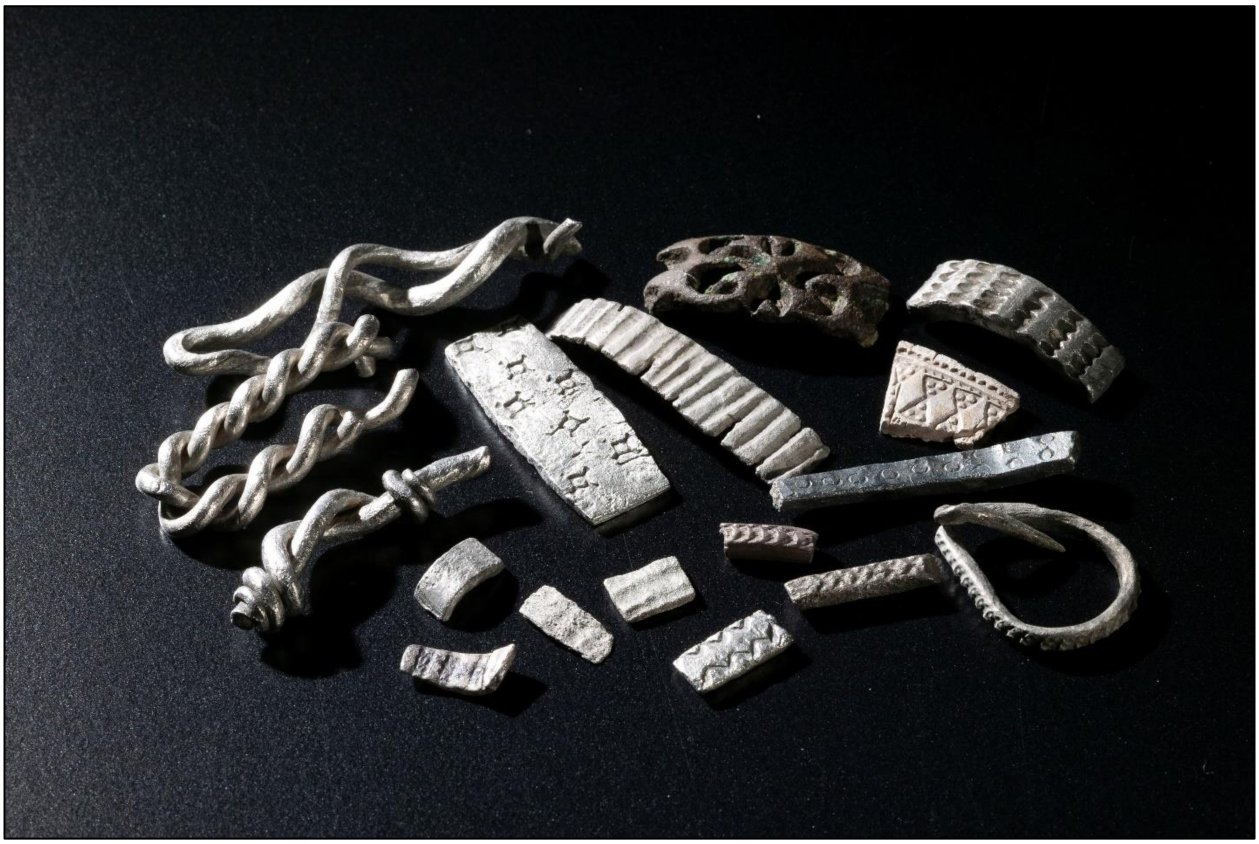
All That Glitters:

A comparative analysis of Late Iron Age non-ferrous metalworking at Kaupang, Ribe, and Birka



Vemund Emil Hoffmann
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Front page illustration:

Fragments of silver and copper alloy arm- and neckrings from Kaupang, photo taken by Eirik Irgens Johnsen, KHM.

Forord

Det siste året har vært en krevende tid preget av usikkerhet, nye utfordringer og en mangel på akademiske ressurser. Å skrive en masteroppgave i løpet av en global pandemi med alle utfordringene dette innebærer er noe jeg aldri hadde sett for meg at jeg skulle bli nødt til å gjøre. Smitteverntiltakene og reiserestriksjonene har gjort det vanskelig å nå gjenstandene jeg studerer, det har ført til perioder hvor forskningslitteraturen ved universitetsbibliotekene var utilgjengelig, og de sosiale konsekvensene av pandemien har vært en sterk påkjenning på både arbeidsmoral og helse. Til tross for disse omstendighetene har jeg gjort mitt beste for å fullføre oppgaven, og arbeidet har i sin helhet vært en svært lærerik og engasjerende opplevelse.

Først og fremst vil jeg takke alle som har lest teksten min og kommet med konstruktiv tilbakemelding, råd og gode diskusjoner.

En stor takk gis til familie og venner som har støttet og oppmuntret meg i denne krevende perioden og som har vært uunnværlige for å holde moralen og viljen oppe. I tillegg vil jeg takke mine medstudenter på lesesalen i Dokkeveien for lange, sosiale lunsjpauser som har sørget for en smule av normalitet i en hverdag sterkt preget av pandemien.

Til slutt vil jeg takke Morten Søvsø ved Sydvestjyske Museer og Antje Wendt ved Statens historiska museum for hjelpen jeg fikk i forbindelse med å bruke deres digitale gjenstandsdatabaser.

Sammendrag

Gjennom en komparativ analyse av arkeologisk materiale tilknyttet finsmedhåndverk fra Kaupang, Ribe og Birka i henholdsvis Norge, Danmark og Sverige undersøker jeg den yngre jernalderens urbane finsmedhåndverk ved å fremheve mulige likheter og forskjeller innen tekniske ferdigheter og kunnskap blant finsmedene i disse byene. Basert på den komparative analysen drøftes de urbane finsmedenes sosiale stilling gjennom temaer som mobilitet og i hvor stor grad disse finsmedene var tilknyttet handelsaktiviteter og andre håndverkere i de urbane bosetningene.

Gjenstandsmaterialet i de tre byene viser til store likheter, og det virker svært sannsynlig at finsmedene i Kaupang, Ribe og Birka behersket mer eller mindre de samme tekniske ferdighetene. Særlig masseproduksjon av tilnærmet identiske gjenstander virker som et grunnleggende trekk ved finsmedhåndverket i disse bosetningene, og det er tydelig at finsmedene produserte store mengder gjenstander og smykker av ulike metaller som messing, bly, sølv og gull. Det er likevel noen forskjeller i form av mindre variasjoner blant typene av smeltedigler som ble brukt i byene, samtidig som materialet peker på en mye større produksjon av blygjenstander i Kaupang enn i Ribe og Birka. Ulikhetene kan trolig knyttes til forskjeller i bevaringsforholdene mellom byene eller til personlige preferanser blant håndverkerne.

Mobilitet blant finsmedene diskuteres med utgangspunkt i ulike nivåer av mobilitet, i stedet for en dikotomi mellom bofast eller ikke bofast, og det virker som finsmedene hadde mange grunner til å bli værende i de urbane bosetningene. Likevel var det tilsynelatende ingen utfordring å bevege seg mellom byene ved hjelp av havtransport, noe som betyr at flere nivåer av mobilitet trolig ble benyttet av de urbane finsmedene. Finsmedene var sannsynligvis svært tilknyttet handelsaktivitetene som fant sted i disse bosetningene gjennom produksjon av blant annet handelsvarer og et forbruk av råmateriale som må ha kommet til byene gjennom handelsnettverkene. Den fysiske plasseringen til finsmedenes verksteder, deres forhold til handelsaktiviteter og mulige samarbeid med andre håndverkere i bosetningene tyder på at finsmedene hadde en svært integrert og veltilknyttet stilling i Kaupang, Ribe og Birka.

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1 Introduction

During the Late Iron Age, a number of settlements which have been interpreted as urban started appearing in Scandinavia. Kaupang, Ribe, and Birka, in Norway, Denmark, and Sweden respectively, were among the earliest of the Scandinavian urban settlements and have all been subject to a number of excavation projects. The material from these excavations have revealed that non-ferrous metalworking was arguably a central element of these settlements, and it is my belief that an understanding of the non-ferrous metalworking activities at these settlements could not only shed light on urban Viking Age craft activities, but also aid in understanding these urban settlements and the central actors therein. As such, the main research objective of this thesis is to compare the non-ferrous metalworking activity at Kaupang, Ribe, and Birka in order to illuminate differences and similarities in the technical skill and knowledge of the Late Iron Age urban non-ferrous metalworkers in Scandinavia. Building on this comparative analysis, I have endeavoured to answer further research questions such as the social position of the urban non-ferrous metalworkers within these settlements, their level of mobility, and to what extent they were connected to other craftspeople and the trade activities that took place in these urban settlements.

The spatial scope of this thesis is primarily contained to the Late Iron Age urban settlements in Scandinavia. In particular, the urban sites Kaupang, Ribe, and Birka, visible in fig. 1.1. However, connections are made to other places within the Viking Age long-distance trade networks as well. The chronological boundaries follow the emergence of the earliest settlement, Ribe at around 710 AD until Kaupang, Ribe, and Birka either disappeared or was strongly reduced sometime around 950 AD (Sigurðsson, 2017:155–156). However, there is a strong chronological focus on the most active periods of the urban settlements stretching from the latter half of the 8th century through the 9th century, of which the vast majority of the material stems from.

Fig. 1.1: Map of the earliest Late Iron Age urban settlements in Scandinavia (Image: adapted from J.K. Øhre Askjem and E. Naumann, in Pedersen, 2016a:14).

The material being compared consists of the remains of non-ferrous metalworking production and other direct and indirect evidence for metalworking activities at the sites of Kaupang, Ribe, and Birka. This includes material such as crucibles, moulds, models, matrix dies, cupellation crucibles, raw materials, casting cones and droplets, and surviving metalworking tools. By discussing the techniques and metalworking activities which are visible through the surviving archaeological material, I am able to compare the technical skill, knowledge, and metalworking activities of the non-ferrous metalworkers at Kaupang, Ribe, and Birka. This comparison allows me to connect the sites and thus create a foundation upon which to discuss more generally the social position of the urban non-ferrous metalworkers within the settlements, their level of mobility, and to what extent they were connected with traders and other craftspeople. These discussions are also built upon previous research into the mobility of the metalworkers, regionalisation, and Viking Age networks.

Before moving on I would like to make a note on a few terms and expressions. Defining a settlement as a town, or as having an urban character, is a much-discussed topic and rarely appears to be a straight-forward matter. This is particularly relevant when dealing with settlements in Northern Europe (e.g. Clarke and Ambrosiani, 1991; Gates, 2011; Hodges, 1982; Sindbæk, 2005). However, for the sake of simplicity I will accept the nature of Kaupang, Ribe, and Birka as urban settlements and refer to them as either "towns", "urban sites", or "urban settlements". Furthermore, when dealing with various alloys of copper, I will be referring to this group of material simply as "copper alloys" unless it has been clearly determined to be of a specific alloy such as brass or bronze, in which case the metals will be referred to as "brass", "bronze", and so forth.

2 Research history

2.1 Viking Age metalworking

In Scandinavian research, the technical aspects of non-ferrous metalworking in the Viking Age have been examined in a wide range of studies from comprehensive works such as Andreas Oldeberg's (1966) *Metallteknik under Vikingatid och Medeltid* and Bjarne Lønborg's (1998) *Vikingetidens metalbearbejdning* which deals with Viking Age metalcrafting in general, to more specialized studies of individual processes, or particular artefact-types or sites (e.g. Brinch Madsen, 1984; Feveile, 2002; Feveile, 2006b; Pedersen, 2016a; Söderberg, 2006). The scholarship dealing with metalworking activity during the Viking Age has unfortunately not been particularly extensive, and for a long period of time the discussion of prehistoric metal technology has been based upon tools and products, grave finds, hoards, and stray finds (e.g. Arwidsson and Berg, 1983; Lønborg, 1998; Oldeberg, 1942; Oldeberg, 1966). However, evidence from various production sites, such as the Viking Age urban sites and excavated workshop have since been uncovered. These new discoveries led to a greater intensity of research and in turn a greater understanding of the techniques that were employed in metalworking contexts in Scandinavia during the Viking Age (Ashby and Sindbæk, 2020a; Feveile, 2006b; Gustafsson, 2011; Hedegaard, 1992; Pedersen, 2015; Pedersen, 2016a; Söderberg and Gustafsson, 2006).

As the research related to Viking Age metalworking activities shifted towards a larger focus on production sites, production waste gained a central role in the research. The waste products from metalworking activities in the form of fragments of clay objects have particularly helped provide a broader understanding of Viking Age metalworking as well as complementing the knowledge derived from the study of tools and finished products (e.g. Brinch Madsen, 1984; Feveile, 2002; Pedersen, 2016a). Initially, fragmentary clay moulds were subject to research, which led to greater understandings of metalcasting (e.g. Brinch Madsen, 1984; Feveile, 2002). Eventually, the various clay waste products which are now termed as "metallurgical ceramics" became central in the study of metalworking. Entirely new types of tools and objects, such as cupellation crucibles and packaging material for soldering, were identified within the bulk evidence of clay and slag material through visual studies, archaeometallurgical analyses, and experimental archaeology (Pedersen, 2016a; Söderberg, 2004).

Outside of Scandinavia, some critiques have been levelled against archaeometallurgical studies and research with a very heavy technical focus claiming that such studies have a one-sided, scientific focus, and that they marginalize or ignore the human element behind the techniques and crafts activity (Budd and Taylor, 1995; Dobres, 2000). Such critiques might be valid and applicable to the research on Viking Age non-ferrous metalworking in Scandinavia. However, Pedersen (2016a) has argued that these critiques are more often applicable to the interpretation based on archaeometallurgical analyses, rather than the use of archaeometallurgical analyses itself. For instance, several studies looking at the technical aspect of Viking Age metalworking have aimed to shed light on craft practices and workshop organisation with the hopes of gaining some knowledge about the craftspeople behind these processes (e.g. Oldeberg, 1966; Söderberg, 2004; Gustafsson and Söderberg, 2005).

A similar focus on the people behind the craft activities is also apparent in Pedersen's (2016a) use of archaeometallurgical analyses where, for example, the analyses gave indications of what metal alloys were in use, and as such could point towards whether the craftspeople chose to use scrap metal or not in their metalworking. Furthermore, Pedersen's (2016a) use of archaeometallurgical analyses also discerned invisible traces in crucibles and moulds connected to a specific workshop, which in turn painted the image of a group of craftspeople who preferred to work with silver and gold rather than with copper alloys and lead. In this manner, the use of archaeometallurgical analyses and technically focussed research on Scandinavian non-ferrous metalworking appear to follow a tradition of not only attempting to illuminate the craft activities themselves, but also the craftspeople behind these activities.

Although there are no written sources from Viking Age Scandinavia, some Medieval texts from Continental Europe from the 9th and 12th centuries, in particular Theophilus' *De diversis artibus* and the *Mappae Clavicula* have been used in some research dealing with Viking Age non-ferrous metalworking in Scandinavia (Feveile, 2006b; Pedersen, 2016a). These texts are written instructions for performing various metalworking activities and have been used as a point of reference or comparison when analysing remains of such activities. Although these texts have been used in reference to Scandinavian metalworking, researchers have generally made sure to problematize their use and makes it clear that such Continental texts cannot be used as if they were some part of the Scandinavian craftworkers' own accounts of what they were doing (e.g. Pedersen, 2016a:30).

2.2 The metalworkers

The Viking Age metalworkers, often referred to as "smiths" in much of the Scandinavian research literature, have had a wide range of social positions and identities attributed to them, such as high status individuals, slaves, and "rulers of fire", on the basis of material from graves, tool deposits, written sources, and ethnographic comparisons (Barndon, 2005a; Grieg, 1922; Hed Jakobsson, 2003; Petersen, 1951; Rønne, 2002; Straume, 1986:45; Østigård, 2007). In particular, the view of Late Iron Age smiths as mystical creatures with connections to magic and the supernatural became prevalent in the research literature after Paul Budd and Timothy Taylor (1995) encouraged research into potential magico-religious aspects of metalworking. In the following decade, a number of studies investigating the social identity and status of Iron Age metalworkers based on written sources, visual representations of myths, and ethnographic comparisons were published (Barndon, 2005a; Barndon, 2005b; Hed Jakobsson, 2003; Rønne, 2002).

Some critiques were launched against the works painting metalworkers as mystical creatures surrounded by taboos and rituals, particularly by Unn Pedersen (2009) and Ny Björn Gustafsson (2011). The main critiques relate to the source material used. For instance, Pedersen (2009) criticised studies using grave goods and deposits as a reflection of regular life while neglecting the ritual contexts of the objects. In her critiques, Pedersen (2009) made a distinction between two entities; what she termed the "real smith" as represented in the physical remains of metalworking activities, and the "ideal smith" as represented in myths and stories. Both Pedersen (2009) and Gustafsson (2011) criticised the use and reliance on written sources, myths, and ethnographic analogies, and argued that the prevalent use of such sources of evidence could be connected to a lack of secure and contextualised archaeological evidence of metalworkers and metalworking. For example, the material from graves termed "smith's graves" is notoriously difficult to confidently attribute to actual metalworkers because of the prevalence of high-status objects such as weapons and jewellery, and tools from a wide range of other crafts (Petersen, 1951; Straume, 1986:47; Wallander, 1989).

However, in the decades following 1980, several production sites were discovered, and subsequent publications have resulted in large new groups of evidence with clear and tangible connections to metalworking activities (e.g. Ambrosiani, 1997; Ambrosiani, 2013; Brinch Madsen, 1984; Feveile, 2006b; Pedersen, 2016a). These production sites, particularly the urban Viking Age settlements, provide great insight into the work and activities of what were undoubtedly metalworkers and have become a focus for recent research on craftspeople. The workshop and production site material have been integral in more finds- and technology-orientated archaeological studies on metalworking and the social identity of metalworkers (Brinch Madsen, 1984; Merkel, 2018; Croix, Neiβ, and Sindbæk, 2019; Pedersen, 2015; Pedersen, 2016a). For instance, Pedersen's (2015; 2016a; 2016b) work on the social identity and status of non-ferrous metalworkers are based on the material from Kaupang which has been subject to significant amount of archaeometallurgical analyses. The material from the Viking Age urban settlements has also been central in recent studies on the social identity and position of craftspeople, as well as communication, contact, and collaboration between craftspeople in urban contexts (Ashby and Sindbæk, 2020a; Croix, Neiβ, and Sindbæk, 2019; Pedersen, 2020).

2.2.1 Mobility

Eldrid Straume (1986:46) pointed out that studies from the 1970s and 1980s arrived at two conclusions regarding metalworkers: (1) the Iron Age smith was versatile and worked with both non-ferrous and ferrous metals, and (2) there was a distinction between “farm smiths” attached to a village or farm who covered the local metalworking need and the “specialised smith” connected to the wealthy and powerful who produced for both local use and wider markets (e.g. Jensen, 1982; Roesdahl, 1980; Wallander, 1989). It is the latter group that the non-ferrous metalworkers in the urban sites would be considered a part of. The “specialised smiths” have been considered itinerant craftspeople, often based on evidence of deposits interpreted as tool hoards, such as the one found at Mästermyr in Sweden (Arwidsson and Berg, 1983; Straume, 1986:46). However, Straume (1986:54–55) has argued based on the distribution of metalworking products that the metalworkers of the Late Iron Age were in fact permanent residents in towns, villages, and larger farms. In more recent research, Pedersen’s (2015; 2016a) discussions surrounding the mobility of metalworkers have illustrated that there appears to be at least some level of mobility among the non-ferrous metalworkers at Kaupang, and rather that some groups of metalworkers could have been itinerant while others were permanently settled, even within the same type of settlement.

2.3 The urban sites

As my main body of evidence is sourced from the research and excavations performed at the urban sites of Kaupang, Ribe, and Birka, I wish to highlight the most notable aspects in the history of the research and excavations that took place at these sites. This is done in order to provide some background and context for the urban settlements, the archaeological material, and the excavations performed at these sites. And as such, potential flaws or biases I might have inherited from these studies could be made visible through a presentation of the relevant research history.

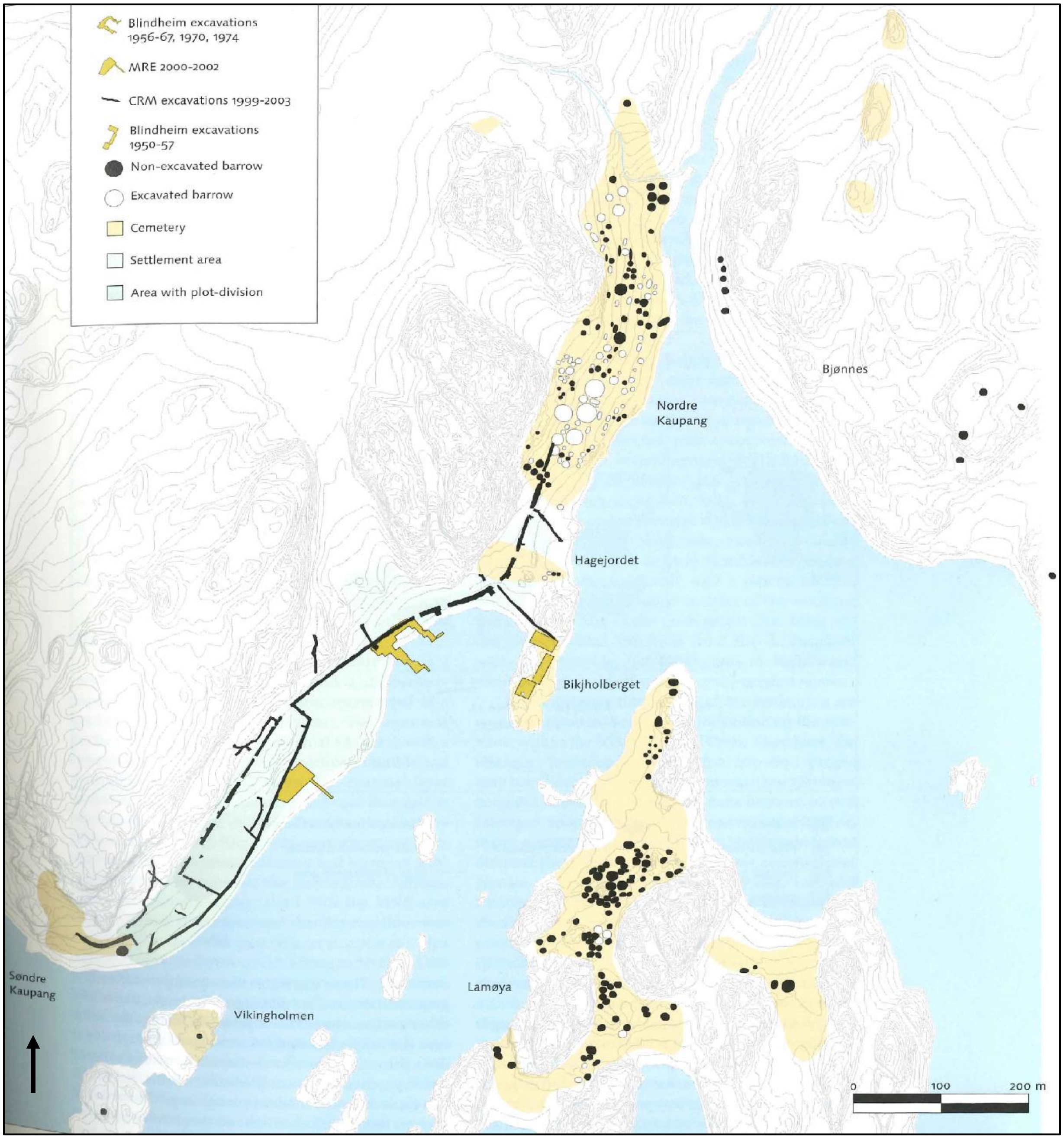

Fig. 2.1: Map of Kaupang with the most important excavations marked (Image: adapted from A. Engesveen and E. Naumann, in Pedersen, 2016a:15).

2.3.1 Kaupang

Kaupang, one of the four 9th century Viking towns in Scandinavia, alongside Ribe, Birka, and Hedeby, is a key site in the study of the Viking Period in Scandinavia (Sigurðsson, 2017:155–157; Skre, 2007:13; Skre, 2008:85). The site of Kaupang held antiquarian interest throughout the 19th century, although little substantial research appears to have been done on the site until Charlotte Blindheim's breakthrough starting in the 1950s (Skre, 2007:13). The urban settlement was discovered by Blindheim in 1956 during a series of excavations in the area spanning from 1950 to 1974, followed by a series of publications in the period 1960–1999 which documented and discussed the urban site of Kaupang and its surrounding cemeteries (Blindheim, 1960; Blindheim, 1975; Blindheim and Heyerdahl-Larsen, 1995; Blindheim et al., 1981; Blindheim et al., 1999).

In the aftermath of Blindheim's work, advances in the understanding of urban sites and central places in Scandinavia, alongside improved methods of field archaeology, led to the planning of a new research project; "The Kaupang Excavation Project" in the late 1990s (Skre, 2007:13). The Kaupang Excavation Project was organized by the University of Oslo and consisted of survey and excavation work that took place between 1998 and 2003 (Skre, 2007:14). The most important element of the fieldwork was the major excavation termed "the Main Research Excavation", or MRE, which took place between 2000 and 2002, see fig. 2.1 (Skre, 2007:14; Pilø, 2007). This research project led to information about many aspects of the urban settlement at Kaupang and urban life in the Viking Age, such as the extent and character of the settlement, international contact and trade, and craftsmanship (Hansen, 2017; Pedersen, 2010; Pedersen, 2016a; Sindbæk, 2007; Skre, 2007; Skre, 2008; Skre, 2011a). Following the fieldwork at Kaupang, a series of publications related to the excavation and finds from Kaupang, called the Kaupang Excavation Project Publication Series, were published. As a part of the Kaupang Excavation Project, Pedersen (2010) wrote her doctoral dissertation on the non-ferrous metalworkers at Kaupang. This dissertation was further refined and translated into English before being published as a part of the Kaupang Excavation Project Publication Series (Pedersen, 2016a).

2.3.2 Ribe

While there had been some antiquarian interest during the late 18th and throughout the 19th century in locating the oldest part of Ribe based on written sources from the 9th century and onwards, no genuine archaeological surveys were undertaken until after the 2nd World War (Bencard, et al., 1981; Feveile, 2006a:13). In 1955 a lengthy research project was initiated by the National Museum of Denmark under the supervision of Hans Stiesdal and Mogens Bencard. This project was carried out, with some interruptions, by Den Antikvariske Samling in Ribe (Bencard, 1984a:9). The goal of this research project was to determine the exact location of the oldest part of Ribe, i.e. the Viking Age town Ribe, and to figure out how long the town had been in existence prior to its earliest mention in written sources around 860 (Bencard, 1984a:9; Bencard et al., 1981). The early archaeological excavations and investigations in the 1950s and 1960s had virtually no archaeological evidence to base their search upon and they were forced to lean on written sources and older topographical descriptions of Ribe (Feveile, 2006a:14).

Most of the excavations in the 1950s and 1960s took place in the centre of the medieval town of Ribe between the streets Grønnegade and Præstegade which runs along the southern bank of the river Ribe Å (Bencard, 1984a:9; Bencard et al., 1981). As the archaeological investigations in the medieval city centre failed to turn up any finds older than 1100, it was postulated that Viking Age Ribe had been moved and as such would be situated elsewhere than the modern day city (Bencard, 1984a:9; Feveile, 2006a:14). Consequently, several small excavations were carried out throughout the hinterlands of Ribe, but these also failed to turn up any signs of the Viking Age town. However, in 1970 an excavation in Ribe on the north side of Ribe Å around the street Sct. Nicolajgade uncovered Viking Age material (Bencard, 1984a:10). This discovery lead to a series of excavations in that area between 1972 and 1976 which provided material that formed the basis of a publication series on the Viking Age town of Ribe (Bencard et al., 1981; Bencard, 1984a:10; Brinch Madsen, 1984). As a part of this publication series, Helge Brinch Madsen (1984) performed a thorough and detailed analysis of the metalworking finds from the excavations that took place between 1970 and 1976.

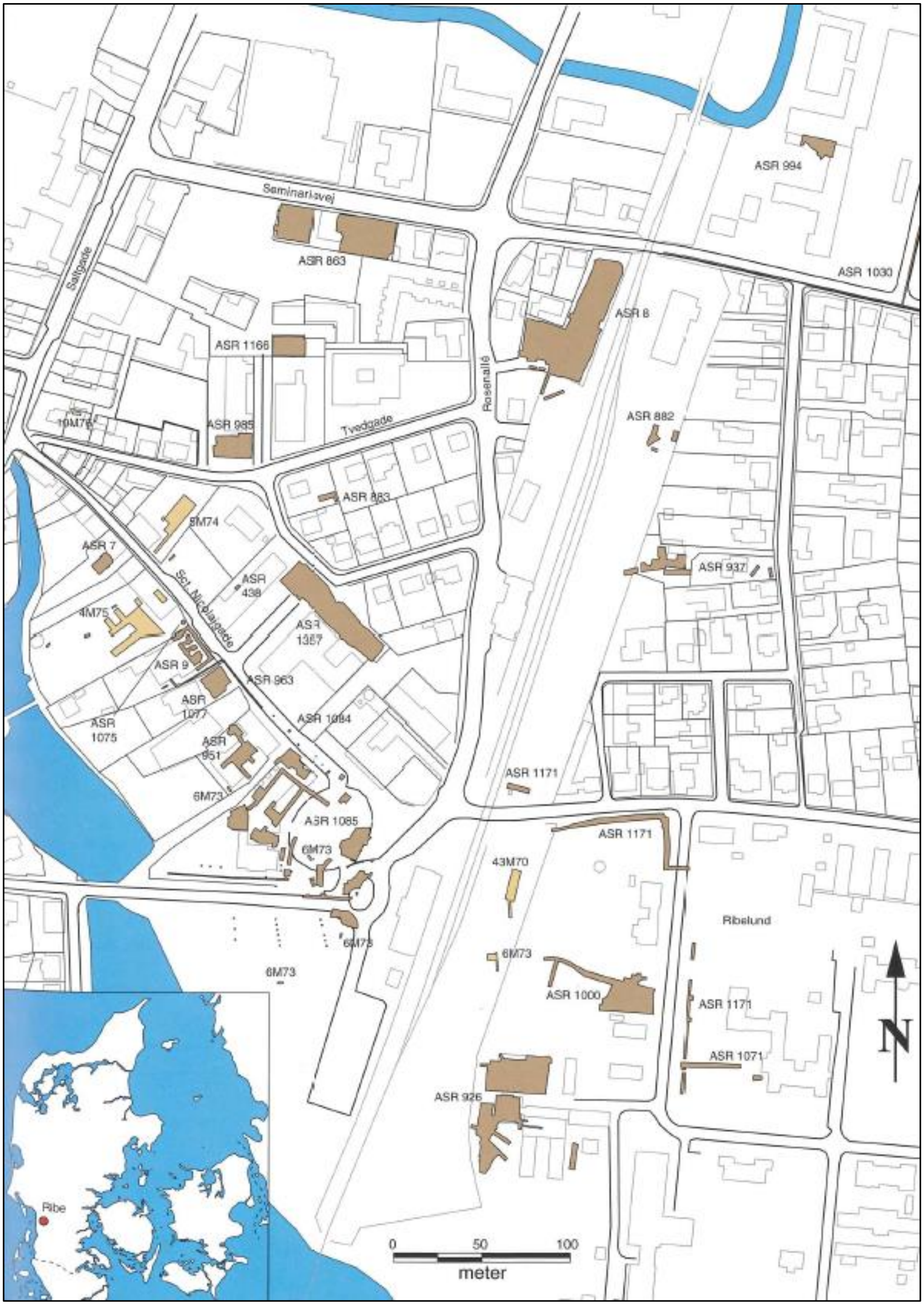

Fig. 2.2: Map of the excavations that took place at Ribe north of Ribe Å between 1970–1976 (marked in a light shade of brown) and 1984–2000 (marked in a dark shade of brown) (Image: Feveile, 2006b:6).

As Ribe is a modern city, it has been subject to a significant amount of rescue excavations in preparation of construction work in the city (Feveile, 2006a; Feveile, 2006b). For instance, during the period of 1984 to 2000, Den Antikvariske Samling in Ribe was responsible for 23 such rescue excavations on the north side of Ribe Å, i.e. the area of the Viking Age town, visible in fig. 2.2 (Feveile, 2006a:9). These excavations uncovered significant amounts of Viking Age and Medieval finds (Feveile, 2006b). Unfortunately, the nature of the rescue excavations resulted in generally low funding and it has been noted that several of these excavations were detrimentally affected by this lack of resources (Feveile, 2006a:9). The excavations that took place between 1984 and 2000 covers a large area, significantly larger than the excavations of the earlier research project and has resulted in a much clearer view of the extent and nature of the Viking Age town (Feveile, 2006a; Feveile, 2006b). Eventually, the material from the excavations that took place between 1984 and 2000 were presented and discussed in a publication series called Ribe Studier (Feveile, 2006a; Feveile, 2006b).

2.3.3 Birka

The site known as Birka, located on the island of Björkö in Mälaren in Sweden, has been identified as the Viking Age centre referred to as "Birca" in 9th century written sources that has long attracted antiquarian and archaeological interest (Ambrosiani and Clarke, 1992:11–14). Unlike the sites of Kaupang and Ribe, occupational layers at Birka have been excavated as early as the 1860s (Ambrosiani and Clarke, 1992:14). Of particular note is Hjalmar Stolpe's series of excavations at Birka in the late 19th century, which left behind a somewhat detailed journal and a collection of Viking Age artefacts (Ambrosiani and Clarke, 1992:14; Hyenstrand, 1992; Jakobsson, 1996:71). The material uncovered by Stolpe remained untouched until the 1930s when Holger Arbman began to process the artefacts, resulting in a number of publications from the 1930s to the 1950s (Ambrosiani and Clarke, 1992:14–15; Arbman, 1943). As a part of his work, Arbman also dug a few trial trenches in what is believed to be the occupational layers of Birka in order to supplement the evidence obtained from Stolpe's excavations (Ambrosiani and Clarke, 1992:15). Further work on Stolpe's Birka material were published in three volumes under the editorial control of Greta Arwidsson, and a number of doctoral dissertations written on Birka subjects were based on the material from Stolpe's excavations (e.g. Arwidsson, 1989; Duczko, 1985; Gräslund, 1980).

New interests in the historical shoreline of the island Björkö in the late 1960s led to a series of excavations, headed by Björn Ambrosiani and Birgit Arrhenius, taking place in the Black Earth area in 1969–1971 (Ambrosiani and Clarke, 1992:15; Ambrosiani et al., 1973). This excavation project took place in the harbourside of Birka, and beside trying to gain new insight into the settlement, the excavations also attempted to locate some of Stolpe's 19th century trenches (Ambrosiani and Clarke, 1992:15). Although they were unable to locate any 19th century trenches, the excavations did reveal landward remains of a jetty and associated stratigraphy, and the results of the project was published in a report (Ambrosiani and Clarke, 1992:15; Ambrosiani et al., 1973).

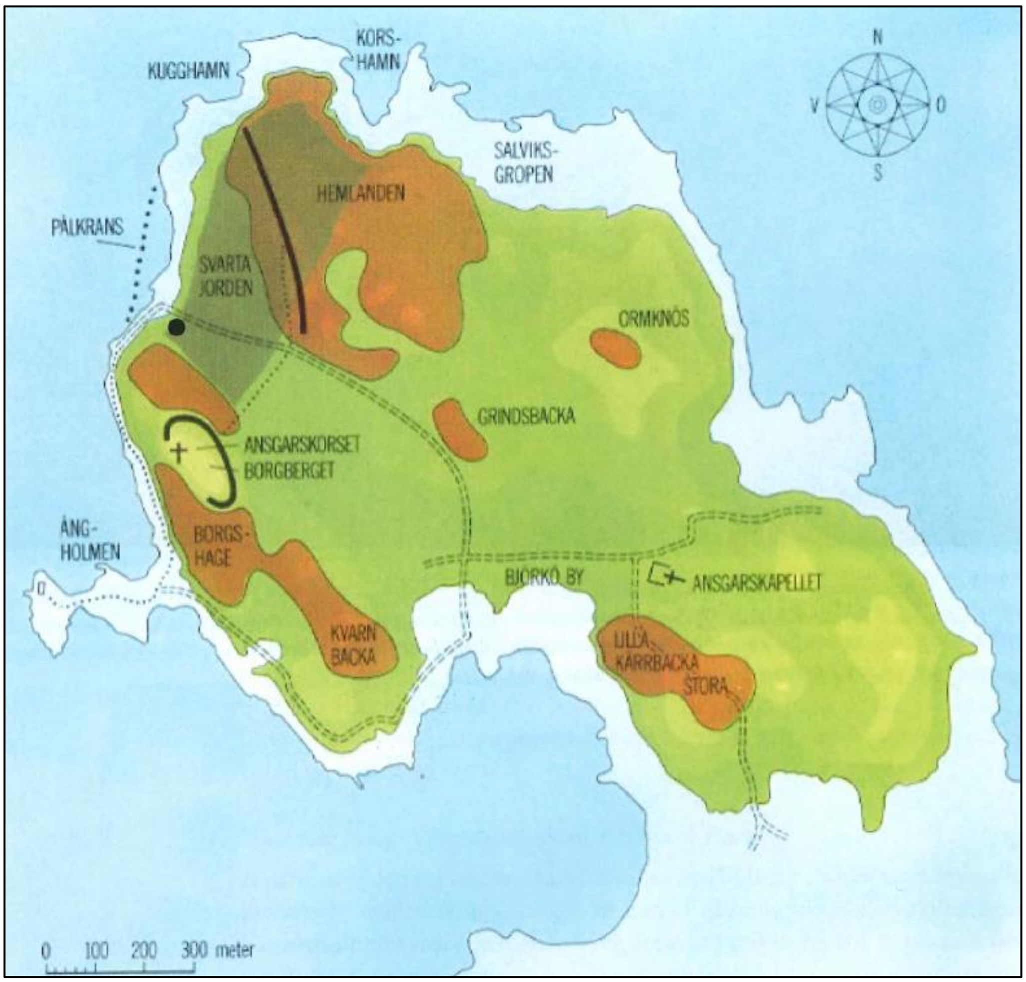

Fig. 2.3: Map of the island Björkö in Mälaren, with the site of the 1990–95 excavations marked with a black circle (Image: Ambrosiani, 2013:13).

After the 1969–1971 excavations there was little activity at Birka until more funds were acquired, allowing a research project to take place between 1990 and 1995 at the Black Earth area, visible in fig. 2.3 (Ambrosiani, 1992:83; Ambrosiani, 2013:15). The main goals of this research project were to determine whether there was a coherent plot pattern in Viking Age Birka, the shapes of the plots, their level of permanency, and which activities took place within the plots (Ambrosiani, 1992:83). As such, the area chosen for excavation was believed to comprise of undisturbed occupational layers in a section of the Black Earth that was presumably untouched by Hjalmar Stolpe's excavations (Ambrosiani, 2013:15). However, when excavations began it was discovered that a rather large section of the planned excavation area had already been excavated by Stolpe (Ambrosiani, 2013:15). Eventually it was revealed that Stolpe had not reached all the way down to the lower occupational layers as well as having left behind several baulks between the trenches which could be excavated by the research project. As such, the site was deemed to not be irreparably damaged by Stolpe's trenches, allowing the project to continue (Ambrosiani, 2013:15). In particular, it was discovered that a significant part of a metalcasting workshop lay completely undisturbed underneath Stolpe's trenches, which was excavated and documented through the research project (Ambrosiani, 2013:26). The fill material from Stolpe's trenches was also excavated and it was discovered that they contained a number of Viking Age artefacts that Stolpe either did not notice or did not consider significant enough to keep, such as casting waste (Ambrosiani, 2013:24). The finds from the 1990–1995 research excavations at Birka is still being studied and published in an ongoing publication series known as "Birka Studies" (Ambrosiani, 2013; Ambrosiani, 2001; Ambrosiani and Clarke, 1992).

3 Theory and method

3.1 Theory

In order to compare and discuss the non-ferrous metalworking activities of urban craftspeople in the Viking Age, I will place my understanding of the craft on a theoretical foundation constructed of works detailing the technological aspects of the skills, tools, and material related to these urban metalworkers (Brinch Madsen, 1984; Feveile, 2002; Hedegaard, 1992; Lønborg, 1998; Oldeberg, 1966; Pedersen, 2016a; Söderberg, 2004; Söderberg, 2006). An understanding of the various techniques and processes involved in the non-ferrous metalworking activities in the Viking Age and how these are made visible in the archaeological record will be an essential part of the theoretical framework when attempting to understand, compare, and discuss the level of skill and what techniques were employed by the urban non-ferrous metalworkers.

When attempting to understand a single aspect of past societies, in this case non-ferrous metalworking, it is important to keep in mind that the subject of study is never entirely isolated from their present. This is particularly pertinent when attempting to compare sites separated by somewhat significant distance, as is the case with Kaupang, Ribe, and Birka. As such, a general understanding of the Viking Age society and urban settlements in Scandinavia will be used to place the urban non-ferrous metalworking within a larger context (Brink and Price, 2008; Clarke and Ambrosiani, 1991; Hårdh, 1996; Sindbæk, 2005; Skre, 2007; Sigurðsson, 2017; Solberg, 2003).

3.1.1 Networks and regionalisation

Of particular relevance when dealing with the urban sites of Kaupang, Ribe, and Birka is their connection with each other through the vast trade networks of the Viking Age (Hodges, 1982; Sindbæk, 2005; Sindbæk, 2007). Søren Michael Sindbæk (2005; 2007; 2008) has written substantial works on the nature and presence of the Viking Age long-distance trade networks, as well as highlighting urban settlements, which he refers to as nodal points, as having a distinct role in long-distance trade and contact. These nodal points appear to be clearly linked through very similar patterns of finds, and the same classes of imports were found in surprisingly similar numbers, as witnessed by Sindbæk's (2005; 2007:121–123) comparison of the nodal points Kaupang, Ribe, Birka, and Hedeby. As such, Sindbæk (2007:122–123) notes, based on the above-mentioned comparison, that it would be fair to imply that these sites were linked by communication and activities of a very similar scale and nature. In this manner, the evident connections between the towns of Kaupang, Ribe, and Birka would inherently imply shared activities in the form of non-ferrous metalworking being prevalent at all three sites, and potentially also hint at significant similarities in the nature of these activities.

When studying long-distance trade networks, Sindbæk (2005) emphasises three phenomena: regionalisation, institutionalisation, and routinisation. Of these, regionalisation appears to be the most relevant as a way of connecting Kaupang, Ribe, and Birka. Sindbæk (2005:38–39) argues that a trade route can serve as significant impetus for regionalisation, and that regionalisation is not entirely a spatial phenomenon, but also considers time. Essentially, regions are space-time entities and as such the time it takes to move between two points in a given region can matter more than the physical distance between them in establishing a region in the first place. Consequently, the ease of sea travel and the large degree of contact between Kaupang, Ribe, and Birka could mean that these sites were interconnected by virtue of existing within a shared region of urban settlements. Such a connection would mean that rather than these settlements being seen as entirely distinct and individual sites, they can be viewed and compared as different parts of the same region. This would imply at least some degree of similarity in the nature of the activities taking place in these urban sites.

3.1.2 Itinerant smiths?

Part of the discussions related to Viking Age metalworkers has pertained to the dichotomy of itinerant versus settled. Often this discussion has been based on metalworkers, or "smiths" in general, such as when Eldrid Straume (1986:54–55) argued that metalworkers typically were not itinerant. While Brinch Madsen (1984:95), when dealing with the distribution of Berdal type oval brooches, emphasises the possibility of itinerant craftspeople being the cause of the widespread distribution of this artefact type. However, there is the possibility that dealing with Viking Age metalworkers within the dichotomy of itinerant or not is misleading, and that we should rather be looking at a scale of mobility. For instance, some metalworkers could have been mostly settled with occasional travels, while others enjoyed a large degree of mobility, and that as a whole, the Viking Age metalworkers could not be placed within clearly defined boundaries as either itinerant or settled. This is a frame of thought which makes itself clear in Pedersen's (2015; 2016a; 2016b) discussions of the non-ferrous metalworkers at Kaupang and whether or not they were itinerant. These works are also particularly relevant as they deal solely with non-ferrous metalworkers of an urban character, rather than metalworkers in general.

Pedersen (2015; 2016b) argues that some groups of non-ferrous metalworkers were essentially permanently settled, while others were highly mobile, even coming from as far away as the Rhine or other Frankish areas. Furthermore, the possibility that metalworkers from Kaupang occasionally spent short periods of time in nearby workshops, such as Heimdaljordet roughly 15 km away has been highlighted (Pedersen, 2016b:266–267). As such, even metalworkers perceived as essentially permanently settled craftspeople could have occasionally travelled to perform their trade at other sites. This highlights the possibility of a situation characterised by varying degrees of mobility amongst craftspeople in the Viking Age, rather than a dichotomy of itinerant or settled. From this perspective, Pedersen (2016b:268) highlights the concepts of "base" and "guest" within a possible model for describing the mobility of craftspeople, with "base" referring to the place a person returns to at regular intervals, and "guest" referring to a person who visits a place or workshop for a period of time. As such, metalworkers can appear both settled when they spend large amounts of time in their "base" and itinerant when appearing or functioning as a "guest". In this vein, some groups of metalworkers could have preferred to spend the vast majority of their time in a "base", while others travelled far more and performed the majority of their craft in a "guest" role. The use of this model, or these concepts, allows for a discussion of varying degrees of mobility amongst craftspeople rather than being limited by the strict dichotomy of itinerant or settled.

3.2 Method

The primary method employed in this work is a comparative analysis of finds from several different types of artefacts related to metalworking activity uncovered in the urban sites of Kaupang, Ribe, and Birka, i.e. production waste, raw materials, and tools. While a comparative analysis of urban non-ferrous metalworking activity is in itself the main research objective of this work, the comparison itself also serves as a method. The idea being that the results of a comparative analysis can serve as a foundation for further discussion on various topics related to the urban non-ferrous metalworkers, such as their social position, degree of contact and interconnectedness, and their degree of mobility. The material from Kaupang, Ribe, and Birka is initially described and presented in their respective chapters. Following that, the individual types of objects related to non-ferrous metalworking from the respective urban settlements is compared and discussed, eventually resulting in a conclusive analysis of the overall technical skill and knowledge of these craftspeople based on the comparisons.

The material being compared and discussed comprises of several different artefact-types and a significant quantity of artefacts, the vast majority of which are highly fragmentary mould and crucible sherds. Furthermore, travel restrictions due to the pandemic has made the artefacts themselves essentially inaccessible to me. Due to these factors, my material and subsequent discussion and analyses will be entirely based on the information available in published literature and online artefact-databases, particularly UNIMUS, Historiska Museets Samling, and Sydvestjyske Museer Samlingen OnLine (SOL). As such, my methods do not include inspecting or analysing relevant artefacts in person and all my conclusions will be based on observations made on the information and images which are available to me.

4 Material

4.1 Material from excavations at Kaupang

4.1.1 Background

Kaupang was a Viking Age urban settlement and trading centre in Vestfold[1] in Norway (Skre, 2007). While the area has been subject to several research excavations, I have based my study on the vast and thoroughly studied material from the Kaupang research project and their main research excavation from 1998 to 2003 and related survey work. This material was chosen in particular because of the detailed and impressive work on the non-ferrous metalworking material (Pedersen, 2016a; Skre, 2007). Furthermore, the material from Kaupang appears to be exclusively Viking Age material. However, the upper strata consist of heavily disturbed plough-layers as the area has unfortunately been used as agricultural land for centuries (Skre, 2007). The surveys undertaken as part of the research project included significant amount of metal-detecting, which in turn has led to significant amounts of metal finds, particularly lead fragments and crafting waste (Pedersen, 2016a). As a result of these metal-detecting surveys, the material related to non-ferrous metalworking from Kaupang appears somewhat skewed towards a larger quantity of metal finds than other similar sites. Due to generally poor preservation conditions for fired clay alongside significant re-deposition caused by agricultural use of the landscape, the clay crucible and mould material is extremely fragmented and has been subject to severe deterioration, further skewing the archaeological record (Skre, 2007; Pedersen, 2016a).

[1] The geographical area of the former administrative region of Vestfold in Norway.

4.1.2 Crucibles

The melting crucible is one of the most basic pieces of equipment for metalcasting and functions as a vessel in which metal was melted. As such, melting crucibles often show signs of having been exposed to high temperatures causing the material to become brittle leading to a high degree of fragmentation (Pedersen, 2016a:111). The melting crucible material from the fieldwork of 1998 to 2003 at Kaupang is highly fragmented and consists of 2 118 crucible fragments and 8 complete, or nearly complete, crucibles (Pedersen, 2016a:111). Some examples are visible in fig. 4.1.1. The fragments are consistently small, with a mean weight of 1.3 g, which highlights the extensive degree of fragmentation (Pedersen, 2016a:111). The distribution of melting crucible fragments implies that the area of the MRE was either on or in very close proximity to an area with intense casting activity (Pedersen, 2016a:117).

Fig. 4.1.1: Half and refitted thimble-shaped melting crucibles from Kaupang (C52516/1687, C52519/12369, C52519/13334, C52519/12987, C52519/13243, C52519/17246, horizontally from top left to bottom right) (Image: E.I. Johnsen, KHM).

The complete and nearly complete melting crucibles have the typically cylindrical form that characterizes the melting crucibles of the Viking period that has been described as "thimble-shaped" (Brinch Madsen, 1984; Feveile, 2006b; Pedersen, 2016a:111). Although the crucibles share a typical form, there is variation in shape and size between the crucibles. As such, Pedersen (2016a) divides the crucibles into different types based on the work of Brinch Madsen (1984), but with some extensions and exclusions. Morphologically, Brinch Madsen (1984:26–27) divided the various crucibles found at Ribe into seven types, visible in figs 4.1.2 to 4.1.4: (1) thimble-shaped crucibles, a cylindrical form with essentially the same thickness from rim to base. (2) Thimble-shaped crucibles with a lug, which closely resembles type 1 except that they are furnished with a lug and are not quite cylindrical with the rim being slightly constricted. The lugs are rectangular projections placed on the side of the crucible. (3) Thimble-shaped crucibles with handle, very similar to type 1 but with a handle added onto the side. (4) Thimble-shaped crucible with thin rim and thick base, resembles type 1 but has a constricted rim and a wider base. (5) Lidded crucibles, which are boat-shaped bowls with a casing of clay that rises above the rim to form a lid. (6) Watch glass-shaped crucibles, which are round crucibles resembling watch glasses with a concave inner surface, and a convex outer surface. (7) Flat rectangular crucibles.

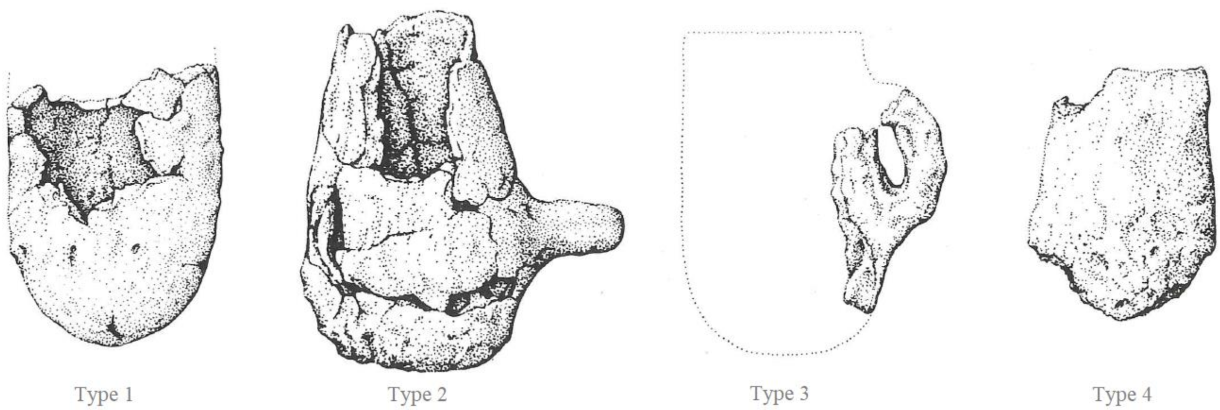

Fig. 4.1.2: Brinch Madsen's type 1 through 4 crucibles, i.e. thimble-shaped melting crucibles (Image: adapted from Brinch Madsen, 1984:26).

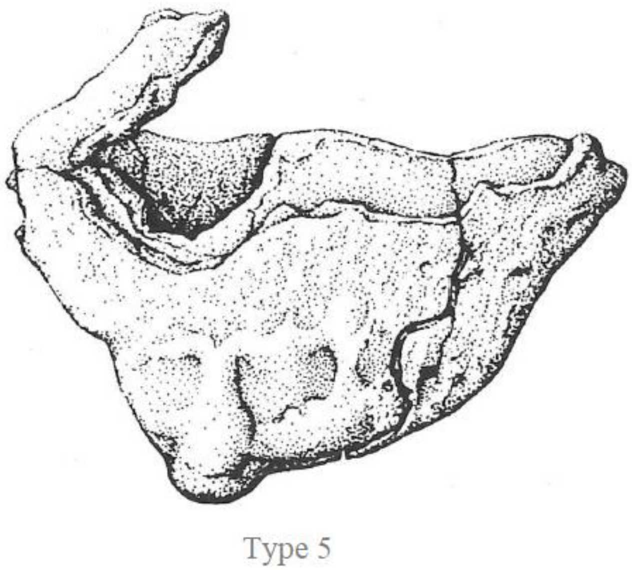

Fig. 4.1.3: Brinch Madsen's type 5 crucible (Image: adapted from Brinch Madsen, 1984:27).

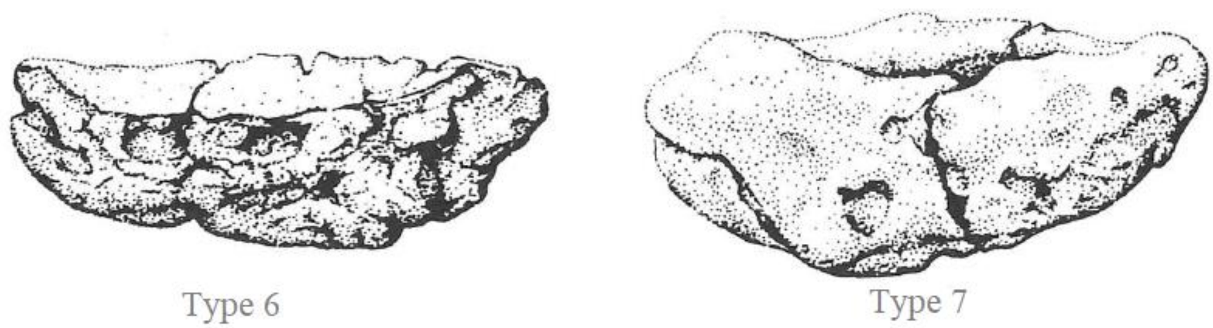

Fig. 4.1.4: Brinch Madsen's type 6 and 7 crucibles (Image: adapted from Brinch Madsen, 1984:27).

The first four of Brinch Madsen's types are various forms of thimble-shaped crucibles which all appear in the Kaupang material (Pedersen, 2016a). However, Pedersen (2016a) notes that Brinch Madsen's type 5 is a type of melting crucible generally dated to the Migration and Vendel periods, and as such would not appear in Kaupang as the type predates the site. Furthermore, Pedersen (2016a:111) points out that Brinch Madsen's types 6 and 7 are not melting crucibles, but rather a different type of metallurgical ceramic called cupellation crucibles. As such, these types should not be included in a typology for melting crucibles.

Within the crucible material, Pedersen (2016a:111–115) identifies several potential new types beyond those described by Brinch Madsen. However, Pedersen (2016:113) also notes that there were likely more types of crucibles in use during the Viking Age than has been identified, or possibly that melting crucibles do not allow themselves to be classified into clearly differentiated types. This could be due to differing personal preference in the shaping of the crucibles between different metalworkers causing large amounts of small variations between the crucibles. While the melting crucible fragments appear to cluster around several typical features, such as being thimble-shaped or outfitted with a lug or handle, it is noted that the occasional melting crucible appear to have been individually formed (Pedersen, 2016a:116).

Fig. 4.1.5: Thimble-shaped melting crucibles from Kaupang (C52516/1705, left) (C52516/1707, middle) (C52519/11946, right) (Image: E.I. Johnsen, KHM).

All the types of thimble-shaped melting crucibles are chronologically tied to the Viking Age and can be considered simultaneous types. This could support the idea of the various types simply being variations based on preference. Additionally, the types identified by Pedersen appear to be formed based on just a few distinct sherds from a heavily fragmented material, and all the types appear to share the basic thimble-shaped form, see fig. 4.1.5 (Pedersen, 2016a:111–115). As such, rather than being expressions of different types, the slight variations between the crucibles could easily be caused by the personal preference of the different craftspeople or groups of metalworkers present in the Viking Age towns. However, there is a possibility that the variations in the material could also have been caused by different crucibles being needed for different purposes (Pedersen, 2016a:118). At the very least, I believe the individuality and personal agency of the non-ferrous metalworkers should not be completely disregarded when considering slight variations found within the crucible material.

The approximate thickness of the melting crucible sherds varies significantly, ranging from 2 to 17 mm along the walls and 4 to 20 mm in the base, and in some cases the curvature of the sherds would imply that the thicker sherds belong to larger crucibles (Pedersen, 2016a:116). These differences in size can likely be attributed to the quantity of metal the metalworkers intended to melt. As metal tends to set within three to five seconds after being removed from the forge, it is likely that the metal in one crucible was meant for casting a single mould (Lønborg, 1998:23). Thus, the size of the melting crucibles would give us an indication of the size of the object being cast (Pedersen, 2016a:116). The size variations in the crucible material therefore proves objects of a wide variety of sizes were being produced at the site.

Parts of the melting crucible material from Kaupang has been subjected to archaeometallurgical analyses. A total of 60 melting crucible fragments, including two complete crucibles, were selected for identification of traces of metal. The objective of these analyses was to produce a more representative view of the use of melting crucibles than what purely visual inspection of visible remains of metal could provide (Pedersen, 2016a:121–123). The results of the archaeometallurgical analyses showed that silver was the most frequently represented metal, being present in more than half of the crucibles, which can be seen in figure 4.1.17. Gold also occurred in four of the crucibles, sometimes alongside other metals indicative of gold-alloys, and the analyses indicate that several of the crucibles were used exclusively for melting silver and gold (Pedersen, 2016a:121–123). There was also a significant presence of copper-alloys in 12 of the crucibles, potentially brass, bronze, leaded bronze, and almost pure copper. Two of the crucibles had been used to melt lead (Pedersen, 2016a:122–124). The analyses show that the melting of silver and gold occurred far more frequently than one could infer from visual observation of metal remains in the crucibles alongside the metal waste found elsewhere at the site (Pedersen, 2016a:122).

To get a clearer understanding of the use of melting crucibles for copper alloys, sherds with visually recognizable remains of copper alloy were subject to further archaeometallurgical analyses (Pedersen, 2016a:126). A total of 13 melting crucible sherds were subject to analysis, and the results indicated that brass, leaded brass, and potentially pure copper, had been melted in these crucibles (Pedersen, 2016a:127). The archaeometallurgical analyses performed on the melting crucibles also provided information on the chemical composition of the clay, which concluded that the crucibles from Kaupang were essentially made using fire-resistant clay, and that the melting crucibles had been tempered using old crucibles as chamotte (Pedersen, 2016a:125).

In order to gain a better understanding of the clay used to make the crucibles, as well as hopefully being able to trace its provenance, 14 melting crucible sherds were selected for petrological analysis. These sherds were examined using a combination of thin-sectioning and chemical analysis (Pedersen, 2016a:127). The results indicate that the melting crucibles consisted of a type of fire-resistant clay called kaolin clay which does not occur naturally in Kaupang or in the surrounding area (Pedersen, 2016a:128; Sørensen et al., 2007). As such, the clay used to create the melting crucibles must have been imported to Kaupang. Unfortunately, it is difficult to determine the provenance as various outcrops of kaolin clay are very difficult to distinguish from one another chemically or through thin-section analysis (Pedersen, 2016a:128). Furthermore, comparisons that have been made between melting crucibles, moulds, and pottery from Kaupang and sites in Sweden and the Baltic region indicates that the clay used in the melting crucibles from Kaupang are different from clay used at every other compared site except for some crucibles found at Birka (Pedersen, 2016a:128; Vince, 2011).

4.1.3 Moulds

A mould can be understood as an artefact within which casting was to take place, thus serving as a vital piece of equipment when casting objects (Pedersen, 2016a:82). As such, moulds can provide information on the technical repertoire of the non-ferrous metalworkers, what raw materials were available and used for casting, and in some cases they can tell us what objects were being produced (Pedersen, 2016a:81 and 95). The casting mould material from Kaupang consists primarily of 3.6 kg of heavily fragmented moulds of fired clay and ten moulds of soapstone or similar material. There were also three moulds of other kinds of stone, possibly volcanic tuff, alum slate, and gabbro respectively (Pedersen, 2016a:84–95). There is also a group of fired clay objects weighing a total of 1.9 kg which was found at Kaupang and has been interpreted as probable moulds, but this is uncertain and the material is extremely fragmented and as such will not be considered in this work (Pedersen, 2016a:95).

The fired clay moulds at Kaupang is affected by severe deterioration, and while the entirety of the material was weighed, only the fragments with a maximum dimension of more than 1 cm had been counted, totalling 1 128 fragments (Pedersen, 2016a:96). The mould material is almost entirely from re-deposited layers, mainly the plough-layer, which alongside poor preservation conditions led to the terrible state of the clay moulds (Pedersen, 2016a:95–96). Pedersen (2016a:95) argues that this material cannot be expected to provide a good picture of the casting that took place at the site. She also claims that the specimens with preserved impressions are so few that they cannot be representative of the artefact output at the site and there were likely moulds for a much wider range of objects that can now be identified (Pedersen, 2016a:95). Despite these flaws, I believe the fired clay moulds from Kaupang can still be somewhat useful when comparing the non-ferrous metalworking activity at Kaupang with that of Ribe and Birka. Additionally, what little information the moulds might provide should still be able to serve as useful glimpses into the metalworking that took place at the site when viewed alongside other related assemblages.

Viking Age clay moulds are almost exclusively "investment moulds" where metal is poured into an enclosed casting hollow in the mould via an inlet shaft and channel. This also appears to be the case with the Kaupang material (Pedersen, 2016a:82). It is generally agreed upon that Iron Age moulds in Scandinavia are practically always composite moulds, which is further corroborated by the fact that not a single mould fragment from Kaupang have been identified as belonging to a single-part mould with any degree of confidence (Feveile and Jensen, 2006:153–160; Pedersen, 2016a:98). Whenever a clay mould is used in casting the clay starts to break down, meaning the moulds cannot be reused (Jansson, 1985:12; Lønborg, 1998:18). As such, the clay moulds can be regarded as consumable implements for non-ferrous metalworking, unlike moulds of material such as stone (Pedersen, 2016a:95). The clay moulds were generally constructed around a model and can therefore be considered intrinsically linked to object models, such as the re-usable lead models found at Kaupang or the consumable wax models used in the lost-wax method (Pedersen, 2016a:95).

Many of the clay moulds from Kaupang appear to contain material other than clay, most often a varying amount of sand. In a significant portion of the moulds there were finds of inclusions of mica or terracotta-coloured particles, the latter which is likely old moulds which have been crushed and used as chamotte (Pedersen, 2016a:97). Some of the moulds also have small pores or fibrous grooves, which is likely the mark of fine organic material having been mixed into the clay (Pedersen, 2016a:97). As such, the mould composition of clay, sand, mica, and fine organic materials appears to be very similar to the moulds excavated in Ribe (Brinch Madsen, 1984; Pedersen, 2016a). Brinch Madsen (1984:33) also observed three different layers of clay in the moulds from Ribe, something that is not clearly reflected in the material from Kaupang. However, there are some fragments that have a fine-grained layer on the inner surface, and several fragments with a reinforced outer layer that appears different from the mould-clay which indicates that a similar type of layering of the moulds also appears in the Kaupang material (Pedersen, 2016a:98). Brinch Madsen (1984:32) has pointed out that mica is not a particularly attractive component for mould-clay but may have been an easily recognizable feature of the clay the non-ferrous metalworkers regarded as well suited for making moulds.

Fig. 4.1.6: Clay mould fragments from Kaupang with imprints (C52519/17391) (Image: E.I. Johnsen, KHM).

In the vast majority of moulds with visible object impressions, only unclear parts of the impressions remained (Pedersen, 2016a:98). Consequently, Pedersen (2016a:98) was unable to identify the motifs and decorations, and in the majority of cases it was deemed impossible to determine what artefact had been cast. In total the artefact type in only 20 moulds could be identified with varying degrees of certainty (Pedersen, 2016a:98). Of these, the impressions of oval and equal-armed brooches are the largest groups, with six and seven mould fragments respectively, visible in table 1 (Pedersen, 2016a:99). Even though the moulds with identifiable imprints represent a small and far from representative group of material, they can still provide some insight into the crafts activity of non-ferrous metalworkers (Pedersen, 2016a:99). To some extent there appears to be a correspondence with the mould impressions and lead models found at Kaupang, as in both types of material equal-armed brooches comprise the largest group, and the same types of equal-armed brooches with the same types of decoration appears as both moulds imprints and models (Pedersen, 2016a:99). The common denominator of the identified impressions would appear to be the fact that these are objects that were manufactured on a large scale in the Viking Period, and when considered alongside the lead models would indicate that metalcasting in Viking Age Kaupang was characterised by serial production of near-identical artefacts (Pedersen, 2016a:99–100).

Object imprint	Quantity
Oval brooch	6
Equal-armed brooch	7
Pin/needle	2–4
Trefoil brooch	2
Rectangular mount	1

Table 1: Artefact imprints identified among the fired clay moulds from Kaupang. Numbers with a range includes uncertain interpretetations (Data from Pedersen, 2016a).

Many of the mould fragments with object impressions also appear to have no traces of decoration even when the original inner surface of the mould is preserved (Pedersen, 2016a:100). This absence of ornamentation can be compared to material from Ribe, where Claus Feveile and Stig Jensen (2006:154) argued that certain objects must have been greatly worked up and decorated after casting. In addition to the imprints of objects, textile impressions have also been observed on moulds and finished products from various parts of Scandinavia during the Viking Age (Ambrosiani and Erikson, 1994:25; Brinch Madsen, 1984:34). There appears, however, to be a conspicuous absence of such textile impressions in the mould material from Kaupang (Pedersen, 2016a:103). Kaupang could potentially differ from the other Viking Age towns in this aspect, although it is a very reasonable assumption that this absence of textile impressions is rather a reflection of the poor state of the evidence than a clear difference in the metalworking activities (Pedersen, 2016a:104).

Just like the melting crucibles, the clay moulds from Kaupang have been subject to archaeometallurgical analyses with the aim of identifying which metals were cast in the moulds. For this purpose, seven fragments of what are believed to be clay moulds were selected (Pedersen, 2016a:108). The only metals that could be identified were copper and zinc, both represented entirely by oxides on the inner side of the moulds (Pedersen, 2016a:108). The use of copper-alloys coincides well with the identified mould impressions of equal-armed and oval brooches, as these were artefact types which occur most frequently as copper-alloy objects (Pedersen, 2016a:108–109). The zinc oxides, however, are less useful as indicators of the metal being cast as zinc is a highly volatile metal and almost any amount of zinc in an alloy could have caused the amount of zinc oxides observed. As such, the zinc oxides were considered to provide little information (Pedersen, 2016a:109). Incidentally, some of the analyses also revealed that the composition of clay was strikingly similar in all seven mould fragments being investigated, indicating a shared provenance, as well as sharing clear features with what is assumed to be local clay from a hearth excavated at Kaupang (Pedersen, 2016a:109).

In order to reject or confirm the hypothesis that the moulds consisted of local clay, the seven mould fragments were examined using a combination of thin-sectioning and chemical analyses (Pedersen, 2016a:109). The moulds were also compared with what is believed to be local clay from Kaupang in the shape of a loom weight and the clay platform of a hearth. The local source of the clay in the loom weights and the hearth was assumed to be reasonably certain based on clear similarities in chemical composition and petrology with clay sampled from the Viksfjord (Pedersen, 2016a:110). The analyses showed that the clay from the moulds was not identical with the local clay used in the loom weights and the hearth. However, this may be because of podsolization which would have led to the washing out of some of the elements of the clay and therefore causing dissimilarities in the chemical composition of the clay (Pedersen, 2016a:110). Such podsolization has been demonstrated at Kaupang (Sørensen et al., 2007:255). As such, it has been argued that the moulds were likely made of local, but specifically chosen, clay and that the washed-out clay potentially had qualities that the metalworkers at Kaupang were attracted to (Pedersen, 2016a:110). Furthermore, the moulds were also compared with a wide selection of ceramic samples from various sites in Scandinavia and the Baltic using factor analyses. The moulds from Kaupang appears to be different from all the other samples which further supports the interpretation of the clay as local (Pedersen, 2016a:110).

During the excavations at Kaupang, ten moulds of soapstone or similar material was found in the settlement layers (Pedersen, 2016a:84 and 87). All of these moulds were categorized as “open moulds” and were immediately recognized as re-usable moulds (Pedersen, 2016a:84). As such, the stone moulds differ significantly from the clay moulds. One of the stone moulds is near-complete, another is a reused soapstone vessel, while the rest are fragmentary (Pedersen, 2016a:84). The majority of these stone moulds appear to have been used to cast ingots, with six out of the ten having several casting hollows for ingots. There were 15 casting hollows for ingots in total, with twelve of them being used to create bar-shaped ingots and three for oblong and nearly rectangular ingots (Pedersen, 2016a:86). One of these moulds appear to be a re-used soapstone vessel sherd which has three casting hollows that have been interpreted as being used to cast weights (Pedersen, 2016a:86). Furthermore, one of the soapstone moulds appears to have a hollow closely related to the ingot hollows but is relatively wide with an almost oval shape. This piece also differs from the others in that the base is heavily sintered and contains a number of gold droplets of varying size. Pedersen (2016a:86) notes that this is potentially a cupellation crucible for purifying gold but could also be a mould for casting ingots or gold blanks. In any case, it would be another representation of the non-ferrous metalworkers at Kaupang working with gold.

With the exception of the soapstone mould with gold droplets, none of the soapstone moulds had visibly identifiable remains of metal. In order to gain further insight into what metals were cast, all ten soapstone moulds were subject to archaeometallurgical analyses (Pedersen, 2016a:90). Traces of metal was found in every single mould, and the results show that they were mostly used for casting silver, gold, and lead, as well as potentially some copper-alloys (Pedersen, 2016a:90–94). Most of the casting hollows contained traces of several different metals, with lead being most frequent. Practically pure lead was cast, and the purity of the metal and the frequency of its use corresponds with the quality and quantity of lead ingots and waste found at Kaupang (Pedersen, 2016a:92). Furthermore, only lead was found in the casting hollows used to make weights, which coincides with the fact that essentially all the weights found at Kaupang were made of lead (Pedersen, 2016a:93). Nine of the casting hollows were most likely used to cast silver, which appeared to have been pure or mostly pure (Pedersen, 2016a:92).

As there are no known soapstone outcrops in Vestfold, the moulds must have travelled some distance to reach Kaupang (Baug, 2011:329). In the hopes of tracing the provenance of the soapstone found at Kapang, chemical analyses of selected soapstone objects were undertaken. A large number of soapstone vessel sherds were selected alongside two of the soapstone moulds and one tuyere fragment (Pedersen, 2016a:84). The results indicated that the vessel sherds shared provenance, while the moulds and tuyere appear to originate from a different quarry (Pedersen, 2016a:84). As such, it appears that the soapstone moulds arrived to the town from a different location than the soapstone vessels, meaning that they could have been brought to Kaupang by different groups of people, for instance the metalworkers themselves (Pedersen, 2016a:84).

Fig. 4.1.7: Melting crucibles and stone moulds from Kaupang (C52519/23426, C52519/23628, C52519/23627, C52519/16411, horizontally from top left to bottom right) (Image: E.I. Johnsen and K. Helgeland, KHM).

Of the moulds consisting of alum slate, gabbro, and volcanic tuff respectively, the first two appear to have been used as ingot moulds, see fig. 4.1.7 (Pedersen, 2016a:94–95). C52519/16411, the mould of volcanic tuff, however, has a clear imprint of a pendant and includes a clever way of making a loop for the pendant, visible in fig. 4.1.8 (Pedersen, 2016a:82). A narrow groove appears to have been carved in across the inlet channel of the mould, which would allow a thin metal rod to be inserted forcing the metal to flow around the rod and into the mould. The metal rod would then be removed, resulting in a cast pendant loop (Pedersen, 2016a:82). Loops of this kind is apparently typical of several locally made pendants of lead, such as the one in fig. 4.1.9, and parallels between the mould impression and local lead pendants indicates that this mould was used to produce similar pendants (Pedersen, 2016a:83 and 172). The volcanic tuff the mould is comprised of does not appear near Kaupang, and this piece likely originated on the European continent, potentially in Germany or Italy (Pedersen, 2016a:83). As such, the material for this mould must have been imported to Kaupang and represents long-distance connections as well as clearly showing that simple lead jewellery was being produced in reusable moulds at Kaupang.

Fig. 4.1.8: Stone mould for casting pendants (C52519/16411) (Image: E.I. Johnsen and K. Helgeland, KHM).

Fig. 4.1.9: Lead pendant from Kaupang (C52519/14056) with a loop made using the same technique that is employed with the stone mould C52519/16411 (Image: E.I. Johnsen, KHM).

Beyond the clay and stone moulds, there was also a peculiar find of a single mould made out of lead which has been interpreted as a mould for making wax models, visible in fig. 4.1.10 (Pedersen, 2016a:74). If the objective was to create a unique object, the wax model would probably have been shaped by hand. With the aid of this model mould however, a long series of essentially identical wax models could be cast within a short period of time (Pedersen, 2016a:98). In terms of serial production, the use of a wax mould would allow the non-ferrous metalworkers to make a series of clay moulds in a close sequence, thus allowing a number of clay moulds to dry simultaneously (Pedersen, 2016a:98). In contrast, a solid, re-usable model made out of for example lead, wood, or antler would have to remain in the moulds until it has dried sufficiently (Pedersen, 2016a:98). As such, the use of re-usable models could represent a serial production over a longer period of time, while the mould for wax models could represent a more intense serial production in a relatively concentrated period, or bursts of production for making sets of objects (Pedersen, 2016a:98). Either way, the lead mould for wax models implies that serial production involving the lost-wax method took place at Kaupang.

Fig. 4.1.10: Lead mould for wax models for making rectangular mounts in the Borre style (C52517/2447) (Image:E.I. Johnsen, KHM).

4.1.4 Cupellation crucibles

Metallurgical ceramics is an umbrella term for clay objects that were used in metalworking such as the furnace-structure itself, melting crucibles, moulds, and other specialized implements made of clay (Pedersen, 2016a; Söderberg, 2004). Essentially, metallurgical ceramics were crucial pieces of equipment used by metalworkers, in much the same way as tongs, files, and hammers (Holback, 1999:6). One such specialized clay implement would be cupellation crucibles, of which 21 definite and nine possible fragments were identified during the excavation at Kaupang (Pedersen, 2016a:129). These fragments are unfortunately quite small, with maximum dimensions ranging from 11 to 36 mm and a thickness measured between 6 and 18 mm (Pedersen, 2016a:130). The cupellation crucibles appear in two main shapes: round, and rectangular, which incidentally lines up with Brinch Madsen's crucible types 6 and 7 (Brinch Madsen, 1984; Pedersen, 2016a:130). This highlights the fact that earlier discussions, such as Brinch Madsen's (1984) work on material from Ribe, often misidentified cupellation crucibles as melting crucibles due to a lack of awareness of this type of material (Pedersen, 2016a:129).

Unlike melting crucibles, the cupellation crucibles are characterized by having a heavily sintered upper surface and a slightly or even un-sintered exterior base (Pedersen, 2016a:129). This pattern of sintering is believed to be a result of the cupellation crucibles being exposed to heat from above by holding the relatively shallow bowl of the crucible in front of the current of air coming from the bellows. The cupellation crucibles tended to be quite small, and Pedersen (2016a:130) notes that the round crucibles from Kaupang likely varied in diameter from 30 to 90 mm, but generally clustered around 60 mm in diameter. Because of their size they were likely used to refine only small amounts of silver and gold (Pedersen, 2016a:130).

Cupellation crucibles functioned as an implement in small-scale cupellation, i.e. the refinement of precious metals (Lønborg, 1998:13). The aim of this cupellation process is to remove base metals from the precious metals, which involves alloys containing gold or silver being added to lead and subjected to oxidizing melting causing the metals in the alloy with a lower melting point than the gold or silver to melt or evaporate while the precious metals remain (Pedersen, 2016a:129). The result of this process is an increased portion of precious metal in the remaining piece of metal alloy. While the cupellation process allowed for the separation of base metals from alloys containing precious metals, silver and gold could not be separated from each other using this method (Pedersen, 2016a:129). The refinement of precious metals in cupellation crucibles is visible in the remains of gold melted drops on four of the sherds, as well as several of the crucibles being coloured red on the surface, which implies that copper had been separated out. Such a red colouration is visible in fig. 4.1.11 (Pedersen, 2016a:129–130).

Fig. 4.1.11: Fragments of cupellation crucibles from Kaupang with red coloration likely caused by copper alloys being separated from gold or silver through cupellation (C52516) (Image: E.I. Johnsen, KHM).

Another physical characteristic of the cupellation crucibles is the presence of a hollow which often occurs on the surface of a used crucible. This hollow is a result of the cupellation process and shows where on the crucible surface the refined metal had collected (Pedersen, 2016a:129). Incidentally, this hollow reveals that the metal was not poured out after cupellation, but rather removed in a solidified state (Pedersen, 2016a:129). Furthermore, after a cupellation crucible had been used, the porosities in the clay would be filled with metal oxides from the lead used in the process, as well as the metals being separated out, consequently rendering the crucible useless

(Pedersen, 2016a:129). As a result of this, a cupellation crucible could only be used for a single cupellation process and would be considered consumable (Lønborg, 1998:15; Pedersen, 2016a:129).

Six of the cupellation crucible sherds were also selected for archaeometallurgical analyses. All of the fragments had a high content of lead oxides, a clear indicator of cupellation processes involving lead which reinforced the interpretation of these fragments as cupellation crucibles (Pedersen, 2016a:131). There was also evidence of the crucibles having been used to melt silver and gold, which is another indication of their use (Pedersen, 2016a:132). The analyses also revealed some information about the clay in the cupellation crucibles and it seems like some were made of imported clay, like the melting crucibles, while others consisted of local clay (Pedersen, 2016a:134). The differences in the clay could represent another aspect of personal preference amongst the non-ferrous metalworkers, or perhaps the metalworkers simply used whatever was available at the time.

4.1.5 Lead models

Perhaps the most striking finds from the research excavations at Kaupang is the assemblage of 25 lead models identified by Pedersen (2016a:38), one of which can be seen in fig. 4.1.12. However, it has been pointed out that the identification of twelve of these lead models should be considered uncertain, and in the case of six other pieces, their interpretation as model is just one of several possibilities. As such, only seven of the lead models can be regarded as definite lead models (Pedersen, 2016a:38). Furthermore, the definition and identification of this material can be considered particularly problematic as it can be difficult to distinguish the models from finished lead artefacts and practice castings (Pedersen, 2016a:38). Despite the problematic nature of the material,

Fig. 4.1.12: Lead model for making equal-armed brooches from Kaupang (C52517/677) (Image: E.I. Johnsen, KHM).

Pedersen (2016a:64) argues that all 25 can be reasonably identified as lead models by viewing these objects in context. As such, I have decided to treat this assemblage of 25 lead artefacts as lead models.

Models are instrumental in the creation of clay moulds and lead was likely not the only material these models were made out of (Pedersen, 2016a:38–39). Casting models of horn, bone, antler, wood, and leather could all have potentially been used in non-ferrous metalworking although poor preservation conditions for organic material at Kaupang means no such items were found (Pedersen, 2016a:39). Models were generally used when making composite clay moulds and the finds of lead models thus correspond with the clay mould material at Kaupang consisting exclusively of composite moulds (Pedersen, 2016a:70). Among the lead models, the by far largest group of artefact type is equal-armed brooches. However, there are finds of lead models for a large variety of objects which highlights a variety in the metalworking production that is not visible in the mould material, see table 2 (Pedersen, 2016a:40–60).

Lead model	Quantity
Equal-armed brooch	8
Penannular brooch	2
Lozenge brooch	1
Matrix dies	1
Mounts	4
Armrings	2
Key-handles	1
Miniature axe	1
Irish disc	1
Owl-like figure	1
Unclassified	3

Table 2: The lead models found at Kaupang and their interpreted product (Data from Pedersen, 2016a).

4.1.6 Matrix dies

Three possible matrix dies were found at Kaupang which were very likely connected to the production of pressed foils. One of these matrices is visible in fig. 4.1.13, and a gold pressed foil can be seen in fig. 4.1.14 The presence of these matrix dies would imply that the non-ferrous metalworkers in the town possessed a wider repertoire than just casting (Pedersen, 2016a:78). Unfortunately, no patrix dies were discovered, but one of the lead models is believed to have been used to produce patrices (Pedersen, 2016a:80). This would also imply that the metalworkers produced at least some of their own implements. The matrix dies found at Kaupang were likely used to produce decorative nail heads and pressed foil decorations for oval brooches (Pedersen, 2016a:80). As such, the pressed foils allowed for the serial production of sets of decorative elements.

4.1.7 A lead punch pad

C52517/2040[2], a rolled up flat piece of lead with a series of different punch-marks was discovered at Kaupang. This object has been interpreted as a punch pad that was used for testing a range of different punches (Pedersen, 2016a:146). On the pad's surface, four flower-shaped and two crescent-moon shaped punch-impressions have been identified (Pedersen, 2016a:146). Punch-decorations appear on a wide range of objects from the Viking Period, and punch pads could have been used to test punches before decorating the object (Pedersen, 2016a:146). As such, the existence of this lead punch pad can serve as indirect evidence that the non-ferrous metalworkers at Kaupang employed punches in their work. The lead model finds at Kaupang also reveals that this form of decoration could have been executed on lead models, as two models for armrings appears to be punch-decorated, see fig. 4.1.15. As such, the metalworker may have tested out how the punch would work on the material in which the decoration would be created, in this case a lead punch pad used for testing before decorating lead objects (Pedersen, 2016a:146).

Fig. 4.1.13: Matrix die from Kaupang (C52517/1289) (Image: E.I. Johnsen, KHM).

Fig. 4.1.14: Gold pressed foil decorated with filigree from Kaupang (C52519/14057) (Image: E.I. Johnsen, KHM).

[2] I have been unable to locate an image of this object in an online artefact database, but it is described in Pedersen (2016a).

Fig. 4.1.15: Lead models for armrings (C52519/20085, left) (C52519/21224, right) from Kaupang decorated with punch marks (Images: E.I. Johnsen, KHM).

4.1.8 Metals

4.1.8.1 Ingots

While ingots have served as an important source of raw material for non-ferrous metalworking activity, it is also important to be aware of their importance, particularly that of ingots of silver and copper alloy, as mediums of exchange (Hårdh, 1996; Lønborg, 1998:10–12; Pedersen, 2016a:146). As such, many ingots could easily be considered raw material for metalworking just as well as being intended for use as payment in exchanges. From the material excavated at Kaupang, Pedersen (2016a:146) interpreted a total of 208 metal objects as ingots. She employs a very broad definition and includes everything from easily identifiable ingots to smaller, worked or corroded fragments. As such, all more or less regularly cast pieces of metal of a reasonable size have been treated as ingots in the material from Kaupang (Pedersen, 2016a:146). Sindbæk (2005:52–54) has pointed out that, from a technical point of view, ingots of regular shape are unnecessary in metalworking as the shape of the lumps of metal are inconsequential when used as raw materials. As such, regularly shaped ingots could be related to an idea of standardised shapes used to promote exchange, therefore connecting the ingots more firmly to the sphere of trade and exchange (Sindbæk, 2005:52–54). With this in mind, I believe Pedersen's broad definition of ingots to be particularly useful when trying to include and examine the raw material utilized by the non-ferrous metalworkers at Kaupang.

Lead ingots constitute the largest group of ingots from Kaupang totalling 100 ingots. This material represents a considerable amount of metal with a cumulative weight of around 6 kg (Pedersen, 2016a:148). Unlike the ingots of silver and copper alloy, lead ingots have a much wider range of variation. The group of lead ingots include bar-shaped, boat-shaped, plano-convex, and oblong ingots (Pedersen, 2016a:148). In addition to shape, the lead ingots also vary greatly in size, from 6 to 330 g, with some of the fragments being indicative of ingots weighing well over a kilogram (Pedersen, 2016a:148). Pedersen (2016a:148) argues that the lead ingots can be classified on the basis of shape, and that several different types appear. Furthermore, she claims that it is entirely reasonable to suppose that lead was also exchanged in the form of ingots (Pedersen, 2016a:148). However, the regularity among smaller lead ingots could potentially be a by-product of metalcasting activities. As the metalworkers would fill their melting crucibles with more metal than necessary in order to ensure that there was enough metal to fill the mould, the excess metal was potentially poured into an open and reusable mould, such as the soapstone moulds uncovered at Kaupang. This would lead to small regular ingots being cast (Pedersen, 2016a:148).

Five complete ingots and eleven fragments of silver ingots were discovered at Kaupang (Hårdh, 2008:103–104; Pedersen, 2016a:146). Birgitta Hårdh (2008:103) notes that there are clear similarities between the five complete ingots, all of which are described as elongated with rounded ends and an almost rectangular cross-section, such as the ingot visible in fig 4.1.16. Amongst the eleven ingot fragments, however, there appears to be greater variation with round, oval, trapezoid, four-sided, and six-sided sections (Hårdh, 2008:104). Two of the complete silver ingots and five of the fragments were selected for archaeometallurgical analyses which revealed that all the ingots consisted of relatively pure silver, with a silver content above 95% (Pedersen, 2016a:153).

Fig. 4.1.16: Silver ingot from Kaupang (C52517/579) (Image: E.I. Johnsen, KHM).

The copper alloy ingots include eleven complete ingots and 81 fragments (Pedersen, 2016a:147). With one exception, the ingots are all bar shaped. However, there appears to be significant variation in terms of size and section (Pedersen, 2016a:147). The width of the ingots falls between 4 and 21 mm, with a thickness between 3 to 17 mm, and a length from 22 to 96 mm. As such, the copper alloy ingots from Kaupang appears to be quite small (Pedersen, 2016a:147). The distribution of the ingots implies that copper-alloy ingots were used over a large part of the town, potentially as both raw material and as means of exchange (Pedersen, 2016a:147).

A total of 22 copper alloy ingots were subject to archaeometallurgical analyses (Pedersen, 2016a:154). Of the 22 ingots, one appears to consist of bronze, three of gunmetal, and 18 proved to be brass (Pedersen, 2016a:154). With one exception, the brass ingots could be divided into four groupings based on their zinc content. The ingot that could not be grouped had a zinc content of 28.8% which is an exceptionally high level of zinc content in the Iron Age (Pedersen, 2016a:154). It was essentially impossible to obtain higher zinc levels with the technology available at the time, and as zinc readily evaporates during casting, the ingot with 28.8% zinc content was undoubtedly primary raw material which had not been used before (Lønborg, 1998:12; Pedersen, 2016a:154). Two of the other groups of brass ingots held a zinc content with around 23–24% and 20–21%. This implies that brass was a primary raw material available to the non-ferrous metalworkers at Kaupang (Pedersen, 2016a:155). Incidentally, the brass ingots from Hedeby also clustered around the exact same ranges of zinc content (Merkel, 2018:296). The brass ingots could have been used directly as raw material for artefacts, as well as being used to add more zinc to scrap metal to "freshen it up" if deemed necessary (Hedegaard, 1992:84; Lønborg, 1998:12; Pedersen, 2016a:158).

The results of the archaeometallurgical analyses show that well-adjusted brass ingots arrived at Kaupang, and many of them must have come from areas where carefully controlled brasses were produced without having been re-melted along the way (Pedersen, 2016a:155–158). The analyses provide no provenance for the brass ingots, but local origins in Scandinavia is hardly possible (Hedegaard, 1982:84; Sindbæk, 2005:64; Pedersen, 2016a:158). A plausible source for the brass ingots is Aachen in the Rhineland area in Germany which re-emerged as a centre for brass-production in the early Viking Age. This is further corroborated by the presence of other groups of artefacts excavated at Kaupang that are seen as indicative of notable contact with Frankish territories (Gaut, 2011; Pedersen, 2016a:158; Pilø, 2011; Wamers, 2011).

4.1.8.2 Metal fragments

A large quantity of metal fragments was found at Kaupang, mostly through the metal-detecting surveys that took place as part of the project (Pedersen, 2016a:158–159). The material classified as metal fragments is a very diverse assemblage that is characterized by not having been identified as belonging to any particular artefact-type or -group (Pedersen, 2016a:159). While some of the metal fragments found at Kaupang could possibly be linked to metalworking as raw material, there appears to be no clear relation to metalworking amongst the copper alloy, silver, and gold fragments (Pedersen, 2016a:159–160). The lead material, however, appears to consist of a diverse collection of fragments which could be linked to metalworking (Pedersen, 2016a:160). 5.5 kg of lead was discovered at the site, including irregular lumps of lead which may have been raw material and several fragments that appear to have been mechanically worked into thinner discs or plates (Pedersen, 2016a:160). Beyond serving as raw material, the flat-hammered lead fragments could also have been used in the process of purifying precious metals, i.e. cupellation (Pedersen, 2016a:160).

4.1.8.3 Casting Waste

A total of 6 kg of melted drops were discovered during the excavation project, primarily through metal-detecting surveys. Lead constitutes by far the largest group of melted drops, followed by copper alloys, silver, and then gold (Pedersen, 2016a:161). Melted drops are small metal objects characterized by signs of having been melted and haphazardly spilt, generally as a result of metal being spilt when poured from a crucible into a mould (Pedersen, 2016a:161). As molten metal sets very quickly and the metalworkers were incapable of adding more metal in the middle of a casting process, they probably over-allowed for the metal required to cast an object in order to ensure that the casting would be successful. Consequently, when the mould and inlet shaft were filled to the brim, the surplus metal would run over the side of the mould and lead to the formation of melted drops (Pedersen, 2016a:161). The term melted "drops" might be considered misleading, as some of the lead and copper alloy drops are substantial lumps of metal. The silver and gold drops, however, are consistently quite small in size (Pedersen, 2016a:161). The differences in size between drops of different metals is likely a result of the metalworkers taking much greater care when pouring precious metals, as well as more carefully reclaiming melted drops than when dealing with more abundant metals like lead and copper alloys.

Casting sprues is a group of waste metal which can be linked to metalcasting with a high degree of confidence and consists of the metal which filled the inlet of a mould during casting and has been cut off in order to finish the cast artefact (Pedersen, 2016a:165). As such, the casting sprues have a characteristic conical shape, like that of the inlet shafts of the Viking Age composite moulds (Pedersen, 2016a:165). A total of 51 casting sprues of varying size were discovered during the project, mostly through metal-detecting surveys, with copper alloy sprues forming the largest group followed by lead, as well as a single silver sprue (Pedersen, 2016a:165). Finished products tend to be difficult to locate in production sites making it a challenge to glean information about the artefacts being produced. However, as the casting sprues are essentially cast in the inlet shaft of a mould, and moulds for larger objects require larger inlets, the size of a casting sprue provides some information about the size of object that was cast (Pedersen, 2016a:165–166). Because the casting sprues consist of the same metal as the cast objects, this material also enables us to look at the chemical composition of the finished products by performing archaeometallurgical analyses on the casting sprues (Pedersen, 2016a:165).

A total of 21 pieces of copper alloy production waste, consisting of 14 casting sprues and seven melted drops, were selected for archaeometallurgical analyses as a part of the Kaupang research project, see fig. 4.1.17 (Pedersen, 2016a:168). The results show that twelve of the 14 sprues were of brass, four of the drops were brass, with three drops of pure or nearly pure copper (Pedersen, 2016a:162–170). Just like the ingots analysed during the project, the brass casting sprues were grouped based on their zinc content, with groups clustering around 20%, 15% and below 10% zinc content which corresponds closely to the brass ingots. This clearly shows that brass ingots were being used as raw material for casting at Kaupang (Pedersen, 2016a:168–170). With regards to the melted drops of essentially pure copper, Pedersen (2016a:162) notes that pure copper was rarely used in casting, and that the copper could have functioned as solder rather than being melted drops, and as such can rather be considered connected with ironworking. While the analyses of casting waste themselves provide limited insight into the non-ferrous metalworking at Kaupang, when viewed in context alongside the results from the analyses of ingots, crucibles, and moulds they form part of a picture showing a consistent use of large amounts of brass in casting activities at Kaupang (Pedersen, 2016a:170).

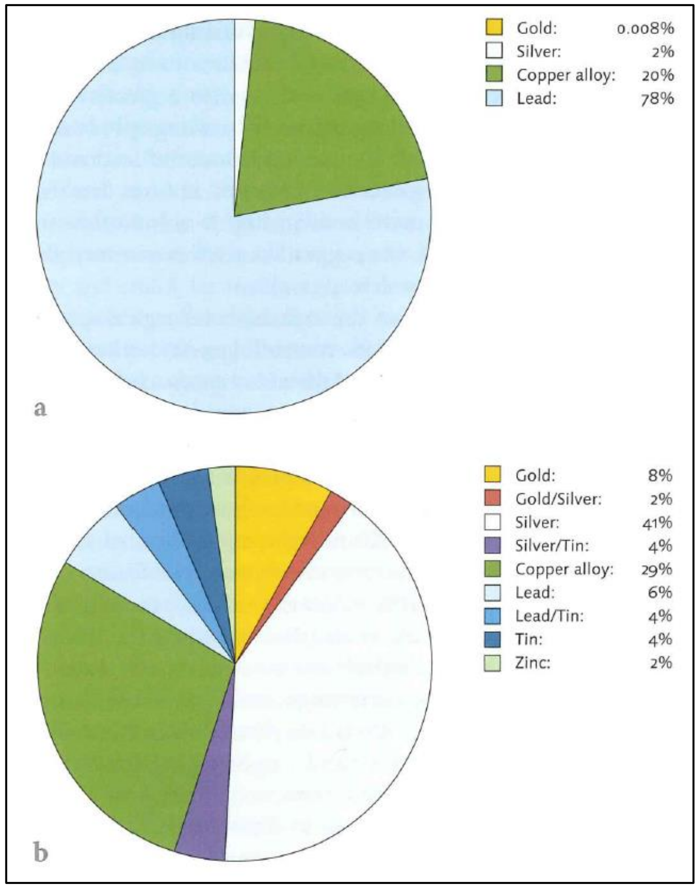

Fig. 4.1.17: Comparison of melted drops of metal (a) and remains of metal in melting crucibles (b) identified at Kaupang. These sector diagrams highlight the disparity between casting activity that is visible in waste material, and the activity visible through analysed crucibles fragments (Image: Pedersen, 2016a:191).

While most of the casting waste from the site is bulk material with no meaningful or particular individual features, there is one significant piece of casting waste worthy of attention. This object, C52517/1737, weighs 29.8 g and consists of the original half-melted contents of a crucible which appears to have completely disintegrated (Pedersen, 2016a:167). This lump, containing around twelve coins and some other pieces of silver, visible in fig 4.1.18, is significant as it shows how silver currency such as fragmented dirhams and arm rings were recycled at the site (Pedersen, 2016a:167). The object has been subjected to archaeometallurgical analyses and consist of essentially pure silver, just like the rest of the analysed silver from the site (Pedersen, 2016a:167). As such, the silver from Kaupang is much more akin to dirhams, with their essentially pure silver content, than it is to contemporary European silver which contained greater amounts of tin and zinc (Pedersen, 2016a:167–168). While the similarities between the silver from Kaupang and dirhams could be explained as the Kaupang silver essentially consisting of recycled dirhams, the purity of the silver at Kaupang could just as easily have been caused by refining silver through cupellation, as evidenced by the cupellation crucibles at the site (Pedersen, 2016a:168).

Fig. 4.1.18: Half-melted lump of silver (C52517/1737) (Image: E.I. Johnsen).

4.1.9 Metalworking workshops

Two of the building plots excavated during the Kaupang research project has been interpreted as sites where non-ferrous metalworking took place; plot 1B and building A302 on plot 3A (Pedersen, 2016a). Plot 1B appears to be a non-ferrous metalworking site with a deliberately deposited layer of clay which has been interpreted as a workshop floor, as well as a layer of charcoal which is believed to be a layer of metalworking waste (Pedersen, 2016a:17, 181 and 182). The workshop contains a significant concentration of finds, with large assemblages of melting crucible sherds, clay mould sherds, and melted drops, as well as a single sherd of a cupellation crucible (Pedersen, 2016a:181). The majority of type 3 melting crucibles found in Kaupang originated from this workshop assemblage (Brinch Madsen, 1984; Pedersen, 2016a:182). The large assemblages related to casting activity implies that casting activity took place on a substantial scale in this building, and the size of the crucible sherds show that a wide range of different amounts of metal was melted (Pedersen, 2016a:182). As no signs of metalworking techniques related to ironworking has been found in the layers of the workshop, the likely interpretation is that a group of metalworkers specializing in non-ferrous metals used this building as their workshop (Pedersen, 2016a:183).

There were no visible traces of metal on any of the melting crucibles, but eleven of the crucibles from plot 1B were subject to archaeometallurgical analyses with the results showing that seven sherds had clear evidence of being used to melt silver and the rest containing evidence of lead, silver and gold alloy, and an alloy of tin and silver (Pedersen, 2016a:182). As a cupellation crucible sherd was found in the workshop, as well as an apparent focus on working with silver, the refinement of silver appears to have been practised alongside the casting of silver objects in this workshop (Pedersen, 2016a:182). As such, it would not be unreasonable to assume that this group of non-ferrous metalworkers specialized as silversmiths, although they still worked with other non-ferrous metals (Pedersen, 2016a:183).

In plot 3A, an assemblage of non-ferrous metalworking finds was excavated from in situ activity layers associated with a building phase named A302 (Pedersen, 2016a:184). The assemblage is much smaller than that of plot 1B, and consists of sherds of moulds and melting crucibles, and some melted drops of different copper alloys (Pedersen, 2016a:184). Archaeometallurgical analyses of melting crucible sherds from this context indicates that silver, leaded bronze, and an unknown copper alloy was melted in the crucibles. As such, the assemblage from this building has been interpreted as casting activity with a focus on copper alloys (Pedersen, 2016a:184). Unlike plot 1B, the casting activity at building A302 appears to have been quite short-lived, and the other layers excavated at plot 3A consists of assemblages related to other crafts such as glass working and textile production (Pedersen, 2016a:184). As such, plot 3A appear to have been a multi-functional location with a short period of non-ferrous metalworking activity (Pedersen, 2016a:185).

4.2 Material from excavations at Ribe

4.2.1 Background

The site of Ribe in Denmark differs from Kaupang and Birka in one way in particular; it is the location of a modern city. This has led to some significant differences in the type of excavations that have taken place, the chronological extent of the material, and the preservation conditions of the site. Early investigations and trial trenches during the 20th century in Ribe managed to determine that the Viking Age settlement was restricted to the northern side of the river Ribe Å that runs through the modern city (Bencard and Brinch Madsen, 1981; Bencard, 1984b). In an effort to locate and learn more about the Viking Age settlement at Ribe, a major research project was started in 1955 which culminated in a series of excavations in the period 1970–1976 where parts of the oldest settlement at Ribe was discovered (Bencard, 1984a:10). These excavations took place in the area surrounding the street Sct. Nicolaj Gade and revealed a plethora of waste material from metalworking activity (Bencard, 1984a:10; Brinch Madsen, 1984).

Beyond the research excavations of 1970–1976, the vast majority of archaeological excavations in Ribe consists of rescue excavations as a result of construction work in modern Ribe (Feveile, 2006a; Feveile, 2006b). In a publication series edited by Claus Feveile (2006b) a total of 23 excavations that took place on the northside of Ribe Å between 1984 and 2000 is presented. However, a significant portion of these excavations lacked any reasonable amount of material related to metalworking and will therefore be excluded. Furthermore, many of these excavations also include material from the Medieval period, and in some cases modern material as a result of disturbed stratigraphy (Feveile, 2006a; Feveile, 2006b). As such, material which has not been confidently dated to the Late Iron Age will be excluded as they fall outside the scope of this thesis. In sum, the Late Iron Age material pertaining to metalworking activity from the research excavations in Ribe that took place between 1970 and 1976 as well as a number of commercial excavations undertaken in the period 1984–2000 will be presented and discussed.

4.2.2 Ribe 1970–1976

4.2.2.1 Crucibles

A total of 225 fragments of crucibles were found during the 1970–1976 excavations in Ribe. Most of these fragments were quite small, but in a few cases a near-complete crucible could be reconstructed (Brinch Madsen, 1984:25). All the crucible fragments consisted of clay mixed with sand, and the outer surface of the fragments were hard-fired and often vitrified (Brinch Madsen, 1984:25). The thickness of the crucible sherds varied from 3 to 15 mm. However, the majority of the fragments fell within the range of 5–8 mm thick. When measured from the rim to the bottom, the height of the crucibles ranged from 31 to 98 mm (Brinch Madsen, 1984:25).

A characteristic for the majority of the sherds is a ca. 1–2 mm thick layer of clay that has been added to the original outer surface when it became vitrified. These additional layers of clay have been interpreted as representing refurbishing of the crucibles, where the clay was used to seal cracks caused by uneven heating (Brinch Madsen, 1984:25). The crucibles were subject to metal analyses; however, the soil conditions of the site had led to the metal remains within the crucibles to corrode, meaning information on the precise alloys present in these crucibles were unobtainable. Despite this, the analyses of the corrosion products show that bronze, brass, silver, and lead have been melted in these crucibles (Brinch Madsen, 1984:28)

As mentioned in the chapter dealing with the material from Kaupang, a prominent typology of Late Iron Age crucibles was created by Brinch Madsen (1984) during his work on the material from the Ribe research excavations. As such, all the crucible types naturally appear in this material. Based on the notes by Pedersen (2016a) regarding this typology, the presence of the Vendel Period type 5 crucibles would indicate that metalcasting took place at Ribe from the early stages of settlement. Furthermore, a reinterpretation of type 6 and 7 crucibles as cupellation crucibles naturally means there are is clear evidence of cupellation activities at Ribe, one of which is visible in fig. 4.2.1 (Brinch Madsen, 1984; Pedersen, 2016a:111; Söderberg, 2004).

4.2.2.2 Moulds

More than 1 600 mould fragments, with a total weight of 7.5 kg, were found at Ribe in the excavations during 1970–1976 (Brinch Madsen, 1984:31). The moulds consisted of micaceous clay with an admixture of sand, chamotte, and fine organic materials. In general, the outer surface of the moulds had a red- or yellow-brown colour, while the inner surface was typically black (Brinch Madsen, 1984:31). Thin sections of three mould fragments were subject to qualitative analyses in order to determine the composition and porosity of the moulds (Brinch Madsen, 1984:31–34). These analyses revealed that the micaceous clay used in the constructions of these moulds were possibly local but did not rule out an origin in northern Germany or Holland. This clay could have been found roughly 15 km from Ribe and was clearly preferred over the much closer and readily available boulder clay at Lustrup, roughly 3 km south of Ribe (Brinch Madsen, 1984:31–32).

The composition of the moulds from Ribe closely resembles natural moulding sand, i.e. quartz sand with a natural content of clay (Brinch Madsen, 1984:33). The Ribe moulds differ from the natural sand moulds significantly in that they are not porous, and as such, air cannot travel through the fabric of the mould (Brinch Madsen, 1984:34). With the exception of a single fragment, every mould fragment derives from composite moulds, which would allow the air to escape through the parting face between the two halves of the mould (Brinch Madsen, 1984:33–34). The single fragment of a single-piece mould could be related to the earliest metalworking in the town, alongside the type 5 crucible, and therefore represents an early craft tradition rather than an exception to the clear dominance of the composite moulds in the material.

191 of the mould fragments retained an impression of the model or object around which the mould was formed, and the majority of these impressions are so well-preserved and distinct that an identification could be made (Brinch Madsen, 1984:37). More than half of the identified impressions are of oval brooches, with the majority being of the Berdal type (Brinch Madsen, 1984:37). However, there were also finds of moulds for undecorated oval brooches, implying that some of the brooches were decorated solely after casting (Brinch Madsen, 1984:37). The other sizable group of mould imprints consists of 23 fragments with key imprints. Further types of

imprints include six fragments with pin imprints, two fragments of equal-armed brooches, and single fragments with imprints of a ring-shaped brooch, a penannular brooch, a horse-shaped brooch, and a possible fitting decorated with animal style. The rest of the fragments with visible impressions appears to be unidentifiable (Brinch Madsen, 1984:78).

4.2.2.3 Other waste products

Among the slags found at Ribe, a few concavo-convex pieces of fused sand and clay were found alongside vitrified lumps of sand. These have been interpreted as deriving from forge-pits and is likely a result of sand at the bottom and sides of a forge-pit fusing with sand thrown into the pit from above (Brinch Madsen, 1984:30). The distribution of this “forge-pit slag” is associated with other foundry waste and thus likely originates from a metalcasting workshop (Brinch Madsen, 1984:30). While these pieces of slag are not particularly relevant themselves, they do represent clear evidence of metalworking workshops in or near the areas of excavation. Other waste products include small fragments of sintered clay which could not be identified as crucible or tuyere sherds that are probably packaging material used in soldering activities (Brinch Madsen, 1984:30–31). Regarding raw materials and waste products, very few pieces of raw metal and waste products of copper alloy were found at the site compared to the significant production activity witnessed through the significant quantity of crucible and mould fragments (Brinch Madsen, 1984:31). The raw metal comprises only of a single bar with a D-shaped section, and two flat-hammered pieces of bronze. The only metalcasting waste of copper alloy that was found consists of a few lumps of metal (Brinch Madsen, 1984:31).

4.2.3 Ribe 1984–2000

4.2.3.1 Crucibles

A total of 2 875 crucible fragments, including a few nearly whole crucibles, which could be confidently dated to the Late Iron Age in Scandinavia were found during the excavations at Ribe during 1984–2000 (Feveile, 2006b). As one might expect, this material is very similar to the assemblages excavated in the earlier excavations. The crucibles appear to have the same composition of clay mixed with sand, with the outer surfaces showing signs of having been hard-fired, and in some cases vitrified (Frandsen and Jensen, 2006:27). The thickness of the crucible fragments varies between 3–9 mm, however the vast majority of the fragments fall within the range of 4–6 mm (Frandsen and Jensen, 2006:27). When the shape of a crucible could be determined, it was generally found that they had a cylindrical or "thimble-shaped" form, and several pieces even had a lug still attached, see fig. 4.2.2 (Feveile and Jensen, 2006:150; Frandsen and Jensen, 2006:27). As such, the majority of the crucibles would likely fit within Brinch Madsen's types 1 through 4, with the fragments containing lugs clearly representing the presence of type 2 crucibles (Brinch Madsen, 1984; Frandsen, and Jensen, 2006:27).

Fig. 4.2.1: Cupellation crucible from Ribe (ASR 1075x001) (Image: SJM)

Fig. 4.2.2: Type 2 crucibles from Ribe (ASR 9x311, left, ca. 6.2 cm tall) (ASR 1077x019, right, ca. 4,7 cm tall) (Images: SJM)

4.2.3.2 Moulds

7 613 fragments of clay moulds were found throughout the 1984–2000 excavations at Ribe (Feveile, 2006b). Unlike the thorough work done by Brinch Madsen (1984), there were no significant analyses done on the moulds found during the later excavations. However, cursory examination of these moulds indicate they consist of the same micaceous clay with an admixture of sand and fine organic material as those analysed by Madsen (Frandsen and Jensen, 2006:23). Many of these moulds also include signs of refurbishment, just like the moulds studied by Brinch Madsen (Brinch Madsen, 1984; Feveile, and Jensen, 2006:153). Furthermore, the material from the later excavations also consists of composite moulds, and a large sample of the mould fragments have visible technical details such as funnels, sprues, and lugs (Feveile, 2006b; Feveile and Jensen, 2006:153; Frandsen and Jensen, 2006:23). In addition to the fired clay moulds there were some finds of re-usable moulds, such as the soapstone mould for ingots, ASR 9x479, see fig. 4.2.3.

Object imprint	**Quantity**
Oval brooch	1 092
Equal-armed brooch	102
Disc brooch	19
Square brooch	27
Small oval fibula	25
Penannular brooch	1
“Remendedup” fibula	3
“Horse with rider” figures	2
Mask-like figures	16
Pin/needle	8
Keys	31
Belt buckle	3

Table 3: Identified imprints in the Late Iron Age clay mould material from Ribe (Data from Brinch Madsen, 1984 and Feveile, 2006b)

Of the 7 613 mould fragments uncovered, 1 344 have been described as possessing imprints of artefacts (Feveile, 2006b). The vast majority of these fragments have imprints of oval brooches, see fig. 4.2.3, with the Berdal type being the most common by a significant margin (Feveile, 2006b; Feveile and Jensen, 2006). Other significant groups of identifiable objects include equal-armed brooches, round brooches, square brooches, keys, and a decorative object described as “horse with rider” which is possibly a fitting of sorts, visible in table 3 (Feveile, 2006b; Feveile and Jensen, 2006; Frandsen and Jensen, 2006).

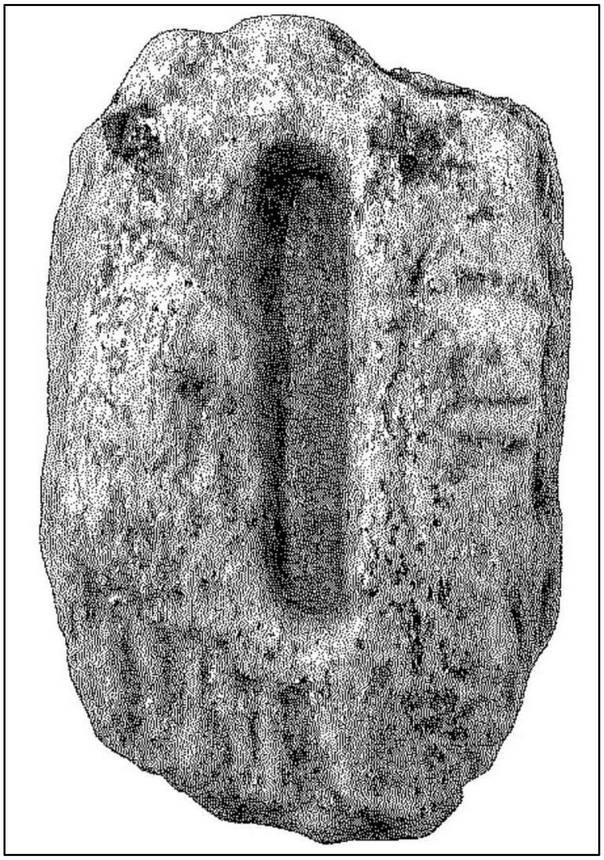

Fig. 4.2.3: Soapstone mould with a casting hollow for ingots from Ribe (ASR 9x479) (Image: SJM).

Fig. 4.2.4: Fired clay mould fragment from Ribe with the imprint of a P12 oval brooch (ASR 1085x047) (Image: SJM).

4.2.3.3 Tools

While tools such as tongs and hammers appear to be conspicuously absent at the Viking Age urban sites, a single hammer with a partially preserved handle was found at Ribe, visible in fig. 4.2.5 (Feveile and Jensen, 2006:143). The hammer is very reminiscent of type R.394, which has generally been interpreted as being used for working with softer metals (Bøckmann, 2007:36–43; Rygh, 1885). This would mean that the hammer could easily have been used by the non-ferrous metalworkers at Ribe in their work. Two lead models and a single matrix die of lead was found among the lead material excavated at Ribe, visible in figs. 4.2.7 and 4.2.8 (Feveile, 2006b; Feveile and Jensen, 2006:144–145). The lead models and the matrix die can both be considered tools employed by non-ferrous metalworkers and were typically used in activities characterised by serial production. Another potential group of tools at Ribe is a group of lead weights which have been interpreted as being used by metalworkers in their craft, rather than being related to trade activities (Feveile and Jensen, 2006:144). This interpretation was based on a perceived correlation in the context between the finds of metalworking waste and finds of lead weights, and that several of the weights have been marked with a punch, visible in fig. 4.2.6 (Feveile and Jensen, 2006:144). If this is the case, then these weights could have been used by the metalworker to measure out the correct amount of metal when creating alloys (Hedegaard, 1992:85). Furthermore, the punch marks on the weights could serve as indirect evidence that punches were in use by the non-ferrous metalworkers at Ribe, despite no finds of actual punches.

Fig. 4.2.5: Hammer with partially preserved handle from Ribe (ASR 9x498) (Image: Feveile, 2006b:432).

Fig. 4.2.6: Lead weights with punch marks from Ribe (ASR 9x448, top) (ASR 9x319, bottom) (Image: SJM).

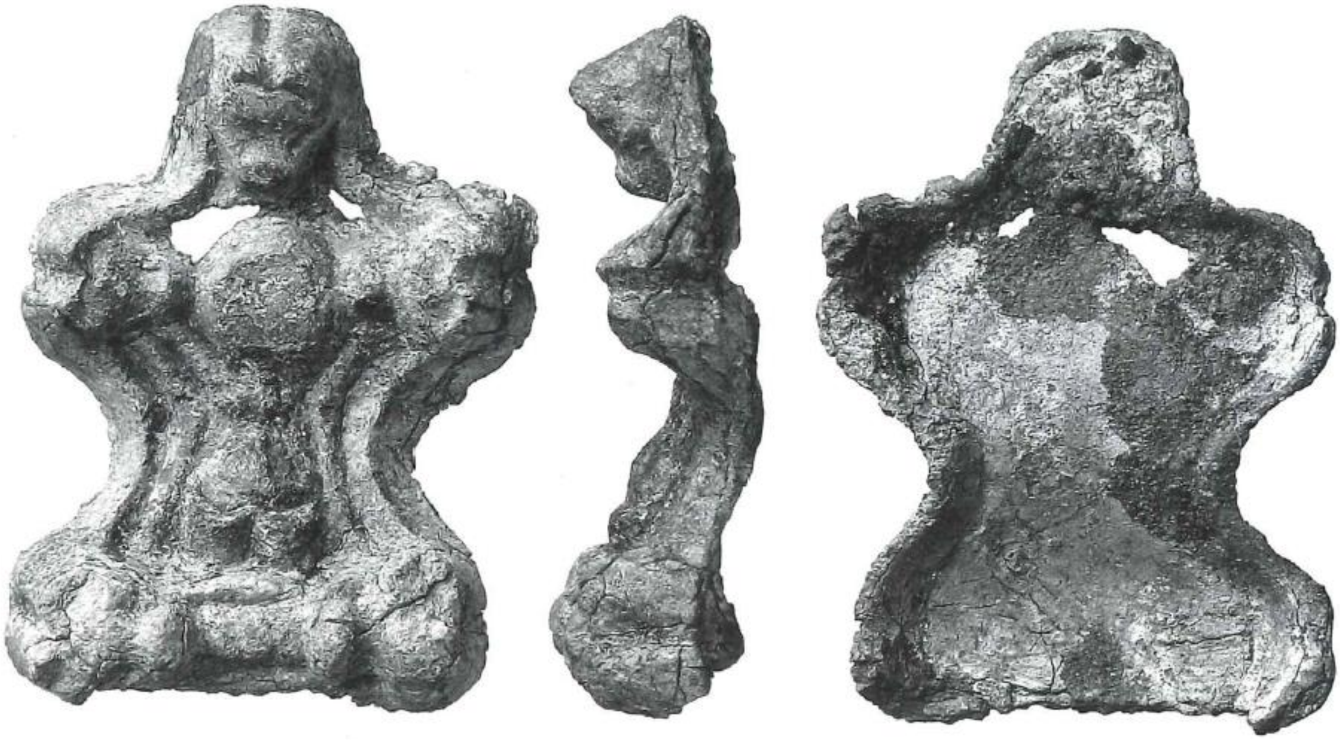

Fig. 4.2.7: Lead model for one half of an equal-armed brooch from Ribe (ASR 9x226) (Image: Feveile, 2006b:433).

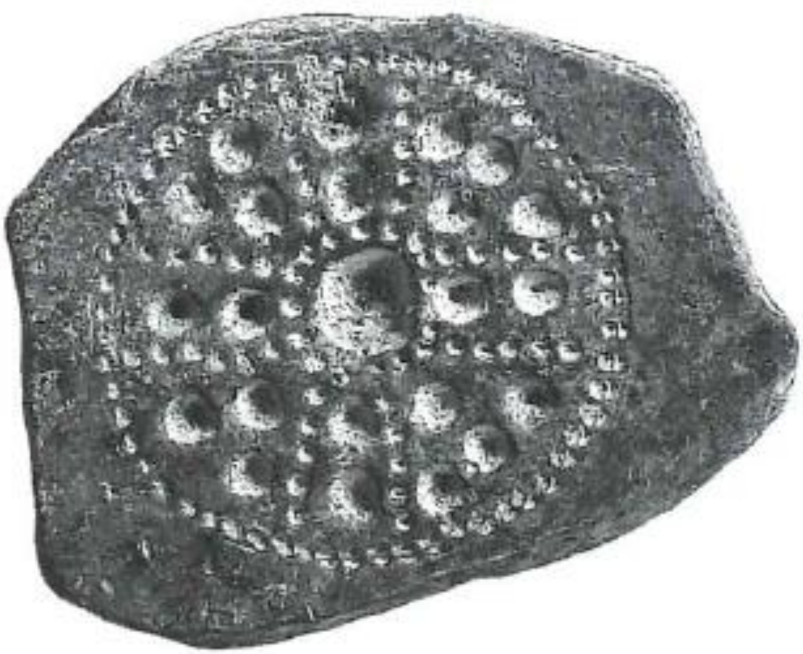

Fig. 4.2.8: Lead matrix die for making pressed foils from Ribe (ASR 9x374) (Image: Feveile, 2006b:433).

4.2.3.4 Metals

Of the copper alloy finds that could be dated to the pre-medieval settlement at Ribe, the vast majority consists of raw materials and waste products related to metalworking activities, i.e. bars and clumps of metal, casting cones, and melted drops (Feveile, 2006b; Feveile and Jensen, 2006:145, Jensen, 2006:30). Several of the crucibles found at the site also included visible remains of copper alloys (Feveile and Jensen, 2006:150). There appears to be some disparity between the small amount of copper alloy and the vast quantities of waste material related to casting, particularly the crucibles and moulds found at the site (Feveile and Jensen, 2006:145; Jensen, 2006:30). This has primarily been attributed to poor preservation conditions as the majority of the copper alloy objects were heavily corroded (Feveile and Jensen, 2006:145). The disparity between evidence of production and a lack of metal waste could also be attributed to the non-ferrous metalworkers taking particular care to recover as much of the raw material as possible. Beyond the copper alloy, there was also finds of several pieces of lead which has been interpreted as raw materials in the form of ingots, metal clumps, and melted drops (Feveile, 2006b; Feveile and Jensen, 2006:143–145).

There appears to be few finds of precious metals at Ribe in the shape of raw materials as well as finished objects. The material includes a total of five gold objects and 22 silver objects (Feveile, 2006b). The gold material includes two thin pieces of sheet metal which measures just under 1 cm^2, a small “pearl” made out of metal threads, and a fragment of a metal sheet which has been decorated on one side (Feveile and Jensen, 2006:145). The undecorated sheet metals likely served as raw material for metalworking and could easily have been used to make pressed foils when considered alongside the matrix found at the site. The silver material uncovered at Ribe includes both raw material such as ingots and various lumps of metal, as well as several finds of Arabic silver coins (Feveile, 2006b). There appears to be a correlation between objects of precious metals and metalworking activity at the site, as the finds of precious metals appear to share a context with the areas and phases of the settlement where significantly large amounts of metalworking waste have been found (Feveile, 2006b; Feveile and Jensen, 2006:146). In sum, the non-ferrous metalworkers at Ribe appears to have been proficient in using a wide range of materials, such as copper alloys, lead, silver, and gold.

4.2.3.5 Notable excavations

While the material includes finds from many of the excavations taking place in Ribe between 1984 and 2000, a few of these have finds or are of a nature particularly relevant to this study and will be noted here. The majority of finds related to metalworking activity was found at the site of ASR 9 Posthuset, which was a sizeable excavation covering roughly 100 m² with large cultural layers generally between 1.7 and 2 m deep (Feveile and Jensen, 2006). As such, the vast majority of the material related to non-ferrous metalworking at Ribe, despite comprising of several excavations spanning all the way back to 1970, will have originated at ASR 9 Posthuset. While another large assemblage of metalworking waste was uncovered at ASR 7 Sct. Nicolaj gade 8, this area is notable because the non-ferrous metalworkers appear to have been the first people to take this area into use. The site has significant evidence of crafts activity clustered around central fireplaces which could indicate that this area was the location of metalworking workshops such as open-air casting workshops (Frandsen and Jensen, 2006).

ASR 926 Ribelund is an area of the settlement which includes a number of buildings and a large trench which has been dated to the 8th and 9th centuries (Feveile, 2006b:217). A few of these structures are sunken featured buildings with finds of crucibles, moulds, copper alloy objects and various slags evenly distributed throughout the building. These objects have been interpreted as waste products used to fill in the sunken featured buildings when they were abandoned sometime in the 9th century, and as such is an indicator of nearby metalworking workshops (Feveile, 2006b:224). The same distribution of waste from craft activities could also be found in the large trench cutting through the site (Feveile, 2006b:234). This excavation illustrates how metalworking was not just confined to certain areas, but rather appears to have taken place throughout the settlement.

4.3 Material from excavations at Birka

4.3.1 Background

The remains of the Viking Age town of Birka is located on the island Björkö in the lake Mälaren in eastern Sweden (Ambrosiani, 1992; Ambrosiani, 2013:23). Although the site, often referred to as "the Black Earth", has been subject to excavations all the way back to the late 19th century, the material used in this study will be confined to the latest material, i.e. the results from the research projects that took place during 1969–1971 and 1990–1995 (Ambrosiani, 2013:23; Ambrosiani and Clarke, 1992; Ambrosiani et al., 1973). The material from Birka appears to be primarily from the Viking Age with a few artefacts from the late Vendel Period. Unfortunately, the upper layers of the site have been heavily disturbed, both through centuries of agricultural activity as well as excavations that took place in the late 19th century (Ambrosiani, 1973; Ambrosiani and Clarke, 1992; Hyenstrand, 1992). Of particular interest is the long-lived metalcasting workshop uncovered in the 1990–1995 research project which has turned up a remarkable quantity of finds related to metalworking (Ambrosiani, 2013). A peculiarity of the site, which can be observed through the collections at SHM, is seemingly extraordinary preservation conditions. Several tools related to metalworking, particularly a large assemblage of punches and a number of hammers, have survived alongside some quantities of bone and antler material.

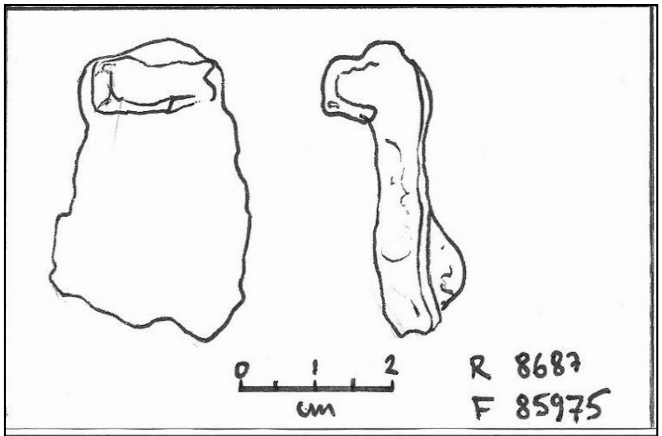

Fig. 4.3.1: Sketch of a type 2 melting crucible from Birka with the lug along the rim (SHM85975) (Image: SHM).

4.3.2 Crucibles

A total of 59 fragments of casting crucibles were uncovered in the cultural layers of the port area excavated in 1969–1971 (Arrhenius, 1973). All of the crucibles appear to be thimble-shaped, and at least one fragment has the remains of a lug, see figs. 4.3.1 and 4.3.2 (Arrhenius, 1973:114). While there were finds of metalcasting waste along the port area of the town, there appears to be no indication of workshops directly on or along the coast (Ambrosiani, 1973). Rather, it appears as if non-ferrous metalworkers were dumping casting waste into the harbour (Arrhenius, 1973:99).

Fig. 4.3.2: Type 1 thimble-shaped melting crucible from Birka (SHM69941) (Image: SHM).

During the 1990–1995 excavations at Birka, roughly 3 500 find-spots containing crucible fragments were discovered (Ambrosiani, 1997:167). All the crucibles uncovered at Birka appears to be thimble-shaped, albeit with a large range of sizes with heights generally in the range of 3–4 and 10–15 cm (Jakobsson, 1996:74). Several of the crucible fragments uncovered in the 1990–1995 excavations also include a lug on the upper half of the crucible, generally quite close to the rim (Jakobsson, 1996:74). In any case, it is clear that various thimble-shaped crucibles in a large variety of sizes was present at this site. Unlike the material from Kaupang and Ribe, there are no published studies providing information on the composition of the crucibles from Birka. However, the mould fragments from Birka are clearly clay crucibles and it is a possibility that they share a number of other qualities with their counterparts at Kaupang and Ribe.

It should also be noted that some groups of metallurgical ceramics were essentially unknown or generally misinterpreted when the material from Birka was classified and interpreted (Söderberg, 2004; Pedersen, 2016a:129). One such example would be cupellation crucibles. Regarding the material from Birka, there is no mention of cupellation crucibles in the main publication series (e.g. Ambrosiani, 2013; Ambrosiani et al., 1973). However, there are several clay fragments in the collection available through SHM's database which clearly resembles cupellation crucibles, and some are even described as potential "testing trays" used to assay metal. Furthermore, Anders Söderberg (2004) has identified a few such cupellation crucibles in material from Birka.

In particular, I would like to point out a number of clay fragments which can be reasonably assumed to be cupellation crucibles. The crucibles SHM89025, SHM89541, and SHM89542, visible in figs. 4.3.3 and 4.3.4, appears to fit the description and falls within the generally accepted shape and size of cupellation crucibles (Pedersen, 2016a:130; Söderberg, 1996). These fragments appear to be small, round, bowl-shaped crucibles, and are very reminiscent of Brinch Madsen's type 6 crucible which Pedersen (2016:111) points out is actually a round cupellation crucible. The diameter of the Viking Age cupellation crucibles was generally between 3 and 9 cm, with a tendency to cluster around 6 cm (Pedersen, 2016a:130). Thus, the fragments from Birka clearly has the correct size and shape to be cupellation crucibles. Furthermore, SHM89025 and SHM89542 are both noted as having copper alloy remains on the surface, which is likely a by-product of the cupellation process where the copper content of the silver has been subjected to reduction (Söderberg, 1996:6). As such, it is highly likely that some of the crucible fragments from the Birka excavations are in fact fragments of cupellation crucibles, and that this type of metallurgical ceramic was in use by the non-ferrous metalworkers at Birka.

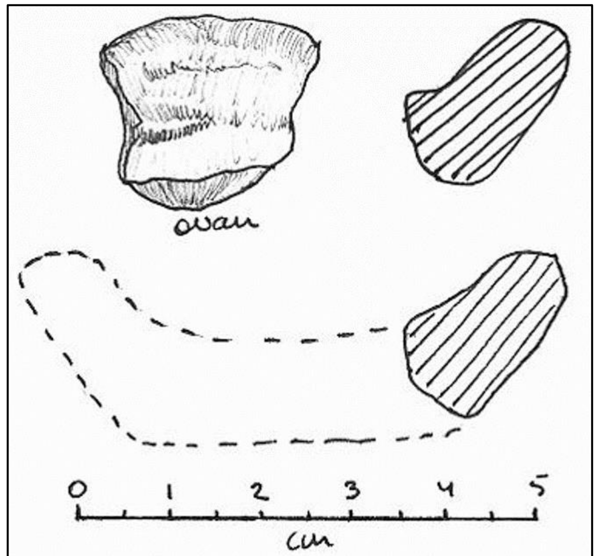

Fig. 4.3.3 Sketch of possible cupellation crucible from Birka (SHM89542) (Image: SHM)

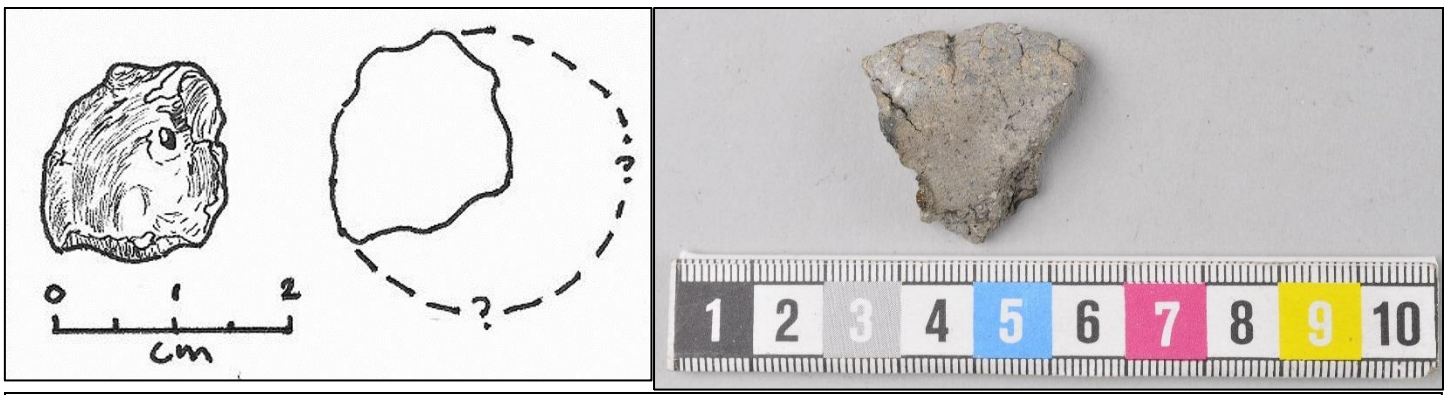

Fig. 4.3.4: Sketch of possible round cupellation crucible (SHM89025, left) and picture of possible round cuppelation crucible (SHM89541, right), both from Birka (Image: SHM).

4.3.3 Moulds

Alongside the crucible fragments in the harbour, the 1969–1971 excavations also found 29 mould fragments that had been dumped into the harbour (Arrhenius, 1973). A few of these moulds have been identified as having imprints of oval brooches and equal-armed brooches, and there appears to be some degree of resemblance between these object imprints and pieces of jewellery excavated from the graves associated with Birka (Arbman, 1943; Arrhenius, 1973:104–110). If that is the case, then locally produced jewellery appears to have been worn by parts of the local populace.

Roughly 25 000 clay mould fragments were discovered during the 1990–1995 excavations (Ambrosiani, 1997:167). Of these, more than 2 100 had visibly identifiable imprints of objects and it is noted that roughly 1 800 mould fragments have been interpreted as being moulds for producing oval brooches, for example fig. 4.3.5, followed by a group of around 300 moulds that have imprints of equal-armed brooches (Ambrosiani, 2013:223). However, only about 1 800 of these mould fragments with imprints could be found in The Swedish Hisory Museum's database and I do not know where the remaining 300 can be found. In any case, there is a clear majority of oval brooch imprints, followed by a significant quantity of equal arm brooch imprints, in the clay mould material from Birka clearly visible in table 4. While the overwhelming majority of the mould fragments from Birka consists of clay moulds, there appears to be a couple of sandstone moulds as well as two pieces of piece of bone or antler that have been interpreted as moulds, visible in figs. 4.3.6 and 4.3.7. The two sandstone moulds appear to have a casting hollow for ingots and some form of decorative mount respectively, one of which can be seen in fig. 4.3.6. One of the bone moulds appear to have casting hollows for an ingot on one side and a hollow for an 8-shaped chain link on the other side. The second bone or antler object interpreted as a mould, SHM55029, has a hollow for casting what appears to be a small round object with pearl-decorations along the rim, potentially some form of button or decorative mount. However, the hollow is also reminiscent of round pressed foils and could perhaps have been a matrix die for making pressed foils, similar to figure 4.1.13.

Object imprint	**Quantity**
Oval brooch	1 471
Equal-armed brooch	302
Needle	15
Fitting or mount	26
Ingot	2
Female figure, "valkyrie"	2
Button	1
Unidentified	6
Total	**1 825**

Table 4: The mould imprints on clay moulds stored at SHM.

The clay moulds appear to consist of clay mixed with sand, although no further study has been done on their composition (Jakobsson, 1996:73). As clay mixed with sand appears to be the standard composition for Viking Age clay moulds, it would be reasonable to assume that this is the composition of moulds from Birka as well (Brinch Madsen, 1984; Feveile, 2006b; Pedersen, 2016a). Furthermore, the identifiable mould fragments found at Birka were interpreted as being fragments of composite moulds, just like the moulds found at Kaupang and Ribe (Jakobsson, 1996:73). Torbjörn Jakobsson (1996:73–74) notes the possibility that several of the mould imprints were made using hard models, rather than for example using the lost wax technique, which could be a reasonably assumption considering the presence of lead models at Kaupang and Ribe.

Fig. 4.3.5: Clay mould from Birka with the imprint of an oval brooch (SHM46272) (Image: SHM).

Fig. 4.3.6: Mould made out of a piece of bone or antler with a casting hollow for an 8-shaped chain link (SHM92872) (left) and mould fragment made out of sandstone with a casting hollow for an ingot (SHM35097) (right) (Image: SHM).

Fig. 4.3.7: Bone/antler mould from Birka (SHM55029) (Image: SHM).

4.3.4 Tools

During the 1969–1971 excavations, several iron tools for various crafts were uncovered (Werner, 1973). However, only a collection of six artefacts which have been interpreted as punches could be confidently linked to metalworking activities (Werner, 1973:95). More tools were discovered during the 1990–1995 excavations, such as three small hammer heads, a single pair of tongs and a significant amount of punches, see figs. 4.3.8, 4.3.11, and 4.3.12 (Jakobsson, 1996:75). While two of the hammers are fragmentary, SHM30952 is a small hammer that resembles Grieg (1922) fig. 2 and R.394, visible in figs. 4.3.9 and 4.3.10, which has been associated with non-ferrous metalworking (Bøckmann, 2007). The tongs, SHM38984, are quite small with a length of about 12 cm and could have been used to handle crucibles. A total of 40 punches appear in SHM's collection, several of which appear to be complete or nearly complete. Ambrosiani (1997) has noted that SHM holds many of the objects from the workshop layers at Birka, thus placing the above tools in a context that is clearly related to non-ferrous metalworking activities. As such, these tools were likely used by non-ferrous metalworkers at Birka.

Fig. 4.3.8: Small hammerhead from Birka (SHM30952) (Image: SHM).

Fig. 4.3.9: Sigurd Grieg's fig. 2: "Klinkhammer" (Image: Grieg, 1922:319).

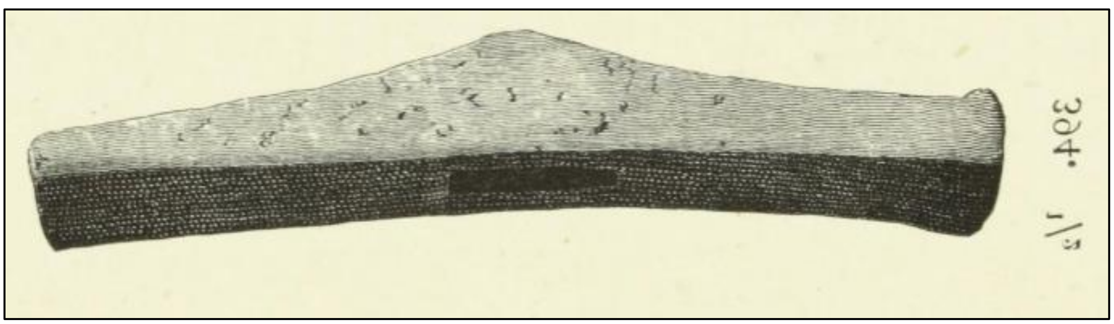

Fig. 4.3.10: R.394 (Image: Rygh, 1885).

Fig. 4.3.11: Pair of tongs from Birka (SHM38984) (Image: SHM).

Fig. 4.3.12: Two punches from Birka, (SHM23358, left) (SHM68237, right) (Image: SHM).

4.3.5 Metal fragments and crafting waste

4.3.5.1 Copper alloy

A total of 525 copper alloy objects were excavated in the harbour area at Birka during the 1969–1971 excavations, visible in table 5 (Kyhlberg, 1973b:156). A significant amount of this copper alloy material comprises of casting waste, ingots, sheet metal, and scrap metal, all of which could have been used as raw material or are otherwise indicative of non-ferrous metalworking activity at the site (Kyhlberg, 1973b:159). Although, one should not disregard the possibility that the ingots and perhaps even sheet metal could have served as means of exchange rather than as raw material.

The 1990–1995 Birka research excavations had a total of 4 000 find-spots containing copper alloy, with the material weighing a total of 5 900 g. Roughly 3 500 of these find-spots consists of workshop waste or raw material like copper alloy ingots, wires, metal sheets, melted drops and scrapped artefacts or miscast jewellery (Ambrosiani, 1997:167; Jakobsson, 1996:74). Several of the melting crucible fragments that was excavated also had small amounts of copper alloy on them, which is clear evidence that copper alloys were used by the non-ferrous metalworkers at Birka (Jakobsson, 1996:74).

4.3.5.2 Lead

Several lead objects were excavated in the harbour area of Birka (Kyhlberg, 1973a; Kyhlberg, 1973b). This material includes 7 or 8 melted drops, 2 ingots, and an indeterminate number of metal lumps, all of which are either raw material or waste from non-ferrous metalworking activity. Furthermore, one of the lead ingots and several lumps of metal apparently have tool marks on them, likely as a result of having been worked or cut into smaller pieces to be melted (Kyhlberg, 1973a:155).

Object type	**Quantity Copper alloy**	**Quantity Lead**
Ingots	7	2
Sheet metal	63	0
Melted drops	29	7
Scrap or lumps of metal	234	N/A
Total	**333**	**9**

Table 5; Lead and copper alloy metal finds from the 1969–1971 research excavations at Birka (Data from Kyhlberg, 1973a).

A considerable amount of lead was discovered in Birka during the 1990–1995 excavations, although less than the copper alloy finds (Ambrosiani, 1997:171). A total of 2 300 g of lead objects were found, mainly in the form of lead weights, workshop waste, and raw material (Ambrosiani, 1997:167 and 171). Notably, the lead weights appear to be concentrated in the workshop layers, and they could have been used by the metalworkers themselves (Ambrosiani, 1997:171). There were also finds of lead remains in some of the melting crucibles, which shows that the non-ferrous metalworkers at Birka also cast lead artefacts (Jakobsson, 1996:74).

4.3.5.3 Silver and gold

Although silver and gold appear to be exceedingly rare finds at Birka, two pressed foil objects, made of silver and gold respectively, were found during the 1969–1971 excavations (Kyhlberg, 1973b:193–194). The occurrence of pressed foil objects on a site with significant production waste could serve as an indicator that the non-ferrous metalworkers at Birka employed the pressed foil technique to make artefacts and jewellery. Further evidence that the non-ferrous metalworkers at Birka worked with silver and gold is evident in some of crucibles from the workshop layers which had microscopic traces of silver and gold in them (Ambrosiani, 1997:170; Jakobsson, 1996:74). Furthermore, Ambrosiani (1997:170) notes that some of the smaller crucibles appear to have been consistently used for silver. Either way, it is clear that the metalworkers at the workshop in Birka worked with silver and gold to at least some extent.

The 1990–1995 excavations also found a total of 180 silver objects, however only 39 of these are classified as workshop waste and raw material, such as the ingot visible in fig. 4.3.13, as the vast majority of this material consists of silver coins (Ambrosiani, 1997:170). The silver finds from most of the workshop layers appear to be limited, and the amount of silver in Birka in general seems to be quite low until the latter half of the 8th century (Ambrosiani, 1997:170). This coincides with the opening of trade routes going east giving Birka access to Arabic silver coins and could entail that dirhams were an important source for silver for the inhabitants of Birka (Ambrosiani, 1997:170).

Fig. 4.3.13: Small silver ingot from Birka (SHM27127) (Image: SHM).

4.3.6 The metalworking workshop at Birka

In the northern section of the Black Earth area on Björkö, a number of plots with divisions between them were discovered in the 1990–1995 excavations (Ambrosiani, 2013). While this area appears to have originally been under water when the town was settled, changes in the water level led to the area being drained of water sometime in the late 8th century (Ambrosiani, 2013:71). This change in water level was quickly followed by construction in the area, and one of the plots became the site of a metalworking workshop from the end of the 8th century until the 860s (Ambrosiani, 2013:71). The early workshop levels also appear to have little or no roof structures based on the lack of post holes, and the site has been interpreted as an open-air metalcasting workshop (Ambrosiani, 2013:87). During this long period of operation, the metalworking workshop underwent numerous changes, such as constantly shifting the location of structures and production areas within the plot. These changes are represented in a complex stratigraphy of floor-layers where each layer represents a period of 3 to 5 years on average (Ambrosiani, 2013:71–72). As such, the workshop appears to have been rapidly shifting and constantly changing.

The workshop at Birka has been interpreted as a non-ferrous metalworking workshop on the basis of crucibles, moulds, other forms of casting waste, various pieces of copper alloys, lead, silver and gold, and some metalworking tools found in the relevant contexts (Ambrosiani, 1997:171; Ambrosiani, 2013:223). The non-ferrous metalworkers at the site appears to have kept the workspace itself quite clean as significant amount of workshop waste had been dumped in the surrounding alleyways or right outside the buildings on the plot (Jakobsson, 1996:72). The vast collection of mould fragments found at the workshop shows that the production of various dress accessories such as oval brooches and equal-armed brooches, as well as various mounts and fittings were essential to the activities taking place at the site (Ambrosiani, 2013:223; Jakobsson, 1996:73). Furthermore, Ambrosiani (2013:223) notes that the workshop appears to have produced most types of jewellery found in the area around Mälaren, as well as several common types of jewellery found elsewhere in Scandinavia, dated to the 8th century. There also appears to be evidence of the production of padlocks, which is interesting as although padlock production was heavily reliant on soldering, a technique which generally used clay packaging material and non-ferrous metals like copper alloys, it is firmly within the realm of ironworking (Ambrosiani, 2013:223; Oldeberg, 1966:67–69; Pedersen, 2016a:135–140).

5 Discussion

5.1 Technical skill

While the technical skill of non-ferrous metalworkers is clearly visible through the elaborate pieces of jewellery from the Viking Age, it can also be witnessed through the techniques employed by these metalworkers when creating artefacts (Lønborg, 1998; Pedersen, 2016a). These techniques are made visible and are reflected in the archaeological material in the form of the waste produced by the work and the equipment required to perform the various techniques (Brinch Madsen, 1984; Pedersen, 2016a; Söderberg, 2004). As such, a comparison of the technical skill of the non-ferrous metalworkers at the urban sites of Kaupang, Ribe, and Birka will primarily be built upon a comparison of the technical details which can be gleaned from the remains of the non-ferrous metalworking activities that took place at these sites.

5.1.1 Casting

The metalworking process with the greatest presence in the Viking Age towns is metalcasting, an activity that is particularly visible through the vast quantities of mould and crucible fragments uncovered at these sites, visible in table 6 (Ambrosiani, 2013; Brinch Madsen, 1984; Feveile, 2006b; Pedersen, 2016b). Metalcasting is a technical process involving many elements and potential sequences such as the creation of models, moulds, and crucibles, and pouring metal into a finished mould, illustrated in fig. 5.1 (Pedersen, 2016b; Pedersen, 2020:245). Consequently, casting activities are evident through various types of material in the archaeological record that can be used to evaluate the level of skill possessed by the craftspeople. The presence of considerable amounts of moulds and crucibles in Kaupang, Ribe, and Birka clearly shows that casting took place, and a comparison of the material related to casting will hopefully shed some light on similarities and differences in the casting activities that took place at these sites.

Site	Crucible fragments	Mould fragments
Kaupang	2 126	1 128
Ribe	~3 260	~9 550
Birka	~3 900	~25 000

Table 6: Quantity of crucible and mould fragments found at Kaupang, Ribe, and Birka. "Crucible fragments" includes complete crucibles.

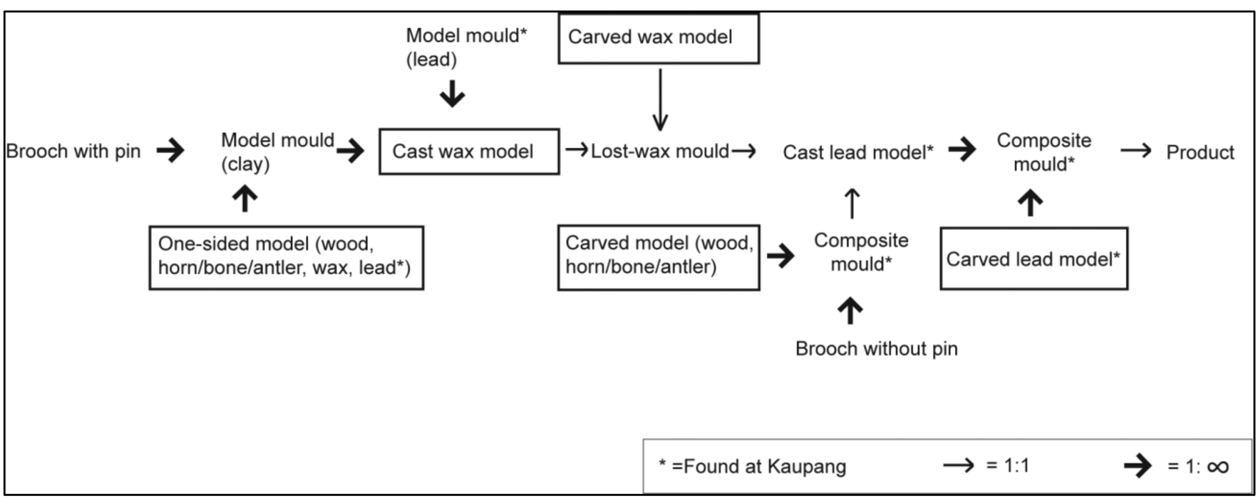

Fig. 5.1: Potential sequences involved in metalcasting (Image: Pedersen, 2020:245).

5.1.1.1 Crucibles

At first glance there is one striking similarity in the crucible material from Kaupang, Ribe, and Birka in that they all, with the exception of some very early crucibles from Ribe, share a typical thimble-shaped form and can be considered to fall within the range of Brinch Madsen's types 1 through 4, all of which are contemporary with each other (Ambrosiani, 2013; Arrhenius, 1973:114; Brinch Madsen, 1984; Feveile, 2006b; Pedersen, 2016a). Furthermore, the melting crucibles from all three sites appear to share a range of sizes, generally with a height ranging from 3 to 10 cm and a thickness between 3 and 15 mm (Brinch Madsen, 1984; Feveile, 2006b; Jakobsson, 1996; Pedersen, 2016a). As the size of the crucibles correlates with the amount of metal that was to be cast, similarities in the melting crucible sizes would imply similarities in the amount of metal being cast in each process, thus indicating that similar types of objects were being cast in these sites.

Despite a generally shared range of shapes and sizes, there appears to be some variations between the crucibles found in the towns. Of particular note is the differences in the type 2 crucibles, characterised by a lug on the side of the crucible. Several of the well-preserved crucibles from Ribe have lugs on one side and these are notably located in the middle or on the lower half of the crucible (Brinch Madsen, 1984:26; Feveile, 2006b). In Kaupang and Birka, however, the lugs on the type 2 crucibles are located along the rim or somewhere on the upper half of the crucible (Jakobsson, 1996:74; Pedersen, 2016a:114). This difference is visible in fig. 5.2. Although some examples from the excavations at ASR 9 Posthuset in Ribe also have the lug placed in the upper half of the crucible, they are generally placed more towards the middle and does not reach the rim like those from Kaupang and Birka, see fig. 5.3 (Feveile, 2006b). The location of the lug should have no bearing on the technical capabilities of the crucible beyond determining where the crucible is gripped with the tongs, and as such likely reflects a personal preference among the non-ferrous metalworkers (Hedegaard, 1992:81). If so, there appears to be a difference in the preferences of the metalworkers at Ribe compared to those working in Kaupang and Birka in regard to the shape of type 2 melting crucibles.

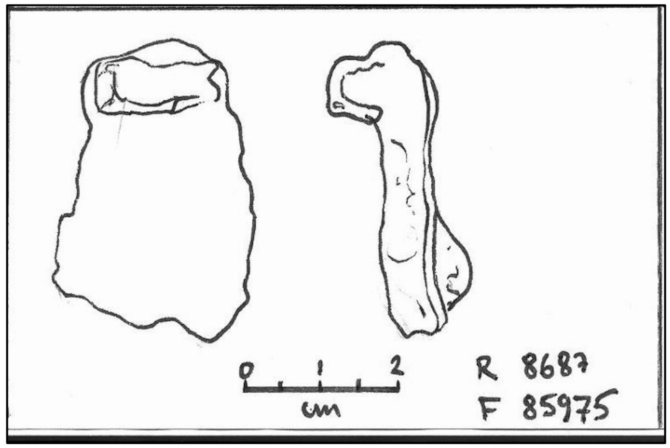

Fig. 5.2: Type 2 crucible from Ribe with a lug in the middle (ASR 9x311, left) and a type 2 crucible fragment from Birka with the lug along the rim (SHM85975, above) (Images: SHM and SJM).

Furthermore, there appears to have been a clear preference for type 2 crucibles in general at Ribe where the lug is present on nearly all well-preserved crucibles alongside finds of many crucible sherds with lugs (Feveile and Jensen, 2006:150). This differs from the Kaupang material where crucibles with handles, i.e. type 3, are far more prevalent than type 2 crucibles (Pedersen, 2016a:114–115). If indeed the driving force behind the variations in frequency of crucible types between the sites is due to personal preference, then this could also explain the presence of the many contemporary types of thimble-shaped crucibles. As the melting crucibles all share the general thimble-shaped form and have a consistent range of sizes, there is essentially little to no technical differences between the types beyond how they were gripped, a difference which very well could reflect varying preferences among groups of non-ferrous metalworkers. For instance, the majority of type 3 crucibles from Kaupang originates from the workshop at plot 1B, where

Fig. 5.3: Type 2 crucible from Ribe with the lug placed on the upper half, but not quite at the rim (ASR 9x100) (Image: SJM).

crucibles with handle dominate the crucible material and could reflect the preference of a single group of craftspeople (Pedersen, 2016a:182). Either way, the crucible material from Kaupang, Ribe, and Birka appear reasonably homogenous in their shape and size, albeit with some differences that could arguably be attributed to the personal preference of individual groups of non-ferrous metalworkers.

5.1.1.2 Clay Moulds

Unlike Ribe and Birka with their immense quantity of mould fragments, the material from Kaupang represents a flaw in a comparative analysis of the clay mould material from these sites. The clay moulds from Kaupang originates almost entirely from re-deposited layers, particularly plough-layers, which alongside the poor preservation conditions for clay artefacts at the site has resulted in a severely deteriorated material (Pedersen, 2016a:95–96). Consequently, there are very few specimens of clay moulds with imprints, and this material by itself cannot be expected to provide meaningful insight into the metalcasting production taking place at Kaupang (Pedersen, 2016a:95). Despite the diminished nature of the mould material from Kaupang, I believe that elements such as the composition of the moulds are still relevant for comparative analyses.

In spite of the fragmentation of the clay mould material from Kaupang, Ribe, and Birka making interpretations of many of the fragments challenging, the material appears to essentially just consist of composite moulds. However, this could simply be because single-piece moulds were not preserved or were too fragmented to be identified as such (Brinch Madsen, 1984:33–34; Feveile, 2002; Feveile, 2006b; Pedersen, 2016a:98). While the moulds from the 1970–1976 excavations at Ribe underwent thin-section analyses revealing a composition of micaceous clay mixed with sand, chamotte, and fine organic materials, no such analyses appears to have been performed on the clay moulds from Birka, and the analyses done on clay moulds from Kaupang were not performed to the same extent as those from Ribe (Brinch Madsen, 1984:31–34; Pedersen, 2016a:109–110). However, visual studies of the clay moulds from Kaupang and Birka suggests a composition of clay mixed with sand and chamotte, with fibrous grooves indicating inclusions of fine organic material (Jakobsson, 1996:73; Pedersen, 2016a:97). This coincides well with what is believed to be a general composition of clay moulds in the Viking Age (Lønborg, 1998:26). As such, it would be reasonable to assume that the composition of the clay moulds from Kaupang, Ribe, and Birka are comparable. It should be noted however, that the clay used in the moulds from Ribe appears to have travelled some distance to reach the town, while the clay used at Kaupang appears to be local (Brinch Madsen, 1984:31–32; Pedersen, 2016a:110). This difference could represent separate preferences in raw material for clay moulds in the respective towns, or perhaps the metalworkers at Kaupang were simply fortunate enough to have access to local clay with the desired properties, while the craftspeople at Ribe were forced to import their clay because of a lack of desirable local clay.

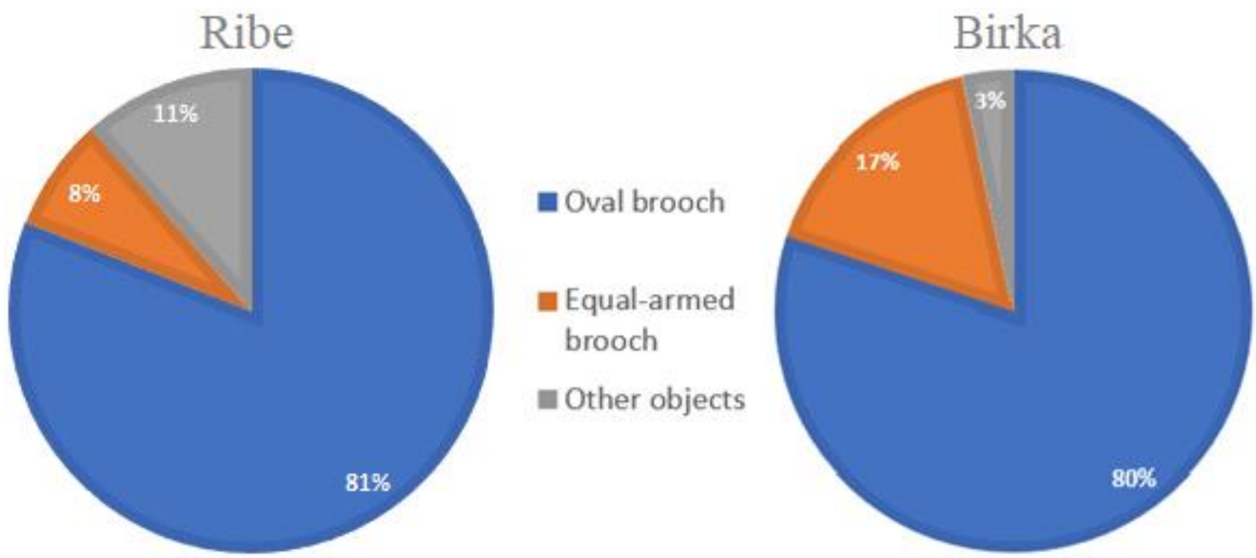

Fig. 5.4: Ratio of clay mould imprints from Ribe (left) and Birka (right) highlighting a prevalence of oval and equal-armed brooches. Kaupang has been excluded due to a lacking sample size. Data from tables 3 and 4.

Many of the clay mould fragments from the urban settlements also possess imprints of artefacts. These imprints provide information about what objects were being cast. Although there are few identifiable mould imprints from Kaupang, making the material far from representative for the production of the site, there appears to be a similar distribution of types across the sites. Of the imprints that have been identified, a significant majority are imprints of oval brooches, particularly in the Berdal style, with the second largest group consisting of equal-armed brooches, see fig. 5.4 (Brinch Madsen, 1984; Feveile, 2002; Feveile, 2006b; Pedersen, 2016a). Thus, there appears to be considerable production of oval brooches, followed by equal-armed brooches, with some examples of various other object such as pins and mounts evident in the material from Ribe and Birka (Brinch

Madsen, 1984; Jakobsson, 1996; Feveile, 2006b). While the clay moulds from Kaupang form too small a sample size to say anything meaningful in comparison, what little material there is hints at significant production of oval brooches and equal-armed brooches. The similarities between the mould imprints is further supported by the comparable range of sizes in the melting crucible material which imply that similar artefacts were being cast across all three towns.

5.1.1.3 Other moulds

In addition to the composite clay moulds, several open moulds made of various types of stone, such as soapstone and sandstone, were uncovered at Kaupang, Ribe, and Birka (Pedersen, 2016a:84 and 87). There were also moulds made out of bone or antler excavated at Birka. The majority of these appear to have been used to cast ingots, with some having cavities for casting jewellery or weights (Pedersen, 2016a:86–95). Unlike the composite clay moulds which were consumable single-use objects, the moulds made of hard materials could be used repeatedly for significant periods of time (Pedersen, 2016a:84). The re-usable moulds for ingots could potentially have been a useful tool for reclaiming leftover metal from a crucible, as the metalcasters would generally melt more metal than was strictly necessary in order to avoid the risk of miscasting due to a lack of metal (Pedersen, 2016a:191). The use of stone moulds for ingots to collect surplus liquid metal is further supported by archaeometallurgical analyses performed on the material from Kaupang which shows that a wide range of metals were cast in these moulds (Pedersen, 2016a:90–94). Assuming that the metalworkers in all three towns collected the surplus metal during casting, and that reusable moulds with ingot hollows are present at all the sites, it is quite likely that these moulds were used to collect the surplus metal and that ingots were being cast at these sites.

One of the moulds from Kaupang, made out of volcanic tuff, appears to have been used to cast lead pendants (Pedersen, 2016a:82). Due to the re-usable nature of the mould and the apparent abundance of lead at Kaupang, it is quite likely that this mould represents a form of mass production of affordable jewellery. While no similar moulds for pendants were uncovered at Birka, there were finds of a potential sandstone mould for mounts and a piece of bone or antler that has been interpreted as a mould with a cavity for an ingot on one side and a cavity for a chain link on the other. As such, there also appears to be mass production of artefacts using re-usable moulds at Birka as well. At Ribe, however, there appears to be no finds of stone moulds for anything other than ingots, but due to the small sample size of stone moulds uncovered at this site it would be reasonable to account this lack of evidence to less than ideal preservation conditions. There were also finds of lead pendants at Ribe which are nearly identical to ones found at Kaupang, visible in fig. 5.5, which are believed to have been cast in reusable stone moulds. As such, there is a very real chance such re-usable moulds were used by the non-ferrous metalworkers at Ribe as well.

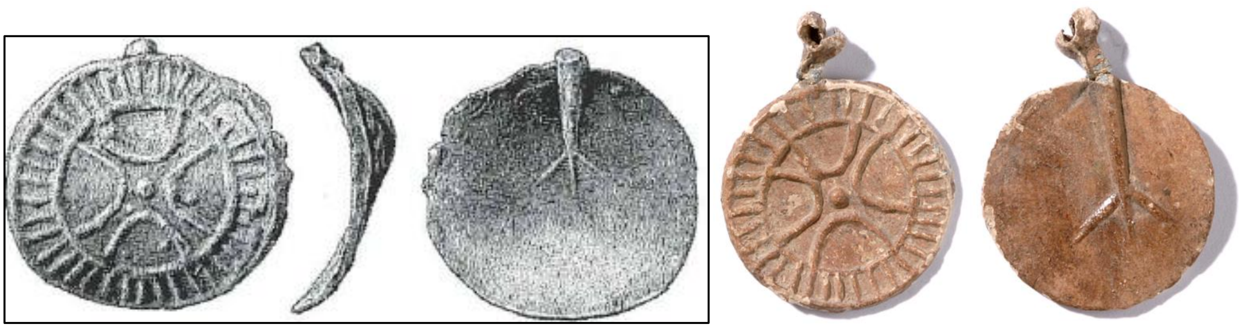

Fig. 5.5: Lead pendant from Ribe (ASR 9x296, left) and a lead pendant from Kaupang (C52519/14056) (Images: Feveile, 2006b:433 and E.I. Johnsen, KHM).

À cire perdue, or the lost-wax method, is generally understood as a common technique for making clay moulds using wax models that was prevalent during the Viking Age (Hedegaard, 1992:77–78; Lønborg, 1998:16; Oldeberg, 1966:80). While the lost-wax method is essentially invisible in the archaeological record due to the nature of the method, it can generally be assumed that when metalcasting activity took place during the Viking Age, the lost-wax method was somewhat involved. For instance, there is a lead mould that was found at Kaupang which has been interpreted as a mould for making wax models (Pedersen, 2016a:74). This mould would have enabled the production of long series of essentially identical wax models in a relatively short amount of time. Such a production of wax models would also have allowed for a rapid serial production of moulds for the same artefact. As such, this lead mould is both evidence for the presence of the lost-wax method at Kaupang, as well as an indicator of a form of potentially explosive serial production of near-identical artefacts. Whether moulds for wax models were in use at Ribe and Birka is difficult to say as no such moulds were uncovered at these sites, but the differences in preservation conditions and excavation methods at Kaupang versus Ribe and Birka could account for this disparity in the material.

5.1.1.4 Hard models

The lost-wax method could just as easily be used with single-piece moulds as with the composite moulds found at the urban sites (Pedersen, 2016a:98). However, unlike single-piece moulds, the composite moulds could be constructed around re-usable models of hard material like metal, bone, antler, wood, and leather (Lønborg, 1994; Pedersen, 2016a:70). Such models would have been a form of serial production that allowed for the production of a large number of essentially identical artefacts. The serial production using wax models could be considered a rapid form of production as the wax models could be produced in sequence and therefore the moulds could dry at the same time. The use of hard moulds, on the other hand, would represent a slow form of serial production as the model had to remain within the mould while drying, and only a single mould could be made at a time for each model (Pedersen, 2016a:98).

While there appears to be no finds of hard models at Birka, 25 lead models at Kaupang and two lead models at Ribe were identified (Feveile and Jensen, 2006:144; Pedersen, 2016a:64). This difference could have been caused by the differences in excavation methods and preservation conditions, especially in light of the extensive metal-detecting surveys which took place at Kaupang where large quantities of lead objects were discovered. However, there is also a very real chance that the prevalence of lead models at Kaupang could be a peculiarity of the site. In general, organic materials such as antler, bone, and wood that could have constituted a fair amount of the hard models used in metalworking are very unlikely to survive, and as such could be an explanation for the lack of hard models uncovered at Birka. Although there is a lack of models at Birka, their presence at Kaupang and Ribe could support the possibility that they were in fact in use at Birka as well due to the overall similarities in the material between the sites. Torbjörn Jakobsson (1996:73–74) has also proposed the possibility of several of the moulds from Birka having been made using such models.

5.1.1.5 Serial production

The casting activity at Kaupang appears to be distinctly characterised by serial production, as witnessed by the use of moulds for wax models and lead models. At Ribe, Brinch Madsen (1984:93) highlights that the casting activities at the site appears to be characterised by a serial production where large numbers of near-identical pieces of jewellery, which were only differentiated by further decorative work applied to secondary models or after the artefact, were being cast. Furthermore, the vast quantities of mould fragments at Ribe and Birka would imply a large amount of casting took place at these sites. This intensity in production was likely made possible or at the very least facilitated by significant amounts of serial production. In particular, the material from Birka is mostly associated with workshop layers spanning some 60 or 70 years, and it would surely be difficult to amass such a quantity of waste material without engaging in serial production (Ambrosiani, 2013:71). As such, the metalcasting activity at Kaupang, Ribe, and Birka all appear to be heavily characterised by serial production, using both rapid sequences with the help of wax models, as well as slower sequences using hard models.

5.1.2 Pressed foils

Unlike metalcasting which deals with heated metal, techniques to produce pressed foils employ cold metal that is shaped using matrices and patrices (Lønborg, 1998:45). Both Kaupang and Ribe have finds of matrix dies, which imply that pressed foils were being produced at these sites. Unfortunately, no such equipment has been found at Birka. However, there have been finds of pressed foils at Birka, and considering the extensive non-ferrous metalworking activity at this site evidenced by casting waste and raw materials as well as evidence that some of the products were used locally, it is quite likely that pressed foils were produced there as well. As such, the non-ferrous metalworkers at Kaupang, Ribe, and Birka all appear to not only having mastered metalcasting but were also proficient at working with cold metals to produce pressed foils of silver and gold.

5.1.3 Decoration

The products of the urban non-ferrous metalworkers appear to have been decorated at several stages of a craft process. For instance, the lead models as well as the lead mould for wax models have been decorated, and when these were used as models the cast object would have inherited these decorations (Pedersen, 2016a). This would allow for a serial production of identically decorated objects. Further decorations could have been performed on the cast objects in order to distinguish them, thus producing more or less unique objects from a common template. This would have reduced the workload required and allowed for a larger production. One of the lead models from Kaupang interpreted as an armring has clear punch-marks which shows that a punch was used to decorate the model, therefore casting the object with the decoration and removing the necessity for punching the armring after casting, evident in fig. 5.6 (Pedersen, 2016a:99). The armring model as well as a lead punch pad found at Kaupang makes it clear that the non-ferrous metalworkers at Kaupang were proficient at decorating artefacts using punches. The presence of punches is also visible in the material from Ribe, where several weights have been marked with a punch (Feveile and Jensen, 2006:144). While at Birka it is abundantly clear that punches were being used at the site, as witnessed by the more than 40 punches found at the site.

Fig. 5.6: Lead model of an armring punched with wave-like decorations (C52519/21224, left), and a fragment of a copper alloy armring with similar wave-like punch decorations (C52517/1979, right) (Image: E.I. Johnsen, KHM).

Beyond the decorations applied to a piece of jewellery by shaping, carving, and punching models and cast objects, much Viking Age jewellery has been decorated with filigree and granulation (Duczko, 1985; Lønborg, 1998:41). Filigree uses fine metal wires to compose patterns, while the granulation technique creates patterns using small metal grains or spheres (Duczko, 1985:15). While direct and clear evidence for filigree and granulation work appears be quite elusive at Kaupang, Ribe, and Birka, there are some potential signs that these decorative techniques were in use by the urban non-ferrous metalworkers. For instance, several strands or clumps of metal wires, both of copper alloy and silver were uncovered at Birka which could be interpreted as wires intended for filigree work (Ambrosiani, 1997:169; Kyhlberg, 1973b:195).

The presence of metal threads and wires when viewed in light of the several pieces of jewellery from the associated graves surrounding Birka which have been decorated with filigree and granulation and are in some cases interpreted as local wares, it is quite likely that non-ferrous metalworkers at Birka performed filigree and granulation work (Duczko, 1985). Another indicator is that pressed foils were commonly decorated with filigree and granulation work, and the presence of pressed foil production at the urban settlements could imply that filigree and granulation work took place as well (Pedersen, 2016a:192). There is also the possibility that some of the smallest melted drops of copper-alloy, silver, and gold from the urban sites could be granules, but this would be nigh impossible to determine, and thus hardly constitutes proof of granulation work. However, as it is generally known that Viking Age non-ferrous metalworkers did decorate jewellery using filigree and granulation techniques, alongside the significant presence of copper-alloy, silver, and gold in what are clearly production sites at Kaupang, Ribe, and Birka, I believe it is a feasible assumption that the urban non-ferrous metalworkers possessed the skills and knowledge to perform filigree and granulation work (Duczko, 1985; Lønborg, 1998:52).

Fig. 5.7: Small gold droplet, fragmented gold jewellery, a piece of gold that has been hammered, and a gold fitting decorated with filigree and granulation work (C52516), all found at Kaupang (Image: E.I. Johnsen, KHM).

5.1.4 Cupellation

Cupellation crucibles are a form of metallurgical ceramic used in the assaying and refinement of alloys containing silver or gold (Lønborg, 1998:13; Pedersen, 2016a:129). The presence of cupellation crucibles is evidenced in Kaupang, Ribe, and Birka, which would indicate that the urban non-ferrous metalworkers employed cupellation crucibles in their work with silver and gold. Furthermore, the cupellation crucibles imply that there were non-ferrous metalworkers in these urban sites who possessed the technical skill and knowledge to perform cupellation and assaying. One of the cupellation crucibles found at Kaupang was located in plot 1B of the site, which has been interpreted as a workshop with a focus on working with silver and gold (Pedersen, 2016a:193). The function of the cupellation crucibles as well as potential shared contexts with other evidence for working with silver and gold implies a link between cupellation crucibles and working with precious metals. As such, evidence of precious metals, cupellation crucibles, tools for creating pressed foil, and potential decorative techniques such as granulation and filigree at these urban sites would imply that urban non-ferrous metalworkers of the Viking Age were quite skilled at working with silver and gold.

5.1.5 Tools

While indirect evidence for the non-ferrous metalworking activities at Kaupang, Ribe, and Birka appear numerous, the finds of actual tools are limited. For instance, hammers and tongs are nearly non-existent with only a few examples that could have been used for non-ferrous metalworking activities being found at Ribe and Birka. As such, this material is hardly useful for comparison, but their presence does mean that the use of such tools is evident, rather than assumed, at these sites and that the metalworkers employed a varied toolbox. Weights were also found in metalworking contexts at the urban sites and could arguably be considered metalworking tools as they would have been imperative when mixing alloys. The finds of cupellation crucibles at these sites also supports the notion that the urban non-ferrous metalworkers were capable of precisely controlling alloys (Ashby and Sindbæk, 2020d:226). However, the weights could also have served as market tools when the metalworkers exchanged their products or acquired raw material. Either way, the weights could imply that the non-ferrous metalworkers in all three of the urban sites were capable of mixing their own alloys as needed. In sum, the same metalworking tools appears to be present at all three sites.

5.1.6 Metals

Although there appears to be broad similarities in the technical skills and knowledge of the non-ferrous metalworkers at Kaupang, Ribe, and Birka based on the crafts processes that are visible, there are other aspects in which these urban craftspeople might differ from each other. For instance, the raw materials used by the non-ferrous metalworkers might shine light upon differences, similarities, or perhaps even varying preferences among different groups of metalworkers within a town.

5.1.6.1 Copper alloys

Copper alloys is the group of metal with the largest quantity of finds that have been interpreted as raw material or production waste at Ribe and Birka (Ambrosiani, 1996; Feveile, 2006b). At Kaupang however, lead forms the largest group, but copper alloys are still present in considerable quantities (Pedersen, 2016a). The copper alloy material from Ribe and Birka has only been subject to visual studies and as such it has not been possible to differentiate between various copper alloys such as brass or bronze in this material (Ambrosiani, 1996; Brinch Madsen, 1984; Feveile, 2006b; Pedersen, 2016a). However, at Kaupang there have been several archaeometallurgical analyses performed on copper alloys and equipment used to cast copper alloys. The results of these show a clear and overwhelming predominance of high-quality brass, i.e. brass with a high percentage of zinc (Pedersen, 2016a:92, 122, 126, 154, and 155). Furthermore, there are some traces of brass corrosion products inside melting crucibles at Ribe that was discovered by Brinch Madsen (1984:28), but this is far from extensive. No archaeometallurgical analyses has been performed on the material from Birka, and as such the presence of brass at this site is not readily apparent. However, I would like to argue based on the similarities in metalcasting equipment, long-range trade networks, the presence of continental ceramics, and previous research done on brass bars in the Viking Age, that brass was also prevalent at Ribe and Birka.

The production of brass in Europe, which was centred at Aachen in Germany during the Roman Period, appears to have ceased sometime in the 2nd or 3rd century A.D., and the methods for manufacturing brass was apparently lost (Jouttijärvi, 2002:37; Sindbæk, 2005:84). After this collapse of brass production in Europe, brass became essentially non-existent in Northern Europe until it reappeared sometime during the Vendel Period (Jouttijärvi, 2002:39; Oldeberg, 1942:156; Sindbæk, 2005:84). While the analyses on the material from Kaupang provides no grounds for determining the provenance of the brass, Aachen has been put forward as a plausible source as it re-emerged as a centre for brass production around the late Vendel period or early Viking Age (Pedersen, 2016a:158). As brass was known as the dominant copper alloy in the Islamic world from the 6th century onwards, there is also a possibility that brass could have arrived to Northern Europe in the Viking Age from the east (Sindbæk, 2005:64–65). However, Sindbæk (2005:65) points out that no brass ingots appear in Staraja Ladoga and other Russian sites until the 10th century, consequently making it highly unlikely that brass ingots reached Northern Europe through eastern trade routes. Rather, it would appear that a brass industry appeared somewhere in the Rhineland, very likely around Aachen, and served as the origin of the brass ingots found in Viking Age Scandinavia (Sindbæk, 2005:65).

Kaupang, Ribe, and Birka are all perceived to be part of a vast long-distance trade network connecting these towns to each other, the British Isles, the European continent, and even far into the east through Russia (Hodges, 1982; Sindbæk, 2007; Sindbæk, 2008:150–151; Skre, 2011b). Furthermore, Sindbæk's (2007:122–123) comparisons of imported goods, such as ceramics and glass beads, at the sites of Kaupang, Ribe, Birka, and others have shown that the same types and classes of imports appear in remarkably similar numbers. This implies that these sites were not only linked to each other through activities and communications of similar scale and nature, but that they also shared connections to other parts of the trade network (Sindbæk, 2007:123). For instance, Badorf-ware, a typical type of ceramic from the Rhineland area, appears abundantly in urban sites but are non-existent in Scandinavia outside of the towns (Pilø, 2011; Sindbæk, 2007:121).

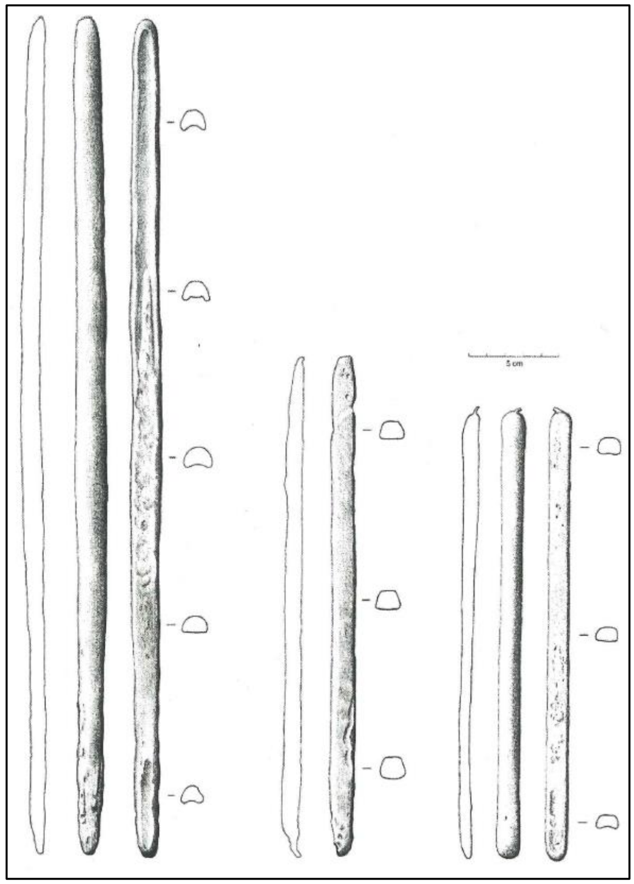

Fig. 5.8: Brass ingots from hoards at Myrvälde (left), Kamänget (middle), and Hedeby (right) (Image: L. Hilmar, from Sindbæk, 2005:56).

The abundant presence of ceramic wares from Rhineland in Kaupang, Ribe, and Birka implies trade connection between these locations, and as the brass was likely produced in Aachen in the Rhineland-area this could indicate that brass was traded between Aachen and the Scandinavian urban sites. Such a trade link is also further exacerbated by the interpretation of the ceramics as "traders' items" which highlights the presence of traders from Rhineland at the Scandinavian towns. Furthermore, there is a perceived correlation between sites with imported Rhenish ceramics and sites with significant and consistent copper-alloy metalcasting activity (Sindbæk, 2007:121–126). In sum, not only did the brass at Kaupang probably originate in Aachen, but there is a very real possibility that much of the copper alloy used at Ribe and Birka was also brass imported from the same area by virtue of the apparent trade connections and similarities in the material between the Scandinavian urban sites. If so, then a prevalence for brass represents another significant similarity between the non-ferrous metalworking at Kaupang, Ribe, and Birka.

The occurrence of hoards containing brass ingots, and brass jewellery from graves also indicate a prevalence for brass as a raw material in Viking Age jewellery production. For instance, Viking Age fibulas appear to be dominated by high-quality brass as the raw material (Hedegaard, 1992:84). Furthermore, rod-shaped brass bars appear in several deposits, three of which have been studied by Sindbæk (2005), see fig. 5.8. One of these deposits were discovered at Hedeby, providing a link between such brass ingots and Viking Age urban sites, see fig. 5.11 (Merkel, 2018; Sindbæk, 2005:59). Through his study of the brass bars in these deposits, Sindbæk (2005) highlights the large similarities in the size and dimensions of these bars and argues that there is a significant degree of standardisation of brass bars in the Viking Age. Such a standardisation of brass bars could arguably be caused by a desire to create easily recognizable products for exchange that could reflect a certain level of quality in the metal, as well as being caused by the bars having a shared origin or having been made through a shared craft tradition (Sindbæk, 2005). Standardised rod-shaped copper alloy ingots appear to be present at Ribe and Birka which could imply the use of brass at these sites, visible in figs. 5.9 and 5.10. Either way, the recognizable shape of the brass ingots would indicate their involvement in trade activities, further supporting the theory of brass ingots being imported to Kaupang, Ribe, and Birka from the Rhineland region, as well as allowing copper alloy ingots from these sites to be interpreted as brass ingots based on their shape and size.

Fig. 5.9: Two roughly 30 cm long rod-shaped copper alloy ingots bound together by organic material found at Ribe (ASR 7x0581) (Image: SJM).

From a technical point of view, the largest differences between casting with bronze or brass would be the volatility of the zinc in the brass due to the evaporation of zinc above 907 °C (Hedegaard, 1992:85; Lønborg, 1998:12; Merkel, 2018:294; Pedersen, 2016a:109). However, brass also possessed other qualities that might have made it a desirable material for the urban non-ferrous metalworkers. For instance, brass has a lower melting point than bronze and is generally more malleable (Ashby and Sindbæk, 2020d:226; Jouttijärvi, 2002:31). The appearance of brass could also have factored into the preference for using this metal over other copper alloys as the more gold-like lustre could have been viewed as more attractive and desirable (Ashby and Sindbæk, 2020d:226; Jouttijärvi, 2002:31; Pedersen, 2020:236). However, the use of brass could cause some challenges compared to casting bronze due to the volatility of the zinc and that brass jewellery could not be recycled because of the zinc evaporating with every cast causing the brass to deteriorate each time it is melted (Ashby and Sindbæk, 2020d:226; Hedegaard, 1992:84–85; Lønborg, 1998:12; Sindbæk, 2005:64).

Fig. 5.10: Corroded rod-shaped copper alloy ingot found at Birka (SHM76549) (Image: SHM).

Fig. 5.11: Rod-shaped brass ingots from the Hedeby harbour hoard (Image: Archäologisches Landesmuseum in der Stiftung Schleswig-Holsteinische Landesmuseen Schloss Gottorf, from Merkel, 2018).

While the reason for the transition into thimble-shaped crucibles during the Late Iron Age has been attributed to structural changes in the forges used by the metalworkers, technical reasons related to the metals used by the Viking Age metalworkers could also be the cause (Arrhenius, 1973). For instance, Ken Ravn Hedegaard (1992:85) claims that the thimble-shaped melting crucibles may have been developed as a result of the non-ferrous metalworkers' desire for taller crucibles in order to hinder oxidization. Essentially, this means that the design of the thimble-shaped crucibles somewhat counteracts the volatility of zinc. As such, the prevalence of thimble-shaped crucibles at Kaupang, Ribe, and Birka could be considered yet another indication that brass was the preferred copper alloy at these sites.

5.1.6.2 Lead

After copper alloys, lead is the most represented metal in the raw material and casting waste from Ribe and Birka (Ambrosiani, 1997:171; Ambrosiani, et al., 1973; Feveile, 2006b). At Kaupang however, lead surpasses copper alloys as the most prominent metal among the raw material and casting waste (Pedersen, 2016a). The significant differences in the amount of lead found at Kaupang versus Ribe and Birka represents another difference between these sites. In particular, the large assemblage of lead ingots found at Kaupang seems to be a peculiarity of the site (Pedersen, 2016a:148–153). Although the differences in excavation methods might be to blame as Kaupang underwent significant metal-detecting surveys and lead produces very clear signals for the metal-detectors which could skew the material (Pedersen, 2016a:163). However, Pedersen (2016a:163) points out that lead is still the largest group of material from excavations and surface surveys, and as such it is entirely possible that the large quantities of lead are representative of the activities at Kaupang. Another potential reason for this disparity between Kaupang and the other towns could be the differences in preservation conditions, which is also reflected in the substantial difference in the quality of the clay mould and crucible materials (Pedersen, 2016a).

Nevertheless, there is a reasonable possibility that the material from Kaupang differs from that at Ribe and Birka in regard to casting waste and raw material of lead. Why Kaupang differs in this aspect is difficult to say, but could potentially be connected to the personal preference, skills, or tradition of the non-ferrous metalworkers. As the technical skills and available tools employed by the non-ferrous metalworkers at Kaupang coincides well with their counterparts at Ribe and Birka, it is unlikely that the difference in raw material used is caused by differences in overall technical skill and knowledge. However, this is only strictly true in a general sense where all the non-ferrous metalworkers at a site can be perceived to possess a similar level of skill. It is entirely possible that there were metalworkers at Kaupang who lacked certain amounts of skill, knowledge, and perhaps even equipment and resorted to casting lead objects rather than working with copper alloy, gold, and silver, which could have aided in creating this division between Kaupang and Ribe and Birka.

Another possible explanation is that there could simply have been a larger demand for lead artefacts at Kaupang. This demand could be connected to market activities through casting lead weights for use as market tools, as well as a potentially significant market for lead pendants or other forms of lead jewellery that could have represented a more affordable option. Both casting of weights as well as lead jewellery appears to be well documented in the material from Kaupang (Pedersen, 2016a). The differences in lead material at Kaupang, Ribe, and Birka could also reflect varying preferences among both the metalworkers and inhabitants of the town, which in turn could have been influenced by the degree of communication these urban sites had with other regions. For instance, there appears to be a similar pattern of large quantities of lead at York and Dublin, and the non-ferrous metalworkers at Kaupang could therefore have had a stronger connection with Britain and Ireland than their counterparts in Ribe and Birka did (Bayley, 1992:810–811;Pedersen, 2016a:197; Pedersen, 2020:238). In any case, there appears to be a larger production of lead artefacts at Kaupang than at Ribe and Birka.

5.1.6.3 Silver and gold

While the abundant finds of copper alloy and lead at Kaupang, Ribe, and Birka clearly demonstrates that the urban non-ferrous metalworkers worked with these metals, there are also finds of silver and gold material which has been interpreted as raw material or casting waste. However, the finds of silver and gold appear to be quite rare. This scarcity could reasonably be explained by a combination of preservation conditions and that the metalworkers took great care to reclaim as much of the precious metals as possible. While objects such as ingots and metal sheets of silver and gold could easily have been used as raw material in sites with such clear evidence of metalworking activities, it is also possible that they served as objects of exchange (Hårdh, 1996; Lønborg, 1998:10–12; Sindbæk, 2005).

However, it is clear that the urban non-ferrous metalworkers did work with silver and gold as witnessed through analyses of crucibles and signs of techniques involving precious metals such as cupellation and pressed foil production. There is also the possibility that most of the silver and gold production at these sites is essentially “invisible” in regard to visual analyses of the archaeological records. This is demonstrated in the material from Kaupang where archaeometallurgical analyses performed on crucibles and moulds revealed clear evidence that several of the sherds, which had no visual indication of metal remains, were involved in casting silver and gold objects (Pedersen, 2016a:125). No such archaeometallurgical analyses have been performed on the material from Ribe and Birka to the same extent, and it is entirely possible that Kaupang differs from the other sites in terms metalworking involving silver and gold. However, it is still a feasible assumption that the silver and gold material at Ribe and Birka mirrors Kaupang in this manner, based on similarities in technical skill, production methods, and the shared connections between these sites.

Furthermore, the archaeometallurgical analyses performed on the silver at Kaupang revealed a preference for essentially pure silver, i.e. >95% Ag (Pedersen, 2016a:153). The high purity of the silver in Kaupang appears to coincide quite well with the composition and purity of the silver in dirhams, which might indicate that the main source of silver was Arabic coins (Pedersen, 2016a:168). The melting down of dirhams is well evidenced at Kaupang through the half-melted contents of a crucible, C52517/1737, and the coins were clearly a source of silver. The interpretation of dirhams as the main source of silver has, however, been noted as a somewhat problematic interpretation as cupellation crucibles from contexts with clear evidence for working with silver have been found at Kaupang (Pedersen, 2016a:168). These cupellation crucibles could have been used to refine silver, which would result in a composition and purity akin to that of the analysed silver from Kaupang and Arabic silver coins. The high purity silver alongside cupellation crucibles could simply mean that the non-ferrous metalworkers at Kaupang preferred to use essentially pure silver, and therefore refined whatever silver they had access to.

Whether this was also the case at Ribe and Birka is difficult to say, but the presence of cupellation crucibles at these sites would at least allow for the metalworkers to purify their silver if desired. Ambrosiani (1997:171) notes that the amount of silver at Birka appears to be quite limited until the introduction of Arabic silver coins during the 8th century. This could indicate that the majority of the silver at Birka consisted of dirhams, which in turn would indicate that the purity of the silver worked at Birka would have been quite high. However, the prevalence of dirhams at Birka could also be a peculiarity of the site, as it is situated with easy access to the Baltic Sea and the eastern trade connections which provided the dirhams (Sindbæk, 2008:151). While the cupellation crucibles could easily have been used for refining silver, it is also entirely possible that the cupellation crucibles merely served as assaying tools in the silver bullion economy of the Vikings. In any case, it remains a possibility that a combination of cupellation crucibles used to refine silver and the melting down of dirhams as raw material took place at Ribe and Birka, which would have resulted in a high purity in the silver material at these sites as well.

5.1.7 Workshops

A significant amount of the non-ferrous metalworking finds at Kaupang, Ribe, and Birka were found in contexts associated with certain plots or areas that have been interpreted as workshops (Ambrosiani, 2013; Frandsen and Jensen, 2006; Pedersen, 2016a). As the workshops were the arenas in which the non-ferrous metalworking activities would have taken place and considering the broad similarities between metalworking finds at the urban sites, it is perhaps not surprising that the workshops seem to share several attributes. For instance, workshops in all three towns can be dated to the early phases of their respective settlements and appear to be located within areas with plot division, and are therefore surrounded by plots with structures and areas for activities other than metalworking (Ambrosiani, 2013:71 ; Frandsen and Jensen, 2006:17; Pedersen, 2016a:180).

Due to preservation conditions, the details of the workshops are somewhat limited, but the material found in related contexts are quite comparable. As the material indicate what metalworking activities took place, and because it can be safely assumed that these workshops were the areas in which these activities took place, similarities in the material could likely be applied to show similarities between the workshops. In the same vein, differences in the material could highlight differences between the workshops. For instance, there is strong evidence for casting activities taking place at all these workshops, and other techniques evident in the material uncovered at Kaupang, Ribe, and Birka were likely also taking place in the workshops. As such, these workshops would have been the characterised by significant amount of serial production. There are, however, some differences. In particular, one of the workshops in Kaupang has evidently a clear preference for silver, while such a preference cannot be clearly stated in other workshops based on the material from Ribe and Birka. However, the material from Ribe and Birka does lend itself towards an emphasis on copper alloys. There are also finds of ceramic packaging material at the workshop in Birka which has been attributed to soldering activities, an activity that is generally associated with ironworking (Ambrosiani, 2013:223; Pedersen, 2016a:135). This could indicate that ironworking, at least in the form of soldering, took place in the workshop at Birka, unlike those in Kaupang and Ribe. There is also an area interpreted as a potential short-lived workshop at Kaupang, which differs from the long-lived workshops present elsewhere in Kaupang, and at Birka (Pedersen, 2016a:184–185).

5.1.8 The urban non-ferrous metalworking activities

The non-ferrous metalworking activities that took place at Kaupang, Ribe, and Birka appears to have shared broad similarities, with only a few notable differences in the raw material and crucibles being employed. The same techniques and products appear to be visible in the material from the respective sites, and as such the urban non-ferrous metalworkers seems to have shared a level of technical skill and knowledge. The production in all three towns appears heavily skewed towards a number of different types of serial production, with an apparent emphasis on the manufacture of oval brooches and equal-armed brooches. Furthermore, the non-ferrous metalworkers at all three sites clearly mastered a range of metals and made their products out of lead, various copper alloys, silver, and gold. As such, they seem to have produced jewellery and dress-accessories that was available to a wide range of different social positions, from cheap and easily manufactured lead pendants, to exquisite brass oval brooches and gold pressed foils. In sum, the non-ferrous metalworking activities at Kaupang, Ribe, and Birka appear consistently similar, with some differences which could be accounted for by preservation conditions, personal preference, or slightly different contact networks.

5.2 Metalworking and trade

Kaupang, Ribe, and Birka are urban sites that have often been described as trade towns, emporia, or nodal points (e.g. Ambrosiani, 2008:94; Hodges, 1982; Sindbæk, 2005). Consequently, trade has often been considered a primary activity of these sites. However, as the material from these towns exhibit, craft and production activities appear to have been quite central as well. If both trade and craft production can be considered central elements of the activities taking place in these urban settlements, what was the connection between the non-ferrous metalworkers and the traders?

The non-ferrous metalworkers at Kaupang, Ribe, and Birka required raw materials in order to produce their wares. For instance, brass ingots highlight how copious amounts of brass was brought to Scandinavia from the Rhineland through a vast trade network. Using the raw materials provided by trade networks, the metalworkers were able to produce objects such as dress accessories, fittings, and mounts. It would not be difficult to imagine a form of interdependence between the urban non-ferrous metalworkers and the traders where the traders provided access to raw materials and markets while the metalworkers provided their products and expertise (Ashby and Sindbæk, 2020b:19–21). The apparent heavy emphasis on serial production serves as another indication of a connection between the urban metalworkers and the urban networks connecting Kaupang, Ribe, and Birka with each other and the rest of the long-distance trade network (Ashby and Sindbæk, 2020b:19). The easy access to raw materials and the serial production techniques employed by the urban non-ferrous metalworkers would have allowed them to supply an urban market, in the form of local and regional consumption, as well as long-distance exports through the trade networks.

Another potential effect of a ready access to raw material provided by the trade networks at Kaupang, Ribe, and Birka is that the non-ferrous metalworkers might have been strongly incentivised to produce at these urban settlements in order to have access to the necessary raw materials. For example, if all the brass available in Scandinavia was funnelled through the urban settlements via long-distance trade, any non-ferrous metalworker wanting to produce brass objects would be inclined to reside in the towns. This could have had an effect on both the level of mobility of the non-ferrous metalworkers, as well as the demand of metal ingots and the supply of finished metal artefacts. For instance, the non-ferrous metalworkers could have been forced to either settle in the towns, or travel between them if they wished to be itinerant. In this manner, the relationship between Viking Age non-ferrous metalworking and trade could have been a factor in determining the physical boundaries of the non-ferrous metalworking activity.

The non-ferrous metalworkers of Kaupang, Ribe, and Birka were also potentially linked to trade activities through the production of what has been termed "exchange tools", such as weights and means of exchange like ingots (Sindbæk, 2005:93). While weights were likely used by the non-ferrous metalworkers themselves to accurately mix metal alloys, they were also potential tools used in the exchange of wares. Ingots of metals such as copper alloys and silver could serve as excellent means of exchange in a bullion-based economy and can also be considered a form of exchange tool. As several of the casting hollows in re-usable moulds at the urban sites have been interpreted as moulds for casting weights and ingots, it would appear that the non-ferrous metalworkers at Kaupang, Ribe, and Birka had the means to provide the traders in their respective towns with such tools of exchange.

Cupellation crucibles are evident at all three sites. This implies that the urban non-ferrous metalworkers could have engaged in assaying and refining of precious metals, particularly silver and gold. The use of cupellation crucibles to assay precious metals could have been especially useful when engaging in large transactions in the Viking Age bullion economy. For instance, the non-ferrous metalworkers could have used cupellation crucibles when exchanging their wares or acquiring raw material in order to assay the silver used as payment in the transaction. Furthermore, the non-ferrous metalworkers at the urban sites could potentially have held a role as a neutral mediator or "middle-man" in large transactions by being responsible for assaying the precious metals involved. In this way, the non-ferrous metalworkers could have been entwined in the trade activities in the urban settlements and cupellation crucibles could have served as an exchange tool as well as being a metalworking implement.

5.3 The social position of the urban non-ferrous metalworkers

5.3.1 Mobility

Rather than attempting to determine whether the non-ferrous metalworkers at Kaupang, Ribe, and Birka were either itinerant or permanently settled, I would like to discuss to what extent these craftspeople were mobile. I find it to be much more productive to examine a potential scale of mobility, rather than the either-or discussion of itineracy, as it allows for more complex social aspects of mobility to be discussed. I would therefore like to adopt the terms "base" and "guest" suggested by Pedersen (2016b:268).

The prevalent trade activities believed to have taken place at the urban sites of Kaupang, Ribe, and Birka would have allowed the urban non-ferrous metalworkers to have easy access to necessary raw materials and markets. Some of the raw materials, like brass, appears to be essentially bound to the trade networks and would only be reasonably obtainable at these urban sites (Ashby and Sindbæk, 2020b:12; Sindbæk, 2005). Furthermore, the urban nature of these settlements would imply that the non-ferrous metalworkers had ready access to other craftspeople. This would have allowed for collaboration between the metalworkers and other specialised craftspeople (Ashby and Sindbæk, 2020b; Croix, et al., 2019; Skre, 2007; Skre, 2011a). For instance, mould fragments indicate that the non-ferrous metalworkers produced metal objects for composite products like belts and harnesses. The production of such composite objects would have required skills and expertise from several different craft specialisations (Croix, Neiβ, and Sindbæk, 2019). In terms of exchange of knowledge, an accumulation of groups of non-ferrous metalworkers within a single settlement could have facilitated sharing of knowledge and techniques between the groups of metalworkers (Ashby and Sindbæk, 2020c:127). Furthermore, the trade networks which connected the towns of Kaupang, Ribe, and Birka, and the seemingly intertwined relationship between trade and metalworking production at these sites, would imply a reasonable degree of contact between the non-ferrous metalworkers at these sites. Such a connection would likely have allowed for further sharing of knowledge between metalworkers in different urban sites and could have been a result of the potential regionalisation of these towns. All of the above factors would arguably make these urban settlements very attractive locations for a base for the non-ferrous metalworkers, and as such could have heavily influenced the urban metalworkers towards a settled lifestyle (Ashby and Sindbæk, 2020b:9).

Although the non-ferrous metalworkers could have become somewhat bound to the urban sites which would imply low mobility, there is also the possibility that Kaupang, Ribe, and Birka, being bound together through trade and accessible to each other through sea travel, formed a region which the non-ferrous metalworkers moved within. This could manifest as, for example, a group of metalworkers having a base in Kaupang while occasionally travelling to other towns and performing their craft there for some time, essentially having a base at one town and having periods as guest metalworkers in the others. This level of mobility between the towns could also be a possible reason for the large similarities in the material related to non-ferrous metalworking at

Kaupang, Ribe, and Birka, as the same people could be practising their craft and sharing knowledge at the different urban sites. Alternatively, the metalworkers could have been bound within a region of urban sites, but having no base of operations, and merely rotating between towns performing their craft as guests. As such, the urban non-ferrous metalworkers could have experienced a level of mobility ranging from sedentary to highly mobile.

Whether all of the non-ferrous metalworkers at Kaupang, Ribe, and Birka shared a level of mobility is difficult to say, and it is quite likely that there was significant variation between different groups of non-ferrous metalworkers. In turn, the behaviour and mobility of these groups could have been influenced by such factors as their personal preferences or differences in knowledge and skill. For example, the group of metalworkers at plot 1B in Kaupang appears to be a highly skilled and long-lived group of metalworkers with an emphasis on working with silver. They also appear to have had some technical preferences in crucibles, as the material is dominated by type 3 crucibles. The longevity of the workshop would imply this group treated Kaupang as their base. Plot 3A in Kaupang, however, appears to be a multi-functional site with evidence of different crafts and a short-lived period of metalcasting with a focus on copper alloys. This could be interpreted as a site where a group of guest metalworkers performed their craft for a period of time before moving on. The focus on copper alloy among the latter group could potentially reflect a different preference or perhaps even a lack of knowledge or skill in working other metals. Either way, these two plots highlight the potential presence of both sedentary as well as mobile groups of metalworkers within the same settlement.

Furthermore, the workshop uncovered at Birka appears to have been in use for an extended period of time. However, the workshop area underwent constant changes every three to five years on average where the structures and production sites within the plot was constantly moving around. The longevity of the workshop and metalworking activity on this site could imply that a fairly sedentary group of metalworkers employed this plot. There is also the possibility, however, that the shifting nature of the plot represents different groups of metalworkers using the site, with each group reorganising the site to fit their preferences and needs. Especially considering breaks or seasonality between the settled phases at the workshop at Birka might not have been visible or preserved in the archaeological record. As such, it is possible that this workshop reflects a long-lived cycle of use by mobile non-ferrous metalworkers who occasionally practised their craft at Birka, rather than a single group of metalworkers using the site for an extended period of time.

Ashby and Sindbæk (2020b:9) have proposed that the question of mobility amongst craftspeople might be resolved through a perspective of life histories where the same individual craftsperson might have travelled widely for years, and later settling in one place. Through this perspective the divide between highly mobile and settled craftspeople could be one of seniority and experience. Perhaps as a part of learning the craft, younger metalworkers would have moved between urban sites and practised their profession, and later on when they were skilled enough could join or start their own group of settled non-ferrous metalworkers. If so, then this could be a factor in explaining the significant similarities between the urban metalworking, as it could simply have been the exact same people learning and performing their craft across all the urban settlements, and the same skills and knowledge would have consistently been diffused across the urban sites.

5.3.2 Integrated or isolated?

The workshops employed by the non-ferrous metalworkers at Kaupang, Ribe, and Birka all appear to be situated inside the settlements surrounded by the domiciles of traders and workshops of other crafts. This would imply that there were no “metalworking districts” or larger areas of the town designated for metalworking activities. As such, there appears to be no clear physical separation between the metalworking workshops and the other residents of the town beyond boundaries of the plot, and on a spatial level they seem rather integrated within the general settlement. Furthermore, the non-ferrous metalworkers appear to have a strong connection to the trade activities taking place at the urban settlements. Consequently, these metalworkers appear to be almost entwined with the rather mundane commercial aspects of these sites.

The potential for collaboration with other craft specialists to create composite products could also represent another factor that links the urban non-ferrous metalworkers with the other activities at these sites. There is also the possibility that the groups of non-ferrous metalworkers included non-metalworkers. For instance, different tasks could have been assigned to different people within the group such as working with clay to make moulds and crucibles, or carving models, i.e. working with other materials than metal while still being a part of the metalworking activities. If this is the case, then other craft specialists could clearly have been included into a group of non-ferrous metalworkers. In sum, the urban metalworkers appear to have held a social position where they were quite integrated within their towns and held potentially strong connections with exchange and trade activities as well as other craft activities at these sites. Consequently, the urban non-ferrous metalworkers appear to have been well-connected and could have been associated with the major activities taking place in these urban sites. If so, these metalworkers must have held a central and integrated social position within these settlements.

6 Conclusive remarks

6.1 Urban non-ferrous metalworking activity

A comparison of the non-ferrous metalworking activities at Kaupang, Ribe, and Birka, based on the material available through scientific publications and online databases, highlights a number of similarities as well as some differences. Through the techniques evidenced at all three sites, such as metalcasting and its associated processes, production of pressed foils, filigree and granulation decoration, and cupellation, the urban non-ferrous metalworkers appears to have been highly skilled and knowledgeable. Furthermore, the metalworking activities at Kaupang, Ribe, and Birka were all characterised by significant amounts of serial production. This serial production took on many forms, such as slow casting sequences using hard models, rapid casting sequences using cast wax models, and the production of pressed foils using matrix dies. The non-ferrous metalworkers appear to have mastered a wide range of metals, such as various copper alloys, silver, gold, and lead. I have also argued that the prevalence of brass that appears at Kaupang is applicable to Ribe and Birka, consequently making brass the most common metal used by the urban non-ferrous metalworkers in general.

Differences in the metalworking activities at these sites is visible in different variations of type 2 crucibles between Ribe and those found at Kaupang and Birka, as well as a prevalence for lead at Kaupang. The differences in the type 2 crucible material could reasonably be considered personal preference, while the lead at Kaupang is arguably more complex. The prevalence for lead at Kaupang could potentially be explained by Kaupang having had a stronger connection with York and Dublin, where lead is also prevalent, than Ribe and Birka had. In any case, it is clear that the non-ferrous metalworking activities at these urban sites shared a prevalence of serial production and that in general the urban non-ferrous metalworkers had an equivalent level of technical skill and knowledge.

6.2 Connections, integration, and mobility

The non-ferrous metalworkers at Kaupang, Ribe, and Birka appears to have been quite well-connected with the traders and trade activities in their respective settlements. This connection is made visible in the potential symbiotic relationship between the traders and the metalworkers where the former provided raw material and access to other urban sites and markets, while the latter provided wares, tools of exchange, and potentially even services through assaying precious metals. The use of cupellation crucibles to assay precious metals could also have provided the non-ferrous metalworkers with a position as a form of middleman in larger exchanges of wares involving silver bullion. In any case, the urban non-ferrous metalworkers at Kaupang, Ribe, and Birka seems to have been intimately connected with trade activities taking place in these sites.

In terms of the level of mobility, there were many factors that could have incentivised the urban non-ferrous metalworkers to stay put within their respective settlements. For instance, the non-ferrous metalworkers would have had access to the necessary raw materials, regional and distant markets to provide their wares to, and other craftspeople to collaborate with. This meant that on a surface level there was no need for the metalworkers to move around and they could easily use an urban settlement as a permanent base of operations. However, there were also factors which provided an ease of mobility which might have made moving around attractive. The large trade networks connecting these urban sites with each other and the ease of travel across the sea could imply that Kaupang, Ribe, and Birka constituted a region, and that moving between these sites would have been very feasible if not easy.

The result of a general view of the level of mobility of the urban non-ferrous metalworkers appears to provide an ambivalent situation. This ambivalence can be resolved by considering the fact that the groups of non-ferrous metalworkers within a given site would differ from each other and that treating them all as one group would be too generalising. It is therefore quite possible that different groups of non-ferrous metalworkers enjoyed different levels of mobility. For instance, a long-lived workshop at Kaupang is indicative of a group of highly skilled silversmiths who most likely used Kaupang as their base of operation, while other plots within the town had short periods of metalworking activities indicating that a group had performed their craft as guests in this location. This essentially points towards a significant variance in the level of mobility between groups of urban non-ferrous metalworkers, and that while some non-ferrous metalworkers could have been settled, others would likely have been quite mobile.

The non-ferrous metalworking workshops at Kaupang, Ribe, and Birka all appear to be located within the standard plot arrangements of these towns and were consequently surrounded by buildings characterised by completely different activities, such as workshops for other crafts and the domiciles of traders. Furthermore, the non-ferrous metalworkers would have easily been able to collaborate with other craftspeople when producing composite objects, indicating further connections between the non-ferrous metalworkers and other parts of the population. If such cooperation was the case, in addition to a strong connection between the metalworkers and the traders at these towns, then the metalworkers would appear to be very well-connected and integrated within the towns, both on a physical and a social plane. Consequently, the non-ferrous metalworkers at Kaupang, Ribe, and Birka likely held a strong and central social position within these settlements.

6.3 Suggestions for further research

This thesis suffers somewhat from a lack of direct access to the material. In particular, as I build my research heavily upon already published research of the material, the disparity between the quality of analyses performed on the material from Kaupang compared to those performed on much of the material from Ribe and Birka poses challenges when attempting comparative analyses on this group of material. As such, further studies or archaeometallurgical analyses performed on the material from Ribe and Birka could provide a clearer picture of the non-ferrous metalworking activities taking place in these sites, allowing for more comprehensive and accurate comparisons. There also appears to be some research on the non-ferrous metalworking at Birka which is yet to be published that could provide new details which might demand a reassessment of my conclusions.

Due to the constraints placed upon a master’s thesis I have been unable to include the material from Hedeby, which is the fourth and last known of the earliest wave of urban settlements in Scandinavia. I believe that while a comparison of Kaupang, Ribe, and Birka should provide an acceptable basis for a more general understanding of urban non-ferrous metalworking in the Late Iron Age, such broad interpretations would be very much improved by including all the early urban sites, i.e. including Hedeby as well. The grave material from cemeteries associated with these urban settlements could also be a useful avenue for comparative analyses, both by comparing the towns with the material in the respective cemeteries as well as comparing the cemeteries with each other.

Another potential issue with my approach is a very strong focus on the visible metalworking techniques themselves, and it may very well be that there exists significant differences between the non-ferrous metalworkers at Kaupang, Ribe, and Birka which are not expressed through craft techniques, and as such could easily have been overlooked. There could also be differences in the settlement caused by varying influences being applied to the sites. For instance, the increase in lead at Kaupang could be caused by a stronger connection to the British Isles, but what about Ribe and Birka? Could there for example have been stronger eastern influences being applied at Birka? Whether or not such connections could have influenced the non-ferrous metalworking activity to such a degree that it is readily visible in the archaeological material could also be a subject of study.

Beyond urban studies, an understanding of the urban non-ferrous metalworking activities could also prove to be a useful tool in understanding metalworking activity in other contexts as it can stand as a contrast to, for example, metalworking activities taking place in contexts related to ritual or cult activity. In a similar vein, the cemeteries associated with the urban settlements, which unequivocally can be interpreted as metalworking production sites, might aid in discussions surrounding “smith graves”. As the urban non-ferrous metalworkers could have been interred in the cemeteries associated with the settlements in which they resided and performed their craft, it is quite possible that these cemeteries could provide a clear example of how metalworkers were buried, at least in an urban context.

In any case, there are several ways in which to either improve or build upon my research to further our understanding of urban non-ferrous metalworking in Late Iron Age Scandinavia. Furthermore, it is my belief that an understanding of the urban non-ferrous metalworking activity is a useful avenue for not only gaining important insight into metalworking and the metalworkers themselves, but also the wider contexts surrounding these activities. For instance, our understanding of the urban settlements of Late Iron Age Scandinavia could be improved by studying the urban metalworkers and their craft, and consequently examine how they potentially affected or helped shape these sites.

Abbreviations

ASR + (number) + (location)	Excavations at Ribe by *Den Antikvariske Samling, Ribe, Sydvestjyske museer*, The Museum of Southwest Jutland
ASR + (number x number)	Finds kept at *Den Antikvariske Samling, Sydvestjyske museer*, The Museum of Southwest Jutland, Ribe
C + (number)	Finds kept at *Kulturhistorisk museum*, Museum of Cultural History, University of Oslo
KHM	*Kulturhistorisk museum* Museum of Cultural History, University of Oslo
R. + (number)	Figure reference in Oluf Rygh (1885) *Norske Oldsager*
SHM	*Statens historiska museum,* The Swedish History Museum, Stockholm
SHM + (number)	Finds kept at *Statens historiska museum*, The Swedish History Museum, Stockholm
SJM	*Sydvestjyske museer,* The Museum of Southwest Jutland, Ribe

References

Ambrosiani, B. (1992) Excavations at Birka 1990–94: Setting up the Project, in: Ambrosiani, B. and Clarke, H. (eds.) *Birka Studies, Volume 1. Early Investigations and Future Plans*. Stockholm: Birka Project for Riksantikvarieämbetet and Statens historiska museer, pp. 83–87.

Ambrosiani, B. (1997) Metallförsörjning i Birka, in: Åkerlund, A., Bergh, S., Nordbladh, J. and Taffinder, J. (eds.) *Till Gunborg. Arkeologiska samtal*. SAR Stockholm Archaeological Reports, vol. 33, Stockholm: Stockholms Universitet, pp. 167–172.

Ambrosiani, B. (2001) *Birka Studies, Volume 5. Excavations in the Black Earth 1990–1995. Eastern Connections Part One: The Falcon Motif*. Stockholm: Birka Project for Riksantikvarieämbetet.

Ambrosiani, B. (2013) *Birka Studies, Volume 9. Excavations in the Black Earth 1990–1995. Stratigraphy Vol. 1. Part One: The Site and the Shore. Part Two: The Bronze Caster's Worskhop*. Stockholm: Birka Project for Riksantikvarieämbetet.

Ambrosiani, B. and Clarke, H. (eds.) (1992) *Birka Studies, Volume 1. Early Investigations and Future Plans*. Stockholm: Birka Project for Riksantikvarieämbetet and Statens historiska museer.

Ambrosiani, B. and Erikson, B.G. (1994) *Birka: Vikingastaden, Volym 4: Smycken och Djurben Bland 40 000 Fynd – Våttensållet Avslöjar Livet För 1200 År Sedan*. Stockholm: Sveriges Radios förlag.

Ambrosiani, B., Arrhenius, B., Danielsson, K., Kyhlberg, O., and Werner, G. (1973) *Birka: svarta jordens hamnområde: arkeologisk undersökning, 1970–71*. Stockholm: Riksantikvarieämbetet.

Arbman, H. (1943). *Birka: Untersuchungen und Studien: 1: Die Gräber: Text*. Stockholm: Kungl. Vitterhets Historie och Antikvitets Akademien.

Arrhenius, B. (1973) Gjutformar och deglar, påträffade i Birka, in: Ambrosiani, B., et.al. (eds.) *Birka: Svarta Jordens Hamnområde: Arkeologisk Undersökning 1970–1971*. Stockholm: Riksantikvarieämbetet, pp. 99–115.

Arwidsson, G. (ed.) (1989) *Birka: Untersuchungen und Studien: II:3: Systematische Analysen der Gräberfunde*. Stockholm: Kungl. Vitterhets Historie och Antikvitets Akademien.

Arwidsson, G. and Berg, G. (1983) *The Mästermyr find. A Viking Age Tool Chest from Gotland*. Stockholm: Almgqvist & Wiksell.

Ashby, S.P. and Sindbæk, S.M. (eds.) (2020a) *Crafts and Social Networks in Viking Towns*. Oxford: Oxbow Books

Ashby, S.P. and Sindbæk, S.M. (2020b) Crafting the urban network, in: Ashby, S.P. and Sindbæk, S.M. (eds.) *Crafts and Social Networks in Viking Towns*. Oxford: Oxbow Books, pp. 1–29.

Ashby, S.P. and Sindbæk, S.M. (2020c) Constructing specialism, in: Ashby, S.P. and Sindbæk, S.M. (eds.) *Crafts and Social Networks in Viking Towns*. Oxford: Oxbow Books, pp. 127–132.

Ashby, S.P. and Sindbæk, S.M. (2020d) Collaboration and expert knowledge, in: Ashby, S.P. and Sindbæk, S.M. (eds.) *Crafts and Social Networks in Viking Towns*. Oxford: Oxbow Books, pp. 225–230.

Barndon, R. (2005a) Håndverk, kunst og kunnskap – noen komparative perspektiver på smedens sosiale identitet i jernalderen, in: Bergsvik, K.B. and Engevik jr., A. (eds.) *Fra funn til samfunn. Jernalderstudier tilegnet Bergljot Solberg på 70-årsdagen*. UBAS. Universitetet i Bergen Arkeologiske Skrifter. Bergen: Universitetet i Bergen, pp. 357–376.

Barndon, R. (2005b) Metall og myter – magi og transformasjon. Refleksjoner omkring den norrøne smedens kunnskap og identitet i et komparativt perspektiv. *Primitive tider*, 8, pp. 61–74.

Baug, I. (2011) Soapstone finds, in: Skre, D. (ed.) *Things from the Town, Artefacts and Inhabitants in Viking-age Kaupang. Kaupang Excavation Project Publication Series, Volume 3.* Århus: Aarhus University Press, pp. 311–337.

Bayley, J. (1992) *The Archaeology of York, 17. The Small Finds, 7. Anglo-Scandinavian Non-Ferrous Metalworking from 16–22 Coppergate*. London: Council for British Archaeology.

Bencard, M. (1984a) Introduction, in: Bencard, M. (ed.) *Ribe Excavations 1970–76: volume 2*. Esbjerg: Sydjysk Universitetsforlag, pp. 9–14.

Bencard, M. (ed.) (1984b) *Ribe Excavations 1970–76: volume 2*. Esbjerg: Sydjysk Universitetsforlag.

Bencard, M., Jørgensen, L.B. and Brinch Madsen, H. (eds.) (1981) *Ribe Excavations 1970–76: volume 1*. Esbjerg: Sydjysk Universitetsforlag.

Blindheim, C (1960) Kaupangundersøkelsen etter 10 år. *Viking*, 24, pp. 43–68.

Blindheim, C. (1975) Kaupang by the Viks Fjord in Vestfold, i Herteig, A.E., Liden, H-E., og Blindheim, C. (red.) *Archaeological contributions to the early history of urban communities in Norway*. Oslo: Universitetsforlaget, pp. 125–173.

Blindheim, C. and Heyerdahl-Larsen, B. (1995) *Kaupang-funnene: Bind II Gravplassene i Bikjholbergene/Lamøya : undersøkelsene 1950–1957 Del A: Gravskikk*. Oslo: Universitetets kulturhistoriske museer, Oldsaksamlingen.

Blindheim, C., Heyerdahl-Larsen, B., and Tollnes, R.L. (1981) *Kaupang-funnene: Bind I*. Oslo: Universitetets kulturhistoriske museer, Oldsaksamlingen.

Blindheim, C., Heyerdahl-Larsen, B., and Ingstad, A.S. (1999) *Kaupang-funnene: B.2 19: Gravplassene i Bikjholbergene/Lamøya: undersøkelsene 1950–1957 Del B: Oldsaksformer: kulturhistoriske tilbakeblikk; Del C: Tekstilene*. Oslo: Universitetets kulturhistoriske museer, Oldsaksamlingen.

Brinch Madsen, H. (1984) Metal-casting, in: Bencard, M. (ed.) *Ribe Excavations 1970–76: volume 2*. Esbjerg: Sydjysk Universitetsforlag, pp. 15–191.

Budd, P. and Taylor, T. (1995) The Faerie Smith Meets the Bronze Industry: Magic Versus Science in the Interpretation of Prehistoric Metal-Making. *World Archaeology*, 27(1), pp. 133–143.

Bøckmann, J. (2007) *"Smedverktøy" fra norske jernaldergraver. En bruksanalyse av redskapene i Jan Petersens oversikt over smedgraver*. Master's thesis. Oslo: Universitetet i Oslo.

Croix, S., Deckers, P., Feveile, C., Knudsen, M., Qvistgaard, S.S., Sindbæk, S.M., and Wouters, B. (2019) Single Context, Metacontext, and High Definition Archaeology: Integrating New Standards of Stratigraphic Excavation and Recording, *Journal of Archaeological Method and Theory*, 26, pp. 1591–1631.

Croix, S., Neiβ, M., and Sindbæk, S.M. (2019) The reseau opératoire of Urbanization: Craft collaborations and Organization in an Early Medieval Workshop in Ribe, Denmark, *Cambridge Archaeological Journal*, 29(2), pp. 345–356.

Dobres, M.A. (2000) *Technology and Social Agency. Outling a Practice Framework for Archaeology*. Oxford: Blackwell.

Duczko, W. (1985) *Birka V. The filigree and granulation work of the Viking Period. An analysis of the material from Björkö*. Stockholm: Almqvist & Wiksell International.

Feveile, C. (2002) Støbning af ovale skålspænder i Ribe – type- og teknikvariation, in: Henriksen, M.B. (ed.) *Metalhåndværk og håndværkspladsser fra yngre germansk jernalder, vikingetid og tidlig middelalder. Skrifter fra Odense Bys Museer vol. 9*. Odense: Odense Kommune, pp. 17–26.

Feveile, C. (ed.) (2006a) *Ribe Studier: Det Ældste Ribe. Udgravninger på nordsiden af Ribe Å 1984–2000. Bind 1.1.* Moesgård: Jysk Arkæologisk Selskab.

Feveile, C. (ed.) (2006b) *Ribe Studier: Det Ældste Ribe. Udgravninger på nordsiden af Ribe Å 1984–2000. Bind 1.2.* Moesgård: Jysk Arkæologisk Selskab.

Feveile, C. and Jensen, S. (2006) ASR 9 Posthuset, in: Feveile, C. (ed.) *Ribe Studier: Det Ældste Ribe. Udgravninger på nordsiden af Ribe Å 1984–2000. Bind 1.2.* Moesgård: Jysk Arkæologisk Selskab, pp. 119–190.

Frandsen, L.B. and Jensen, S. (2006) ASR 7 Sct. Nicolajgade 8, in: Feveile, C. (ed.) *Ribe Studier: Det Ældste Ribe. Udgravninger på nordsiden af Ribe Å 1984–2000. Bind 1.2.* Moesgård: Jysk Arkæologisk Selskab, pp. 9–64.

Gaut, B. (2011) Vessel Glass and Evidence of Glassworking, in: Skre, D. (ed.) *Things from the Town, Artefacts and Inhabitants in Viking-age Kaupang. Kaupang Excavation Project Publication Series, Volume 3.* Århus: Aarhus University Press, pp. 169–279.

Grieg, S. (1922) Smedverktøi i norske gravfund. *Oldtiden. Tidsskrift for norsk forhistorie*, 9, pp. 21–95.

Gräslund, A. (1980) *Birka IV. The Burial Customs. A Study of the graves on Björkö*. Stockholm: Almqvist & Wiksell International.

Gustafsson, N.B. (2011) Beyond Wayland – thoughts on early medieval metal workshops in Scandinavia. *Historical Metallurgy*, 45(2), pp. 20–31.

Hansen, G. (2017) Domestic and exotic materials in early medieval Norwegian towns: an archaeological perspective on production, procurement and consumption, in: Glørstad, Z.T. og Loftsgarden, K. (eds.) *Viking-Age Transformations: Trade, Craft and Resources in Western Scandinavia*. Abingdon: Routledge, pp. 59–94.

Hedegaard, K.R. (1992) Bronzestøberhåndværket i yngre germanertid og tidlig vikingtid i Skandinavien – teknologi og organisation. *LAG*, 3, pp. 75–93.

Hodges, R. (1982) *Dark Age Economics: The origins of towns and trade A.D. 600–1000*. London: Duckworth.

Holback, T.J. (1999) Svårtolkade spår efter en metallurgisk process – ett dansk exempel och dess paralleller i omvärlden. *By, marsk og geest*, 11, pp. 5–12.

Hyenstrand, E. (1992) Early Discoveries in the Black Earth, in: Ambrosiani, B. and Clarke, H. (eds.) *Birka Studies, Volume 1. Early Investigations and Future Plans*. Stockholm: Birka Project for Riksantikvarieämbetet and Statens historiska museer, pp. 23–51.

Hårdh, B. (1996) *Silver in the Viking Age. A Regional-Economic Study*. Stockholm: Almquist & Wiksell.

Hårdh, B. (2008) Hacksilver and Ingots, in: Skre, D. (ed.) *Means of Exchange. Dealing with Silver in the Viking Age. Kaupang Excavation Project Publication Series, Volume 2.* Århus: Aarhus University Press, pp. 95–118.

Jakobsson, T. (1996) Bronsgjutarverkstäderna på Birka – en kort presentation, in: Forshell, H. (ed.) *Icke-järnmetaller, malmfyndigheter och metallurgi*. Stockholm: Jernkontorets bergshistoriska utskott, pp. 71–75.

Jansson, I. (1985) *Ovala spännbucklor. En studie av vikingatida standardsmycken med utgångspunkt från Björkö-fynden*. Doctoral dissertation. Uppsala University.

Jensen, S. (2006) Metal, in: Feveile, C. (ed.) *Ribe Studier: Det Ældste Ribe. Udgravninger på nordsiden af Ribe Å 1984–2000. Bind 1.2.* Moesgård: Jysk Arkæologisk Selskab, pp. 30–34.

Jouttijärvi, A. (2002) Kobberlegeringer i jernalder og vikingtid, in: Henriksen, M.B. (ed.) *Metalhåndværk og håndværkspladsser fra yngre germansk jernalder, vikingetid og tidlig middelalder. Skrifter fra Odense Bys Museer vol. 9*. Odense: Odense Kommune, pp. 27–40.

Kyhlberg, O. (1973a) Bly och tenn exkl viktlodd, in: Ambrosiani, B., et.al. (eds.) *Birka: Svarta Jordens Hamnområde: Arkeologisk Undersökning 1970–1971*. Stockholm: Riksantikvarieämbetet, pp. 153–155.

Kyhlberg, O. (1973b) Brons, guld, silver, exklusive mynt och viktlod, in: Ambrosiani, B., et.al. (eds.) *Birka: Svarta Jordens Hamnområde: Arkeologisk Undersökning 1970–1971*. Stockholm: Riksantikvarieämbetet, pp. 155–196.

Lønborg, B. (1998) *Vikingetidens Metalbearbejdning. Fynske studier 17*. Odense: Odense Universitetsforlag.

Merkel, W. (2018) Archaeometallurgical investigations of a Viking brass ingot hoard from the Hedeby Harbor in Northern Germany, *Journal of Archaeological Science: Reports*, 20, pp. 293–302.

Oldeberg, A. (1942) *Metallteknik under förhistorisk tid: Del 1*. Lund: Otto Harrassowitz.

Oldeberg, A. (1966) *Metallteknik under Vikingatid och medeltid.* Stockholm: Victor Pettersons bokindustri.

Pedersen, U. (2009) Den ideelle og den reelle smed, *Oslo Archaeological Series*, 12, pp. 129–146.

Pedersen, U. (2010) *I Smeltedigelen: finsmedene i vikingtidsbyen Kaupang.* Doctoral dissertation. Universitetet i Oslo.

Pedersen, U. (2016a) *Into the Melting pot. Kaupang Excavation Project Publication Series, Volume 4*. Århus: Aarhus University Press.

Pedersen, U. (2016b) Non-Ferrous Metalworking in Viking Age Scandinavia: A Question of Mobility, in: Turner, V.E., Owen, O.A., and Waugh, D.J. (eds.) *Shetland and the Viking World: Papers from the Seventeenth Viking Congress, Lerwick*. Lerwick: Shetland Heritage Publications, pp. 263–269.

Pedersen, U. (2020) From bronze-casting to non-ferrous metalworking: complexity, choices and cooperation in urban Scandinavian Viking-Age workshops, in: Ashby, S.P. and Sindbæk, S.M. (eds.) *Crafts and Social Networks in Viking Towns*. Oxford: Oxbow Books, pp. 231–250.

Pilø, L. (2007) The Fieldwork 1998–2003: Overview and Methods, in: Skre, D. (ed.) *Kaupang in Skiringssal. Kaupang Excavation Project Publication Series, Volume 1*. Århus: Aarhus University Press, pp. 141–160.

Pilø, L. (2011) The Pottery, in: Skre, D. (ed.) *Things from the Town, Artefacts and Inhabitants in Viking-age Kaupang. Kaupang Excavation Project Publication Series, Volume 3.* Århus: Aarhus University Press, pp. 281–304.

Rygh, O. (1885) *Norske Oldsager: 1. Afd.: Afbildninger og Oversigter*. Christiania: Cammermeyer.

Sindbæk. S.M. (2005) *Ruter og rutinisering. Vikingetidens fjernhandel i Nordeuropa*. København: Multivers.

Sindbæk, S.M. (2007) Networks and nodal points: the emergence of towns in early Viking Age Scandinavia. *Antiquity*, 81(311), pp. 119–132.

Sindbæk, S.M. (2008) Local and long-distance trade, in: Brink, S and Price, N (eds.) *The Viking World*. New York: Routledge, pp. 150–158.

Sigurðsson, J.V. (2017) *Skandinavia i vikingtiden*. Oslo: Pax.

Skre, D. (ed.) (2007) *Kaupang in Skiringssal. Kaupang Excavation Project Publication Series, Volume 1*. Århus: Aarhus University Press.

Skre, D. (2008) The Development of Urbanism in Scandinavia, in: Brink, S and Price, N (eds.) *The Viking World*. New York: Routledge, pp. 83–93.

Skre, D. (ed.) (2011a) *Things from the Town, Artefacts and Inhabitants in Viking-age Kaupang. Kaupang Excavation Project Publication Series, Volume 3.* Århus: Aarhus University Press.

Skre, D. (2011b) The Inhabitants: Origins and Trading Connexions, in: Skre, D. (ed.) *Things from the Town, Artefacts and Inhabitants in Viking-age Kaupang. Kaupang Excavation Project Publication Series, Volume 3.* Århus: Aarhus University Press, pp. 417–441.

Straume, E. (1986) Smeden i jernalderen, bofast – ikke bofast, høy eller lav status. *Universitetets Oldsaksamling Årbok*, 1984/1985, pp. 45–58.

Söderberg, A. (1996) Schmelzkugeln – identifikation av en hantverksprocess. Fyndmaterial från Birka och Sigtuna, In: *CD-uppsatser i Laborativ Arkeologi 95/96. Del 2.* Stockholm: The Archaeological Research Laboratory, Stockholm University.

Söderberg, A. (2004) Metallurgic ceramics as a key to Viking Age worshop orgnaisation. *Journal of Nordic Archaeological Science*, 14, pp. 115–124.

Söderberg, A. (2006) Om två metallurgiska processer knutna till vikingatidens betalningsväsende. *Situne dei. Årsskrift för Sigtunaforskning*, pp. 65–80.

Söderberg, A. and Gustafsson, N.B. (2006) A Viking-period silver workshop in Fröjel, Gotland. *Fornvännen*, 101, pp. 29–31.

Sørensen, R., Henningsmoen K.E., Høeg, H.I., Stabell, B. and Bukholm, K.M. (2007) Geology, Soils, Vegetation and Sea-levels in the Kaupang Area, in: Skre, D. (ed.) *Kaupang in Skiringssal. Kaupang Excavation Project Publication Series, Volume 1*. Århus: Aarhus University Press, pp. 251–272.

Vince, A. (2011) Characteristation Studies of Pottery, Industrial Ceramics and Fired Clay, in: Skre, D. (ed.) *Things from the Town, Artefacts and Inhabitants in Viking-age Kaupang. Kaupang Excavation Project Publication Series, Volume 3.* Århus: Aarhus University Press, pp. 305–309.

Wamers, E. (2011) Continental and Insular Metalwork, in: Skre, D. (ed.) *Things from the Town, Artefacts and Inhabitants in Viking-age Kaupang. Kaupang Excavation Project Publication Series, Volume 3.* Århus: Aarhus University Press, pp. 65–97.

Werner, G. (1973) Järn, in: Ambrosiani, B., et.al. (eds.) *Birka: Svarta Jordens Hamnområde: Arkeologisk Undersökning 1970–1971*. Stockholm: Riksantikvarieämbetet, pp. 84–99.

Østigård, T. (2007) Transformatøren – Ildens mester i jernalderen, in: Goldhahn, J. and Østigård, T. (eds.) *Rituelle spesialister i bronse- og jernalderen*. Göteborg: Göteborg universitet, Institutionen för arkeologi och antikens kultur, pp. 1–186.

Appendix A: Metalworking waste products and raw material from Kaupang, Ribe, and Birka

	Crucible fragments	Clay mould fragments total	Clay mould fragments with imprints	Stone moulds	Cupellation crucible fragments
Kaupang	2 118	1 128	109	13	30
Ribe	~3 260	~9 550	~1 595	2	3*
Birka	~3 900**	~25 000	7 000 – 8 000	2	4*

* The cupellation crucibles from Ribe and Birka were interpreted as melting crucible fragments. As such, these numbers are based on my reinterpretation of a few select examples and the reidentification of Brinch Madsen's type 6 and 7 crucibles as cupellation crucibles by Pedersen (2016a) and are probably quite inaccurate.

** "3 900 find-spots" of crucible fragments, which would mean at least 3 900 crucibles. Ambrosiani (2013) states that there are 10 000 pieces of crucibles and solder packages but does not provide any further details or differentiations within this group. As such it is entirely unclear exactly what amount of crucible material has been found at Birka, but it is obviously a substantial amount.

Ingots and casting waste from Kaupang

	Ingots	Melted drops	Casting sprues
Copper alloy	92	~174 (4 718 g)	35
Lead	100	~456 (1 212 g)	15
Silver	16	25 (117 g)	1
Gold	0	1 (0.4 g)	0

(Data from Pedersen, 2010)

Ingots and casting waste from Ribe

	Ingots	Melted drops	Casting sprues
Copper alloy	~43	17	3
Lead	3	1	N/A
Silver	5	3	N/A
Gold	N/A	N/A	N/A

(Data from Feveile, 2006b and SJM's database SOL)

Regarding the data in the table, the publications on the material from Ribe groups the metal objects into categories based on type of metal, i.e. copper alloy artefacts, ingots, melted drops, and random lumps of metal are solely listed as "bronze". As such I have only included what is clearly described as either an ingot, melted drop or casting sprue. Consequently, the numbers for copper alloy and lead objects in this table is far lower than what they reasonably should be as the 1970–1976 and 1984–2000 excavations uncovered a total of 1 131 copper alloy objects and 104 lead objects which would include jewellery, miscasts, casting cones, melted drops, ingots, and various pieces of metal.

Ingots and casting waste from Birka

	Ingots	Melted drops	Casting sprues
Copper alloy	58	1 092	N/A
Lead	4	62	N/A
Silver	1	N/A	N/A
Gold	N/A	N/A	N/A

(Data from Ambrosiani, et al., 1973 and SHM's online artefact database)

Appendix B: Catalogue of finds related to non-ferrous metalworking at Kaupang, Ribe, and Birka

This catalogue provides a brief overview of a selection of finds from Kaupang, Ribe, and Birka related to non-ferrous metalworking. The artefacts which have either been used as an example or have been referred to in the main body of this work will be included here.

Crucibles

Identifier	Interpretation	Material	Location	Figure	Notes	Source
C52516/1687	Thimble-shaped crucible	Fired clay	Kaupang	Fig. 4.1.1		KHM
C52516/1705	Thimble-shaped crucible	Fired clay	Kaupang	Fig. 4.1.5	Small and irregular. Potentially shaped around a finger.	KHM
C52516/1707	Thimble-shaped crucible	Fired clay	Kaupang	Fig. 4.1.5	Tall and narrow with a pointed base. Part of the exterior surface has been pared with a knife.	KHM
C52519/11946	Thimble-shaped crucible	Fired clay	Kaupang	Fig. 4.1.5		KHM
C52519/12369	Thimble-shaped crucible	Fired clay	Kaupang	Fig. 4.1.1		KHM
C52519/12987	Thimble-shaped crucible	Fired clay	Kaupang	Fig. 4.1.1		KHM
C52519/13243	Thimble-shaped crucible	Fired clay	Kaupang	Fig. 4.1.1		KHM
C52519/13334	Thimble-shaped crucible	Fired clay	Kaupang	Fig. 4.1.1		KHM
C52519/17246	Thimble-shaped crucible	Fired clay	Kaupang	Fig. 4.1.1		KHM
C52519/23627	Thimble-shaped crucible	Fired clay	Kaupang	Fig. 4.1.7		KHM
C52519/23628	Thimble-shaped crucible	Fired clay	Kaupang	Fig. 4.1.7		KHM

D6210	Type 5 crucible	Fired clay	Ribe	Fig. 4.1.3	Used as the type example for Brinch Madsen's type 5 crucible.	Brinch Madsen, 1984
D6236	Type 2 crucible	Fired clay	Ribe	Fig. 4.1.2	Used as the type example for Brinch Madsen's type 2 crucible.	Brinch Madsen, 1984
D7327	Type 4 crucible	Fired clay	Ribe	Fig. 4.1.2	Used as the type example for Brinch Madsen's type 4 crucible.	Brinch Madsen, 1984
D9499	Type 3 crucible	Fired clay	Ribe	Fig. 4.1.2	Used as the type example for Brinch Madsen's type 3 crucible.	Brinch Madsen, 1984
D10492	Type 6 crucible	Fired clay	Ribe	Fig. 4.1.4	Used as the type example for Brinch Madsen's type 6 crucible. Presumably a cupellation crucible.	Brinch Madsen, 1984
D10511	Type 7 crucible	Fired clay	Ribe	Fig. 4.1.4	Used as the type example for Brinch Madsen's type 7 crucible. Presumably a cupellation crucible.	Brinch Madsen, 1984
D10830	Type 1 crucible	Fired clay	Ribe	Fig. 4.1.2	Used as the type example for Brinch Madsen's type 1 crucible.	Brinch Madsen, 1984
ASR 9x100	Type 2 crucible	Fired clay	Ribe	Fig. 5.4	Lug placed on the upper half of the crucible.	SJM
ASR 9x311	Type 2 crucible	Fired clay	Ribe	Fig. 4.2.2	Centrally placed lug.	SJM
ASR 1075x001	Fragment of a round, flat crucible	Fired clay	Ribe	Fig. 4.2.1	Probably a cupellation crucible reminiscent of Brinch Madsen's type 6 crucible.	SJM
ASR 1077x019	Type 2 crucible	Fired clay	Ribe	Fig. 4.2.2	Complete, small closed crucible. Centrally placed lug.	SJM
SHM69941	Thimble-shaped crucible	Fired clay	Birka	Fig. 4.3.2	Type 1 crucible.	SHM
SHM85975	Fragment of a type 2 crucible	Fired clay	Birka	Fig. 4.3.1	Lug placed along the rim.	SHM

SHM89025	Fragment of a round, flat crucible	Fired clay	Birka	Fig. 4.3.4	Probably a cupellation crucible reminiscent of Brinch Madsen's type 6 crucible.	SHM
SHM89541	Fragment of a round, flat crucible	Fired clay	Birka	Fig. 4.3.4	Probably a cupellation crucible reminiscent of Brinch Madsen's type 6 crucible.	SHM
SHM89542	Fragment of a round, flat crucible	Fired clay	Birka	Fig. 4.3.3	Probably a cupellation crucible reminiscent of Brinch Madsen's type 6 crucible.	SHM

Moulds

Identifier	Interpretation	Material	Location	Figure	Notes	Source
C52517/2447	Flat, rectangular mould	Lead	Kaupang	Fig. 4.1.0	Mould for making wax models of mounts in the Borre style.	KHM
C52519/16411	Reusable mould for casting pendants	Volcanic tuff	Kaupang	Fig. 4.1.8	One half of an investment mould with a hollow for casting pendants and a groove for making the loop.	KHM
C52519/17391	Two fragments from the same composite mould	Fired clay	Kaupang	Fig. 4.1.6	The fragments have visible imprints of decorative lines and the rim of the cast object.	KHM
C52519/23426	Open reusable mould	Gabbro	Kaupang	Fig. 4.1.7	Casting hollows for bar-shaped and oblong ingots.	KHM
ASR 9x479	Open reusable mould	Soapstone	Ribe	Fig. 4.2.3	Hollow for casting an ingot.	SJM
ASR 1085x047	Fragment of a composite mould	Fired clay	Ribe	Fig. 4.2.4	The fragment has an imprint of a type P12 oval brooch.	SJMs
SHM35097	Open reusable mould	Sandstone	Birka	Fig. 4.3.6	Hollow for casting an ingot.	SHM
SHM46272	Fragment of a composite mould	Fired clay	Birka	Fig. 4.3.5	The fragment has an imprint of an oval brooch.	SHM
SHM55029	Open reusable mould	Bone/antler	Birka	Fig. 4.3.7	Hollow for casting a round object with a pearly rim. Potentially a matrix die reminiscent of C52517/1289?	SHM
SHM92872	Open reusable mould	Bone/antler	Birka	Fig. 4.3.6	Hollows for an 8-shaped chain link on the upper surface and a hollow for an ingot on the backside.	SHM

Ingots

Identifier	Interpretation	Material	Location	Figure	Notes	Source
C52517/579	Ingot	Silver	Kaupang	Fig. 4.1.16		KHM
ASR 7x0581	Two rod-shaped ingots bound together	Copper alloy	Ribe	Fig. 5.10	Potentially standardised brass ingots.	SJM
SHM27127	Small ingot	Silver	Birka	Fig. 4.3.13		SHM
SHM76549	Rod-shaped ingot	Copper alloy	Ribe	Fig. 5.11	Potentially standardised brass ingots.	SHM

Models

Identifier	Interpretation	Material	Location	Figure	Notes	Source
C52264/2	Potential model for making strap-ends	Lead	Kaupang	N/A		KHM
C52516/2781	Potential model for making miniature axes	Lead	Kaupang	N/A		KHM
C52517/140	Potential model, unidentified product	Lead	Kaupang	N/A		KHM
C52517/220	Potential model for making mounts	Lead	Kaupang	N/A		KHM
C52517/240	Model for making key-handles	Lead	Kaupang	N/A		KHM
C52517/557	Model for making equal-armed brooches	Lead	Kaupang	N/A		KHM
C52517/635	Model for making irish discs	Lead	Kaupang	N/A		KHM
C52517/673	Potential model for making penannular brooches	Lead	Kaupang	N/A		KHM

C52517/677	Model for making equal-armed brooches	Lead	Kaupang	Fig. 4.1.12		KHM
C52517/721	Model for making dies for cruciform pendants	Lead	Kaupang	N/A		KHM
C52517/1775	Model for making equal-armed brooches	Lead/tin	Kaupang	N/A		KHM
C52517/1953	Model for making equal-armed brooches	Lead	Kaupang	N/A		KHM
C52517/1993	Model, unidentified product	Lead	Kaupang	N/A		KHM
C52517/2172	Model for making horse-shaped mounts	Lead	Kaupang	N/A		KHM
C52517/2173	Model for making equal-armed brooches	Lead	Kaupang	N/A		KHM
C52517/2200	Model for making equal-armed brooches	Lead	Kaupang	N/A		KHM
C52517/2413	Model for making owl-like mounts	Lead	Kaupang	N/A		KHM
C52517/2445	Model for making lozenge brooches	Lead	Kaupang	N/A		KHM
C52519/14050	Model for making strap-ends	Lead	Kaupang	N/A		KHM
C52519/14051	Model for making equal-armed brooches	Lead	Kaupang	N/A		KHM
C52519/15490	Model for making equal-armed brooches	Lead	Kaupang	N/A		KHM
C52519/15491	Model, unidentified product	Lead	Kaupang	N/A		KHM
C52519/15707	Model for making penannular brooches	Lead	Kaupang	N/A		KHM
C52519/20085	Model for making armrings	Lead	Kaupang	Fig. 4.1.15	Decorated with punch marks.	KHM

C52519/21224	Model for making armrings	Lead	Kaupang	Figs. 4.1.15 and 5.7	Decorated with wave-like punch marks.	KHM
ASR 9x226	Model for making equal-armed brooches	Lead	Ribe	Fig. 4.2.7		SJM
ASR 9x561	Model for making keys	Lead	Ribe	N/A		Feveile, 2006b

Matrix dies

Identifier	Interpretation	Material	Location	Figure	Notes	Source
C52517/934	Potential matrix die for making pressed foils	Copper alloy	Kaupang	N/A	Pressed foils for decorated nails.	KHM
C52517/1289	Matrix die for making pressed foils	Volcanic tuff	Kaupang	Fig. 4.1.13	Pressed foils for decorated nails.	KHM
C52517/1759	Matrix die for making pressed foils	Copper alloy	Kaupang	N/A	Pressed foils for decorated nails.	KHM
ASR 9x374	Matrix die for making pressed foils	Lead	Ribe	Fig. 4.2.8		SJM

Tools

Identifier	Interpretation	Material	Location	Figure	Notes	Source
ASR 9x498	Hammer with partially preserved handle	Iron and wood	Ribe	Fig. 4.2.5	Hammerhead reminiscent of R.394.	SJM
SHM23358	Punch	Iron	Birka	Fig. 4.3.12	Punch with a rounded point.	SHM
SHM30952	Hammerhead	Iron	Birka	Fig. 4.3.8	Hammerhead reminiscent of R.394.	SHM
SHM38394	Tongs	Iron	Birka	Fig. 4.3.11	Fairly small pair of tongs, likely involved in non-ferrous metalworking.	SHM
SHM68237	Punch	Iron	Birka	Fig. 4.3.12	Punch with a sharp point.	SHM

Weights

Identifier	Interpretation	Material	Location	Figure	Notes	Source
C52517/685	Circular weight with a flat top	Lead	Kaupang	N/A	Three or four circular punch marks on the surface.	KHM
C52519/14053	Circular weight with a flat top	Lead	Kaupang	N/A	Three or four quadratic punch marks on the surface.	KHM
ASR 9x319	Circular weight with a flat top	Lead	Ribe	Fig. 4.2.6	Three triangular punch marks on the surface.	SJM
ASR 9x448	Circular weight with a flat top	Lead	Ribe	Fig. 4.2.6	Four circular punch marks on the surface.	SJM

Miscellaneous objects

Identifier	Interpretation	Material	Location	Figure	Notes	Source
C52517/1737	Half-melted contents of a crucible	Silver	Kaupang	Fig. 4.1.18	A lump of half-melted silver, including various pieces of jewellery, hacksilver, and dirhams. The crucible has presumably decayed after deposition.	KHM
C52517/1979	Fragment of an armring	Copper alloy	Kaupang	Fig. 5.7	Wave-like punch decorations on the surface, very reminiscent of the decorations on C52519/21224.	KHM
C52517/2040	Punch pad	Lead	Kaupang	N/A	Rolled up flat piece of lead with a series of different punch marks. Likely used to test punches.	
C52519/14056	Pendant	Lead	Kaupang	Fig. 4.1.9	Presumed local product. The loop was made using the technique evident in the mould C52519/16411.	KHM
C52519/14057	Square pressed foil	Gold	Kaupang	Fig. 4.1.14	Decorated with filigree.	KHM
ASR 9x296	Pendant	Lead	Ribe	Fig. 5.6	Nearly identical to C52519/14056.	SJM