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Multivariate evaluation of criteria for differentiating cut marks created from steel and lithic implements

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ABSTRACT

The identification of cut marks has been integral to expanding the understanding of hominin behavior ranging from the origins of meat consumption to the role of human hunting in megafaunal extinctions and the timing of the peopling of the Americas. Paleoanthropological and archaeological research demonstrates cut mark placement can be indicative of activity, but cut mark morphology is more complex and influenced by multiple variables such as raw material, tool shape, and bone density. Significant overlap in the 'classic' features of cut marks, such as V-shaped cross-sections, has also been recognized in numerous processes including carnivore gnawing and trampling. Before researchers can refer to modified animal remains as proxies for a hominin presence, diagnostic patterns representative of past human behavior in the archaeological record must first be identified and distinguished from modern cultural processes. This paper develops an empirical multivariate and probabilistic approach for differentiating cut marks created by lithics from those by steel. The results identify no single diagnostic attribute of cut marks produced by lithics. However, an approach which includes excavation history, stratigraphic context, location, orientation, and mark color significantly improve the likelihood with which cut marks are identified accurately.

1. Introduction

A cut mark is produced on bone when it comes into direct contact with an implement, especially during butchering, mortuary activities, excavation, storage, and transport (Binford, 1981; Bunn, 1981, 1983; Potts and Shipman, 1981; Shipman and Rose, 1983a; Bunn and Kroll, 1986; Lyman, 1994). When preserved, cut marks are direct evidence of human manipulation of a carcass but can only be identified through deliberate comparative analyses. Neotaphonomic bone modification studies investigating cut mark frequencies, placement, and morphology have been integral to establishing the antiquity of and reconstructing hominin behaviors especially meat acquisition (Walker and Long, 1977; Potts and Shipman, 1981; Shipman and Rose, 1983a, 1983b, 1984; Bunn and Kroll, 1986; Blumenschine and Selvaggio, 1988, 1991; Domínguez-Rodrigo, 1997, 1999, 2002).

Ludwig Rütimeyer described cut fox bones in 1862 as evidence the meat had been consumed by humans (Davis, 1987). Since then cut marks have been described as V to U-shaped in cross section (Walker and Long, 1977; Potts and Shipman, 1981; Shipman and Rose, 1983a, 1983b, 1984; Bromage and Boyde, 1984). A cut mark apex usually displays multiple elongate or short parallel striae but may lack apex striae altogether (Eickhoff and Herrmann, 1985; Lyman, 1987a). Cut marks created by stone tools may display paired straight and concave walls due to the shape of cutting edges (Greenfield, 1999, 2006). Cut marks produced by metal may possess vertical sides with cross-sections ranging from steep to wide edged V or |__| shapes with striae and stepped sides but true V-shaped cross sections are uncommon (Greenfield, 1999, 2006). For comprehensive lists of cut mark definitions see Fisher (1995), Lyman (1994) and Monnier and Bischoff (2014).

In the Americas numerous sites reportedly predating 11,500 rcybp, before the appearance of Clovis technology, lack stone tools but contain modified proboscidean remains with attributes interpreted as prehistoric cut marks (Carlson et al., 1984; Fisher, 1984, 1987; Solórzano, 1989; Fisher et al., 1994; Cinq-Mars and Morlan, 1999; Morlan, 2003; Johnson, 2005, 2006, 2007; Joyce, 2005). Many of these sites were discovered inadvertently and/or recovery techniques included the use of shovels and trowels which may have produced these marks on bone. Consensus on their interpretation has not been achieved because neotaphonomic

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research has demonstrated multiple processes create marks which also possess the ‘diagnostic’ features described in cut marks especially when compared to trampling, sediment abrasion, carnivore gnawing, and biochemical alterations (Haynes, 1980, 1985, 1987, 1988, 1991, 2002, 2007; Shipman and Rose, 1984; Behrensmeyer et al., 1986, 1989; Marshall, 1989; Lyman, 1994, 2004; Domínguez-Rodrigo and Barba, 2006). For example, Eickhoff and Herrmann (1985:2635) examined marks on a Neolithic grave in which they discarded Shipman's (1981) cut mark criterion of striations in slice marks because “longitudinal striations were found in carnivore tooth scratches as well.”

The Mud Lake mammoth locality near Kenosha, Wisconsin was discovered fortuitously in the 1920s and 1930s during water diversion projects (Johnson, 2007). Paleontologists and archaeologists did not recover the remains and methods were less than ideal likely creating bone surface modifications on specimens. Remains of a single mammoth (*Mammuthus* sp.) were recovered from intermorainal depressions within lacustrine clays overlying peats (Johnson, 2006, 2007). Details on the discovery, the site's exact location, and collection are lacking. Its provenience was based on generalizations from regional stratigraphy (Overstreet and Kolb, 2003). They could have been accidentally modified during recovery or during their decades-long museum storage where numerous processes could have marked their surfaces, such as accidental dinging and stacking under other bones (Johnson, 2006, 2007; Haynes and Krasinski, 2010).

No artifacts were recovered from the site, but an articulated “ulna, radius, carpals, and metacarpals from the right lower front leg of a subadult mammoth” were recovered (Johnson, 2006:59). Bone samples pretreated conventionally and with XAD-purified gelatin hydrolyzate techniques dated to 13,440 $\pm$ 50 and 13,460 $\pm$ 50 rcybp (Overstreet and Stafford, 1997; Overstreet and Kolb, 2003; Joyce, 2005). Taphonomic analyses identified numerous surface marks on the remains most of which were interpreted as prehistoric cut marks produced during butchering of a stiffened carcass (Johnson, 2007). Mark placement was interpreted as evidence for disassembling the foot for access to its fatty pads and “muscle bundle stripping” (Overstreet et al., 1993:77).

Krasinski (2010) conducted a multivariate analysis of the Mud Lake ulna cortical surface and demonstrated none of the marks fell within or near the cut mark category. Nine marks fell well within the score category, two were steel marks (excavation damage or preparator's marks) and 11 (52%) were indeterminate. All were the same color as the unmodified cortical surface as was the broken distal end of the specimen. While the Mud Lake mammoth was reported as a proxy for a pre-Clovis human occupation of North America, taphonomic research integrated with the context of discoveries (lack of stone tools, non-professional recovery, high potential for mark creation after recovery) demonstrates this mammoth does not support a pre-Clovis occupation of the Americas.

Recently, the reevaluation of bone surface modifications has demonstrated taphonomists still have not developed a universal system which accounts for this morphological variation (James and Thompson, 2015). For example, the 3.4 Ma material from Dikika, Ethiopia was reported as the oldest documented cut marks and indirect evidence for stone tool use by hominins (McPherron et al., 2010). The discovery would have been revolutionary because it extended the evidence of stone tool use and meat access 800,000 years and to *Australopithecus afarensis* (McPherron et al., 2010). However, Domínguez-Rodrigo et al. (2010, 2012) demonstrated the modifications were morphologically and contextually most consistent with trampling, not cut marks. The Dikika fossils were recovered in a course-grained depositional context and contained randomly oriented striations which are more typical of post-depositional movement and not hominin behavior.

While few researchers rely on single attributes to identify cut marks, attributes are unstandardized and the few multivariate analyses documenting how multiple variables interact to produce resulting cut mark morphometrics do not specifically differentiate cut marks created by lithic from steel implements (Domínguez-Rodrigo and Yravedra, 2009; Domínguez-Rodrigo et al., 2009; de Juana et al., 2010; James and Thompson, 2015). Multivariate analyses are essential to understand how cut mark morphology is dependent on bone and tool properties including bone density and bone tissue type (Bromage and Boyde, 1984; Pobiner, 2007), raw material, length of cutting edge (Walker and Long, 1977; Greenfield, 2006), carcass size and condition, and cutting edge shape and sharpness (Gifford-Gonzalez, 1991; Lyman, 1992, 1994, 2005; Bar-Oz and Dayan, 2003; Dewbury and Russell, 2007; Domínguez-Rodrigo and Yravedra, 2009). In the absence of recovery details, it is imperative to differentiate these types of cut marks which may be produced incidentally during recovery from those created prehistorically.

2. Materials and methods

2.1. Hypotheses and predictions

This research seeks to determine whether diagnostic metric and qualitative attributes distinguish cut marks made by steel from those produced by stone implements through multivariate analyses of mark morphometrics to develop a more refined approach to identifying the effector and timing of cut mark creation, information which is essential to evaluate reported evidence for human continental diasporas including the earliest human occupation of the New World (Gifford-Gonzalez, 1991). Adcock and Arbuckle (2009) found the ratio of cut mark widths to depths differentiated lithic and metal cut marks while Bello and Soligo's (2008) research demonstrated that cut marks produced by metal knives possessed smaller floor radii relative to cut marks produced by lithics. Further, Potter (2005) measured the minimum force required for a cut mark to be visible on bone after penetrating flesh, but did not control for flesh thickness or bone density. Chert tools required 30% more force than obsidian to create visible cut marks and this difference was likely a function of tool thickness (Potter, 2005). Later, cut mark widths and depths were directly correlated with butchery action, carcass size and bone density, and weakly correlated with tool type, weight, and edge angle (Merritt, 2012). Cut mark cross sections have been the most widely used criterion to differentiate lithic from metal implements as well as cut marks from trampling (Domínguez-Rodrigo et al., 2009). While cut marks traditionally have been characterized as V-shaped in cross-section (Walker and Long, 1977; Potts and Shipman, 1981; Fisher, 1995; Monnier and Bischoff, 2014), Greenfield (1999) differentiated implement raw material on the basis of cut mark cross section. Based on these studies the following predictions were developed to differentiate cut marks created by lithics and steel through multivariate analyses:

(1) Metrics differ between cut marks created by lithic and metal implements;
(2) Carcass attributes such as bone type, carcass size, and preservation state influence cut mark morphology; and
(3) Cut mark morphological attributes differ between cut marks created by lithic and metal implements.

2.2. Experimental design

Initially butchering fleshed cattle (*Bos taurus*) limbs and a sheep (*Ovis aries*) carcass was employed to generate unintentional cut