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Human remains, context, and place of origin for the Salme, Estonia, boat burials

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ABSTRACT

Isotopic proveniencing of all individuals from the ship and boat burials at Salme, Estonia, is the subject of this study of the interred human remains from around AD 750, at the beginning of the Viking period. The isotopic results indicate that the majority of these individuals came from a region with higher strontium isotopic ratios than those found in Estonia. There were five individuals, buried in Salme II—the ship burial with 34 individuals—who exhibited lower strontium isotope ratios that might have come from the Swedish island of Gotland or several other possible places. The combination of isotopic signals and archaeological information suggests that the majority of buried individuals (those with higher strontium isotope ratios) came from the Mälaren Valley in east-central Sweden.

1. Introduction

Boat and ship burial are well-known features of Viking-Age funerary ritual (McGuire and Erin-Lee, 2010). However, the Salme finds differ from other Scandinavian ship burials in terms of the large number of buried individuals (a mass grave of warriors, a number of whom clearly perished in battle), the abundant find material, and the single tragic event that took place at the beginning of the Viking Age. This makes the Salme complex unique in all of Europe.

In autumn 2008 remains of human skeletons and ancient artifacts (sword fragments, rivets, gaming pieces, dice, etc.) were brought to light during construction activities in the town of Salme on the island of Saaremaa in western Estonia (Fig. 1). The shape of the weapon fragments suggested they dated to the period c. AD 600-800, spanning the end of the so-called Vendel Period and the beginning of the Viking Age. The date of the burial of the ships is now largely confirmed by radiocarbon determinations that corroborate a date around AD 750 (Peets et al., 2013).

Archaeological rescue excavations revealed that the finds came from a boat burial (Salme I), which had been partially destroyed by the construction activities. Late in autumn of the same year the digging of an adjacent trench brought similar finds to light. In the course of archaeological excavations between 2010 and 2012, the Salme II ship burial was discovered and investigated.

Ship and boat graves in northern Europe date between ca. AD 550–950 (Bill, 2019). The custom of ship burial spread in Northern Europe during the Vendel Period and became common in the Viking Age (750–1050 CE). Ship and boat burials have been found in Central, Eastern and Southern Sweden, the Danish islands, Jutland, coastal areas of Norway—primarily around the Oslo fjord, on the western and southwestern coast of Finland, in the Åland Islands, and also in Iceland, Great Britain, on the Île de Groix near the southern coast of Brittany in France, and in the estuaries of the large rivers in Germany. Vendel Era boat burials in Finland are cremations (Anderson, 1963). Boat and chamber burials evidently belonging to Scandinavians also are known in the territories of the Western Slavs (e.g. Buko et al., 2013). Usually the boat contained a single individual buried with rich grave goods.

The Salme burial ships are the first found in Estonia and a number of publications have covered various aspects of the excavations and analysis (Allmäe, 2011, Allmäe et al., 2011, Konsa et al., 2009, Peets and Maldre, 2010, Peets et al., 2011, 2013). A preliminary report on the isotopic proveniencing of a few of the human remains from Salme appeared in Price et al. (2016).

The study presented here focuses on the individuals buried in the ships and their place of origin. We initially present brief summaries of the find circumstances and contents of the ships as well as the anthropology of the human remains, followed by an introduction to isotopic proveniencing. Isotopic ratios in human enamel are understandable only in terms of local levels or baseline values. We consider the baseline values in Sweden, on Gotland, and in Estonia and on

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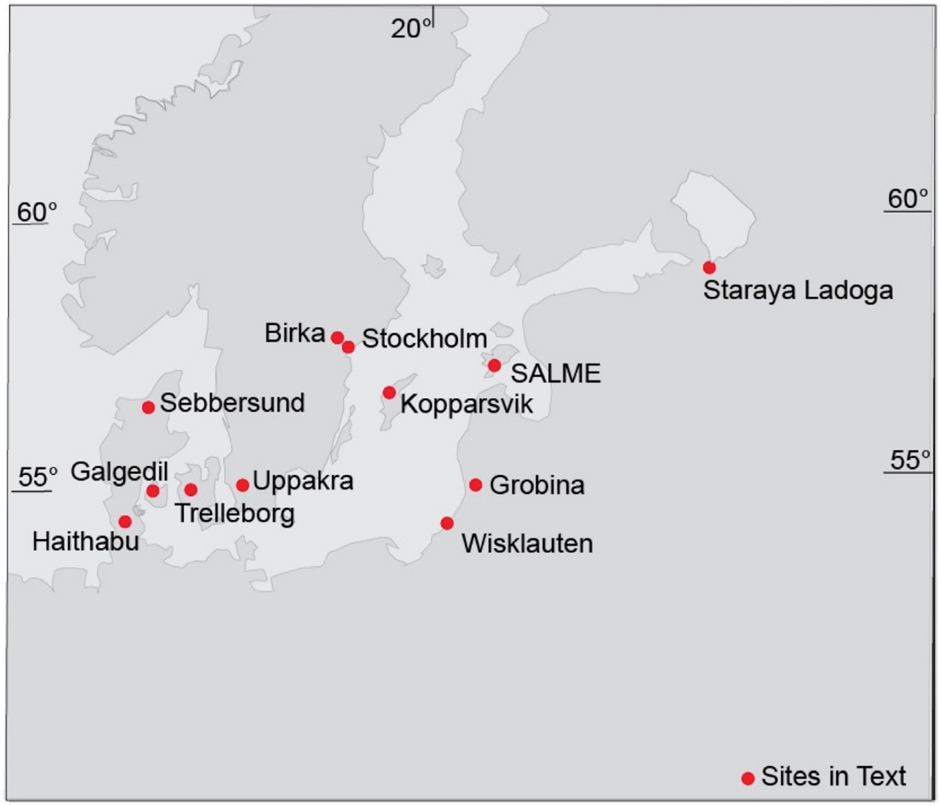

Fig. 1. The location of archaeological sites mentioned in the text.

Saaremaa in the main text of this article, and other places of potential, but lesser, interest in the Supplementary Material. These include the Baltic Sea, Denmark, the Latvian site of Grobina, and the Russian sites of Staraya Ladoga and Wiskiauten. We next consider the results of the isotopic proveniencing of the burials from the Salme ships and we conclude with some suggestions for the place of origin of these individuals.

2. The Salme I ship

At the time of their original interment on a coastal ridge only 1.5 m asl, the ships were about 100 m from the shore and only partially covered with stones and soil. Storm waves and ice hummocks must have reached this area and deposited thick marine sediments composed of stones of various size, gravel and sand, which covered the ships. Both ships had been set in a more or less northeast–southwest direction, the general custom with Scandinavian ship burials (*e.g.* Larsson, 2007).

When discovered, the remains of Salme I had been heavily damaged by the construction activities, so that only one half, the northeast part of the ship, remained to a height of three rivet rows. An assemblage of rivets from the southwest part was also preserved in their original position. Calculations based on measurements together with changes in the soil suggest that these rivet rows were most likely the remains of a rowing ship with six pairs of oars, with a presumed maximum length of 11.5 m, a width of 2 m and a depth of 75 cm. Perhaps boat is a better term for the small ship represented by Salme I. The planks, only 1.5–2 cm thick and about 30 cm wide, had been joined with iron rivets using clinker technique. The shape and size the craft resembled later, smaller Viking watercraft and this boat was also apparently swift, light, and easily maneuvered (Konsa et al., 2009).

The remains of seven male skeletons, only partly in their original position (the upper parts of three skeletons were in situ) were found along with a few grave goods in the heavily damaged central and southwestern preserved parts of the ship (Fig. 2). The majority of the

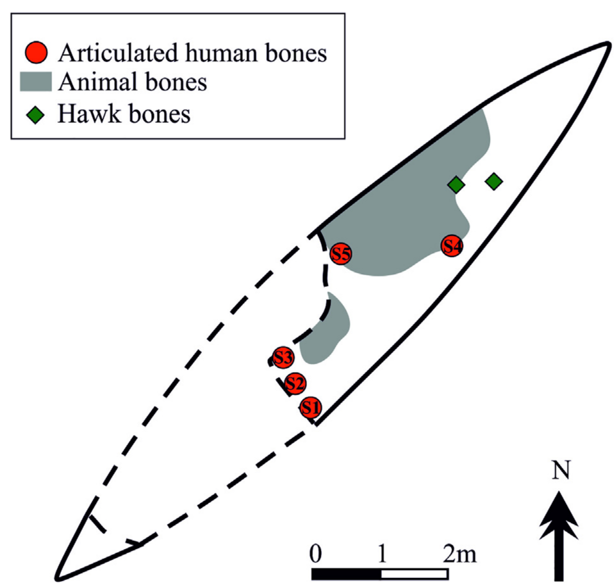

Fig. 2. Location of bones recovered in the Salme I ship burial. (After Allmäe et al. 2011. Drawing by R. Maldre).

archaeological finds were found in soil heaps outside the ship outline, placed there by the construction workers. The finds included sword fragments, spear- and arrowheads, knives, a small socketed axe, fragments of an ornamented antler comb, and 75 gaming pieces of whale and cattle bone, belonging to at least two separate sets, together with dice (Konsa et al., 2009, Peets and Maldre, 2010, Allmäe, 2011).

The placement and possible position of the bodies in the Salme I ship are shown in Fig. 3. Animal bones (a few pig, sheep and goat, and cattle bones), evidently from a funeral feast (skulls and limbs were

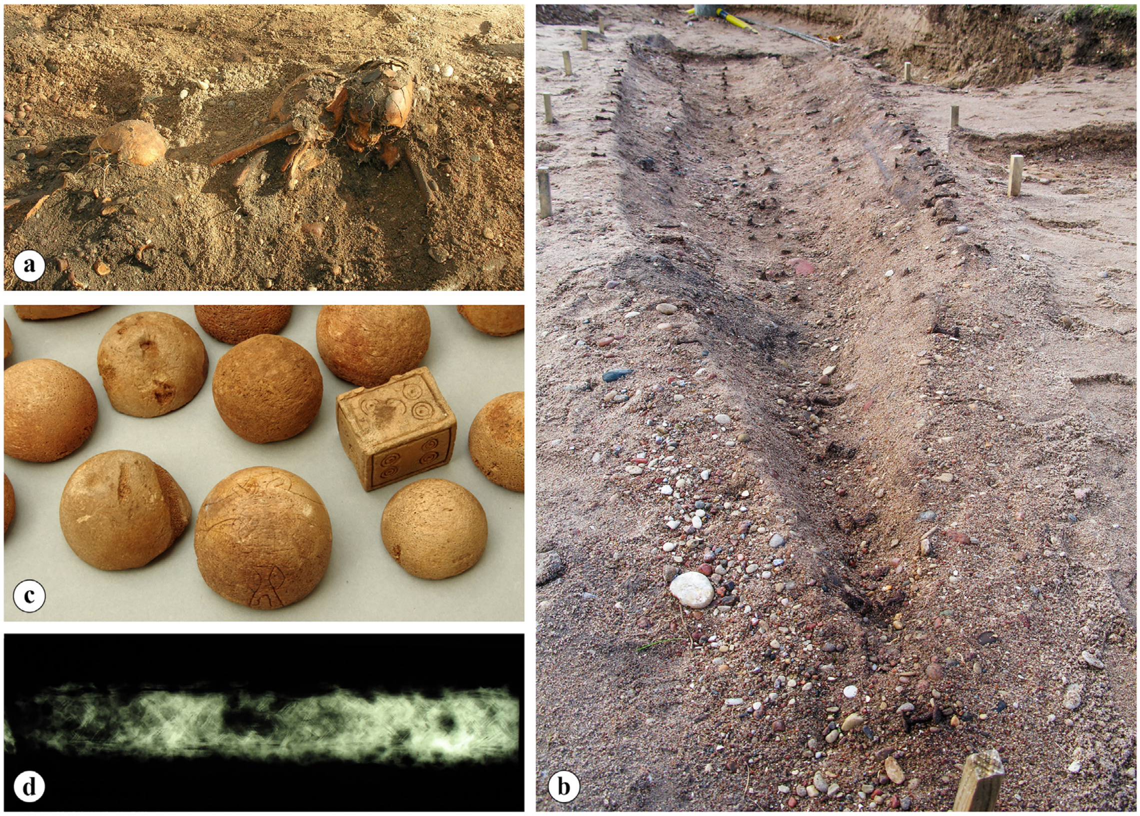

Fig. 3. Salme I ship burial. Skeletal remains in situ in (a); about a half of the ship had been preserved (b). 75 gaming pieces of whale and cattle bone were found from the Salme I ship; five pieces had engraved ornaments on them (c); a fragment of a double-edged sword (SM 10601: 78) with the middle part of pattern-welded steel (d). (Photos: Külli Rikas, Maili Roio, Reet Maldre).

missing), were also found. The headless remains of two hawks – a goshawk and sparrow hawk – can be interpreted as funerary sacrifices. Together with other high status finds, especially the sword fragments and gaming pieces, they may reflect the elite status of the buried men.

3. The Salme II ship

The archaeological excavations in 2010 were intended to examine the connection between the weapon fragments and human bones discovered in late autumn of 2008, after the end of the excavations of Salme I. The geoarchaeological survey before the fieldwork established that the surroundings of the site were heavily disturbed by human activities, i.e. old and new buildings, at least six cable trenches, and various digging connected with road construction. The discovery of another ship seemed unlikely. Nevertheless, soon after beginning excavations in July 2010, the second ship came to light, very close to the surface. The first artifacts and rivet rows of this contemporaneous ship (Salme II) were discovered immediately beneath the sod (Fig. 4), together with modern material that consisted mostly of construction debris – broken pails, paint jars, brick fragments, and the like.

At the same depth, two shield bosses, well-preserved human skeletons, a well-preserved and complete dog skeleton with slashing traces, and sword fragments were uncovered inside the western side of the ship outline. The first human skeleton's *humerus* had been chopped through in three places; the second individual had traces of two sword or axe blows on the frontal part of the skull. Surprisingly the site, lying so close to the surface and disturbed by cable trenches, was quite well preserved.

As a result of two summers of fieldwork (2010–2011) the entire ship outline, which in the middle part was recorded to the height of 5–6 rivet rows, together with the remains of 34 warriors, buried in layers, richly furnished, and mostly preserved as whole skeletons, was unearthed.

Fig. 4. Excavation of the Salme II ship in three stages. (After Peets et al. 2013. Photos by J. Valt, J. Peets, R. Maldre).

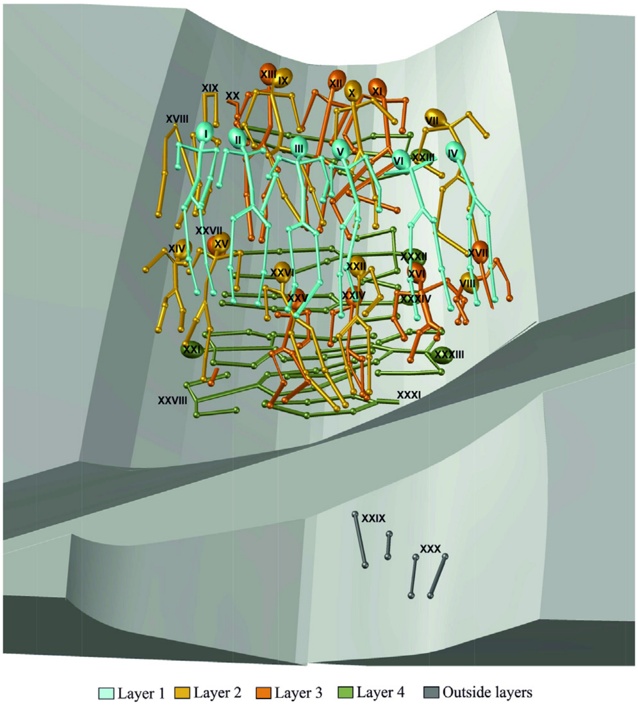

Fig. 5. Burial positions in the Salme II ship. (After Peets et al. 2013; drawing by R. Maldre).

The skeletons lay, partly covering one another, in four layers in an area of approximately 3 × 4 m in the central part of the ship (Fig. 5). In the three upper layers, the warriors had been placed with their heads pointing northeast, in the same direction as the ship. In the bottom layer the individuals had been placed between the sides, transverse to the longitudinal axle of the ship, with their heads pointing alternately east and west (Peets et al., 2011, 2013).

The dead had been provided with rich grave goods, mostly weapons, including single-edged and double-edged swords. At least five of these had splendid hilts of gilded bronze; one was additionally decorated with garnets. All in all, about 40 swords were found (whole and broken). The dead had been covered with broad, round shields, of which 15 deliberately dented iron bosses and some handles were preserved. Arrowheads were the most numerous (more than 50) of other weapons. Among otherwise relatively common weapon types, only a few spearheads were found, and no axes. Other grave goods included long, ornamented antler combs (about 15), broken shears, some beads, pendants of bear canines, bronze and iron plaques, small padlocks, and the like. The skeletons were literally strewn with gaming pieces made from whalebone, with some examples of walrus ivory.

The main part of the animal bone finds consisted of domestic mammals (sheep and goat, pig, cattle, dog and some horse bones).

The horse bones have recently been 14C-dated to 1659-1880 CE and do not appear to belong to the Salme ship remains. Besides the mammal bones, the remains of several raptors (goshawk, peregrine falcon and an undetermined falcon) were found. Other bird species, primarily mallard, and fish bones and scales were also represented (Peets et al., 2011, 2013; Maldre et al., 2018).

Numerous arrowheads were stuck in the boards of the ship, in the wood of the shields, or found in the humus layer of the decayed wood. Slashing traces, and arrow or spear marks on the bones of some of the deceased also provided dramatic evidence of the battle that had taken place. The burial ships had not been completely covered with stones and soil, as was the custom with most Scandinavian ship burials; a mound of stones, sand, and gravel covered only the central part of the ship, where the layers of the dead and the grave goods had been placed.

The Salme II ship was approximately 17–17.5 m long and about 3 m wide, a swift and sea-worthy vessel, travelling under sail or propelled by rowing. The use of sail is suggested primarily by the proportions of the cross section of the amid ship, humic impressions of a T-shaped keel, discovered in the bottom part of the ship (Peets et al., 2010, Fig. 4; 2012, Fig. 5), typical for a Late Iron Age sailboats and sailing ships (e.g. Larsson 2007, 40 *et seq*) and several other constructional elements not seen on the first vessel. If the Salme II was a sailing vessel, it is the earliest example in Scandinavia. As both ends of the ship were preserved, it was possible to establish quite accurately the orientation of the ship, which was northeast–southwest (Peets et al., 2011, 2013).

The rowing vessel discovered in 2008 (Salme I) and the sailing ship investigated in 2010–2012 (Salme II) together with the burials were almost certainly part of the same event. Still, the existence of more ship remains could not be precluded. To study that possibility, three search trenches of different length, all 1 m wide, were dug in the higher part of the coastal ridge between the two ships, crosswise to their longitudinal direction. The trenches were dug a little deeper than the bottom level of the ships. Nothing was found that could be related to the time period or ship remains.

An important question regarding these finds concerns the origin of the individuals on the ships. The artifactual finds were non-local in origin and pointed westwards across the Baltic to Sweden, to places such as the Mälaren region west of Stockholm, the Swedish island of Gotland, Denmark and the island of Bornholm, or south to the Swedish colony of Seeburg (also known as Grobina) near Liepaja in Courland in present day Latvia (Nerman 1958). Another possibility might be Scandinavian colonies in present-day Russia, e.g. Staraya Ladoga (Old Ladoga) established in middle of the 8th century CE (Chernykh, 1985, 79). Our preliminary investigation of the isotopic provenience of the dead at Salme considered eight individuals from the two ships (Price et al., 2016) and argued for the Mälaren region of Central Sweden as the probable homeland of the deceased. In this article, analyses of the complete set of Salme skeletons, looking at isotopic ratios of strontium, carbon and oxygen in dental enamel, are compared with local baselines in Estonia, Finland, Sweden, Denmark, Latvia and Russia.

4. Anthropology of the human remains

The physical anthropology of the deceased individuals at Salme is very interesting. Methodology is provided here followed by the results of our analysis. The biological age at death and sex assessments of the skeletons were made according to standard criteria (Buikstra and Ubelaker, 1994, WEA, 1980, White and Folkens, 2000, Mays, 2010). This information is summarized in Table 3. For stature calculations, the maximum length of left femoral bone was used for the individuals on the second ship. For first vessel the average was calculated on the basis of available left side long bones. To estimate the body height of the individuals, the formulas of Ruff and colleagues (2012) and of Trotter and Gleser (1958) were used —the latter is given in parentheses. The average body weight was calculated according to a formula presented by Ruff and colleagues (2012). The perimortem sharp force injuries were recorded according to the methods and criteria described and used in Kjellström (2005) and Lewis (2008).

4.1. Salme I

The human skeletal remains from Salme I came to the laboratory largely as a mixed and fragmentary osteological material. Only partial skeletons and some articulated bones of five men were found in original positions in the middle and stern area of the ship (Allmäe, 2011, Allmäe et al., 2011). The collected bone material itself is quite well preserved in comparison to Salme II.

All the buried individuals in Salme I were male. Four of seven were young adults, one was a young to middle-aged adult, and two males, whose skeletal remains were commingled among the bones in stern, were middle-age adults. The average stature of these men was 172.5 cm and body weight estimates averaged 78.2 kg.

There are some cranial fragments among the commingled bones with fractures characteristic of blunt force injuries. The continuing investigation of the bone material has revealed two incised wounds on one left zygomatic bone found in the soil heaps.

4.2. Salme II

The human skeletal remains collected from Salme II included whole and partial skeletons, as well as commingled and fragmentary bone material gathered inside and around the ship. The number of registered loose bone finds was 516. The preservation of bone material from Salme II varies from well preserved skeletons to highly eroded and decayed ones. The latter were often observed as dark imprints in the sandy soil. The weight from the heavy machinery used during construction of a schoolhouse and road caused the fragmentation of some of the bones.

The skeletal remains of 34 individuals were found. The biological sex assessment based on osteological criteria was reliable for 27 skeletons – all males—and was uncertain in five cases. The average age at death was more varied in the second ship: from adolescent to old adult. The latter age group was absent in the first ship. The skeletons were aged in the following classes: one adolescent, one adolescent/young adult, twelve young adults, six young/middle-age adults, six middle-age adults, two middle-age/old adults and two old adults. Four individuals could be determined only as adults. The average stature of men in the second ship was 173.3 cm and body weight was 74.4 kg.

The second Salme ship burial was quite different from the first one. Firstly, it was distinguished by the regular placement of the corpses, which suggests a respectful attitude towards the buried individuals. Another discrepancy is the striking evidence for injuries from sharp-edged weapons (Fig. 6). Sharp force injuries were identified on thirteen skeletons, nine of them exhibited multiple injuries. Three certain cases of decapitation were recorded due to the character of the sharp force traumas. The fourth example does not show blade wounds as evidence but is the burial of an isolated skull. The placement of dismembered body parts in anatomically correct positions is a third peculiarity of this ship burial, one that also might reflect respect for the deceased.

5. Isotopic proveniencing

The isotopic composition of tooth enamel can provide information on diet and place of origin. Isotopes of carbon, oxygen and strontium are deposited in the enamel apatite during formation and remain largely unaltered after death. In archaeology, these isotopic ratios in enamel are used as a signal of place of birth. If an individual moves to a new location in a different geologic context, or is buried in a new place, the enamel isotope ratio often will differ from the new location, allowing the designation of that individual as non-locally born.

Fig. 6. Human remains with sharp-edge weapon trauma (photo by R. Allmäe).

Strontium isotope analysis provides a robust means of examining past mobility. The strontium isotope ratio of $^{87}Sr/^{86}Sr$ varies among different kinds of rocks, based on their age and composition (Faure and Mensing, 2004). Strontium moves into humans from rocks and sediment through the food chain (Sillen and Kavanagh, 1982; Price, 1985, 2000) and is deposited in the skeleton.

Oxygen isotopes have been widely used as a proxy for temperature in many climate and environmental studies, and vary geographically in surface water and rainfall (Dansgaard, 1964). The oxygen isotope ratio in the skeleton reflects that of body water, and ultimately of drinking water (Luz et al., 1984; Luz and Kolodny, 1985; Kohn, 1996), which in turn predominantly reflects local rainfall. Major factors affecting rainfall $\delta^{18}O$ values are primarily geographic: latitude, elevation, amount of precipitation, and distance from the evaporation source (e.g. an ocean). There is significant variation in oxygen isotope ratios that makes their application in provenience studies less straightforward.

Light isotopes of carbon in enamel provide information on childhood diet, e.g. marine *versus* terrestrial resources or certain species of plants. The isotopic ratio of carbon was measured in these teeth, but the results are not discussed in great detail as they did not inform on the question of mobility. In this study we have measured carbon and oxygen in apatite carbonate as a component of tooth enamel using the reference standard PDB (Pee Dee Belemnite).

6. Isotopic baselines

The following discussion will provide some information on isotope ratios for proveniencing in the Baltic. Focus of the discussion will be on the Stockholm region and the island of Gotland as these are considered to be likely candidates for the origins of the buried warriors at Salme based on the artifacts that were recovered. Isotopic baseline information from the Baltic region is not widely available, but there are several useful sources and this information is summarized and presented in the supplementary material for this article. A map of the Baltic region with the location of sites and places is provided in the main text (Fig. 1). Below we discuss oxygen and strontium baselines in general and in detail with a focus on Central Sweden and Gotland.

Stockholm and Gotland are two of the areas with substantial Viking settlements closest to Estonia. The island of Gotland is approximately 200 km to the southwest of Saaremaa, while the Stockholm region is roughly 250 km to the northwest. Gotland was densely settled during the Viking Age, with many notable settlement and cemetery sites excavated, including Kopparsvik. The region around Stockholm and the Mälar Valley directly to the west were also important centers of Viking population. The agricultural lands on the shores and islands of Lake Mälar are some of the richest in Sweden. One estimate suggests there were 4000 farms in *Mälardalen* (the Mälar Valley) during the Viking period and perhaps 40,000 people (Hyenstrand, 1982). Another major Viking center in this part of Middle Sweden was located around Uppsala at the northern edge of the *Mälar* region, 70 km northwest of Stockholm. In addition, as discussed earlier, the archaeological evidence from Salme points in the direction of either east-central Sweden or Gotland.

6.1. Oxygen isotope baselines

Oxygen isotope ratios vary largely with latitude, temperature, and elevation. For that reason there is pronounced variation in $\delta^{18}O$ from south to north in Sweden. Burgman et al. (1987) measured $\delta^{18}0_{SMOV}$ in annual precipitation and run-off from a number of sites in Sweden and published a map of estimated ratios for the entire country (Fig. 7). Values range from −14‰ in the north to −8‰ in the southwest.

Slightly more negative $\delta^{18}0$ values should be expected to the east in Estonia. Aarpe (2014) compiled a map (Fig. 8) that provides some estimates for $\delta^{18}O$ in Eastern Europe. Values for $\delta^{18}O$ in ground waters in Estonia vary from −10.8‰ to −12.8‰ (Punning et al., 1987). An

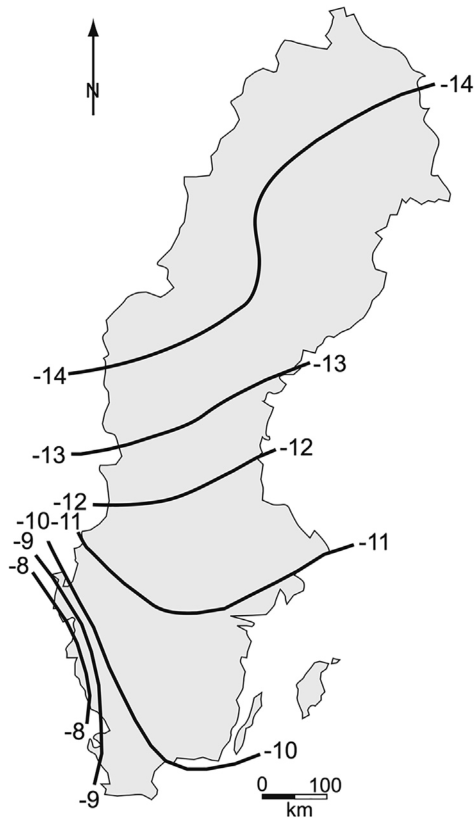

Fig. 7. Oxygen isotope ratios in modern rainfall in Sweden (Burgman et al. 1987).

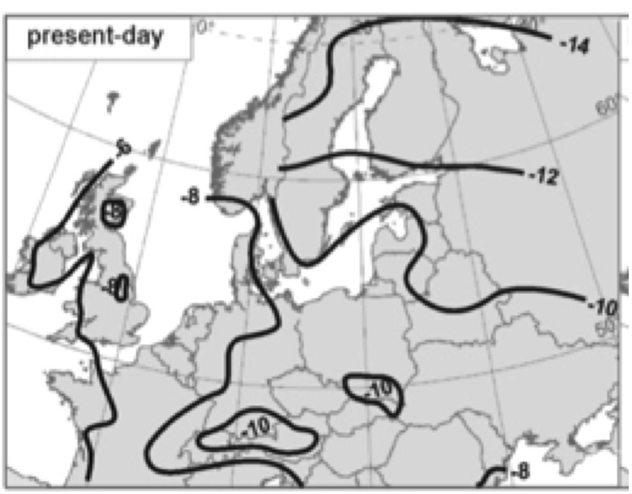

Fig. 8. Oxygen isotope ratios in modern rainfall in northern Europe (Arppe and Karhu, 2010).

annual average for rainwater is assumed to be ca. −10.4‰ by local scientists (pers. comm.). Although little data exists for Estonia, there is information from Riga in Latvia where average monthly values for modern rainfall range between ca. −12.0‰ and −7.0‰ over 12 months of the year. These $\delta^{18}O_{SMOW}$ values correspond to a range in $\delta^{18}O_{PDB}$ in enamel between approximately −5‰ and −9‰ (Chenery et al., 2012).

We have also measured $\delta^{18}0$ in human enamel from Viking Age sites elsewhere in Scandinavia, including the Stockholm area, Birka, and Gotland. Some of these data are presented in Table 1. Particularly notable in this table are the very similar values between −4.0‰ and −5.0‰ for all of the locales except Stockholm with a value of −6.4‰. Nearby Birka has an average oxygen isotope ratio of −4.9‰.

Carbonate $\delta^{18}O_{en}$ is measured and reported in this study using the PDB reference material.

7. Strontium isotope baselines

An essential aspect of strontium isotope analysis involves the determination of the local strontium isotope signal (Price et al., 2002, Sillen et al., 1998). The actual level of strontium isotopes in human tissue may vary from local geology for various reasons (Price et al., 2002). It is necessary to measure *bioavailable* levels of $^{87}Sr/^{86}Sr$ to determine regional and local strontium isotope ratios for comparison with the human remains.

Because the archaeological materials found with the Salme ship burials have a distinct Viking affiliation we have focused on eastern Sweden as potential homelands for these individuals. Denmark, Sweden and Norway were the primary center of Viking culture. It seems unlikely that Norway and Denmark might have been place of origin for the individuals buried on the ships at Salme because of the distances involved. In the following pages we present a very brief summary of the geology and strontium isotope sources in the Baltic and eastern Sweden. The discussion of baseline values concentrates on the island of Gotland and the region around Stockholm as possible homelands of the Salme burials. We then look in more detail at Estonia and the island of Saaremaa. The isotopic baseline of the larger region of the Baltic including Denmark, Finland, Latvia, and Russia is discussed in the supplementary material for this article.

7.1. The Baltic

The Baltic Sea, 1600 km long and averaging 190 km in width, is one of the major bodies of water on the planet. The Baltic fills a relatively shallow depression in the earth's surface in northern Europe, bordered by the countries of Denmark, Sweden, Finland, Russia, Estonia, Latvia, Lithuania, Poland, and Germany. A major geological division in the region runs through the south Swedish coast, crosses the Baltic toward Finland and continues through the Gulf of Finland, separating the Fennoscandian (or Baltic) Shield from the East European Platform to the east.

The Fennoscandian Shield in the Scandinavian Peninsula is a region of ancient craton exposed on the surface. Such ancient cratons with a Precambrian basement (> 543 mya) were part of the cores of the earliest continental blocks of Archaean Age (> 2.4 bya) and contain some of the oldest rocks on earth. These Precambrian crystalline rocks often crop out along the Swedish and Finnish coasts. The Eastern European Platform is characterized by a younger basement of crystalline rocks of Proterozoic age beneath a thick Palaeozoic sedimentary cover (younger than 543 my) that is sometimes found on the surface in the eastern Baltic area, particularly along the coast (Tuuling et al., 2011).

7.2. Sweden

Sweden's geology is rather complex but generally can be divided into three main components: Precambrian crystalline rocks (which are part of the Baltic or Fennoscandian Shield), the remains of a younger sedimentary rock cover, and a component called the Caledonides formed during an ancient mountain building episode in the Mesozoic, ca. 400 mya.

The oldest rocks in Sweden are Archaean (> 2400 million years old), but these only occur in the northernmost part of the country. Most of the northern and central parts of Sweden are composed of Precambrian rocks belonging to the Fennoscandian Shield, an ancient craton of mantle rock with generally high strontium isotope ratios. This rock is covered in places by glacial moraine but is exposed intermittently to frequently on the surface. Further to the south, Phanerozoic

Table 1
Carbonate $\delta^{18}O_{en}$ in various archaeological sites in Scandinavia.

Site	Co.	Age	n	Min‰	Max‰	Mean ± 1 s.d.	Source
Hamar	N	IA	17	−7.7	−4.9	−6.3‰ ± 0.8	Unpub.
Bryggen	N	IA	15	−5.3	−3.2	−4.3‰ ± 0.7	Unpub.
Trondheim	N	IA	9	−7.6	−4.5	−6.0‰ ± 1.1	Unpub.
Kopparsvik	S	V	44	−6.4	−2.5	−4.7‰ ± 1.1	This Study
Uppåkra	S	LIA	10	−6.8	−3.3	−5.0‰ ± 0.9	Price (2013)
Sala	S	Med	19	−8.3	−3.9	−6.3‰ ± 1.1	Bäckström/Price et al. (2016)
Sebbersund	D	V	7	−4.7	−3.3	−4.0‰ ± 1.5	Price et al. (2012)
Trelleborg	D	V	41	−5.8	−1.7	−4.4‰ ± 0.7	Price et al. (2011)
Galgedil	D	LIA	34	−6.0	−2.5	−4.2‰ ± 0.7	Price (2015)
Ndr. Grødbygaard	D	Med	36	−6.4	−3.6	−4.9‰ ± 0.6	Price et al. (2013)
Haithabu	G	V	53	−6.8	−2.7	−4.0‰ ± 0.8	Unpub.
Birka	S	V	35	−7.4	−2.2	−5.0‰ ± 1.2	Price et al. (2018)

sedimentary rocks rest upon the Precambrian shield. They are less than 545 million years old and cover large parts of Skåne, the islands of Öland and Gotland, the Östgöta and Närke plains, the Västgöta mountains, the area around Lake Siljan in Dalarna, and areas along the Caledonian front in northern Sweden.

The youngest rocks in Sweden are from the Tertiary, formed about 55 million years ago. They occur in the most southerly and southwestern parts of the province of Skåne in southwest Sweden. Quaternary deposits formed during and after the latest glaciation (when Sweden was completely covered by an ice sheet) partially cover this bedrock. Southernmost Sweden is a glaciated landscape much like the neighboring area of Denmark and strontium isotope ratios are similar to that area.

There is a growing body of baseline $^{87}Sr/^{86}Sr$ values from central and southern Sweden (Fig. 9). The Swedish Geological Service has measured $^{87}Sr/^{86}Sr$ across the country and reports very high rock values from most of the area, generally greater than 0.722. There is some information from environmental studies. For example, Åberg et al. (1990) sampled soil and water from five different locations (none in the southwest) and reported values higher than 0.715 at all five sites, often above 0.725. Arcini (2018) has compiled a substantial list of baseline values for Sweden. Most of the Fennoscandia Shield across Sweden exhibits similar high values for $^{87}Sr/^{86}Sr$. We have some baseline data from the greater Stockholm region. The site of Birka in the Mälar Valley west of modern Stockholm was a major Viking center and gateway to the east. Samples of five archaeological rodents from Birka averaged 0.7256, while 29 human enamel samples provided a mean of 0.7207 ± 0.0073 with a range from 0.7103 to 0.7343, values that include a number of non-local individuals. We also have several other human samples of Viking Age from central Sweden including three from Uppsala with a mean of 0.7260 and three from the medieval cemetery of Helgeandsholmen in Stockholm. One of the three from Stockholm appears to be non-local with a value of 0.711, while the other two are similar with an average of 0.7206. In general human and faunal values from much of Central Sweden appear to have $^{87}Sr/^{86}Sr$ values between 0.720 and 0.726.

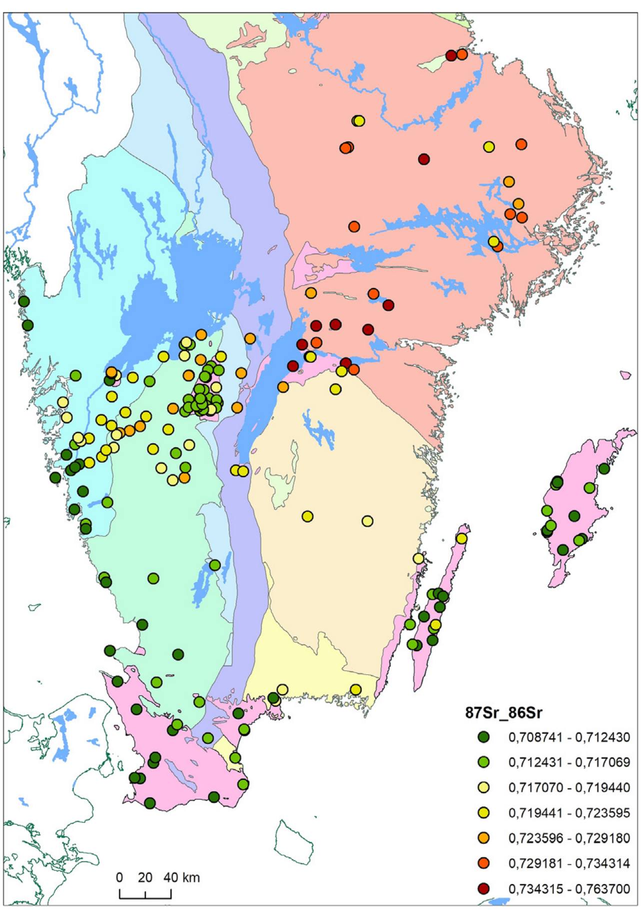

Fig. 9. Geological map of Sweden with strontium isotope ratio baseline information (Sjögren et al. 2019).

There are a few exceptions to the generally high values found across much of Sweden. As noted, the southwest corner of the southwestern province of Scania has a geology and strontium isotope ratios similar to Denmark, around 0.708–0.711 (Price, 2013). The southeastern island of Öland has a distinctive geology and faunal samples from archaeological sites on the island have an average $^{87}Sr/^{86}Sr$ value of 0.7144 (Wilhelmson and Price, 2017). 106 samples of human enamel from the island averaged 0.7160 ± 0.008, including a number of non-local individuals.

7.3. Gotland

Gotland, in the middle of the Baltic, was an important center of trade during the Viking period. Gotland has slight relief with generally flat erosion surfaces. Most of the island is composed of Silurian limestone, covered by glacial deposits of till and outwash. The sedimentary rocks that outcrop on Gotland were deposited in a shallow, warm, and salty sea, on the edge of an equatorial continent. The limestone-based rocks on the surface have weathered into characteristic karst formations known as *rauks*. Higher areas usually are limestone, while lower areas commonly have deposits of marl. $^{87}Sr/^{86}Sr$ values in Silurian limestones on Gotland have been measured and show a very narrow range from 0.7084–0.7085 (Azmy et al., 1999). Glaciation left thin blankets of fine-grained boulder-clay till. The till includes rocks of Archean age transported from Fennoscandia. Where the till blanket is absent, bare rock surfaces are exposed. Higher $^{87}Sr/^{86}Sr$ may be expected in areas where ancient rocks from the Scandinavian craton were incorporated in the till.

Archaeological materials have also been analyzed. From the east coast and Gotland we have ca. 140 samples, of which 11 are archaeological fauna. These 11 baseline samples of hare, fox, dog, hedgehog, and beaver from several sites around the island average 0.7112. Human samples from Gotland, which include a high proportion of non-local individuals, average 0.7135 ± 0.0057 with a range from 0.7083 to 0.7389.

Peschel (2014, Peschel et al., 2017) examined strontium isotope ratios in human burials from the Viking Period site of Ridanäs (Kahl, 2009) under the modern village of Fröjel on the east coast of Gotland (Fig. 1). The northern cemetery was the oldest and largest, in use from the 7th to 10th century CE with both inhumations and cremations. The smaller southern cemetery from the 11th century CE contained mostly male inhumations buried with weapons such as axes and spearheads (Peschel et al., 2017). $^{87}Sr/^{86}Sr$ values were measured on 60 of the 80 individuals buried in the two cemeteries. Eleven animal teeth from large domestic fauna were also collected from the Ridanäs excavations to establish a local baseline range and included *Bos taurus* (cow), *Ovis aries* (sheep), and *Sus scrofa* (pig). Samples were considered of local origin if their isotope values fell within the range of two standard deviations of the values of the local fauna samples.

The range of values from the fauna selected for the local baseline (domesticated pig, goat, and cow) was 0.7105–0.7153 with a mean of 0.7125 ± 0.0016. The local baseline, based on two standard deviations from the mean of the faunal samples, was 0.7092–0.7156. For the 60 humans measured there were no distinct differences observed due to age or sex. Approximately 75% of the individuals were argued to be local and the authors concluded that "the hypothesis that there would be a mix of locals and non-locals was proven incorrect".

Fraser et al. (2018) employed mtDNA and strontium isotope analysis to investigate a Middle Neolithic group of Funnel Beaker farmers and Pitted Ware hunter-gatherers on Gotland. Their results indicate a pattern of "cultural dualism" with genetic differences observed between the two groups suggesting genetic origins to the south and the east respectively. Eleven individuals from the collective burial in the Early Neolithic Ansarve dolmen on Gotland were sampled for strontium isotope analysis and had an average value of 0.7131 ± 0.0020, ranging between 0.7115 and 0.7176. A series of baseline soil and local faunal tooth samples were taken from different Stone Age sites (Hemmor, Visby, Ajvide, Häffinds, and Ansarve) in several geographic locations on the island. These measured baseline samples were combined with the results of Peschel et al. (2017) into a new estimate for the strontium isotope baseline of 0.7121 ± 0.0016 for local isotope variation on the island (Fraser et al., 2018).

Both of these studies provide questionable estimates of the local baseline for strontium isotope ratios, in part because of the variation in strontium sources present on and around Gotland, and in part due to the use of a standard deviation to calculate the local range. Gotland, as an island in the middle of the Baltic Sea, is also heavily influenced by marine values, both from sea food in the diet and from sea spray and rainfall coming from the sea. It is important to remember than the foods that people eat play the major role in determining $^{87}Sr/^{86}Sr$ levels in the body. If marine foods are an important part of the diet (Kosiba et al., 2007), then the approximate value of Baltic Sea water (ca. 0.7092) will contribute significantly to the enamel $^{87}Sr/^{86}Sr$ value. If terrestrial foods provide the predominant part of the diet, then $^{87}Sr/^{86}Sr$ values should reflect terrestrial baseline isotope ratios. Measures of the local baseline on Gotland are summarized in Arcini and Price (in prep.). The average ± one standard deviation $^{87}Sr/^{86}Sr$ for the 38 samples is 0.7121 ± 0.0017, with a large range from 0.7098 to 0.7169. These values are all terrestrial in origin. A bar graph of these values is shown in Fig. 10, where a break in the curve of values is apparent at approximately 0.712.

In addition, we have some information from the Pitted Ware Culture site of Västerbjers on the east coast of Gotland (Åhlstrom and Douglas Price, in press). Here analysis of modern leaves and grass provided

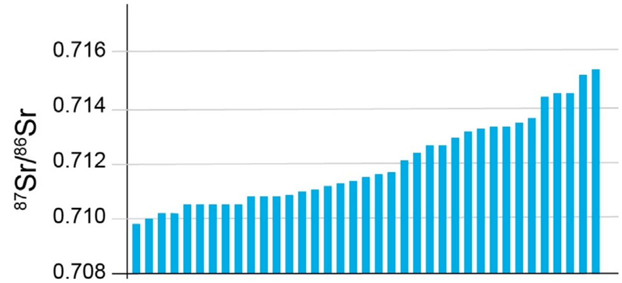

Fig. 10. Bar graph of ranked $^{87}Sr/^{86}Sr$ values (x-axis) for terrestrial baseline samples of soil, fauna, and flora from Gotland.

baseline values for $^{87}Sr/^{86}Sr$ between 0.711 and 0.713. $^{87}Sr/^{86}Sr$ values for 33 individuals from the Västerbjers cemetery had a mean of 0.7101 ± 0.0003 with a range between 0.7096 and 0.7110. Given the intense use of marine mammals and other marine resources in the diet of these individuals, it is likely that the terrestrial baseline value is lowered in human enamel by the consumption of 0.7092 values in seafood.

It is essential to include marine values in the baseline range for Gotland given the importance of marine foods. In addition, the effects of sea spray and rainfall with marine origins increase the amount of $^{87}Sr/^{86}Sr$ at 0.7092 on the island. The majority of terrestrial values fall between 0.710 and 0.713, in part a reflection of the high values in the blanket till across much of the island. We would suggest that the values between 0.709 and 0.713 probably include the major portion of the range of $^{87}Sr/^{86}Sr$ variation on Gotland.

7.4. *Estonia, Saaremaa, and Salme*

Estonia sits on the northwestern East European Shield at the edge of the Fennoscandian Shield (Raukas and Teedumäe 1997). The Proterozoic igneous and metamorphic rocks of this shield form the bedrock of the country and lie at depths greater than 100 m, increasing to the south. The sedimentary cover is composed of Cambrian, Ordovician, Siluarian and Devonian materials, consisting largely of limestones and sandstones. Quaternary deposits largely of glacial origin normally cover these sedimentary layers at depths of 5 to more than 100 m across the rather level landscape. Alvar formations are visible in areas where the glacial cover materials are particularly thin or absent. Although there is very little strontium isotope data from mainland Estonia, there are a few samples from northern part of the country. Values range from 0.7106 to 0.7159 (Oras et al., 2016).

The island of Saaremaa lies on the western edge of the East European Shield, off the east coast of mainland Estonia. The crystalline basement underlying Saaremaa is composed primarily of metamorphic rocks (various forms of gneiss) in eastern Saaremaa, while acidic, igneous rocks (mostly types of granite) dominate under the western part of the island (Raukas et al., 2009). The sedimentary platform on top of this basement is meters in thickness and composed entirely of Silurian carbonate rocks, primarily limestones. This limestone is exposed as alvar in areas of thin or absent surface materials.

The surface materials and topography of the island of Saaremaa are the result of the last glaciation and changes in sea level at the close of the Pleistocene. Glacial lobes moved across the island from several directions, depositing sediments from different sources primarily to the east and west of the island. The weight of glacial ice depressed the earth's surface in the Baltic substantially and the rise of sea level following the disappearance of this ice flooded the area during the Late Glacial. The island gradually emerged from the sea after 10,000 years ago and large parts of the surface are covered with marine sediments from that period. The map in Fig. 11 provides information on the location and extent of quaternary deposits on Saaremaa. The archaeological site at Salme lies at the head of the narrow peninsula of Sörve,

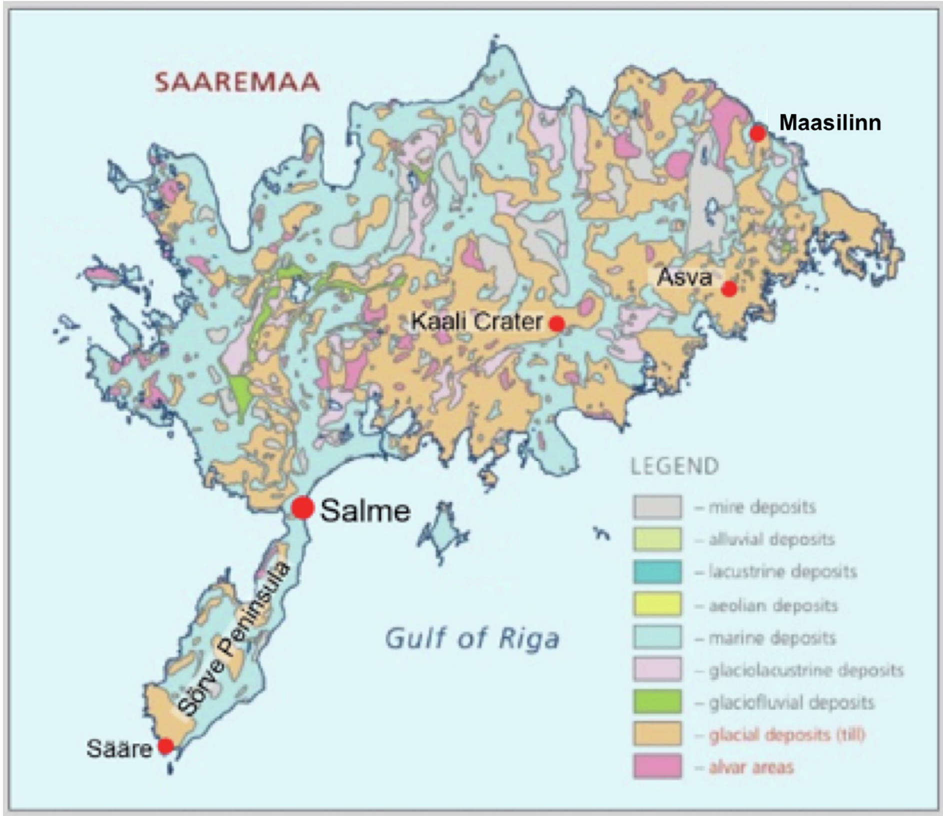

Fig. 11. Quaternary deposits on the island of Saaremaa (Raukas et al. 2009).

a remnant of a large esker from the late Pleistocene. The immediate area around the site is low-lying and covered with marine sediments—clays, sands, and gravels. This peninsula was a separate island until the medieval period when post-glacial rebound attached it to the mainland.

We have obtained a number of modern and archaeological faunal samples from Saaremaa to determine the local bioavailable strontium isotope ratios on the island. These data are presented in Table 2. There are samples of fauna from the site of Salme itself and the site of Asva approximately 44 km east of Salme. The higher faunal values from the site of Asva are probably more representative of the terrestrial baseline strontium values on the eastern side island.

Measurements of 10 samples of fauna and snails from the Salme site itself exhibit a narrower range of values with a bimodal distribution (Fig. 12). The lower values of strontium values at Salme may be a consequence of the snail shells and marine influence. The sea has a ratio ca. 0.7092 and the snail shell from Salme is much closer to this value

Table 2
Baseline faunal $^{87}Sr/^{86}Sr$ samples from the island of Saaremaa.

Lab No.	Site	Catalog	Species	Element	$^{87}Sr/^{86}Sr$
F9105	Asva	AI 3658:729	Vole	*mandibula*	0.7188
F9107	Asva	AI 3799:467 (625)	Vole	*mandibula*	0.7199
F9109	Asva	AI 3799:467 (492)	Rodent	*mandibula*	0.7130
F9984	Salme II	SM10602: 77	horse	Left upper dM1	0.7121
F9985	Salme II	SM10602: 33	dog	Right upper M2	0.7308
F9986	Salme II	SM10602: 249	dog	Left upper M2	0.7162
F9987	Salme II	SM10602: 155b	dog	Left lower M2	0.7240
F9988	Salme II	SM10602: 155a	dog	Left lower M2	0.7184
F9989	Salme II	SM10602: 230	sheep	Left femur	0.7122
F9990	Salme II	SM10602: 224	pig	Left tibia	0.7122
F9982	Salme I	SM10601: 6-8	cattle	Right tibia	0.7117
F9983	Salme I	SM 10601: 14	sheep	Left humerus	0.7126
F9170	Salme	na	*Snail Shell*		0.7094

than the remaining samples. In all likelihood the snail shell is low due to marine influence. In general the snail and fauna values from the Salme site and the island suggest that local values should be below 0.720. The four dogs among the ship burials with higher $^{87}Sr/^{86}Sr$ values almost certainly came with the individuals buried on the ships.

In sum, acceptable baseline $^{87}Sr/^{86}Sr$ values from Salme fall between 0.7104 and 0.7139 and are distinct from both the Stockholm-Mälaren region and Gotland. There is some overlap with the values recorded on Gotland, but in general the Salme baseline strontium isotope ratios tend to be lower than those on Gotland.

8. Isotopic proveniencing of Salme humans

Light and heavy isotope ratios were measured in samples of tooth enamel from the seven individuals buried at Salme I and 27 individuals from Salme II. Premolars were normally sampled, as they are easier to extract and provide less diagnostic information than other teeth for various kinds of research. These are permanent teeth, and the enamel forms between 1.5 and 7 years of age (Woelfel and Scheid, 2002).

Information on the samples and isotope ratios for the human remains from Salme are available in Table 3 and graphed in Fig. 12. The humans from both ships, with 5 exceptions have strontium values greater that 0.720 and were not born on Saaremaa. Moreover, based on the samples reported by Oras et al. (2016), they did not come from Estonia. Table 4 provides descriptive statistics for isotope ratios from Salme I and II. In general terms the individuals from the two ships are similar with the exception of the five samples with lower $^{87}Sr/^{86}Sr$ values (between 0.710 and 0.714) in Salme II. These individuals lower the mean and increase the standard deviation of the values from Salme II.

The five values below 0.715 among the human remains from the Salme II ship are of particular interest. These individuals are clearly distinct among the Salme dead and yet were mixed among the burials

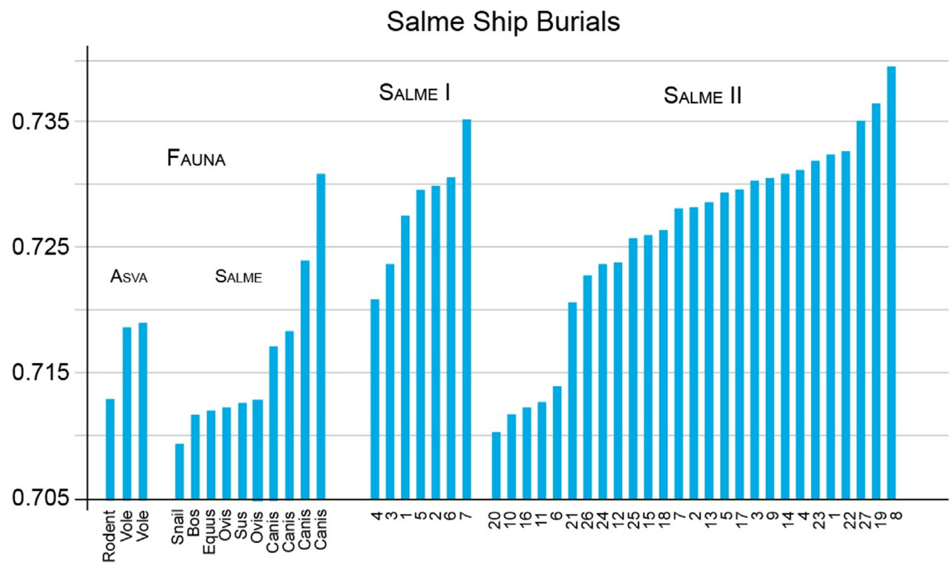

Fig. 12. Bar graph of ranked $^{87}Sr/^{86}Sr$ values (x-axis) for fauna from Salme (I & II) and Asva on Saaremaa Island and human remains from the Salme ships.

found on Salme II. It is also useful to consider the other isotope ratios. Both ship crews are generally similar in terms of carbon and oxygen isotope ratios. A plot of $^{87}Sr/^{86}Sr$ vs $\delta^{18}O$ is informative (Fig. 13). In this plot, the five low $^{87}Sr/^{86}Sr$ values stand out and fall into two groups which suggests two places of origin based on the $\delta^{18}O$ values. The remaining individuals from the two Salme ships generally fall into one large group. Plots of $^{87}Sr/^{86}Sr$ vs $\delta^{13}C$ and $\delta^{13}C$ vs. $\delta^{18}O$ are less informative. The group of three individuals with more positive $\delta^{18}O$ values are very distinct in terms of place of origin. The two individuals with low $^{87}Sr/^{86}Sr$ values and more negative oxygen isotope ratios could be local to the island or from a variety of other places across Scandinavia.

The five individuals with lower $^{87}Sr/^{86}Sr$ values on board the Salme II ship did not come from Estonia or east Central Sweden (or isotopically similar landscapes), but exhibit strontium values that might fit with Gotland. Perhaps a few members of the crew of these ships came originally from the island of Gotland. As noted, there were two groups among these five individuals and in all likelihood the persons with more

Table 3
Information on the samples and isotope ratios for the human remains from Salme.

Lab number	Grave	Find No.	Sample number	Species	Specimen	$^{87}Sr/^{86}Sr$	$\delta^{13}C$	$\delta^{18}O$
F9956	Salme II	XXIV	SaII2/6	human	Right upper P1	0.7140	−14.7	−4.0
F9957	Salme II	XXII	SaII2/7	human	Right lower P1	0.7281	−14.1	−5.7
F9958	Salme II	XVII	SaII2/8	human	Left lower P2	0.7393	−14.5	−5.8
F9959	Salme II	XVI	SaII2/9	human	Right upper P1	0.7305	−11.3	−4.9
F9960	Salme II	XXV	SaII2/10	human	Left lower P2	0.7117	−14.5	−5.8
F9961	Salme II	XXVII	SaII2/11	human	Right upper P2	0.7128	−15.2	−5.7
F9962	Salme II	VIII	SaII2/12	human	Left upper P1	0.7238	−15.8	−5.2
F9963	Salme II	XXXIV	SaII2/13	human	Left upper P1	0.7286	−14.1	−5.6
F9964	Salme II	XV	SaII2/14	human	Right lower P1	0.7308	−14.6	−5.5
F9965	Salme II	IX	SaII2/15	human	Right upper P2	0.7259	−14.6	−5.7
F9966	Salme II	XIII	SaII2/16	human	Right lower P1	0.7123	−13.7	−3.8
F9967	Salme II	XXVIII	SaII2/17	human	Right lower P2	0.7296	−12.9	−5.2
F9968	Salme II	XXXIII	SaII2/18	human	Left upper P2	0.7263	−13.4	−5.1
F9969	Salme II	III	SaII2/19	human	Right lower P2	0.7364	−14.1	−5.5
F9970	Salme II	XI	SaII2/20	human	Left lower P2	0.7104	−14.9	−4.4
F9971	Salme II	II	SaII2/21	human	Right lower P1	0.7207	−13.2	−5.7
F9972	Salme II	X	SaII2/22	human	Left lower P1	0.7327	−14.4	−5.4
F9973	Salme II	VII	SaII2/23	human	Left lower P1	0.7319	−14.2	−5.3
F9974	Salme II	V	SaII2/24	human	Right lower P2	0.7236	−14.2	−6.2
F9975	Salme II	VI	SaII2/25	human	Left lower P1	0.7257	−14.2	−6.2
F9976	Salme II	XXVI	SaII2/26	human	Right lower P1	0.7228	−14.7	−5.9
F9977	Salme II	XXI	SaII2/27	human	Right lower P1	0.7351	−14.1	−5.6
F9100	Salme II	XXIII	SaII/1	human	Right lower P2	0.7324	−15.1	−6.4
F9101	Salme II	XII	SaII/2	human	Left lower P2	0.7282	−14.5	−4.3
F9102	Salme II	XIV	SaII/3	human	Right lower P2	0.7303	−14.8	−6.0
F9103	Salme II	I	SaII/4	human	Left lower P2	0.7311	−13.6	−5.2
F9104	Salme II	XXXII	SaII/5	human	Right lower P2	0.7294	−14.3	−5.6
F9978	Salme I	4	Sam 1/4	human	Right upper M1	0.7209	−15.1	−6.4
F9979	Salme I	5	Sam 1/5	human	Right lower P1	0.7296	−14.5	−4.3
F9980	Salme I	6	Sam 1/6	human	Left lower P2	0.7305	−14.8	−6.0
F9981	Salme I	7	Sam 1/7	human	Left upper P1	0.7352	−13.6	−5.2
F9097	Salme I	1	Sam 1/1	human	Right lower P2	0.7275	−14.8	−5.9
F9098	Salme I	2	Sam 1/2	human	Right lower P2	0.7299	−15.3	−6.2
F9099	Salme I	3	Sam 1/3	human	Right upper P2	0.7237	−15.3	−5.9

Table 4
Descriptive statistics for isotope ratios from Salme I and II.

Ship	Isotope	Mean	St.Dev.	Min.	Max.	Count
Salme I	$^{87}Sr/^{86}Sr$	0.7282	0.0047	0.7209	0.7352	7
Salme II	$^{87}Sr/^{86}Sr$	0.7261	0.0079	0.7104	0.7393	27
Salme I	$\delta^{13}C$	−14.8	0.6	−15.3	−13.6	7
Salme II	$\delta^{13}C$	−14.1	0.8	−15.8	−11.3	27
Salme I	$\delta^{18}O$	−5.7	0.7	−6.4	−4.3	7
Salme II	$\delta^{18}O$	−5.4	0.6	−6.2	−3.8	27

negative $\delta^{18}O$ were from more northerly homelands. Values for $\delta^{18}O$ around −4.0‰ and −5.5‰ characterize the two sets of individuals. Oxygen isotope ratios in modern rainfall across the Baltic region are variable but $\delta^{18}O$ in human enamel is rather homogeneous, generally between −4.0‰ and −6.5‰. The three samples from Stockholm average −6.4‰. The three Uppsala samples are highly variable ranging from −4.6‰ to −7.3‰. At Birka the average was −4.9‰. Oxygen isotope ratios in the human enamel samples from Gotland average −4.7‰. Across Denmark and southernmost Sweden $\delta^{18}0$ in human enamel generally falls between −4.0‰ and −5.0‰. The average oxygen isotope ratio values in the Salme humans was around −5.5‰.

In general terms there are significant differences among several potential homelands for the Salme burials. The baseline range of values in Denmark and southwestern-most Sweden falls between 0.708 and 0.711 in the glacial moraine landscape that covers that region and does not fit with the majority of the Salme dead. The Swedish island of Gotland has a different geology with late Pleistocene glacial deposits on top of Silurian bedrock and equally distinctive $^{87}Sr/^{86}Sr$ values around 0.711 to 0.713. It is clear that the older rocks of the Fennoscandian Shield across most of Sweden result in higher $^{87}Sr/^{86}Sr$ values. The Stockholm region, for example, reflecting the very old Fennoscandian Shield on which it sits, exhibits $^{87}Sr/^{86}Sr$ values generally above 0.715 and often greater than 0.720. The Mälaren region appears to be the best candidate for the homeland for many of those buried on the Salme ships. At the same time, it is important to reiterate that isotopic proveniencing is constrained by the fact that similar isotopic ratios are known from different areas and identifying homeland is a difficult proposition.

9. Other considerations and conclusions

The isotopic proveniencing of the Salme dead points to East-Central Sweden as the likely homeland of many of these individuals. We are fortunate that there is other evidence to corroborate this suggestion. The grave goods that accompanied the burials were rich and included swords (about 40), antler combs (15) and shield bosses (15), among other things. The sword hilts, decorated with Scandinavian designs, and ornamented scabbard remnants, preserved on some sword blades, provide particularly useful information. The sword hilts have close parallels with ship burials found near Uppsala, Sweden (Nørgård Jørgensen, 1999: fig. 49: 1–3). A gilded bronze decoration on the upper edge of a scabbard from Salme has an exact analog found with the Ultuna ship burial near Uppsala (Nerman, 1958: fig. 241; Nørgård Jørgensen, 1999: fig. 49: 2). A frieze-like ornament of gold wire inlay (Price et al., 2016, fig. 9) on the blade of the sword with garnet decorated pommel (fig. 14) bears the similar motif.. The pommel of gilded bronze (Fig. 14) decorated with the image of a human-faced beast and 25 almandines, a form of garnet, also has close parallels, e.g. with the pommel depicting a beast with almandine eyes from the warrior grave with cremation burial at Ägget in the Mälaren district in Sweden, and several burials from south-western Finland (e.g. Kivikoski, 1973).

A central Swedish provenience is also supported by the location of trade routes, probably established in the Bronze Age. There were two major trade routes across the Baltic Sea. The northern route was under the control of the Svears (aka Swedes), centered in the Mälaren district (Andersson, 1975, Sawyer and Sawyer, 1993). The northern route from Mälaren to the eastern part of the Baltic probably ran first across the archipelago of the Åland islands between Sweden and Finland, and either entered the Gulf of Finland heading to the Great Eastern Way (*Austrvegr*), or turned south through the straits at Salme, along the island of Saaremaa to the amber-rich Courland region of Latvia and the site of Grobina (aka Seeburg). The Great Eastern Way was the major route from Scandinavia to Constantinople via the Gulf of Finland, the Neva River and the Dnieper River to the Black Sea, or down the Neva and Volga rivers to the Caspian Sea, and then eastwards.

One possible explanation for the Salme individuals in Estonia is as members of a diplomatic mission bearing gifts to promote trade and alliance. This interpretation is supported by the fact that dogs and hawks had been placed with the Salme warriors as grave goods, in

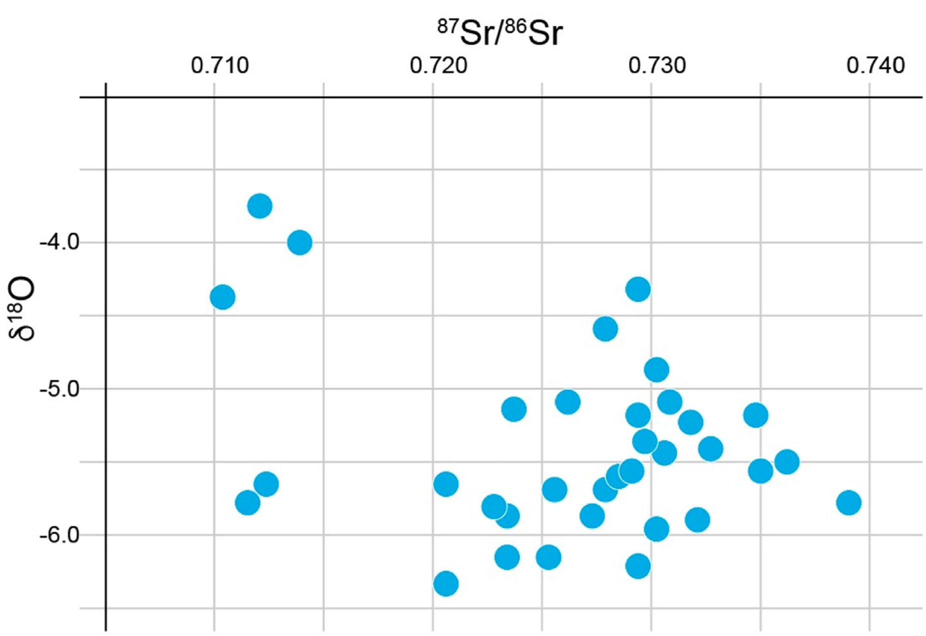

Fig. 13. Scatterplot of $^{87}Sr/^{86}Sr$ vs $\delta^{18}O$ for all Salme humans.

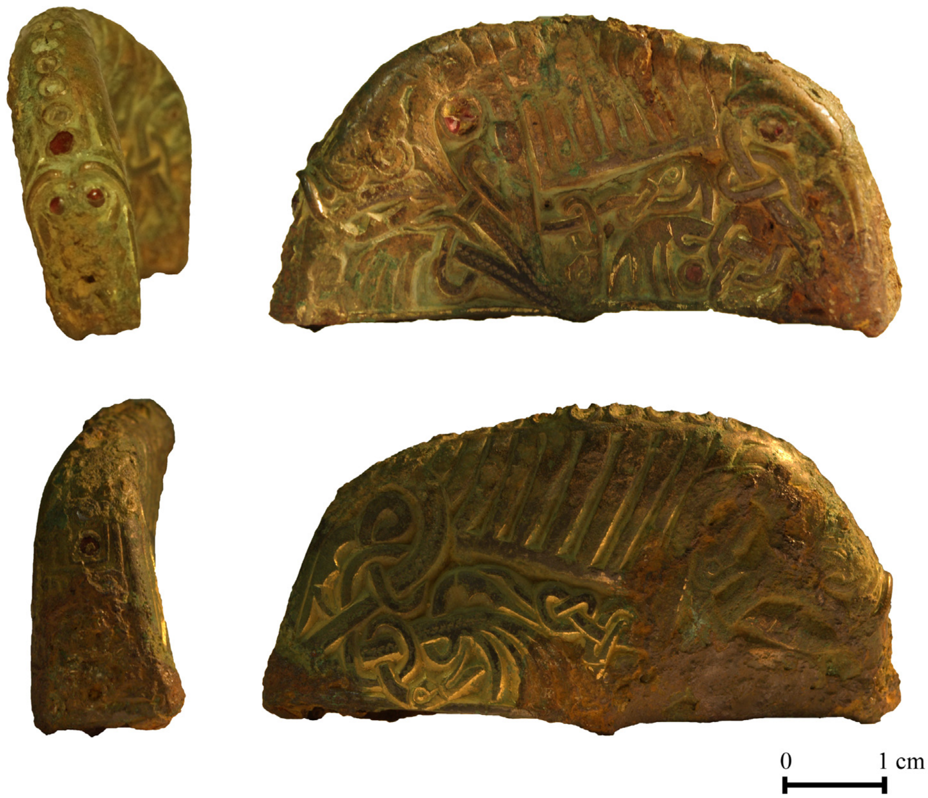

Fig. 14. Gilded bronze sword pommel with almandine eyes from Salme. (Photo by R. Maldre).

addition to luxury weapons and the abundant gaming pieces. These items would not have been particularly suitable for a military campaign, but may be more appropriate for an entourage of envoys. Diplomatic deputations at that time always travelled with a well-armed cohort of elite warriors.

The research reported in this study was focused on the question of the origins of the individuals buried on the two ships at Salme. The combination of isotopic and archaeological evidence clearly points toward the Mälaren region in central Sweden as the probable homeland of many of the men who travelled to Salme, died violently and were buried in two ships in around AD 750. A further few individuals from Gotland joined them in life and death. Our conclusions are also supported by genomic studies of the Salme skeletons (Margaryan et al., 2019).

9.1. *Epilogue*

It should be obvious from this study that isotopic proveniencing has become an important tool for bioarchaeology. There are problems, often associated with establishing ancient baselines for various isotopes. Analysis is expensive. The method only works for first generation immigrants. It is also the case that determining the place of origin for non-local individuals is rarely possible. Nevertheless, the ability to identify non-local burials has revolutionized our understanding of human movement in the past and contributed to an understanding that mobility and migration have always characterized the human condition.

Declaration of Competing Interest

The authors declared that there is no conflict of interest.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaa.2020.101149.

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