



# Strontium isotope evidence of early Funnel Beaker Culture movement of cattle



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## ABSTRACT

The movement of livestock across and within landscapes is increasingly being recognized as common in northern European prehistoric contexts, and was performed for various purposes. However, almost nothing is known about the movement of livestock in the earliest phase of the southern Scandinavian Neolithic Funnel Beaker Culture (ENI, TRB, 4000–3500 cal BC), or even if such movement is indicated. In this study, domestic cattle (*Bos taurus*) teeth from the early Neolithic sites Almhov, Sweden (N = 6) and Havnelev, Denmark (N = 7) were analyzed in order to determine the presence and character of potential livestock movement in this period. Tooth enamel strontium isotope analyses indicated a range of variation in local origin of the animals: some probably local and some non-local. Importantly, both sites yielded an individual exhibiting strontium isotope ratios indicating movement from elsewhere and over a body of water via boat. Although based on a small number of cattle, the movement of livestock is indicated in the earliest Neolithic in the region and provides evidence of social, economic, or other connections over substantial distances.

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## 1. Introduction and background

Little is known about animal husbandry in the first five-hundred years of Scandinavia's Neolithic (Funnel Beaker Culture, Early Neolithic I, c. 4000–3500 cal BC). Any new understanding of practices is desirable as the character of early farming has the strong potential to inform current knowledge of agricultural origins in the region and the role of domestic animal species in human subsistence economies. Information concerning the movement of livestock may also permit interpretations to be made concerning the interplay between husbandry, land-use, and society.

It is increasingly apparent that the movement of livestock across landscapes was a characteristic practice of northern European prehistoric societies (Sjögren and Price, 2012; Towers et al., 2010; Viner et al., 2010). Previous research has shown that by the middle Neolithic (c. 3300–2400 cal BC) cattle (*Bos taurus*) were circulated in central Sweden (Sjögren and Price, 2012), but the antiquity of this practice in the region is unclear. The purposes for movement may have been, and probably were, multifold and unlikely to be solely related to practical concerns. Therefore, it may not be possible to determine the precise purpose or purposes of such movement.

Early Neolithic faunal assemblages from southern Scandinavia are not abundant. They usually consist of limited materials from transitional shell middens, material in poor or highly fragmentary condition, and are

only in some cases dominated by domestic species (Andersen, 1991; Bratlund, 1993; Gron, 2013; Hallgren, 2008; Johansen, 2006; Koch, 1998; Skaarup, 1973). Therefore, it is often problematic to apply traditional zooarchaeological methods in order to understand animal husbandry practices because it is only really possible to construct a cattle mortality profile from one ENI site, Almhov, and those data possibly do not represent a residential breeding population (Gron et al., 2015). Given the inaccessibility of comparative contemporaneous zooarchaeological data, opportunities are limited regarding methodological approaches to understanding cattle husbandry.

In this context, we ask a very simple question using strontium isotopes in cattle tooth enamel: Is there evidence for movement of cattle in Scandinavia's earliest Neolithic? Given the relatively homogenous, yet well-established baseline strontium isotope ratios across the region (Frei and Frei, 2011; Frei and Price, 2012; Price et al., 2012a, 2012b, 2015), we expect that local transhumance may not be visible. Nonetheless, given the slight, yet consistent, variation across the landscape, the potential for long-distance movement and the complete lack of any information in this regard from the earliest Neolithic in the region, such an approach is appropriate.

## 2. Materials and methods

Two sites were selected for sampling: Almhov, Sweden, and Havnelev, Denmark (Fig. 1). These sites have yielded two of the largest domestic species-dominated early Neolithic faunal assemblages from

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**Fig. 1.** The locations of the sites. The dashed arrows highlight the closest potential region of origin for Sample #2 and the solid arrows highlight the same for Sample #23 (see Results and discussion). Figure modified from Gron et al. (2015).

southern Scandinavia. These materials present, therefore, the only opportunities for selecting more than one or two different *individual* cattle for analysis from particular sites. Furthermore, both sites are located in regions where aurochs (*Bos primigenius*) were extinct during the early Neolithic (Aaris-Sørensen, 1999; Ekström, 1993), so all teeth are of domestic origin. Previous strontium isotope data are available from the teeth from Almhov (Gron et al., 2015), but in the interest of comparability with the cattle from Havnelev, the samples analyzed previously were re-analyzed here to ensure analytical consistency. The primary reason for this redundancy was the closure of the laboratory used since those analyses. Therefore, in this paper Samples 1, 2, 3, 4, 5, and 16 correspond to Tooth Numbers 2, 4, 6, 7, 10, and 35 respectively in Gron et al. (2015).

Almhov was excavated in the early 2000s as part of an infrastructure project aimed at improving the transportation links between southern Sweden and eastern Denmark (Rudebeck, 2010). In the course of construction, a series of primary depositional pits surrounding several earthen long barrows were uncovered. From these pits, what is probably the largest early Neolithic faunal assemblage from the region was obtained. While relatively modest in size (c. 2000 identified specimens) in comparison with other time periods, this assemblage was dominated by domestic species, particularly cattle. Teeth (Table 1) were selected only from pits  $^{14}\text{C}$ -dated to the ENI (4000–3500 cal BC): Sample 1

from Feature 35862 (3790–3630 cal BC); Samples 2, 4, and 16 from Feature 19049 (3970–3710 cal BC); Sample 3 from Feature 25594 (3980–3690 cal BC); and Sample 5 from Feature 6 (3980–3630 cal BC) (Gron et al., 2015; Rudebeck, 2010).

In contrast to Almhov, the farming settlement at Havnelev was excavated numerous times: 1922, 1933, and 1936 by the National Museum of Denmark, and again in 1973 (Mathiassen, 1940; Nielsen, 1994). The 1922 excavation was of a shallow but very rich pit yielding the remains of predominantly domestic animals which were dated through the associated finds of Svaleklint-type (or Type B) Funnel Beaker ceramics, for which the settlement is the type-site. The 1933 excavations took place in a depression 120 m to the east of the pit dug in 1922. The hollow was oval in shape and measured c. 15 by 10 m, reaching a depth of 1 m from the top of the subsoil. From this campaign, again the overwhelmingly predominant ceramic was of Svaleklint-type. The excavation in 1936 took place 60 m to the west of the 1922 excavation. It produced a more mixed find material that also contained pottery from the ENII (c. 3500–3300 cal BC). In 1973 the precise location of the two major excavations in 1922 and 1933 was established and four smaller pits were excavated.

While confidently dated to the period between c. 3800–3500 cal BC using ceramics, absolute dating of finds from the 1922 and 1933 excavations has proven problematic due to very poor organic collagen preservation, and despite numerous efforts, no AMS radiocarbon dates have previously been obtained. As a last attempt, two mandible fragments from domestic cattle were submitted to the ChronoCentre at Queen's University Belfast for AMS dating. One had insufficiently preserved collagen, but the other, from the 1922 excavations (UBA-30023), was  $4978 \pm 37$  radiocarbon years old ( $2\sigma$  range, 3929–3659 cal BC), and in complete agreement with the dates assigned by the associated ceramics.

Sampling at Almhov focused on dextral mandibular first molars in order to minimize the possibility of sampling multiple teeth from the same individual. One sinistral molar was sampled, but could be differentiated from the other individuals based on toothwear. No loose teeth were sampled. From Havnelev, mandibular teeth were selected from the 1922, 1933, and 1936 excavation collections at the Zoological Museum Copenhagen. However, all teeth eventually sampled derived from the 1922 and 1933 excavations, as National Museum records list no mandibular teeth of cattle recovered in the 1936 campaign. In this case, only loose teeth were available (except Sample 24), so sampling focused on dextral teeth with one exception (again Sample 24) which was chosen to bolster the sample. First molars (M1s) were selected on qualitative morphological grounds, but in full acknowledgement of the difficulties differentiating loose M1s from second molars (M2s), we admit that pairs of teeth with similar strontium isotopes (Samples 18 and 21, and Samples 19, 20 and/or 24) could potentially derive from the same animal's M1 and M2. This is unlikely however. Firstly, Samples 18 and 21 had the same wear stage (Table 1), and given that the M1 erupts before the M2, it is nearly impossible for these teeth to be from

**Table 1**

Teeth sampled and data obtained (wear according to Grant, 1982). ERJ = Enamel-root junction.

Site	Sample number	Species	Element	Side	Grant Wear Stage	$^{87}\text{Sr}/^{86}\text{Sr}$	2SE	Cusp sampled (all buccal)	Sample location (mm from ERJ)
Almhov	1	<i>Bos taurus</i>	M1	dx	f	0.710170	0.000008	Mesial	28.0–18.7
Almhov	2	<i>Bos taurus</i>	M1	dx	d	0.709028	0.000009	Distal	25.2–20.9
Almhov	3	<i>Bos taurus</i>	M1	dx	b	0.710060	0.000015	Distal	25.8–20.8
Almhov	4	<i>Bos taurus</i>	M1	dx	f	0.709711	0.000008	Mesial	27.0–20.9
Almhov	5	<i>Bos taurus</i>	M1	dx	e	0.710854	0.000008	Distal	24.0–20.4
Almhov	16	<i>Bos taurus</i>	M1	sn	c	0.709609	0.000008	Mesial	23.9–20.5
Havnelev	18	<i>Bos taurus</i>	M1	dx	f	0.710868	0.000013	Mesial	25.6–21.8
Havnelev	19	<i>Bos taurus</i>	M1	dx	f	0.711291	0.000007	Mesial	24.0–20.6
Havnelev	20	<i>Bos taurus</i>	M1	dx	b	0.711339	0.000010	Mesial	26.2–22.4
Havnelev	21	<i>Bos taurus</i>	M1	dx	f	0.710909	0.000019	Distal	23.9–20.8
Havnelev	22	<i>Bos taurus</i>	M1	dx	g	0.711417	0.000017	Distal	23.8–20.8
Havnelev	23	<i>Bos taurus</i>	M1	dx	f	0.712103	0.000012	Mesial	23.3–20.1
Havnelev	24	<i>Bos taurus</i>	M1	sn	g	0.711308	0.000015	Mesial	23.4–20.3
Repeat #1	16	<i>Bos taurus</i>	M1	sn	c	0.709620	0.000007	Mesial	23.9–20.5
Repeat #2	21	<i>Bos taurus</i>	M1	dx	f	0.710906	0.000018	Distal	23.9–20.8

the same animal. Secondly, Sample 24 was the only Havnelev tooth that was not loose, and was extracted from a mandible also containing an M2. As such it cannot be from the same animal as Sample 19 on the grounds that identical teeth from two sides of a mandible will not have dissimilar wear stages, and that the M1 cannot be less worn than an M2. Therefore, only Sample 20 could potentially be from the same animal as either Sample 19 or 24, which, if true, only reduces the number of individuals by one.

Buccal lobes of the molars were first cleaned through abrasion using a high speed diamond-tipped dental drill. Damage to individual teeth necessitated the sampling of a mixture of mesial and distal cusps in order to ensure a consistent zone of sampling. Samples were taken from the same general overlapping zone of the tooth (Table 1) in order to ensure similar developmental timing in the period of strontium incorporation (Brown et al., 1960; Soana et al., 1997). In this case, the sampled region near the center of each tooth crown starts to mineralize in M1s in the period at, or around birth (Brown et al., 1960; Soana et al., 1997; Towers et al., 2014). Strontium was separated from the tooth enamel matrix and measured at the Durham Geochemistry Centre (DGC) at the Durham University Earth Sciences Department. The enamel samples were prepared for strontium isotope analysis using column chemistry methods outlined in Charlier et al. (2006). Samples were heated on a hot plate overnight in 500  $\mu\text{l}$  of 3 N  $\text{HNO}_3$ . Once dissolved the samples were loaded onto cleaned and preconditioned columns containing 60  $\mu\text{l}$  of Eichrom Sr specific resin.  $2 \times 250 \mu\text{l}$  3 N  $\text{HNO}_3$  was passed through the column to elute the waste, followed by  $2 \times 200 \mu\text{l}$  MQ  $\text{H}_2\text{O}$  to elute the strontium fraction. This was then acidified to yield a solution of  $\sim 3\%$   $\text{HNO}_3$  for subsequent analysis. Following the preparation, the size of the  $^{86}\text{Sr}$  beam was tested for each sample to assess the strontium concentrations. From this analysis, a dilution factor could be calculated for each sample and each was diluted to yield a beam size of approximately 20 V  $^{88}\text{Sr}$  to match the intensity of the international Isotopic Reference Material (IRM), NBS987. Strontium samples were analyzed by Multi-Collector Inductively Coupled Plasma Mass Spectrometry (MC-ICP-MS) using a Neptune MC-ICP-MS at the DGC. Samples were introduced into the Neptune using an ESI PFA-50 nebulizer and a micro-cyclonic spraychamber. Instrumental mass bias was corrected for using an  $^{88}\text{Sr}/^{86}\text{Sr}$  ratio of 8.375209 (the reciprocal of the  $^{86}\text{Sr}/^{88}\text{Sr}$  ratio of 0.1194) and an exponential law. Corrections for isobaric interferences from Rb and Kr on  $^{87}\text{Sr}$  and  $^{86}\text{Sr}$  were performed using  $^{85}\text{Rb}$  and  $^{83}\text{Kr}$  as the monitor masses. In all cases the intensity of monitor

mass was  $<0.1$  mV and isobaric interference corrections therefore insignificant. Samples were analyzed in one session during which the average  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio and reproducibility for the IRM NBS987 during this study was  $0.710250 \pm 0.000013$  (2 $\sigma$ ;  $n = 11$ ).

### 3. Results and discussion

Thirteen strontium isotope ratios were obtained from domestic cattle molars from Havnelev ( $N = 7$ ) and Almhov ( $N = 6$ ) (Table 1). Additionally, two repeated measurements show variation within the reproducibility for reference standards, and are not considered further. The  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios range from 0.70903 to 0.71210. The Almhov ratios are lower than those from Havnelev with no overlap although several ratios are very similar between the sites. In context with the most recent baselines for the region (Price et al., 2015; Frei and Frei, 2011; Frei and Price, 2012), all ratios fall within the usual range of variation for eastern Denmark or southern Sweden (Fig. 2). Despite some overlap between eastern and western Denmark (Frei and Price, 2012), there is no reason to identify any of the cattle as originating further afield in the west when they are also consistent with origins in the east. However, this cannot be conclusively ruled out.

As one moves southwest through Scania and across the Øresund into Zealand (Fig. 1), there is a trend of decreasing strontium isotope ratios in modern baseline animal samples (Price et al., 2015). However, the cattle data from Almhov and Havnelev do not conform to this modern geographical trend insofar as the Almhov ratios are lower. Previous analyses of the samples from Almhov were interpreted as being local to southern Scandinavia broadly (Gron et al., 2015), but on the finer regional scale, more can be said. The range of variation at each site implies the presence of individuals that were not all from the same place, while at the same time indicating that some individuals had similar origins (Fig. 2). Ultimately, the current baseline resolution is insufficient to resolve possible places of origin further but this dataset suggests that at both sites movement of cattle at least locally to each site may be indicated.

Two cattle are of particular interest (Samples #2 and #23), as they may offer some further information regarding movement. Firstly, one ratio from Almhov (Sample #2, 0.70903), is lower than the available baseline ratios for Scania (Price et al., 2012a, 2012b, 2015). Importantly, it is lower than the accepted seawater strontium isotope ratio of 0.7092 (McArthur et al., 2001; Fig. 2) indicating that this ratio is unlikely to be

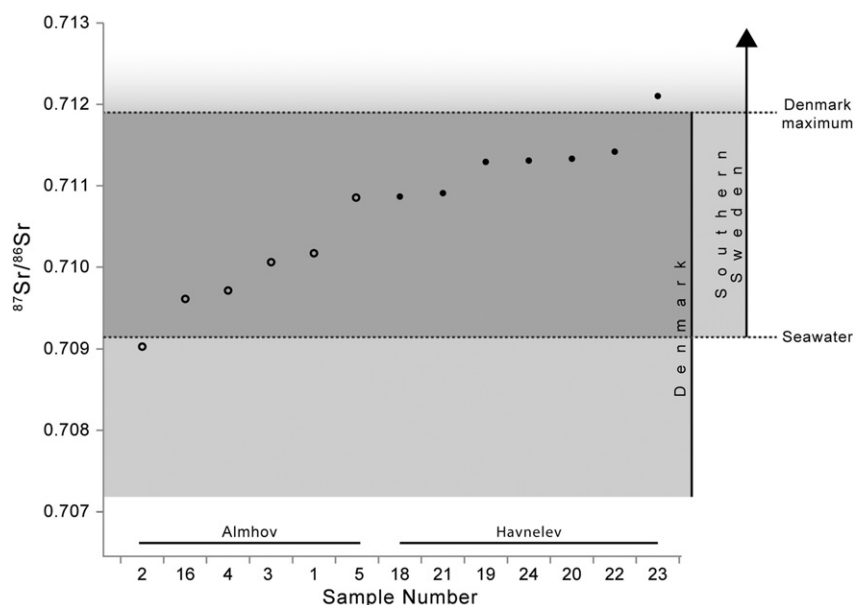


Fig. 2. Strontium isotope data from Almhov (southern Sweden) and Havnelev (eastern Denmark). Baseline ranges and seawater value from (Frei and Price, 2012; McArthur et al., 2001; Price et al., 2012a, 2012b, 2015; Wilhelmson and Ahlström, 2015).

simply a statistical outlier of the dataset. There are no baseline values from Scania lower than seawater (Price et al., 2012a, 2012b, 2015; Wilhelmson and Ahlström, 2015). If indeed sea spray or rainwater via plant ingestion is contributory in temperate maritime environments (Montgomery, 2010), it is likely that this ratio is an intermediate value resulting from the mixing of sea/rainwater with geologically derived strontium, most likely in this region to be from marine carbonates such as chalk which have  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios of circa 0.7075 (McArthur et al., 2001). In this case, it is probable that this animal is from somewhere with lower biosphere ratios; the closest geographic candidate being Zealand, Denmark (Fig. 1; Frei and Price, 2012). However, this animal could be from essentially anywhere within the northern European lowland region of strontium isotope similarity, stretching from the Low Countries to Poland.

Secondly, one animal from Havnelev (Sample #23) has a markedly higher strontium isotope ratio than the usual range of variation for eastern Denmark. In fact, its ratio (0.71210) is higher than the absolute maximum baseline value ever obtained from Denmark, except for the values from the island of Bornholm in the Baltic (Frei and Price, 2012; Price et al., 2012a). Save for this possibility, and despite being found in Denmark, this individual is *almost certainly not from Denmark*. The geographically closest potential source to Havnelev is to the northeast of what is today Lund, in Sweden (Fig. 1).

The overall picture is that of local and non-local movement of cattle. That is, some cattle are almost certainly being moved some distance, while others are being moved locally, or not at all. At no point in the latest Mesolithic and earliest Neolithic was the Øresund dry land (Christensen, 1995; Fig. 1), mostly owing to the massive sea-level rise in the region during the Atlantic period. It is for this reason that the two non-local cattle must have been moved by boat.

#### 4. Conclusions

Two-way movement of cattle across the Øresund during the earliest Neolithic period in southern Scandinavia is indicated, albeit on the basis of two individuals. We have also presented evidence that suggests more local movement of cattle within the early Neolithic landscape. It is important to remember that we do not argue for any specific provenience of origin for any of the cattle in this study, just for the presence of non-local individuals. We also suggest that in some cases the closest potential origin lies across the Øresund and that at the very least a body of water must have been crossed. We propose possible origins simply on the basis of proximity to where the remains were found, but transport by boat in such a marine environment increases the possibilities of origin by an order of magnitude.

The multi-directional movement of cattle during this crucial early period of the Neolithic potentially extends the antiquity of younger Neolithic cattle circulation practices (Sjögren and Price, 2012), or may indicate a completely different system altogether. Regardless, such movement indicates the presence of a system of livestock movement, which hints at social, economic, or other connections over substantial distances in the early Neolithic Funnel Beaker Culture.

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