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Chapter 8

A Comparative Compositional Study of 7th- to 11th-century Copper-Alloy Pins from Sedgeford, England and Domburg, the Netherlands.

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In this paper we present the results of a compositional study of two small groups of early medieval pins. One group comes from the middle Anglo-Saxon/late-Saxon excavations at Sedgeford (Norfolk, England); and the other group was recovered from the beach near Domburg, on the former Island of Walcheren (Zeeland, the Netherlands). Both groups are contemporary in date, deriving from the 7th and 11th centuries, and derive from coastal settlement contexts.

In contrast to the pre-Christian period, copper-alloy artefacts from this time remain relatively rare, mainly due to the transition from furnished to unfurnished burial practices. As a result, knowledge regarding copper-alloy working at this time remains less well understood. The evidence so far, however, suggests a revival in metalworking activities, signalled by the large assemblages recovered from excavations in England such as at Flixborough, Lincolnshire and Hamwic, now Southampton, Hampshire (Blades 1995, 38; Rogers et al. 2009 for Flixborough and Wilthew 1996 for Hamwic). Although the numbers of pins measured in our study fall short of these larger assemblages, the pins considered here were found at similar types of site, at early medieval coastal settlements whose position within the maritime cultural landscape is of archaeological interest (e.g Callmer 2001; Deckers 2010; Hodges 2012, 8–10; Barrett and Gibbon 2015). It is unlikely that further quantities of pins will be recovered from Domburg or Sedgeford as these sites are now either eroded away, or have been systematically excavated. As a result this study compares just a limited quantity and variation in pin type, but it presents significant results useful for future large-scale comparisons with additional assemblages recovered from sites connected by the North Sea trading zone.

Frankish customs and their social and cultural influence on both England and Scandinavia have received considerable scholarly attention over recent decades, especially in the exploration of social identity and cultural affiliations within the North Sea region (e.g Loveluck and Tys 2006; Willemsen and Kik 2010; Bates and Liddiard 2015). There has been a tendency, however, within England to interpret metalwork within 'Anglo-Saxon' or 'Scandinavian' frames of reference (Thomas 2012, 487). Frankish influence on metalwork items found in England, either through inspired copies or imported goods, has received less coverage (Ibid, 488), with more emphasis given to the eastern coastal areas and in particular to the Anglo-Scandinavian nature of metal finds, especially in terms of copper-alloy personal items (Margeson 1996; Leahy and Patterson 2001; Kershaw 2009). The technology behind the production of these items can contribute to our understanding of the nature of contacts within the North Sea region if comparisons can be made between items recovered from differing locations. This is true not only in terms of the desired shape or function of objects, but also with regards to the choice of raw materials; the characteristics of which may differ and change as a result of local or regional geographical or chronological conditions.

While detailed pin typologies now exist, and demonstrate a degree of chronological variation (Capelle 1976; Ross 1991; Haldenby and Richards 2009; Rogers et al 2009), the exact use of pins during this period is not fully understood, but it is assumed that they were used for pinning hair, clothing and veils (Ross 1991, 22), and funerary shrouds in cemetery contexts (Hinton 2005, 92). Broadly speaking they can be considered as decorative and functional personal fasteners that were likely to have been used visibly in daily life and are therefore an object category susceptible to cultural trends. The 7th century, which is the earliest date to which we attribute the pins considered in this study, witnessed a change in female costume in Anglo-Saxon England that reflected the influence of the Frankish world located just across the North Sea (Owen-Crocker 2004, 128). Written accounts from the 8th century attest to the regular travel of scholars between Anglo-Saxon England and the Carolingian Empire. The missionary Boniface, for example (originally born in Wessex, England), was appointed the Bishop of Frisia and Old Saxony in 718. Surviving correspondence between Boniface and Charlemagne describe clothing as a common gift between the two individuals. This evidence pertains to an elite, ecclesiastical context, but it attests to the exchange of clothing and fashions between English and continental courts (Ibid, 27). It is not surprising that in this world of cross-cultural contact, personal items such as the pins discussed here appear to have developed along very similar typological lines on both sides of the North Sea. It has been suggested that pins as an artefact group are a rich data source for studying continuity and change in the Anglo-Saxon world (Ross 1991, 5), and that they can offer information on cultural change and economic variation, in terms of the spatial patterning of finds and the evidence of variation in production techniques. It has also been suggested that the large numbers of pins found in the archaeological record in comparison to other copper-alloy artefact types is evidence of large-scale production, centralised in this period around *wic*s, churches and royal estates, and possibly produced by a specialist workforce (Hinton 2005, 92). Seamus Ross observed that the workmanship of the pins from the 7th century onwards is significantly reduced in terms of skill than in previous centuries, with pins roughly cast, typically in base metals, then finished by hand (Ross 1991, 148). Ross has also proposed a change to the mass production of pins starting in the late-7th century (Rogers et al. 2009, 41).

While evidence of large-scale production is suggested by the frequency and type of the decorative head-styles from known assemblages, it is unclear whether this extended to the choice of alloy. If large-scale production was centrally organised, then it is possible that the alloy mixtures used may have been controlled to a degree reflecting, perhaps, the large-scale acquisition of raw materials, or a consistent school or genre of production with craftsmen working within a well-proven alloy tradition. Furthermore, if some level of material organisation took place at production level, it should not be assumed that this was identical in Anglo-Saxon England and on the Frankish Continent, even if the pin design was similar.

A compositional approach to the study of these artefacts may thus tell us something meaningful about the way in which production was organised. We ask here if the metal composition of pins can provide information on the organisation of production at Sedgeford and Domburg? To answer this question we assess how similar or not the alloy choice was between pin forms from these settlements. This study employs the use of handheld, portable X-Ray Fluorescence Spectrometry (hhXRF). This is an analytical device commonly used in archaeology for exploring the compositional nature of ancient materials. Used in a semi-quantitative way, respecting the principles of scientific validity and reliability (Speakman and Shackley 2013), the data collected by this non-destructive technique, may tell us something about the character of craft production, within the interconnected early medieval North Sea world.

HISTORY OF RESEARCH ON ARCHAEOLOGICAL COPPER-ALLOYS

Much has already been published on a broad range of copper-alloy personal items including brooches, equestrian gear, and decorative mounts, as well as dress and ring pins. Taking the publication by Torsten Capelle as a departure point for Domburg, useful typologies now exist for the copper-alloy dress pins discussed in this paper. The artefact assemblages from York (Yorkshire, England), Flixborough, and Hamwic provide important comparisons for Anglo-Saxon Sedgeford (See Ross 1991 in particular for detailed geographical, chronological analysis, then Rogers et al. 2009 for Flixborough).

Ancient copper-alloy objects have been the subject of typological interest for well over two centuries, but the ability to study them from a compositional aspect has only really been available from the 1950s through the invention of new scientific X-ray instruments, including Optical Emission Spectrometry (OEM), Neutron Activation Analysis (NAA) and laboratory based wavelength dispersive X-ray Fluorescence Spectrometry (labXRF). The late 1950s and 1960s saw the first studies of small metal objects using labXRF (Feretti 2014, 17531), but it was only in the early 1970s through the development of Energy Dispersive XRF (EDXRF), that the technology became small enough to transport to museums and archaeological depots, while at the same time offering non-destructive analysis, an important consideration when curating a finite supply of archaeological material. The earlier generation of equipment is commonly referred to as Portable XRF (pXRF), with the latest generation of 'point and shoot' devices being referred to as Handheld XRF (hhXRF, see Frahm and Doonan 2013, 1426). The equipment used in this study is the latter, therefore we employ the term hhXRF to distinguish it from the bulkier benchtop systems.

The results of past alloy studies have already shed light on the compositional and technical choices available to ancient craftsmen. The main alloying agents to copper were tin to make bronze, and zinc for brass, with or without a quantity of lead. Alternatively, a mixture of tin and zinc (in brass form being added to bronze) could be used, a choice that is usually termed ‘gunmetal’. The deployment of inductively coupled plasma atomic emission spectrometry (ICP-AES) in the investigation of copper-alloy use from early medieval archaeological sites in England has produced useful results (Blades 1995). Nigel Blades analysis of 151 middle Anglo-Saxon period artefacts (mainly pins) from Brandon (Suffolk, England) suggested that there were two basic choices of alloy in use at the time. A relatively pure brass composition and also bronze (with varying degrees of lead) were used for casting. No correlation was observable between artefact typology and alloy choice. For the late-Saxon period in England, Blades analysed 78 objects from Ipswich, Beverly and Lincoln (Suffolk, Yorkshire and Lincolnshire respectively), only 12 of which were small cast finds. Again no correlation between artefact type and alloy choice was observed and the alloys measured were similar to those at Brandon, mainly bronzes, then brass, with a small amount of gunmetal. This lack of gunmetal suggested that fresh metal was available and was being used in preference to the recycling of scrap (Ibid, 161). Energy dispersive X-ray fluorescence (edXRF) was also deployed in an analysis of middle Anglo-Saxon copper-alloy finds from Hamwic (Wilthew 1996). Approximately 140 pins were analysed of which 34 were produced in brass and only 15 produced in gunmetal, with or without added lead. The remainder were produced in bronze or leaded bronze. The alloy results for the polyhedral-head-types suggested that no correlation between composition and head-type, with all alloys being present in the assemblage. A different situation was observed for the biconical-head-types. The pins with simple biconical heads and those with median bands were made in brass, while the rest of the pins were produced in bronze or gunmetal. From these results Paul Wilthew suggested that different pin types may have been produced separately, either at a single or a limited number of sites and that composition may have been deliberately controlled (Ibid, 67–8). These past studies have suggested close interconnected relationships between composition and typology (Dungworth 1997, 902), including the technical limitations of different alloy combinations used in casting (as a molten liquid) for example, or in cold working such as hammering and stretching. A large-scale, non-destructive, compositional approach, especially focused on items from the early medieval period, and the Netherlands in particular, has until now been limited (e.g. Bayley 1991; Baker 2013; Pollard et al 2015; Roxburgh et al. 2014; 2016a). This is because the application of hhXRF in the study of corroded copper-alloy items is still developing (See Roxburgh et al. 2018).

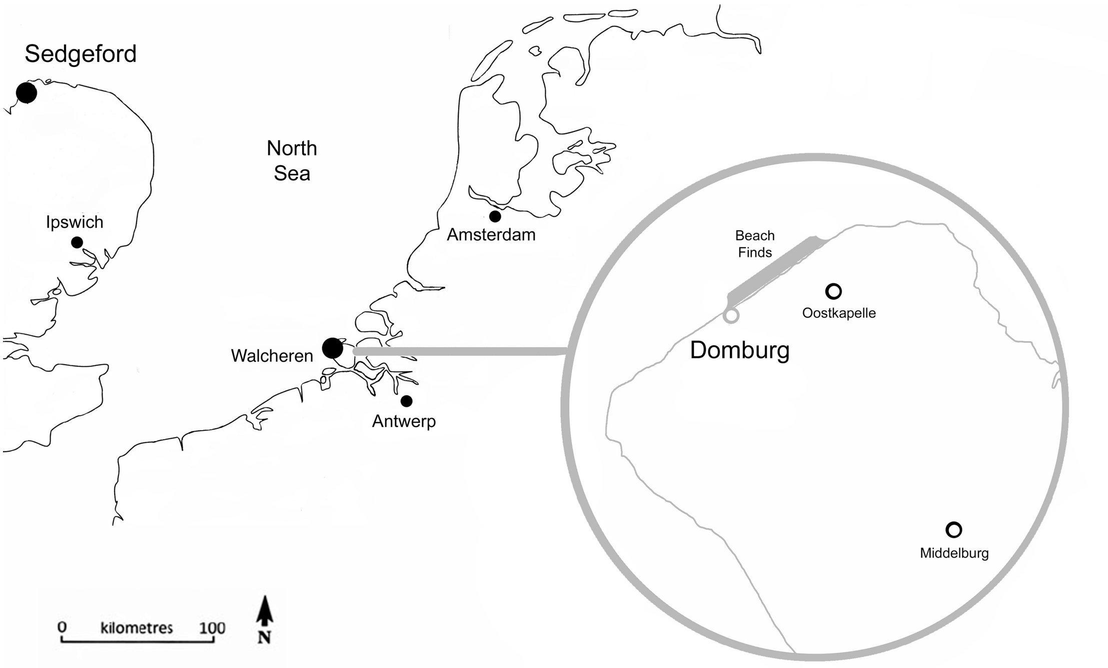

FIG 1
Locations of Domburg (Zeeland) and Sedgeford (Norfolk), as mentioned in this study.

THIS STUDY: FIND LOCATIONS AND HISTORICAL CONTEXT

Of the 33 dress pins presented in this study, 19 were recovered near to modern day Domburg (see Fig 1). These were mainly beach finds washed ashore after heavy storms and collected at low tide in the 19th and early 20th centuries (Op Den Velde and Klaassen 2004, 3). Ocasionally at very low tides the North Sea still reveals the remains of the early medieval cemetery and settlement structures. There has been much discussion about early medieval Domburg, with suggestions that the site was a trading settlement or emporium during the late-6th to 9th centuries, involved in interregional trade around the North Sea (Ibid, 2). Repeated Viking raids are said to have contributed to the gifting of Walachrium (believed to be the medieval name of the settlement at Domburg) as a fiefdom to Danish warlords by the Frankish emperor Lothar I (795-855), but during this time its role as a trading centre seems to reduce significantly as other trading sites became more influential (Ibid; Van Heeringen et al. 1995, 230; Theuws 2004). This settlement is believed to have been the centre of the royal manor of Walachrium, from which the island (Walcheren) takes its name. Its rural hinterland is believed to have consisted of numerous specialised coastal farms, many of which involved in the raising of sheep. Trade activities at Domburg (continuing with the modern name) therefore, would have included exchanges of both rural- and craftsperson-produced goods, and its position within an interconnected

North Sea trade network would have facilitated the movement of both types of produce over longer distances (Tys 2010, 172).

In 2017 the excavations at Sedgeford, a rural village on the coast of Norfolk, entered its 22nd season. The project conducted by the Sedgeford Historical and Archaeological Research Project (SHARP), has systematically revealed a middle Anglo-Saxon to late-Saxon settlement and associated burial ground (Davies 2010, 252–73). The site is located besides the River Heacham and lies just 5 km from the present coastline. The location of the settlement is also associated with two major N/S trackways, the prehistoric Icknield Way and the late Roman-period Peddars Way. Although evidence for trade remains elusive at Sedgeford itself, its location places it in close proximity to small-scale trading sites such as Burnham, Bawsey and West Walton. Their market-like assemblages and proximity to possible beach or river landing sites suggest a connection to the wider North Sea world (Deckers 2010, 165). Analysis of the artefacts recovered from this rural settlement can provide useful comparisons for the study of activity at trading posts such as Domburg (McCormick 2001, 1; Hodges 2006, 16). Mass-produced items such as pins could have been produced for either local consumption or, because their small (and very portable) size, may have been destined for trade at these interconnected markets. A comparison of pin compositions from both of these sites contributes to the debate surrounding the nature of trade and production at both emporia and lesser rural settlements alike.

EARLY MEDIEVAL COPPER-ALLOYS AND THEIR PRODUCTION

The most frequently used copper-alloy in early medieval Britain was bronze (copper alloyed with tin) and the closest tin-producing area would have been Cornwall, in south-western England (Penhallurick 1986). A significant amount of bronzes at this time were not pure, containing a mix of other alloying ingredients, whether added on purpose or not (Baker 2013, 228). The other major alloying component was zinc, to make brass, possibly favoured in ancient and early medieval times for its distinctive golden colour. Zinc is not mined in England and the closest mining area would have been at La Calamine in Belgium, well within the Frankish hinterland (Boni and Large 2003). Brass also needed a different technological process to bronze — the cementation process — where the zinc enters the copper in a gaseous form in a closed vessel (Ibid, 234). The production of items in brass appears to decline rapidly in Antiquity, and was replaced by production in gunmetal, which is a mixture of brass and bronze (in varying proportions) and would have been a suitable mechanism for recycling scrap objects of both alloys. Gunmetal could also be a preferred choice in its own right as a zinc-rich leaded alloy would have good casting properties, while the addition of 1–2% zinc to a bronze acts as a deoxidant, making the object more resistant to corrosion (Bayley and Butcher 2004, 15, also see Tylecoat 1977 and Nazeran 2013, 5). That said, the addition of 1–2% zinc to a bronze could also be the result of reusing old crucibles (Baker 2013, 90).

By the 7th century, therefore, most pure brass in the Anglo-Saxon kingdoms may be considered as either reworked Roman scrap, or freshly imported from the

Frankish world, perhaps in the form of ingots such as those found at Kingsway, London, or those found much further north in the Baltic region (Bayley et al. 2014; Sindbæk 2001). A relative scarcity of brass during this time in comparison to a wider availability of gunmetal and bronze, combined with its popularity as a more golden copper-alloy, may well have created a difference in cultural value when selecting between brass- or bronze-based objects (Baker 2013, 33). In addition, brass allows for more elaborate cold working of the object such has hammering, drawing and bending; making it the metal of choice for more high-status jewellery, perhaps including pins. Bronze on the other hand, especially leaded bronze, is easier to cast in thinner objects, and therefore easier to mass-produce. However, it is very difficult to cold work (leaded) bronze as it will break or tear more easily than brass (Cameron 1974, 217–19). A trading centre at Domburg would have been in a good geographic position to be involved in the trade of brass around the North Sea, and to Britain in particular, if in demand by Anglo-Saxon craftsmen.

The organisational characteristics of early medieval craft activities and the social standing of the artisans who produced them is still under debate, but it is clear that different organisational structures for production must have existed, Anders Söderberg, a Swedish archaeologist and craftsman, proposed several classification models for the organisation of copper-alloy crafting activities (Söderberg 2004, 116). Adriaan Verhulst, from a historical perspective, suggested that artisan production was mainly centred around royal courts, abbeys, large estates and urban centres, but with a small amount of production by travelling artisans, perhaps less controlled than that produced by those working within more sedentary environments (Verhulst 2002, 72).

Artisans would have been the main decision makers in the production techniques employed to make different types of copper-alloy artefacts. They controlled the production technology, the choice of raw materials and hence the quality of the finished item. If a pin was the product of organised large-scale production, then the level of consistency present, both in terms of shape and composition, could be higher than might be expected from more ad hoc production events. The consistency of the raw material supply such as brass or bronze would be a factor in the decision-making process, however, but if regular duplication took place then the possibility exists that the raw material supply and hence alloy choice became more standardised. Craft specialisation and standardisation have been attracting archaeological interest since the work of Gordon Childe in the 1930's (e.g. Childe 1930; 1936). In more recent times craft specialisation, standardisation and the organisation of labour have been explored using portable X-ray fluorescence, focusing analytically on chemical clusters and the concept of batch production of weaponry in ancient China (Martinón-Torres et al. 2012). Standardisation of alloy choice has also been observed in hhXRF studies of Frankish brooches from across the Netherlands. The small long brooches of the 'Domburg'-type dating to the 7th century were only produced in tin-rich gunmetal (Roxburgh et al. 2016a, 123, fig 4; Heeren and van Der Feijst 2017, 211, type 82h). Furthermore, an overwhelming majority of Carolingian- and Ottonian-period disc brooches, again from across the Netherlands, are produced in leaded brass (Roxburgh et al. 2016a, 126, fig 5). It would be of interest therefore to see if this standardised choice of alloy extended itself to pins, which are another mass-produced and widely distributed object.

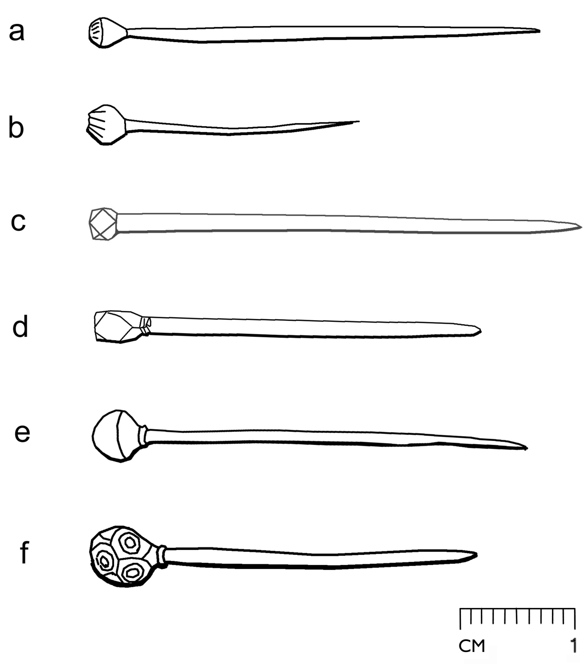

FIG 2
The pin types. Domburg: (a) Biconical (0032-122); (b) Biconical (0032-120); (c) Polyhedral (0032-109). Sedgeford: (d) Polyhedral (SH01BYDOT793); (e) Biconical (SH03BYDNT1173); (f) Biconical, ring-and-dot decoration (SH01BYDNT709). *Drawn by first author.*

MATERIALS

The pins found near to the modern seaside town of Domburg were eventually placed into the care of the Zeeuws Museum and the Cultural Heritage Agency of Zeeland's archaeological depot (SCEZ, Partly as the collection of the Koninklijk Zeeuwsch Genootschap der Wetenschappen (KZGW; the Royal Zeelandic Society of Sciences), Middelburg). The pins were first accessed for hhXRF analysis by a research masters student, with scientific support from the Dutch Cultural Heritage Agency (Van Tendeloo 2017, supervised by the second author). The compositional measurements from this study were subsequently absorbed into a larger doctoral project undertaken by the first author ('Charlemagne's Workshops' is an investigation into the social organisation of production behind Roman to early medieval period copper-alloy objects).

The pins from the archaeological excavation at Sedgeford were accessed in 2016, with measurements subsequently undertaken by the first author, using the same portable device as at Domburg, on loan from the Dutch Cultural Heritage Agency. We selected examples from two coherent groups of pins based on the shape of their heads (see Fig 2), then subsequently studied them from compositional, typological and contextual viewpoints. An extensive typological study of non-ferrous Anglo-Saxon pins was published by Seamus Ross in 1991, and subsequently a comparable study was produced by Nicola Rogers on the pins recovered from the excavations at Flixborough (Rogers et al. 2009). From these studies we were able to assign a classification to pins from both Sedgeford and Domburg (Tab 1, also see Ross 1991, 371–80; Rogers et al. 2009, 35). Archaeological dating from Flixborough suggested that both the polyhedral-head series and the biconical-head series were found in layers dating to between the late-7th century and late-10th century. The chronology proposed by Ross places the polyhedral head series between the mid-7th century to mid-9th century, with the biconical head series starting a decade or two earlier and lasting into the mid-9th century. The excavations at Cottam in Yorkshire enabled a better glimpse of these pin chronologies (Haldenby and Richards 2009, 309). The drifting nature of the site across the Anglian to Anglo-Scandinavian periods enabled chronological analysis across the two phases. This revealed evidence for the continuation of the biconical series across both phases and the disappearance of the polyhedral pin at the beginning of the Anglo-Scandinavian phase, in favour of a new disc-headed pin form (Haldenby and Richards 2009, 314).

METHODOLOGY

The principles of the hhXRF portable device are very much the same as for laboratory based XRF versions, both of which can be used to assess the quantities (and hence ratios) of metallic elements present in an object (See Shackley 2011 and Shugar and Mass 2012 for additional technical details, including examples of archaeological applications). For this study a Niton XL3t GOLDD XRF device was used. These devices are factory calibrated with several internal standards for metals and metallic alloys, allowing a suitable mode (electronic metals) to be selected with which to gather data. This mode, although developed for modern electronic equipment, was the most suitable because it recognised most of the elements found in medieval alloys, namely; copper (Cu), tin (Sn), silver (Ag), zinc (Zn), gold (Au) and the potentially hazardous lead (Pb), mercury (Hg), arsenic (As), and selenium (Se). Time trials subsequently determined that the signal was found to be stable after a reading time of 35 seconds, therefore sufficient enough to determine an elemental count of 10ppm for most elements and adequate for the level of analysis required. Two spectrum readings were taken at 35 second intervals, the first for the main range of elements at 50kV (Cu-K to Ba-K, and Au-L to Pb-L) and the second for the low range at 10kV (Al-K to Cu-K). One measurement per dress pin was taken (on the head) and after the analyses, the spectra were processed using dedicated Niton software and subsequently checked for unexpected peak overlaps.

The patina or outer corroded surfaces can be contaminated to a degree with soil residues (typically sand, clay and iron hydroxides), therefore an external normalisation of the completed dataset was undertaken using Microsoft Excel.™ The concentrations of the alloying elements were subsequently normalised on a light elements (Si-Fe) free basis. For the purpose of this study we only focused on the main alloying elements (Sn, Zn, Pb). The addition of these elements can be considered a conscious act by medieval craftsmen, the ratios of which, when added to copper (which is always present) give different alloying properties. The factory calibration of the device was also checked against the CHARM –certified, heritage copper-alloy – reference set (See Fig 3, left, and Heginbotham et al. 2014) and the bias introduced due to corrosion was also evaluated by comparison to recent studies on corroded Roman finds (Roxburgh et al. 2018). This revealed that copper and zinc are the principle elements lost during the corrosion process, creating the patina and permanently altering the original metal surface layer (Fernandes et al. 2013; and also Roxburgh et al. 2016). The deviation in alloy ratio between corroded and non-corroded measurements is visualised in the following ternary diagram (Fig 3, right). The trend in zinc loss is clear and had it been possible to destructively clean all the pins measured for this paper, it could be expected that the results displayed in Figure 4 would deviate in a similar way. The pins from Domburg, probably by nature of being found on a beach, showed little patina, allowing the measurements to take place directly on the altered outer metallic surface. The pins from Sedgeford conversely had an even patina as commonly seen on most artefacts recovered from buried contexts. This difference would be expected to increase any deviation between the two datasets, but not to the extent that the alloy interpretation could be affected.

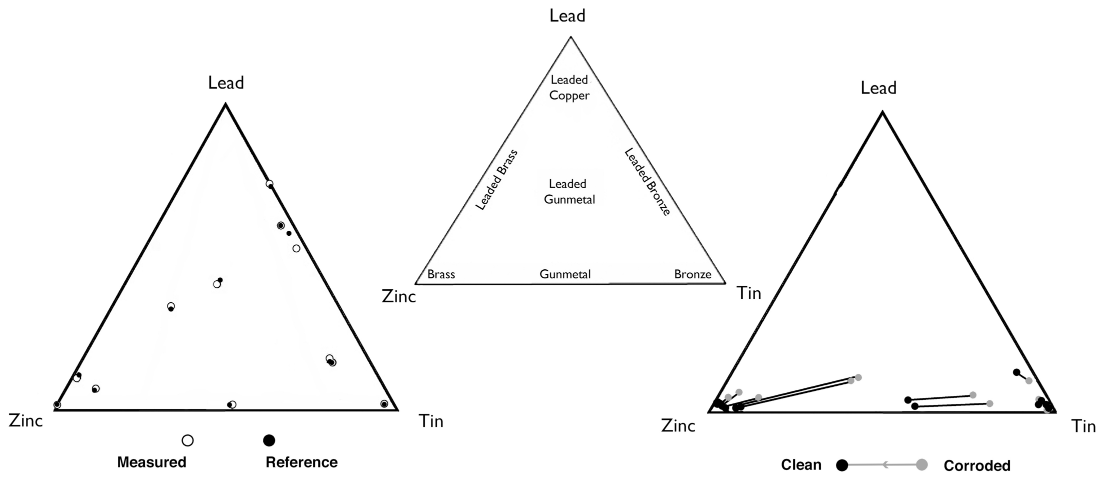

FIG 3
Ternary diagrams. Compositional classifications (after Bayley and Butcher, 2004, fig 7) in centre, measurement bias versus the CHARM heritage standard (left) and deviation in measurement due to corrosion (right). *Drawn by first author.*

RESULTS

These results are based on two groups of corroded objects, necessarily so to avoid destructive surface removal. The normalised results are presented in Table 2, their relative alloy groups are presented as ternary diagrams in Figure 4, and the interpretative classification (adjusted for the corrosion bias discussed earlier) is presented in Table 1.

TABLE 1
Results classified by alloy type.

Head Type	Alloy	Domburg	Sedgeford
Polyhedral	Brass	3	2
	Gunmetal	0	1
	Gunmetal (+Lead)	2	0
	Bronze (+Lead)	7	3
Biconical	Brass	1	1
	Brass (+Lead)	0	1
	Gunmetal	0	1
	Gunmetal (+Lead)	2	0
	Bronze (+Lead)	4	5
		Total 19	Total 14

TABLE 2
Finds ID, typological classification and normalised results. Description based on Rogers et al 2009.

Finds ID	**Description**	**Cu %**	**Sn %**	**Pb %**	**Zn %**
Domburg					
0032-107	Polyhedral	82.0	1.5	1.5	15.0
0032-108	Polyhedral	79.0	7.5	10.0	3.5
0032-109	Polyhedral	85.0	7.5	5.0	2.0
0032-110	Polyhedral	63.5	15.0	19.0	2.5
0032-111	Polyhedral	86.5	10.5	2.5	0.5
0032-112	Polyhedral	55.5	30.0	14.0	1.0
0032-114	Polyhedral	82.5	5.0	4.0	8.5
0032-115	Polyhedral	67.5	27.0	4.5	1.0
0032-117	Polyhedral	85.0	10.0	4.0	1.0
0032-94	Polyhedral	84.5	0.5	0.5	14.5
GA0112	Polyhedral	69.0	20.0	9.5	1.0
0032-119	Polyhedral	54.5	24.0	19.0	2.5
GA0115	Biconical	84.5	12.0	2.5	1.0
GA0111	Biconical	79.0	10.5	8.0	2.0
0032-84	Biconical	83.0	8.5	6.0	2.0
0032-120	Biconical	83.0	2.0	5.5	9.5
0032-123	Biconical	83.0	11.0	5.0	1.0
0032-118	Biconical	67.0	20.5	10.5	2.0
0032-122	Biconical	87.5	9.0	3.0	0.5
Sedgeford					
SH98 104	Polyhedral	82.0	9.0	3.5	6.5
SH99 1399	Polyhedral	90.0	0.0	1.5	8.5
SH02 933	Polyhedral	83.5	1.0	5.5	10.0
SH97 60	Polyhedral	49.0	30.0	21.0	0.0
SH97 14	Polyhedral	58.5	20.0	21.0	0.5
SH01 793	Polyhedral	52.5	32	15.0	0.5
SH97 6	Biconical	76.5	3.0	7.5	13.5
SH96 8	Biconical	71.0	1.5	15.5	12.0
SH99 347	Biconical	65.0	30.0	5.0	0.5
SH01 709	Biconical	45.0	16.0	38.0	1.5
SH09 3064	Biconical	53.5	17.0	29.5	0.0
SH97 4	Biconical	81.0	10.5	8.5	0.0
SH03 1173	Biconical	54.0	33.5	7.0	5.5
SH09 3042	Biconical	46.0	9.0	44.5	0.0

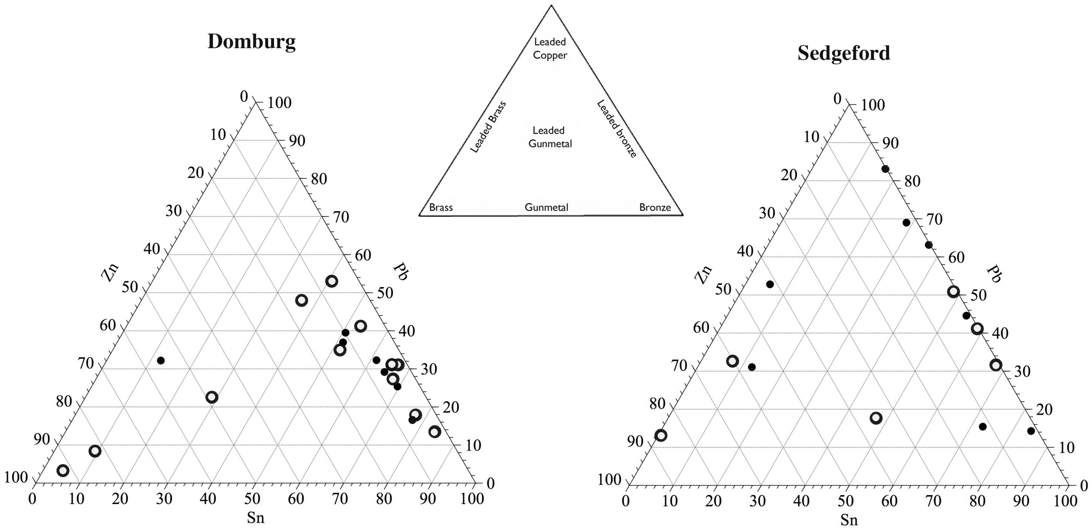

FIG 4
Ternary diagrams. Showing ratios of tin (Sn) to zinc (Zn) to lead (Pb) circles = polyhedral heads; dots = biconical heads.

DISCUSSION

The pins from the settlement at Sedgeford provide a closer geographic comparison for the previous alloy studies by Nigel Blades and Paul Wilthew, so we start the discussion here. All three alloy groups are present in this assemblage, with bronze being the most frequent choice, then brass, then gunmetal. Blades' analyses of the middle and late-Anglo-Saxon pin alloys found at Brandon, Ipswich, Lincoln and Beverley suggest that craftsmen had a preference for production in bronze, then brass, and lastly gunmetal. This preference in alloy choice matches, to some extent, the results for the pins from Sedgeford. The results published by Wilthew for Anglo-Saxon Hamwic are also comparable. Production in bronze was the most frequent choice, then brass, then gunmetal.

A comparison of alloy to head types on the Sedgeford pins failed to identify any correlation between the two. This is in line with Blades' observations, and to some extent those of Wilthew, whose results suggest that the production of some sub-types of polyhedral pins were restricted to brass. Unfortunately an inspection of the two polyhedral-head-types, produced in brass, from Sedgeford was inconclusive. The suggestion by David Haldenby and Julian Richards from the excavations at Cottam that polyhedral-head-types go out of fashion during the 9th century provide an opportunity to observe a chronological change in alloy use. Blades, however, found that there was little difference in alloy choice between the middle Anglo-Saxon and late-Saxon periods, suggesting that the typological changes observed at Cottam, if comparable to other areas, are more likely to be independent of alloy choice.

A further suggestion made by Blades was that the lack of pins produced in gunmetal could be due to an availability of fresh metal supply being on hand for production, with the craftsmen selecting it in preference to recycled material. This could therefore be the case for the pins found at Sedgeford as bronze and brass are also the dominant alloys in the assemblage. Wilthew also suggested that there may have been a degree of deliberate compositional control, perhaps with manufacture being organised through a limited number of production centres that specialised in different pin forms. It could be argued that an avoidance of production in gunmetal, perhaps as a result of avoiding recycled material, is evidence of deliberate compositional control. To avoid this choice, craftsmen would have to have had regular access to a supply of fresh bronze or fresh brass, perhaps in the form of trade ingots. We assume that bronze ingots would have been made closer to the tin-mining areas in south-western England and then widely distributed. If we exclude recycled Roman brass due to a probable inconsistency of supply, making it unsuitable for mass production, then fresh brass would have entered England from the Continent, in ingot form via the North Sea trade network, perhaps through routine long-distance exchange similar to that suggested by Soren Sindbæk for Viking-Age bars/ingots (mentioned above). The main entry points for regular supplies of brass would most likely have been ports such as Ipswich and Hamwic, perhaps destined, along with bronze, for consumption at these growing craft centres. Verhulst's suggestion that craft production was concentrated around urban centres, abbeys and royal courts matches the view held by David Hinton, who also suggested that the large-scale production of pins, by a specialist workforce, was most likely centralised around markets, churches and other similar centres. If this model is applied to the results from Sedgeford, the pins found there were most likely produced at a larger centre, such as at Ipswich, and then distributed in quantity via smaller-scale markets, such as at Burnham on the northern Norfolk coast. The alternative hypothesis is that pin production was still quite localised, perhaps operating at small-scale markets, such as Burnham. Localised production may have been able to take better advantage of scrap metal recycling techniques in preference to sourcing fresh metal stock, especially overseas brass. As pins produced using scrap metal, in the form of gunmetal, is the most infrequent alloy choice observed here, it can be suggested that this is the least likely scenario.

The results from Domburg are similar in that the majority of the pins were produced in a bronze alloy with a much smaller group being made in brass. Unlike the bronze results from Sedgeford, the bronze measurements from Domburg in Figure 4 demonstrate the presence of a small amount of zinc. As outlined in the methodology section earlier, dezincification is a main contributor to the formation of the patina on a corroding copper-alloy surface. Therefore, it is very likely that the proportion of zinc in the Domburg pin group was originally higher, possibly in line with the corrosion diagram in Figure 3. This observation suggests that the craftspeople making the pins used a less pure bronze than that found at Sedgeford. Depending on how strict the definition is applied in classifying the group, it could also be described as a tin-dominant gunmetal. If we assume that craft production, including the making of pins, took place at Domburg then its geographic position within the North Sea coastal area would have meant that it was in a strong position to engage in the trade or exchange of brass and bronze ingots. This slightly higher ratio of zinc could have entered at the ingot casting stage of the process, perhaps introduced through the recycling of a small amount of scrap into the mixture. Or it could have been through the deliberate addition of a small amount zinc-rich copper-alloy just prior to pin production itself. The deliberate addition of just a few percent of zinc to a bronze acts as a corrosion inhibitor, especially useful in saline coastal or maritime conditions such as those experienced at Domburg. However a low percentage of zinc could also be picked up from the residues left behind in crucibles in a busy production centre. The latter would imply a by-product of the process, rather than a conscious act however.

As at Sedgeford there is no indication that the craftsmen producing polyhedral or biconical-headed pins reserved a particular alloy for either head form. This result contrasts with the results for the small long 'Domburg'-type and Carolingian-period disc brooches mentioned earlier, whose alloys remained constant for a considerable time. That said, the 'Domburg'-type brooch was produced in a tin-rich gunmetal not dissimilar to the most common alloy choice for the pins. This could be because this alloy was a common local choice, reflecting metal availability in the region. If so, the presence of some pins in brass infers a different kind of organisation for production. The latter could well have been produced at Domburg, in brass, rather than the local alloy, but equally being small and highly portable they could be evidence of non-local production, perhaps at a site some distance away where production in brass was the norm. The richer, more gold-like colour of brass pins, perhaps imported from elsewhere, may have provided competition for locally produced pins made in duller bronzes and gunmetals.

CONCLUSION

Two similar groups of pins from both sides of the North Sea were analysed non-destructively by hhXRF. The aim was to qualitatively assess how closely craftsmen controlled the alloys in view of the argument for large-scale production starting in the 7th century. One group of pins came from the site of a suggested coastal emporia, at Domburg, the Netherlands and the other from a rural site on the Norfolk coast, England. The evidence for both groups was comparable to previous alloy research at other locations. Although a relatively smaller amount, the pin alloys from Sedgeford generally matched those measured at a number of other English sites. Bronze was the most common alloy, followed by brass, then by a smaller number produced in gunmetal. For Domburg the results were similar, but the bronze-alloy exhibited a small proportion of zinc within it that, whether added deliberately or not, would have had anticorrosion properties, especially useful in a coastal maritime setting. Unlike some types of Frankish brooches from the period, a single standard alloy choice was not present. Ross' suggestion for mass production centralising around *wics*, churches and royal estates may well hold true as fresh metals were favoured over recycled material, implying a closer connection to the supply than that of a small rural settlement at Sedgeford, where more local metalworkers may have favoured using up scrap material first over more valuable fresh alloys. The results for Domburg also suggest that some pins may have been produced in a common local alloy, implying that pins made in brass were from a different production event, perhaps organised separately if produced at Domburg itself. Alternatively due to their small and highly portable nature, pins made in brass could easily have been made a considerable distance away, perhaps at a site where production in brass was the norm.

The study of medieval copper-alloys using hhXRF is still developing and its non-destructive process and fast throughput of objects allows for analysis of greater numbers of objects from more locations than ever before. It was in this context that the analysis took place and we view it as a basis for future, large-scale comparisons of copper-alloy artefacts recovered from the interconnected regions around the North Sea.

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