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Can Experimental Archaeology Confirm Ethnographic Evidence? The Case of Aboriginal Boomerangs Used as Retouchers

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In this article, an experimental programme is used to examine how boomerangs may be used to retouch stone tools. The programme's findings confirm ethnographic data pertaining to the employment of hardwood boomerangs in retouching activities and investigate their technological similarities to Palaeolithic bone retouchers. For the first time, the use-wear produced on boomerangs during retouching is defined and added to a reference collection. This information

may be used in future studies to identify one of the many functions of boomerangs stored in museum collections in Australia and other parts of the world.

> Boomerangs are seen as very adaptable tools among Aboriginal cultures, used not just for hunting but also for a variety of utilitarian activities in daily life such as chopping, digging, making fire, and even playing music. Although ethnographic evidence supports the majority of these functions, the idea of the boomerang's multifunctional nature is rarely studied as a stand-alone issue in archaeological or anthropological research...

Introduction

Although the multipurpose nature of boomerangs is well-established in Australian Aboriginal traditional knowledge, archaeologists and ethnographic researchers have paid little attention to this (Mountford, 1941; McCarthy, 1961; Pahlow and Silady, 1986; Akerman, 1998; Jones, 2004; Hayes et al., 2014). A review of the literature on Aboriginal tools and technologies revealed that most previous boomerang-focused papers concentrated on the aerodynamic features associated with the boomerang's ability to return. Non-returning boomerang's technological and functional characteristics, including their usage as retouchers, are only mentioned in passing in wider accounts of Indigenous Australian lives and everyday activities, for example, woodworking. As a result, the extraordinary variety of non-returning boomerangs is generally overlooked.

A boomerang is composed of two arms, or wings, converging at the point of maximum curvature known as the elbow. The morphological classification of boomerangs considers the angle formed by the elbow and the length of each arm. If the arms are of equal length, the boomerang is categorised as symmetrical (i.e., returning boomerangs); if the lengths differ, it is considered asymmetrical (i.e., non-returning boomerangs). Despite the returning boomerang's widespread recognition in the public imagination, in the real lives of Aboriginal communities, they represented a small percentage of functioning tools. Returning boomerangs were primarily used for recreation or as practice tools. In contrast, non-returning boomerangs were the predominant morphology used across Aboriginal communities in Australia. These multipurpose tools served various functions, including hunting large prey like kangaroos, as well as tasks such as digging, creating fire, and producing music (Martellotta, Brumm and Langley, 2022).

During the second half of the twentieth century, anthropological studies on boomerangs appear to have stagnated in terms of establishing techniques for their research. Although early ethnographic literature contributed to contemporary understanding about boomerangs, it may be argued that they are now less appropriate for contributing to a broader and more scientific approach to ancient technology. Davidson's 1936 book, however, remains the most complete research of boomerangs, with the author himself finishing his article by expressing the need for a more technologically oriented approach to boomerangs rather than a typological one (Davidson, 1936, p.90).

The lack of research into boomerangs in recent decades is a significant concern given how far ideas and methodologies for studying ancient technology have progressed over at least the previous 30 years. Boomerangs have only been the subject of infrequent classifications over this time period (Jones, 2004; Bordes, Lefort and Blondel, 2015; Bordes ,2021) or had a minor part in experimental programmes (Moore, 2004; Bordes, Lefort and Blondel, 2015). Finally, they were mentioned when rare boomerang archaeological remnants were discovered (Langley et al., 2016; Roberts et al*.,* 2021). This approach has understated the importance that these tools have played, and continue to play, in Aboriginal Australian society.

In this paper, an experimental procedure for demonstrating the efficacy of boomerangs as lithic tool retouchers is described. There is no previous methodological foundation for this investigation since no experimental practises have been used on boomerangs in this manner. The anthropological literature, on the other hand, reveals a technical similarity with Palaeolithic bone retouchers (for references and discussion, see Martellotta, Brumm and Langley, 2022). Traceological studies for bone retouchers are many and widely available, and they provide an excellent starting point for describing retouch-induced use-wear on boomerangs.

Experiment Objectives

The key objective of the experimental programme was to demonstrate how to utilise hardwood boomerangs as retouching tools and to detect typical use-wear.

There were two major questions to address:

1. What factors influence the usage of boomerangs to retouch lithic tools?
2. How does the observed use-wear relate to that of bone retouchers?

The replica boomerangs are predicted to be able to generate intensely polished lithic flakes, mirroring morphologies documented in the archaeological record. One of the expected outcomes of the experiment is the development of a comprehensive description of retouch-induced use-wear on boomerangs. Based on the literature review, similarities in morphology, distribution, and internal cross-section were predicted to be identified between the impact traces of bone and boomerang retouchers.

This study adds to the approaches used in the traceological study of boomerangs, which had thus far received just a cursory examination (Langley et al*.,* 2016; Bordes, 2021; Roberts et al,*.* 2021). Furthermore, these results might be utilised as a reference in the research of technological similarities between osseous and wooden tools in Aboriginal Australia and Palaeolithic Europe archaeological studies.

Materials and Methods

The experimental programme includes two retouching sessions: one with boomerangs and one with bone retouchers as a control group for traceological investigation. Both sessions were documented in text, pictures and footage. The operators were asked to provide the following information:

1. Level of comfort in grasping and using the retouching tool.
2. Technical objectives, that is, the goal of retouching.
3. Problems encountered during the retouch activity.
4. Solutions offered by the operator to complete the retouch objective.

Flintknapping Supplies (https://flintknappingsupplies.com/) supplied two cobbles of Texas chert from Meadville (Pennsylvania, USA) to make the experimental lithic flakes utilised in this work.

The petrographic and lithological properties of the lithic raw material are comparable to flints recovered from Palaeolithic European sites and some of the finer cherts reported in Australian settings. Although the Australian continent has a wider lithological variation, the experiment is confined to only one kind of lithic raw material to minimise extraneous variables interfering with the use-wear study on the boomerangs.

Following the retouching sessions, the resultant use-wear was examined and compared using R software to create a database and perform simple statistical analyses (R Core Team, 2017). Photographs and videos of the experimental materials and sessions were taken with a Canon PowerShot SX400 IS digital camera, a GoPro HERO7 White camera (v.02.10), and a GoPro HERO7 Black camera.

The experimental osseous and wooden tools were studied using low-to-high-powered magnifications of the use areas under an Olympus DSX10-UZH optical microscope, alternating the use of three lenses (DSX10-SXLOB plan 1x/0.03, DSX10-SXLOB plan 3x/0.09, and DSX10-XLOB plan FL 10x/0.30). For each morphological type of impact traces, micrometric 3D scans were conducted. The use of 3D imaging microscopy allows for the identification of morphological traits that aid in the definition of the morphology of impact traces on boomerangs used for lithic tool retouching. The photographs were taken with the Olympus DSX1000 software (v. 1.1.5.13).

The 3D pictures were analysed using the following criteria: cross-section, depth, cross-section internal area measurement, length for linear impressions, and surface and perimeter for punctiform impressions. The interior area of single cross-sections of markings was measured; the sections are obtained by slicing the 3D scan of the mark and moving a plane along its primary axis, capturing each section at regular intervals. Due to the great morphometric variability of the traces, the number of sections required is determined by the size and form of the markings.

Using Boomerangs for Retouching Tasks

In this experiment, four hardwood boomerangs were utilised, each labelled with the letter 'B' and a sequential number. Two competent Indigenous Australian craftspeople created these tools.

1. Paul Craft, a Birrunburra Bundjalung Yugambeh Yuggera Turrbal man from South-east Queensland and North-east New South Wales, handmade B1 and B2. The terms for a returning (symmetrical) boomerang in this area's indigenous language are 'bargan' or 'burragunn', but the asymmetrical variety is called 'baring'. B1 (See Figure 1a) is a symmetrical boomerang composed of black wattle wood (*Acacia mearnsii*) and covered in acrylic paint. The paint was scraped from one area of the boomerang's surface to see if it interfered with the observation of retouch-induced use-wear. B2 (See Figure 1b) is a varnished asymmetrical boomerang (or hunting boomerang) constructed of ironbark wood (*Eucalyptus* sp.). B1 and B2 both have a plano-convex cross-section.
2. Millmullian – Laurence Magick Dennis, a Wailwaan and Yuin man from New South Wales's south-east, created B3 and B4. 'Bubarra' (Gamilaraay/Yuwaalaraay language), 'garrbaa' (Wiradjuri language), and 'biyarr' (Wailwaan language) are the traditional terminology for 'hunting boomerang' in this area. B3 (See Figure 1c) and B4 (See Figure 1d) are asymmetrical boomerangs made of mulga wood (*Acacia aneura*) with a vegetable-based oil finish and a bi-convex cross-section.

The first retouching session was carried out at the Griffith Experimental Archaeology Research Facility (GEAR) by an experienced knapper using the four boomerangs. The operator wanted to create flakes that may be used for cutting or scraping, inspired by retouched tools from Australian archaeological and anthropological evidence. Each boomerang retouching action lasted two minutes on average, with a minimum of six and a maximum of 145 blows delivered (average=86 blows). The average thickness of the boomerangs, in accordance with the usage regions, is 13 mm (average=0.7), whilst the radius of the arch is 7.4 mm (average=0.98).

The operator performed percussion retouch with boomerangs using an elliptical trajectory, with a tangential point of contact between the wooden surface and the lithic edge (See Figure 2), based on the technique used for the bone retouchers and the literature-based evidence for boomerangs used in retouching activities. Despite using the same approach as bone retouchers, the ellipse of the trajectory used in this session appeared to have a smaller diameter. As a result, the movement applied followed a more circular trajectory compared to the use of bone retouchers.

Boomerang 1's surface was explored in four areas, each of which was used to retouch one lithic flake (See Figure 3). Three of these usage zones are towards the tip of the arm, whereas the fourth is in the centre of one of the arms. With approximately 100 strikes, all usage areas are utilised.

The original artist painted Boomerang 1, and for the experiment, this paint was scraped away with sandpaper before the session, although just in use area 3. The use area 1 retouched flake has paint remnants on its ventral surface.

The fourth use area is between the elbow and the tip. The previously used movement was judged undesirable while using this area of the boomerang's surface since it hurt the operator's thumb, which they use to steady the lithic flake. As a result, the operator altered the retouching action, continuing an elliptical trajectory but aiming for a contact point more parallel to the lithic edge. According to the operator, this adjustment allowed for a more comfortable and balanced hold of the boomerang. The flake retouched with usage area four satisfied all of the operator's technical requirements.

Boomerang 2 was used on four different parts of its surface, all towards the tips (See Figure 4). The number of strikes varied from 26 to 129, with each use area being utilised for an average of two minutes. The retouched flake shattered after 129 strikes during the exploitation of use area two. It was nonetheless regarded satisfactorily retouched according to the operator's technical aims. Finally, because the retouched flake does not require significant retouch activity, the exploitation of use area four finishes after 26 strikes.

Except for use area three, which is placed on the centre region of the arm, Boomerang 3 is the only boomerang that is utilised on five different areas of its surface, all of which are near the tips (See Figure 5). As with Boomerang 1, while employing the piece of the boomerang's surface between the elbow and the tip, the operator had to aim for a parallel contact point. Each retouch activity lasted around two minutes on average, and the number of strikes ranged from 50 to 145.

Boomerang 4 was used on four different parts of its surface, all of which were close to the tips (See Figure 6). Each retouch activity lasted two minutes on average, with a minimum of six and a maximum of 80 strikes. The activity was terminated after six blows during the exploitation of use area three because the flake was considered inappropriate for retouching due to the working edge becoming excessively obtuse. It was decided here to regard use area 3 of the Boomerang 4 as a short retouching dataset, possibly associated with a resharpening activity, rather than starting a fresh retouching activity involving the same use area.

Bone Retouchers as a Control Group

Fourteen bone blanks were made from the forelimbs and hindlimbs (N=8) of two sub-adult female *Bos taurus* individuals and used as retouchers. Of these tools, six were constructed on tibias, with a lesser percentage manufactured on femurs (N=4), humeri (N=3), and radii/ulnae (N=1).

Inspired by retouched tools from Palaeolithic sites, for instance, Discoidal and Quina Mousterian, the operators attempted to make flakes that they considered would be practical for cutting or scraping tasks. The retouching was done using a percussion action that follows an elliptical trajectory with a tangential point of impact.

The operators were not limited by time, or the quantity of blows hit with the retoucher; each activity tried to retouch the flake's edges to the operator's arbitrary satisfaction.

On average, each retouching action lasted two minutes. The number of strokes per retoucher ranged from a minimum of four to a maximum of 189 (mean=52). On seven retouchers, only one portion of the bone surface was employed; two portions were used on six retouchers; finally, one retoucher was exploited in three portions of its surface.

Results

Measurements of Use Areas

On the experimental boomerangs, the morphological types of retouch-induced impact traces commonly found on Palaeolithic bone retouchers were discovered (See Table 1); 3D analysis of single impact traces revealed similarities between osseous and wooden retoucher samples.

Tool ID	Knapper	N. of blows	Length use area (mm)	Width use area (mm)	Surface use area (mm2)	Circumference use area (mm)	Linear impressions	Punctiform impressions	Striations	Notches	Scraping marks	Intensity	Average Length Linear I. (mm)	Average Surface Punctiform I. (mm2)	Avg. Circumference Punctiform I. (mm)	Retouched flake ID
B1_1	Y.L.P.	109	34.13	33.74	824.26	211.61	265	13	0	2	yes	S	1.53	0.13	1.42	F56
B1_2	Y.L.P.	98	27.61	23.38	508.28	114.88	219	67	0	0	no	C	1.09	0.04	0.67	F59
B1_3	Y.L.P.	105	44.5	35.4	1047	224	211	43	0	3	no	C	2.18	1.21	1.42	F51
B1_4	Y.L.P.	103	97.2	38	2193	400.7	264	46	5	2	yes	D	1.64	0.17	1.48	F90
B2_1	Y.L.P.	104	58.5	34	1342.8	334.5	347	109	1	2	yes	C	1	0.03	0.66	F100
B2_2	Y.L.P.	129	41.6	41.2	952.5	257.3	353	112	1	2	yes	C	1.38	0.04	0.76	F71
B2_3	Y.L.P.	69	46.5	27.9	974.4	268	427	97	1	2	yes	S	1.16	0.03	0.67	F17
B2_4	Y.L.P.	26	32.3	30.8	500.2	230	277	76	1	1	yes	C	1.1	0.04	0.81	F83
B3_1	Y.L.P.	63	29.1	19.3	319.2	149.3	257	67	2	2	yes	C	1.34	0.09	1.09	F36
B3_2	Y.L.P.	81	35.9	21.8	457.7	234	559	70	2	0	yes	C	0.83	0.05	0.88	F73
B3_3	Y.L.P.	50	96.9	19.7	1121	435.4	309	112	1	0	yes	D	0.98	0.04	0.79	F03
B3_4	Y.L.P.	145	50.9	29.3	811.7	271.7	452	209	6	1	yes	C	1.19	0.06	0.91	F76
B3_5	Y.L.P.	61	29.4	43.7	721	250.5	319	111	0	2	yes	S	1.2	0.06	0.91	F40
B4_1	Y.L.P.	29	36.4	23.4	487.5	217.4	450	89	2	2	yes	C	1.2	0.06	0.91	F60
B4_2	Y.L.P	45	41.1	21.1	464.7	221.9	491	171	3	1	yes	C	0.96	0.04	0.79	F35
B4_3	Y.L.P.	6	39.3	36.7	606.7	311.7	694	173	4	0	yes	D	1	0.05	0.83	F81
B4_4	Y.L.P.	80	32.2	31.8	575	203.7	467	86	2	0	yes	C	0.88	0.04	0.76	F41
R1	Y.L.P.	136	25.9	21	366.4	92.1	114	18	0	1	yes	S	1	0.07	1.04	F07
R6_1	Y.L.P.	28	25.9	10	165.3	80.7	249	38	0	1	yes	S	1	0.04	0.79	F74

R6_2	Y.L.P.	61	52.9	12.9	276.1	125.9	106	7	0	2	yes	S	1.3	0.08	1.06	F74
R7_1	T.R.M.	7	12.3	30	157.2	88.2	14	0	0	0	no	D	1.5	0	0	F37
R7_2	T.R.M.	53	39.6	20.7	397.6	133.8	118	8	0	0	no	S	1.3	0.11	1.25	F37
R8_1	Y.L.P.	189	7.9	6.1	237.4	22.9	165	13	2	3	yes	C	1	0.06	0.9	F50
R8_2	Y.L.P.	9	29.3	22	362	103.7	31	0	0	0	no	C	0.9	0	0	F50
R9	T.R.M.	59	43.4	20.6	529.1	201.9	432	69	4	4	yes	S	0.9	0.05	0.83	F55
R10_1	T.R.M.	4	25.2	26.2	249.7	93.6	31	27	0	0	no	D	1	0.06	0.9	F78
R10_2	T.R.M.	46	16.4	16	131.9	57.8	9	0	0	1	no	C	1	0	0	F78
R11_1	T.R.M.	12	17.6	29.6	285.9	85.7	4	0	0	1	yes	I	1.6	0	0	F54
R11_2	T.R.M.	25	21	28	245.1	71.1	21	0	1	0	no	D	1.3	0	0	F54
R11_3	T.R.M.	31	11.7	13.4	771.4	43.4	28	0	1	1	no	C	0.8	0	0	F54
R12	Y.L.P.	50	38.2	29	650.6	116.9	154	7	2	1	yes	S	1.5	0.04	0.77	F47a
R15_1	Y.L.P.	27	32.9	25.9	426.3	102.3	43	31	1	0	yes	C	1	0.03	0.68	F06
R15_2	Y.L.P.	76	12.8	24.3	114.2	74.8	23	11	0	0	no	D	0.9	0.04	0.82	F06
R17	T.R.M.	63	39.2	23	274.1	108.4	42	12	0	0	no	C	1	0.04	0.74	F05
R18	T.R.M.	9	21.2	16.3	176.7	103.8	79	6	1	0	yes	D	1.1	0.03	0.64	F25
R19_1	T.R.M.	28	25.6	22.2	254	95.1	45	0	0	0	yes	D	0.8	0	0	F58
R19_2	T.R.M.	25	21.5	15.9	151.8	67.1	51	0	1	1	yes	D	0.8	0	0	F58
R20	Y.L.P.	100	36.6	22.6	375.4	154.4	148	5	0	1	no	C	1	0.05	0.86	F30
R21	Y.L.P.	118	36.4	25.1	448.6	128.3	208	4	2	2	yes	C	0.8	0.04	0.76	F39

TABLE 1. ANALYSIS OF THE USE AREAS PRODUCED IN THE EXPERIMENTAL SESSIONS. MULTIPLE USE AREAS ON THE SAME TOOL ARE INDICATED WITH A LOW DASH SYMBOL AND ASCENDING NUMBER FOLLOWING THE TOOL ID (EXAMPLE: B1_1). 'NA' STANDS FOR "NOT APPLICABLE'. IN THE 'INTENSITY' COLUMN, 'C'='CONCENTRATED', 'SP'='SUPERIMPOSED', 'D'='DISPERSED', 'I'='ISOLATED'.

The measurements of the usage regions were more consistent on boomerangs and less consistent on bone retouchers; it appears that use areas on boomerangs are larger than those on bone retouchers. This disparity might be attributed to the size difference between boomerangs and bone retouchers: boomerangs have more surface area, which results in a greater number of alternatives for flaking surface intersections, that is, bigger use areas. The average surface of use area reported on bone retouchers is 300 mm2, but boomerangs had use areas ranging from 500 to 1000 mm2 in their extension. Similarly, use areas for bone retouchers average 100 mm2 and 200 mm2 on boomerangs.

The impact of profound structural variations between osseous and wooden materials cannot be ruled out. Additional mechanical and physical testing should be carried out to resolve this issue.

Impact Traces: Morphology and Features

The intensity of the retouch created on bone retouchers indicated that concentrated (36%; N=8) and dispersed (32%; N=7) patterns are the most typically found, with 27% (N=6) of the use wear superposed and 5% (N=1) found in isolated distributions. The majority of use areas on boomerangs are concentrated (65%; N=11), followed by dispersed (18%; N=3) and then superposed (18%; N=3) patterns. On the used boomerangs, no isolated use areas were seen.

Although this finding might be understood as a difference in intensity and distribution of use-wear between bone and boomerang retouchers, it is important to note that retouching session one featured two operators, whereas session two had just one. The presence of numerous individuals involved in the experiment appears to alter the intensity of retouching, possibly representing the various approaches of separate operators.

The impact traces revealed that the four morphological groups previously established on ancient bone retouchers were also present in the experimental boomerangs' use areas. The 3D analysis allows for a comprehension of these parallels. Linear impressions on bone retouchers have an extended form and an asymmetrical V-shaped profile that deeply penetrates the osseous surface. The same diagnostic traits may be found on the boomerang's surface: deep, elongated usage marks defined as linear impressions with an asymmetrical V-shaped profile (See Figure 7).

Punctiform impressions (shallow, circular depressions with a typically U-shaped cross-section) are evident on the experimental bone retoucher sample, as well as on boomerang usage regions. Most of the latter are shallow, but others can penetrate deeper through the hardwood surface (See Figure 8).

The traceological investigation reveals that linear imprints predominate on both bone retouchers and boomerangs, accounting for 88% and 78.9% of the total discovered impact traces, respectively (See Table 1). Punctiform impressions account for 11% of the detected impact traces on bone retouchers and 20.47% of the identified impact traces on boomerangs.

The third type of retouching use-wear discovered are notches. They account for 0.8% of overall use-wear on bone retouchers and 0.27% of total use-wear on boomerangs.

Bone retouchers have a disorganised distribution of notches that penetrate the bone surface. Notches are also common on boomerangs, with this kind of use-wear having an uneven profile due to the repetitive stacking of different impact traces. Indeed, 3D research indicated that notches are created by superimposing multiple linear and punctiform imprints that interact and obliterate each other (See Figure 9).

Previous experimental research on the usage of bone retouchers discovered a very varied relationship between the number of strikes and the presence of impact marks. Since such proportions never reflect complete equivalence (that is, 1 blow = 1 mark), accessing retouch activity is subject to several factors.

The findings of this experiment, however, show a link between the number of strikes and the dimension of the notches. For example, Boomerang 3 use area 4 has a single, long notch and the largest number of blows (145). The presence of linear marks is minimal in this usage area. In contrast, notches are absent or less prolonged in use areas generated by a lesser number of strikes (for example, Boomerang 4 use area 3), and linear imprints and striations are more prevalent. As a result, the existence of a negative proportional association between linear impressions and notches specified by retouch intensity may be tested.

Striations (See Figure 10a) are the fourth morphological group related with retouch action. They can be found in 0.6% of bone retoucher usage regions and 0.3% of boomerang use areas. These markings are small and shallow, and they are frequently clustered and parallel to one another.

Finally, scraping marks (See Figure 10b) were found on both bone retouchers and boomerangs in considerable quantities. They are related with 12 (55%) of the usage regions on 10 bone retouchers and 88% (N=15) of the use areas on boomerangs. Scraping marks are shallow and lengthy in nature, and they frequently interact with other impact traces. They cover a larger area of usage than other markings.

The experiment also revealed distinctive markings on use areas of boomerangs that are rarely seen on bone retouchers. Some of these marks (See Figure 10c) appear as small detachments of a thin layer of wood surface in correspondence with linear impact traces (Boomerang 3 use area 3); their characteristics are similar to 'peeling' marks observed on broken bones (Fernandez-Jalvo and Andrews, 2016), or weathered bones used in knapping activities (Mallye et al*.,* 2012; Doyon et al*.,* 2018). Additionally, certain small, shallow, and parallel markings were discovered that extend perpendicularly from the borders of the linear imprints (See Figure 10d) and defined as 'tool-edge scratches' (Bello et al*.,* 2021).

Finally, a large number of stone micro-flakes (visible only under magnification) were discovered embedded in the impact traces (See Figure 10e), in both linear and punctiform imprints. Each boomerang usage region had an average of 60 micro-flakes, which were also seen on the experimental bone retouchers (See Figure 10f).

Discussion

This study's experimental programme completes a circle of relevant anthropological evidence supporting the usage of hardwood boomerangs as retouchers. The programme's two key goals were met. First, the research shows that boomerangs may be used successfully as retouchers. Secondly, that their usage as a retoucher produces use-wear similar to that seen on bone retouchers.

The functionality of the boomerang as a retouching tool is defined by:

1. the description of the obtained retouched lithic edges,
2. operator feedback on effectiveness and comfort,
3. traceological similarities between retouch-induced impact traces observed on boomerangs and bone retouchers.

Boomerangs Used as Retouchers: Confirming Literature Evidence through an Experimental Programme

This investigation proved that boomerangs are efficient instruments for retouching lithics from a practical standpoint, which supports the short descriptions in the literature.

The lithic edges retouched during the experiment revealed characteristics compatible with the sort of retouch sought by the operator, whose favourable comments suggested that they found the boomerang easy to handle during the retouching procedure. Both experimental retouching sessions 1 and 2 met their technical goals, proving that hardwood boomerangs and bone pieces perform similarly in retouching tasks. The operators' technical goals for retouched lithic edges included the creation of retouched lithic instruments appropriate for scraping or cutting actions. The end products closely resemble the retouched lithic artefacts recovered accompanying bone retouchers at several archaeological sites.

Ethnographic evidence may give relevant insights regarding the shape of the retouched flakes. Detachments on retouched lithic edges are characterised in the literature as "miniature flakes...broken off" from the edge itself (Mountford, 1941, p.315). This definition corresponds to the micro-flakes which separated from the experimental lithic flakes, actively contributing to the formation of use-wear. Another line of evidence also characterised the lithic edge polished with the boomerang as "a regular series of tiny semicircular stepped flake scars" (Tindale, 1965, p.135). This description is similar to the retouched lithic edges made in the experiment and recovered from archaeological sites, all of which had stepped and scaled retouch scars.

In this study, it was demonstrated that the movement involved in employing boomerangs as retouching tools is comparable to that reported in previous bone retouching research. The action needs a percussive movement along an elliptical trajectory, with the retoucher's surface making tangential contact with the lithic edge. There are subtle distinctions between boomerangs and bone retouchers in the extent of the elliptical trajectory, with the former having a slightly smaller diameter of the ellipse than the latter. This difference can be related to boomerangs' bigger size and weight, which has a stronger effect on the percussion action performed. The knapper's capacity to execute retouch and the consequent use-wear were unaffected by the variation in boomerang movement. The most comfortable posture for using a boomerang as a retoucher, according to operator input, is to line the concavity generated by the elbow with the operator's trunk, allowing for a comfortable hold with the right hand (for right-handed knappers).

The percussive action used and observed throughout the experiment closely reflects the words used in anthropological literature to describe the movement involved in retouching with boomerangs ("to tap," "to strike"). References in the literature to the use of the flat surface of the boomerang in retouching (Roth, 1904, p.17; Tindale, 1965, p.136; Davis, 1979, p.55) were corroborated by the experiment.

Finally, this study demonstrated similarities in the grasping of boomerangs and bone pieces for retouching tasks which had been reported in the literature and validated throughout the experiment. According to the concept of retouching as a 'complex bi-manual action' (Mosquera et al., 2012; Uomini and Meyer, 2013), the right-handed operator holds the boomerang in their dominant hand and stabilises the lithic flake in the other. The lithic flake is held at an acute angle for successful retouching, supporting ethnographic evidence that Aboriginal knappers utilised comparable procedures.

The Implications of this Study for Archaeological and Ethnographic Research

Boomerangs are seen as very adaptable tools among Aboriginal cultures, used not just for hunting but also for a variety of utilitarian activities in daily life such as chopping, digging, making fire, and even playing music. Although ethnographic evidence supports the majority of these functions, the idea of the boomerang's multifunctional nature is rarely studied as a stand-alone issue in archaeological or anthropological research (McCarthy, 1961; Pahlow and Silady, 1986; Akerman, 1998; Jones, 2004).

The findings of this study help to expand the capabilities of boomerangs by adding stone tool retouching to the list of scientifically investigated uses of boomerangs. This research yielded a comprehensive reference collection of the use-wear developed on boomerangs throughout the retouching process.

The analysis of 3D pictures of use-wear revealed that percussion marks occur in comparable ways on both wooden and osseous retouching instruments. The experimental results on boomerangs and the extensive archaeological literature on bone retouchers in European contexts support this view. It adds to the ongoing discussion about the interchangeability of wood and bone as raw materials for toolmaking in ethnological and archaeological contexts (O'Connor, Robertson and Aplin, 2014). The experimental method proved that hardwood retouching tools may be just as effective as well-known bone retouchers. The link between Aboriginal technology and Palaeolithic data involving organic retouching tools has technological merit.

Considering the long-term diagenetic processes in Palaeolithic sites (for example, Aranguren et al., 2018; Conard et al., 2020), conducting experimental research into the functional aspects of hardwood boomerangs used as retouchers could be highly significant.

The findings reported here have several ramifications for the importance of wooden implements in ancient technology. In Palaeolithic archaeology, for example, there is relatively little evidence for wooden tools employed as percussors, although indirect evidence implies that organic tools were more common than they seem in the archaeological record (Gürbüz and Lycett, 2021). Wooden tools discovered from archaeological sites in Australia, on the other hand, are much uncommon due to the severe Australian weather conditions, although wooden artefacts from non-archaeological settings are numerous. As a result, a new technique is required to appraise these instruments and assess the quality of ethnographic data.

In addition, while boomerang-like tools are seldom found in the Palaeolithic record, they do exist, as discussed in Bordes, Lefort and Blondel (2015). The scarcity of these tools makes it challenging to definitively reconstruct their uses and functions. However, the methodology developed in this study can be extended and applied to these tools, offering a potential avenue to elucidate their role in Palaeolithic archaeology.

Future Directions and Conclusion

Now that the utilisation of boomerangs in retouching activities has been empirically proven, the next step will be to broaden the range of parameters in the experiment in order to completely understand the link between percussive movement, wooden surfaces, and the lithic edge. Investigating the influence of the operator in the distribution of impact traces and scraping marks, for example, by including additional operators with differing degrees of ability and experience in duplicating various lithic methods. To prevent compromising traceological comparisons, the current study only comprised two experienced knappers. When researching the human history, the knapper's abilities and learning processes should constantly be taken into account.

While previous research on bone retouchers has shown that different lithic raw materials have no significant influence on the features of the impact traces, it would be interesting to investigate if this holds true for wooden retouchers, or if a coarser-grained stone may impose some limitations on the retouching.

It is also worthwhile to investigate the functional consequences of utilising different hardwoods or even softwoods in the retouching process. Finally, recent research (Rots, 2010; Fasser, Fontana and Visentin, 2019) suggested ways for distinguishing between different types of soft hammers using lithic detachments and scars. As a result, incorporating timber refinishers in future experiments may be interesting.

Overall, full research is necessary to answer the issue of comprehending boomerang technology, which includes local Indigenous groups to appreciate the significance of these instruments in their own culture. To address gaps in the study of boomerangs in Australia, it is vital to collect as much knowledge on the background of these items as possible.

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Keywords throwing stick
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Gallery Image

FIG 1. EXPERIMENTAL BOOMERANGS. (A) B1; (B) B2; (C) B3; (D) B4. IMAGE BY EVA FRANCESCA MARTELLOTTA

FIG 2. ILLUSTRATION OF THE ELLIPTICAL PERCUSSION MOVEMENT APPLIED TO THE USE OF BOOMERANGS IN RETOUCHING ACTIVITY. IMAGE BY EVA FRANCESCA MARTELLOTTA

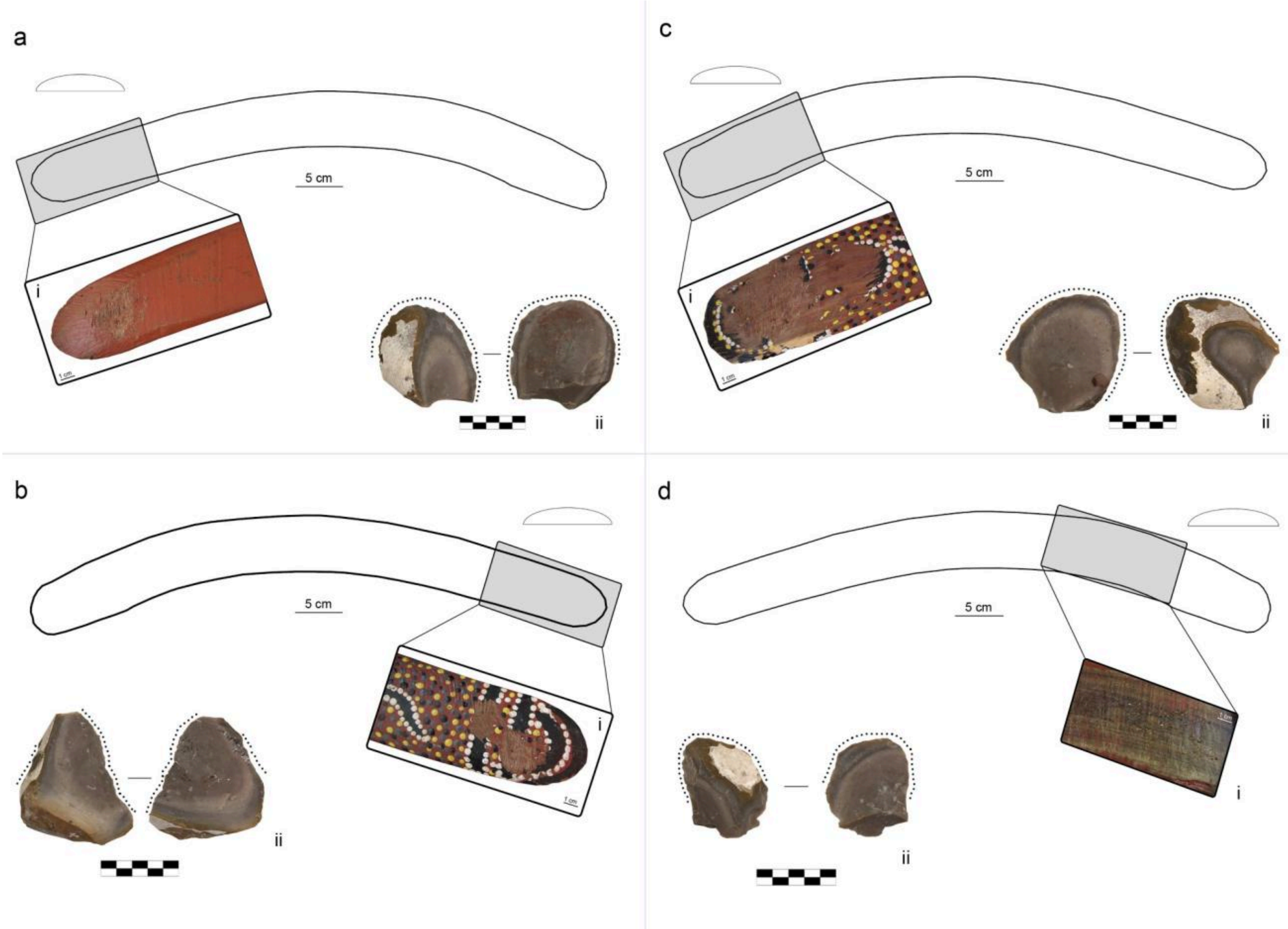

FIG 3. RESULTS OF EXPERIMENTAL RETOUCHING SESSION 2 ON BOOMERANG B1 (PLANO-CONVEX CROSS-SECTION AND LOCATION OF USE AREAS). (A) LOCATION OF USE AREA B1_1, (I) USE AREA B1_1 (1X), (II) RETOUCHED FLAKE F56; (B) LOCATION OF USE AREA B1_2, (I) USE AREA B1_2 (1X), (II) RETOUCHED FLAKE F59. (C) LOCATION OF USE AREA B1_3, (I) USE AREA B1_3 (1X), (II) RETOUCHED FLAKE F51; (D) LOCATION OF USE AREA B1_4, (I) USE AREA B1_4 (1X), (II) RETOUCHED FLAKE F90. IMAGE BY EVA FRANCESCA MARTELLOTTA

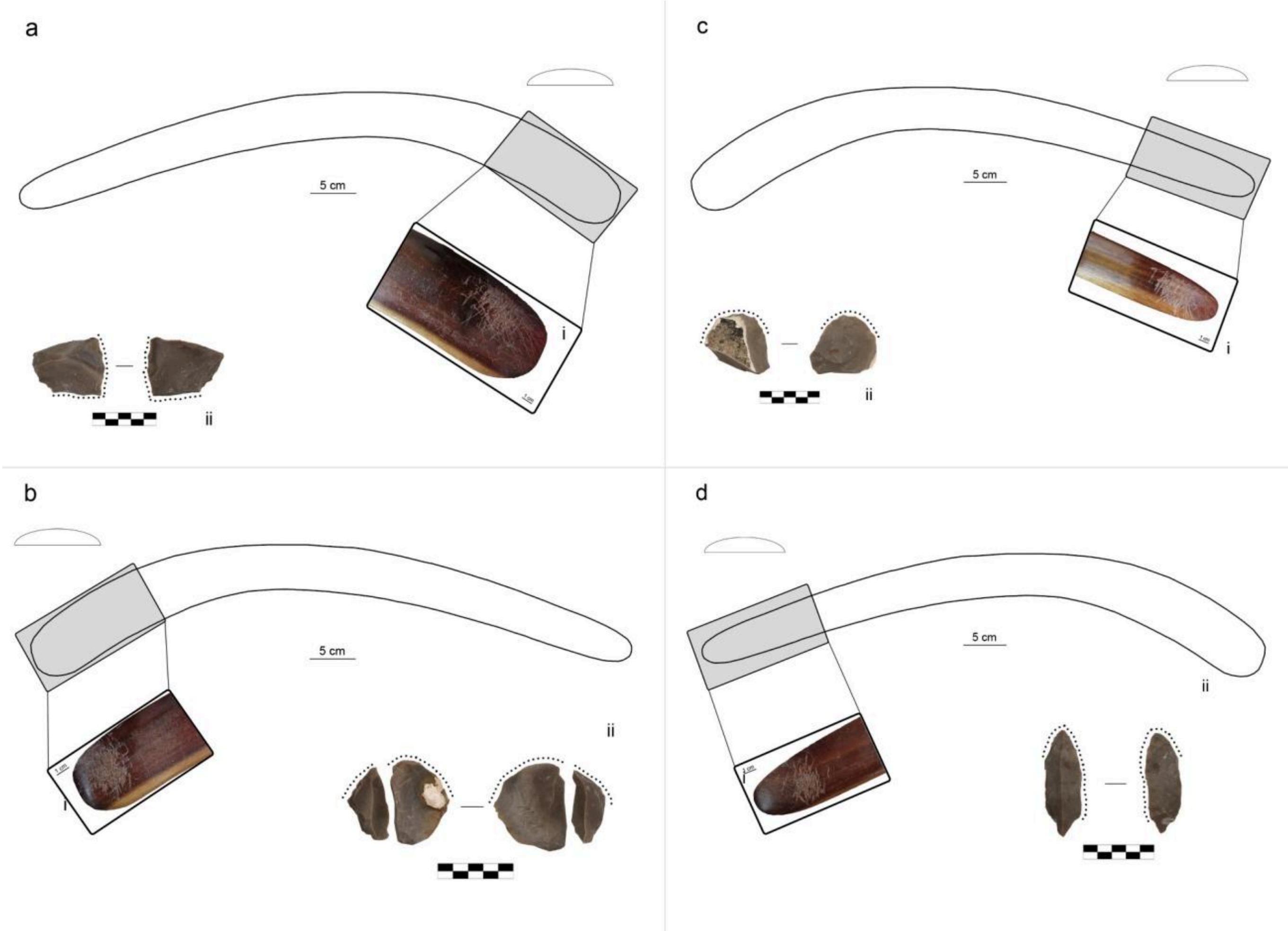

FIG 4. RESULTS OF EXPERIMENTAL RETOUCHING SESSION 2 ON BOOMERANG B2 (PLANO-CONVEX CROSS-SECTION AND LOCATION OF USE AREAS). (A) LOCATION OF USE AREA B2_1, (I) USE AREA B2_1 (1X), (II) RETOUCHED FLAKE F100; (B) LOCATION OF USE AREA B2_2, (I) USE AREA B2_2 (1X), (II) RETOUCHED FLAKE F71. (C) LOCATION OF USE AREA B2_3, (I) USE AREA B2_3 (1X), (II) RETOUCHED FLAKE F17; (D) LOCATION OF USE AREA B2_4, (I) USE AREA B2_4 (1X), (II) RETOUCHED FLAKE F83. IMAGE BY EVA FRANCESCA MARTELLOTTA

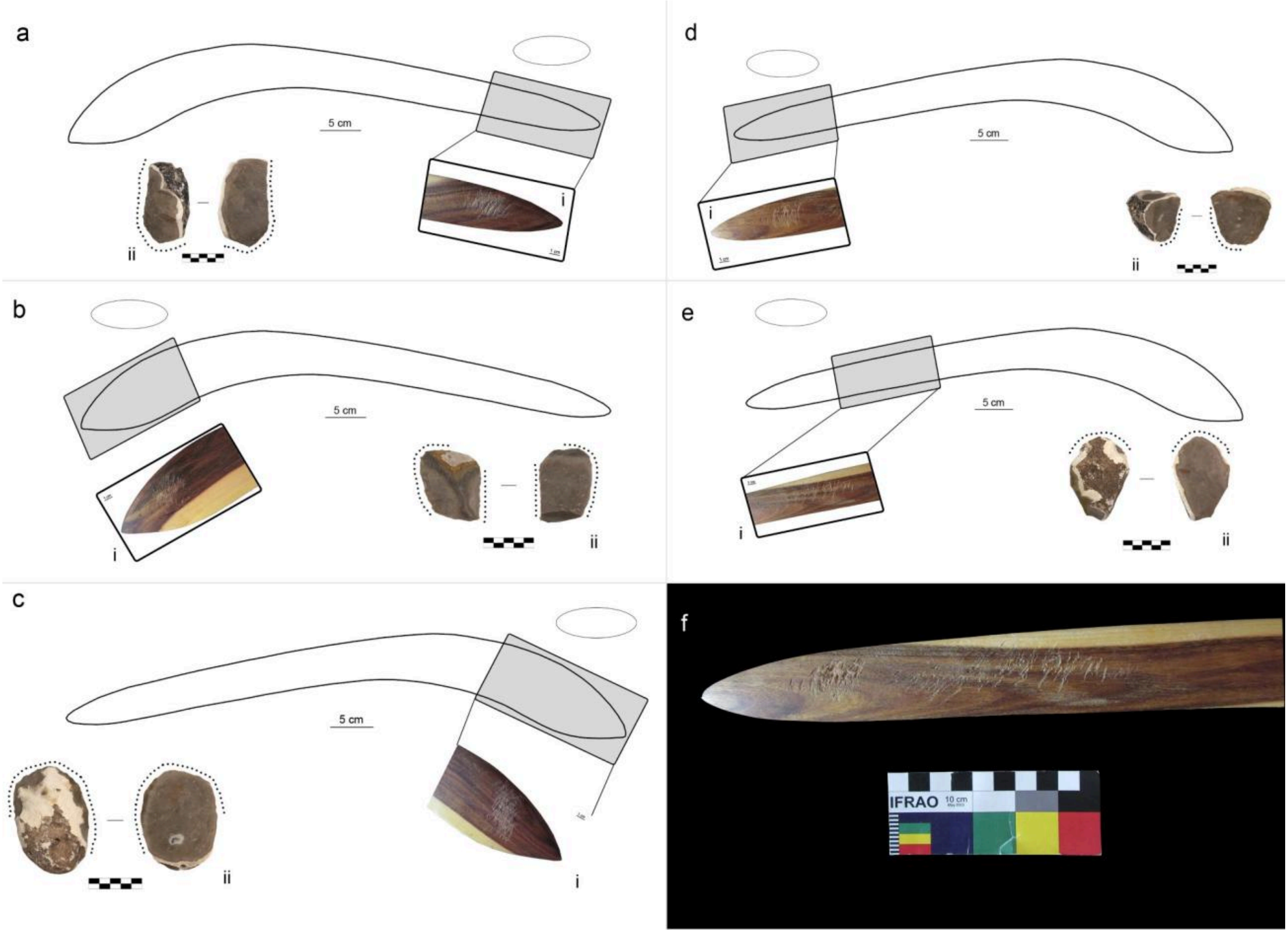

FIG 5. RESULTS OF EXPERIMENTAL RETOUCHING SESSION 2 ON BOOMERANG B3 (BI-CONVEX CROSS-SECTION AND LOCATION OF USE AREAS). (A) LOCATION OF USE AREA B3_1, (I) USE AREA B3_1 (1X), (II) RETOUCHED FLAKE F36; (B) LOCATION OF USE AREA B3_4, (I) USE AREA B3_4 (1X), (II) RETOUCHED FLAKE F76; (C) LOCATION OF USE AREA B3_5, (I) USE AREA B3_5 (1X), (II) RETOUCHED FLAKE F40. (D) LOCATION OF USE AREA B3_2, (I) USE AREA B3_2 (1X), (II) RETOUCHED FLAKE F73; (E) LOCATION OF USE AREA B3_3, (I) USE AREA B3_3 (1X), (II) RETOUCHED FLAKE F03; (F) ADJACENT USE AREAS B3_2 AND B3_3. IMAGE BY EVA FRANCESCA MARTELLOTTA

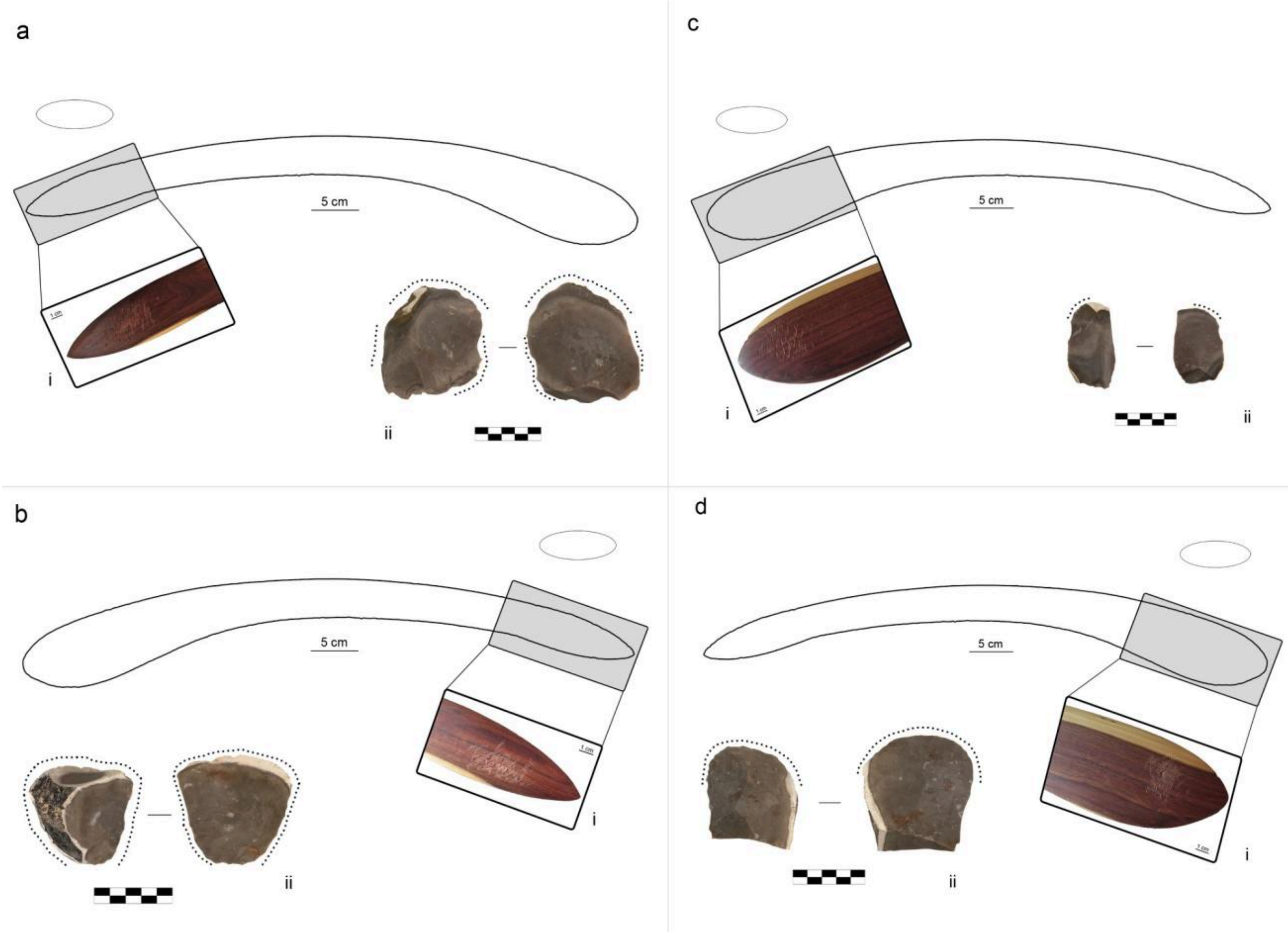

FIG 6. RESULTS OF EXPERIMENTAL RETOUCHING SESSION 2 ON BOOMERANG B4 (BI-CONVEX CROSS-SECTION AND LOCATION OF USE AREAS). (A) LOCATION OF USE AREA B4_1 (I) USE AREA B4_1 (1X), (II) RETOUCHED FLAKE F60; (B) LOCATION OF USE AREA B4_2(I) USE AREA B4_2 (1X), (II) RETOUCHED FLAKE F35. (C) LOCATION OF USE AREA B4_3, (I) USE AREA B4_3 (1X), (II) RETOUCHED FLAKE F81; (D) LOCATION OF USE AREA B4_4(I) USE AREA B4_4 (1X), (II) RETOUCHED FLAKE F41. IMAGE BY EVA FRANCESCA MARTELLOTTA

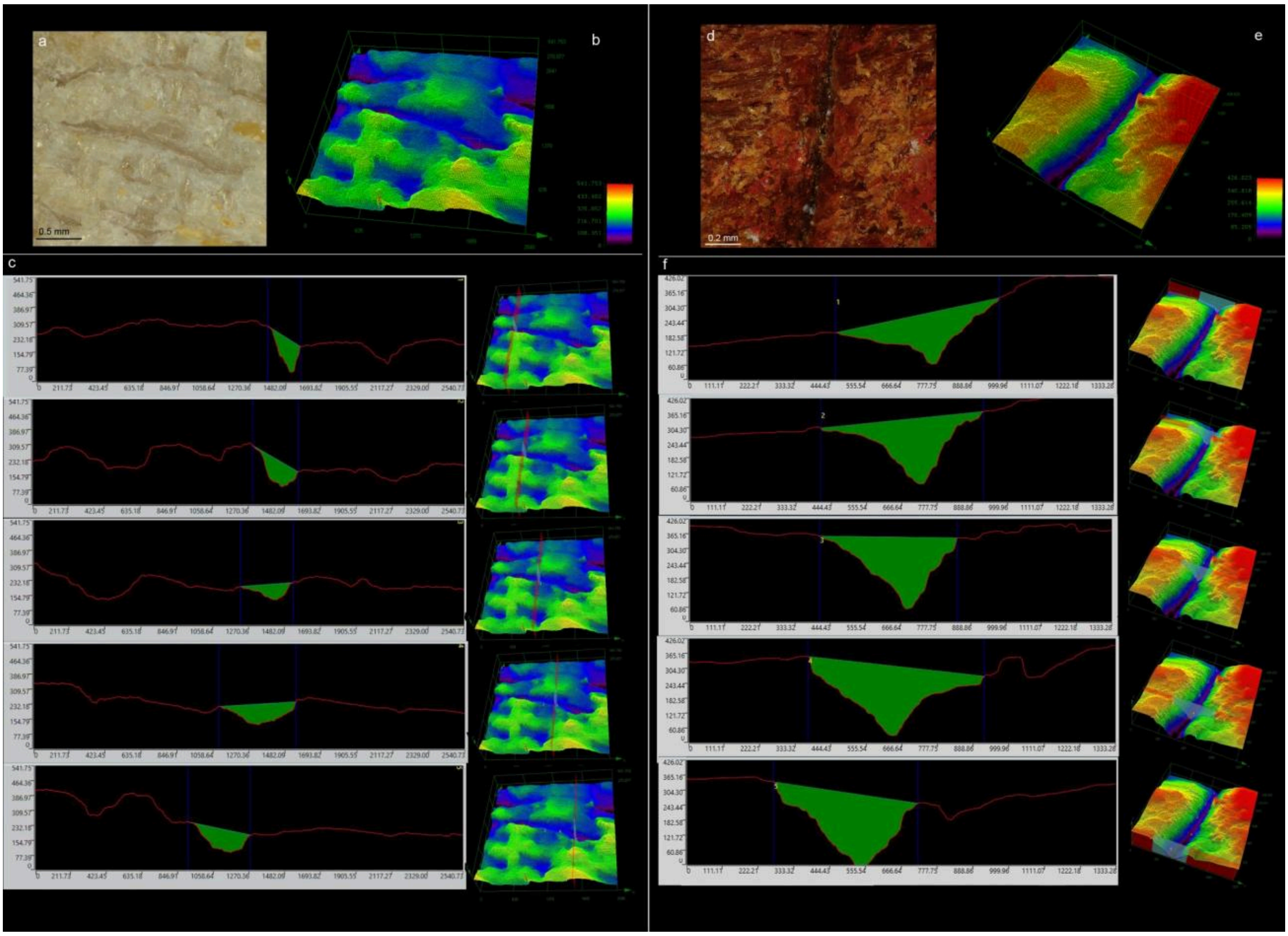

FIG 7. 3D ANALYSIS OF A SINGLE LINEAR IMPRESSION ON ONE OF THE EXPERIMENTAL BONE RETOUCHERS (LEFT) AND A BOOMERANG (RIGHT). (A) COLOUR 2D IMAGE OF A LINEAR IMPRESSION ON BONE RETOUCHERS (10X); (B) IMAGE OF THE SAME STIGMA WITH 3D HEIGHT DATA; (C) V-SHAPED PROFILE MEASUREMENTS AND CROSS-SECTION INTERNAL SURFACE MEASURED IN DIFFERENT PORTIONS OF THE LINEAR IMPRESSION ON BONE RETOUCHER; THE DEEP PENETRATION OF THE USE MARK IN THE BONE SURFACE CAN BE OBSERVED. (D) COLOUR 2D IMAGE OF A LINEAR IMPRESSION ON BOOMERANG (10X); (E) IMAGE OF THE SAME STIGMA WITH 3D HEIGHT DATA; (F) V-SHAPED PROFILE MEASUREMENTS AND CROSS-SECTION INTERNAL SURFACE MEASURED IN DIFFERENT PORTIONS OF THE LINEAR IMPRESSION ON BOOMERANG; THE DEEP PENETRATION OF THE USE MARK IN THE WOODEN SURFACE CAN BE OBSERVED. IMAGE BY EVA FRANCESCA MARTELLOTTA

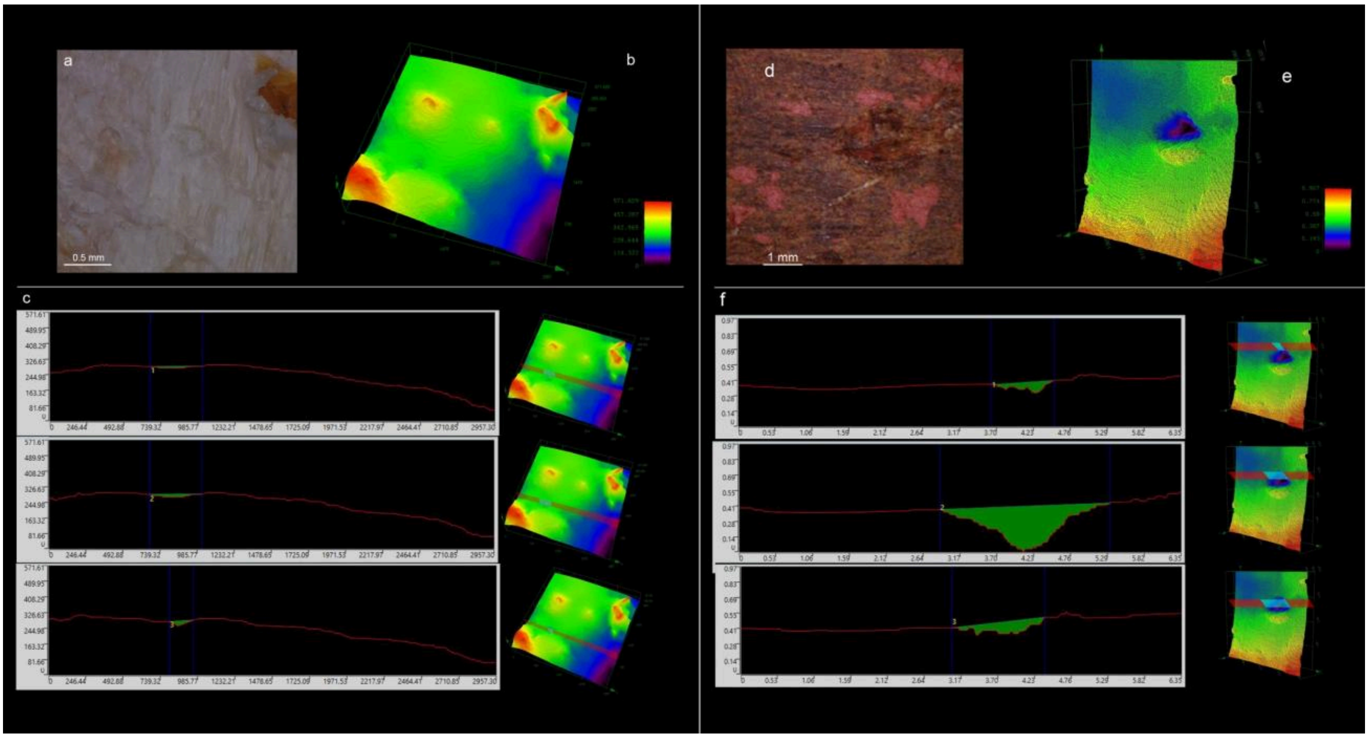

FIG 8. 3D ANALYSIS OF A SINGLE PUNCTIFORM IMPRESSION ON AN EXPERIMENTAL BONE RETOUCHER (LEFT) AND BOOMERANG (RIGHT). (A) COLOUR 2D IMAGE OF A PUNCTIFORM IMPRESSION ON BONE RETOUCHER (10X); (B) IMAGE OF THE SAME STIGMA WITH 3D HEIGHT DATA; (C) U-SHAPED PROFILE MEASUREMENTS AND CROSS-SECTION INTERNAL SURFACE MEASURED IN DIFFERENT PORTIONS OF THE PUNCTIFORM IMPRESSION ON BONE RETOUCHER; WE CAN OBSERVE HOW THE PUNCTIFORM MARK DOES NOT PENETRATE DEEPLY IN THE BONE SURFACE. (D) COLOUR 2D IMAGE OF A PUNCTIFORM IMPRESSION ON BOOMERANG (3X); (B) IMAGE OF THE SAME STIGMA WITH 3D HEIGHT DATA; (C) U-SHAPED PROFILE MEASUREMENTS AND CROSS-SECTION INTERNAL SURFACE MEASURED IN DIFFERENT PORTIONS OF THE PUNCTIFORM IMPRESSION ON BOOMERANG; WE CAN OBSERVE HOW THE PUNCTIFORM MARK PENETRATES DEEPLY IN THE WOODEN SURFACE, BUT IT REMAINS SHALLOWER THAN THE LINEAR IMPRESSION. IMAGE BY EVA FRANCESCA MARTELLOTTA

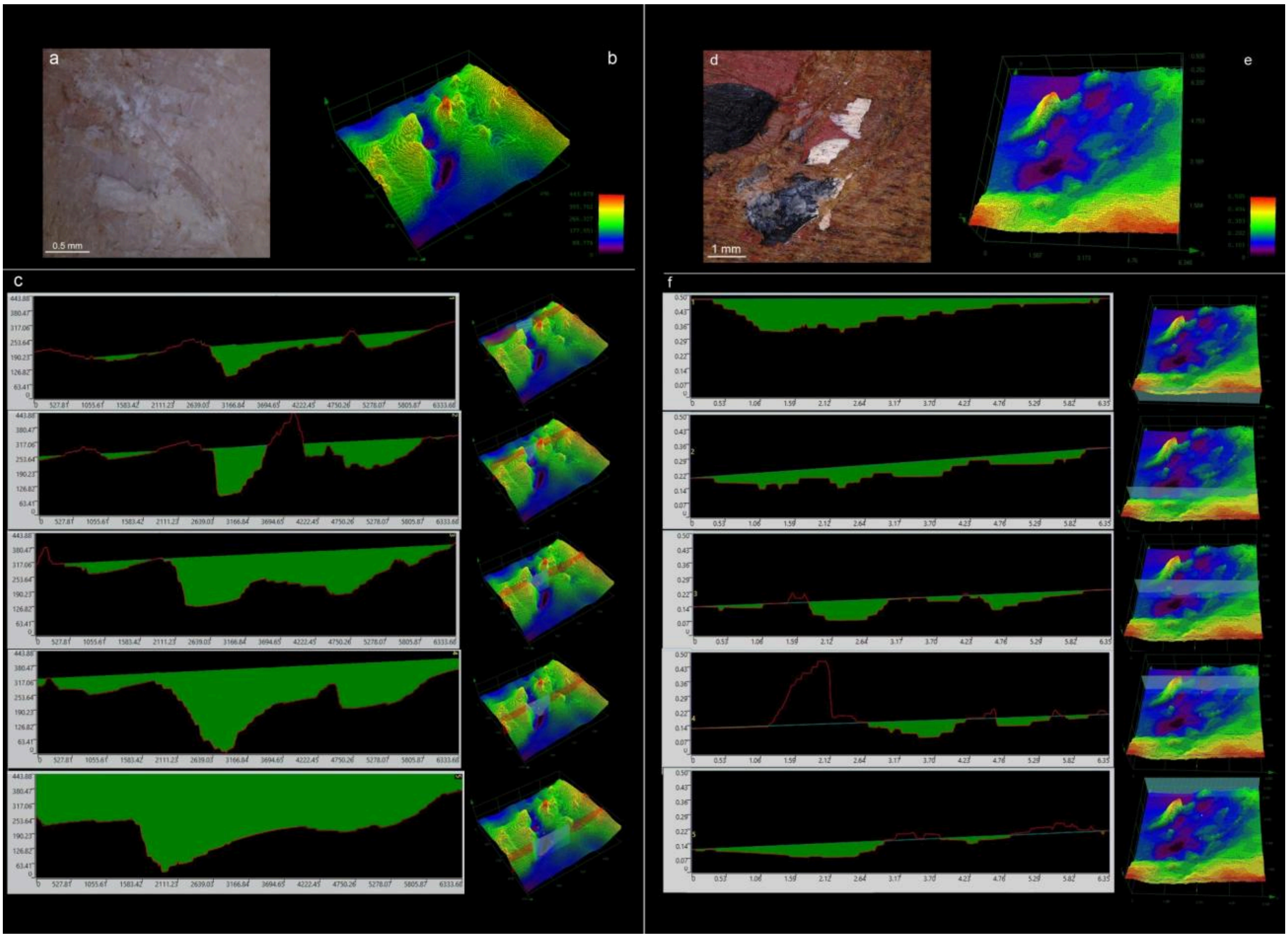

FIG 9. 3D ANALYSIS OF A SINGLE NOTCH ON EXPERIMENTAL BONE RETOUCHER (LEFT) AND BOOMERANG (RIGHT). (A) COLOUR 2D IMAGE OF THE NOTCH ON BONE RETOUCHER (10X); (B) IMAGE OF THE SAME STIGMA WITH 3D HEIGHT DATA; (C) PROFILE MEASUREMENTS AND CROSS-SECTION INTERNAL SURFACE MEASURED IN DIFFERENT PORTIONS OF THE NOTCH ON BONE RETOUCHER; THE ANALYSIS SHOWS THAT THE NOTCH IS COMPOSED OF THE SUPERPOSITION OF LINEAR AND PUNCTIFORM IMPRESSIONS, PENETRATING DEEPLY IN THE BONE SURFACE. (D) COLOUR 2D IMAGE OF THE NOTCH ON BOOMERANG (3X); (B) IMAGE OF THE SAME STIGMA WITH 3D HEIGHT DATA; (C) PROFILE MEASUREMENTS AND CROSS-SECTION INTERNAL SURFACE MEASURED IN DIFFERENT PORTIONS OF THE NOTCH ON BOOMERANG; THE ANALYSIS SHOWS THAT THE NOTCH IS COMPOSED OF THE SUPERPOSITION OF LINEAR AND PUNCTIFORM IMPRESSIONS, PENETRATING VERY DEEPLY IN THE WOODEN SURFACE. IMAGE BY EVA FRANCESCA MARTELLOTTA

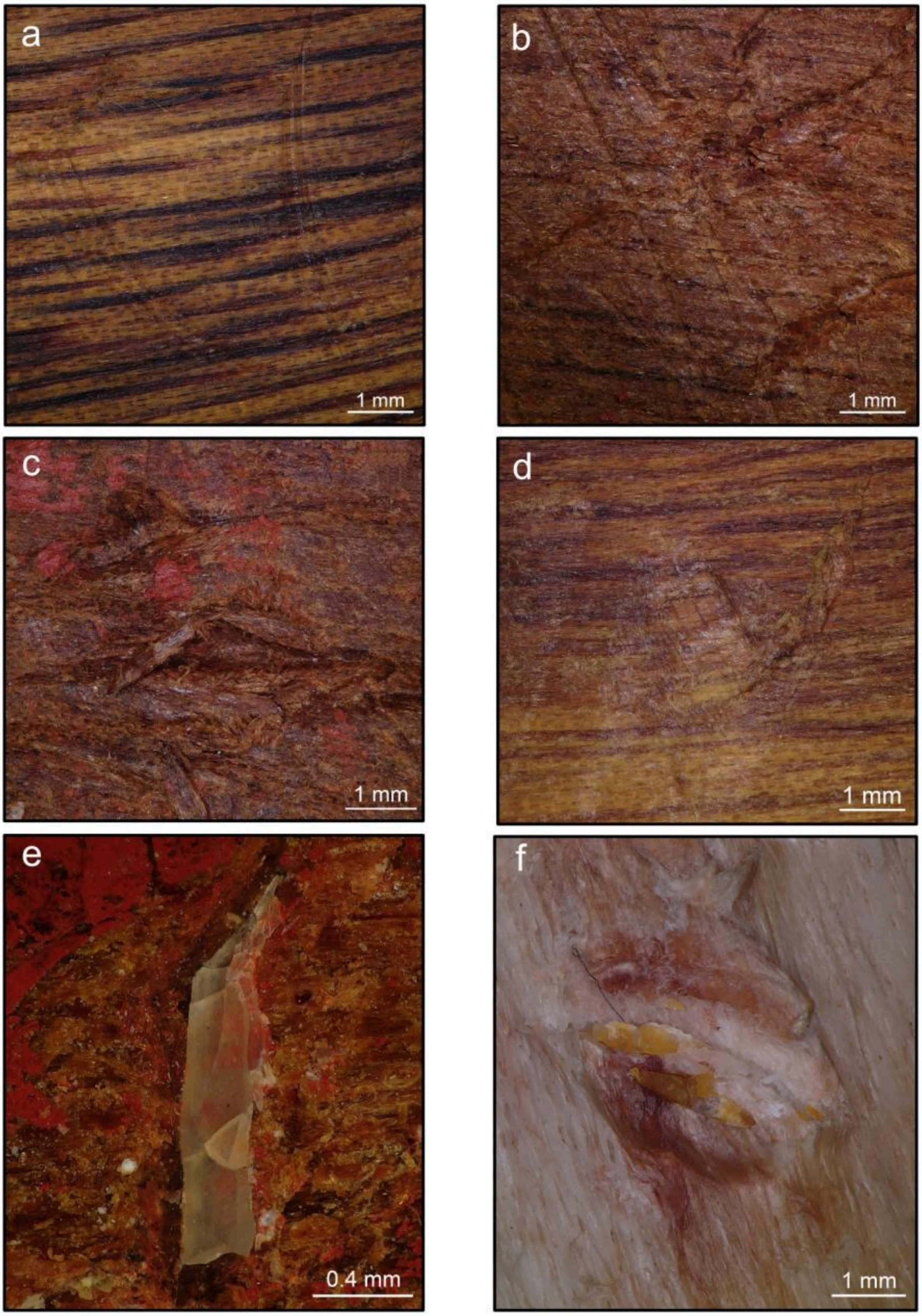

FIG 10. IMAGES OF OTHER MARKS IDENTIFIED WITHIN THE USE AREAS ON THE EXPERIMENTALLY USED BOOMERANGS. (A) STRIATIONS ASSOCIATED WITH PUNCTIFORM AND LINEAR IMPRESSIONS (3X); (B) SCRAPING MARKS INTERACTING AND INTERSECTING WITH LINEAR AND PUNCTIFORM IMPRESSIONS (3X); (C) PEELING-LIKE USE-WEAR (3X); (D) TOOL-EDGE SCRATCHES INTERACTING AND INTERSECTING WITH LINEAR IMPRESSIONS (3X); (E) FLINT CHIP EMBEDDED IN LINEAR MARK ON BOOMERANG SURFACE (10X); (F) FLINT CHIP EMBEDDED IN LINEAR MARKS ON BONE RETOUCHER SURFACE (R6_2) (3X). IMAGE BY EVA FRANCESCA MARTELLOTTA