From the Fabricae of Augustus and the Workshops of Charlemagne: A compositional study of corroded copper-alloy artifacts using hand-held portable XRF

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Chapter 7

A workshop at the edge of the world? A compositional analysis of copper-alloy finds from Early Medieval Walcheren, (in Press).

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INTRODUCTION

Over many years a large and diverse number of early medieval copper-alloy artefacts have been recovered from the former island of Walcheren (Zeeland, the Netherlands). In this chapter we present the results of a combined typological and compositional study of six groups of these artefacts dating between the seventh and twelfth centuries, encapsulating a period in time better known as the (long) Viking-Age. This study employs the use of Handheld X-Ray Fluorescence Spectrometry (hhXRF), a portable device commonly used in archaeology for exploring the compositional nature of ancient materials. The valuable new qualitative data collected by this non-destructive technique sheds light not only on the character of ancient technology and the organization of craft production, but also allows a reconsideration of the role of these personal objects in expressing social identity within an interconnected North Sea world.

We focus therefore on the copper-alloys used to make disc brooches, ansate brooches, dress and ring pins, stirrup-strap mounts and zoomorphic mounts, which have been found in large numbers, particularly along the beach between Domburg and Oostkapelle. Some additional finds will also be discussed for geographical comparison, including items collected in the vicinity of Middelburg and from Westenschouwen on the neighbouring island of Schouwen.

Our aim is to explore the ways in which production was organised for these typological groups, and this will be achieved through a combined typological and compositional analysis of the consistency (or otherwise) found within each group. Hypotheses will be formulated regarding the social organization of production (workshop organization) based on previously proposed models. The distinction between local and non-local production will be discussed, which in turn will allow for a reconsideration of the role of these personal objects in expressing social identity.

In the rest of this introduction the history of typological research and the technical developments of compositional analysis will be expanded upon. Afterwards, we will present the find locations and the associated historical contexts, followed by an explanation of the organizational models for early medieval production. The introduction ends with a broader presentation of our objectives and questions. The

second section of the chapter presents a short explanation of the materials, methodology and equipment, together with a discussion of the biases in alloy research caused by corrosion. The most important section containing the results and a discussion of the compositional study follows next. Finally, before concluding, we present a discussion regarding the organization and likely locations of the production of these objects, together with new hypotheses regarding the roles these objects may have had in expressing social identities.

History of research on early medieval copper-alloys

A literature search of early medieval copper-alloys reveals that much has already been published on disc and ansate brooches, dress and ring pins, stirrup-strap mounts and more recently the zoomorphic mounts. Taking the publication by Capelle as a departure point (Capelle1976), useful typologies now exist for the brooches found on Walcheren (Frick 1992; Thörle 2001; Bos 2006a, 2006b ; Weetch in press), as well as for the dress and ring pins (Rogers et al. 2009), the stirrup-strap mounts (Williams 2007) and to some extent the zoomorphic mounts (Roxburgh et al. in press; Webley in press).

Typological interest in ancient copper-alloy objects can be traced back well over two centuries, but it has only been since the mid-twentieth century, with the invention of X-ray techniques such as Optical Emission Spectrometry (OEM), Neutron Activation Analysis (NAA) and X-Ray Fluorescence Spectrometry (XRF), that research into alloy composition has been widely undertaken. Small metal items were amongst the first material groups to be studied using large immobile laboratory XRF equipment (labXRF) in the late 1950s and 1960s (Feretti 2014). By the early 1970s, however, a new generation of energy dispersive XRF spectrometers (EDXRF) allowed for an increasing miniaturisation of the technology which – being portable – allowed for non-destructive, *in situ* analysis at museums and other storage locations. This miniaturised equipment is commonly known as Portable XRF (pXRF) or Handheld portable XRF (hhXRF, also see Frahm and Doonan 2013). The equipment used in this study was a handheld instrument; therefore we adopted the term hhXRF to distinguish it from the bulkier portable benchtop systems.

Studies using XRF techniques have revealed a lot about the technical choices presented to ancient craftsmen. The technical choices between different alloying agents added to copper, namely tin to make bronze or zinc to make brass – with or without a quantity of lead – have been revealed, telling us much about the complex relationship between composition and typology (Dungworth 1997, 902). The limitations imposed on certain artefact types for example have been given particular attention, especially differentiating between items cast in liquid form into a mould (for example where a small addition of lead is beneficial), or items that have been wrought, or beaten into a desired shape with a hammer, where too much lead for example can cause the item to break (for example, Unglick 1991; Bayley and Butcher 1995, 2004; Craddock 1998). However, combined typological and compositional

approaches to studying copper-alloy items, looking in particular at the level of alloy consistancy within artefact groups – especially those from the early medieval period – have until now been limited (for example, Bayley and Butcher 2004; Martinón-Torres 2012), particularly in the Netherlands, where research has mainly centred upon typological concerns (see Capelle 1976; Thörle 2001; Bos 2006). We therefore present a combined analysis of this interesting range of objects and formulate new ideas about their purpose and cultural associations.

Find locations and their historical context

Of the 299 objects presented in this study, 261 came from locations near to modern-day Domburg. These were mainly beach finds, recovered after heavy storms and collected at low tide between Domburg and Oostkapelle in the nineteenth and early twentieth centuries (Op Den Velde and Klassen 2004). An additional five items came from excavations in the *ringwalburg* or ringfort (constructed in the ninth century) in the present-day town of Domburg, one of three ringforts on the island. These items were found during excavations by a developer funded archaeological company (ARC-Archaeological Research & Consultancy) in 2010 (Ufkes 2011). An additional eleven items are presented from the area around Middelburg and a further twenty-two items from Westenschouwen on the island of Schouwen-Duiveland, which were included for comparative reasons.

The sheer number of finds, particularly of coins, have led to suggestion that this was the site of an emporium, a trading settlement that facilitated interregional trade around the North Sea, a trade that is believed to have taken place between the late sixth and tenth centuries (Ufkes 2011). The late seventh and eighth centuries in particular appear to have been very prosperous (Ten Harkel 2013, 237-238), and arguably its importance in the Carolingian period may almost have matched that of Dorestad (Capelle 1976, 5). Walcheren was given as a fiefdom to Danes by the Frankish emperor Lothar I and from that point trade at the lost settlement appears to decline rapidly. This decline during the last quarter of the century coincides with a large defensive ring fort or 'burg' being built nearby. Traditional interpretations consider these ringforts to be part of the coastal defences that the Franks put in place to resist Viking attacks; however, more recently this interpretation has been questioned by various scholars, who have instead proposed the idea that these fortresses were part of a Danish tradition.

Danish rule is believed to have come to an end by AD 884 at the latest, when power over the Danish benefices transferred to local counts (Coupland 1998). The 'burg' at Domburg remained inhabited from the late ninth until the early eleventh century and connections between the Frisian coast, Scandinavia and the British Isles seem to have continued during this period, despite the end of Danish involvement in the benefices (IJssennagger 2015, 134). A handful of finds recovered from excavations in the fortress in 2010 and dated to the late ninth or early tenth century may be evidence of this Viking past in Domburg (Ufkes 2011), The other place on

Walcheren from which finds are included in this survey is Middelburg, again developed from an early medieval ringfort, but less well studied than Domburg (Ten Harkel 2013, 234). Middelburg is now the capital of the province of Zeeland and is located approximately twelve km inland from Domburg. But the settlement possibly dates back as far as the late eighth or early ninth century. By the start of the second millenium the town had become an important trading centre between England and Flanders in particular. Finds from Westenschouwen, an area on the westerly tip of the neighbouring island of Schouwen, were included in the survey to provide a close comparison for items found on Walcheren. Westenschouwen is situated some fiveteen km north-east of Domburg across the Oosterschelde estuary.

The material selected from these locations and subject to our analysis is generally thought to date between the seventh and eleventh centuries, but the bulk of the finds probably date from the late eighth century onwards, thus dating the assemblage broadly to the Viking Age or 'long'Viking Age.

Alloys and the organization of production

Copper in its pure form is quite soft and therefore not suitable for many uses. But alloying it with other metals such as tin, zinc and lead greatly improves its range of applications (Bayley and Butcher 2004, 15). Choices would need to be made regarding the alloy composition, knowing in advance whether an object was to be cast at high temperatures from a mould, or cold worked, perhaps annealed or finished by hand carving. Bronze was created in a crucible, by heating copper with tin, but brass was created quite differently, using the cementation process developed during the early the Roman period, initially for coins and military equipment (Dungworth 1997, 903). That said an ingot of brass once produced, could be remelted in a similar way to an ingot of brass. Gunmetal alloys were mixtures of both brass and bronze and therefore could contain mixed properties of either, or be a good way to recycle mixed scrap bronze and brass metal. Then, finally lead could sometimes be added to any of the mixtures, to improve casting or machining qualities (Bayley and Butcher 2014, 15). Tin and zinc, as a raw material were also mined from quite different areas to each other, adding a trade and supply aspect to the choices made in production. A major tin source was from Cornwall in England, whereas zinc was probably mined, then supplied from the Ardennes region of modern day Belgium (Roxburgh et al. 2014, 19). All of these factors become interesting when artefact groups of a uniform typological nature become available to study. How uniform or otherwise was the choice in alloy? Especially when considering large geographical distribution areas or lengthy periods of time. The level of uniformity (or standardisation) can subsequently be compared conceptually to the organisation required to maintain that standard. Furthermore, changes in scale and standards of craft production may also be indicative of changes to economic fortune (Wickham 2005, 700).

Although archaeological evidence is scarce, the social organization of early medieval craft production has received much interest (for example, Bayley 1992; Callmer 2001;

Hansen et al. 2015; Hinton 2010). Verhulst 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 those working within more sedentary environments (Verhulst 2002, 72). It is clear that different organizational structures for artisan production must have existed. Söderberg, a Swedish archaeologist and craftsman, adopted a classification system for an organizational study of copper-alloy crafting activities (2002, 116, from an earlier suggestion by Hedegaard 1992). This classification system differentiated the activities as follows:

a) Royal centres, with professional craftsmen possibly engaged as bondsmen, concentrating on unique high-status objects. Highly skilled, demonstrating a variety of techniques.
b) Supra-regional, professional, intensive seasonal production at permanent workshops, with the products destined for periodic markets.
c) Permanent administered urban production sites, such as emporia; products destined for market.
d) Infrequently used primitive workshops, making consumer-driven goods and exhibiting little experimentation.
e) Merchants, whilst travelling, producing simple items such as ingots and weights.
f) Domestic households, non-professional, including simple jewellery and repairs.

The available technology together with the artisanal skill required to produce different groups of copper-alloy artefacts can be compared to these theoretical workshop models (by evaluating compositional and typological consistency for example). This allows us to suggest something about the organization of their production. Artisans engaged at royal or elite centres would have had a certain amount of control of the raw materials they chose to work with, both in terms of the quality and in terms of the quantities needed - to regularly create the artefacts that they were skilled at making. Craft activities at domestic households in contrast may have been undertaken with less control, as both access to raw materials, equipment, and specialist knowledge would likely to have been more inconsistent by comparison. Therefore morphological consistency can be assessed in conjunction with alloy choice. Consistency (or otherwise), based on intentional choice, when studied over wide geographic areas can add to our understanding of how standardised production was (Martinón-Torres et al. 2012, 536). An assessment of the level of standardisation can then be compared conceptually against organizational structures such as those presented above and new hypotheses can be formulated about how artefacts interacted within the wider economy (for example Roxburgh et al. 2016; Roxburgh et al. in press Nov).

Objectives and questions

The main hypothesis in this chapter is that a compositional approach to the study of artefacts can tell us something about the social dynamic of craft production A second hypothesis is that something useful can be gained by conceptually modelling the workshop organization behind the production of these objects. This could result in the ability to distinguish between local and regional production, or indeed (in the case of unusual items) be suggestive of non-standard copying - perhaps by local artisans - of items produced elsewhere. Furthermore, based on the alloy choices (consistent or otherwise), present in different object groups, we assume that something new can be inferred regarding their associations to one another and subsequently their cultural context.

The questions we address are as follows: can we draw conclusions about the likely organization of production and the subsequent distribution of these artefact groups from the compositional analysis? If so, can we suggest what, when, how and – indeed – if local production took place, or whether the artefacts from Walcheren represent imports to the island? If the previous questions can be addressed, what can we infer about the cultural associations attached to these objects, either in a local Walcheren or a wider North Sea context? Can we support for example Anglo-Saxon, Anglo-Scandinavian, Frisian or Frankish contexts for these objects, or do we need to consider a more multicultural solution that includes several or all of them?

MATERIALS AND METHODOLOGY

Materials

As mentioned earlier, a large proportion of the objects studied here were beach finds, found near the modern seaside town of Domburg and subsequently catalogued in the publication by Capelle (1976).

These objects were eventually placed into the care of the Zeeuws Museum (Zeeland Museum) and the Stichting Cultureel Erfgoed Zeeland (SCEZ; Zeeland Cultural Heritage Foundation), partly as the collection of the Koninklijk Zeeuwsch Genootschap der Wetenschappen (KZGW; the Royal Zeeland Society of Sciences), located in Middelburg (also see Feldbrugge in press). The material was first accessed for HHpXRF measurements by the third author, Van Tendeloo, with scientific support from the Dutch Cultural Heritage Agency (van Tendeloo 2017, supervised by the fourth author, Huisman). The data from this initial study was subsequently absorbed into the much larger project undertaken by the first author, Roxburgh, as part of his ongoing PhD research ('Charlemagne's Workshops' - is a qualitative and semi quantitative investigation into the composition of early medieval copper-alloys. The project attempts to model the chronological and geographical nature of alloy choice

employed by the craftsmen and those organising production. It then attempts to model the social organization of production and its role in the early medieval economy). A follow-up visit was subsequently undertaken in late 2014, which widened the geographic area to include finds from Middelburg and, as a comparison, from the neighbouring island of Schouwen. It was observed at this point that trends were appearing in the choice of alloy use for some of the typological groups. The groups that presented the clearest trends were disc and ansate brooches, dress and ring pins, stirrup-strap mounts and a large number of zoomorphic mounts, all of which warranted a closer investigation. We selected these coherent typological groups of items from the Walcheren collections and decided to study them from an interrelated compositional, typological and contextual perspective (see also Roxburgh et al. 2016 roman brooches).

Disc brooches - AD 800 to AD 1100

This is an artefact group that is being found in ever increasing numbers across North Western Europe (see fig. 1 and table 1). One of the most useful typologies for this group is the one published by Bos in 2006 (2006b). This is because it draws on earlier typologies from North Western Europe, including chronological criteria, before approaching the subject from a Frisian perspective (see Frick 1992; Hübener 1972; Wamers 1999). The catalogue therefore is a good starting point for studying the disc brooches found across the Netherlands. Bos broadly places these brooch types in the ninth- to eleventh-centuries, but tentatively suggests that a few of the subgroups may start as early as the late eighth century and that a few later groups may still have been in use as late as the twelfth century (for example Bos 2006b, 767, for early subgroup 2.7.1. Saints brooches, 722, for late subgroup, 2.3. central cloisson). Typologically speaking the brooches presented in this study conform reasonable well to the categories in Bos's Frisian study. Although dating from the Carolingian/Ottonian period, from a cultural perspective they cannot be considered uniquely Frisian, and there are great numbers of them all over North-Western Europe

Ansate brooches- AD 600 to AD 1000

The typology chosen for this group of ansate brooches was that proposed by Thörle (2001, this typology is also followed by Weetch, in press). A careful inspection of the ansate brooch classifications proposed by Bos - for Frisia - confirmed his suggestion that the brooches found at Domburg represent a different typological spectrum to those from northern Dutch coastal area (Bos 2006a, 455). The brooches date broadly between the seventh to tenth centuries and therefore possibly include some late Merovingian examples (see fig. 2 and table 2). The larger proportion would seem to date from the Carolingian/Ottonian period; however, Thörle's chronology suggests that they may have gone out of use earlier than the different types found in the north. He considers them to be a Western Frankish group (confined to Neustria, Burgundia, Aquitania).

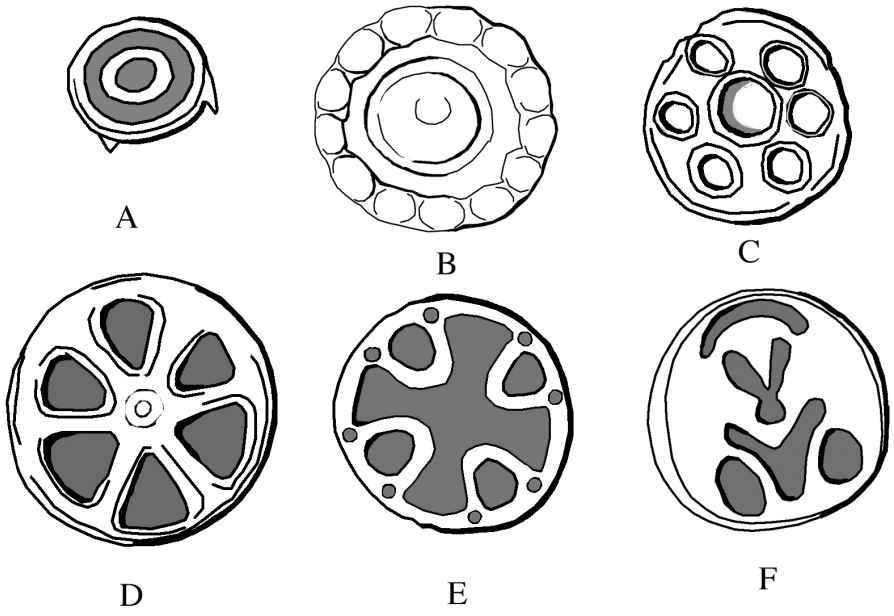

Figure 1. Disc brooches, A - Type 2.1, B - Type 2.2, C - Type 2.3, D - Type 2.4, E - Type 2.5, F - Type 2.7 (schematic drawings by first author).

Location	Domburg	Westenschouwen	Middelburg
No.	23	21	9
Type (Bos)	**Description**	**No.**	
2.1	circle-and-dot(s) or concentric circles	2	
2.2	central convex boss	1	
2.3	central cloison	11	
2.4	pseudo-cloison	3	
2.5	one of more crosses	32	
2.7	human or animal figures	4	

Table 1. Number of disc brooches per location and per type.

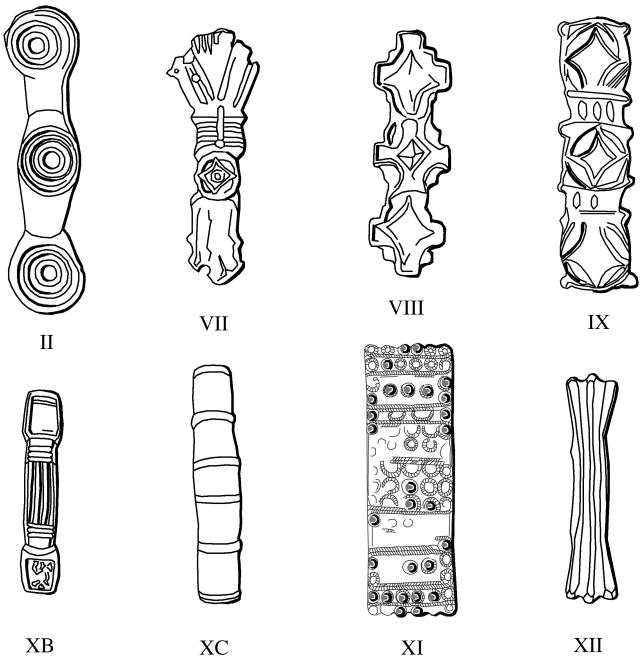

Figure 2. Ansate brooches from Thörle's types (schematic drawings by first author).

Location	Domburg
No.	82
Type (Thörle)	**No.**
II	10
VII	7
VIII A&B	5
IX E&F	3
X B	8
X C	12
XI B&C	6
XII A	30

Table 2. Number of ansate brooches per location and per type.

Dress pins - AD 600 to AD 1100

A detailed typology for non-ferrous dress pins has been published from 407 examples excavated at the contemporary early medieval settlement of Flixborough, England (Rogers et al. 2009, 32). The polyhedral-headed pins from Domburg (see fig. 3 and table 3) seem to conform to the Flixborough Type 2 series. They only account for 18% of the pin types found in Flixborough, whilst the polyhedral-headed type at Domburg accounts for 50% of the measured assemblage. The earliest polyhedral-headed Type 2 pins at Flixborough are from the late seventh- to early eighth-century layers and are accordingly dated as such. The next-largest group of pins from Domburg generally conforms to the Flixborough Type 3 biconical series (see fig 3, - 3a, 3b, and 3c), the earliest of which - for Flixborough - were found in late seventh-century layers, with both types present in the latest tenth-century layers. There is an additional Type 1 globular pin, which were in use at Flixborough from the mid-seventh to early eighth until the tenth century. Like the disc brooches discussed previously, these objects are numerous all along the coast and cannot easily be culturally assigned.

Figure. 3 Dress pins, Type 1 Globular, Type 2 Polyhedral Type 3a Biconical, 'berry' shaped, Type3b - Biconical, Type3c - Biconical with collars (schematic drawings by first author).

Location	Domburg	
No.	26	
Type (Rogers *et al.*)	**Description**	**No.**
1	Globular	1
2	Polyhedral	13
2	Sub Polyhedral	2
3	Biconical	6
3	Biconical, Berry Shaped	4

Table 3. Number of dress pins per location and per type.

Ring pins - AD 600 to AD 1100

Hinton describes this type of pin as a ring pin (see fig. 4 and table 4; and Hinton 2005, 86, fig. 3.5). There are two options for the function of these pins. The first option is that they could have been worn as a dress accessory, perhaps at the opposite ends of a chain (They could therefore be described as linked pins, see Rogers et al. 2009, 36, 62, fig. 1.26). A pair linked by a chain was recorded as being located at the shoulder of the skeleton in a seventh-century grave in England (Meaney and Hawkes 1970, 37). The second option is that they were attached to a ring, (sometimes an adjustable type called a slip ring), presumably for attaching onto a belt or other part of personal apparel. In both cases, the pins are morphologically the same and in many cases they are missing either the ring or the chain, so it is not possible to determine which type the pin belonged, or indeed if they had a ring or chain at all. For that reason, the two types are grouped together (It should also be noted that these pins should not to be confused with the typical Viking ringed pins discussed elsewhere by Fanning, Viking age Ringed Pins from Dublin).

From the Roman period onwards, pins such as these could also be part of toilet sets mounted on chatelaines, usually together with tweezers or ear scoops (D'Ambra 2007, 116-117). A number of tweezers were found at Domburg and published by Capelle (1976, table 35). Capelle also recorded a number of chains (1976, tables 29, 30), some of which conceivably could have had pins attached to them. A silver toilet set from the ninth or tenth century, which comprises of a small ear-spoon and a ring pin with a filigree-decorated head, was found on the beach of Domburg (Collection of the Zeeuws Museum (M97-034). See Van Heeringen 1990).

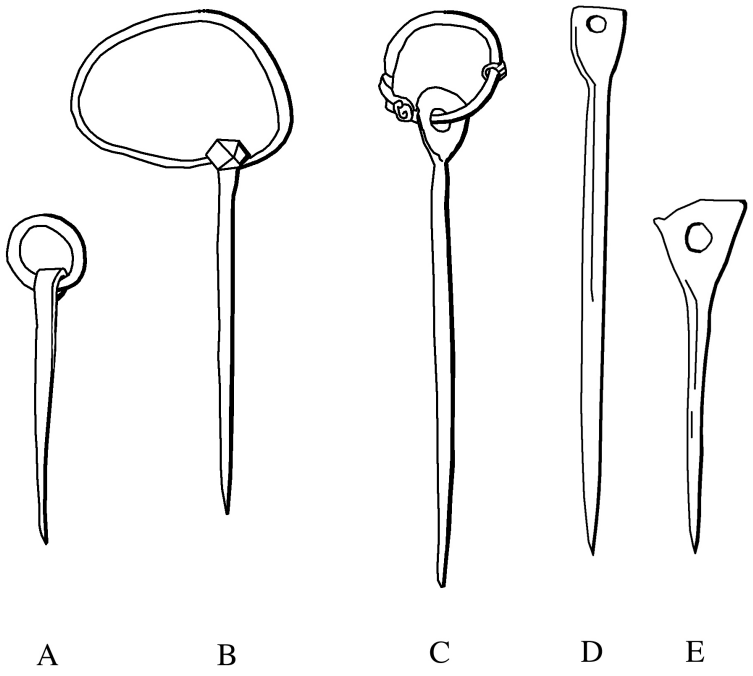

Figure 4. Ring pins, A - Rolled head on ring, B - Polyhedral head on ring, C - Flat round head on slip ring, D - Flat Sub rectangular head, E - Flat triangular head (schematic drawings by first author).

Location	Domburg	
No.	38	
Type	**Description**	**No.**
Pin with ring	Biconical head	1
Pin with ring	Rolled head	2
Pin with ring	Polyhedral head	1
Pin with slip ring	Flat, round head	5
Pin with slip ring	Flat, round head, knob, double collar	1
Pin with slip ring	Flat, sub-rectangular head	2
Pin with slip ring	Polyhedral head	1
Pin with no ring	Flat, round head	11
Pin with no ring	Flat, oval head	2
Pin with no ring	Flat, sub-rectangular head	5
Pin with no ring	Flat triangular head	1
Pin with no ring	Rolled head	4
Pin with no ring	Polyhedral head or collar	3

Table 4. Number of ring pins per location and per type.

Stirrup-strap mounts AD 900 to AD 1100

The typology published by Williams for late Saxon stirrup-strap mounts attempts to classify and catalogue the large number of examples found in England (1997, 105). In achieving this aim, however, some attention is given to mounts found on the continent, including those found at Domburg (see fig. 5 and table 5). The objects included in our compositional study have been classified as stirrup-strap mounts either because they are directly referenced in Capelle, by Williams, or they are fragmentary objects that have strong morphological affiliation to Williams's Class B typology, i.e. other possible continental types. All eleven of the objects therefore show a close similarity to the class B typology. Williams suggests that the Netherlands could be the source of origin for Class B mounts, which first appear on the English east coast before spreading westwards into the interior (1997, 105). One item (similar to Class B Type 3) was included from Westenschouwen for comparative purposes.

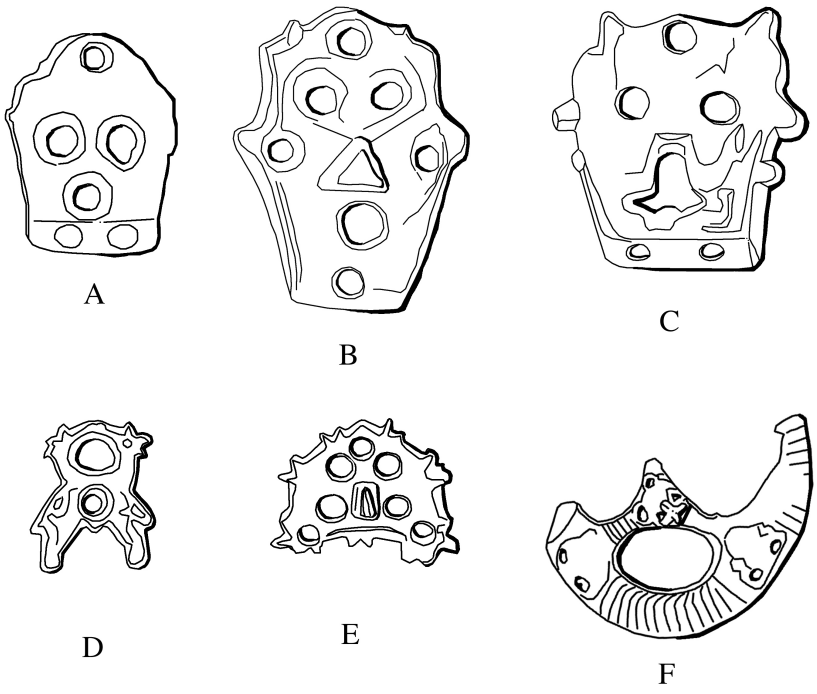

Figure 5. Stirrup-Strap mounts - Class B; A - Type 2, B - Type 2, C - Type 2, D - Type 2 similar, E - Type 3 similar., F - Type 1 similar (schematic drawings by first author).

Location	Domburg	Westenshouwen
No.	10	1
Type (Williams)	**No.**	
1	1	
2	6	
3	4	

Table 5. Number of stirrup-strap mounts per location and per type.

Zoomorphic mounts and associated items, AD 800 to AD 1200

In our study area the largest number of zoomorphic mounts and associated items were found at the beach near Domburg (see fig. 6 and table 6) and were subsequently published in a catalogue by Capelle (1976). A more recent study was undertaken in 2015 and subsequently published by the authors, and the classification presented above stems from this article (Roxburgh et al. 2018 in press). Also the reader can refer to Webley (in press). A few similar items have been found in other areas around the North Sea but in relatively small numbers by comparison to Walcheren. Also, mounts like these in the northern Dutch coastal area are usually decorated with an antropomorphic head rather than a zoomorphic one and may be slightly different in size. The results of the study of the Domburg mounts suggested that the production was likely to have been local and that their compositional and typological characteristics matched certain forms of Viking-Age equestrian gear, such as Williams Class B stirrup-strap mounts, mentioned above. The small size of these zoomorphic mounts in comparison to equestrian harness fittings allowed for discussions around their use as personal dress accessories, suggesting that the decorative style was not just reserved for equestrian gear.

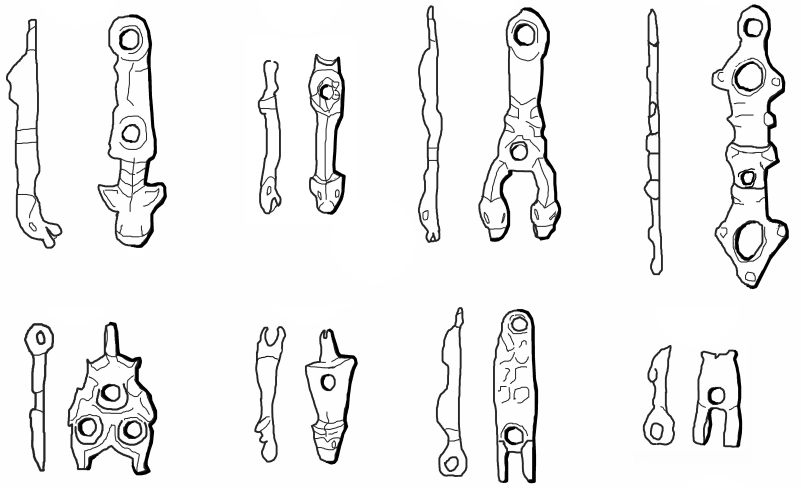

Figure 6. Zoomorphic mounts (schematic drawings by first author).

Location	Domburg - beach finds	Domburg - ring fort	Middelburg
No.	83	5	2
Classification	**No.**		
Pendant	5		
Pendant mount	6		
Strap-end mount	57		
Strap-link	22		

Table 6. Number of zoomorphic mounts per location and per type.

METHODOLOGY

As stated in the introduction, the compositional study that underlies this chapter was carried out with hhXRF (see Shackley 2011; Shurgar and Mass 2012, for more technical details and applications in archaeology). An X-Ray tube with a silver anode fires a primary X-Ray beam at the object of interest. As a result, this beam causes the atoms in the object to become excited, resulting in the release of electrons. The energy given off by the release of electrons is unique for each chemical element present, and can be measured by a detector, mounted within the equipment. From

these measurements, an assessment of the ratio of each element present in the object can then be made.

A Niton XL3t GOLDD XRF device was used for the study. These are factory calibrated, with different internal standards for metals and alloys, and consequently the 'electronic metals mode' was used to gather the data. The advantage of this mode is that it was developed for measuring the metals used in modern electronic equipment (Cu, Sn, Ag, Zn, Au), including a number of - as identified in modern times - potentially hazardous ones as well (Pb, Hg, As, Se), all of which can be found in medieval alloys. After testing with longer measuring times, the signal was found to be stable after a reading time of 35 seconds, so this was deemed sufficient to determine a minimal elemental count of 10ppm for most elements. Two spectrum readings per 35 second intervals were taken, 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 artefact was taken and after the analyses, the spectra were processed using dedicated Niton software and subsequently checked for unexpected peak overlaps.

An external normalization of the completed dataset was undertaken using Microsoft Excel, which corrected for the contribution of light elements present due to contamination from soil residues (such as sand, clay and iron hydroxides). The elemental concentrations of the alloying elements were subsequently normalised on a light elements (Si-Fe) free basis. For the purpose of our research, only the alloying elements (Sn, Zn, Pb) were considered. This is because in addition to copper, which is always present in a copper-alloy, the addition of these elements can be considered as a deliberate act, especially in terms of their mixing ratios. The factory calibration of the device was also checked against the CHARM - bronze reference set (See fig.7, left; also see Heginbotham et al. 2015) and bias due to corrosion was evaluated by comparison to recent studies on corroded Roman finds, which revealed that copper and zinc are the main elements that degrade during the corrosion process, creating the green or brown patina and also permanently altering the original metal surface layer (see Fernandes et al. 2013; and also Roxburgh et al. 2016a). The ternary diagram (fig.7, right) demonstrates the deviation in alloy ratio between corroded and non-corroded measurements. The trend in zinc loss is clear, therefore if it had been possible to destructively clean all the artefacts measured for this paper, it could be expected that the results presented in the diagrams in fig. 8 (below) would deviate in a similar way.

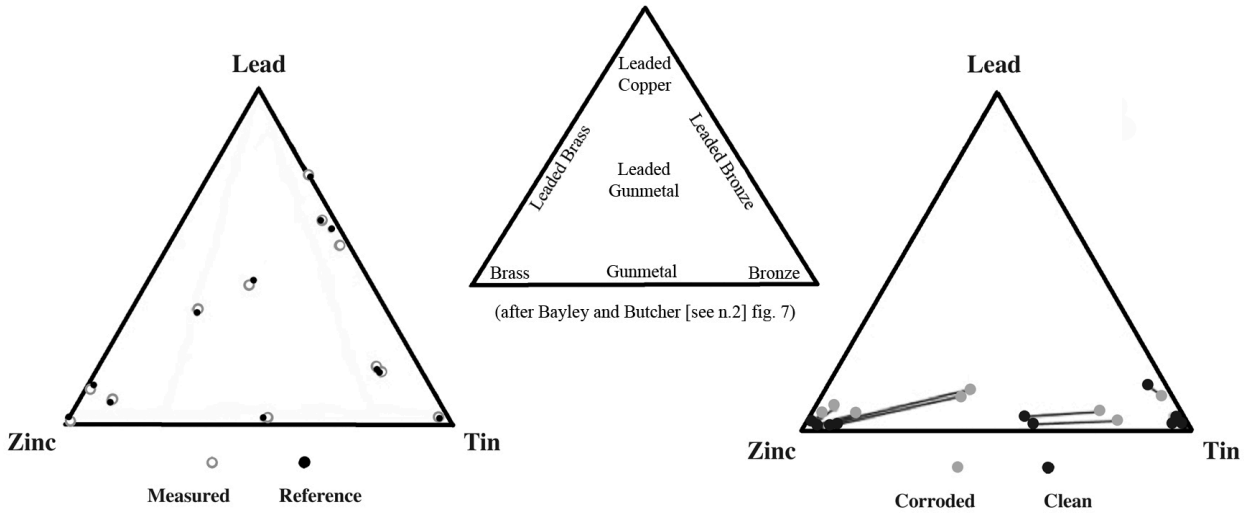

Figure 7. Ternary graphs showing - compositional classifications in centre (after Bayley and Butcher, 2004, fig.7); measurement bias compared to the CHARM standard (left) and deviation in measurement due to corrosion (right). Drawn by first author.

RESULTS

The compositional survey initially included a number of other object types that have not been included in these results. Belt buckles, strap-ends and keys were so diverse typologically that, not surprisingly, their alloys were equally diverse as well, not conforming to any trend in compositional choice. This could be due to the types being created over an uncertain length of time and over an uncertain distance from Walcheren. More and more of these artefacts are being recovered all the time, which may reveal more standardised groups, but at the moment the lack of objects belonging to distinct typological subgroups and that are available for analysis is a drawback. The other hypothesis of course is that the early medieval craftsmen (deliberately) chose not to organise the production of these items along compositional guidelines, perhaps as an outlet for recycled metal, which would also have produced the unorganised result. The wide range of stylistic variability for strap-ends found at Domburg bears some comparison to the variability found at excavations at Flixborough in England. Thomas has suggested for Flixborough that this may be because the markets were supplied by many different workshops rather than a limited number of more standardised regional production centres (Thomas et al. 2009). This model could be true of the Domburg strap-ends as well, but a more seductive argument links this to identity, perhaps the diversity in strap-end styles at Domburg together with the diverse alloy choices within them are representative of a diversity of people or their fashions and affiliations passing through a central place. Further investigations of these diverse and fascinating objects, combining typological and compositional research, may reveal more in the future.

The results presented in the following ternary diagrams (fig. 9) are for groups of objects that demonstrated a compositional trend, typically in a brass or a bronze alloying tradition. The results are discussed in more detail in the next section.

DISCUSSION

Disc brooches - Fig. 8, graph A

The measurements on thirty-eight of the brooches showed a strong correlation to the results found in other parts of the Netherlands. These brooches were produced from a leaded copper-zinc-alloy containing no tin (For comparable results from Friesland/Groningen and Nijmegen in particular see Roxburgh et al. 2016, fig. 5). But the remaining fifteen brooches, even considering changes introduced by corrosion, have been produced with different alloys. Middelburg has four brooches made from tin, and two from gunmetal. Domburg has four made from bronze, two from pewter, and three from gunmetal. Noticeably, the brooches from across the Oosterschelde at Westenschouwen conform to the rest of the Netherlands, so it is only at Domburg and Middelburg that these differences are present (For the fiveteen deviating alloy results see measurements plotted as circles in fig. 8, graph A).

Ansate brooches - Fig. 9, graph B

The measurements on these brooches strongly suggest a preference for production in a leaded bronze or leaded gunmetal tradition. Only eight of the brooches appear to have been produced from brass. Two groups appear to be present in this brass category: one group of five appears to have been made in a high-quality brass, whilst the other three may have had more lead in them or possibly lost more zinc in the corrosion process. From the brooches just mentioned, three of those produced in the brass tradition are group II brooches (Thörle 2009, group II E2; Capelle 1976, table 5, fig 54, fig 56). A further three brooches belong to group X C. Another brooch belongs to group XII A1 (Capelle 1976, table 4, fig. 47), and the final one can be identified as group VIII B (Capelle 1976, table 3, fig.21).

All of the other brooches appear to be made in the bronze or gunmetal traditions.Bos suggested that the northern Dutch (Friesland) anseat brooches are regionally different to those from Belgium and Northern France, and importantly from Domburg (Bos 2006a, 455, comparing studies by Hübener 1972; Van Bellingen 1988; and Capelle 1976). The choice of gunmetal or bronze in the production of the brooches found at Domburg appears to support this as the Frisian ansate brooches were made in a different leaded brass alloy (Roxburgh et al. 2014, 25).

Dress pins - Fig. 8, graph C

Two alloy groups are present amongst these dress pins. The largest, comprising 80% of the assemblage, is a group in the leaded bronze tradition. The smaller group has been made in a brass tradition, two of which may have contained a higher proportion

of lead than the others. There is no typological trend to the compositional results. Ross suggests that the late seventh century sees the beginning of the mass production of cast pins (1991, 110). The preferred composition for these items was perhaps a leaded bronze because of its ability to be finished by cold working, either by filing or beating with a hammer. The few made in brass may indicate the recycling of older objects. Good-quality brass was produced in the Roman period up until the second century (Bayley and Butcher 1995, 118). In other words, it is possible that this alloy was Roman in origin and cold-worked into the new pin shape.

Ring pins - Fig. 8, graph D

For the ring pins, the composition of the pins was measured, and not the wire ring. The results demonstrate a clear preference for production in a leaded bronze or leaded gunmetal. The craftsmen may have had a choice between hammering these items from ingots or scrap pieces of copper-alloy or casting them in a mould, or using a combination of both techniques. Unfortunately, perhaps due to the lack of better chronological dating, no other alloy trends can be detected using hhXRF.

Stirrup-strap mounts - Fig. 8, graph E

The results for the stirrup-strap mounts and associated items show that they group well within the brass making tradition. It has been shown in figure 7 (right) that the effects of corrosion on this data produces lower zinc levels than if we were able to analyse fresh, uncorroded alloys. This suggests therefore that the stirrup-strap group of measurements (if destructive cleaning took place) would cluster more closely together and that originally they were produced with a higher zinc content, more than for example, the majority of the disc brooches in Figure 8, graph A.

Zoomorphic Mounts - Fig. 8, graph F

The results also show that zoomorphic mounts group well within the brass-making copper-alloy tradition. A comparison to the other artefact types in the survey reveals a strong relation to the group of measurements taken for the stirrup-strap mounts. The measurements for the zoomorphic mounts suggest that they share the same composition as the stirrup-strap mounts.

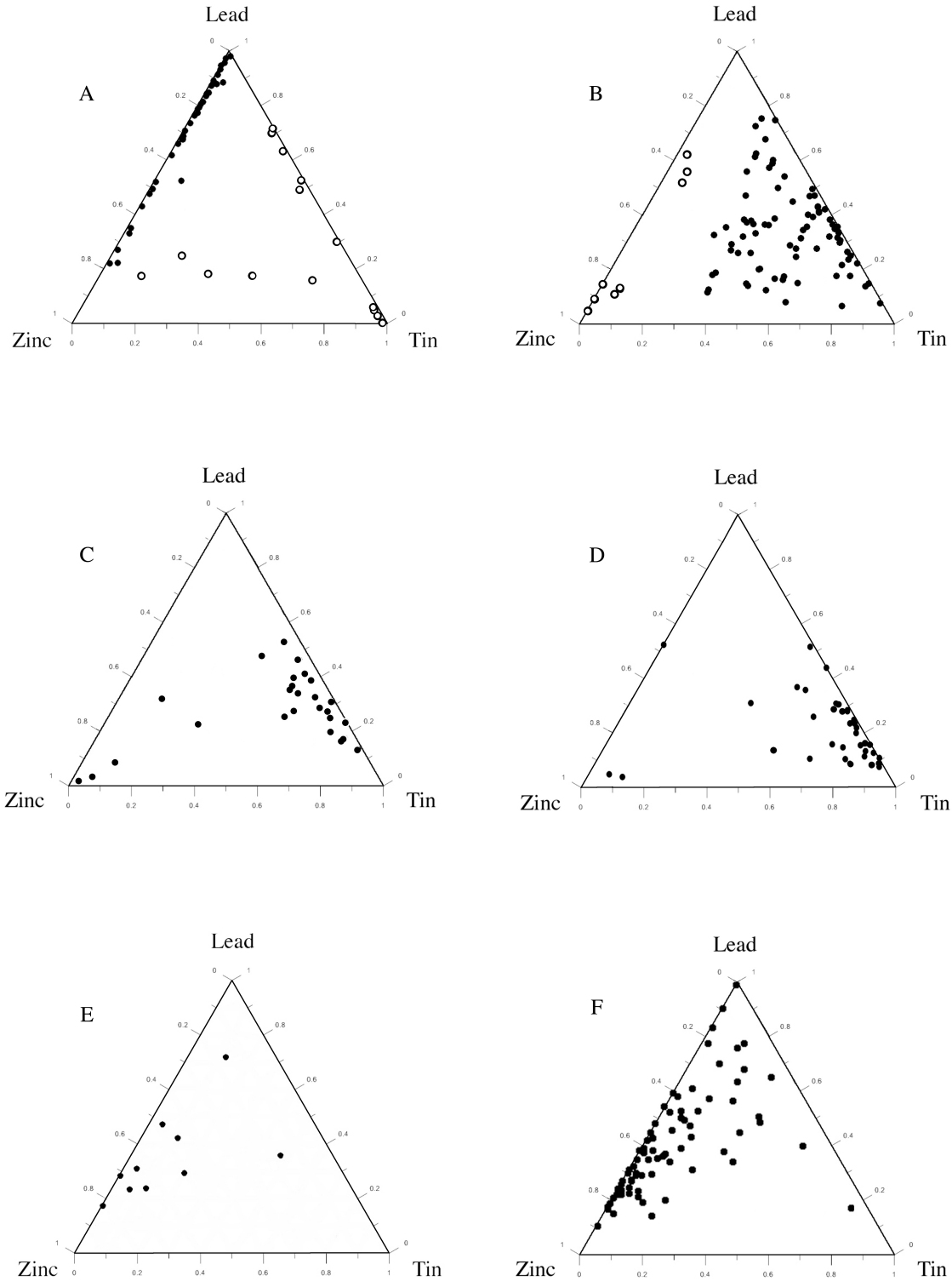

Figure 8. Ternary graphs, A - Disc brooches, B - Ansate brooches, C - Ring pins, D - Dress pins, E - Stirrup-strap mounts, F - Zoomorphic mounts.

Discussion

The most important observation from the compositional analysis is that the craftsmen were controlling the use of different alloys. Whilst corrosion has affected the original metal composition to an extent, we can see that different alloys tended to be reserved for different artefact groups. The production of brass at this time - needing lidded crucibles to trap the gasses - was a technologically different process than that used to produce bronze. The craftsmen could have been well aware of this when producing these objects, even if they were primarily concerned with production using premade ingots (The ore calamine was needed for brass production along with a technical process called cementation, Bayley and Butcher 2004, 12-13). The colour difference between brass (with its yellower appearance) and tin rich bronze and gunmetals, was one of the main ways craftsmen identified it from the other alloys, therefore enabling choice when it came to production decisions (Bayley and Butcher 2004, 13; also Baker 2013, 429). They would also have been aware of the quantities of lead added, or the amount of scrap metal to recycle into a certain object type. The alloy groups presented in the results section can to some extent be considered evidence of conscious decisions, taken individually or collectively within an organized craft and remaining consistent over several generations of craftsmen. In this section we attempt to form hypotheses about the organization behind the production of these items, by comparing the results against the workshop models presented in section 7.1.3. These hypotheses will allow distinctions to be made between local and non-local production, which in turn will inform the final part of the discussion, which focuses on identities and the social meaning behind these functional but deliberately styled objects.

Workshop organization and access to materials

Disc brooches

As mentioned earlier, Bos has suggested a broad date between the ninth and eleventh centuries for these items, with the earliest Carolingian brooches appearing around AD 800, if not slightly earlier. The wider compositional survey by the first author (Roxburgh) has shown that from this early phase the alloys consisted of a leaded copper-zinc mixture with an absence of tin. This mixture or tradition seems to have been maintained across what is now the Netherlands for a period of three hundred years. This tradition therefore would have needed controlling over several generations of craftsmen if other alloy choices were to be avoided, especially in the disposal of scrap bronze. This would have introduced variable levels of tin into the alloy, which is not the case. This would be the situation for Walcheren as well, except that it is as yet the only location that has produced disc brooches in deviating alloys. This has some very interesting implications for the organization of brooch production.

A hypothesis for the workshop organization of Carolingian disc brooches has been suggested in more detail elsewhere (Roxburgh et al. 2016, 125-128). The consistency of alloy choice rules out production at primitive workshops, domestic households and by travelling merchants, because of the greater freedom of choice - to work with whatever was at hand - under these conditions. No recycled material containing tin for example, in the form of gunmetal or bronze, is apparent in these results. Furthermore, the skill levels required to consistently produce these brooches, most of which are enamelled, would most likely not be present under these conditions. Therefore it can be suggested that the source of production lies within the more organised models, such as at royal estates, emporia, or monastic production at the great abbeys; either on a regional or supra-regional scale.

Whilst there is good evidence for monastic landholdings from distant monasteries on Walcheren, production appears to have been agricultural in nature rather than metalworking (Henderiks in press). If we assume therefore that the disc brooches made from the standard alloy, originated from a monastic production model - perhaps produced at a site some distance away, serving a much larger region - the fifteen disc brooches that were made from deviating alloys require a different explanation. If we consider them to be copies of the more commonly found brooches, it would be reasonable to suggest that a craftsman skilled in working with copper alloys could copy a disc brooch if required to do so. The end result would be to meet similar functional and visual standards as the original. What might be less apparent, however, is the compositional mixture. If the copying was done outside of the control of the main workshop, in this case probably a monastic one, the specific alloy, or the knowledge to replicate this alloy, may not have been available to the person replicating the brooch. This would leave him free to choose a different alloy, such as a bronze, gunmetal or pewter, as we have seen in the results above. On the assumption that these disc brooches were produced on Walcheren in the first place, an hypothesis for the deviation in alloy - subsequently produced under a different workshop organization - can then be proposed. It is clear that the island was gifted to Danish warlords in the ninth century and it is not unreasonable to suggest that one of the requirements of local craft workers on Walcheren, including metal workers, would be to meet the demands of a new non-Frankish elite. The exact timespan for Danish rule is yet unclear and it might have only lasted a few decades. But a change in workshop organisation and its metalworking traditions brought about during this time may have continued - in some form - long after its return to control by a local elite. This change could account for the break in knowledge regarding the alloy composition. That to an extent, production was taking place in isolation from the main centre, perhaps situated some distance within the Frankish heartland. The two organisational models that best fit this scenario are as follows: either Model A, involving top-down control from a royal centre, in this case associated with Danish warlords, with professional craftsmen possibly engaged as bondsmen. Or Model C, involving a permanently administered urban production site, for example associated with an emporium or trading post, with products destined for a market. If we assume that craftsmen working at a royal centre would have been more occupied with producing elite goods, then the latter model

seems the best fit, although it might still have been working under Danish administration for a time.

Ansate brooches

Unlike the disc brooches discussed above, the ansate brooches do not appear to be imbued with Christian meaning. The vast majority are made from bronze or gunmetal, which is at odds with ansate brooches found in the northern areas of Frisia, which are made from the same alloys as the disc brooches discussed above. This suggests two separate workshop traditions producing a separate range of typological styles for either the Frankish or the Frisian areas. The use of leaded bronze or gunmetal for brooch production is the norm for the Merovingian period, as zinc was not mined during this time. The dating for the ansate groups found at Domburg is quite broad, encompassing the seventh to tenth centuries One could therefore propose that the bronze or gunmetal alloying tradition started in Merovingian times but then continued unbroken into the Carolingian period, when zinc and hence brass alloys had become available again. This consistency – at a time when production in brass *could* have replaced this earlier tradition – suggests a degree of organization and control.

There are a small number of brooches whose alloy measurements deviate from this norm, as seen in the left of figure 8, graph B, which have been produced from brass (For the brass results see measurements plotted as circles in fig. 8, graph B). This production could be associated with the stirrup-strap mounts or zoomorphic mounts, as they are made from a similar alloy group and therefore could be local in origin perhaps copies of styles more commonly found on the Frankish mainland. As with the disc brooches discussed above, production at primitive workshops (model D), merchants (model E), and domestic households (model F), are the least likely options, based on the same reasoning. Production at royal estates (model A) is also less likely due to the likelihood that these would be focused on making high-quality items (Such as the craft production at the Royal Palace at Aachen, see Schutz, 2004, 386), which leaves either model B (supraregional, professional, intensive seasonal production at permanent workshops), or model C (production at permanent administered urban production sites, such as emporia or trading posts). Both of these models involve the production of items destined for a market. Therefore the majority of the ansate brooches found on Walcheren were most likely produced at a number of urban centres within the western Frankish heartlands, producing stylistically different decorations, perhaps evolving over time. Alternatively (but less likely), they may have been produced at a supra-regional production centre, possibly monastic, again in the Frankish heartlands, whose output changed stylistically over a long 400-year period. That said, one of these production sites could have been on Walcheren, giving rise to a local ansate brooch style and including a small number – mentioned earlier – that were produced from brass.

Zoomorphic mounts

The disproportionate number of zoomorphic mounts found around Domburg by comparison to other areas suggests that they perhaps were produced locally (see Webley in press). This could therefore be associated with production at the trading post (if it was still active; Deckers, this volume), or at an administered workshop, where both the required skills and a continued availability of zinc ore (to produce brass), or brass ingots - traded from elsewhere - would have produced the consistent alloy ratios seen in the results (For archaeological evidence of Brass ingots, see Bayley et al. 2014; Sindbæk 2001*).* This hypothesis matches Söderberg's model C: a permanent administered workshop site manufacturing objects for trade.

It is less likely that production took place within models A or B, i.e. casting within royal or supra-regional centres. The professional craftsmen engaged at these places may have been more concerned with higher-quality items in the first instance and then secondly, regional or supra-regional production would presumably have produced higher volumes distributed over a wider geographic area, resulting in more of them being found in other locations. Thirdly, in considering the Christian nature of the Frankish world, many copper-alloy items found within the heartlands bear Christian motifs. This is not the case for the mounts in this analysis: indeed, they appear to be influenced by animal styles, Many Scandinavian zoomorphic art styles were adopted and developed over time into local forms within the Christian Anglo-Saxon and Frankish world, and metalwork styles in particular were appropriated and integrated into local cultural traditions (Kershaw 2010; Thomas 2012). However the large-scale production of items bearing motifs that were not explicitly Christian in their design would seem at odds with production at Frankish royal estates and monastic workshops. It is more likely therefore that production took place at a more neutral workshop, such as one associated with a different power-base such as a trading site.

Production at primitive workshops (model D) seems equally unlikely, because the skills and knowledge required to apply the zoomorphic decoration would have to have been maintained over long periods of inactivity. The technological knowledge required for casting in brass would also have had to be maintained over these gaps. It would also seem likely in this model that scrap items would be poorly sorted, allowing bronze or gunmetal to enter the mixture, which does not appear to be the case in this instance.

It is also less likely that travelling merchants (model E) produced these mounts. They may well have had something to do with the production of - or trade in - brass ingots, such as those found in excavations as distant as London, Hedeby and Gotland (see Bayley et al. 2014; Sindbæk 2001). It is more likely that travelling merchants would have been primarily interested in trading finished goods, rather than overseeing their production. Finally, the least likely option of all is production in a domestic setting (model F). In contrast to simple repairs and alterations, the more advanced craft skills needed to cast in brass and to decorate in a zoomorphological style, do not fit this model.

The most likely model therefore is that of an urban production site (model C) under a Church neutral administration - possibly Scandinavian or Frisian in nature rather than Frankish.

Stirrup-strap mounts

As discussed earlier, the alloy measurements for this artefact group generally exhibit the same leaded brass composition as the zoomorphic mounts. Therefore a similar argument for the organization of their production could be made, i.e. a local permanent administered workshop (model C) making items for a market. Like the zoomorphic mounts, they are found in other areas around the North Sea as well, including England, Flanders and the modern province of Friesland, but not in numbers comparable to the zoomorphic mounts found at Domburg. For those found in England, Williams suggests a continental influence, if not a production source, possibly within the Netherlands. This is based on the fact that the distribution of the find locations was limited to the eastern coastal counties from Lincolnshire in the north to Kent in the south (Williams 1997, 23). Assuming that stirrup-strap mounts were solely reserved for equestrian equipment and not used to protect the leather strap-ends of some more heavy duty personal equipment (Huggins 1988, 145-147, for example of non-equestrian context), they would have been made in smaller numbers than if they had been produced for personal use. Hence at Domburg they would occur in more limited numbers than the zoomorphic mounts, which is the case. As mentioned earlier, the most likely organizational model is a more permanent administered workshop, possibly on Walcheren, but also possibly in the Northern Frisian areas or in England.

Dress pins

This artefact group represents a class of personal objects that is a relatively common find around the North Sea area. As mentioned earlier, Ross suggests that from the 7th century onwards these items were mass-produced through the adoption of the casting process. Like all of the artefact groups presented in this paper, they are easily transportable, and therefore their find locations could be at significant distances from their points of manufacture. Conversely, the relative simplicity of production by a metal worker means that they could also have been made locally.

The least likely organizational model is that of domestic production (model F). Perhaps repairing took place, but initial casting seems unlikely as it would have required access to moulds, crucibles, specialist tools and raw materials, unlikely to have been found in everyday households, even assuming the skills to use them were commonplace, which is unlikely. The craftsmen engaged at royal estates (model A), whilst probably preoccupied with more elite production, could have produced dress pins quickly and easily in order to satisfy a local demand. Merchants (model E) may also have cast these relatively simple objects as an alternative to ingots and weights, maybe as a way to turn scrap-metal into goods for market. The remaining models (B:

supra- regional production at permanent workshops; C: permanent administered urban production sites, such as emporia or trading posts; and D: infrequently used primitive workshops, making socially determined goods - all producing items for market) therefore remain the most likely sources of these items.

Ring pins

The debate over the production of ring pins follows similar lines to that of the dress pins. The simplicity of these objects including their alloys would allow for production to have taken place within any of the organizational models presented above. However, we can consider models D (infrequently used primitive workshops, making socially determined goods and exhibiting little experimentation) and F (domestic households, non-professional, including simple jewellery and repairs) as particularly valid sources for these items. This is because the ring pins found at Domburg offer little in the way of stylistic consistency, unlike the dress pins with their shaped heads. Functionality appears to be the main criterion and even though a number of them have hexagonally shaped heads, they could have been altered in a domestic setting to take the ring. The ring pins with rolled heads (fig x A); could also have been made by simply taking a thin fragment of scrap copper alloy and then bending one end around a ring.

Identities: Frankish, Frisian, Scandinavian or Anglo-Saxon?

Many of the items are so common and distributed across such a wide area that it is hard to establish a specific cultural sphere to which they belong or to a location to which they were manufactured. This would particularly be the case for the various pin-types. Also there is a chronological dimension as well, as some objects such as the anseat brooches and stirrup-strap mounts can be seperated in time by a century or so. Other objects, more specifically the zoomorphic mounts, seem – in terms of both decoration and distribution – connected to a particular cultural sphere along the North Sea coast, whilst the widespread disc brooches with cross-motifs in form seem to belong to a Frankish sphere. The analysis of the items from Walcheren indicate that these different items with various cultural connections were present simultaneously, like - in the wider context - the dress pins found in Frisia and Flixborough on opposite sides of the North Sea.

An analysis of the alloys in combination with typological data suggests that identities on Walcheren were constructed using objects drawn from both local and non-local sources. This was done either by producing items for various groups in a local workshop, or by using items acquired from sources elsewhere, such as the ansate brooches. A hypothesis would be that the copper-alloy assemblage on Walcheren and in particular from the trade settlement Walichrum reflects a multicultural group, perhaps drawn together by the trading post. This trading post would most likely have

been a neutral site where people from Christian and non-Christian backgrounds, from the Frankish and Frisian areas as well as from the British Isles and Scandinavia, could all come together to exchange items.

In that sense disc and ansate brooches represent a personal connection with people within the Frankish/Ottonian cultural hegemony whilst the zoomorphic mounts and stirrup-strap mounts contributed to an identity constructed from connections with people from Frisian, Anglo-Saxon, and/or Scandinavian areas. Apart from the various individual identities and affiliations that people expressed via this portable metalwork, the general 'identity' of Walcheren as we see it reflected in the archaeological material would have been constructed using a combination of both local and non-local personal items, with Christian and non-Christian decorative styles, and from various workshops. In addition, the local workshop on Walcheren would have produced a range of objects as well, such as copies in different alloys of the Frankish disc-brooches.

Historical evidence indeed suggests the presence of people from diverse backgrounds, drawn together by the opportunities the trading site had to offer. Bearing in mind that within a large coastal area there would most likely have been regional differences, as part of a greater Frisian sphere, some people related to Walcheren may have been called Frisian. In the eighth century, it had become part of the Frankish sphere and Frankish counts seem to have been connected to it. During some time in the ninth century, due to Viking attacks and the measures taken against them, Danish war-lords and their followers (probably being multi-ethnic) were present in Walcheren when it became a Danish benefice.

Despite the many items that belong to widespread continental types, the use of materials on Walcheren distinguishes some of them from their parallels. As such, the metalworking in Domburg and Middelburg stands out through the choices seen in the alloys. The choices in alloy may reflect a local identity in terms of production from a local workshop, as suggested by the zoomorphic mounts in terms of both typology and composition. Together they point to a North Sea identity at the island, which possibly was under Danish administration for some time and which, throughout time, combined Frankish, Frisian and Anglo-Scandinavian influences. This suggests that there is a metalworking tradition on Walcheren, which was able to combine items from the above-mentioned spheres and produce them locally, reflecting the multi-ethnic presence and connections on the island.

CONCLUSION

The nature of the metallurgical tradition at Walichrum is discussed further, elsewhere (see Copeland, Deckers and Weetch in press). The evidence here however suggests that for copper-alloy production at least, it was most likely organised along the lines of a permanent administered urban production site, such as an emporium or trading post, with products destined for market. This model seems the best overall fit as it

would allow for the local production of zoomorphic mounts, stirrup-strap mounts, dress pins, ring pins, and a smaller group of ansate brooches. It would also account for small number of disc brooches produced in a deviating alloy to those found in the rest of the Netherlands. The bulk of the disc brooches and the ansate brooches however, are more likely to have been produced somewhere within the Frankish heartlands. They are likely to have found their way to Walcheren as trade items, perhaps at the demand of the locals, or as personal items worn by people from the Frankish sphere who could have been involved with the trading site. This allows us to consider the existence of a multicultural group of inhabitants, perhaps drawn together by the trading post, which most likely would have been a religiously neutral and multicultural site. For future research, it will be interesting to combine compositional and typological analysis on items from other areas, to see if this can shed further light on the organization of workshops and a possible relations to different cultural spheres.

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