Journal of Archaeological Science: Reports 49 (2023) 103943

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Ivory from early Anglo-Saxon burials in Lincolnshire – A biomolecular study

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ARTICLE INFO

Keywords:
Anglo-Saxon
Ivory rings
ZooMS
Strontium
Radiocarbon dating

ABSTRACT

Ivory bag rings have been found in more than 70 cemeteries across southern, central, and eastern England dating to between the late-5th and 7th centuries AD. These rings are most frequently found in richly furnished female graves, and would have served as the framework for bags that hung at the waist. Debate over the source of this ivory has prevailed since the 19th century, with walrus and mammoth ivory considered as possible contenders to elephantid ivory. Recent excavations at an early Anglo-Saxon cemetery in Scremby, Lincolnshire revealed a number of elaborate female burials containing such bag rings. Using radiocarbon dating this study aimed to establish whether the rings were contemporary with the burials before seeking to identify the species of ivory through Zooarchaeology by mass spectrometry (ZooMS). Strontium analysis was also used to identify the place of residence of the elephantids at the time of tusk formation. Through a multi-methodological approach, we have established that the ivory used for the Scremby bag rings came from elephants living in an area of young volcanic rocks in Africa at some point during the 5th and 6th centuries AD. This preliminary evidence allows us to consider the networks and socio-economic factors that facilitated the distribution of ivory from Africa to the British Isles at this time.

1. Introduction

Between 2017 and 2019 excavations at Scremby, Lincolnshire revealed a previously unknown Anglo-Saxon cemetery dating from the late-5th to mid-6th centuries AD (Fig. 1). Although heavily disturbed by agricultural activity, 49 inhumations including men, woman and infants survived sufficiently well to be recovered. Of these, seven female inhumations included within their grave assemblages circular ivory rings, which would originally have formed the rigid opening to an organic bag (Figs. 2, 3) (Vogt, 1960: 86-88; Hills, 2001). Since most rings have been recovered near the hip, it is thought that the bags were suspended from the waist alongside other objects such as iron knives, pairs of copper alloy girdle hangers, and iron 'latch lifters' (Vogt, 1960: 86-88; MacGregor, 1985: 111) (Fig. 3).

1.1. Ivory in early Anglo-Saxon England – walrus, mammoth or elephant?

The earliest references to ivory bag rings in early Anglo-Saxon (5th-7th century AD) graves in England come from antiquarian reports dating to the 19th century. In 1812, Colt Hoare published the earliest known engraving of a bag ring as part of a wider barrow assemblage from Woodyates, Dorset (Colt Hoare, 1812: plate 32). They were initially assumed to be arm rings or bracelets, but their first correct identification as bag rings came in 1857 with Akerman's excavations at the Anglo-Saxon cemetery in Brighthampton, Oxfordshire (Akerman, 1860: 92). Of the two ivory rings encountered, one retained a fabric impression on its surface, leading Akerman to identify these as 'the framework of a kind of bag' (Akerman, 1860: 92). This interpretation is still accepted today not least because of their large size, with rings often varying between 10 cm and 15 cm in diameter (Hills, 2001: 133), but also because of their placement at the hip rather than around the arms or wrists (Myres and Green, 1973: 101; MacGregor, 1985: 110).

Ivory bag rings have been found in cemeteries across southern, central, and eastern England, and they are usually found in richly furnished female graves dating to between the late-5th and 7th centuries AD (Meaney, 1981: 249-52; Lucy, 2000: 46-7). Ivory bag rings of similar

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https://doi.org/10.1016/j.jasrep.2023.103943
Received 16 June 2022; Received in revised form 30 January 2023; Accepted 5 March 2023
Available online 24 March 2023
2352-409X/

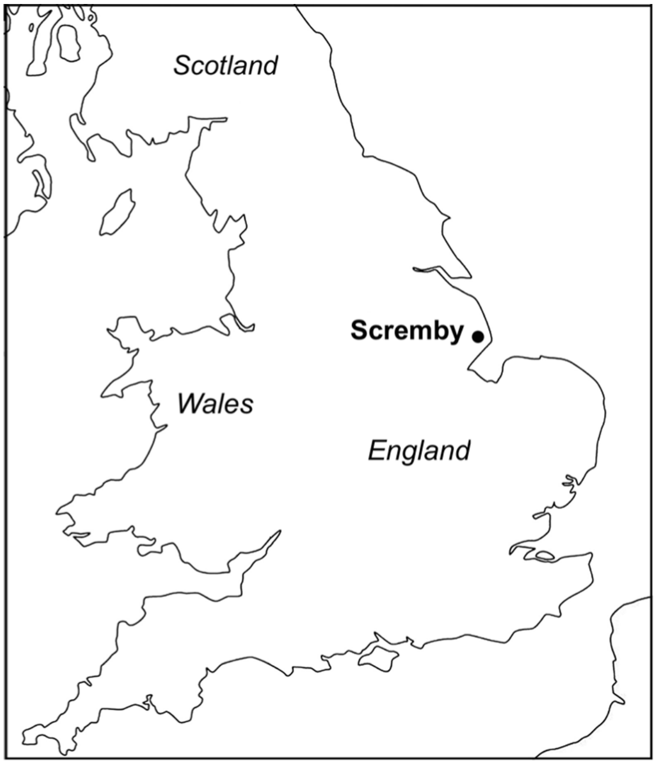

Fig. 1. Map of mainland Britain illustrating the location of the late-5th to mid-6th century AD cemetery at Scremby, Lincolnshire.

Fig. 2. Burial of an adult female (SK17) from the early Anglo-Saxon cemetery at Scremby, Lincolnshire. Girdle hangers and a bag with an ivory ring are positioned at her left hip (white arrow / inset), whilst a pair of annular brooches were worn at the shoulders, strings of beads were hung around her neck, and a stone spindle whorl was placed near her right foot.

date have also been found in cemetery excavations in Northern Germany, although notably in far smaller numbers (Vogt, 1960; Hills, 2001: 137-8). Rings were worked to round and smooth the edges, and were probably highly polished when first made. Reconstructions suggest a material bag was attached to the ring so that the ivory was still clearly visible (Myres and Green, 1973: 103). The rarity of such material, since it was not naturally available in 5th-7th century England, suggests they may have been used for the conspicuous display of status as much as a practical utility (Vogt, 1960: 86-88; Myres and Green, 1973: 103; Meaney, 1981, Fig. VII.1).

The presence of ivory in early Anglo-Saxon graves has generated considerable scholarly interest and debate. As early as the 1st century BC, historical sources such as Pliny's '*Natural History*' recall the use of elephants in Ptolemaic military expeditions (Bostock, 1885 §8.1.1–8.13.35; Sidebotham, 2011: 39-53). During the later Roman period, ivory from extant African elephants (*Loxodonta africana*, *Loxodonta cyclotis*) and Asian elephants (*Elephas maximus*) was distributed from ports in Egypt across the Mediterranean (MacGregor, 1985: 39; Coutu and Damgaard, 2019: 511-512). The use of extant elephant ivory in the immediate post-Roman period was, however, dismissed by scholars on the grounds that the end of the western Roman Empire resulted in the disruption of those former trade routes which would have bought ivory to Northern Europe (MacGregor, 1985: 38; Huggett, 1988: 68). Instead, the possibility of other sources of ivory including mammoth (*Mammuthus* sp.) and marine species, such as the Arctic walrus (*Odobenus rosmarus)*, were proposed (Myres and Green, 1973; MacGregor, 1985; Huggett, 1988). For example, walrus was considered a possibility on the basis that, by the later Anglo-Saxon period, it had become the dominant source of ivory (Huggett, 1980; Hills, 2001: 132). MacGregor (1985: 40), however, suggested that mammoth ivory may have been preferred because of the tusks' tendency to laminate which would have facilitated its use for manufacture. Doubt has, however, since been cast on the possible use of mammoth and walrus ivory. For example, bag rings from Anglo-Saxon burials are made from a single piece of tusk, and the ring diameters are far greater than reported for marine mammals; for example, the mean diameter for fossil walrus tusks reported by Dyke et al. (1999: 167) is c. 5 cm ± 2, which is half the diameter of the average ivory bag ring (Hills, 2001: 133). Moreover, walrus tusks are oval, whilst elephant tusks are circular like the rings used for the bags (Gillman, 2017: 89). The suggestion that mammoth ivory might have provided an accessible source has also been discounted in some instances through radiocarbon dating. Bag rings from Anglo-Saxon cemeteries at Chatham Lines, Kent and Fairford, Gloucestershire dating to the 5th-6th centuries AD suggest the only probable source of ivory at these sites came from a contemporaneous African or Asian elephant (Hills, 2001: 134). Whilst, in the absence of the absolute dating of every ivory ring found, the use of ancient ivory cannot be entirely discounted, to date not a single example has been shown to have come from a mammoth, making it increasingly unlikely that it was a source exploited in the Anglo-Saxon period.

Conflicting historical accounts by contemporary writers have also confounded the issue of which species of elephant was hunted for its ivory in the 5th-7th centuries AD. For example, writing in the 7th century, Isidore of Seville suggested a reliance on Asian elephants following the exhaustion of African herds during the preceding Roman period. Hills (2001: 135-6), however, makes a convincing argument that ivory entering Northern Europe at this time originated in East Africa, in particular via the Christian Kingdom of Aksum located in modern-day Eritrea and northern Ethiopia. Excavations at the site of Aksum have revealed considerable evidence for ivory working, and it is said the kingdom was a major manufacturer and distributor of ivory between the 3rd and 7th centuries AD (Phillipson, 2000a).

Fig. 3. Ivory bag ring and girdle hangers associated with skeleton SK12 at Scremby, Lincolnshire.

Recent excavations at the late-5th to mid-6th centuries AD cemetery at Scremby, Lincolnshire revealed seven female burials containing ivory bag rings (Figs. 2, 3). The decision was made to undertake biomolecular analyses on five fragmentary rings from the most richly furnished burials (Table 1). Radiocarbon dating was undertaken in order to confirm whether or not the ivory rings derived from extant (e.g. *Loxodonta* sp., *Elephas*) or extinct (*Mammuthus* sp.) elephantid species. Zooarchaeology by Mass Spectrometry (ZooMS) was employed to identify whether the ivory came from African (*Loxodonta africana*, *Loxodonta cyclotis*) or Asian (*Elephas maximus)* elephantids, whilst strontium analysis was undertaken to determine where the elephantids may have resided at the time of tusk formation since strontium incorporated into the ivory reflects the underlying geology of the area where they sourced their food (van der Merwe et al., 1990: 793). In taking a multi-methodological approach, this pilot study sought to establish how the bag rings from Scremby might contribute towards our understanding of ivory distributed to England during the early Anglo-Saxon period.

2. Materials and methods

Elephantid tusks are a second upper incisor with an enamel tip, dentine core, pulp cavity, and an outer layer of cementum. The dentine core consists of 30% collagen and 70% bioapatite, with dentinal tubules embedded in a mineralised collagen matrix (Ziegler et al., 2016). The size, shape, distribution, and orientation of the dentinal tubule sheets (microlaminae) are species specific (Virág, 2012), and their arrangement creates a distinctive checkerboard 'Schreger Pattern' that can be used to distinguish extant from extinct elephantid ivory, and to distinguish elephantidae from other proboscideans (Espinoza and Mann, 1993, 1999; Virág, 2012; Trapani and Fisher, 2003). The ivory rings from Scremby were made from a single transverse slice cut at the proximal end of the tusk. Due to their fragmentary nature, an estimation of their size suggests they varied between 11 cm and 12.5 cm in diameter on their external edge, and measured approximately 1–1.5 cm in thickness (Fig. 3).

2.1. Radiocarbon dating

Similarities between the burials in terms of their stratigraphy within the cemetery and the nature of their grave goods suggests they were broadly contemporaneous and dating from the late-5th to the second quarter of the 6th century AD. In order to establish whether the ivory bag rings associated with these burials derived from extant or extinct elephantid species, radiocarbon dating was undertaken prior to any further biomolecular analyses. A fragment of ivory weighing 2.7 g was sampled from the bag ring associated with skeleton SK17 and submitted to Beta Analytic for Accelerator Mass Spectrometry radiocarbon dating (Lab. No. Beta-499851).

2.2. ZooMS

ZooMS collagen peptide mass fingerprinting was carried out on a sample of ivory associated with skeleton SK12 following van der Sluis et al., (2014), which involved the incubation of the sample with 1 mL 0.6 M HCl for ~ 18 h. The HCl-soluble collagen was then ultrafiltered with 10 kDa filters (Vivaspin, UK) for 20 min, washed twice with 50 mM ammonium bicarbonate (ABC), and 0.1 mL retentate collected for an overnight tryptic digest (0.4ug Promega sequencing grade trypsin, UK) at 37 °C. 1uL of the digest solution was then spotted with an equal volume of 10 mg/mL hydroxycinnamic acid in 50% acetonitrile/0.1% trifluoroacetic acid. Once dried, the crystalised sample was analysed using a Rapiflex MALDI-ToF mass spectrometer with *m/z* range

Table 1
Details of the five burials from Scremby, Lincolnshire; the biomolecular analyses undertaken on the ivory bag rings is indicated by (**X**).

Burial number	Skeleton	Grave goods	Material analysed	Radiocarbon (C^{14}) dating	ZooMS	$^{87}Sr/^{86}Sr$
B17	SK17 – Adult Female	Ivory bag ring with knife, pair of annular brooches, large pin, sleeve clasps, belt knife, silver finger rings, bone comb, stone spindle whorl, bead assemblage, beaver tooth pendant	Ivory – bag ring	X		
B12	SK12 – Adult Female	Ivory bag ring, girdle hangers, pair of annular brooches, large spangle headed pin, beads assemblage, sleeve clasps, silver finger rings	Ivory – bag ring		X	X
B21	SK21 – Adult Female & SK24 – Neonate	Ivory bag ring, bag contents, bead assemblage	Ivory – bag ring			X
B36	SK36 – Adult Female	Ivory bag ring, pair of annular brooches, sleeve clasps, girdle hangers, silver finger rings, bead assemblage	Ivory – bag ring			X
B45	SK45 – Adult Female	Ivory bag ring, three annular brooches, sleeve clasps, bead assemblage (amber), girdle hangers, knife,?strike light	Ivory – bag ring			X

700–3,700 and the spectra compared with those obtained from African and Asian elephant reference material (Buckley et al., 2011).

2.3. Strontium analysis

The outer surface of each ivory piece was first cleaned using a diamond dental burr to remove any dirt and surface contaminants, then c.30 mg of clean ivory was cut from each sample. The resulting samples were transferred to a clean (class 100, laminar flow) working area for further preparation. In the clean laboratory, the samples were first cleaned ultrasonically in high purity water to remove dust. They were then leached for 5 minutes using 10% Ultrapur acetic acid with the aim of removing possible diagenetic carbonates. Samples were then rinsed twice and soaked for an hour at 60°C, before being rinsed twice again, dried, and weighed into pre-cleaned Teflon beakers. The samples were mixed with ^{84}Sr tracer solution and dissolved in Teflon distilled 8 M nitric acid (HNO_3) and converted to chloride form using 6 M hydrochloric acid (HCl). Strontium was collected using Eichrom AG50 X8 resin columns. Strontium was loaded onto a single Re Filament following the method of Birck (1986) and the isotope composition and strontium concentrations were determined by Thermal Ionisation Mass spectroscopy (TIMS) using a Thermo Triton multi-collector mass spectrometer. The international standard for ^{87}Sr/^{86}Sr, NBS-987, gave a value of 0.710262 ± 0.000020 (2σ, n = 8) during the analysis of these samples. Data are corrected to an accepted value for this standard of 0.710250.

3. Results

3.1. Radiocarbon dating

The radiocarbon date obtained for the sample of ivory associated with skeleton SK17 was calibrated using BetaCal 3.21 and the IntCal13 database (Reimar et al., 2013). The ivory bag ring was dated to AD 428–598 at 95.4% probability (Fig. 4, Table 2) suggesting that it was broadly contemporaneous with the burial in which it was placed. These results rule out extinct elephantid species as the source of ivory at Scremby since the last of the mammoth species is said to have died out on Wrangel Island, Siberia around 2000 BC (Arslanov et al., 1998; Arppe et al., 2019). The δ^{13}C‰ (-13.5‰) and δ^{15}N‰ (13‰) values obtained routinely as part of the radiocarbon analysis are comparable to data obtained by Coutu et al., (2016b: 12, 14–15) for modern and historical ivory, and are thought to reflect an arid habitat consisting of bushland and grassland. Given the dating evidence, and compared to similar results from other early medieval cemeteries (Hills, 2001: 134), it can be confidently stated that the ivory rings from Scremby came from extant elephantid species.

3.2. African or Asian elephant? Using ZooMS for species identification

The radiocarbon dating evidence demonstrated that the ivory derived from an extant elephantid species either from Africa or Asia. The African elephants (*Loxodonta* sp.) separated from their Asian counterparts (*Elephas*) approximately 6.6–8.8 million years ago (Rohland et al., 2007). Based on divergence time alone it is unsurprising that the ZooMS collagen peptide mass fingerprint can separate these at the genus level (Buckley, 2018), despite initial failure to do so (Buckley et al., 2011). It requires observation of peaks at either m/z 1540.8 and 1576.8 for *Loxodonta* (representing peptides 2 t26 and 2 t76 respectively; see Buckley (2016) for nomenclature), or 1568.8 and 1590.8 for *Elephas* (Buckley et al., 2019). The sample of ivory associated with skeleton SK12 from Scremby yields peaks at m/z 1540.8 and 1576.8 reflecting African elephant origins (Fig. 5).

3.3. Strontium isotope analysis

The predicted strontium isotope biosphere range for the Scremby area of Lincolnshire is 0.7088–0.7101 (Evans et al., 2010). This range is based on the interquartile range of strontium values obtained from plants growing on the underlying lithology, known as the Roach formation, which consists of cretaceous limestone and mudstone (BGS Geology Viewer). Values obtained from the analysis of human tooth enamel sampled from skeletons buried at Scremby also yielded a mean ^{87}Sr/^{86}Sr of 0.7094 ± 0.0003 (n = 10, 1SD), which is consistent with the local predicted biosphere values (Hemer et al., forthcoming). In comparison to these values were those obtained for the four ivory bag rings, which gave ^{87}Sr/^{86}Sr between 0.7065 and 0.7076 and strontium concentrations between 178 and 248 ppm (Fig. 6, Table 3).

Unlike tooth enamel, ivory is dentine, and dentine can react and partially or fully equilibrate with the burial environment. Such a process is well documented in Montgomery et al. (2014) and shows that re-equilibrium is usually accompanied by an increase in strontium

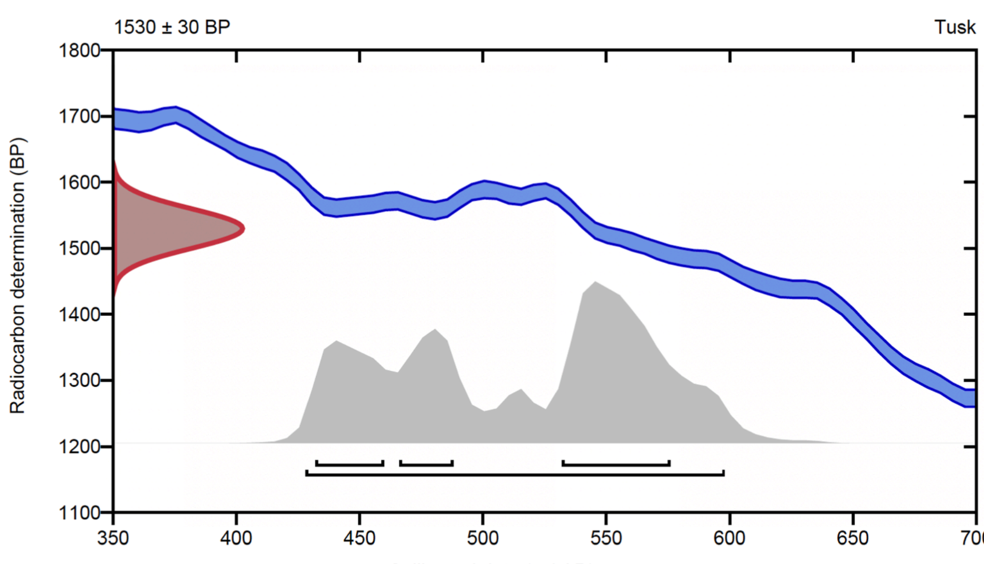

Fig. 4. OxCal calibration for the ivory associated with skeleton SK17 which dates the ring to AD 428–598 at 95.4% probability; this indicates the ivory came from an extant and not an extinct elephantid species.

Table 2
Radiocarbon measurements obtained by Accelerator Mass Spectrometry and dates calibrated using the IntCal13 calibration curve (Reimer et al., 2013). The δ13C‰ and δ15N‰ values were measured separately by IRMS and are relative to VPDB-1.

Lab number	Sample	Material	F14C	1σ	14C age BP	Calibrated radiocarbon date range 95.4% probability	Calibrated radiocarbon date range 68.2% probability	C:N	%C	%N	δ13C ‰	δ15N ‰
Beta-499851	Screm18 - SK17	Elephantid tusk	0.8266	0.0031	1530 ± 30 BP	428–598 cal AD (1522–1352 cal BP)	AD 532–576 cal (1418–1374 cal BP) (37.3%); AD 432–460 cal (1518–1490 cal BP) (16.4%); AD 466–488 cal AD (14.5%) (1484–1462 cal BP)	3.2	42.0	15.2	−13.5	13

concentrations in the dentine compared to the associated tooth enamel. The question of whether the ivory bag rings retained sufficient primary signature to help exclude certain regions of Africa and propose the elephants' place of origin is therefore considered since diagenesis is central to this issue. Firstly, our sample preparation methods were rigorous, and the ivory was prepared so as to minimize the impact of any remaining diagenetic component. Secondly, the $^{87}Sr/^{86}Sr$ for the ivory are well below values that could be attributed to a local diagenetic signal whilst the strontium concentrations are also at the lower end of values measured in ivory (143–883 ppm) suggesting our reported values reflect the original strontium concentrations (Prozesky et al., 1995). We therefore conclude that whilst it cannot be *proven* that there is no diagenetic component to the $^{87}Sr/^{86}Sr$ in the ivory, any contamination present is not so great that it obliterates the original life signal, and as such, the results can be used to restrict the areas of Africa where the elephants may have roamed. $^{87}Sr/^{86}Sr \leq 0.707$ are largely confined to areas of basaltic rocks (Rogers et al., 2000). As such, areas of cratonic lithology in Africa can be excluded, whilst areas of young geological formations such as those found in the East African Rift Valley which runs through Kenya and Ethiopia, and other areas of similar lithology, cannot be excluded.

4. Discussion

The radiocarbon dating, strontium analysis, and ZooMS undertaken as part of this pilot study provide convincing evidence that the elephant ivory recovered from the burials at the early Anglo-Saxon cemetery of Scremby, Lincolnshire was procured from African elephants who lived between the fifth and sixth centuries AD. This makes the ivory contemporaneous to the burials in which it was placed, and allows us to rule out the possibility that it was sourced from mammoth or marine species, as once proposed by scholars such as MacGregor (1985) and Huggett (1988). The potential origins of those elephants within Africa, however, requires further consideration.

Previous studies of elephant ivory sourced from archaeological (e.g. worked ivory chips) and historical (e.g. piano keys) contexts have demonstrated the potential use of isotope analysis as a means of identifying the origins and habits of elephantids in the past (Coutu, 2015; Coutu et al., 2016a, 2016b; Coutu and Damgaard, 2019). For example, a study by Coutu et al., (2016b) analysed carbon ($^{13}C/^{12}C$), nitrogen ($^{15}N/^{14}N$), oxygen ($^{18}O/^{16}O$) and strontium ($^{87}Sr/^{86}Sr$) from modern and historic ivories from museum collections in Africa, North America, UK and Europe. According to archival evidence, ivories were traded from East Africa around the turn of the 20th century, and therefore the aim of their study was to track the movement of this material and how such trade impacted on the distribution of elephants within the landscape (Coutu et al., 2016b). As part of their analysis, low strontium values were reported from regions of young volcanic geologies from Ethiopia and Kenya. For example, an ivory sample from the Arda-Arto region of the Awash West Reserve in Ethiopia produced a strontium value of 0.7067 (Coutu et al., 2016b: Supplementary Information 1). Similarly, strontium isotope values between 0.705 and 0.707 were recorded for multiple ivory samples from the Eastern Rift area of Kenya (Coutu et al., 2016b: 13). Complimentary to this material evidence are whole-rock strontium values for young, tertiary trap volcanics in the Amba Aradam Formation in the region of Harlaa, eastern Ethiopia, which ranged between 0.7068 and 0.7078 (Pryor et al., 2020: 124). Given the similarities between the strontium values reported from ivory in Kenya and Ethiopia and the strontium values for the ivory sampled from the Scremby bag rings, it is possible that this ivory was sourced in East Africa. As such, further consideration should be given to Hills's (2001) suggestion that ivory entering Northern Europe originated from the Kingdom of Aksum, located in modern-day Eritrea and northern Ethiopia.

By the 4th century AD, the Kingdom of Aksum had grown to dominate the systems of exchange in the Red Sea region (Seland, 2014: 378-

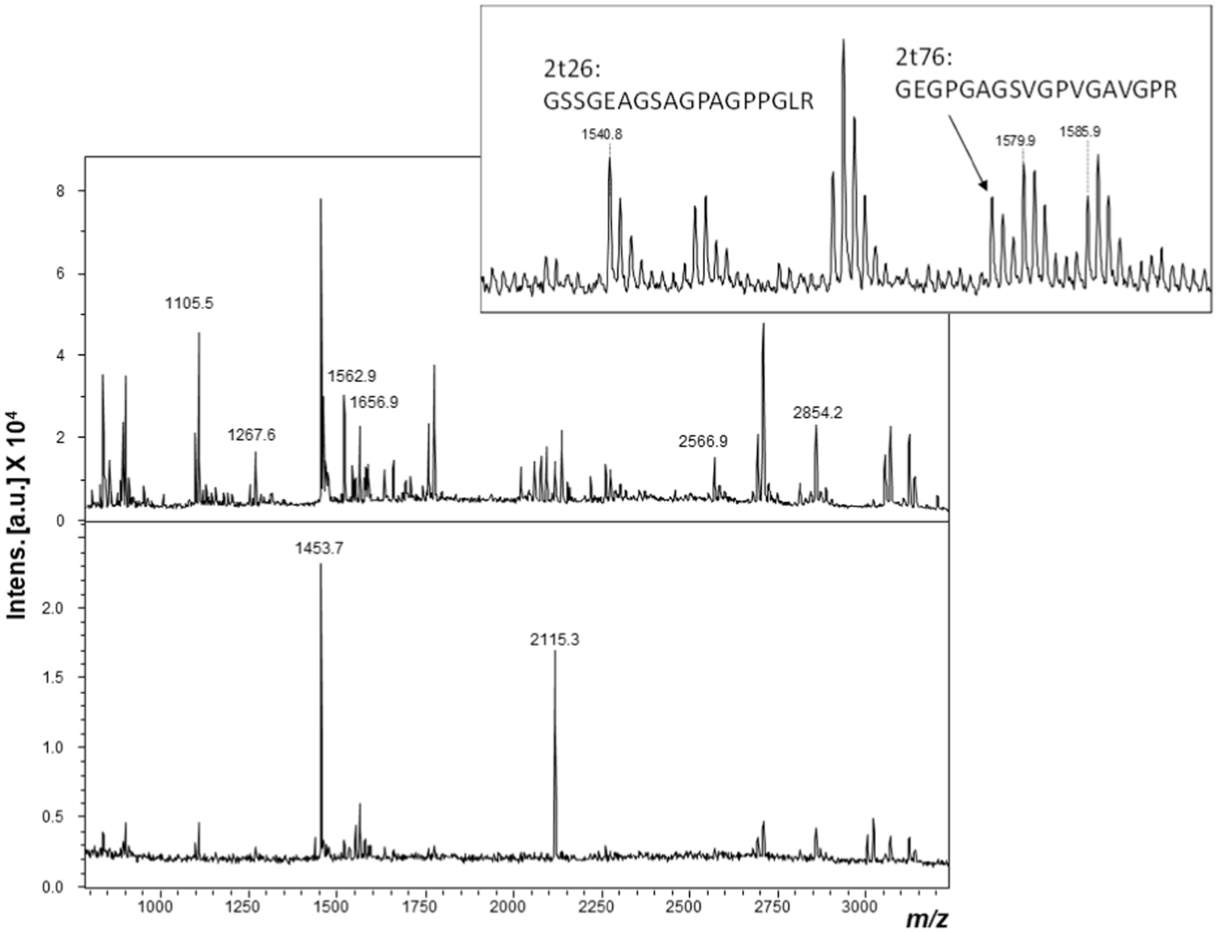

Fig. 5. MALDI-ToF mass spectra of the 10% acetonitrile (top) and 50% acetonitrile (bottom) fractions of a collagen tryptic digest showing peptides that identify the specimen as deriving from African elephant (inset).

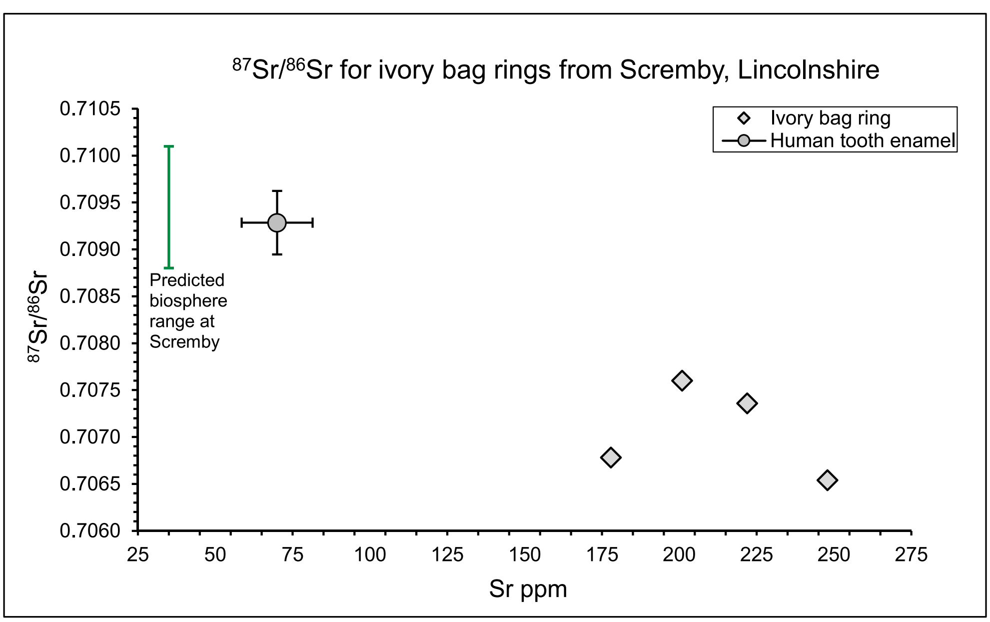

Fig. 6. Plot illustrating $^{87}Sr/^{86}Sr$ and strontium concentrations (ppm) for the ivory sampled from four bag rings associated with burials at Scremby, Lincolnshire (grey diamonds). The mean $^{87}Sr/^{86}Sr$ (0.7094 ± 0.0003, 1σ, n = 10,) and mean concentration (70 ppm ± 11.49, 1σ, n = 10) for human tooth enamel from Scremby is also represented by the grey circle, whilst the predicted biosphere range for the area is illustrated by a green bar. These data illustrate the difference between the values we expect for the local area and the $^{87}Sr/^{86}Sr$ of the sampled ivory (mean ivory $^{87}Sr/^{86}Sr$: 0.7071 ± 0.0005, 1σ, n = 4; mean ivory concentration: 212 ppm ± 29.8, 1σ, n = 4). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 3
Results of the strontium analysis undertaken on four ivory bag rings from Scremby, Lincolnshire.

Burial number	Material analysed	^{87}Sr / ^{86}Sr	Strontium concentration (ppm)
B12	Ivory – bag ring	0.7074	222
B21	Ivory – bag ring	0.7065	248
B36	Ivory – bag ring	0.7068	178
B45	Ivory – bag ring	0.7076	201

81), and there are records for the export of ivory from Aksum to Persia in the 6th century (Wolska-Conus, 1973: 348-54). Excavations in the town of Aksum led by D.W. Phillipson between 1993 and 1997, which included an area of the urban town known as K site, provided evidence for ivory working in the 6th century (Phillipson, 2000a). A waste piece of ivory from which a disc or ring had been removed was recovered from this area, and suggests the use of sophisticated lathe-turning techniques to remove perfectly rounded pieces of ivory (Phillipson, 2000b: 461). It is noteworthy that this piece looks remarkably similar in size and shape to the rings recovered from the burials at Scremby. Additional evidence from nearby Beta Giyorgis, northwest of Aksum, have also revealed workshops containing obsidian scrapers which, it has been suggested, were associated with ivory working between AD 450–800 (Munro-Hay, 1991; Phillipson, 2009). The absence of evidence for ivory working in the form of off-cuts and waste on early Anglo-Saxon settlements suggests that ivory bag rings were imported ready-made from trade centres where skilled craftspeople were already established. Additional isotope analysis, including carbon, nitrogen, oxygen and sulphur, of the ivory from Scremby will be undertaken to build on this pilot study and help further refine the potential origins of the elephants in East Africa as part of a wider investigation into the trade of ivory to England during the early Anglo-Saxon period.

The Kingdom of Aksum played a prominent role in the supply of ivory until the 7th century AD, when its influence declined. This coincided with the early Islamic conquests and expansion into North Africa which established a trade monopoly between the region and the Mediterranean (Munro-Hay, 1991; Seaver, 2009: 275). The demand for ivory in China and India is also said to have increased at this time and diverted much of the available ivory from Africa through the trade system to the East (Wilson and Ayerst, 1976: 24–25; Seaver, 2009: 275). Perhaps related to the disrupted trade routes to the West was the marked decline in the occurrence of ivory bag rings in Anglo-Saxon graves dating from the 7th century onwards (Geake, 1995: 182-5). This was also a time of flux in England that saw wider changes to burial practices in part due to the re-establishment of Christianity. Concurrent factors may therefore be responsible for the apparent decline of ivory bag rings in burials by the 7th century AD.

5. Conclusions

The biomolecular evidence presented in this paper has identified bag rings made from extant elephant ivory sourced in Africa during the 5th and 6th centuries AD. Strontium analysis suggests the elephants inhabited an area of young volcanic lithology, as found in East Africa, whilst carbon and nitrogen data obtained as part of the radiocarbon dating hints to the elephants' inhabiting an arid grass or bushland environment. The data presented here still raises a number of questions around the trade mechanisms and connections between the West and elite powers, such as the Kingdom of Aksum, in the East. We are confident that future research building on this pilot study will provide the opportunity to better understand how and why this exotic material found its way into a select number of female graves in rural Lincolnshire.

CRediT authorship contribution statement

Katie A. Hemer: Conceptualization, Investigation, Resources, Formal analysis, Visualization, Writing – original draft, Writing – review & editing, Project administration, Supervision, Funding acquisition. **Hugh Willmott:** Conceptualization, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization. **Jane E. Evans:** Methodology, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing. **Michael Buckley:** Methodology, Validation, Formal analysis, Investigation, Resources, Visualization, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

We are incredibly grateful to the landowner (J. Hoff) who gave us access to their land so that we could excavate the site in Scremby, Lincolnshire. Thanks is also given to students from the University of Sheffield, Department of Archaeology and other volunteers who made the excavation possible each year. The analysis of the ivory bag rings was made possible thanks to the generous funding awarded to KH from the Society of Antiquaries of London (Phillips Fund). We would like to thank the anonymous reviewers for their suggestions, and the Editor for his input.

Declarations.

Funding Information.

This work was supported by a grant awarded to KH from the Society of Antiquaries of London (Phillips Fund).

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