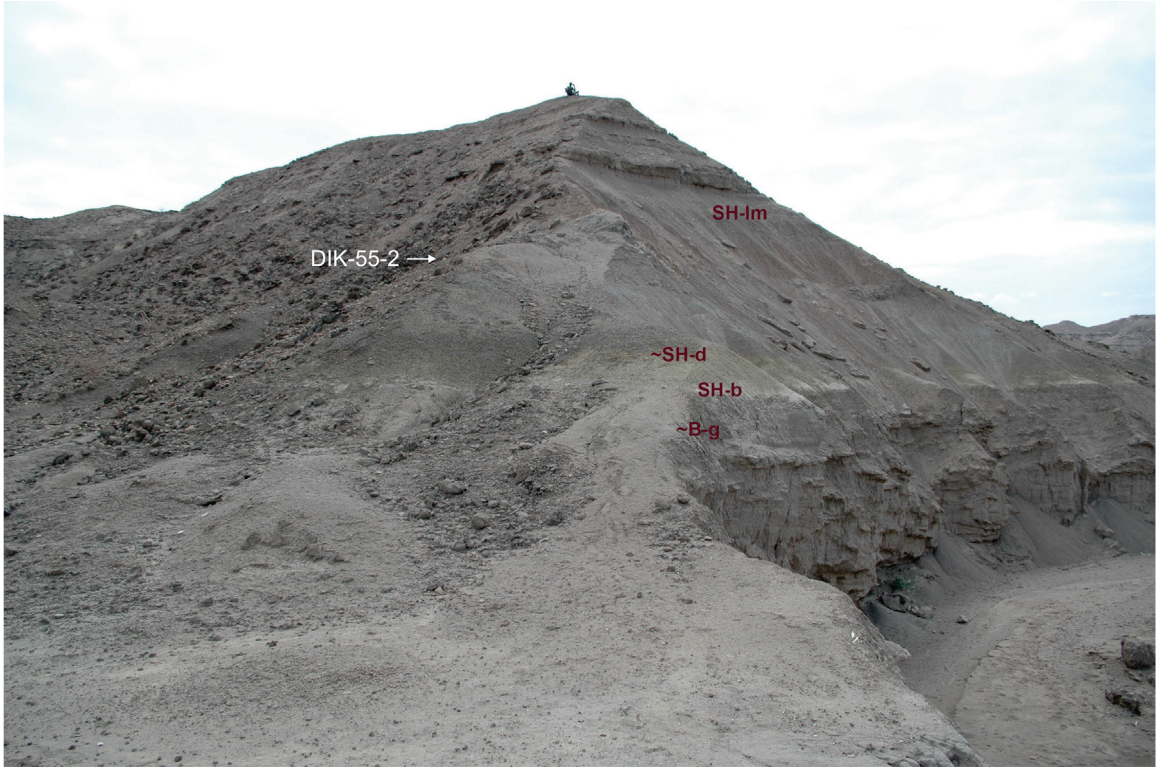
3. Stratigraphic and palaeoenvironmental context

DIK-55 consists of a ridge of exposures in the Andedo drainage (Figure 1 from main text and Supplementary Figure 1), the drainage which also contains the DIK-1 hominin locality[1,2]. The ages of both localities are determined by two stratigraphic sections (Supplementary Figure 2). Only one radiometrically dated unit is recognized in Andedo (the Sidi Hakoma Tuff; SHT; 3.42±0.03 Ma; age of Walter[3] recalculated in Campisano[4]; this unit is exposed as a bentonite in the Andedo drainage (SH-b) that can be traced to channels containing vitric tephra of the SHT in the nearby Shibele[5]). The upper Andedo section can be correlated and extended into the adjacent Simbeldere drainage, which contains a second radiometrically dated unit (the fourth of what were originally dubbed the five "triple tuffs"; TT-4, Triple-Tuff-4; 3.24±0.01 Ma, age of Walter[3] recalculated in Campisano[4]). The composite of these two sections can be referenced to the nearby type locality of the Hadar Formation in the Hadar Area[6,4], and several intervening stratigraphic markers recognized (SH-g; Sidi Hakoma gastropodites; 3.30 Ma by stratigraphic scaling between SH-b and TT-4; and the Sidi Hakoma ostracodite; SH-o; 3.24 Ma by stratigraphic scaling). Based on this correlation to the type section of the Hadar

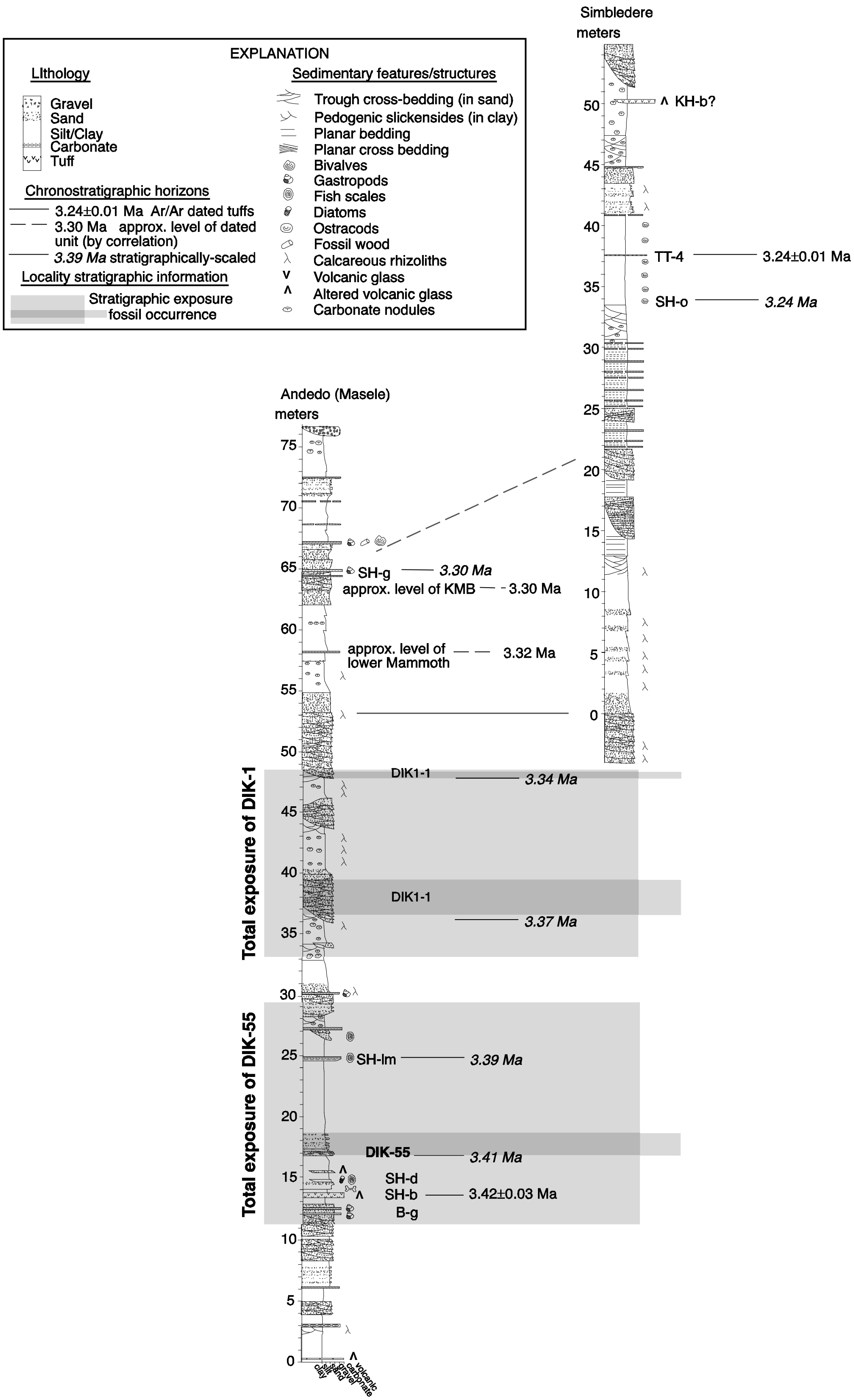
Formation, two chronostratigraphic markers can be estimated to be just below the SH-o and TT-4 units: the Kada Damoumou Basalt (3.30 Ma), and the lower boundary of the Mammoth chron (C2An.2r; 3.330 Ma[7],[8]). A bentonite that may be attributable to the Kada Hadar Tuff (3.20±0.01 Ma; age of Walter[3] recalculated in Campisano[4]) is exposed above the Sidi Hakoma ostracodite (KH-b).

DIK-55 is stratigraphically below the area excavated at the DIK-1 locality[1,2]. Markers exposed at the DIK-55 locality include: a widespread sequence of two distinct gastropod-bearing bioclastic limestones (B-g; Basal gastropodites), the widespread white bentonite (SH-b; Sidi Hakoma bentonite) that is laterally traceable in continuity to channels of the Sidi Hakoma Tuff (SHT; 3.42±0.03 Ma; age of Walter[3] recalculated in Campisano[4]), a thinly bedded buff diatomite (SH-d; Sidi Hakoma diatomite), and a regionally extensive 5-10 cm thick limestone unit that often contains fish scales and fragments of plant organic matter (SH-lm; 3.39 Ma by stratigraphic scaling between SH-b and TT-4[5]). Exposures within the entire Andedo drainage basin include up to ~ 10 meters above a series of gastropod-bearing bioclastic limestones (SH-g; Sidi Hakoma gastropodites; 3.30 Ma by stratigraphic scaling between SH-b and TT-4).

The specific fossils described here from DIK-55 are surface finds which can be attributed to an uncemented, massive and poorly sorted sandstone unit between about 17 and 18.5 meters in the Andedo stratigraphic section shown in Supplementary Figure 2. The average grain size of this sand is 1-2ϕ (medium grained), with particles that range from fine sand to fine gravel (3 to -3ϕ). Thin beds containing well-rounded gravel clasts form lag deposits at the base of erosional scours within the sands. These sands are within a sequence of weakly bedded to massive clays, limestones containing fish scales and plant fragments, and a diatomaceous bed—all of which indicate shallow freshwater lacustrine conditions[5]. Based on the features of the sands that contain the DIK-55 cut-marked fossil material, we interpret these specific beds as sheetflood events that were deposited within the shallow lake. The sands that produced the fossils at DIK-55 clearly differ from those that produced the DIK-1-1 specimen in their lack of significant cementation and cross bedding. The lack of cementation in the DIK-55 sands is likely key to the excellent preservation of bone surface modification because surface fossils are preserved "clean" of adhering matrix that may otherwise obscure the bone surface (such as the preservation of the DIK-1-1 specimen[1]).



Supplementary Figure 1. Find location of the DIK-55-2 specimen. See Figure 1 in the main text, Supplementary Figure 2, and supplementary text for an explanation of the marker horizons and for more information on their stratigraphic position within the Sidi Hakoma Member. Specimen DIK-55-3 was found directly down slope from DIK-55-2, below the SH-b horizon, in an area just to the left of the photo.


EXPLANATION
LIthology
Gravel
Sand
Silt/Clay
Carbonate
Tuff
Sedimentary features/structures
Trough cross-bedding (in sand)
Pedogenic slickensides (in clay)
Planar bedding
Planar cross bedding
Bivalves
Gastropods
Fish scales
Diatoms
Ostracods
Fossil wood
Calcareous rhizoliths
Volcanic glass
Altered volcanic glass
Carbonate nodules
Chronostratigraphic horizons
3.24±0.01 Ma Ar/Ar dated tuffs
3.30 Ma approx. level of dated unit (by correlation)
3.39 Ma stratigraphically-scaled
Locality stratigraphic information
Stratigraphic exposure
fossil occurrence
Simbledere
meters
KH-b?
TT-4
3.24±0.01 Ma
SH-o
3.24 Ma
Andedo (Masele)
meters
SH-g
3.30 Ma
approx. level of KMB
3.30 Ma
approx. level of lower Mammoth
3.32 Ma
Total exposure of DIK-1
DIK1-1
3.34 Ma
DIK1-1
3.37 Ma
Total exposure of DIK-55
SH-lm
3.39 Ma
DIK-55
3.41 Ma
SH-d
SH-b
3.42±0.03 Ma
B-g
clay
silt
sand
gravel
carbonate
volcanic

Supplementary Figure 2. Stratigraphic section of the Andedo and Simbeldere regions showing major chronostratigraphic marker horizons exposed throughout the region. The position of the DIK-1 excavation and fossil-bearing sandstone beds from Wynn et al.[2] are also shown with ages updated from the recalculated ages of Campisano[4].

4. Surface modification on the fossil specimens

Identification and Diagnosis Methods

All diagnoses and identifications were made on the original specimens under a Nikon SMZ1000 zoom binocular microscope with a 0.75x ED Plan lens with magnifications ranging from 8-80x under adjustable incident light from a bifurcated light source in the Arizona State University Zooarchaeology Laboratory. While we used an ESEM to further document the marks, this was not needed for confident diagnosis and identification. One hundred percent of the specimen surfaces were examined under the conditions described above, and all surfaces were examined from multiple angles to assure that the surfaces were illuminated by a variety of different angles of light. A large collection of experimentally generated stone tool cutmarked, percussion marked, and carnivore toothmarked comparative specimens curated at the Arizona State University Zooarchaeology Laboratory were used to assist with the identifications.

There are a variety of processes that may cause surface modification on bone surfaces, including modern collection and curation damage, trampling, scoring by teeth, and cutting and percussion by stone tools. As described in the main text, the modifications on the Dikika bones clearly do not result from biochemical damage as they lack the well-described characteristics of these damages[9,10].

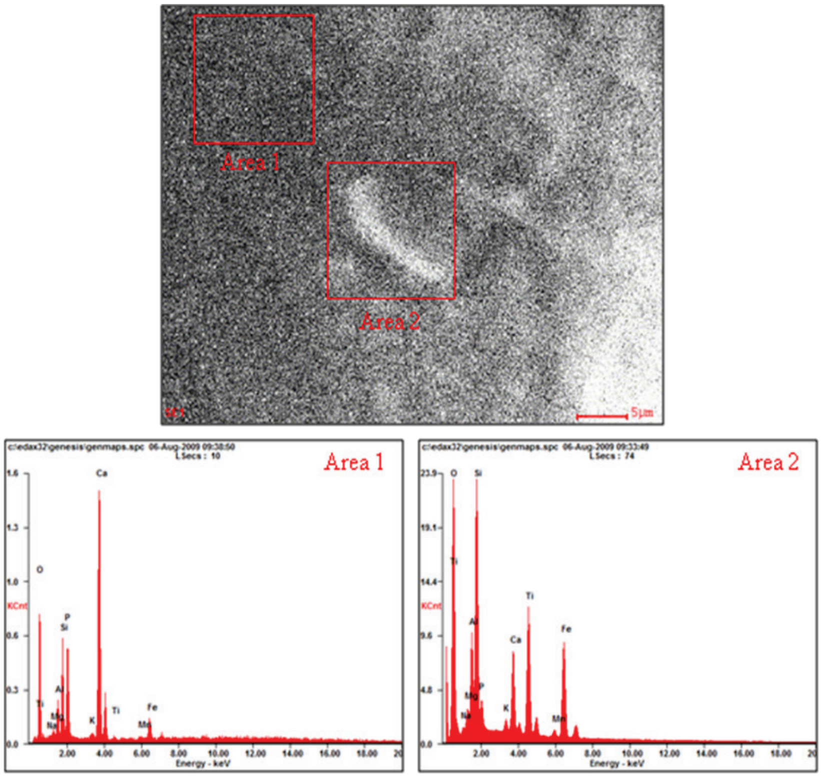
Trampling damage as a source for cutmark mimics is of course a cause for concern[11] and has recently received detailed study[12]. The Domínguez-Rodrigo et al.[12] study used 5 sediment types ranging from fine-grained sand to gravel. The grain size of the sand that bears fossils at DIK-55 is medium grained sand (1-2ϕ) with particles that range from fine sand to fine gravel (3 to -3ϕ). The gravel forms lag deposits at the base of erosional scours, and gravel particles are unusually well rounded. Domínguez-Rodrigo et al.[12] produced cutmarks by simple flakes (no retouch) and retouched tools, but did not compare percussion marks to the trampling damage. Thus the study is not a perfect analogy for the Dikika specimens since the Dikika marks were produced at a time that may predate flaked stone technology and where we can only speculate as to the stone type and form, and percussion damage clearly plays a role in most of the marks and their production. This is immediately clear when comparing some of the Dikika marks to those illustrated in Domínguez-Rodrigo et al.[12] – many of the Dikika marks are much more "percussion-like" in morphology. Importantly for this study, Domínguez-Rodrigo et al.[12] identify two criteria that are nearly always diagnostic of trampling damage: 1) "microabrasion in the form of very shallow randomly distributed striae, which occupy various parts of the specimen", and 2) "the presence of (frequently shallower) striae running oblique to the axis of the trampling mark and either intercepting it or crossing it"[12:2652-2653]. None of the specimens identified here as having stone tool inflicted marks (DIK-55-2 and 55-3) have these features, but the two specimens diagnosed as not having stone tool inflicted marks (DIK-41-133 and 41-164) do have these trampling features.

Were the surface modifications induced by stone tools?

In following figures, we present secondary electron imaging (SEI) and energy dispersive X-ray (EDX) spectrometry of the ESEM data that support our postulate that these surface modifications were induced by stone tools. On DIK-55-2, a rock fragment was found imbedded in the bone in mark A2 (the cut to the right in Fig. 2a). The long axis of this rock fragment is inclined with respect to the bone surface at an approximate angle of 45º, though it was not possible to measure this. SEI and EDX analyses of this inclusion and of an adjacent area in the surface modification are shown in Supplementary Figure 3. Note that the images are rather grainy because we performed these analyses on the original fossils and 1) the samples were not coated; 2) images were taken in "analysis mode", not "imaging mode", and 3) high voltage (20 kV) was used to excite elements present, therefore, by the time the EDX line scan ended, the sample charging has affected the quality/resolution of the image.

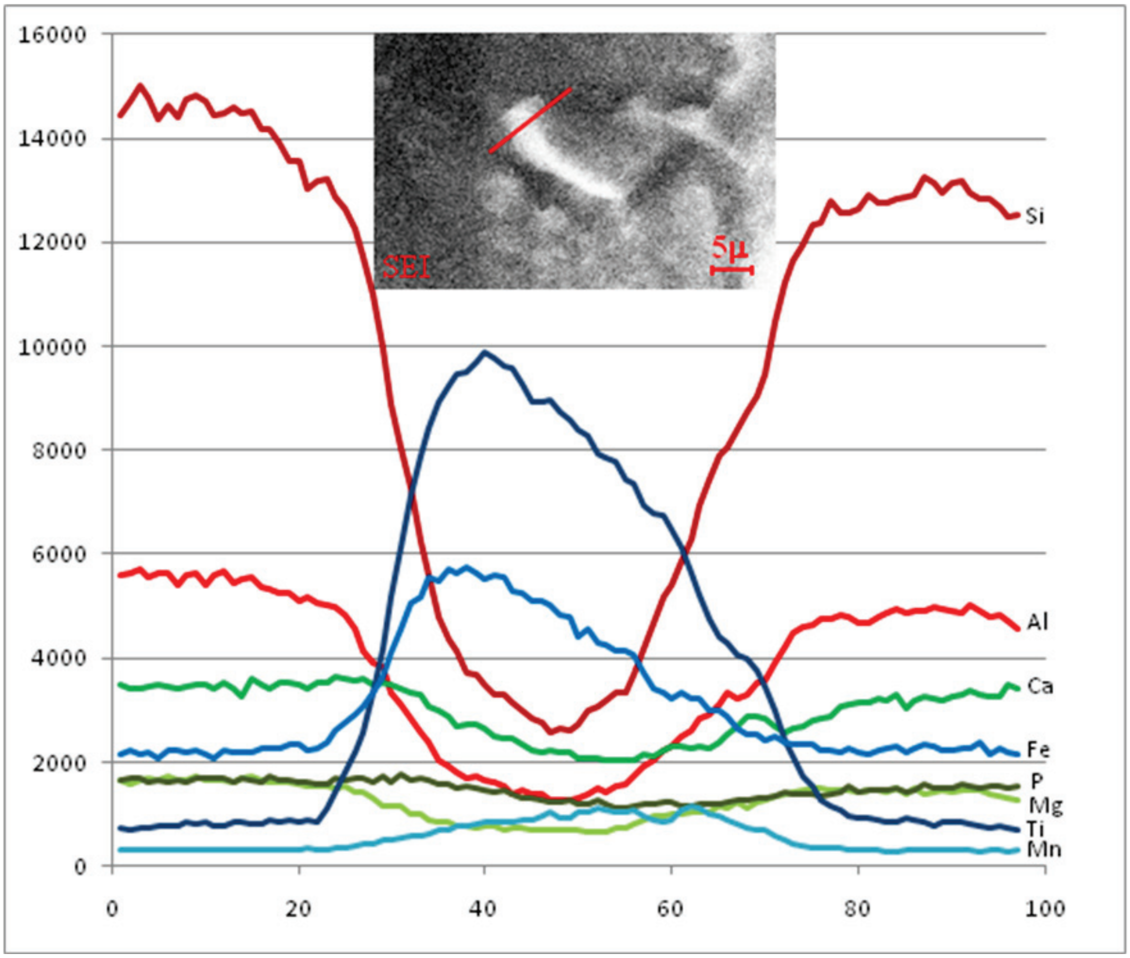
The quantitative analyses of both areas are also given in the table of Supplementary Figure 3. Area 1 shows a typical composition of the bone material (high Ca and P), but coated with a deposition layer rich in Si, Al, and Fe. We consider this area as a basis for comparison. Area 2, which includes the imbedded rock fragment, has increased concentrations of Si, Al, Fe, Ti, and Mn. Concentrations of Ca and P drop dramatically in this area because of the shielding effect of the rock fragment and of the deposition layer. Furthermore, an X-ray scan across the fragment was performed and the chemical profiles of the major elements are shown in Supplementary Figure 4. This scan shows concentrations of Ti, Fe, and Mn to be strongly, and positively, correlated in the rock fragment. Whereas strong correlation is to be observed between Si and Al; their concentrations also increase relative to Area 1.

The correlation of chemical profiles of Fe, Ti and Mn distinct from the correlation of Si and Al suggests that the rock fragment is composed of at least two mineral phases and/or glass, one component rich in Ti, Fe, and Mn and the other in Si, Al, Fe, and has a minor amount of K. Mio-Pliocene volcanics of the Ethiopian Rift contain abundant generally alkaline to subalkaline, titanium rich (2-5% TiO_2) flood basalts with rhyolitic volcanic centers built on the lava piles[13,14,15]. A variety of titanium-rich minerals occur in the basaltic rocks, which may account for the Ti-,Fe-,Mn-rich phase. These include ilmenite (which is part of a solid solution series; $(Fe, Mg, Mn,Ti)O_3$), titanaugite, $Ca(Mg,Fe,Ti,Mn)(Si,Al)_2O_6$, titanomagnetite $Fe^{2+}(Fe^{3+},Ti)_2O_4$, and rutile (TiO_2), many of which contain abundant Fe and Mn in solid solution or as impurities. On Mohs scale, these minerals have hardnesses of 5-6. Hydroxyapatite which is the main mineral component of the bone has a hardness of 5 on Mohs scale. Given this, it is implied that for a material to affect a change (scratching) in the bone surface, the hardness should be equal or greater than that of apatite. Thus, since these minerals, common in Ethiopian Rift volcanics have hardness values greater or equal to that of apatite, then the stone tool is likely to have been at least this hard to make an impact into the surface. Many of these minerals are present in the sediments of the Hadar Formation, which are weathered from the volcanics[16], and we cannot eliminate the possibility that the rock fragment comes from these local sediments. It seems more likely, however, that this rock fragment is a fragment of a stone tool of an igneous origin used for work on the bone. These rocks are strong, hard, and usually flake with sharp edges. In another surface modification from sample DIK-55-3, a large fragment (~0.4x0.8mm) was observed (Supplementary Figure 5). The surface features of this fragment are very similar to those of the adjacent bone surface. EDX spectrum and quantitative analysis of the indicated area are shown in Supplementary Figure 5. Analysis shows a typical composition of the bone material (high Ca and P contents) and a deposition layer rich in Si, Al, and Fe. Minor elements present are Na, Mg, and K. This composition is very similar to that obtained for Area 1 in Supplementary Figure 3. Therefore, we think that this is a fractured/dislocated bone fragment produced by percussion or cutting at the same time that the surface marks were produced.

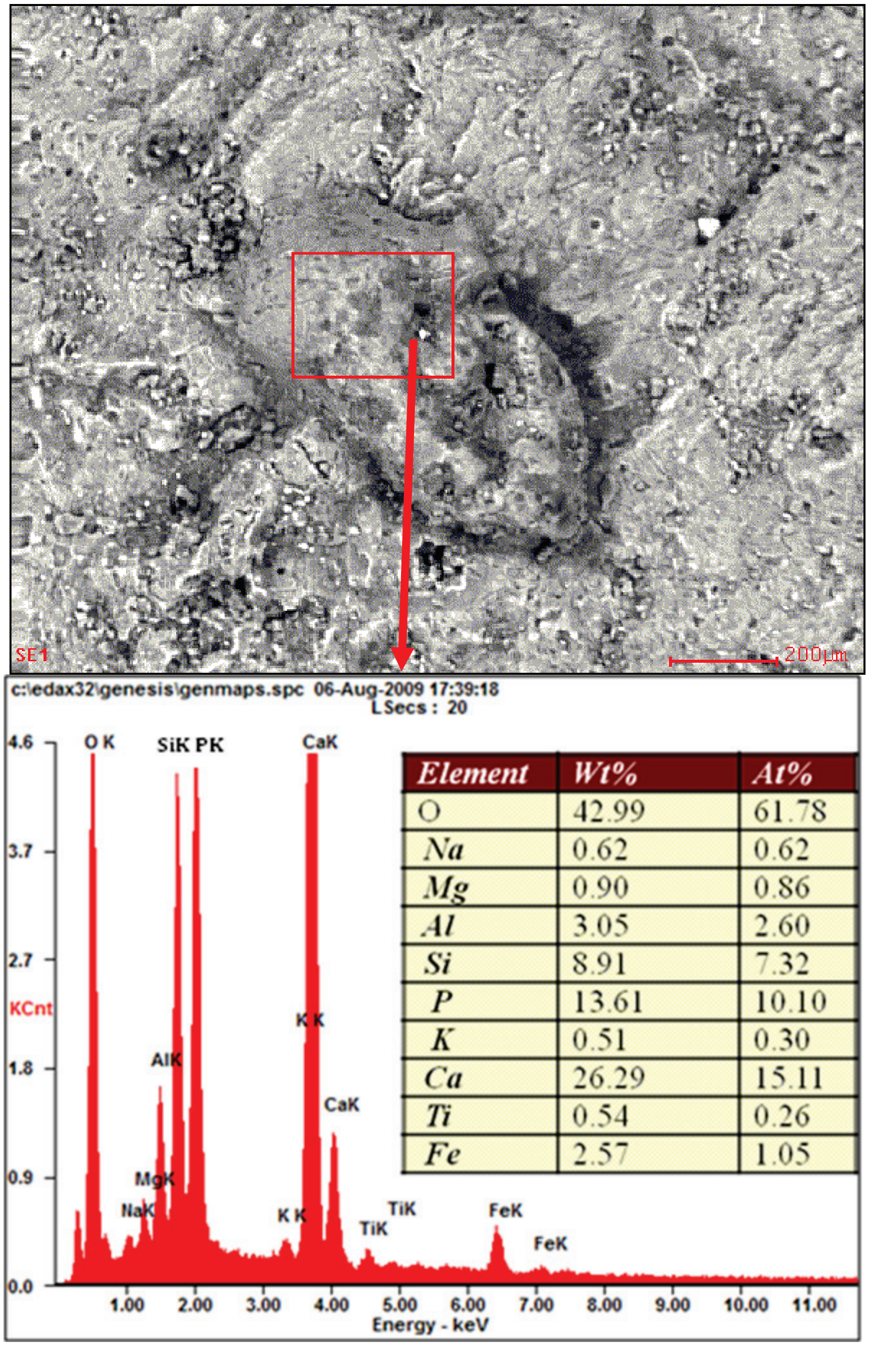


	Area 1		Area 2	
Element	*Wt%*	*At%*	*Wt%*	*At%*
O	51.45	69.54	51.58	70.78
Na	1.07	1.01	0.00	0.00
Mg	1.60	1.42	1.21	1.09
Al	3.42	2.74	5.51	4.48
Si	7.65	5.89	14.54	11.36
P	7.99	5.58	0.74	0.53
K	0.42	0.23	0.68	0.38
Ca	22.01	11.88	4.37	2.39
Ti	0.14	0.06	8.89	4.07
Mn	0.31	0.12	0.78	0.31
Fe	3.94	1.52	11.71	4.60

Supplementary Figure 3. SEM/EDX analysis of a rock fragment observed in a stone tool inflicted mark and neighbouring area from sample DIK-55-2. The analyzed areas are indicated by squares in the SEI image. EDX spectra of the two areas are shown. Quantitative analyses are given in the table. Area 1 has the typical composition of the bone material (high Ca and P), but coated with a deposition layer rich in Si, Al, Fe, Mg and Na. Area 2, which includes the rock fragment, has increased contents of Si, Al, Fe, Ti, and Mn.



Supplementary Figure 4. Chemical profiles of the major constituents across the rock fragment shown in Supplementary Figure 3. Note the strong correlation between Ti, Fe and Mn and between Si and Al.



Element	Wt%	At%
O	42.99	61.78
Na	0.62	0.62
Mg	0.90	0.86
Al	3.05	2.60
Si	8.91	7.32
P	13.61	10.10
K	0.51	0.30
Ca	26.29	15.11
Ti	0.54	0.26
Fe	2.57	1.05

Supplementary Figure 5. SEM/EDX analysis of a dislocated bone fragment observed in a stone tool inflicted mark in sample DIK-55-3. The analyzed area indicated by the red frame is 400µ X 800µ. Quantitative analyses are given in the table. It has the typical composition of the bone material (high Ca and P) but coated with a deposition layer rich in Si, Al, and Fe, with minor amounts of Na, Mg, Ti, and K.

Are the surface modifications old or modern?

Surface modifications that significantly post-date the depositional event of a bone fragment, such as by trampling, typically have lighter internal surfaces as the surface patina is removed. None of the marks on DIK-55-2 and DIK-55-3 have these features. However, we did further examinations of the surface modifications and surrounding bone surface of DIK-55-2 and DIK-41-133 using secondary electron imaging (SEI) and energy dispersive X-ray spectrometry (EDX) of the environmental scanning electron microscope (ESEM) to study the pattern of chemical deposition. No coating was needed as analysis was done in H_2O vapour mode. Bone surfaces were imaged at the surface modification and adjacent areas; several EDX spectra were collected for each sample. The quantitative data were recalculated as oxide weight %, normalized, and averaged for the surface modification and an adjacent area, respectively. Oxide weight (Wt.) % concentrations collected for several spots in one surface modification and its adjacent area from samples DIK-55-2 and DIK-41-133 are given in Supplementary Table 2. The complete SEM/EDX analyses of all 3 samples along with modelling bone surface modification will be reported in a separate technical paper that expands on the methodology. The data presented here are representative, and it is unnecessary to include all the data here.

For each bone fragment, comparison of bone surface composition is done between surface modification and adjacent area. SEI images and typical EDX spectra of the analyzed spots in a surface modification and an adjacent area from sample DIK-55-2 are shown in the Supplementary Figures 6 and 7 and from sample DIK-41-133 in Supplementary Figures 8 and 9. According to the model we developed, if the bone surface modification is recent, then the bone surface at the surface modification would show a deposition layer chemically distinctive from the bone material itself. The chemical composition of this layer will depend on many factors that control the interaction of the bone with its depositional environment. Because of variation in the rate of deposition and erosion of this layer in the surface modification with respect to the intact smooth bone surface (called here “adjacent area”), the deposition layer is expected to be thicker in the cutmark, but has qualitatively the same chemical composition. However, if the surface modification is modern, then it should expose a fresh surface of the bone or at least thinning of the deposition layer. In chemical terms, this means that relative to the adjacent area EDX analysis of the surface modification should show more of the intrinsic bone elements calcium and phosphorus and hence less of the extrinsic elements.

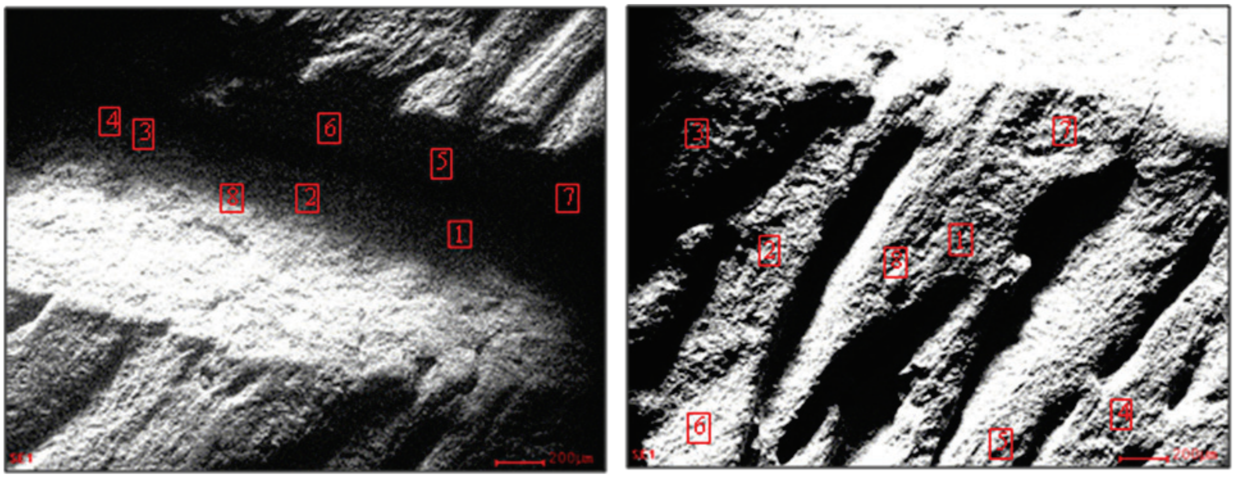
EDX analyses of the bone fragments from this locality show that the soil environment favoured deposition of a layer rich in silicon, aluminium, and iron. So, in Supplementary Table 1 two groups of elements are in contrast: Ca and P (bone constituents) and Si, Al, and Fe (deposition layer major constituents). It is evident from the data that in DIK-55-2 the surface modification is old and predates the deposition of the bone. Indeed the surface composition at the surface modification is higher in Si, Al, and Fe (and hence lower in Ca and P) than the adjacent area. The same effect was observed in DIK-55-3. In DIK-41-133, where the surface modification is modern, it is just the opposite effect. The bone surface at the surface modification is higher in Ca and P (and hence lower in Si, Al, and Fe) than the adjacent area. Scratching of the surface has removed part of the deposition layer, thus diminishing the shielding of the bone constituent (i.e. Ca and P). The

SEM/EDX data thus provide strong evidence that the surface modification in both DIK-55-2 and DIK-55-3 are old and predate the sedimentary deposition of the bones.

	DIK-55-2		**DIK-41-133**	
	SM1 Mean (n=8)	ADJ.A Mean (n=8)	SM1 Mean (n=4)	ADJ.A Mean (n=5)
Na_2O	1.43	1.10	3.46	0.12
MgO	1.79	1.26	1.47	0.42
Al_2O_3	4.96	3.14	5.24	8.86
SiO_2	13.26	8.21	18.23	34.98
P_2O_5	33.50	36.89	29.19	20.15
K_2O	0.41	0.31	0.61	0.87
CaO	41.51	46.85	38.67	27.58
TiO_2	0.33	0.11	0.42	1.03
FeO	2.24	1.61	2.72	5.24

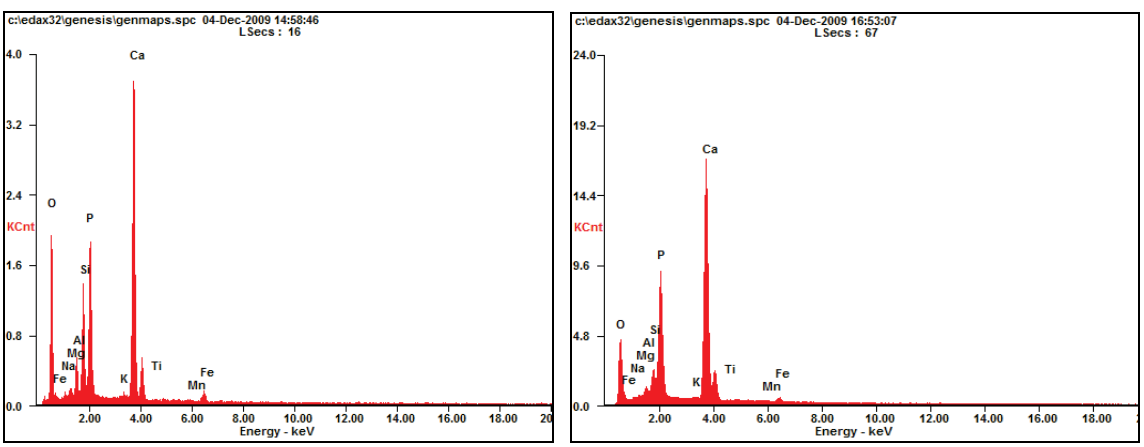
SM = surface modification; ADJ.A = adjacent area to surface modification; n = number of spots analyzed

Supplementary Table 2. Chemical composition of the bone surface in the surface modification and adjacent areas for the DIK-55-2 and DIK-41-133 fragments examined. Concentrations are expressed as normalized oxide Wt. %.



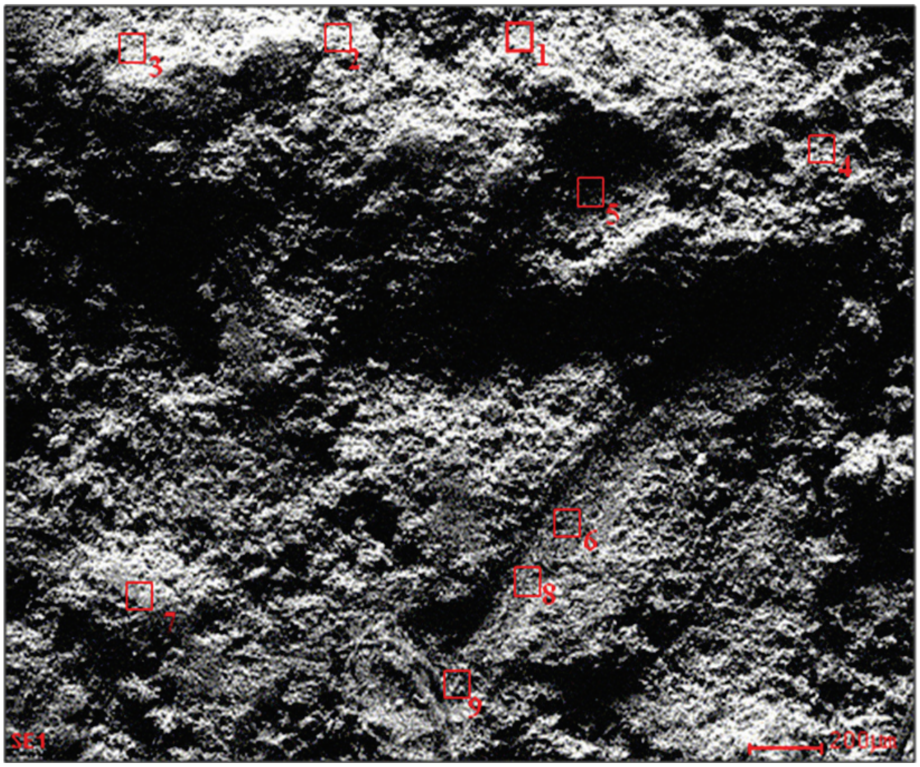
(a) (b)

Supplementary Figure 6. Secondary electron images (SEI) of (a) cutmark and (b) adjacent area in sample DIK-55-2. Numbered squares indicate spots analyzed with EDX.

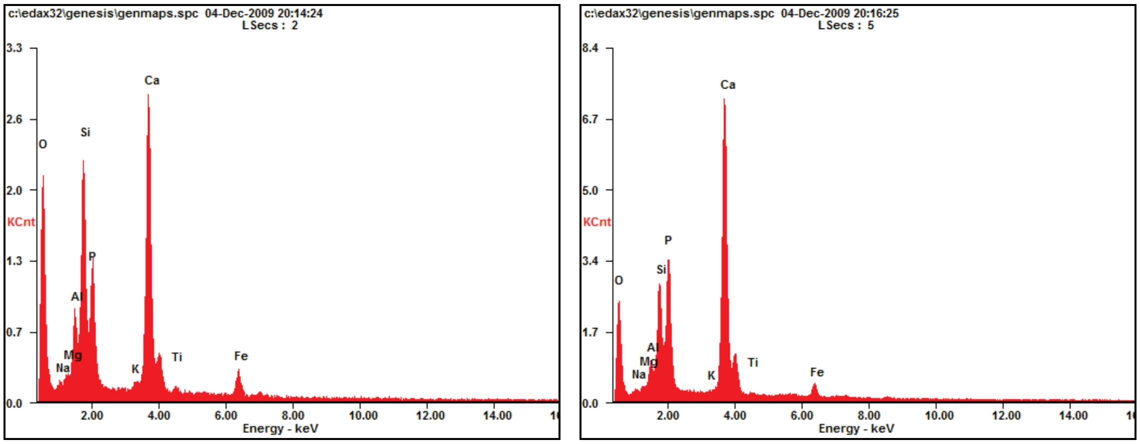


(a) (b)

Supplementary Figure 7. EDX spectra (a) acquired from spot 3 in Supplementary Figure 6a above (surface modification); (b) from spot 1 in Supplementary Figure 6b above (adjacent area). Note the higher counts for Si, Al, and Fe in the spectrum collected in the surface modification (a) with respect to that collected in adjacent area (b).



Supplementary Figure 8. Secondary electron image (SEI) of surface modification 1 and adjacent area of sample DIK-41-133.



(a) (b)

Supplementary Figure 9. EDX spectra acquired from spots 4 and 8 in the SEI image above, respectively. Note the higher counts for Si, Al, and Fe in the spectrum from adjacent area (a) with respect to that from the surface modification (b).

Description of the Surface Modification

All three analysts (see below) who studied the Dikika marks made the general observation that these marks appear rather “heavy” in that the damage is massive and deep relative to stone tool inflicted marks we have seen on experimental, South African Middle Stone Age faunas, and Zagros Mountains Palaeolithic faunas. The result is that the Dikika stone tool inflicted marks sometimes seem to transition from cutmarks to percussion marks in morphology and do not fall easily into either category. This is perhaps expected, since the Dikika specimens predate the currently known origins of flaked lithic technology. We do not know what type of stone was used to inflict these marks, but it is possible that a stone was picked up off the ground surface and used in an expedient manner. We speculate that the stone tool inflicted modification was produced by forceful action with coarse-grained stone. With larger fossil samples, followed by careful experimental replication using the naturally occurring stone at Dikika, it could be possible to quantify this qualitative impression.

Thus, the most likely agents for the production of the Dikika surface modification marks on specimens DIK-55-2 and 55-3 (Figure 1 and 2 main text and Supplementary Figures 10-20) are either hominins wielding stone (cutmarks and percussion marks) or hominins and/or carnivores chewing bones (toothmarks). It is difficult to resolve the agent of toothmarks[17,18] and we will not attempt that here. Rather, our focus is at two levels: 1) determining if the marks were inflicted by tooth versus stone, and 2) determining if the marks (if stone tool inflicted) were produced by cutting with stone or percussion with stone. The morphological distinctions between cutmarks, percussion marks, and toothmarks are well known and described[19,20,21,22,23,24,25,26,27,10,28,9,29]. However, analysts with actualistic experience with surface modification know that cutting, chopping, and hammering of carcasses can all occur together during butchery[30,31,32], and that it is not always strictly possible to confidently assign individual marks to cutting with heavy action with a large flake stone from percussion using a smooth or angular hammerstone. We found that to be the case here, and as noted above this difficulty is probably multiplied by the fact that given the age of the Dikika finds it is unclear whether naturally occurring sharp stones or flaked stones were used.

The first identifications, and the descriptions included here, were done by CWM. To cross-check the identifications, two other analysts examined the fossils and diagnosed the surface modifications using the same optical methods discussed above. Jessica Thompson (JT) is a Ph.D. with a specialty in zooarchaeology and taphonomy. She has extensive experience with both actualistic and zooarchaeological fossil collections[33,34,35]. Sarah Lansing (SL) is a Ph.D. candidate at ASU with a specialty in zooarchaeology and taphonomy. She also has extensive experience with actualistic and zooarchaeological fossil collections and has particularly strong experience with naturalistic carnivore collections from East Africa and South Africa[36]. JT and SL were trained in surface modification studies by CWM, but both have substantial experience beyond what they have received in CWM's laboratory. All three (CWM, JT, and SL) examined the specimens independently and recorded their observations separately, and these were then collated by CWM. All three analysts have passed successive blind tests of the type described by Blumenschine[21] comparing stone tool inflicted marks to tooth marks. The results of their diagnoses are compared in Supplementary Table 3.

The diagnoses are separated into “General” (stone, tooth, unidentifiable) and “Specific” (cutmark, percussion mark, etc.). There is a high degree of correspondence at both levels. In only two cases (DIK-55-3 G1 and J) is there a difference in General diagnoses – SL and JT considered mark G1 to be unidentifiable, while CWM considered it stone inflicted. SL and JT considered J to be stone inflicted, and CWM considered it unidentifiable. Similarly, the correspondence at the Specific level is also very high, with DIK-55-3 G1 and J providing the only contradictions. DIK-55-3 Marks B, C, D, H and I have partial correspondence in that some analysts coded them as “percussion mark” while others coded them as “percussion mark + cutmark”, reflecting the overlap between heavy cutting and percussion discussed above. DIK-55-2 Mark B was diagnosed as a percussion mark by JT and SL, while CWM diagnosed this as a scrape mark. All three analysts diagnosed DIK-41-33 and 41-164 as lacking stone tool inflicted marks. These results lend strong support to the interpretation that the marks on DIK-55-2 and 55-3 are stone tool inflicted, and include both cutting and percussion activities. DIK-41-133 and 41-164 are presented here as well (Supplementary Figures 21-23), but neither has stone tool inflicted damage.

doi: 10.1038/nature09248

Supplementary Table 3. The diagnoses of the marks by three analysts who examined the specimens independently.

DIK 55-3 Femur						
	Sarah Lansing		**Jessica Thompson**		**Curtis Marean**	
Mark	**General Identification**	**Specific Identification**	**General Identification**	**Specific Identification**	**General Identification**	**Specific Identification**
A	stone	cutmark	stone	cutmark	stone	cutmark
B	stone	percussion mark + cutmark	stone	percussion mark + cutmark	stone	cutmark
C	stone	percussion mark + cutmark	stone	percussion mark + cutmark	stone	cutmark
D	stone	cutmark	stone	percussion mark + cutmark	stone	percussion mark + cutmark
E	stone	cutmark	stone	cutmark	stone	cutmark
F	stone	cutmark	stone	cutmark	stone	cutmark
G1	unidentifiable	unidentifiable	unidentifiable	unidentifiable	stone	cutmark
G2	unidentifiable	unidentifiable	unidentifiable	unidentifiable	unidentifiable	unidentifiable
H	stone	percussion mark	stone	percussion mark	stone	percussion mark + cutmark
I	stone	percussion mark	stone	percussion mark	stone	percussion mark + cutmark
J	stone	percussion mark	stone	percussion mark	unidentifiable	unidentifiable

DIK 55-2 Rib						
	Sarah Lansing		**Jessica Thompson**		**Curtis Marean**	
Mark	**General Identification**	**Specific Identification**	**General Identification**	**Specific Identification**	**General Identification**	**Specific Identification**
A	stone	cutmark	stone	cutmark	stone	cutmark
B	stone	percussion mark	stone	percussion mark	stone	scrape mark
C	stone	percussion mark	stone	percussion mark	stone	percussion mark

DIK-55-2 Description

DIK-55-2 (Supplementary Figures 10-12) is a right rib of a large ungulate, probably size 4 and perhaps size 5 using Brain's categories[37]. It is most likely from one of the more proximal ribs, as its shape is rather oblong in cross section and it is relatively thick in cross-section. It is also probably near to the proximal end, or perhaps the middle.

The specimen has three areas (Marks A, B, and C) where there is surface modification (see below). Marks A and B are illustrated in the main text. All modification is on the exterior of the rib.

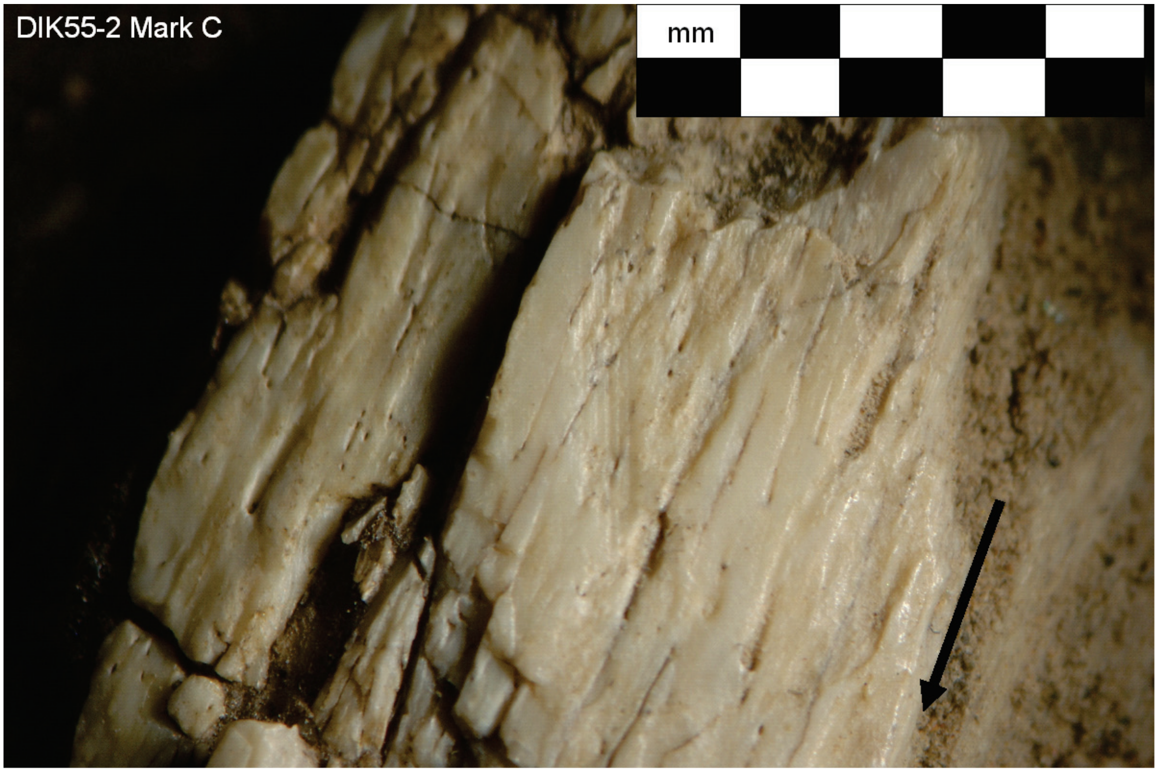
Breakage

The break across the proximal end is primarily right angle[38], and approximately transverse to intermediate in shape. There is little to no matrix on the surface of the break, and there is some change in the darkness of the patina from dark grey to light grey going from the exterior to the interior. This suggests that this break may have occurred after being fossilized, perhaps while still in the matrix.

The distal break is right angle[38] and transverse in shape. There are traces of cemented matrix on the break surface, and the patina on the break is mostly uniform and similar to that on the bone surface, suggesting that this break is not post-fossilization or recent. The bone is splintered and cracked at this end, likely from percussion damage associated with Mark C (see below).

Supplementary Figure 10. Overview of DIK-55-2, external surface. Each of the marks referred to more specifically in the main text and below is indicated here. The black arrow indicates the direction of the rib head.

Supplementary Figure 11. Overview of DIK-55-2, internal surface. The black arrow indicates the direction of the rib head.



Supplementary Figure 12. DIK-55-2 Mark C – This mark is associated with breakage and compression of the bone, and it has numerous clear micro-striations. All three analysts diagnosed it as stone tool inflicted, and all analysts agreed it indicated percussion. The black arrow indicates the direction of the rib head.

DIK-55-3

DIK-55-3 (Supplementary Figures 13-20) is a femur shaft fragment, almost certainly left though this is not entirely clear. It is from a size 2 bovid, but it is not possible to determine if it is from a small or larger size 2. The relatively thin cortical bone and somewhat porous nature of the shaft suggest that it may be juvenile. It preserves the nutrient foramen on the far proximal end of the bone just below its break. The break transects the very proximal end of the foramina opening. For the purposes of this study, we will assume this is a left.

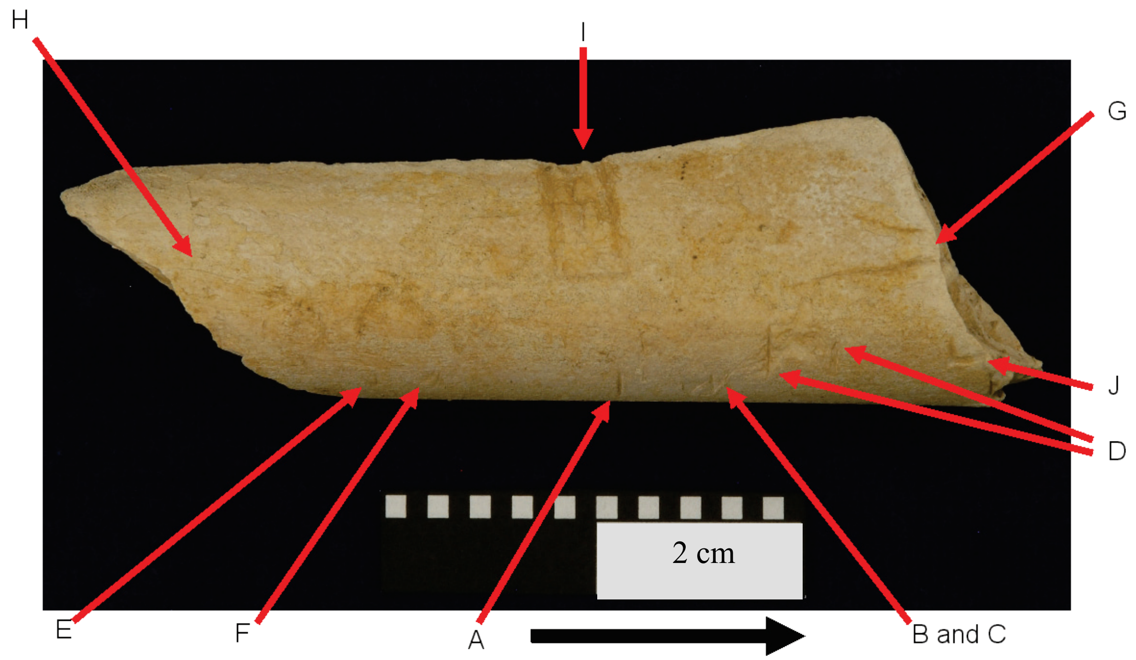
The specimen has a wide range of surface modifications on the cortical (outer) surface of the fragment (Supplementary Figure 13). There are no surface modifications on the medullar (internal) surface (Supplementary Figure 14). Medullar surface marks are common from carnivore chewing, but not typical of hammerstone percussion or cutting. This specimen has 10 marks or mark clusters (Marks A-J).

Breakage

The break across the proximal end is primarily right angle[38] and approximately transverse. There are traces of cemented matrix and patina on the break that are similar to those on the bone surface, suggesting that this break is not recent. This would suggest that the break occurred when the bone was no longer fresh but rather degreased, since less than 5% of long bones broken either by hammerstone percussion or hyena breakage produce such breaks[39].

Both longitudinal breaks have oblique angles that are consistent with breakage when the bone is still fresh and greased (Supplementary Figure 14). Neither has a clear "notch" from either passive or active force typical of breakage caused by tooth or hammerstone, respectively[40].

The distal break is curved in shape and oblique in angle, though there is some jagged and rough morphology. On the surface of this break there are traces of cemented matrix and patina similar to the bone surface, suggesting that this break is not recent. Overall, this break is consistent with breakage in a state when the bone is not degreased.

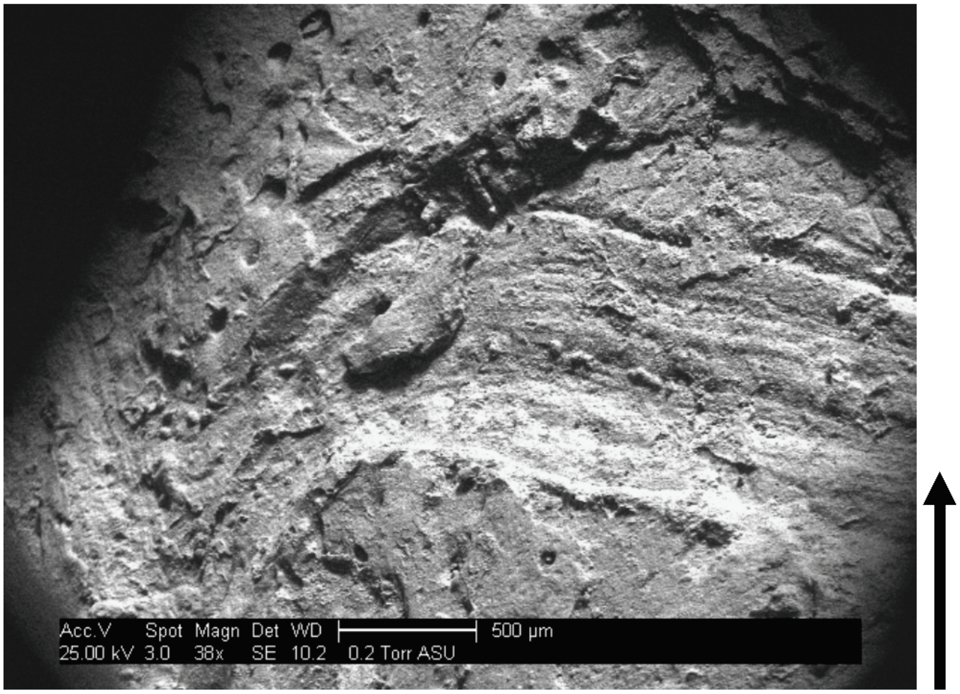


Supplementary Figure 13. Overview of cortical surface of DIK-55-3. Each of the marks referred to more specifically in the main text and below is indicated here. The black arrow points to the proximal end.

Supplementary Figure 14. Overview of medullar (internal) surface of DIK-55-3.

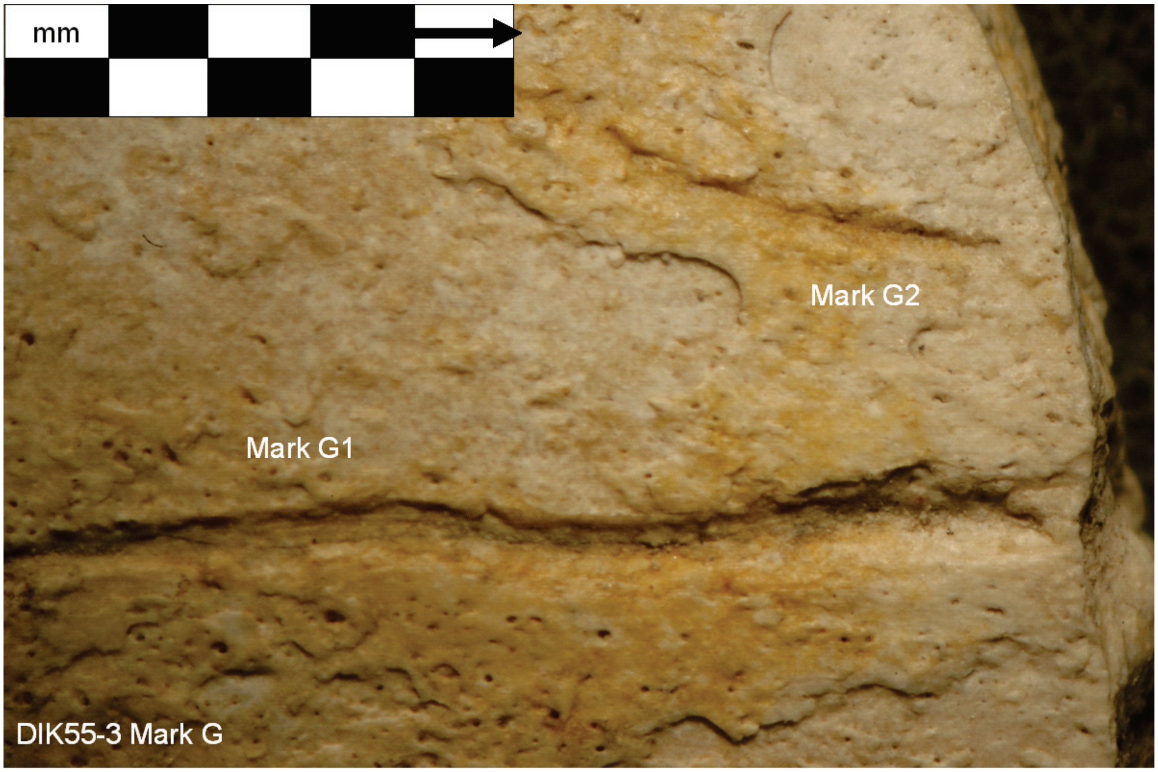
Supplementary Figure 15. DIK-55-3 Mark B and C - These are connected and could be one mark. To the proximal end there is a distinct V-shaped mark. Micro-striations are evident. This is a high confidence stone tool inflicted mark that appears to include both cutting and percussion. The black arrow in the scale points to the proximal end.

DIK55-3 Mark D Medial Side



Supplementary Figure 16. ESEM of Mark D - This ESEM image is a continuation of Figure 3f in the main text. The black arrow points to the proximal end.

Supplementary Figure 17. DIK-55-3 Mark F - This mark is shallow and has three shoulders. Micro-striations are throughout the mark. This is a high confidence stone tool inflicted mark that is almost certainly a cutmark. The black arrow in the scale points to the proximal end.



Supplementary Figure 18. DIK-55-3 Mark G1 and 2 - There are 2 marks at this location, both linear in shape and running longitudinal to the long axis of the bone. The longer of the two, G1, has micro-striations within it. The far distal end of G1 intersects with Mark D. As discussed above, CWM diagnosed G1 as a cutmark while SL and JT considered it unidentifiable. All analysts classified G2 as unidentifiable, however its parallel proximity to G1 suggests it is associated with that mark and thus could also be a cutmark. The black arrow in the scale points to the proximal end.

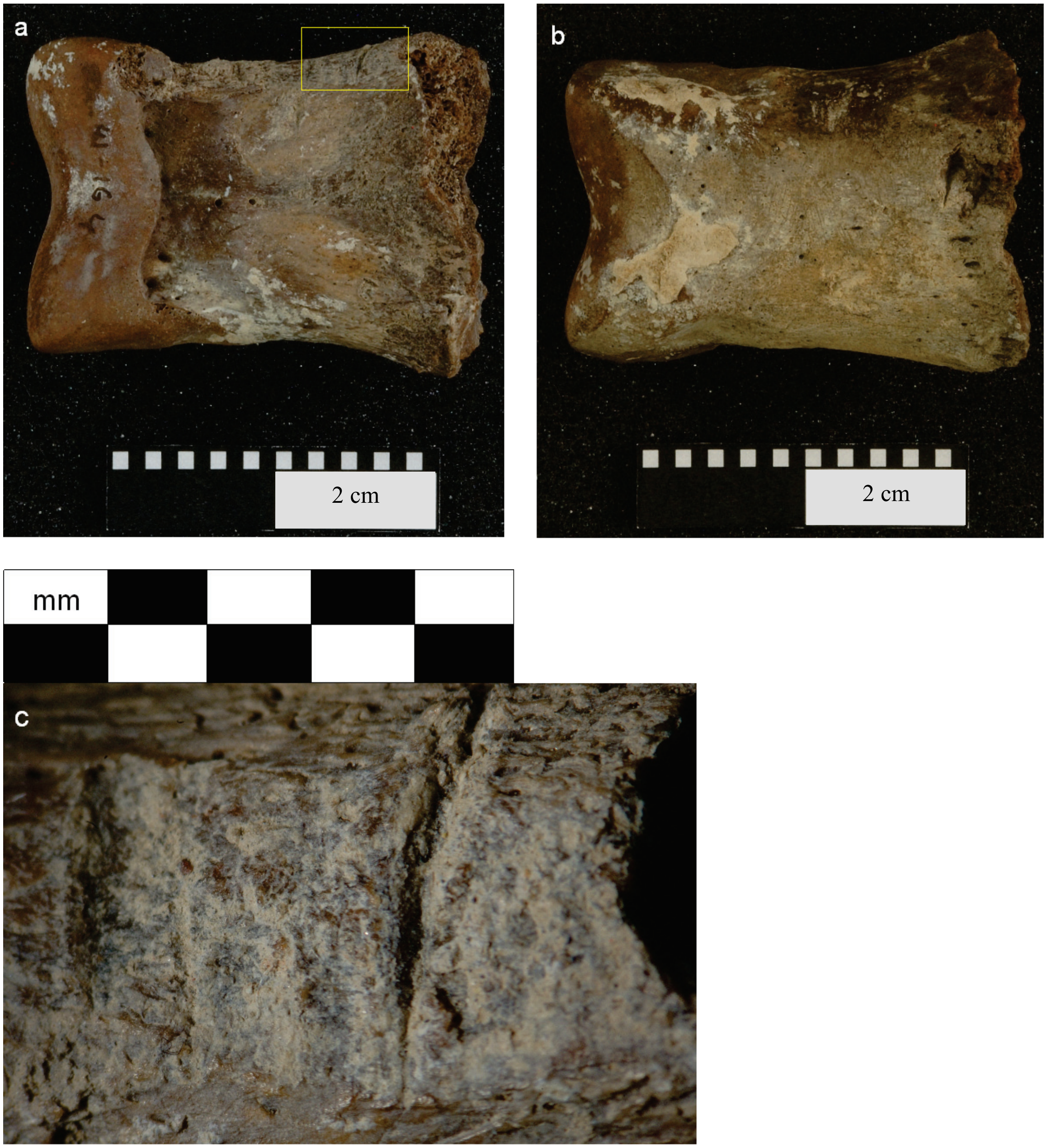
Supplementary Figure 19. DIK-55-3 Mark J - This mark intersects the break across the proximal shaft. It compresses the cortical bone surface, and there are very faint micro-striations in it. However, the curving nature of the mark is also consistent with carnivore tooth marking, and therefore the mark is difficult to diagnose and the causal agent is unclear. The black arrow in the scale points to the proximal end.


mm
DIK55-3 Mark I Posterior
mm
DIK55-3 Mark I Medial

Supplementary Figure 20. DIK-55-3 Mark I - This mark is unusual in that it does not fit perfectly with any of our experimentally produced marks. Micro-striations are evident, particularly just below the steep shoulder. The mark is relatively deep, and there is some compression of the bone, suggesting a percussion action. But it also has features suggestive of cutting, such as its long straight shape. It is a high confidence stone tool inflicted mark, and includes features suggesting both cutting and percussion. The arrow indicates the proximal end.

Supplementary Figure 21. DIK-41-133. Bovid calcaneum, medial view. There is no stone tool inflicted surface modification on this specimen. The black arrows indicate some exfoliation perpendicular to the long axis of the bone.

Supplementary Figure 22. DIK-41-133. Bovid calcaneum, lateral view. There is no stone tool inflicted surface modification on this specimen. The black arrows indicate some exfoliation perpendicular to the long axis of the bone.



Supplementary Figure 23. DIK-41-164. Equid phalanx. a) posterior view, b) anterior view, and c) close-up of mark indicated with yellow rectangle in a). There is no high confidence stone tool inflicted mark on this specimen. The indicated mark is unidentifiable.

5. Acknowledgements

CWM and HAB acknowledge the valuable assistance of the Research Professionals in the John M. Cowley Center for High Resolution Electron Microscopy, LE-CSSS, ASU in conducting the E-SEM imaging, and Jessica Thompson and Sarah Lansing for participating in the blind test. The authors gratefully acknowledge the use of facilities in LeRoy Eyring Center for Solid State Science at Arizona State University. Partial funding for the ASU analyses was provided by the Hyde Family Foundation.

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