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When felids and hominins ruled at Olduvai Gorge: A machine learning analysis of the skeletal profiles of the non-anthropogenic Bed I sites

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ABSTRACT

In the past twenty years, skeletal part profiles, which are prone to equifinality, have not occupied a prominent role in the interpretation of early Pleistocene sites on Africa. Alternatively, taphonomic studies on bone surface modifications and bone breakage patterns, have provided heuristic interpretations of some of the best preserved archaeological record of this period; namely, the Olduvai Bed I sites. The most recent and comprehensive taphonomic study of these sites (Domínguez-Rodrigo et al., 2007a) showed that FLK Zinj was an anthropogenic assemblage in which hominins acquired carcasses via primary access. That study also showed that the other sites were palimpsests with minimal or no intervention by hominins. The FLK N, FLK NN and DK sequence seemed to be dominated by single-agent (mostly, felid) or multiple-agent (mostly, felid-hyenid) processes. The present study re-analyzes the Bed I sites focusing on skeletal part profiles. Machine learning methods, which incorporate complex algorithms, are powerful predictive and classification methods and have the potential to better extract information from skeletal part representation than past approaches. Here, multiple algorithms (via decision trees, neural networks, random forests and support vector machines) are combined to produce a solid interpretation of bone accumulation agency at the Olduvai Bed I sites. This new approach virtually coincides with previous taphonomic interpretations on a site by site basis and shows that felids were dominant accumulating agents over hyenas during Bed I times. The recent discovery of possibly a modern lion-accumulated assemblage at Olduvai Gorge (Arriaza et al., submitted) provides a very timely analog for this interpretation.

1. Introduction

The earliest interpretations of the discrete (vertically-concentrated) archaeological levels from the Olduvai Bed I sites coincide in that the sites represented living areas (a.k.a "home bases") of early hominins (Leakey, 1971). Based on ethnographic analogs, prehistoric home bases were defined as special *loci* in the landscape were carcasses were actively accumulated by hominins and where food-sharing activities took place (Leakey, 1971; Isaac, 1978). Subsequent to these interpretations, other studies about these sites produced an intense debate during the 1980s. Binford (1981) argued that hominins were marginal scavengers based on analyses of skeletal part representation and assuming an interaction between hominins and carnivores that was never taphonomically-supported. Carnivores and/or other natural agents could have either independently or through interaction played a major role in the formation of the Bed I sites (Binford, 1981). During the period in which these interpretations were introduced, research on modern African savanna ecosystems was carried out in order to understand the paleolandscape of the Olduvai Bed I lake basin. Neo-taphonomic studies about density of bones naturally accumulated and scattered in several modern savanna habitats showed that the density of bone remains unearthed at early sites was higher than in modern savannas and that skeletal part profiles differed from those reported in natural death scenarios (e.g. Hill, 1975; Behrensmeyer, 1983; Potts, 1988).

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The following step in the research of early site formation at Olduvai was to discriminate the carnivores involved in the potential accumulation and modification of bone assemblages. The leopard was the only felid which had been proposed as an accumulating agent in modern savanna ecosystems (Brain, 1981). Since leopards do not regularly prey on medium-sized ungulates (Schaller, 1972; Kruuk and Turner 1967), the only carnivores considered as potential accumulating agents in Olduvai Bed I sites were hyenas (Binford, 1981; Potts, 1988). However, the paleoecological location of the sites, the anatomical distribution and frequencies of cut and percussion marks and the frequency of tooth marks on bones suggested that hominins were transporting carcasses to some locations instead of hyenas (see summary of this discussion in Domínguez-Rodrigo et al., 2007a).

The use of skeletal part profiles became, thus, an important focus of debate on hominin agency in early site formation and hominin carcass acquisition strategies, fueling the hunting-versus-scavenging debate. The skeletal profiles of FLK Zinj, biased towards long limb bones, initially sparked the controversy by providing supporting arguments for both sides (e.g., Binford, 1981, 1988; Bunn and Kroll, 1986, 1988; Oliver, 1994; Potts, 1988; Blumenschine, 1991). Using modern ethnographic analogs, skeletal representation at some of the Bed I sites (e.g., FLK Zinj) were interpreted as indicating primary access by hominins to carcasses and selective transportation of remains (e.g., Bunn and Kroll, 1986, 1988). Using the same profiles, others argued for a secondary access to carcasses, which could have been initially accumulated by other carnivores at sites (Binford, 1981) or scavenged at kills and transported by hominins to sites (Blumenschine, 1986, 1995; Capaldo, 1995; Selvaggio, 1994). It should be remarked that controversial interpretations on whether early humans hunted or scavenged have been mainly focused on one site (FLK Zinj, Olduvai Gorge). Some of the partisans of passive scavenging for this site are supporters of an increase of meat and marrow consumption or persistent hominin carnivory through hunting or a combination of hunting and scavenging for older (Ferraro et al., 2013) and younger sites (Pobiner et al., 2008). Interpretations of scavenging at FLK Zinj have been mainly based on an initial interpretation of high frequencies of tooth marked bones identified at the site (Selvaggio, 1994; Blumenschine, 1995; Capaldo, 1995; Pobiner, 2007; Pante et al., 2012). The frequencies of toothmarked bones at the site have been independently reassessed to be much lower and similar to human-carnivore experimental scenarios (Domínguez-Rodrigo et al., 2007a; Parkinson, 2013), thereby lending support to a primary access scenario. However, this did not mean that all the Bed I sites were interpreted as hominin-made (Table 1). The most recent taphonomic study of all Bed I sites concluded that with the exception of FLK Zinj, which was interpreted as fully anthropogenic, the remaining Bed I archaefaunas were palimpsest with minimal or non-existing hominin input and that they were accumulated mostly by felids (Domínguez-Rodrigo et al., 2007a). This revived Binford's (1981) idea that some carnivores might be considered primary agents in site formation.

All the interpretations of the timing of access to carcasses by the different taphonomic agents in Olduvai Bed I sites assumed that large felids such as lions do not create bone assemblages (e.g., Potts, 1988; Domínguez-Rodrigo, 1994). Recently, the first bone assemblage potentially accumulated by modern lions has been discovered and described (Arriaza et al., submitted). Given that most sites (except FLK Zinj) are taphonomically interpreted as having been made by carnivores (Domínguez-Rodrigo et al., 2007a), a new revision of the Olduvai Bed I skeletal profiles is necessary. Domínguez-Rodrigo et al. (2007a) reported skeletal representation at these sites but did not consider them of enough resolution for discerning agency in site formation. These authors relied, instead, on taphonomic variables related to bone breakage and surface modifications (Table 2).

The analyses of bone assemblages based on skeletal part profiles have been subjected to controversy because of several reasons. Partly, this is related to the way we construct analogs: researchers are reporting on human carcass transport decisions at different stages of the carcass consumption sequence (from kill site to their abandonment at sites, prior o after carnivore disturbance) (e.g., O'Connell et al., 1988; Bunn et al., 1988; Bunn, 2007). When this information is reconciled, it is shown that humans tend to transport complete or mostly complete small and medium-sized carcasses (Bartram et al., 1991; Monahan, 1996). This is why it is very difficult to separate humans from felids when using skeletal part profiles alone. However, humans exhibit a far greater variability in carcass transport decisions than any other carnivore. Bartram (1993) showed how the same human group could transport the same carcass type in widely opposing ways. Other studies have supported this by showing that humans make carcass decision transports based on a set of variables which are difficult to control, involving time of the day in which carcass is acquired, distance to camp, number of carriers, time of the year or preferences depending on carcass health (e.g., Binford, 1978; Speth, 1987; Bunn et al., 1988; Bartram et al., 1991; Bartram, 1993; Monahan, 1998). This results in overlapping bone accumulation patterns at kills and camps, which occupy divergent positions in the carcass reduction sequence (See Fig. 1). Humans are, therefore, a biasing factor in generating standardized anatomical profiles. In addition to this, another biasing factor is introduced by non-human carnivores. Carnivore postdepositional ravaging of human-made bone accumulations further bias the original hominin-created assemblages (e.g., Blumenschine and Marean, 1993; Marean et al., 1992; Bartram, 1993). This makes it very difficult to differentiate the action of several agents in bone modification, and diagnostic patterns in the way that agents (humans and carnivores) transport and accumulate remains are variable (e.g., Bunn and Kroll, 1986; Klein, 1982a,b; Domínguez-Rodrigo, 1999). This is why during the debate of early site formation at Olduvai held during the 1980s, researchers admitted equifinality in the use of carcass transport profiles: limb and head dominated assemblages could be the result of selective transport propitiated by early access to carcasses (Bunn and Kroll, 1986, 1988) or, alternatively, the exploitation of brain and marrow through passive scavenging from felid kills (Blumenschine, 1995; Capaldo, 1995; Pante et al., 2012).

The aim of this paper is to resurrect the use of skeletal part representation in the interpretation of non-anthropogenic site formation, given the more restricted variability of carcass transport decisions by different carnivore types when compared to humans. For this purpose, we used actualistic analogs of the three potential accumulating agents: hyaenids, felids and humans. The results show that felids were the primary accumulating agent in site formation during Bed I times, although hyaenas contributed to bone modification in some assemblages. Here, we show that skeletal part representation is a useful variable to test agency in bone accumulation when using machine learning methods.

These methods are based on programmed algorithms, which target pattern recognition. The name is derived from the implementation in these algorithms of learning processes, which consist of using arrays of variables in training sets to make classifications or decisions and their application to testing sets for evaluating their accuracy. The final goal is the application of the learned patterns to predict new data outcomes. Machine learning methods are behind robot behaviors that involve pattern recognition and behavioral response. Their heuristics are so high that the potential of their application to taphonomic problems is unveiled in the present study.