Towards an understanding of hominin marrow extraction strategies: a proposal for a percussion mark terminology

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Abstract:

Percussion marks have been studied in the field of archaeology for more than a century. Researchers have identified, characterized and analysed them in order to distinguish them from traces of environment modification to bone and reconstruct hominin subsistence strategies. The multiplicity of studies based on percussion marks in different languages has led to a proliferation of different terminologies used for the same marks, especially in English. In addition, as a result of numerous experimental studies or ethnological observations, it is possible to accurately identify the different steps of the butchery process and each of the related marks. We know from experimental studies that the morphology of percussion traces inflicted by the same tools can differ as their morphology depends on many factors (i.e., location and intensity of blows, intrinsic bone variables). In addition to this, carnivore and hominin traces can be superimposed, which sometimes renders their interpretation difficult. Renewed interest in these percussion marks owing to the emergence of new technical means highlighted the need to review their classification and clarify the nomenclature. With this in mind, we reviewed the abundant scientific literature to propose a refined and descriptive nomenclature. The aim is to provide a coherent terminology for the description and analysis of impact fractures in different European languages. We also propose classifying percussion marks into three categories: 1) percussion marks *sensu stricto*; 2) traces consecutive to bone breakage and 3) striation marks related to marrow extraction.

Key-words: Percussion marks; Terminology; Zooarchaeology; Taphonomy; Long bone breakage.

1. Introduction

Animal exploitation strategies by hominins are still poorly understood. This is particularly true of the extraction of marrow from animal long bones. Yet, yellow marrow recovery may be quasi-systematic among Palaeolithic hunter-gatherers, e.g.., Neanderthals, mainly due to their important dietary fat requirements, especially in dry and cold environments (Speth 1989; Speth et al. 2012). The reasons underpinning this poor comprehension include the absence of a well-defined terminology, especially when anthropogenic percussion marks are reported. A well-defined terminology is the basis for every comparative study and is an essential prerequisite for our understanding of butchering practices. A huge variety of characteristics are currently considered to represent evidence of bone breakage. In recent years, the increasing interest in subsistence strategies has highlighted the problem. The identification and analysis of percussion marks is crucial for understanding human interaction with animal carcasses in terms of anatomical know-how, exploitation techniques, and the gestures employed during marrow removal.

Percussion and cut marks on animal bones, especially mammals ones, are among the most commonly observed butchery traces and have been widely studied at Palaeolithic sites since the beginning of the twentieth century (Martin 1906; Breuil 1938). Throughout time, zooarchaeologists have used different terminologies to describe the same types of marks (i.e., percussion notch, impact cone, conchoidal flake scars, etc.). In addition, these terminologies have been created in different languages. The diverse and rich scientific literature focused on the percussion marks was written in various European languages. Taking this into account, it is necessary to confront all the synonymous terms used in those previous work also in different languages. In this context, it is imperative to use consistently the same terminology for comparative studies in order to share data across borders. Moreover, new methodologies (e.g., microscopic observations, geometric morphometric, 3D modelling or GIS analyses of distribution along the diaphysis…) have increased our knowledge and present new challenges for the study of these traces (Njau 2012; Blasco et al. 2013; García-Moreno et al. 2014; Arriaza et al. 2018; Maté-González et al. 2019; Stavrova et al. 2019).

We aim to overcome this shortfall by providing a coherent terminology for the description and analysis of impact fractures based on the collation of currently existing terms and definitions from different European languages (English, French, Spanish, Italian and German). We begin with a historical and methodological perspective to contextualize the problems exposed and assess the difficulties encountered by zooarchaeologists. For a better understanding of fracture dynamics, the bone structure of long bones is described followed by an outline of the most important dynamic loading techniques. Finally, we propose a consistent terminology.

2. Long bone breakage: a historical and methodological perspective

2.1. Bone breakage patterns against the background of taphonomy

Following Weigelt (1927) with his "biostratinomy" defined as a paleontology discipline; Efremov (1940) used the term “taphonomy” and added a methodological framework to a poorly defined field of science. This new field of research provided indicators for distinguishing natural alterations from anthropogenic modifications, allowing for the identification of the impact of human activities on bone assemblages. Taphonomy used the model of analogical thinking based on actualism and defined as follows by Gifford-Gonzalez (2018 – p.62): “a methodologically uniformitarian approach offers the historical sciences a practical research strategy for learning more about the past using modern analogies”. Through ethology (animal behavior studies), ethnology (human behavior studies) and archaeological experiments, archaeologists aim to made hypotheses about the various processes causing bone damage. They follow the “visual model for a nested set of causal relationships” defined by Gifford-Gonzalez (2018, – p. 62) to identify the origin of percussion marks. Using her terminology, the actor caused the traces via the effector. For example, a hominin (actor or agent) caused a percussion notch (trace) with a hammerstone (effector). Actualistic studies can provide information on the processes that caused the breakage and help to identify the actors who broke the bones (e.g., Martin 1910; Breuil 1938; Leroi-Gourhan 1952; Dart 1957; Poplin 1973; Blumenschine 1988; Oliver 1989; Anconetani 1999; Pickering and Egeland 2006; Galán et al. 2009; Blasco et al. 2013, 2014; Njau and Gilbert 2016; Moclán and Domínguez-Rodrigo 2018; Parkinson 2018).

2.2. Historic perspective and context of the recognition of the Paleolithic marrow recovery process

At the beginning of the twentieth century, researchers attempted to understand the reasons for the presence of numerous bone splinters among prehistoric bone assemblages (Martin 1910; Black et al. 1933; Breuil 1938; Pei

1938; Breuil and Boyle 1939). Some experimental studies focused on natural and anthropogenic bone breakage processes. In addition, comparisons between archaeological and paleontological sites also contributed to distinguishing hominin traces from those of other agents. As a result of these attempts, two explanations were advanced for systematic long bone breakage by humans: marrow extraction and bone tool making (Martin 1910; Breuil 1938; Pei 1939, 1938; Dart 1957, 1960; Poplin 1973, 1978; Dauvois 1974; Noe-Nygaard 1977; Bonnichsen 1979; Morlan 1979, 1980). In the first half of the twentieth century, Breuil (1938) developed the theory of the "Bone and Antler Industry of Choukoutien", and some years later, Dart (1957) defined the osteodontokeratic technology as a hominin "bone, tooth, and horn" culture (Breuil and Lantier 1959; Wolberg 1970).

2.3. Identifying the agents that cause green bone breakage

Through works focused on Lower and Middle Pleistocene archaeological sites in eastern Africa, Isaac categorized the sites based on the concentration of bones and lithic artefacts and faunal assemblage modifications (Isaac 1971, 1978, 1983). In addition, during the early eighties, ethological and ethnological observations provided reading keys for long bone breakage processes. Some authors began to record spiral fractures among extant carnivore accumulations (i.e., Washburn 1957; Miller 1975; Hill 1976; Bonnichsen 1979; Binford 1981; Brain 1981; Haynes 1982; Haynes and Stanford 1984; Gonzales 1991). After that, actualistic studies succeeded in showing that both carnivores and humans could accumulate broken bones in archaeological and paleontological contexts Carnivores and hominins could consecutively occupy the same sites and accumulating accumulate bones at the same place bones. Moreover, carnivores could scavenge piece of carcasses abandoned by humans and inversely or they could transport bones from kills or consumption site to places occupied by humanshuman occupations. That is means that both actors could intricate create mixed bone accumulations (e.g., Potts and Shipman 1981; Brain 1981; Blumenschine 1986; Bunn et al. 1986; Hill 1989; Cavallo and Blumenschine 1989; Blumenschine and Selvaggio 1991; Bunn 1991; Marean et al. 1992; Blumenschine and Marean 1993; Selvaggio 1994; Capaldo 1995, 1997; Blumenschine et al. 1996).Fossil fauna accumulations are often palimpsests and identifying the actors of bone fracturing can be difficult. In addition, the use of ethnographic studies provided new perspectives for past behaviors (Poplin 1973; Delpech and Rigaud 1974, 1977; Teleki 1975). Binford (1978, 1981) highlighted breakage patterns for marrow extraction among the Nunamiut in Alaska, depending on intra and intergroup factors. He mentioned that blows were not random but focused on the most fragile areas of the bone. Furthermore, Binford (1984) theorized scavenging behaviors through ethnographic observations. In addition, the environmental context may also play a preponderant role in bone fragmentation, as ambient temperatures and humidity level. Myers et al. (1980), and then Behrensmeyer et al. (1989) also demonstrated that trampling by ungulates can cause breakage features. Dauvois (1974) even suggested that blocks from cave collapse could also cause bone damage similar to animal and hominin marrow recovery processes. Oliver (1989) and Griggo (2013) confirmed this with examples from Shield Trap Cave (Montana, U.S.A., Holocene period) and Tempiette Cave (France, Holocene period).

After the above-mentioned works, many researchers defined criteria to differentiate sub-contemporaneous fractures (green bone fractures) from those due to post-depositional agents (dry bone fractures) (e.g., Haynes 1983; Morlan 1984; Johnson 1985). In 1991, Villa and Mahieu (1991) described the criteria in order to distinguish green bone from dry bone fractures: outline, edge texture and angle, and long bone shaft length and circumference. Thereafter, Outram (1999, 2001, 2002) combined these criteria proposing the Fracture Freshness Index (FFI) more efficient to categorize the breakage temporality. Hominins, carnivores or other environmental factors were able to create similar green bone spiral fractures. It then became necessary to establish clear features to differentiate the cause of breakage, with for example, the associated bone surface modifications (tooth marks, percussion marks, cut marks, etc.). Identifying and categorizing the various marks caused by percussion may help to understand the actors and processes. By contrast, our aim is not to designate the function that caused the breakage. Indeed, anthropogenic green bone fractures can be part of various "*chaînes opératoires*" including activities such as marrow recovery, or bone retouchers manufacturing for example..

Besides, ethnological observations have shown that current hunter-gatherers could extract marrow in a specific way, producing breakage patterns (Binford 1978; Enloe 1993; Abe 2005; Costamagno and David 2009). Indeed, some groups may systematically hit each bones element at a same location. Thus, the percussion marks distribution could design specific patterns to break bones. Therefore, zooarchaeological analyses tested the presence of butchering traditions for Middle and Upper Palaeolithic periods based on the distribution of percussion marks on long bones (Blasco et al. 2013; Masset et al. 2016; Vettese et al. 2017). Consequently, a common nomenclature and categorization of percussion damage now appears essential in order to compare the percussion marks distributions along the diaphysis for various Palaeolithic sites.

3. Why revise the terminology?

The current nomenclature used by the scientific community is varied and is frequently based on a wide diversity of terms and definitions. For example, the notch caused by hominin percussion is described by many names, such as impact mark, notch or fracture cone (Bonnichsen 1979; Archer et al. 1980; Binford 1981; Bunn 1982; Haynes and Stanford 1984). The term notch corresponds to a strict morphological description of the marks, regardless of the actors, i.e., humans or carnivores. Even if breakage mechanisms are different (static loading by carnivores [pressure] and dynamic loading by hominins [percussion]), the marks can be similar in shape (Lyman 1987; Gonzales 1991; Gifford-Gonzalez 2018). Thus, for isolated notches, it can be difficult to distinguish between a tooth notch and a percussion notch, although some features may help with the distinction. For example, the ratio between the length and the width of the notches, especially on small and medium-sized ungulate long bones, can identify the agent. The presence of associated human or carnivore marks or the type of notch (isolated, double or opposite) can also be an identification feature (Capaldo and Blumenschine 1994; Voormolen 2008; Moclán and Domínguez-Rodrigo 2018).

The notch is not the only mark in question. Blumenschine and Selvaggio (1988) proposed identifying percussion activity based on the types of pits and grooves and the presence of related microstriations: "percussion marks". To describe these traces, they used the terminology of pits and grooves for the first time, similar to the terms used to describe carnivore tooth marks (e.g., (Maguire et al. 1980; Blumenschine 1995; Barba and Domínguez-Rodrigo 2005; Galán et al. 2009; Saladié et al. 2013). Indeed, except for microstriations, there are few morphological differences between tooth pits and percussion pits, even if the mechanisms are different (static or dynamic loading) (Blumenschine and Selvaggio 1988; Capaldo and Blumenschine 1994; Yravedra et al. 2018). In our opinion, using the term "percussion marks" is ambiguous. On one hand, it describes some particular traces present in the context of anthropogenic breakage, and on the other hand, it corresponds to a generic term, which is used to describe all the marks resulting from the impact between a hard material and the bone.

The multiplicity of terms in the currently used nomenclature and the use of descriptive or interpretative (agents) terminology can cause confusion and lead to interpretation problems. Indeed, current categories can induce misinterpretations or complexity in the identification process of the origin of marks. Many researchers have attempted to clarify the nomenclature and have suggested typologies (Patou-Mathis 1985; White 1992; Capaldo and Blumenschine 1994; Fisher 1995; Boulestin 1999; Costamagno 1999; Domínguez-Rodrigo 2002; Pickering and Egeland 2006; Domínguez-Rodrigo et al. 2009; Symes et al. 2014; Gifford-Gonzalez 2018). However, they have been faced with many challenges. For example, the chopping mark (Bonnichsen and Will 1980; Binford 1981; Shipman 1981; Bunn 1981; Johnson 1985; White 1992; Capaldo and Blumenschine 1994; Fisher 1995; Outram 2002; Pickering and Egeland 2006; Lyman 2008; Galán et al. 2009; Blasco et al. 2013; Gifford-Gonzalez 2018), despite its classification as a cut mark (cf. Lyman, 2008), could be the result of hammerstone percussion and batting (Blasco et al. 2014). It could be conceived as a hybrid mark between cutting and percussion (Gifford-Gonzalez 1989; Lyman 2008). Nevertheless, percussion action is sometimes used to cut tissues during the disarticulation stage. These marks can thus result from both percussion and cut marks. Moreover, some traces categorized as percussion marks are not directly caused by impacts, for example, peeling or scraping marks. The former is the result of the pullout of the two parts of the bone still connected after the impact and the latter is due to the cleaning of bone surfaces before the blow. Finally, to identify butchery traditions, it is fundamental to differentiate the marks directly linked to the impact from auxiliary marks (scraping marks, microstriations, pseudo-notches, cracking, peeling, fracture lines, etc.). Moreover, recording the exact location of the percussion impact may enable the identification of a potential standardized and counterintuitive pattern expressing specific butchery practices and differentiate them from other agents (Blasco et al. 2013; Masset et al. 2016; Vettese et al. 2017; Parkinson 2018; Stavrova et al. 2019). Indeed, to compare butchering traditions between several sites, percussion traces should be recorded by a solid nomenclature and common definitions.

4. Long bone structure and response to dynamic percussion

Percussion mark identification is directly linked to an understanding of the raw material, in this case, bone. When the physical and chemical perimortem composition of a bone is known, it should be possible to estimate its response to the dynamic force applied during marrow recovery. These data are crucial for identifying the type of action, the tool used to break the bone and the techniques and gestures employed. Moreover, individuals who regularly break long bones acquire an empirical approach to bone and develop specific skills that enhance efficiency. Thus, their skills include habits and preferences gained by experience and/or group traditions. This know-how cannot be assessed without differentiating between physical bone features and socio-cultural practices.

In addition, some extrinsic factors due to the life of the animal could play a minor role in the formation of the fracture lines and marks produced by the percussion process, such as animal disease (e.g. osteoporosis) or bone injuries. Moreover, the shape of each long bone influences the technique employed and the blow location, as well as the position adopted for breakage and marrow extraction (Bonnichsen 1979). The tools and the techniques employed vary according to individuals or groups, but also according to the size and the cortical thickness of the bone.

4.1. The physical and chemical composition of bone

The composition of bone as a biological hard tissue is well known, notably in biomechanics (Currey 1984, 2012; Weiner and Wagner 1998; Ritchie et al. 2009; Wang and Gupta 2011). Archaeologists focus on the specific mode of bone breakage (Johnson 1985; Balasse et al. 2015; Fernández-Jalvo and Andrews 2016; Brugal 2017). Bone is a composite material with seven levels of hierarchical structures. These hierarchical levels interact with each other and improve the mechanical strength and toughness of the bone (Currey 1984; Wang and Gupta 2011). Bone has a compact, heterogeneous, viscoelastic and anisotropic structure. An anisotropic material does not present a unique response to mechanical constraints. The trabecular (compact bone at the microstructural level) is a composite material: (1) the mineral phase accounts for 45% (hydroxyapatite), (2) the organic phase constitutes 35% of bone weight (collagen) and (3) the last part is composed mainly of water (Follet 2002; Gifford-Gonzalez 2018). Perimortem, both elastic and plastic deformations are responsible for the two phases (organic and mineral). Fresh bone with a high water content does not react in the same way as dry bone. The internal structure of a bone dictates the response to stress depending on the direction of the applied force.

4.2. Long bone specificity

The vertebrate skeleton is composed of different types of bones: short bones (carpal, tarsal…), flat bones (scapula, coxal…) and long bones (femurs, humerus…) (Barone 1976). These bones have different shapes, and varying proportions of spongiosa and compacta tissues. Moreover, bones contain different proportions of yellow marrow. Long bones have the highest yellow marrow content in relation to mandibles or phalanges (Jones and Metcalfe 1988; Madrigal and Holt 2002). Most herbivores have 12 long bones, consisting of pairs of radio-ulnas, humeri, metacarpals, femurs, tibias and metatarsals. Contrary to primates or carnivores, herbivore metapodials are long and also contain a high quantity of yellow marrow.

All these long bones have a similar shape: one diaphysis and two epiphyses. The diaphysis has a cylindrical shape and is full of yellow marrow (adipose tissue), surrounded by a solid matrix called compacta. In addition, this dense part of the bone is covered by the periosteum; a fibrous membrane that absorbs the impact of the blows (Blasco et al. 2014; Balasse et al. 2015). The endosteum is, for its part, a membrane coating the medullary cavity. The spongiosa is an alveolar structure composing the epiphyses and enclosing the red marrow. These latter have a more or less rounded shape. When the long bone is placed on a flat surface, it stands on the two epiphyses, and the diaphysis is elevated most of the time. The thick part is much denser than the spongy tissue. The specific morphology, structure and moisture of the bone present an extraordinary energy-absorbing capacity (Evans 1961; Johnson 1985). Due to the heterogeneity of the articular portions, they absorb the impact better. Applying a sudden force or an impact produces most of the fractures. Johnson (1985) claimed that, "the bone is stronger in compression and shear than in tension and failure starts on the tension side". The fracture line could appear at the opposite side of the impact point. The direction of force application, in which stress impact bone, dictates the type of fractures or incipient cracks (Lynn and Fairgrieve 2009; Gifford-Gonzalez 2018). Each long bone presents its own characteristics, which respond differently during the breakage process. It is thus necessary to adapt the position of the bone. One of the main differences lies in shaft morphology. The humerus and the femur have a rounded section, while tibias have a more rectangular-shaped or even triangular section. Radio-ulnas, like metapodials, have a semi-lunar cross-section. The fusion between the radius and the ulna strongly constrains the shape of the bone. The proximal portion of the ulna is thin and does not ensure the stability of the bone when it lies on its posterior side. In addition, spongiosa is not homogeneously distributed for all long bones, although it is mainly restricted to the articular part. For example, the distal part of the humerus has an internal structure with partitions inside the medullary cavity. Moreover, the metapodial shaft is denser than that of other long bones (Lam et al. 1999).

4.3. Inter-species and intra-species differences

Handling and breakage are not as easy according to the different sized-class of ungulates like an elephant, a megaceros or a chamois limb element. In addition, these actions depend on long bone size, density, cortical thickness or weight. Indeed, although herbivores have the same types of long bones, interspecies differences exist. First, long bone measurements and weight depend on herbivore size. For example, a bison femur is bigger and heavier than a roe deer femur. Likewise, cortical thickness and bone density vary with the size of the animal and according to the species (Metcalfe and Jones 1988; Kreutzer 1992; Lyman 1992, 1994; Elkin 1995; Mullender et al. 1996; Lam et al. 1999). Depending on the species, the difference in thickness can double or even be multiplied by five (Barba and Domínguez-Rodrigo 2005). Proboscidean long bones are among the largest and have a proportionally reduced medullary cavity in comparison to other herbivores (Shoshani et al. 1985; Boschian and Saccà 2015; Boschian et al. 2019).

Finally, it is also necessary to consider the extrinsic factors related to the individual. Differences linked to the sex, age or ontology of an animal can occur within the same species. Robustness and medullary cavity size or even the quantity of spongiosa may vary. Moreover, long bone elements can be altered and weakened by different pathologies, such as bone diseases or macro or micro bone fractures. These can play a minor role in the formation of fracture lines during the percussion process.

5. Dynamic loading and percussion techniques

5.1. Techniques used to break bones

It is possible to discriminate percussion traces from other types of marks and understand the circumstances of their production by exploring the different techniques used to open the medullary cavity. This also highlights the abilities of hominins to recover marrow and the various techniques used to break long bones. To fully understand marrow extraction techniques, it is important to note that this individual activity is mainly used for small-, medium- or large-sized ungulates, but not for very large-sized animals. For example, it appears that several individuals are needed to break elephant long bones in order to recover the yellow marrow (Holen et al. 2017). It is thus possible to identify the gestures used during marrow recovery processes based on fossil percussion marks thanks to the different techniques and tools documented by ethnographic observations and archaeological experiments.

Following the observations of Oliver (1993) made among the Hazda in Tanzania and subsequent works, we differentiate four techniques for marrow exploitation:

- static loading; groups the pressure techniques, between an anvil and a stone or wooden tool, or tooth (gnawing a bone). Static loading is characteristic of carnivores and primates. They press bones between their jaws to recover yellow marrow and usually chew the spongy parts. Chimpanzees also use their teeth to break the long bones of other monkeys (*Colobus* sp.) or various small animals. They use a previously fashioned wooden stick to extract marrow after removing the articular head with their teeth ((Boesch and Boesch 1989). Prey caught by humans can be much larger and great strength is usually required to break long bones. The human jaw is weaker than that of large carnivores, such as hyenas and wolves, for example. Hominins did not have the necessary force to break large ungulate long bone shafts and epiphyses with their teeth. Thus, these types of anthropogenic traces are rare and, in any case, may be distinguished from those of carnivores, by their size and shape (Saladié et al. 2013). Archaeological data show that hominins applied static loading using pressure tools. Traces are consequently different from carnivore tooth marks, with some associated micro-striations.

- torsional loading; by wrenching or twisting a bone and flexing a bone by hand. Faunal remains from some archaeological sites provide evidence of bone breakage by hand or mouth by twisting, most often on flat bones. The mouth, in this case, is used like a third hand to facilitate breakage. For example, a rib fragment from Atapuerca (TD6) shows human tooth marks and peeling (Saladié et al. 2011; Fernández-Jalvo and Andrews 2016). Based on an experimental work, Pickering et al. (2013) defined three types of peeling damage according to their cortical expansion on ungulate ribs. Ethnological observations on the Koi people by Brain (1969) indicated rib breakage by hand, creating some peeling marks. Nevertheless, we have to take special care when identifying peeling on fossil bones, since this damage can also be generated by carnivores (and not only by humans). Recent neotaphonomic observations have documented this modification among faunal remains consumed by brown bears and, to a lesser extent, by red foxes (Arilla et al. 2014, 2019). However, the use of twisting or flexing techniques to break long bones of middle or large-sized ungulates is uncommon and required great strength. These last techniques could leave some surface traces, and fracture lines and peeling traces, depending on bone type (White 1992; Martínez 2009; Saladié et al. 2013). Moreover, torsional loading could be used in addition to dynamic loading, after the first cracking or fracture.

- friction loading; when a bone is sliced or sawed. This technique is specific to humans.

- dynamic loading; summarizing techniques using percussion: bone clubs on an anvil, use of a hard object (a hammerstone, a panga machete, an axe or a knife) to strike a bone directly or indirectly with an intermediary object. Dynamic loading serves as an umbrella for all the percussion techniques and is mostly specific to humans extracting marrow (like sawing). The morphology of the human hand with the opposable thumb allows for the handling and grasping of bones and hammerstones (Young 2003). Some animals may have used dynamic loading, such as extant bears, which have been observed throwing cow femurs against a wall to break them and recover the marrow (personal observation) and bearded vultures which drop long bones on the rocks from a high altitude (Marín-Arroyo and Margalida 2012). In ethnological contexts, most of the percussion techniques observed involve iron tools. During the Pleistocene and early Holocene, humans used stones for percussion, i.e., chopper and chopping tools with sharp edges or pebbles. The Nunamiut also used unretouched pebbles as hammerstones (Binford 1981). In this paper, we focus on two dynamic loading techniques where bones play an active and passive role: (1) the bone-batting technique and (2) the hammerstone on anvil technique.

5.2. The batting technique

5.2.1. Background

Humans can use long bones as tools. In this case, the bone plays an active role during the percussion process, and directly strikes the surface. Before the 21st century, different terminologies were used to describe this type of active percussion, such as clubbing, beating or batting (Noe-Nygaard 1977; Blasco et al. 2014). The first author to mention this is Noe-Nygaard (1977). During her experiments, she broke the hind limb of a roe deer" by holding the bone by one end and beating it against a hard object of wood or stone using it as a club". In 1980, Archer and his colleagues set up an experiment with kangaroo long bones to better identify breakage patterns. They held fresh femurs in one hand and hit the diaphysis on the edge of hard stone. Oliver (1993) also described this technique of clubbing long bones on an anvil in the course of his ethnological observations on the Hazda. Lastly, a systematic experimental approach to bone fracturing, adopting this technique, was held by Anconetani (Peretto et al. 1996).

5.2.2. Description

This type of percussion is the simplest technique for breaking bones since it does not involve any tools. The individual takes a bone by one of its epiphyses or by the shaft and hits or clubs it on a hard surface (plane, rounded or with a sharp edge). This surface can be a large stone, a wall or the ground, a piece of wood or even a bone. Depending on whether the individual holds the bone by the epiphyses or diaphysis, it can hit either: the opposite epiphysis, the diaphysis far from the epiphysis to remove the opposite epiphysis or the middle part of the diaphysis to break the diaphysis in half. Due to long bone morphology, the diaphysis can only be struck against a prominent surface. Alternatively, the individual can hold the bone with one hand on each epiphysis. In this case, only the diaphysis can be stuck against a sharp or rounded edge.

5.3. The hammerstone on anvil technique

5.3.1. Background

The "hammerstone on anvil" technique is the most studied technique in experimental archaeology. The bone plays a passive role using percussion by a hammerstone on anvil. At the beginning of the 20th century, a paper mentioned this kind of experiment to recover marrow (Martin 1910). The author described how he broke equid long bones with rounded pebbles on a rectangular anvil with the help of two colleagues. Several similar studies have been reported, describing how Pleistocene hominins might have extracted marrow. Most of the studies are based on experiments combined with ethnological observations (i.e., Binford 1981; Turner 1983; Blumenschine and Selvaggio 1988; Capaldo and Blumenschine 1994; Lyman 1994; Fisher 1995; Peretto et al. 1996; Karr et al. 2005; Pickering and Egeland 2006; Domínguez-Rodrigo et al. 2009; Karr and Outram 2012, 2015; Yravedra et al. 2017).

5.3.2. Description

The name of this technique explicitly indicates the tools used to open the medullary cavity: a hammerstone and an anvil. The anvil is a passive instrument for placing the bone where a second instrument (hammerstone) hits it (Mourre 2004). The anvil is made of relatively hard material (the ground, stone, wood or bone). Its size and morphology (flat, rounded or sharp) vary according to the technique employed and animal size. The hammerstone is a stone used to break the bone and could be a pebble, manufactured or not, with a sharp or rounded surface or edge, a piece of wood or another bone.

In the case of the use of an anvil larger than the length of the bone, the complete long bone is placed on the anvil, with the epiphyses lying on their surfaces, while the diaphysis is not in contact with the anvil. Alternatively, the diaphysis or one of the two epiphyses are placed on the anvil with the opposite epiphysis touching the ground. It is also possible to place the bone vertically with one of the epiphyses on the anvil and to hit the opposite epiphysis with a hammerstone.

5.4. The mixed technique: a hybrid "*chaine opératoire*"

Marrow extraction from a long bone can require repeated hitting and breaking. Initial percussion often results in a broken bone with a large part of the shaft attached to an epiphysis and some splinters of varied sizes and sometimes a shaft cylinder. The broken bone has both sharp and smooth parts. Its size is reduced compared to the complete bone. The batting technique might initiate the fracture and the hammerstone on an anvil can help to continue fracturing. Experiments show that the opposite is also possible, i.e., fracturing the bone with a hammerstone on an anvil and once the first fissures appear, finishing breaking by hitting the bone against the sharp edge of an anvil, holding the bone by both epiphyses. The use of two percussion strategies on the same bone has been described as "mixed" percussion (Peretto et al. 1996). Depending on skills, habits or traditions, hominins could use one or several techniques. Current studies indicate the importance of the anatomical position of percussion traces to identify techniques and butchering traditions in archaeological contexts (Blasco et al. 2013; Masset et al. 2016; Vettese et al. 2017; Moclán and Domínguez-Rodrigo 2018).

6. Terminology and classification of percussion marks

6.1. Process and production of percussion marks

The morphology of percussion marks and their anatomical location differ according to the breakage techniques and tools used. The distribution and location of the marks vary depending on whether the bone is broken by batting or by a hammerstone (Blasco et al. 2013, 2014; Moclán and Domínguez-Rodrigo 2018). The results of a blow depend on the bone structure, i.e., whether compacta or spongiosa is involved and if the bone retained its periosteum. In addition, the strength and the abilities of the knapper, as well as the type of hammerstone (shape, size and weight), also affect the type of percussion marks. Hitting a bone can have several consequences (adapted from Boulestin 1999):

- The periosteum absorbs the impact and protects the bone surfaces; the bone remains unaffected.

- The bone surface is modified, with or without cracking (pits, grooves);

- The bone surface is both modified and deformed, the cortical part is pushed into the bone cavity, with or without cracking or breakage (crushing);

- The bone is deformed by flake detachment, the mark left is the negative of this (notch);

- The bone is broken showing several fracture lines, without percussion marks.

The appearance of fracture lines is not related to percussion marks. Nevertheless, the percussion mark types are influenced by the appearance of the fracture lines. The impact produces a conchoidal cone of percussion which could create a notch on the shaft bone because as fractures radiate off or a crushing mark on the articular portion when the radiating fractures are stopped (dispersed) by the trabecular bone. The periosteum absorbs the impact and the fracture lines can appear on the opposite side of the blow. The long bone is weaker in tension than in compression (Johnson 1985).

Analyses focusing on percussion marks have highlighted two major problems of very different kinds: a double equifinality during percussion mark formation and the abundant terminology used to characterize them, which is currently not standardized (Lyman 2004).

Firstly, a double equifinality, some researchers have observed, through experimental studies, that the same tools leave different percussion traces and two different tools could leave same percussion marks (Blasco et al. 2013; Blasco et al. 2014; Vettese 2014; Chevillard 2018). The type of mark depends on many factors: location and intensity of the blow, or if the surface is hit many times in the same place with or without removal of the periosteum and the extrinsic factors related to the animal. The shape of percussion marks corresponds to the shape of the striking tool. Batting a long bone against a sharp edge or batting the bone with a retouched pebble may produce similar traces. If the instrument is round and smooth, marks are rounded or semi-circular, whereas, if the edge of the instrument is sharp, the scar is also sharp. One of the differences for the hammerstone on anvil technique is the possible presence of counterblow marks. These marks appear on the opposite side of the hitting surface as a result of the rebound effect on the anvil (e.g., Johnson 1985; Capaldo and Blumenschine 1994; Outram 1999; Galán et al. 2009; Gifford-Gonzalez 2018). These marks are pits, microstriations, notches or pseudo notches. Due to the multiplicity of traces, it is sometimes difficult to discriminate blow marks from counterblow marks (Table 1).

Secondly, as we exposed previously the current terminology is variable according to the authors and thus could be ambiguous. In this study, we aim to provide a common vocabulary, based on descriptive nomenclature.

We propose a standardized classification and nomenclature, which should enable researchers to differentiate direct traces caused by percussion, from indirect marks due to the anvil or percussor rebound effect or from marks consecutive to the breakage (peeling, scraping, etc.). We list below all types of percussion traces divided into three categories. The first category represents marks directly due to the impact. They are percussion marks *sensu stricto*. The second category groups the traces consecutive to the opening of the medullary cavity. The third group summarizes auxiliary striations related to marrow extraction. They are common to all the bone breakage techniques. Using these categories, we define a descriptive name for each type of mark. This usually corresponds to the most widely employed name in the current literature. We then propose a compilation of all the terms used in different languages (English, French, Spanish, Italian and German) in order to standardize and connect each type of mark with the appropriate terms in different languages. Each mark is illustrated with pictures from our own experiment performed in order to extract marrow (Vettese 2014; Stavrova et al. 2019).The experimenters used both a non-retouched hammerstone and a sharp-edged anvil.

6.2 Terminology and classification proposal

6.2.1 Percussion marks sensu stricto

Adhering flake

English: Adhering flake; chips; incipient notch; wide impact scars.

French: Eclat adhérent; point de frappe avec esquillement prolongé.

Italian: Bordo d'impatto con sfogliature; schegge secondarie; schegge incipienti; schegge parassite (meno usato).

Spanish: Esquirla parásita; lasca parásita.

German: anhaftender Knochen-Abschlag**.**

Definition: An adhering flake is a flake whose fracture line is incomplete and, thus, still attached to the bone (Figure 1 A, A' and B). The flake has a semi-circular shape visible on the cortical surface caused by two inflection points that cut a fracture edge. Sometimes, adhering flakes can show an inner conchoidal or semi-circular scar. If it were detached, it would form a notch on one hand and a flake on the other. The adhering flake can be related to crushing marks.

References: (Martin 1910; Binford 1981; Villa et al. 1986; White 1992; Capaldo and Blumenschine 1994; Fisher 1995; Boulestin 1999; Díez et al. 1999; Rovira Formento 2010; Rovira Formento and Caceres 2013; Masset et al. 2016; Vettese et al. 2017).

Crushing mark

English: Crushed area; crushing; depressed margin; splintered.

French: Ecrasement; enfoncement.

Italian: Sfondamento incompleto; incrinamento dell'impatto; collassamento dell'area d'impatto.

Spanish: Aplastamiento; machacamiento.

German: Eindrückungen.

Definition A crushing mark is a lesion in the thin cortical bone covering the spongiosa, often located near articular portions (Figure 1 C and C'). This alveolar structure absorbs the shock of the impact differently than the more robust cortex of the shaft. The roundish lesion is formed by multiple dented in adhering flakes and is sometimes located at the origin of one or more fracture lines. Crushing marks can form by repeated blows to the same location, which lacked the force to create fracture lines. In this case, these marks could also appear on the diaphysis of long bones.

References: (Binford 1981; White 1992; Fisher 1995; Peretto et al. 1996; Boulestin 1998; Costamagno 1999; Thiébaut et al. 2009; Masset et al. 2016; Gifford-Gonzalez 2018) Vettese 2014; Chevillard 2018.

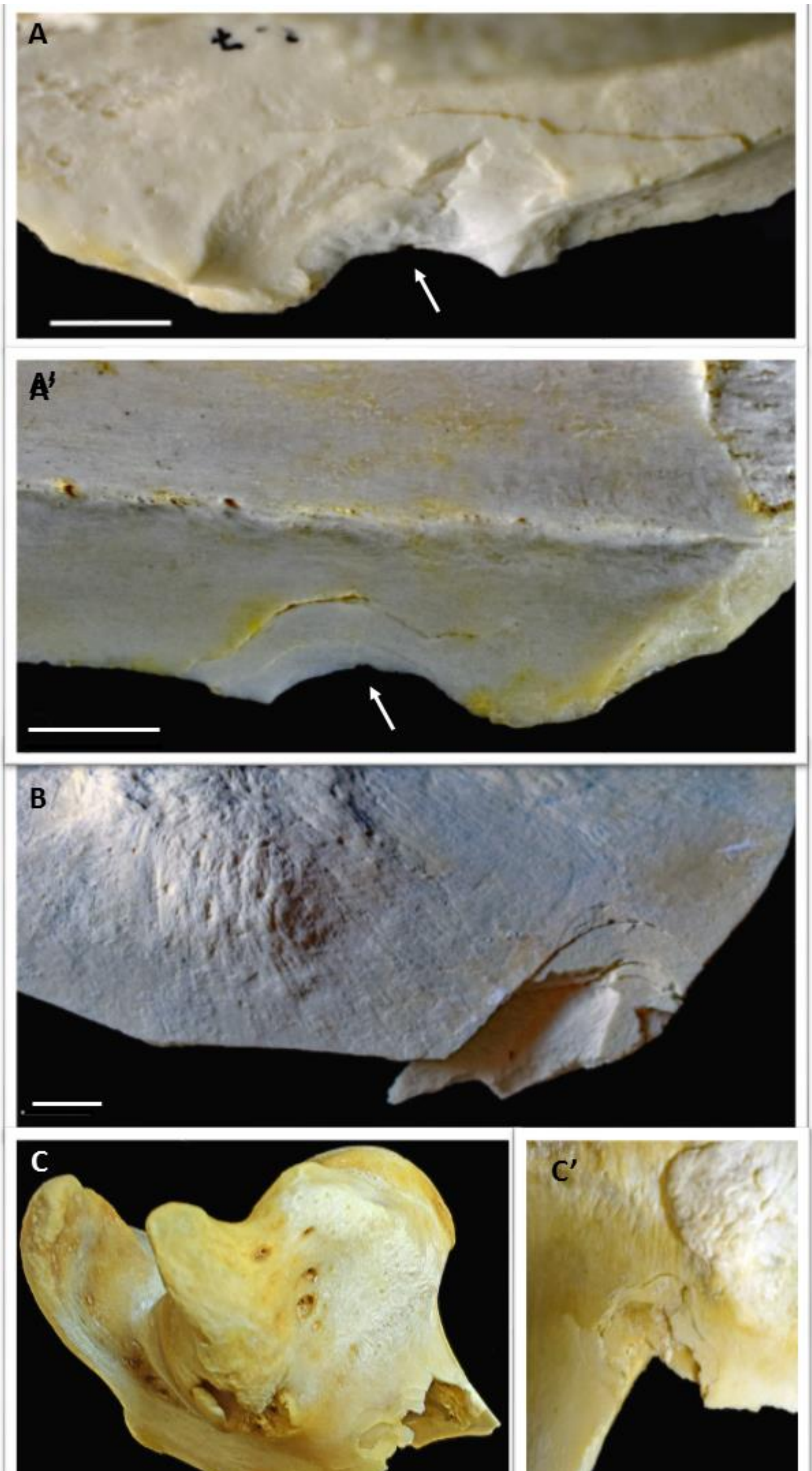

Figure 1: Direct percussion marks: some examples of crushing mark and adhering flakes on experimental bones

(two adult *Bos taurus* species humerus). (A-A') Percussion notch with adhering flakes and inner conchoidal scar and micro-notch (white arrows) (medullary (A) and cortical (A') views); (B) Adhering flake still attached; (C-C') Crushing mark on a proximal epiphysis with some adhering flakes. Bare scales represent 1 cm.

Flake

English: Bone flake; flake; impact flake; positive flake; positive percussion flake; small percussion flakes.

French: Eclat; positif d'éclat.

Italian: Scheggia; scheggia d'osso; scheggia da impatto; scheggia corticale; scheggia midollare.

Spanish: Cono de percusión; lasca medular/cortical.

German: Knochen-Abschlag.

Definition: The percussion bone flake shares the same characteristics as lithic flakes produced by stone tool manufacturing (Figure 2 B). As mentioned by numerous authors, bone flakes may display:

- A platform at the impact point,
- A percussion bulb below the platform,
- Some ripple or hackle marks originating at or near the bulb,
- Greater breadth than length,
- Absence or reduction of the cortical surface.

References: (Brain 1981; Johnson 1985; Blumenschine and Selvaggio 1988; O'Connell and Marshall 1989; Fisher 1995; Costamagno 1999; Pickering and Egeland 2006; Rovira Formento 2010; Blasco et al. 2013; Vettese et al. 2017; Gifford-Gonzalez 2018)

Brain 1981; Johnson 1985; Blumenschine and Selvaggio 1988; Marshal 1989; Fisher 1995; Costamagno 1999; Pickering and Egeland 2006; Rovira, 2010; Blasco et al. 2013; Vettese et al. 2017; Gifford-Gonzalez 2018.

Percussion notch

English: Chopper mark; chopping mark; chopping scar; Clactonian notch; complete or classic notch; conchoidal flake scar; conchoidal scar; dynamic impact scar; hammerstone impact notch; impact notch; impact scar; internal flake scars; loading point; normal notch; notch; outer conchoidal scar; percussion impact notch; percussion notch.

French: Coche; encoche; point d'impact; trace de percussion; zone de point d'impact.

Italian: Incavo; incavo di percussione; impatto; punto d'impatto; area d'impatto; sfondamento completo; scheggia concoidale; distacco; distacco in faccia midollare; distacco in faccia corticale; distacco corticale; distacco midollare; cono di percussione.

Spanish: Muesca de percusión; impacto de percusión; punto de impacto.

German: Schlagspur; Schlagmarke**.**

Definition: The percussion notch is located on a fracture edge (Figure 2 B). Two inflection points cut this edge. From these points, a semi-accurate notch appears with an internal conchoidal scar and sometimes an outer conchoidal scar. The percussion notch is the negative flake scar (Figure 2 B).

We follow the division established by Capaldo and Blumenschine (1994) and modified by Galán et al. (2009) and ourselves:

- Complete or classic notch: notch with two inflection points visible on the cortical surface and with a non-overlapping negative scar (Figure 2 A and A').

- Double opposing complete notches: two isolated notches situated on the two opposite sides of the diaphysis (Figure 2 C).

- Incomplete notch: a notch that has only one inflection point. The second is missing because the fracture line separates the notch into two parts or because a second notch overlaps this first notch (Figure 2 B).

- Double overlapping notches: two notches that share the same inflection point. They are on the same fracture edge; the inner conchoidal scar of one overlaps the other. In some cases, there can be more than two notches (Figure 2 D and D').

- Inverse notch or bifacial notch: notch characterized by both inner and outer conchoidal scars.

- Micro-notch: a notch measuring less than 1 cm.

We propose that a micro-notch can appear inside a notch. This micro-notch could localize the exact point of contact between the bone surface and the hard material during the blow. Likewise, a groove or a triangular pit can appear if the contact surface with the bone is sharp.

- Notch with internal conchoidal micro-notch on the edge of the notch.

- Notch with an internal triangular pit or a groove.

References: (Dauvois 1974; Bonnichsen and Will 1980; Binford 1981; Bunn 1981; Shipman 1981; Johnson 1985; Blumenschine 1988; Brugal and Defleur 1989; Noe-Nygaard 1989; Blumenschine and Selvaggio 1991; White 1992; Capaldo and Blumenschine 1994; Fisher 1995; Boulestin 1999; Costamagno 1999; Outram 2005; Domínguez-Rodrigo and Barba 2006; Pickering and Egeland 2006; Lyman 2008; Galán et al. 2009; Thiébaut et al. 2009; Rovira Formento 2010; Blasco et al. 2013; Masset et al. 2016; Vettese et al. 2017; Gifford-Gonzalez 2018).

Figure 2: Direct percussion marks: some examples of percussion notches on experimental bones (adult *Bos taurus* species humerus and femur). (A-A') Complete percussion notch with an inner conchoidal scar (cortical (A) and medullary (A') views); (B) Incomplete percussion notch with the associated flake (medullary view); (C) Opposite percussion notches (medullary view); (D-D') Double percussion notches (white arrows) (cortical (D) view) and

an opposite percussion notch (red arrow) at the double percussion notches (medullary (D') view). Bare scales represent 1 cm.

Percussion pit and groove

English: Chopper mark; chopping mark; chopping scar; deep puncture; grooves; isolated pits; percussion marks; percussion pit; pit; punched-out lesion; score.

French: Cupule; dépression ; zone d'écrasement.

Italian: Coppelle**;** sbrecciature; tracce da percussione; stigmate di percussione.

Spanish: Depresión; estigma de percusión; golpe; percusión; ranura de percusión.

German: Schlagnarbe.

Definition: Percussion pits are roughly round or sharp superficial pits that appear on the cortical surface of the bone (Figure 3). Sometimes they are associated with the abrasion of the cortical surface and even some micro-striations. The rebound effect may produce these marks without the formation of the fracture line.

We differentiate two types of pits modified from Mallye and colleagues (2012):

- Ovoid pit: a pit with a round shape. It could have a scaled area. This mark is due to the impact of a non-retouched cobble (Figure 3 C).

- Triangular pit or linear pit: a pit with a sharp shape (Figure 3 D).

Percussion grooves are superficial grooves appearing on the cortical surface of the bone. Their shapes are elongated ovals and in cross-section they are V-shaped. They are longer than pits. It is also called chopping mark (Figure 3 A).

References: (Shipman 1981; Blumenschine and Selvaggio 1988; White 1992; Fisher 1995; Peretto et al. 1996; Boulestin 1999; Costamagno 1999; Pickering and Egeland 2006; Lyman 2008; Galán et al. 2009; Thiébaut et al. 2009; Mallye et al. 2012; Blasco et al. 2013; Masset et al. 2016; Vettese et al. 2017; Gifford-Gonzalez 2018).

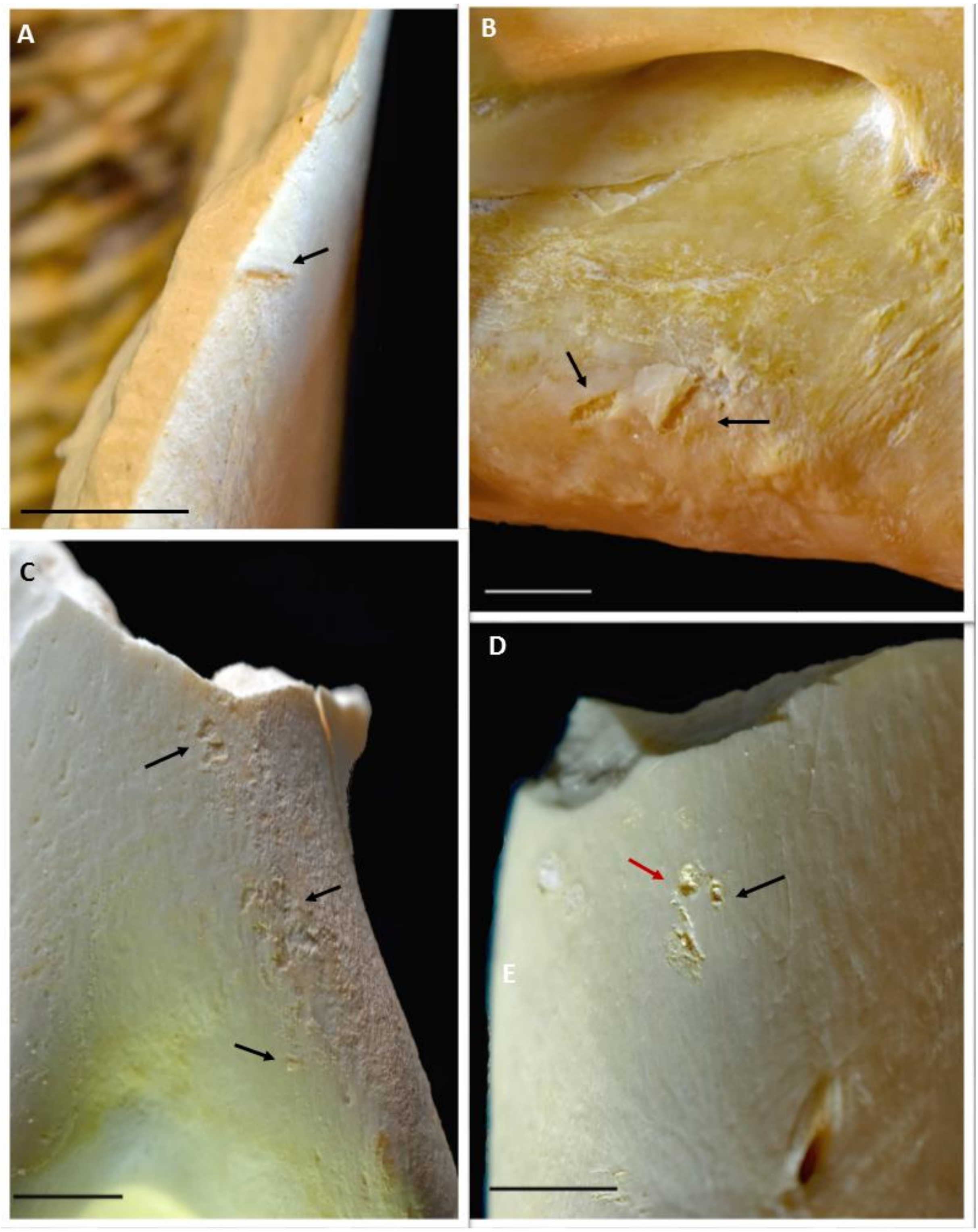

Figure 3: Direct percussion marks: some examples of percussion pits and grooves on experimental bones (adult *Bos taurus* species humerus and radio-ulna). (A-B) Percussion grooves; (C) Some ovoid percussion pits; (D) Triangular (red arrow) and ovoid (black arrow) percussion pits with related microstriations. Bare scales represent 1 cm.

6.2.2 Traces consecutive to bone breakage

Fractures and cracking

A fracture line is a breach in the cortical thickness of the bone. A fracture edge is located on each side of the fracture line.

The texture and the shape of the fracture edge can be indicative of the stage in the taphonomic sequence in which bone breakage occurred, i.e., ante-mortem, perimortem or post mortem. For example, perimortem green bone fractures are characterized by acute angles; they are curved with V-shaped fractures and smooth margins (Villa and Mahieu 1991). Regarding their curve, some green bone fractures can mimic marks related to percussion. Their shape can be similar to that of a notch or an outer conchoidal scar.

Incipient cracks are bone weaknesses running through the thickness of the fragment and stopping before breakage.

Ripple marks

English: Hackle marks; ripple marks; stress marks.

French: Glacis; hachure d'onde; marque en peignage.

Italian: Onde di percussione.

Spanish: Marcas concéntricas; marcas de stress; ondas; ondulación.

German: Schlagwellen.

Definition: Ripple marks or hackle marks are located at or near the bulb or platform. Dauvois (1974) considered that they were hatching waves originating from shock waves (Figure 4 B). For Johnson (1985), they indicate a dynamic impact. Ripple marks can occur on the fracture edge of the bone compacta, not only on the percussion flake. In this case, these marks could be made of stress 'relief'. These can also happen if the fracture is propagated round a tight corner in thick cortical bone. They are associated with green bone fractures.

References: (Dauvois 1974; Johnson 1985; Fisher 1995; Boulestin 1999; Pickering and Egeland 2006).

Peeling

English: Peeling.

French: Arrachement.

Italian: -

Spanish: Pelado; astillamientov; marcas de flexión.

German: Abschälen der Knochen-Oberfläche.

Definition: Peeling is a mark characterized by a roughened surface with parallel grooves or a fibrous texture due to the separation of two parts of a fresh bone when the fracture is not complete and still attached (Figure 4 C). White defined this trace for the first time in 1992. In addition, Pickering and colleagues (2013) defined three types of cortical peeling damage on rib related to their extent on bone surface: "classical peeling", "general peeling" and "incipient peeling".

References: (White 1992; Costamagno 1999; Pickering and Egeland 2006; Blasco et al. 2013; Fernández-Jalvo and Andrews 2016).

Pseudo-notch

English: Pseudo notch.

French: Pseudo-encoche.

Italian: Pseudo-incavo

Spanish: pseudo-impacto; pseudomuescas.

German: Pseudo-Schlagmarke; Pseudo-Schlagspur

Definition: The pseudo-notch is basically shaped like a notch but lacks its other characteristics. The two inflection points or the negative flake scar can be lacking. Its shape can be more angular and not semi-circular. They do not result from an impact during marrow extraction; but are formed by fractures or counterblows.

We follow a modified division established by Capaldo and Blumenschine (1994):

- Outer conchoidal scar: Conchoidal-shaped scar on the cortical surface (Figure 4 A). The semi-circular shape cuts the edge of a fracture line. This scar does not cut through the cortical thickness.
- Inner conchoidal scar: Like the previous type, but on the medullary cavity surface.
- Grouped micro-notches: Many micro-notches lined up on the fracture edge.

References: (Dauvois 1974; White 1992; Capaldo and Blumenschine 1994; Pickering and Egeland 2006; Thiébaut et al. 2009; Masset et al. 2016; Gifford-Gonzalez 2018).

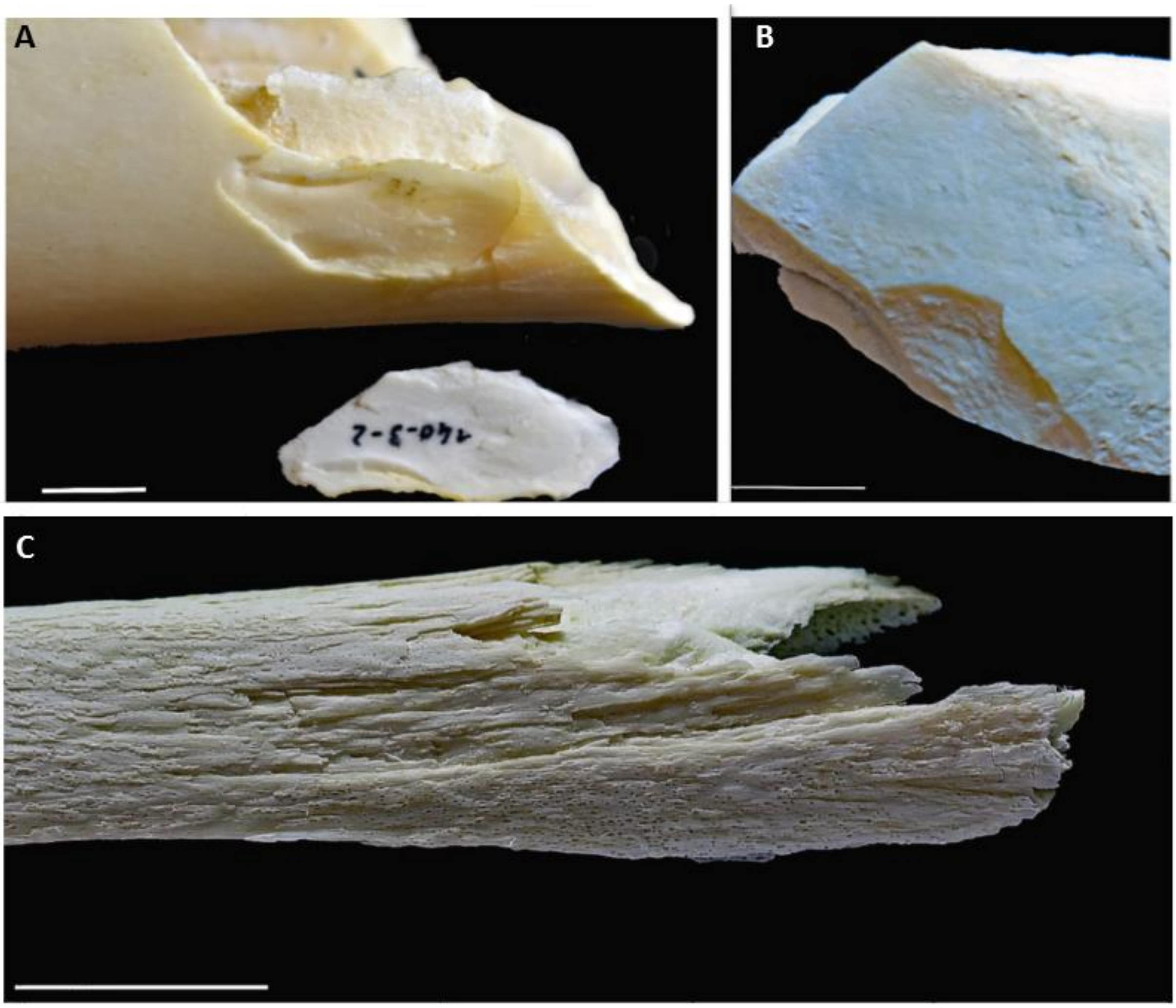

Figure 4: Auxiliary marks related to the marrow extraction: some examples of ripple marks, peeling and pseudo-notch on experimental bones (one radio-ulna and one humerus of adult *Bos taurus* species and one *Ovis capra* tibia). (A) Outer conchoidal scar with the related flake; (B) Ripple marks within outer scar; (C) Peeling. Bare scales represent 1 cm.

6.2.3 Striations related to the percussion marks

Scraping marks

English: Scraping marks

French: Marques de raclage.

Italian: Raschiature; tracce di raschiatura.

Spanish: Raspados.

German: Schabespuren

Definition: Scraping marks are made with the cutting edge of a lithic tool to remove muscles, tendons or the periosteum. Ethnological observations show that the Nunamiut, for example, remove the periosteum before the breakage of a long bone. These marks are long and parallel. They are thin, plural and more superficial than incisions. However, experiments have shown that the removal of the periosteum is optional for the breakage process (Galán et al. 2009; Vettese 2014).

References: (Binford 1981; Villa et al. 1986; White 1992; Galán et al. 2009); Vettese 2014.

Microstriations and striations

English: Anvil scratches; anvil striae; microstriations; percussion microstriations; percussor striae; random striae; striae fields.

French: Stries d’enclume; stries de percussion.

Italian: Tracce da percussione; strie da percussione; striature da percussione; strie da percussore; abrasioni da impatto

Spanish: Estrías de yunque; estrías de percussion; microestriaciones; microestrías de percusión.

German: Mikro-Schrammen

Definition: These marks originate from the roughness of an anvil or percussor (Figure 5). During the impact, they form when the cortical surface of the bone scrubs the surface of the anvil or the hammerstone. They are superficial, short and parallel. They are sometimes associated with percussion pits or notches.

References: (Blumenschine and Selvaggio 1988; White 1992; Fisher 1995; Boulestin 1999; Pickering and Egeland 2006)

Blumenschine and Selvaggio 1988; White 1991; Fisher 1995; Boulestin 1999; Costamagno 1999; Pickering and Egeland 2006.

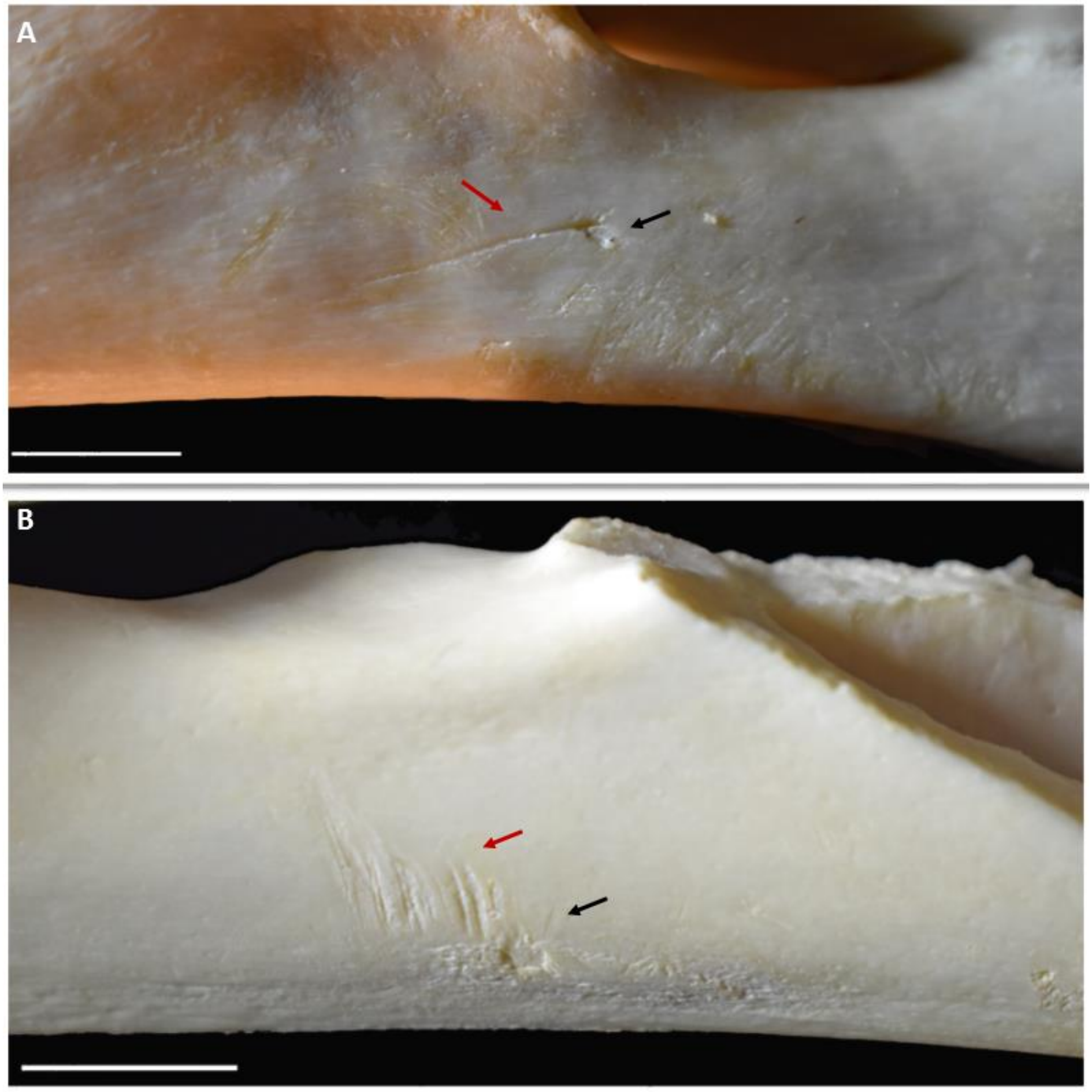

Figure 5: Auxiliary marks related to the marrow extraction: some examples of striations, micro-striations and scraping marks on experimental bones (one adult *Bos taurus* species radio-ulna). (A) Striation (red arrow) related with triangular percussion pit (black arrow), numerous micro striations associated; (B) Microstriations (red arrow) with associated ovoid percussion pit (black arrow). Bare scales represent 1 cm.

7. Conclusion

Through a historical perspective of the study of bone breakage in archaeological contexts, we have outlined two main problematics. First of all, the equifinality of the traces left on bones by different taphonomical agents and secondly, the multiple and arborescent terminology existing for identifying percussion marks.

Concerning the equifinality, the knowledge of the physical-chemical structure of large ungulate long bones enhances our understanding of the extrinsic and intrinsic factors that may affect the marks. We also present the different techniques of marrow recovery to highlight the specificity of dynamic loading, taking into account the shape of the striking tools. Despite the numerous experimental and ethnological studies, it is still difficult to identify the techniques used based on percussion mark morphology.

For this reason, we propose a descriptive terminology for traces related to dynamic loading. We put forward a new classification to differentiate direct percussion marks *sensu-stricto* from the other traces formed during the marrow recovery process. Ongoing research will take into account percussion marks not as single traces but as a package of different sorts of marks in archaeological faunal assemblages. Considering percussion marks as a whole can bring to light patterns which otherwise go unnoticed, particularly in terms of spatial distribution. This research will facilitate the use of percussion marks in a more accurate and detailed manner for reconstructing hominin butchering practices.

Marrow processing can be considered as a hallmark of hominin adaptation to high energetic nutrition. Speth (1989) hypothesized that the main purpose of hunting or scavenging large mammals by early hominins would have been lipids and not proteins. He assumed they were able to extract "the precious lipids" of both the medullary cavity and the cancellous tissue of bones. Moreover, current work of Thompson et al. (2019 -p1.) proposes "an emphasis on percussion-based scavenging of inside-bone nutrients, independently of the emergence of flaked stone tool use". They suggest that the archaeologists might find evidence of percussion activity for marrow extraction predating the use of stone flakes in order to remove meat. The marrow could then represent one of the oldest animal nutrients recovered by hominins. Thus, the first anthropogenic traces could be percussion marks and not cut marks. Therefore, for understanding this basic nutritional behaviour it is imperative to appreciate bone breakage mechanics and traces resulting from marrow processing. Nevertheless, this field of research is still underestimated. Many studies tried to detail percussion techniques or focused on identifying various percussion traces, but our work has the merit of synthesizing it and proposing a solid nomenclature to rely on. Thus, the current study must be understood as a first comprehensive attempt to heal this breach.

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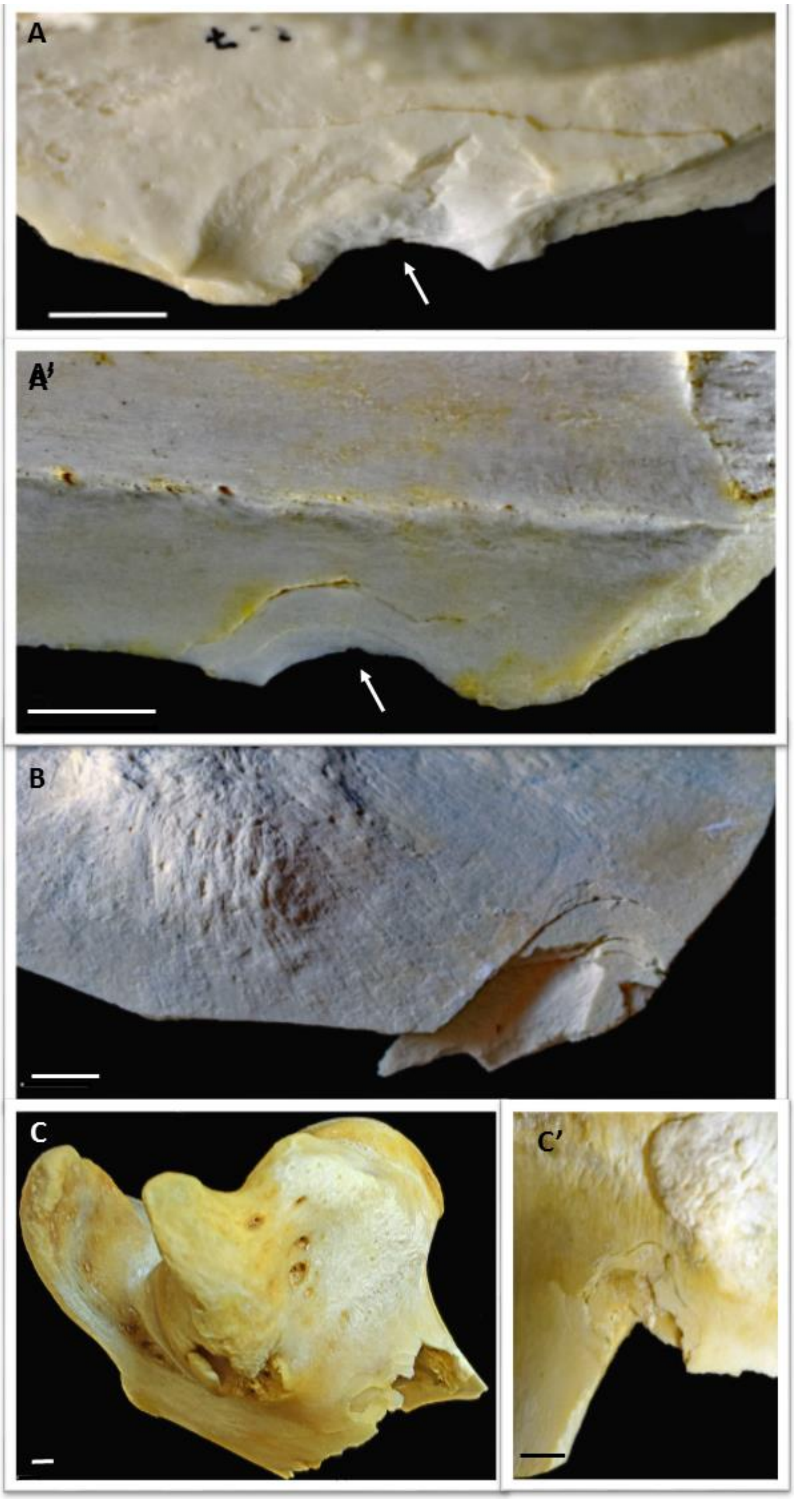
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