Title
Gaining traction on cattle exploitation: zooarchaeological evidence from the western Balkan Neolithic (6000-4500 cal BC)

Authors
Jane S. Gaastra¹*, Haskel J. Greenfield² and M. Vander Linden³
¹University College London, United Kingdom
²University of Manitoba, Canada (haskel.greenfield@umanitoba.ca)
³University of Cambridge, United Kingdom (mv297@cam.ac.uk)
*Corresponding author: jane@gaastra.co.uk

Abstract
This study examines sub-pathological alterations to cattle foot bones from eleven central and western Balkan Neolithic sites (c.61/6000 to 4500 cal BC). Systematic comparisons of bone remodelling in those elements shown to be most directly affected by traction is used to determine the potential use of cattle as engines across this region throughout the period. This study provides the earliest direct evidence for the use of cattle for light traction, long before the hard usage pathological evidence previously observed.

Keywords
Traction
Domestic cattle
Neolithic
Europe
Balkans
Sub-pathology
Pathology
Introduction

Andrew Sherratt’s seminal argument for a ‘secondary products revolution’, or the intensification in the use of domestic livestock for dairy, wool and traction during the Old World Chalcolithic, was initially advanced in the absence of a substantial body of zooarchaeological evidence (Sherratt 1981, 1983). Over the subsequent three decades, the acquisition of abundant and high quality zooarchaeological data has advanced significantly our understanding of the changing roles of domestic livestock in prehistory (see Greenfield 1988, 2010; 2014b for extensive summaries of the relevant literature). As suggested by early criticisms (e.g. Chapman 1982, Bogucki 1984), it is widely acknowledged today that the picture is more complicated than originally envisioned, with no single revolutionary point in time or space to be found. The extensive research into secondary products has led to a much improved understanding of the scale and diversity of the early use of dairying and – to a somewhat lesser extent – wool production in both Europe and Asia (e.g. Arbuckle 2014; Becker et al. 2016; Breniquet and Michel 2014; Evershed et al. 2008; Ethier 2017; Greenfield 2014a, b; Greenfield and Arnold 2014; Outram et al. 2012; Pipes et al. 2014; Salque et al. 2012; Spiteri et al. 2016).

In contrast, both the earliest use of traction and its eventual intensification remain debated. Most research into the use of cattle for traction has focused on later periods, often on the basis of non-osteological data (e.g. Bakker et al. 1999; Bartosiewicz et al. 1997; Bondár & Székely 2011; Pétrequin et al. 2006; Milisauskas & Kruk 1991; Mischka 2011; Piggott 1983; Rowley-Conwy 1987). Numerous studies have used both osteological and non-osteological data to argue for the use of cattle for traction from the early 4th millennium cal. BC onwards, parallel to the earliest evidence for carts and ploughing (e.g. Bălășescu et al. 2006; Bogucki 1993; De Cupere et al. 2000; Galindo-Pellicena et al. 2015; Johanssen 2006; Lingereux et al. 2006; Milisauskas & Kruk 1991). The possible earlier use of cattle for traction has been suggested for Europe but never systematically investigated (e.g. Isaakidou 2006; Tarrús et al. 2006). Here, we fill this damaging documentary gap by providing systematic positive identifications of traction by domestic cattle from the earliest Neolithic in the central and western Balkans (c.6000 BC).

Traction – what do we mean and what are we looking for

Traction in prehistoric Europe is often conflated with ploughing or the use of carts (e.g. Bondár & Székely 2011; Pétrequin et al. 2006). However, at its most essential interpretation, traction is the use of animals as engines in order to pull loads. While ploughing and cartage are forms of traction, they form only portions of a much broader spectrum of exploitation practices. Such specific use is commonly assumed to indicate the training and long-term management of specialized animals, in particular castrated males (oxen) of which identification is inferred from age profiles, sex comparisons and pathological studies (e.g. Bogucki 1993; Galindo-Pellicena et al. 2015; Tarrús et al. 2006). Ethnographic examples indicate that oxen are privileged due to the increased strength and stamina provided by their larger size, but also that cows (even while pregnant) can be used for traction when deemed necessary, or when labour demands are less intensive (Bartosiewicz et al. 1997; Halstead 2014). This is seen in the interpretation of age profiles, sex comparisons and pathological studies (e.g. Bogucki 1993; Galindo-Pellicena et al. 2015; Isaakidou 2006; Milisauskas & Kruk 1991; Tarrús et al. 2006). The identification of castrates in archaeological contexts is often implicitly linked with their putative exploitation for labour, as though castrate=oxen=traction (Galindo-Pellicena et al. 2015; Milisauskas & Kruk 1991). Perhaps a better way of viewing traction would be as a continuum, rather than a binary positive or negative value. There is a wide middle ground in which animals may be used for more occasional pulling activities, or used for regular labour over a shorter number of years. It is
identifying this more limited or ‘light’ use of animals for traction which will inform us both as to how the more specialised traction-animal developed and the economic context of their emergence and maintenance.

Available data on early exploitation of domesticates for other secondary products, in particular dairy, do not indicate specialized secondary-product-maximising management. Rather, a more variable ad-hoc exploitation is indicated, often for prolonged periods prior to targeted management practices (Arbuckle 2014; Ethier et al. 2017; Greenfield 2014b; Spiteri et al. 2016). This has led to research focusing on both evidence for the early use of dairy products as well as a separate analysis of the increasing reliance on dairy products in animal management. A similar approach is advocated here for investigations of traction – by examining both early evidence and changes in the intensity of exploitation over time. The occasional use of a good-natured cow or young bull to haul timber would be traction exploitation, but one which would not necessarily alter either management profiles or significantly impact upon bone development across an entire faunal sample (De Cupere 2000; Lin et al. 2016). In this way, we may expect a certain period of limited traction exploitation, confined to a few individuals, possibly for only a portion of their lifetime, and which would thus not alter the larger age-at-death profiles for the herd as a whole. This paper aims at identifying this hypothesized early ‘light’ phase of exploitation of cattle.

**Bone remodelling and stress**

Bone surfaces remodel in response to stress and injury. Stress can relate to carrying the weight of the live animal as well as any additional load that is placed upon individual elements (Wolff 1892). Bone remodelling takes many forms, including enlargement of muscle and ligament attachments, and alterations to articular surfaces as a result of increased loading. Remodelling to bone surfaces can be classified into two groups (Bartosiewicz 2008; Bartosiewicz et al. 1997): those brought about by traumatic injury and/or old age (pathological) and those brought about as the result of increased strain (sub-pathological). The degree of remodelling in both cases relates to the intensity of strain (through time) or injury. The intensity of sub-pathological alterations developing from repeated additional strain on an element or set of elements relates to the type, duration and intensity of work involved. With regards to the effect of traction upon cattle skeletons, sub-pathological alterations are primarily directed through the medial articular surfaces of foot elements (metacarpus, metatarsus and phalanges: Bartosiewicz 2008).

**Case-study: Neolithic cattle in the central and western Balkans**

In order to test for the presence of such horizon of limited traction, we investigate cattle foot bones from twelve samples representing eleven sites covering the entire Neolithic period within the central and western Balkans (c.61/6000 – 4500 cal BC; see Table 1). Previous zooarchaeological work in this region has shown a relative initial diversity in animal exploitation strategies during the Early Neolithic, including sites focusing on the management of ovicaprines as well as others focusing cattle and pigs. During the Middle and Later Neolithic, we observe a shift to a pattern of domesticate exploitation generally focused on the exploitation of cattle and pigs, parallel to increased levels of hunting (Ethier et al. 2017; Greenfield 1986, 1991, 2008; Orton et al. 2016). Temporal changes are observable in relation to the age, sex and size distributions of cattle kept at sites, although there is no evidence for the retention of individuals into advanced age, castrated males, over-representation of male animals, or an increase in mean body size (Gaastra & Vander Linden in prep; Greenfield 1986, 1991; 2008).

All zooarchaeological material used in this study was directly studied by JSG and HJG, using the same protocol and recording of bone alterations. Seven assemblages were
entirely recorded, whilst five were partially exported for curation, meaning that only a sub-sample was available for the present study. An overview of the sites studied by each analyst is given in Table 1 and their locations are shown in Figure 1. Radiocarbon dates are available for nine site samples and are provided in in SI1.

Methods

Foot elements (metacarpals, metatarsals and first and second phalanges) of both domestic cattle (*Bos taurus*) and aurochs (*Bos primigenius*) were examined for all sites. These elements were selected as they are the best direct reflection of traction in the osteological record, being both the most directly affected by the stress of pulling (versus age or increased body weight) as well as commonly found at low levels of fragmentation (Bartosiewicz 2008; Bartosiewicz et al. 1997). A summary of the phases represented from these sites and the number of elements studied is given in Table 1.

Foot elements were studied for both pathological and sub-pathological alterations. These were scored on the basis of their Pathology Index (PI hereafter) values following Bartosiewicz et al. (1997) and the distributions of PI values were compared between sites. Sub-pathological alterations consistent with traction were recorded and their frequencies per sample are given in Table 2.

Measurements were also taken for the distal metapodia following the traction index osteometric system developed by Lin et al. (2016). The diagnostic index “e/D1” was measured for all distal metapodia of both cattle and aurochs. This index describes the degree of remodelling and extension of the medial condyle, with a value of 0.75 or higher indicating a degree of remodelling consistent with traction usage in modern reference specimens (Lin et al. 2016).

The combination of both systems allows for the comparison of alterations across all foot elements (PI) as well as a direct index of metapodial remodelling independent of the more subjective PI approach. Where it was possible to estimate the sex of individuals (e.g. through metrical comparisons of distal metapodia) this was included as part of the recording of pathological and osteometric data. Elements were studied from aurochs as a control group for both PI and osteometric comparisons.

Results

All studied Neolithic sites demonstrate pathological and/or sub-pathological alterations to cattle bone. The overall level of pathological or sub-pathological alterations remains low, with the majority of alterations being graded as minor to moderate (Grades 1-3 on the Bartosiewicz et al. 1997 system). The number of pathological or sub-pathological specimens from each site is small (see Table 2), in keeping with the findings of researchers working on later periods (e.g. De Cupere et al. 2000). All sites studied demonstrate a combination of age/trauma (pathological) and usage-related (sub-pathological) remodelling to bone surfaces. Pathological remodelling was identified on remains of both domestic cattle and wild aurochs and include exostoses present at tendon and ligament attachments on the distal surfaces of phalanges and metapodia, to medial and/or lateral faces of distal metapodial shafts (Figures 2 and 6), to proximal shafts of metapodia, and the posterior surfaces of proximal phalanges.

[Table 2]

[Figure 2]
By contrast, sub-pathological remodelling of bones from traction was identified only on domestic cattle. These include extension of the margins of the medial condyle of metapodia (Figure 3) as well as extension of the medial facet of the proximal articular surface of both first (Figure 4) and second (Figure 5) phalanges. The restriction of such sub-pathological remodelling to domestic cattle only is significant. This form of remodelling (in particular on hind limbs) has been shown to relate most directly to the motion and strain of pulling rather than to other factors such as the age or weight (Bartosiewicz 2008; Bartosiewicz et al. 1997; Lin et al. 2016). These alterations show no chronological or geographical patterning in the frequency or intensity of remodelling (Table 2).

Previous research has been shown that only a sub-set of the cattle population provides evidence of traction and that the distribution of PI values is of far more importance than the sample’s mean PI value in identifications of traction (De Cupere et al. 2000). Therefore, PI value distributions are plotted here as histograms (Figure 2). The majority of elements for both taxa across all sites scored between 0-1 and 1-2, both of which categories can be considered as indicating normal bone development. In domestic cattle, a small proportion of each assemblage exhibited sub-pathological alterations consistent with bone remodelled due to the strain of traction (2.5-3 and 3-3.5 in PI score, see Figure 2 and Table 2). These alterations included broadening of medial condyles for both metacarpal and metatarsal as well as extension of the medial proximal articular facet to both first and second phalanges (see Figures 3, 4, and 5). These were present on a subset of cattle elements from all three Neolithic periods. The distribution of PI values provides some indication of more extensive remodelling to bones in cattle of Late Neolithic sites (Figure 2), although this variation is too minor to draw any conclusions.

Osteometric analysis of distal metapodia following the criteria of Lin et al. (2016) also points to the usage of cattle for traction from at least the beginning of the Neolithic in the western Balkans. The index “e/D1” indicated traction-positive cattle metacarpals and metatarsals from sites in all three Neolithic periods. All traction-positive metapodia came from domestic cattle only and all had distal PI values of three or higher (Bartosiewicz et al. 1997). These indices can be seen in Figures 5 and 6, where the “e/D1” index has been plotted alongside distal breadth/Bd (Lin et al. 2016) to indicate the sex of animals measured. From these data, we can see not only the presence of traction-positive cattle from both distal metacarpals and metatarsals but also a bias towards evidence from the hind limb. This is consistent with the findings of Lin et al. (2016) and further confirms that these sub-pathological alterations are the result of the strain of traction, which is more strongly expressed in the hind limb (Bartosiewicz 2008; Lin et al 2016) These data also indicate the usage of both females and males for traction during the Neolithic, although given the small sample sizes available it cannot be determined at present whether or not male animals were more commonly used for traction in the Late Neolithic (Figures 7 and 8).

Conclusion

This study has demonstrated the existence of ‘lighter’ use of cattle for traction long before the hard-usage pathological evidence seen from previous studies (e.g. De Cupere 2000; Galindo-Pellicena et al. 2015). As indicated by the two techniques used here, it appears that some cattle, both males and females were already being used for traction from the time...
of their introduction onwards across the central and western Balkans. Small numbers of animals that were used for traction are identifiable in earliest Neolithic settlements, a pattern observable throughout the entire 1500 years duration of the local Neolithic, and thus presumably afterwards.

Comparative analysis of sub-pathological and osteometric comparisons for cattle thus provides firm indications for the exploitation of cattle labour dating back much earlier than generally considered. This exploitation is not only systematic across multiple sites over a long period of time, but also only points to non-intensive use of cattle for traction. It is also noteworthy that this widespread, non-specific use of cattle for traction recalls similar patterns observed for contemporaneous dairy production. Traction is not an all-or-nothing affair; we need instead to think about it as a more complicated process with multiple ways in which animals can be used as engines. This repeated identification of draught exploitation of cattle calls into question the current scope of analysis and interpretation of such exploitation in prehistoric Europe.

These data indicate a need for investigators to systematically employ analytical techniques to further document this crucial phase of initial cattle traction utilization detectable through sub-pathological alteration of foot bone elements. From our study, it is clear that cattle are being exploited for traction from the onset of the Neolithic. Such studies need to be replicated in other regions of Europe in order to determine the extent and duration of this form of traction utilization. It is still unknown whether this form of traction is seen in only a selection of Neolithic groups or was a common component across Europe. A firm understanding of the nature of early traction evidence in prehistoric Europe has significant implications of such practices for our understanding of both management practices and the nature of labour and movement in prehistoric societies. What is needed now is a wider comparative assessment of sub-pathological evidence for cattle traction in Neolithic (and post-Neolithic) Europe to determine both how widely distributed was this pattern of early traction, and at what point we begin to see evidence of specialized heavy-traction animals.

Acknowledgements
This paper is an output from the European Research Council project EUROFARM, funded under the European Union’s Seventh Framework Programme (FP/20072013; ERC Grant Agreement no. 313716), led by MVL and hosted by UCL. Haskel Greenfield’s data were collected while being funded by the Social Science and Humanities Research Council of Canada and the University of Manitoba, the International Research and Exchanges Board of Washington, DC, and the Fulbright-Hayes Program. We thank all team members and project partners for their support and for the use of their data.

References


List of Figures

Figure 1: Locations of the sites used for this study.

Figure 2: Distribution of Pathology Index (PI) values for elements from the largest site assemblages examined for this study as well as for *Bos primigenius* elements from all sites. PI values have been assigned following Bartosiewicz et al. (1997).

Figure 3: *Bos taurus* metatarsal from Kneževi Vinograd showing sub-pathological remodelling to the medial condyle resulting from traction usage. This bone was directly dated to 6015-5897 cal BC (see SI1 for details).

Figure 4: Proximal articular surfaces of *Bos taurus* anterior first phalanges from Blagotin (A) and Stragari (B). Specimen A shows broadening of the medial articular facet in comparison with a normal articular surface as seen in specimen B.

Figure 5: Proximal articular surfaces of *Bos taurus* anterior second phalanges from Foeni-Salaş (A) and Blagotin (B). Specimen A shows broadening of the medial articular facet in comparison with a normal articular surface as seen in specimen B.

Figure 6: A first phalanx of *Bos primigenius* from Potporanj with examples of age-related pathological alterations observed on foot elements in this study.

Figure 7: Osteometric comparisons of medial remodelling of distal metacarpals from domestic cattle (*Bos taurus*) and wild aurochs (*Bos primigenius*) using the index developed by Lin et al. (2016).

Figure 8: Osteometric comparisons of medial remodelling of distal metatarsals from domestic cattle (*Bos taurus*) and wild aurochs (*Bos primigenius*) using the index developed by Lin et al. (2016).

List of Tables

Table 1: Summary of site samples used in the present study. Site names are given along with cultural affiliation, calibrated radiocarbon dates (where available) and the number available for each element studied. The number of elements identified as aurochs (*Bos primigenius*) is given in brackets. The Early Neolithic cultural complex Starčevo-Körös-Criș is abbreviated here to ‘SKC’.

Table 2: Distribution of elements with positive (PI >2.5) indications of sub-pathological alterations relating to traction. As in Table 1, the number of aurochs (*Bos primigenius*) elements are given in brackets.
Table 1: Summary of site samples used in the present study. Site names are given along with cultural affiliation, calibrated radiocarbon dates (where available) and the number available for each element studied. The number of elements identified as aurochs (*Bos primigenius*) is given in brackets. The Early Neolithic cultural complex Starčevo-Körös-Criş is abbreviated here to ‘SKC’.

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Site</th>
<th>Cultural Group</th>
<th>Date (cal BC)</th>
<th>Analyst</th>
<th>Metacarpal</th>
<th>Metatarsal</th>
<th>Phalanx 1</th>
<th>Phalanx 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Blagotin</td>
<td>SKC</td>
<td>6000-5900</td>
<td>HJG</td>
<td>6 [1]</td>
<td>4 [1]</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Foeni-Salaş</td>
<td>SKC</td>
<td>6057-5971</td>
<td>HJG</td>
<td>4 [1]</td>
<td></td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>At Vršac</td>
<td>SKC</td>
<td>5665-5471</td>
<td>JSG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Stragari</td>
<td>Vinča Tordoš</td>
<td>-</td>
<td>HJG</td>
<td>2</td>
<td>3 [1]</td>
<td>7</td>
<td>8 [1]</td>
</tr>
<tr>
<td>8</td>
<td>Sândrei</td>
<td>Banat</td>
<td>-</td>
<td>JSG</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Early Neolithic: c.61/6000 to 55/5400 cal BC

Middle Neolithic: c.55/5400 to 5000 cal BC

Late Neolithic: 5000-4500 cal BC
<table>
<thead>
<tr>
<th>Site</th>
<th>Metacarpal</th>
<th>Metatarsal</th>
<th>Phalanx 1</th>
<th>Phalanx 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early Neolithic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blagotin</td>
<td>[0]</td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Foeni-Salaș</td>
<td>[0]</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>At Vršac</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belišče</td>
<td>1 [0]</td>
<td>2 [0]</td>
<td>3 [0]</td>
<td>2 [0]</td>
</tr>
<tr>
<td>Kneževi Vinograd</td>
<td>1 [0]</td>
<td>2 [0]</td>
<td>2 [0]</td>
<td>3 [0]</td>
</tr>
<tr>
<td></td>
<td>Middle Neolithic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potporanj</td>
<td>1 [0]</td>
<td>2 [0]</td>
<td>3 [0]</td>
<td>2 [0]</td>
</tr>
<tr>
<td>Stragari</td>
<td>1 [0]</td>
<td></td>
<td>2</td>
<td>1 [0]</td>
</tr>
<tr>
<td>Sânandrei</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Late Neolithic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At Vršac</td>
<td>[0]</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Petnica</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hermanov Vinograd</td>
<td>5 [0]</td>
<td>4 [0]</td>
<td>7 [0]</td>
<td>3 [0]</td>
</tr>
<tr>
<td>Kosjerovo</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2**: Distribution of elements with positive (PI >2.5) indications of sub-pathological alterations relating to traction. As in Table 1, the number of aurochs (*Bos primigenius*) elements are given in brackets.