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An isotopic perspective on the socio-economic significance of livestock in Bronze Age West-Frisia, the Netherlands (2000–800 BCE)

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ABSTRACT

The Bronze Age is increasingly characterised as a period in which the search for and trade in metals dominates mobility and exchange in Europe. Chiefs travelled the lands and seas and dominated the acquisition and possession of critical resources. Most research focuses on the provenance and distribution of metals and on the mobility of people. Yet, the mobility of one the most obvious sources of social and economic wealth in the Bronze Age has got little attention: livestock. This study explores the possible social role of livestock of cattle and sheep, both in the household sphere and in the sphere of exchange as a means of 'connecting people'. Here, strontium isotope data are presented from 58 cattle and sheep from settlement contexts from Bronze Age West-Frisia (2000–800 BCE), the Netherlands, with the aim to gain an isotopic perspective on the socio-economic significance of livestock. The data provide evidence for long-distance trade or exchange of livestock. Besides their monetary value, we suggest that livestock, and in particular cattle, may have been perceived as equal to people in terms of labour and production and as members of the household. Their mobility and exchange therefore signal more than just economic trade, it signals a social practice. By changing our perspective towards the social ideology of farming life, we will move closer to understanding Bronze Age societies in more diverse and inclusive ways. Research into livestock mobility is therefore considered fundamental for a more diverse understanding of Bronze Age farming life.

1. Introduction

"*The political economy of Bronze Age Europe would thus represent a transformation in how would-be leaders mobilized resources to support their political ends. The long-distance trade in metals and other commodities created a shift from local group ownership towards increasingly individual strategies to obtain wealth from macro-regional trade*" (Earle et al., 2015, 633).

The passage quoted above is a quintessential example of the dominant view among researchers since the 1970s on the political economy of Bronze Age Europe. In this narrative, long-distance interpolity elite exchanges were of paramount importance. These exchange-networks have been archaeologically documented through the distribution studies of, for instance, tin, copper, silver, and prestige objects (e.g., Ling et al., 2013, 2014, 2018; Earle et al., 2015; Melheim et al., 2018). Besides metals, it is evident that other commodities such as amber (Shennan, 1982, 1993; Earle et al., 2015) and glass (Varberg et al., 2015) also played a fundamental role within the exchange networks in Bronze Age Europe.

In recent years, biomolecular evidence has also become available for the trade in or the exchange of animal products like wool and hides. Through the isotopic investigation of Bronze Age and Iron Age textiles, it is shown that secondary animal products were also key constituents of Bronze Age economies. In Denmark, for example, large quantities of wool may have been imported during prehistory (cf., Frei et al., 2009, 2017, but see Von Holstein et al., 2015). Additionally, the ox hide that the girl of the well-known Egtved burial was laid down on may also have been imported from outside of Denmark (Frei et al., 2015, but see Thomsen and Andreasen, 2019).

These studies complement a growing body of isotopic evidence for the mobility of livestock, primarily cattle, in the Neolithic and Bronze Age (e.g., Bentley and Knipper, 2005; Towers et al., 2010, 2017; Viner et al., 2010; Sjögren and Price, 2013; Gron et al., 2018). Yet, the discussions on the extensive mobility in Bronze Age Europe are still predominantly focussed on the exchange of goods and the movement of people, and much less so on the exchange of living animals or animal

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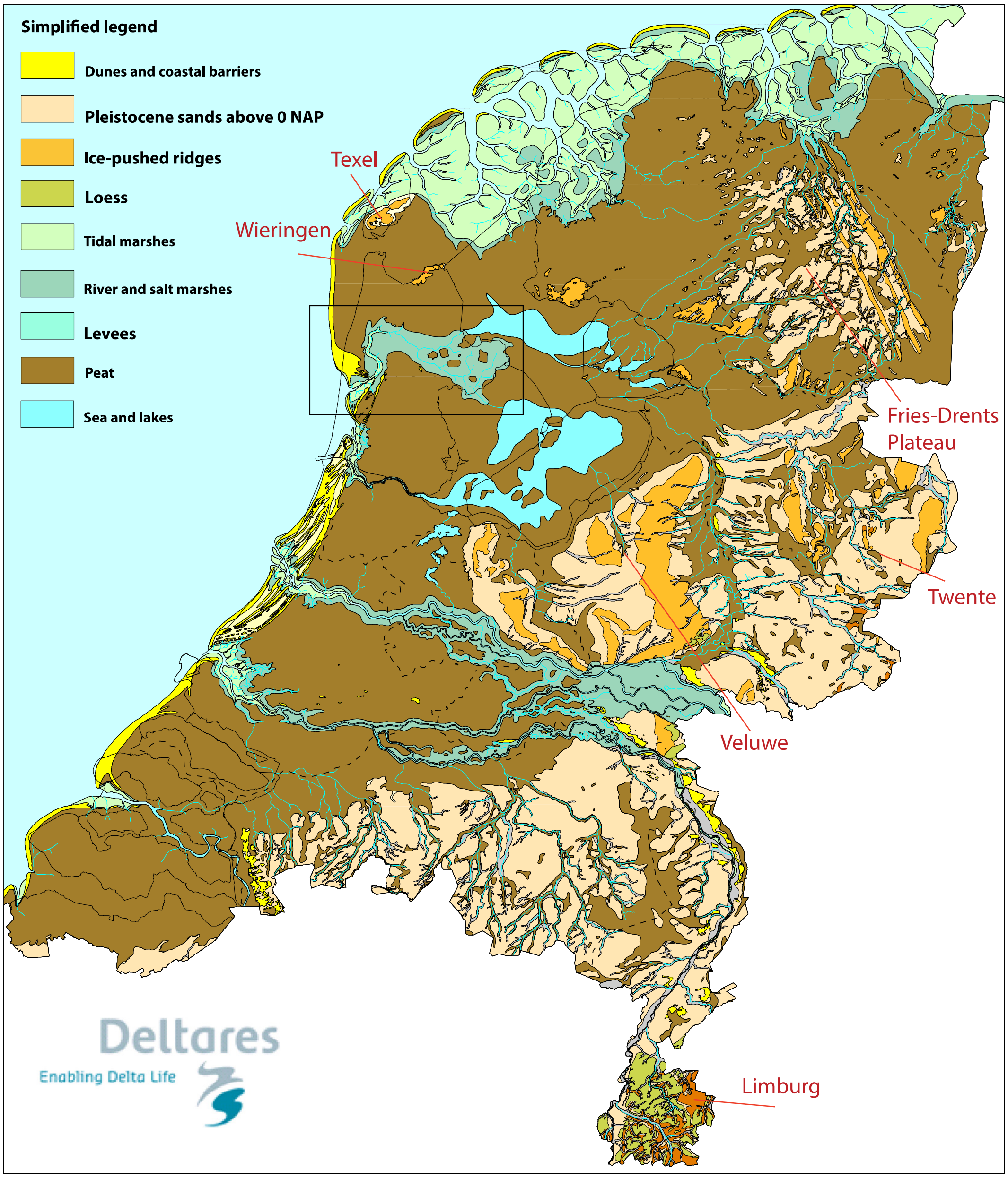

Fig. 1. Palaeogeographical map of Bronze Age the Netherlands (after Vos and de Vries, 2013) showing the regions mentioned in the text. Boxed area indicates the location of West-Frisia from where the samples were selected (larger-scale map displayed in Fig. 2).

products and, more importantly, the socio-economic significance thereof. This paper aims to address these issues through a study of the first strontium isotopic data available on prehistoric faunal palaeomobility patterns from Bronze Age the Netherlands. It explores the evidence for the movement or exchange of cattle (*Bos taurus*) and sheep/goats (*Ovis aries*/*Capra hircus*), in West-Friesland (*West-Frisia*) in the north-western Netherlands (Fig. 1).

From settlement evidence it has become clear that in large parts of the Nordic and Atlantic areas, cattle bones dominate prehistoric faunal assemblages, undisputedly underlining the importance of cattle within the subsistence economy from the Middle Neolithic (3400–2900 cal BC) onwards, with an increased importance towards the Middle Bronze Age (1800–1100 cal BC) (e.g., Arnoldussen and Fontijn, 2006; Vretemark, 2010; Bartosiewicz, 2013). Livestock may have been kept to provide meat, but were also exploited for their secondary products, such as milk, traction, manure, hides, and wool (e.g., IJzereef, 1981; Bogaard et al., 2013; Bakels, 2016). Furthermore, cattle remains are found in a variety of Bronze Age ritual contexts and always in larger quantities than other domestic animals such as sheep/goats and pigs (e.g., Rasmussen, 1999; Hvass, 2000; Horváth, 2012; Johannsen and Laursen, 2010; Vretemark, 2010). In the Low Countries and further northeast in Denmark, the intensification of the exploitation of livestock, and in particular the increase in the use of cattle manure fertilisation, coincides with the emergence of the three-aisled Bronze Age farms. In the north-eastern Netherlands and parts of Denmark, there is evidence for stall partitions in these houses and thus the stabling of livestock indoors (Fokkens, 1999; Kristiansen, 2006; Bech and Olsen, 2013).

Considering this evidence for the importance of livestock, in particular cattle, in the Bronze Age and the evidence for the exchange of the secondary products of cattle and sheep, it is conceivable that livestock played an important role in the exchange networks of this period as well. This paper provides a tentative assessment of the use of livestock within Bronze Age exchange networks between local communities or regions. Ultimately, this study contributes to a more comprehensive understanding of trade and exchange in Bronze Age continental Europe.

2. Strontium isotopes in zooarchaeology

Following the general trend in archaeology, isotope analysis has gradually become a staple in zooarchaeological research (see Pilaar Birch, 2013 for an overview). The stable isotopes or carbon, nitrogen, oxygen, and strontium are nowadays frequently used to infer information about diet (e.g., Millard et al., 2011), and animal husbandry and seasonality (e.g., Towers et al., 2011). In particular, the use of radiogenic strontium isotopes has revolutionised the study of animal mobility (e.g., Towers et al., 2010, 2017; Viner et al., 2010), and animal trade and exchange in archaeological contexts (e.g., Thornton, 2011; Van der Jagt et al., 2012; Minniti et al., 2014; Laffoon et al., 2015; Arnold et al., 2016; Sharpe et al., 2018). The ratio $^{87}Sr/^{86}Sr$ derived from faunal dental enamel reflects the strontium isotopic signature of the underlying geology of the area the animal spent its life on during amelogenesis. Like human isotope mobility studies, the method relies on the basic assumption that the animal tissues reflect the strontium isotope ratio $^{87}Sr/^{86}Sr$ of the food and water it consumed that, in their turn, reflect the $^{87}Sr/^{86}Sr$ value of the geology they originate from. The Sr^{2+} that is taken up into the animal's food chain becomes incorporated into the crystal structure of bone and dental enamel where it substitutes for Ca^{2+}. Due to the fact that dental enamel is highly mineralised, and exhibits a low porosity and organic content, it is most resistant to diagenetic change. It is, therefore, the material of choice in archaeological mobility studies (Kohn et al., 1999; Kendall et al., 2018). Moreover, dental enamel does not remodel once mineralised and matured and therefore exhibits an isotopic composition reflective of the diet consumed during the period of formation. In contrast to human dental enamel, tooth enamel from animals with hypsodont dentition, such as cattle, mineralises continuously, which allows for an incremental sampling strategy. In cattle, mineralization of the first molar (M1) starts in utero (apex, circa 4 weeks prior to birth) and enamel maturation is completed at the age of circa 3 months (cemento-enamel junction CEJ: the line at which the enamel of the tooth crown meets the cementum of the tooth root). Crown formation in the second molar (M2) starts at the age of one month and is completed at circa 13 months old, and the third molar (M3) mineralises between 9 and 24 months of age (Brown et al., 1960). The estimated age at which enamel starts to mineralises in sheep is roughly similar to that of cattle, but it takes approximately twice as long for the enamel to mature (except for the M1, see Brown et al., 1960, Silver, 1969). Intra-individual sequential sampling of the dental enamel can therefore allow for a reconstruction of the animal's mobility pattern over several months per dental element, depending on the degree of wear of the dental element (see e.g., Gerling et al., 2017).

3. Environmental and archaeological context

West-Frisia is well known for its fossilised Late Neolithic and Bronze Age settled landscapes. The clay and silt substrate, and the fact that the area was largely submerged or overgrown with peat after the Late Bronze Age, has provided ideal conditions for the conservation of sites and of the organic materials in them. In the 20th century, several sites were extensively excavated and hundreds of very clear Bronze Age house plans have been investigated (Roessingh, 2018). Recently the unpublished results of these excavations were the subject of a large research project funded by the Dutch Organisation for Scientific Research (NWO): The farmers of the coast project (Leiden University). The present study was initiated as part of that project.

One of the key environmental factors that were responsible for shaping West-Frisia's geomorphology was the Bergen inlet and its accompanying tidal basin (Fig. 2). Until about 2000 BCE, the tidal influence of the large Bergen channel reached into the eastern part of West-Frisia. In that brackish to fresh tidal delta, Late Neolithic Corded Ware/Vlaardingen and Bell Beaker sites were situated on levees and on former silted-up channel and crevasse deposits (Fokkens et al., 2016; Van Zijverden, 2017). According to Van Zijverden (2017), between 1950 BCE and 1700 BCE the character of the landscape changed, possibly due to storm events that blocked the channels connecting to the river Vecht basin. The landscape transformed to a classic tidal flat-tidal marsh landscape, with open tidal channels to the west. The northern course of the river Vecht was blocked, resulting in a large fresh water lake in the north east (Fig. 2). The river Vecht found its route to the sea further south (Van Zijverden, 2017). During the Middle (1800–1100 BCE) and the Late (1100–800 BCE) Bronze Age, the area was characterised by a freshwater environment that was eminently suited for grazing cattle and sheep, but also for fishing, hunting, and fowling (Van Amerongen, 2016). There is evidence for large surfaces of ploughed arable land (Van Amerongen, 2016, Roessingh, 2018). The area was surrounded by peat marshes (Fig. 2). Access to ice-pushed uplands to the north, east, and south-east may have been possible by boat, but most probably less so by foot or with wagons and carts; water transport probably was of prime importance (Fokkens et al., 2016).

Because of the in-permeability of the soil, West-Frisian farms, yards, and settlements were surrounded by ditches, increasing the archaeological visibility of the Bronze Age settlements and burial landscape. These ditches were filled with settlement debris, including bone material and many other find categories. The samples discussed in this study are from these settlement and house ditches. For this pilot study they were selected from sites in different parts of the region and from different periodic contexts (Middle to Late Bronze Age). The idea was that a cross-cultural study could provide a first general idea about the range in time and place of animal palaeomobility and its significance in socio-economic terms.

4. Material and analytical methods

Compared to other regions of the Netherlands and surrounding countries, the preservation of bone and other organic material in West-Frisia is excellent due to the silt and clay deposits. These circumstances have resulted in the presence of a high quantity of high-quality archaeological faunal bone. Subsequently, zooarchaeological investigations have produced significant insights into and a fundamental understanding of animal husbandry and arable farming in Bronze Age West-Frisia (IJzereef, 1981; see for an overview Van Amerongen, 2016). Six Bronze Age sites from five locations in West-Frisia were selected for sampling: Bovenkarspel-'t Valkje, Enkhuizen-Kadijken and Enkhuizen-Haling, Zwaagdijk-Oost, Westwood-Westdijk 1514, and Opmeer-Hoogwoud Oost (Fig. 2). All sites were inhabited in the Middle Bronze Age (1600–1100 BCE) and/or the Late Bronze Age (1100–800 BCE). The zooarchaeological assemblages from these sites are generally dominated by cattle remains, followed by sheep or goats, and pigs (*Sus domesticus*) (see Supplementary data).

For the purpose of this study, sampling focussed on mandibular first molars of cattle and sheep/goat. If absent, deciduous third (n = 1) or fourth premolars (n = 5) and in one case a second molar was selected. In three individuals, the M1 could not be distinguished from the M2, thus are identified as M1/2. Per site and per species either left or right elements were selected in order to reduce the possibility of multi-sampling the same individual. No loose teeth, (i.e., elements without associated mandibular bone or mandibular bone fragments) were sampled. In total, dental elements of 52 unique cattle individuals were selected from all archaeological sites mentioned above, except for Opmeer-Hoogwoud Oost. Six unique sheep/goat specimens from Opmeer-Hoogwoud Oost and Zwaagdijk-Oost were also included in the study. None of the elements came from ritual find contexts or were linked to special assemblages, but are considered to have been the result of rubbish disposal. The selected dental elements are therefore considered to be representative remains of Bronze Age livestock in West-Frisia.

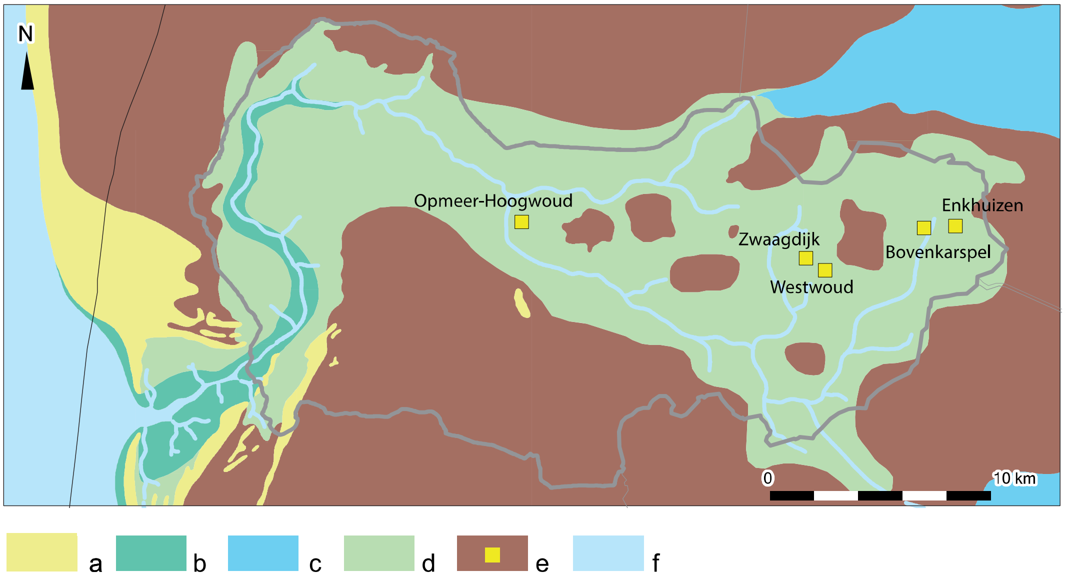

Fig. 2. Palaeographic map of West-Frisia 1500 BCE (after Van Zijverden, 2017, fig. 2.10, and Vos, 2015, 73). Legend: a: dunes and beach barriers, b: tidal marshes, c: tidal flats, d: peat, e: fresh water, f: salt and brackish water.

Depending on the physical quality of the crown, the mesial surface of the buccal or lingual lobe of the molars was mechanically cleaned through abrasion using a 10% HCl cleaned diamond-tipped drill. Approximately 1–3 mg of enamel power was sampled from the top of the crown, the apex, and sealed in an acid pre-cleaned 2 ml polyethylene Eppendorf centrifuge tube. A detailed description of the column extraction and the sample loading procedures is given in (Kootker et al., 2016a). The strontium isotope compositions were measured on a MAT-Finnigan 262 multicollector mass spectrometer and on a ThermoFinnigan Triton at the Vrije Universiteit Amsterdam. The ratios were determined using a static routine and were corrected for mass-fractionation correction. The NBS987 gave mean $^{87}Sr/^{86}Sr$ values for the MAT262 and Triton of 0.710246 ± 0.000009 (N = 4) and 0.710258 ± 0.000009 (N = 7) respectively. The measurements were all normalised to 0.710240 for NBS987. The procedural blanks contained an average of < 25.0 pg strontium (n = 6), a negligible amount compared to the average amount of strontium present in enamel samples (50–500+ ng/mg: Kohn et al., 1999). The data were analysed using SPSS 25.0 (IBM SPSS Statistics for Macintosh, Armonk, IBM Corp.).

5. Results and interpretation

The results are provided in Table 1 and a visible representation is given in Fig. 3. The archaeological bioavailable strontium ratio of the local environment in West-Frisia is well defined. Based on 85 rodent teeth from West-Frisia and landscapes with a similar geogenesis from other parts of Holocene the Netherlands, the $^{87}Sr/^{86}Sr$ ratio of archaeological West-Frisia is defined as 0.7088–0.7092 (Kootker et al., 2016b).

The faunal $^{87}Sr/^{86}Sr$ data vary between 0.70897 and 0.71092 and between 0.70900 and 0.71343 for the cattle and sheep/goat respectively. A statistical assessment shows that the data significantly deviate from a normal distribution (Shapiro-Wilk: W = 296, df = 58, $p = 0.000$). Removal of four statistical outliers resulted in a normally distributed data set (W = 974, df = 54, $p = 0.301$) in which the mean (0.709072) and median (0.709070) coincide. The trimmed 'local' data set comprises values between 0.70897 and 0.70921, that overlap with the defined range of Sr isoscape B (0.7088–0.7092: Kootker et al., 2016b). However, during the Bronze Age, the landscape of West-Frisia was characterised by a mixture of (former) tidal marsh deposits and peatlands. Samples from the current "Holland peat area" exhibit values around 0.7093 and are defined by isoscape C (0.7092–0.7095: ibid.). As a result, and to avoid the possibility of over-representing foreign born individuals, the local (regional) bioavailable strontium signal in Bronze Age West-Frisia is defined as 0.7088–0.7095, with 0.7093 as a more probable maximum value.

The vast majority of the individuals exhibit values that are indistinguishable from the local signal (0.7088–0.7093: 94,8% of the dataset). The data of two cattle (150/3/1 – LBA – Bovenkarspel-'t Valkje and 58/1/865 – MBA – Enkhuizen-Kadijken) and one sheep or goat (50/1/146B – LBA – Zwaagdijk-Oost) are not congruent with the local West-Frisian $^{87}Sr/^{86}Sr$ values. They all exhibit more radiogenic values of > 0.7108. Ratios as high as 0.7108 are indistinguishable from the signature $^{87}Sr/^{86}Sr$ ratios of the Dutch Pleistocene cover sand and loess areas and possibly with the boulder clay areas as well (McManus et al., 2013; Kootker et al., 2016b). Most Pleistocene sediments are found over circa 80 km distance from the most eastern part of West-Frisia in the three northernmost provinces of the Netherlands (Fries-Drents Plateau and Twente), as well as the central Netherlands Veluwe region (Fig. 1). However, during the Bronze Age, the subsurface configuration of the Wieringen and Texel regions in the north of the current province of North Holland was dominated by Pleistocene sediments and boulder clay deposits as well. These regions are located 40 and 65 km, respectively, northwest of West-Frisia. Distance-wise, Wieringen could be accessible within a day's walk; however, the route might have been inaccessible due to the extensive peat-marshes that blocked the 'routes' in the Bronze Age. Loess can only be found in the southernmost part of the Netherlands, in Limburg, which is located at least 160 km southeast of West-Frisia.

For each non-locally born animal, additional samples were taken close from the cemento-enamel junction (CEJ) of the first molar (M1), and, in two cases, from the CEJ of the second (M2) and third molars (M3) to investigate whether these animals were transported within the time period that enamel mineralization took place. The enamel close to the CEF mineralizes last, hence the isotopic signature resembles the dietary strontium intake during the last few weeks of the mineralization phases, at circa 2–2.5 months old in the M1 up to circa 20–24 months old in the M3. The data in Fig. 4 clearly show a decrease in $^{87}Sr/^{86}Sr$ ratio between the M2 and M3 of the sheep/goat 50.1.146B from Zwaagdijk-Oost. The $^{87}Sr/^{86}Sr$ ratios of the M1 and M2 are fairly similar, which is indicative of a stable dietary strontium source.

Table 1
Dental elements sampled and strontium isotope data obtained. Key: MBA – Middle Bronze age (1800–1100 BCE); LBA – Late Bronze Age (1100–800 BCE); 2SE – 2 standard error. Latitude and longitude information conform to WGS84 geodetic datum.

Site	Project	Latitude	Longitude	Period	Taxon	Element	Symmetry	Sample ID	$^{87}Sr/^{86}Sr$	2SE
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	117/2/11	0.70897	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	105/2/5	0.70901	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	125/1/2	0.70901	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	92/3/20	0.70902	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	126/1/1	0.70903	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	15/1/1	0.70905	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	117/2/24	0.70906	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	40/1/49	0.70906	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	122/2/12	0.70908	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	117/1/10	0.70909	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	118/1/13	0.70909	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	40/1/49/12	0.70909	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	102/2/34	0.70910	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	97/1/12	0.70910	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	97/2/4	0.70912	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	102/2/31	0.70917	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	102/2/14	0.70919	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	97/2/28A	0.70919	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	97/2/28B	0.70932	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	150/3/1	0.71081	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M1	Right	150/3/1-CEJ	0.71085	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M2	Right	150/3/1/M2	0.71118	0.00001
Bovenkarspel	‘t Valkje	52.698	5.250	LBA	*Bos taurus*	M3	Right	150/3/1/M3	0.71120	0.00001
Enkhuizen	Haling	52.704	5.289	LBA	*Bos taurus*	M1/2	Left	V368	0.70901	0.00001
Enkhuizen	Haling	52.704	5.289	MBA	*Bos taurus*	M1/2	Right	V517	0.70912	0.00001
Enkhuizen	Haling	52.704	5.289	MBA	*Bos taurus*	M1/2	Right	V434	0.70913	0.00001
Enkhuizen	Kadijken	52.704	5.291	MBA	*Bos taurus*	M1	Right	58/1/839	0.70904	0.00001
Enkhuizen	Kadijken	52.704	5.291	MBA	*Bos taurus*	dP4	Right	58/1/863B	0.70909	0.00001
Enkhuizen	Kadijken	52.704	5.291	MBA	*Bos taurus*	M1	Right	58/1/863A	0.70911	0.00001
Enkhuizen	Kadijken	52.704	5.291	MBA	*Bos taurus*	M1	Right	58/1/865	0.71092	0.00001
Enkhuizen	Kadijken	52.704	5.291	MBA	*Bos taurus*	M1	Right	58/1/865-CEJ	0.71056	0.00001
Opmeer	Hoogwoud Oost	52.705	4.943	MBA	*Ovis aries/Capra hircus*	M1	Left	4/1/387	0.70901	0.00001
Opmeer	Hoogwoud Oost	52.705	4.943	MBA	*Ovis aries/Capra hircus*	M1	Left	4/1/274	0.70903	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MLBA	*Bos taurus*	M1	Left	V1050/ID2872	0.70899	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MBA	*Bos taurus*	M1	Left	V1107/ID2602	0.70912	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MLBA	*Bos taurus*	M2	Left	V1547/ID1787	0.70906	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MLBA	*Bos taurus*	M1	Left	V1666/ID3347	0.70905	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	LBA	*Bos taurus*	M1	Left	V1871/ID3482	0.70900	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	LBA	*Bos taurus*	M1	Left	V2150/ID3654	0.70908	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MLBA	*Bos taurus*	dP3	Left	V2305/ID3740	0.70907	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MLBA	*Bos taurus*	M1	Left	V2305/ID3744	0.70904	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	LBA	*Bos taurus*	M1	Left	V2601/ID5223	0.70911	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	LBA	*Bos taurus*	M1	Left	V2636/ID4990	0.70915	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	LBA	*Bos taurus*	dP4	Left	V485/ID2925	0.70908	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MLBA	*Bos taurus*	M1	Left	V601/ID2	0.70900	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MLBA	*Bos taurus*	M1	Left	V601/ID203	0.70910	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MLBA	*Bos taurus*	dP4	Left	V601/ID3	0.70907	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MLBA	*Bos taurus*	dP4	Left	V601/ID44	0.70903	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MLBA	*Bos taurus*	M1	Left	V601/ID59	0.70906	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MLBA	*Bos taurus*	M1	Left	V601/ID61	0.70898	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	MLBA	*Bos taurus*	M1	Left	V861/ID4680	0.70910	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	LBA	*Bos taurus*	M1	Left	V901/ID2487	0.70907	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	LBA	*Bos taurus*	M1	Left	V901/ID2488	0.70912	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	LBA	*Bos taurus*	M1	Left	V909/ID2835	0.70901	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	LBA	*Bos taurus*	M1	Left	V915/ID2462	0.70915	0.00001
Westwoud (N23)	Westdijk 1514	52.685	5.134	LBA	*Bos taurus*	dP4	Left	V931/ID1278	0.70911	0.00001
Zwaagdijk	Zwaagdijk-Oost	52.698	5.116	LBA	*Bos taurus*	M1	Left	50/1/146	0.70902	0.00001
Zwaagdijk	Zwaagdijk-Oost	52.698	5.116	LBA	*Bos taurus*	M1	Left	110/1/1189	0.70907	0.00001
Zwaagdijk	Zwaagdijk-Oost	52.698	5.116	LBA	*Ovis aries/Capra hircus*	M1	Right	15/1/67	0.70900	0.00001
Zwaagdijk	Zwaagdijk-Oost	52.698	5.116	LBA	*Ovis aries/Capra hircus*	M1	Right	50/1/145	0.70907	0.00001
Zwaagdijk	Zwaagdijk-Oost	52.698	5.116	LBA	*Ovis aries/Capra hircus*	M1	Right	109/1/1167	0.70921	0.00001
Zwaagdijk	Zwaagdijk-Oost	52.698	5.116	LBA	*Ovis aries/Capra hircus*	M1	Right	50/1/146B	0.71343	0.00001
Zwaagdijk	Zwaagdijk-Oost	52.698	5.116	LBA	*Ovis aries/Capra hircus*	M1	Right	50/1/146B-CEJ	0.71371	0.00001
Zwaagdijk	Zwaagdijk-Oost	52.698	5.116	LBA	*Ovis aries/Capra hircus*	M2	Right	50/1/146B/M2	0.71344	0.00001
Zwaagdijk	Zwaagdijk-Oost	52.698	5.116	LBA	*Ovis aries/Capra hircus*	M3	Right	50/1/146B/M3	0.71127	0.00001

However, the food source drastically changed after mineralization of the M2, so after circa 12 months and before 22 months of age. Given the relative isotopic homogeneous geological conditions in prehistoric West-Frisia, this drop in $^{87}Sr/^{86}Sr$ ratio must reflect a radical change in living environment, thus the physical displacement of the living animal.

The strontium value of the sheep/goat M3 coincides with the $^{87}Sr/^{86}Sr$ ratio of the M3 from the cattle sample 150/3/1 (0.7112). Both $M3_{CEJ}$ values do not match with the expected local signal ($^{87}Sr/^{86}Sr_{max.}$: 0.7095). As a result, we can conclude that both individuals were traded/exchanged with or transported to West-Frisia after circa the age of 2.

For the sheep/goat, there is also an alternative explanation. The

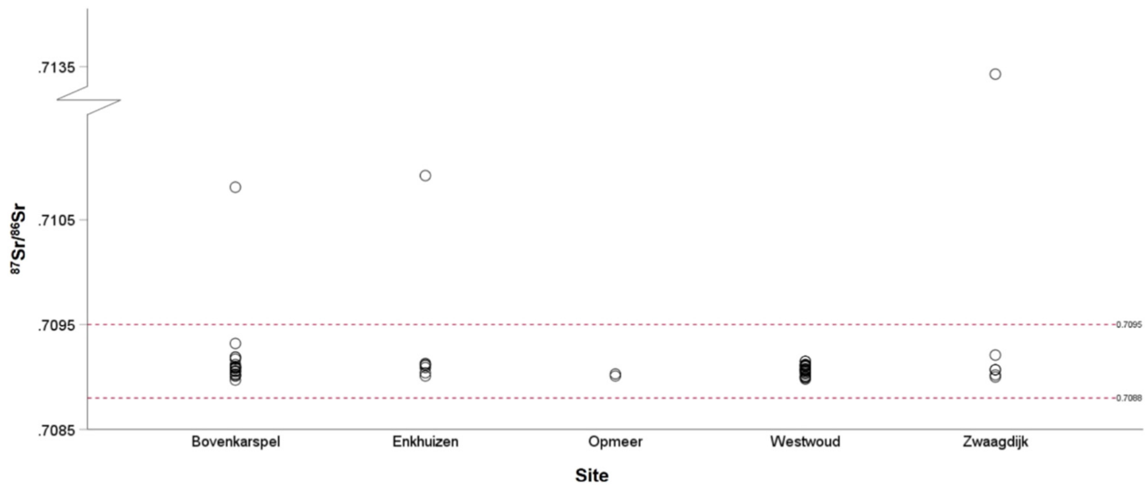

Fig. 3. $^{87}Sr/^{86}Sr$ values for Bronze Age cattle from West-Frisia. The 2σ error is contained within the symbols. The range of archaeological bioavailable $^{87}Sr/^{86}Sr$ values expected for West-Frisia and its environs is that provided by Kootker et al. (2016a, 2016b).

animal might have been kept in an area with an $^{87}Sr/^{86}Sr$ ratio of approximately 0.7134, similar to the M1 and M2 values, and then moved to West-Frisia during the time of the mineralization of the M3, resulting in a mixed $^{87}Sr/^{86}Sr$ ratio of 0.7113 for the M3.

No additional data was available for the third individual, the cattle sample 58/1/865, except for the $M1_{CEJ}$ value. The fact that this value also reflects a more radiogenic $^{87}Sr/^{86}Sr$ ratio than the local West-Frisia livestock indicates that the animal was not transported to West-Frisia before the age of 3 months old.

6. Discussion

The aim of the strontium isotope analysis was to determine whether there was movement of cattle and sheep or goats to West-Frisian settlements during the Bronze Age and thus test the hypothesis that herd animals played a role in inter-regional exchange networks. The isotope results provide the first evidence that livestock was indeed transported over large distances in West-Frisia during the Middle and Late Bronze Age. The number is small; of the 58 samples measured only three animals from different settlements and periods exhibit strontium isotope ratios that undoubtedly point towards an origin outside West-Frisia (5.2% of the investigated population). No isotopic evidence for transport was generated for the remaining 49 animals. However, as > 60% of Bronze Age the Netherlands is characterised by $^{87}Sr/^{86}Sr$ ratios ranging from 0.7088 to 0.7095, non-local origins for these animals cannot be excluded.

Based on the available isotope data, it cannot be inferred that there was a general mobility of herd animals to (and perhaps from) West-Frisia between 1500 and 800 BCE. However, it is noteworthy that the non-local animals come from three different sites and different periods. Long-distance trade or exchange was evident at the sites of Bovenkarspel-'t Valkje (LBA), Enkhuizen-Haling (MBA) and Zwaagdijk-Oost (LBA). This suggests that the movement of animals into West-Frisia was a regional phenomenon that took place throughout the Middle to Late Bronze Age.

These results are significant in light of the widespread evidence for the economic importance of cattle and, to a lesser extent, sheep in Bronze Age Europe. There are several lines of reasoning possible to interpret this significance. A pragmatic argument could be that the import of cattle and sheep was prompted by the need of new input for livestock bloodlines (e.g., Towers et al., 2010). An economic argument could be that these cattle and sheep were traded in exchange for metal. This hypothesis has already been discussed before (e.g., Earle, 2002), so this argument will not be pursued here but the premise for the economic argument will be addressed below. A third line of argument has so far had less attention: the possibility that livestock – cattle in particular – played a fundamental role in cosmology and ideology and therefore was used in social exchanges rather than in economic trade.

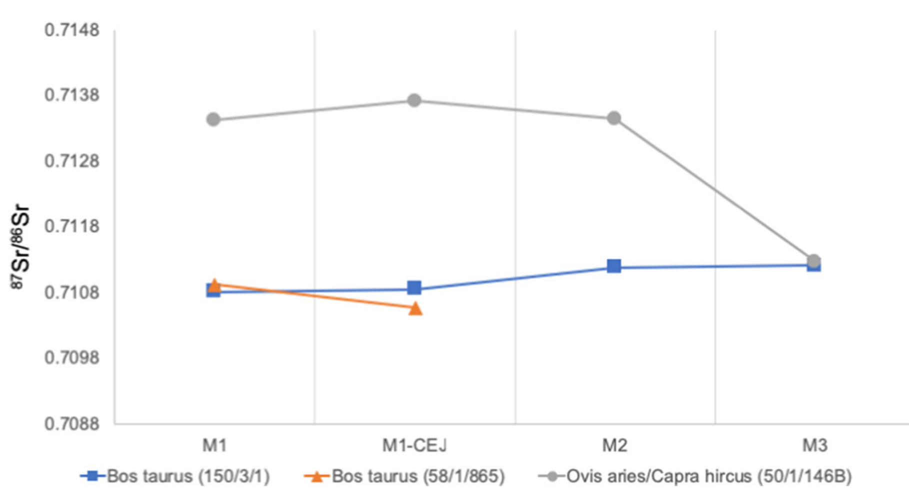

Fig. 4. M1, $M1_{CEJ}$, M2, and M3 $^{87}Sr/^{86}Sr$ values for two non-local cattle from Bovenkarspel-'t Valkje (LBA, 150/3/1) and Enkhuizen-Kadijken (MBA, 58/1/865), and one sheep or goat from Zwaagdijk-Oost (LBA, 50/1/146B).

It is possible that cattle and sheep were imported as a way to manage livestock bloodlines. The non-local individuals in this study were not slaughtered until adulthood, suggesting that they may have kept for breeding purposes. In domesticated herds, 15–20 cattle of breeding potential are needed to avoid inbreeding and ensure a healthy herd (Van Amerongen, 2016). Cattle with breeding potential includes cows with reproductive ability and excludes calves and bulls. Van Amerongen (2016) calculates that on every farm there could have been on average 5–8 cattle, 5–15 sheep, and 1–3 pigs. West-Frisian settlements consist of 1–2 farmsteads; thus an average Bronze Age settlement would not have had a sufficient number of cattle with breeding potential (Van Amerongen, 2016). Therefore, exchange with other cattle populations must have been necessary. Long-distance import, however, is unnecessary to maintain sufficient genetic variation in livestock populations. Exchange with the neighbouring settlement or within the local community would suffice. West-Frisia was densely populated throughout the Bronze Age (cf. Roessingh, 2018), so this option certainly was available. For example, Bovenkarspel and Enkhuizen are in close proximity of each other and could easily have exchanged cattle. It would have been unnecessary to invest extra time and energy to bring the cattle from at least 50 km away (cf., Viner et al., 2010).

Therefore, it is plausible that the need to maintain genetic diversity in livestock was not the prime motivation for moving cattle and sheep. Some scholars have interpreted the importance of cattle in the Bronze Age as evidence that these animals were indicators of status and prestige, functioning as wealth and owned primarily by the elite. As such, it has been argued, ‘the dramatic increase [in the Early Bronze Age] in cattle may well represent production for export for long-distance trade involving imported metals’ (Earle, 2002, 309). Equally, Kristiansen and Larsson interpret the Bronze Age byre houses as demonstrating possession of ‘the most costly prestige good’ (Kristiansen and Larsson, 2005, 277). They continue the argument, suggesting that houses without stalls are the houses of commoners: ‘This displays in a concrete way the economic hierarchy indicated also by the metalwork of the period’ (Kristiansen and Larsson, 2005, 278). In this perspective, the significance of cattle is economic wealth, equal to, and therefore traded for, metal. However, in our view this reduction of farming life to mere economic and prestige values and their almost self-evident portrayal of the Bronze Age ‘chiefly society’ and its supposedly uniform social structure anywhere in Europe does no justice to the regional diversity in complexity and structure of farming communities. We suggest that careful contextual analysis of (regionally specific) evidence should be the point of departure.

To give an example of why the reductionist approach does not work, the above cited vision of an economic hierarchy (or political economy in Earle's terms) predicts that in the Netherlands, where we see the same farms and village structures similar to those in Denmark (cf., Arnoldussen and Fokkens, 2008), an identical social structure can be expected. The model predicts few ‘chiefly residences’ with cattle stalls and many smaller houses without evidence for stalls. Yet, the evidence shows otherwise. In the northern Netherlands, for instance, almost all farms are very large and show evidence for stalls, even with the exact same structure and size as the chiefly residence of Legård (Fig. 5D) that Kristiansen and Larsson refer to (Bech and Olsen, 2003, Kristiansen and Larsson, 2005, 277). These are indicated as the Emmerhout-type (Fig. 5C, D), all showing a stable inserted between two ‘living’ areas (Kristiansen and Larsson, 2005; Fokkens and Arnoldussen, 2008; Bech and Olsen, 2013). In contrast, in West-Frisia all houses are shorter (15–20 m on average) and none shows any signs of stalls even if the structure of the house ditches suggests livestock-stalling on the east side of most houses (Fig. 5E, Roessingh, 2018, 330). There simply is no way of hypothesising social or structural differences between farms in West-Frisia. Yet there is abundant evidence for the same dominance of cattle on all of the West-Frisian sites (see Supplementary data). It is therefore unlikely that cattle were only the property of the elite and that the presence of houses with stalls signals chiefly residences.

There is an alternative explanation for the byre houses, which provides a clue for how to interpret the significance of livestock and their exchange in the Bronze Age. The development towards housing livestock indoors signifies not a just a change in the physical household and settlement structure, but a change in the social space as well. Humans and livestock were now sharing living space. Various scholars have successfully argued that there are no functional reasons that explain this development and that could not also have been achieved by keeping the animals in a separate stable. The appearance of the byre house must be seen as part of a change in social attitude towards animal husbandry (Fokkens, 1999, 2002; Olausson, 1999; Rasmussen, 1999; Zimmermann, 1999). The architecture of these houses ‘means that prior to building the house, there was a notion of who belonged to the household, and evidently humans and animals were both perceived as household members’ (Oma Armstrong, 2013, 170).

The emergence of a shared life-space for livestock and humans coincides with the increasing use of cattle in ritual practices in northwestern Europe. This indicates that cattle, and possible sheep/goats as well, had a significance in Bronze Age society that went beyond the economic; it was socio-ideological (Brusgaard, 2016; Fokkens, 1999, 2002). While livestock may have symbolised wealth, and thus status and prestige, this was not merely due to their economic value but more pronouncedly due to their social and ideological value. Anthropological research has shown that in societies in which cattle play a crucial economic, ritual, and social role, such as in many East African societies, these animals are integral part of all aspects of life, including the rites of passage that punctuate daily life, such as birth, marriage, and death (Herskovits, 1926; Lincoln, 1981; Kuper, 1982; Russell, 2012). Herskovits (1926, 252) noted that in all phases of their lives, these ‘cattle complex’ societies are touched by their ownership of cattle. These animals form an important part of the societies' social and ritual (gift) exchanges, such as bridewealth payments for marriage (Herskovits, 1926; Goody, 1973; Lincoln, 1981; Kuper, 1982; Russell, 2012). Various scholars have argued that the reason why cattle are used as bridewealth, and in other social and ritual exchanges, is not because of their economic importance but because of their social significance. Goldschmidt (1969, 10) states that ‘in these cattle-keeping societies, cows are not merely cows; in a symbolic but very real sense, they are people’. For this reason, sheep or goats could not suffice for bride wealth, ‘for only cattle can really restore to a person or group what has been lost in the value of a human member’ (Lincoln, 1981, 15). As such, cattle are seen as equal to people.

We argue that the exchange or trade of cattle, and potentially sheep too, in the Bronze Age should be considered from this perspective rather than as an economic transaction of ‘cattle for metal’ or ‘cattle for people’. There is ample evidence to suggest that we should interpret prehistoric gift exchange from a Maussian perspective in which the subject and object of the exchange are not separated but incommensurable (Bazelmans, 1999; Fontijn, 2002; Brück, 2006). This fits with the numerous examples from West-Frisia that suggest that human and cattle remains were treated in similar ways in the burial and depositional record (for an overview see Brusgaard, 2014). For instance, in a Middle Bronze Age burial mound in Bovenkarspel, no grave was found, but instead, in the centre, a pit was found which contained a small pot with a cattle rib in it (IJzereef, 1981, 15). There are other examples of such (ritual) deposits as well (cf., Van der Waals, 1961). This suggests that cattle occupied a position in Bronze Age society that was of equal socio-economic significance to people. They may have been seen equally as members of the household, as demonstrated by the emergence of houses with stalls. Thus, as argued elsewhere, if cattle were used as, for example, bridewealth payments, the exchanging of wives for cattle may be interpreted as the transformation of people into cattle and cattle into people (Brusgaard, 2016, 15).

These results reveal the first evidence from Netherlands that livestock was exchanged over large distances in the Bronze Age. We cannot determine why the animals were transported to West-Frisia, but we

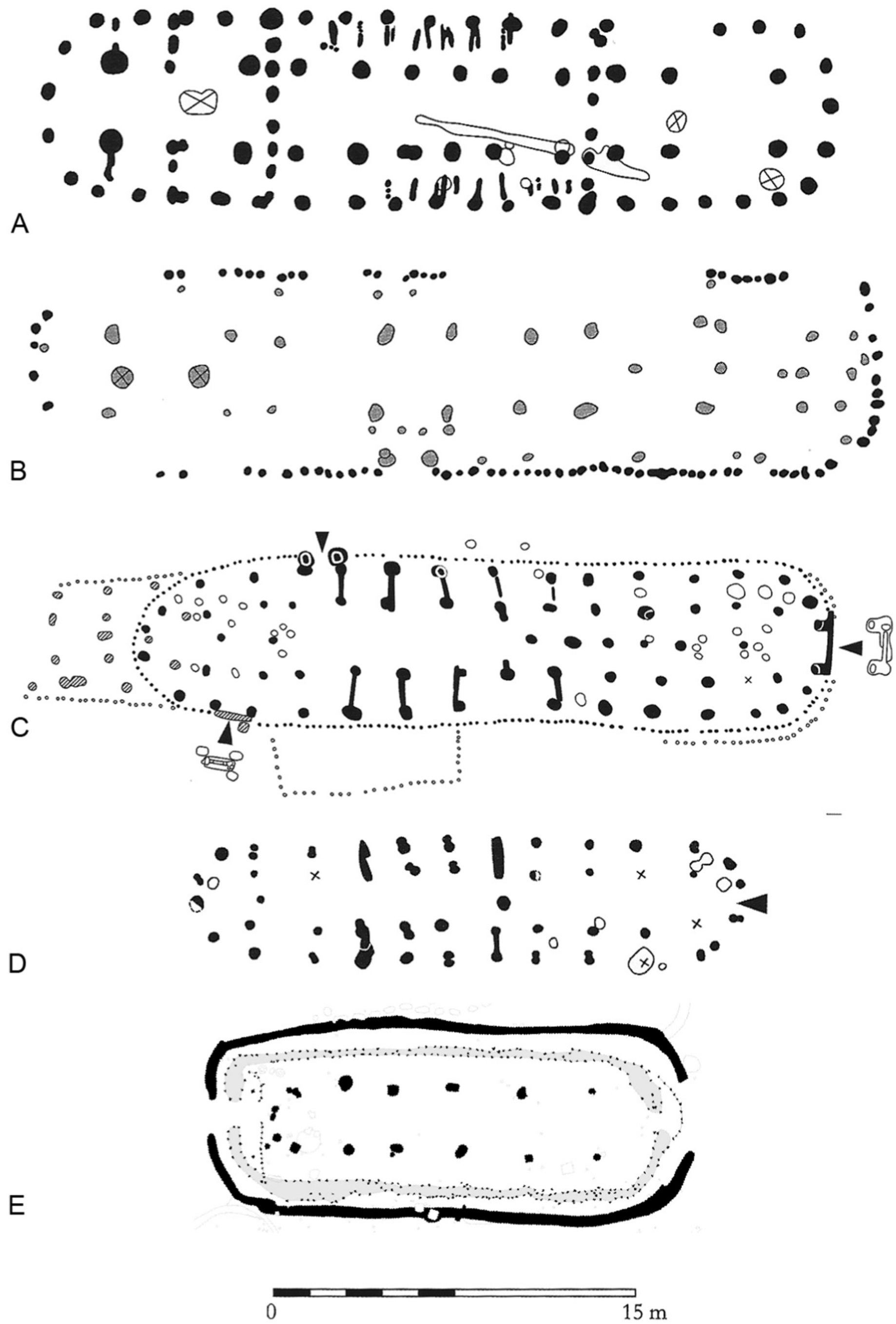

Fig. 5. Houses of type Højgård: A - Legård 3; B - Øster Ørbaek, type Emmerhout; C - Angelsoo-Emmerhout 32; D - Dalen 2 (after Donat, 2018, 38, 50); and E - of type Zijderveld - Andijk 5 (after Roessingh, 2018, 18).

argue that interpreting this in terms of economic trade for metal or the functional managing of bloodlines does not do justify to the widespread evidence for the socio-ideological role of especially cattle in Bronze Age society. It is more likely that the exchange of these animals was paired with a multitude of complex social and ritual relations, among which may have been bridewealth payments. It is interesting to note that in human isotopic signals, similar mobility patterns are starting to emerge. Bronze aged human individuals from Westwoud and Hoogkarspel exhibit a broad range of $^{87}Sr/^{86}Sr$ ratios, varying from 0.70847 to 0.71467 (n = 5, Kootker, 2018). Moreover, of the recently analysed Late Neolithic Oostwoud burials some of the persons came from similar isotopic regions as the cattle and sheep in this study (Fokkens et al., in prep). Exchanges of people and cattle, and maybe also sheep and/or goats, with the uplands like Wieringen/Texel, Eastern Frisia, the Veluwe, or even Limburg or further abroad may therefore have been a long-standing tradition, and more integrated in daily life than we have realised so far.

7. Conclusion

Based on the generated $^{87}Sr/^{86}Sr$ data from 58 cattle and sheep/goat from West-Frisia, the Netherlands, it can be concluded that that there is clear proof for the import of livestock, in this case from regions possibly at least 50 km away and probably only accessible over water. Despite the relatively limited sample size, the data show that analyses of faunal dental remains provide an important contribution to enhance our understanding of Bronze Age daily life. Yet, instead of translating this into evidence of the economic value of cattle and sheep, it would be fruitful to move to a perspective which places cattle as equal to people in terms of their socio-economic status and as members of the household. At the moment this is only a hypothesis; this pilot study serves as a starting point for comparable hypotheses with more dedicated research.

To date, the image of the Bronze Age is dominated by (male) elites, (male) warriors and (male) farmers. The importance of animals socially is hereby neglected. Similarly, women are virtually absent from our images of the past, both in the past and in the present (Van den Dries and Kerkhof, 2018). By changing our perspective towards the social ideology of farming life, we will move closer to understanding Bronze Age societies in more diverse and inclusive ways. We may discover, like Weiner did for the Kula exchange (Weiner, 1988), that women and livestock were just as important as their brawling and travelling husbands for the maintenance and creation of social networks. Insight into the mobility of livestock, but also into the genetic composition and development of different domestic breeds of cattle and sheep/goat is fundamental for a more diverse understanding of Bronze Age farming life.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2019.101944.

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