Journal of Archaeological Science: Reports 21 (2018) 584–592

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Identification and examination of inconspicuous carnivore modifications

Caroline E. Rowe

University of Minnesota-Twin Cities, 301 19th Ave. S, Minneapolis, MN 55454, United States of America

ARTICLE INFO

Keywords:
Taphonomy
Abrasion
Inconspicuous modifications
Experimental model
Scavenging
Bioerosion

ABSTRACT

Bone modifications are associated with a broad range of agents, including carnivores, stone tools, sediments, etc., and can be categorized as one of two types: conspicuous or inconspicuous. Contrary to the larger, more easily identifiable conspicuous modifications, inconspicuous modifications are small, shallow and almost unnoticeable without the aid of a hand lens and strong light, making them harder and more time consuming to identify. This has led to arguments for their omission from tooth mark counts, even though their presence on the bones of archaeological and paleontological faunal assemblages have been recognized and mentioned in literature as having interpretive potential.

This study employs visible light microscopy and high resolution scanning electron microscopy to present evidence that positively identifies inconspicuous carnivore modifications as abrasions that also have diagnostic morphology which differentiates them from abrasion created by other taphonomic agents. These inconspicuous carnivore marks may also be associated with the presence of soft tissue and so may help reconstruct the amount of flesh present at specific stages of carcass consumption. This study shows the interpretive potential of ICA may be substantial, requiring their inclusion in tooth mark counts for more accurate reconstructions of past carnivore behavior.

Furthermore, understanding the etiology and implications of inconspicuous carnivore marks may provide a new way to interpret faunal assemblages that exhibit such marks, such as those associated with FLK *Zinjanthropus*, Tanzania. Such interpretations may be able to help develop stronger inferences regarding methods of hominin carcass acquisition.

1. Introduction

1.1. Conspicuous and inconspicuous modifications

One of the ways the science of taphonomy is used during the examination of vertebrate remains by forensic investigators, archaeologists and paleontologists is to identify agents of post mortem processes (Efremov, 1940; Lyman, 1994). When bone is all that remains, taphonomic analysis of surface modifications can reveal evidence of direct interaction between agents of modification and carcasses that can assist in the reconstruction of peri-mortem events (Fisher, 1995; Lyman, 1994). Modifications exist as one of two types: conspicuous or inconspicuous. The difference between the two types is that because of their large size, key morphological features of conspicuous modifications, make them identifiable as tooth marks, cut marks, abrasion, etc., without magnification (Binford, 1981; Blumenschine et al., 1996; Capaldo, 1997; Dominguez-Rodrigo, 1999; Dominguez-Rodrigo et al., 2007; Fisher, 1995; Haynes, 1983; Lyman, 1994, Pobiner, 2007). Conversely, inconspicuous marks refer to shallow, obscure modifications whose variable features are too small to be visible with the naked eye and are only detected by either a slight color change within the interior of the modification or the presence of polish (Amore and Blumenschine, 2016; Blumenschine et al., 1996; Blumenschine, 2007; Capaldo, 1997; Fisher, 1995). Both conspicuous and inconspicuous carnivore tooth marks have been identified on bone assemblages at archaeologically significant sites, such as the FLK *Zinjanthropus* site in Olduvai Gorge, Tanzania (Blumenschine, 1986; Blumenschine, 2007; Blumenschine, 1995; Blumenschine et al., 1996; Bunn and Kroll, 1986; Capaldo, 1997; Dominguez-Rodrigo and Barba 2006, 2007; Dominguez-Rodrigo et al., 2007; Pante, 2013; Pante et al., 2012, 2015; Pobiner, 2007; Selvaggio, 1994). While problems with collecting congruous bone surface modification data have revolved around both conspicuous and inconspicuous modifications, problems with the latter, such as requiring significantly more time to locate, quanify and identify to an agent, are inherently worse due to their small size and perceived ambiguous morphology (Blumenschine et al., 1996; Fisher, 1995; Lyman, 1994; Cruz-Uribe and Klein, 1994; Dominguez-Rodrigo and Barba, 2006). It is because of these problems that arguments have been made for their exclusion from examinations of bone surfaces (Blumenschine, 1995; Blumenschine et al., 1996; Cruz-Uribe and Klein, 1994;

E-mail address: Rowe0101@umn.edu.

https://doi.org/10.1016/j.jasrep.2018.08.037
Received 28 March 2018; Received in revised form 26 July 2018; Accepted 13 August 2018
2352-409X/

Dominguez-Rodrigo, 1999; Oliver, 1994). Regardless of these challenges, Blumenschine et al. (1996) encourage the inclusion of inconspicuous modifications, suggesting that their omission results in tooth mark counts that fail to accurately reflect the true scope of carnivore scavenging activity on an assemblage. To facilitate the reduction of inter-analyst error and to improve reproducibility, researchers have advocated the consistent use of "a hand lens under strong light, systematically examining all parts of the surface at different angles with respect to the incoming light for conspicuous and inconspicuous marks" (Blumenschine et al., 1996; Pante et al., 2012).

But researchers *have* recognized special circumstances that may require more intensive microscopic analyses, such as microstructural differences among bones of separate species, modification ambiguity or modification mimicry, and when identifying marks of unknown origin (Archer and Braun, 2013; Bell, 1990; Bello et al., 2009; Behrensmeyer et al., 1986; Bromage, 1984; Madgewick, 2014; Pante et al., 2017; Shipman and Rose, 1983). For example, the microstructural differences among the bones of terrestrial and aquatic animals influence the morphology of modifications made by the same agents, making them smaller and more inconspicuous on the bones of aquatic species (Archer and Braun, 2013). This alters how effectively seasoned researchers can identify the smaller, more inconspicuous modifications (Archer et al., 2014; Archer and Braun, 2013). In these cases, the use of a hand lens to observe and identify smaller, inconspicuous modifications is considered insufficient to maintain accurate, reproducible results between observers, but microscopic analysis using visible light microscopy at 40× of the same modifications increased agreement between observers (Archer et al., 2014; Archer and Braun, 2013).

Earlier work by Shipman and Rose (1983) compared various criteria for identifying unknown bone surface modifications, such as the width of the mark, cross sectional shape and microscopic criteria. Their study illustrated that the magnification and resolving power of scanning electron microscopy for visualizing and documenting diagnostic features and normal variation within known surface marks, such as cut marks, trampling, tooth marks, and sedimentary abrasion, was superior to that of visible light microscopy. Because this method provided a means to characterize the features of known modifications, it was also more reliable for identifying unknown surface marks.

1.2. Tooth mark mimicry by microbial agents at FLK Zinjanthropus

For as long as bone surface modifications have been studied at the FLK *Zinjanthropus* site in Olduvai Gorge considerable disagreement has existed among researchers regarding models of hominin carcass acquisition that are based on tool and tooth mark data (Bunn, 1986; Bunn and Kroll, 1986; Blumenschine, 1988, 1995, 2007; Pante et al., 2012, 2015; Capaldo, 1997; Dominguez-Rodrigo and Barba, 2006, 2007; Pante et al., 2017; Selvaggio and Wilder, 2001; Shipman, 1986). In 2006, Dominguez-Rodrigo and Barba contended that Blumenschine's tooth mark counts at FLK *Zinj*, which include both conspicuous and inconspicuous tooth marks, were inflated due to the misidentification of inconspicuous modifications as tooth marks (Blumenschine, 1986, 1995, 2007; Dominguez-Rodrigo and Barba, 2006, 2007). Their argument is based on the assertion that the morphology of the marks in question fail to follow all the criteria for tooth mark identification which has been widely accepted among researchers and defined by Blumenschine as having "U-shaped cross-sections that commonly show crushing that is conspicuous under the hand lens, and which, macroscopically, gives the mark a different patina than the adjacent bone surface" (Binford, 1981; Blumenschine, 1995: 29; Bunn, 1986; Dominguez-Rodrigo and Barba, 2006; Haynes, 1983; Lyman, 1994; Oliver, 1994; Pobiner, 2007; Pokines and Symes, 2013; Selvaggio, 1994; Selvaggio and Wilder, 2001; Shipman and Rose, 1983). Instead, Dominguez-Rodrigo and Barba asserted that many of these modifications are the result of microbial activity which he observed as producing modifications that do not penetrate the cortical surface of bone and do not produce microfracturing.

1.3. Purpose and research goals

The purpose of this paper is to determine the interpretive potential of inconspicuous tooth marks by examining their microscopic morphology and etiology. The goal of this study is to begin answering the following questions:

1) Are there unique microscopic identifiers that will unambiguously identify inconspicuous marks made by carnivorous actors?
2) Can the etiology of inconspicuous tooth marks be used to make stronger inferences regarding hominin carcass acquisition?

This paper will show that using visible light microscopy at 25× reveals inconspicuous tooth marks exhibit characteristics consistent with that of abrasion, such as a compacted surface, polish, and a lack of visible penetration into the cortical surface. But, when examining inconspicuous tooth/beak mark abrasion using high resolution scanning electron microscopy at 50× reveals the same features that universally characterize conspicuous tooth marks, such as a 'u' shaped cross section and microfracturing within the tooth mark. Data collected here also support assertions that soft tissue adhering to bones may mask the damaging effect of a carnivore's teeth/beak by limiting penetration into the bone, hypothesizing that ratios of inconspicuous tooth mark abrasion to those of the conspicuous tooth marks may be an indicator of soft tissue presence.

2. Materials and methods

2.1. Background

Data presented in this paper come from a larger study, which tested the null hypothesis that North American carnivore consumption sequences do not differ from those of African animals (Rowe, 2015). To acquire data regarding consumption and disarticulation sequences, the study protocol involved placing legally acquired carcasses of road killed white tail deer (*Odocoileus virginianus*), that were no more than a few hours old in areas with known wild coyote (*Canis latrans*) populations. Prior to placement carcasses were examined to record the ages of the deer and any perimortem injury sustained by the deer (Table 1). No constraints were put in place to control for wild scavengers and the carcasses were not secured in any of the trials. Other than coyotes, scavenger species that were observed feeding on carcasses include bald eagle (*Haliaeetus leucocephalus*), turkey vulture (*Cathartes aura*), raven (*Corvus corvax*), crow (*Corvus brachyrynchos*) and red fox (*Vulpes vulpes*). Carcasses were also placed in enclosures of captive species, including coyote, wolf (*Canis lupus*) and mountain lion (*Puma concolor*).

2.2. Study trials

The inability to acquire multiple salvageable road kill at the same time disallowed synchronous placement of all trials. The study took place from September 29, 2014–November 10th, 2014. Table 1 shows the dates of placement and collection dates for all 5 trials. Two different locations were used for trials involving wild coyotes based on evidence of established coyote populations in Elk River (ER) and Linwood (LW), Minnesota and were labeled as WC (wild coyote). Location ER is on the private property of a quarry and gravel pit. This location has equal amounts of dense tree cover and tall grass and abuts undeveloped forest to the north. For trial 1ER-WC the deer was placed in an area of dense tree cover with open grass to the north and a water source 400 m to the south. In trial 2ER-WC the deer was placed in an open area with only two small trees in the vicinity. Open grass surrounded the site and a water source could be seen from the site about 200 m to the east. Trial 4LW-WC used wild coyote and was on the property of the Wildlife