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Denmark's Not-So-Oldest Sheep: An Update on Domestic Animals from the Femern Project

Daniel Groß[1,5], Samantha Presslee[2], Ulrich Schmölcke[1,3], Elena A. Nikulina[4], Jessica Hendy[2]

[1] Museum Lolland-Falster, Nykøbing F., Denmark
[2] BioArCh, Department of Archaeology, Department of Chemistry, University of York, York, United Kingdom
[3] Leibniz-Zentrum für Archäologie, Zentrum für Baltische und Skandinavische Archäologie (LEIZA-ZBSA), Schleswig, Germany
[4] formerly Zentrum für Baltische und Skandinavische Archäologie (ZBSA), Schleswig, Germany
[5] Corresponding author (dag@museumlollandfalster.dk) ORCID: 0000-0002-1328-1134

ABSTRACT

Sheep and goats are often considered to be the oldest livestock animals in Denmark. In this contribution, we present the results of ZooMS measurements from seven ovicaprid bones from the Femern project, an excavation in the area of the former Syltholm Fjord (Lolland, Denmark). The bones were morphologically identified as sheep or goats and represented the oldest dated remains of both species in Denmark. However, the ZooMS analysis showed that more than half of the morphological identifications were incorrect. For the other samples, we refined the identifications. Hence, our study confirms that indications of sheep and goat husbandry based on bone morphology alone should be treated with caution. The probability of misidentification in our case was high, even in the case of well-preserved bones.

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Introduction

The extensive archaeological excavations associated with the construction of the Fehmarn Belt tunnel between Denmark and Germany revealed not only significant insights into the prehistory of the Danish Baltic Sea island of Lolland, but are also of general interest for understanding the cultural, economic, and social development from the last foragers to the first metallurgists in southern Scandinavia (see contributions in Groß and Rothstein 2023). Among several remarkable artefacts and features (e.g. Jensen et al. 2019; Jensen et al. 2020; Koch et al. 2024), large assemblages from the transitional phase between Mesolithic and Neolithic lifestyles were uncovered (Gron et al. 2024). In particular, understanding the introduction of the first livestock is crucial for addressing the shift from the regional Late Mesolithic Ertebølle Culture to the Early Neolithic Funnel Beaker Culture in the centuries around 4000 cal. BCE. It is not yet fully understood how these two archaeological cultures represent population exchange (e.g. Allentoft et al. 2024), parallel societies (Jensen and Sørensen 2023), and/or migration processes (cf. Fischer et al. 2024). Current research indicates that the Danish Baltic Sea islands appear to have followed a different pattern regarding the introduction of agriculture and husbandry compared to the continental, western part of the Jutland peninsula (cf. Gron and Sørensen 2018; Lucquin et al. 2023; Philippsen 2023). Hence, knowledge of the first introduced livestock is paramount for understanding this fundamental social, economic, and environmental change in the area in focus.

In this contribution, we present eight recently reviewed species determinations from previously published finds from the Femern project, as well as one new date. All these animal bones were previously morphologically identified as sheep (*Ovis* sp.) or goats (*Capra* sp.) and have been dated to between *c.*4450 and 3100 cal. BCE, hence representing the oldest dated ovicaprids in the assemblages. Two of the specimens predate the previously known presence of elements of the 'Neolithic package' on Lolland, and therefore the traditional Mesolithic/Neolithic transition in Denmark, while seven bones date just after.

Adding another dimension to the population perspective, the selected bones are highly significant, as much understanding of prehistoric socio-cultural development is implicitly embedded in the division between the Mesolithic and the Neo-

Figure 1. Two of the sampled specimens show the different, but generally good preservation conditions (a: MLF00906-II X3691; b: MLF00939-I X3043).

lithic and, accordingly, the introduction of livestock. We use Zooarchaeology by Mass-Spectrometry (ZooMS) as a means of refining the species identification, as sheep, goat, and roe deer bones are often challenging to differentiate morphologically, especially when fragmented (Buckley et al. 2009; 2010).

Materials and methods

The study analysed nine morphologically determined and AMS-dated bones from putative ovicaprids from the Femern project which produced radiocarbon ages between 4450 and 3100 cal. BCE (Table 1). The samples were excavated as part of the Femern project (Groß and Rothstein 2023) during developer-driven archaeology, and dating samples were selected during the project. The analysed samples come from three different archaeological sites and were morphologically identified at Copenhagen University on a contract basis. The preservation conditions for the selected bones were excellent to average with surface damage to the bones (Figure 1). All samples were recovered from the refuse zone of the former Sylteholm Fjord, near the northern shoreline (cf. Måge et al. 2023). The selected bones come from large sites with varying osseous inventory sizes (MLF00935-II: n=311; MLF00939-I: n=267; MLF00906-I: n=2784; MLF00906-II: n=2407). A full analysis of the respective faunal data is still pending. The selection of dating samples was generally done based on association and contextualization to obtain ages for the archaeological assemblages or single finds.

For this study, we selected specimens that produced the oldest ages. Additional samples were not obtained for economic and conservation reasons. All selected samples were considered reliably morphologically identified, and the ZooMS analysis was intended as a double-check measure due to the relevance of the finds.

Except for one sample, which was bone powder, all measurements were conducted using collagen extracts obtained during sample preparation for ^{14}C-dating.

Lab ID	Site	MLF-no	Find ID	Sample ID	Species morpho-logical	Bone	Species ZooMS	Samples	Col-lagen yield	14C age	14C STD	d13C	d15N	Reference
AAR-27432	Sylthom II	00906-I	X8821	P202	Ovis/ Capra	Pelvis pubis, right, female	roe deer*	collagen	0,012	5194	29	-23.19 ± 0.11	5.15 ± 0.2	Måge et al. 2023
AAR-27434	Sylthom II	00906-I	X10077	P207	Ovis/ Capra	Vertebra lumbal, cut marks	goat	collagen	0,043	4765	32	-20.99 ± 0.15	5.92 ± 0.28	Sørensen 2020
AAR-27437	Sylthom II	00906-I	X11371	P201	Ovis/ Capra	Vertebra lumbal, cutmarks	roe deer*	collagen	0,05	5122	30	-22.91 ± 0.11	4.98 ± 0.2	Måge et al. 2023
AAR-33777	Sylthom II	00906-II	X3654	P43	Ovis/ Capra	Vertebra cervical	sheep	collagen	0,098	5142	33	-23 ± 0.1	5.2 ± 0.2	Måge et al. 2023
AAR-33778	Sylthom II	00906-II	X3697	P44	Ovis/ Capra	Tibia, pro-mixal, right, cut marks	roe deer*	collagen	0,072	5313	32	-24.2 ± 0.1	6.1 ± 0.2	Måge et al. 2023
AAR-33779	Sylthom II	00906-II	X4397	P45	Ovis/ Capra	Astragalus, right	sheep	collagen	0,066	5122	33	-22.9 ± 0.1	5.3 ± 0.2	Måge et al. 2023
AAR-33781	Sylthom II	00906-II	X4516	P47	Capra hircus	Astragalus, left	roe deer*	collagen	0,105	5040	33	-22.8 ± 0.1	5.7 ± 0.2	Måge et al. 2023
AAR-26547	Sylthom IX	00935-II	X1672		Ovis aries	Humerus, right, cutmarks	sheep	bone	0,04	4506	26	-21.33 ± 0.1	9.9 ± 0.2	Måge et al. 2023
AAR-33747	Sylthom XIII	00939-I	X3043	P16	Ovis/ Capra	Femur, diaphysis, left, young individual (unfused)	red deer/ elk*	collagen	0,048	5483	40	-22.6 ± 0.1	7 ± 0.3	This study

Table 1. Radiocarbon dates and species identification via ZooMS for the selected samples. Samples marked with an asterisk are corrected species identifications (cf. Måge et al. 2023).

The bone powder was demineralised in 0.6 M hydrochloric acid for 48 hours, followed by three washes, once with 0.1 M sodium hydroxide to remove possible contamination, such as humic acids from the burial environment, and twice with 50 mM ammonium bicarbonate. The bone sample was heated for one hour at 65°C in 100 µL ammonium bicarbonate to denature the collagen into solution. After this step, the rest of the preparation for both the collagen samples and the bone sample was the same. All samples were digested overnight (~18 hours) in ammonium bicarbonate using the enzyme trypsin. Digestion was stopped with the addition of 5% trifluoracetic acid, and the peptides were purified using C18 ZipTip pipette tips before being eluted in 100 µL of conditioning solution (0.1% TFA in 50:50 ACN: Water). 1 µL of the sample was spotted onto a Bruker ground steel target plate and mixed with 1 µL of matrix (alpha-cyano-4-hydroxycinnamic acid). The samples were spotted in triplicate alongside calibration standards, and the plate was run on a Bruker UltrafleXtreme MALDI ToF MS.

The spectra were analysed using mMass, an open-source mass spectrometry tool (Strohalm et al. 2010). The three replicates were averaged, and the resulting averaged spectrum was cropped to 800-3500 *m/z* and peak-picked using a signal/noise of 4-6. The sample spectrum peak list was compared to a list of published markers, allowing for identifications to be made (Buckley and Collins 2011; Buckley et al. 2009; Buckley et al. 2010; Welker et al. 2016). The individual replicate data for all the samples are available via the Zenodo depository.

Results

Three of the nine analysed specimens were positively identified as sheep, and one as goat (Table 1). The results from five samples indicate morphological misidentification, with four specimens attributed to roe deer, and the oldest analysed bone in the assemblage identified as belonging to a large cervid, i.e. red deer or elk (Figure 2). As elk was not present on Lolland in the Final Mesolithic (Aaris-Sørensen

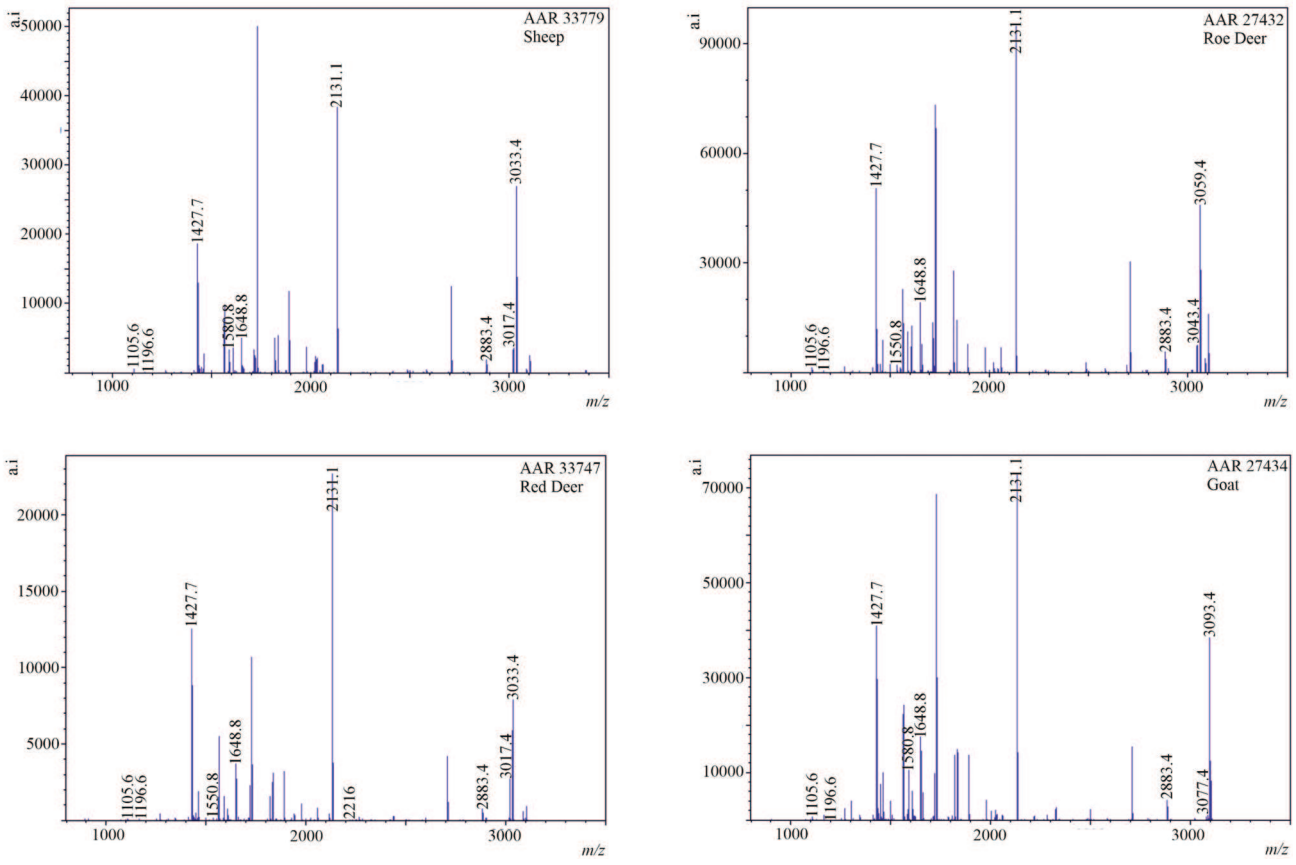

Figure 2. ZooMS spectra for the four identified species from the study.

Lab ID	Site	Morphological species	aDNA species	14C age ± STD	calibrated BCE 2 sigma	Reference
KIA-41338	Rosenhof LA 58	wild boar	pig	5800 ± 25	4720-4583	Krause-Kyora et al. 2013; Rowley-Conwy and Zeder 2014
OxA-27064	Havnø	sheep/goat		5329 ± 35	4313-4046	Sørensen 2014
KIA-7127	Wangels LA 505	sheep/goat		5325 ± 45	4323-3999	Hartz and Lübke 2006
KIA-7129	Wangels LA 505	sheep		5295 ± 35	4242-3995	Hartz and Lübke 2006
KIA-30590	Neustadt LA 156	cattle	cattle	5235 ± 31	4226-3967	Craig et al. 2011; Glykou 2016
KIA-28210	Rosenhof LA 58	cattle	cattle	5231± 25	4221-3970	Scheu et al. 2008
KIA-29091	Neustadt LA 156	goat		5214 ± 32	4222-3961	Glykou 2016
AAR-4998	Wangels LA 505	cattle	cattle	5165 ± 45	4158-3804	Scheu et al. 2008
AAR-4031	Lollikhuse	sheep/goat		5120 ± 55	4045-3781	Fischer 2002
AAR-1459	Rosenhof LA 58	sheep/goat		5110 ± 90	4222-3654	Hartz et al. 2000
KIA-7128	Wangels LA 505	sheep		5085 ± 35	3964-3794	Hartz and Lübke 2006
KIA-30591	Neustadt LA 156	sheep		5060 ± 40	3963-3767	Glykou 2016
KIA-39767	Neustadt LA 156	cattle	cattle	5055 ± 28	3952-3787	Glykou 2016
AAR-3104	Jorløse Mose	sheep/goat		5020 ± 60	3958-3674	Heinemeier and Rud 1999
KIA-29092	Neustadt LA 156	cattle	cattle	5010 ± 34	3943-3706	Glykou 2016

Table 2. Overview of the oldest directly dated domesticates in Schleswig-Holstein and Denmark.

2009), we can assume that the bone is correctly identified as red deer, unless it was imported.

Discussion

Our re-identifications of Stone Age ovicaprid remains from Lolland could not confirm a first appearance of either species in the North before 4000 cal. BCE. We identified the first appearance of sheep in the Sylthom Fjord area around 3900 cal. BCE (between 4040 and 3800 cal. BCE), while the oldest goat is clearly younger and dating to 3640–3380 cal. BCE. Since our sample size is too small to reach solid conclusions regarding the introduction of sheep and goats on Lolland, especially against the background of two-thirds of the samples not being ovicaprids, we cannot conclusively determine that goats were introduced later than sheep, as appears to be the case in southern Sweden (cf. Sjögren et al. 2023). The mismatch between morphological and ZooMS species identification in our case is significant but should not be generalized. However, considering Gron et al.'s (2020) results on interobserver errors, we can conclude that morphological criteria for identifying sheep and goat bones cannot be applied reliably. As in our case, roe deer should also be considered. Our study further emphasises that "If we are to understand the purpose(s) for which caprines were raised, we first must understand whether sheep or goats were present or both"

(Gron et al. 2020, 178) in Early Neolithic assemblages.

It is possible that ovicaprids were indeed the first domestic animals brought to the North, as several bones from Wangels LA 505 (located only 70 km southwest of the Sylt holm Fjord in eastern Holstein) and Havnø (Nordvestsjælland), identified as sheep, date to around 4100 cal. BCE (Table 2). Additionally, a goat skull fragment from Neustadt LA 505 (located 100 km southwest) dates to about 4000 cal. BCE. Cattle bones from Neustadt LA 156 and Rosenhof LA 58 (60 km southwest), which have been genetically confirmed as belonging to domesticated animals, are of a similar age to these morphologically identified ovicaprid remains.

As it stands, there is little research on the introduction of sheep and goats into Scandinavia from a regional perspective (Nikulina and Schmölcke 2020; Sjögren et al. 2023). Current genetic studies indicate that the first stock of ovicaprids in Central Europe came from two distinct lineages (Nikulina and Schmölcke 2020). The first, older lineage was the direct successor of animals from early farmers in Greece and the Balkan area and reached Central Europe with the Linearbandkeramik culture. A younger lineage followed one millennium later from southern France and is found at sites from, for instance, the Michelsberg culture and presumably the Swifterbant culture. This lineage appears to be the origin of the first Scandinavian sheep and goats. However, due to the limited data base, these considerations are preliminary and tentative (cf. Brusgaard et al. 2022).

As regional studies have shown (e.g. Gron et al. 2020; Sjögren et al. 2023), a refined evaluation of the introduction of ovicaprids in the Funnel Beaker culture might yield interesting and localized differences. Particularly regarding goats, regional differences seem apparent with them either being absent or at least very scarce in southern Sweden until around 2000 cal. BCE (Sjögren et al. 2023). Additionally, when considering ancient DNA analysis of "cattle" remains (Scheu et al. 2008; Schmölcke and Nikulina 2015), statistical re-analysis of Late Mesolithic and Neolithic aurochs/cattle (Schmölcke and Groß 2020) and criticism regarding the correct attribution of the oldest pig bone in northern Germany (Rowley-Conwy and Zeder 2014), it becomes obvious that the details of the transformation processes throughout the Neolithization of southern Scandinavia and north-central Europe need a critical re-evaluation at the taxonomic level. It is expected that our understanding of the pathways, velocities, and intergroup contacts concerning the introduction of domesticates will be significantly improved, when approached from mixed methodological and source-critical perspectives.

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Declaration of interest statement

The authors declare no conflict of interest.

Data availability

The raw text files from the MALDI-ToF MS analysis are available on Zenodo under the DOI 10.5281/zenodo.13312316

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