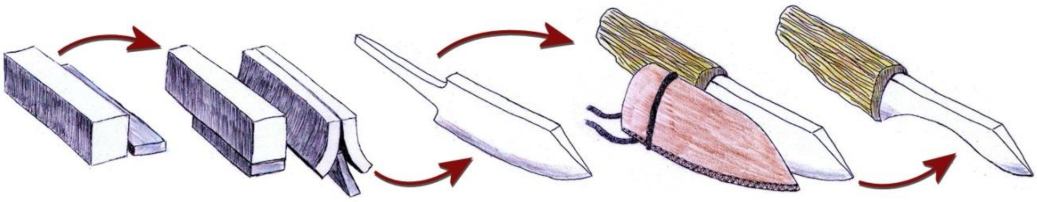

The Early Medieval Cutting Edge of Technology:

An archaeometallurgical, technological and social study of the manufacture and use of Anglo-Saxon and Viking iron knives, and their contribution to the early medieval iron economy

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Eleanor Susan BLAKELOCK

BSc, MSc

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Division of Archaeological, Geographical and Environmental Sciences

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Abstract

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An archaeometallurgical, technological and social study of the manufacture and use of Anglo-Saxon and Viking iron knives, and their contribution to the early medieval iron economy

Eleanor Susan Blakelock

A review of archaeometallurgical studies carried out in the 1980s and 1990s of early medieval (c. AD410-1100) iron knives revealed several patterns (Blakelock & McDonnell 2007). Clear differences in knife manufacturing techniques were present in rural cemeteries and later urban settlements. The main aim of this research is to investigate these patterns and to gain an overall understanding of the early medieval iron industry. This study has increased the number of knives analysed from a wide spectrum of sites across England, Scotland and Ireland. Knives were selected for analysis based on x-radiographs and contextual details. Sections were removed for more detailed archaeometallurgical analysis.

The analysis revealed a clear change through time, with a standardisation in manufacturing techniques in the 7th century, and differences between the quality of urban and rural knives. Analysis of cemetery knives revealed that there was some correlation between the knife and the deceased. Comparison of knives from England, Dublin and Europe revealed that the Vikings had little direct impact on England's knife manufacturing industry, although there was a change in manufacturing methods in the 10th century towards the mass produced sandwich-welded knife. This study also suggests that Irish blacksmiths in Dublin continued their 'native' blacksmithing techniques after the Vikings arrived. Using the data gathered, a chaîne opértoire of the iron knife was re-constructed. This revealed that there was a specific order to the manufacturing process and decisions were not only influenced by the cost of raw materials, the skill of the blacksmith and the consumer status, but also by cultural stimulus.

Keywords

Anglo-Saxon, Viking, Iron, Steel, Knives, Manufacture, Archaeometallurgy, Settlements, Cemeteries, Status,

This PhD is dedicated to

Granddad Blakelock and Grandpa Ogden

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1.1 Introduction

Previous archaeometallurgical research has shown that during the early medieval period the iron economy was highly sophisticated, with blacksmiths utilising a variety of iron alloys and producing highly efficient tools. These studies have revealed that iron production and manufacturing technology reached a peak, in terms of hardness and quality, during the 7th to 9th centuries AD which was not surpassed again until the 19th and 20th centuries AD (Mack *et al.* 2000; Blakelock & McDonnell 2007).

The early medieval period (c. AD 410-1100, *since this research only deals with post-Roman periods all the dates given are AD*) in Britain covers a crucial time of change which has been linked to an influx of new people and ideas (Arnold 1997: 1-18; Hamerow 2002). There are few contemporary written sources; so the archaeological evidence from two main types of context, settlements and cemeteries, provides most of our knowledge about this period (Yorke 1993; Williams 2006: 4-5). As the Roman way of life collapsed, there was a shift from a substantially urban population to small sized settlements. Our knowledge of this period has been hampered by the limited and small scale excavations carried out on early Saxon settlements, although there are some exceptions (Hamerow 2002: 1-8). For example, the excavations at Mucking, Essex and West Stow, Suffolk revealed that the focus of the settlement shifted over a large area and it is likely that these were small scale settlements with only ten household units standing at any one time (Welch 1992: 30-31; Hamerow 2002: 94). In the 7th century urban trading settlements were founded. These were trading settlements and ports, with streets and defined plots for properties. They were home to small industries producing all sorts of goods, including iron tools such as knives (Andrews 1997: 1-18).

During the 5th century cremation burial was re-introduced into eastern Britain. This practice involved cremating the body on a pyre, after which the ashes were collected and placed into a pottery urn, sometimes elaborately decorated, which was then placed into the burial pit. This did not entirely replace inhumation burial, which was still the most common form of burial practice (Lucy 2000: 1-14). Analysis of Anglo-Saxon burial grounds have revealed evidence that the deceased was sent to the after-life fully clothed (Drinkall *et al.* 1998: 283), with many of their possessions, including knives, and food offerings (Lucy 2000: 63-64).

1.2 Early Medieval Knives Review Paper

During the 1980s-1990s metallographic examination was carried out on knives from Early Medieval settlements and cemeteries (Blakelock & McDonnell 2007). Due to the types of sites being excavated at the time, the majority of these studies focused on iron knives from early rural Saxon cemeteries or from middle-late urban settlements (Blakelock & McDonnell 2007). In 2005-6 these studies were reviewed and consolidated in light of new research undertaken at Bradford University. This new research, carried out by McDonnell and Mack (McDonnell 1989a; Mack *et al.* 2000; Swiss & McDonnell 2003), has shown that there was a high level of skill achieved by early medieval blacksmiths, particularly in the use of alloys and manufacturing techniques to produce edged tools. This review was published in the Historical Metallurgy Journal in 2007 and a copy is provided on the appendix CD. The main aim of this review paper was to investigate and summarise the technology used in the manufacture of early medieval iron knives spanning the period c. AD 400-900.

Knives in early medieval societies were an essential everyday tool and may have been used for many purposes throughout the day (Hamerow 1994; Arnold 1997: 39; Hamerow 1997). In cemeteries knives are the most common grave good deposited (Härke 1989). The frequency of deposition in cemeteries should not be used to draw conclusions about the value of the artefact as it is not possible to know how expendable a knife was (Arnold 1997: 39). The knife was so prominent that even during the 10th century a traveller from Baghdad, Ibn Fadlan, commented that: ‘each of them [Rus/Viking] has an axe, sword, and a knife with him’ and that the women had a brooch with ‘a ring to which a knife is likewise fixed’ (Frye 2005: 63).

Knives are particularly useful for archaeometallurgical studies because, as mentioned above, they are found in a range of archaeological contexts. In addition they are often composite artefacts using more than one type of iron alloy. During construction early medieval smiths often added a small amount of steel to iron to create a cutting edge. Previous research had shown that there were at least six different manufacturing methods (Figure 1.1). This harder cutting edge could then be re-sharpened when it became blunt. Knives can therefore provide a wealth of technological data. Metallographic analysis of iron edged tools provides an insight into the methods of fabrication, the iron alloys available, levels of technological sophistication and in some cases the function of the tool (Blakelock & McDonnell 2007).

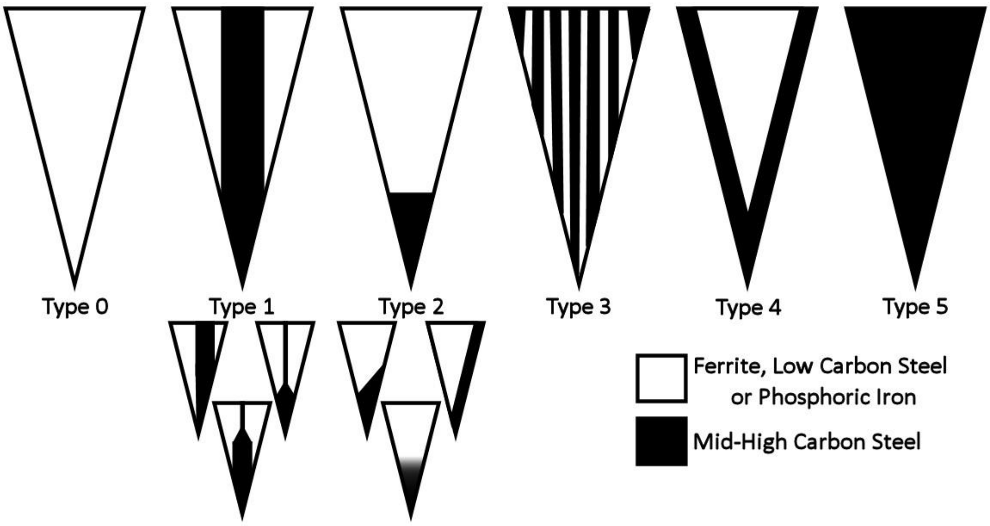


Figure 1.1: Simplified knife manufacturing typology based on blade cross sections (adapted from Tylecote and Gilmour 1986). Some of the variations on the type 1 and 2 blades are also shown below.

The review article demonstrates some clear patterns in the manufacturing types found in cemetery and settlement sites. The first and most striking observation was that 81% (26 out of 32) of the settlement knives were Type 2 (Figure 1.1.) compared to only 16% (7 out of 43) from cemetery sites (Blakelock & McDonnell 2007). Instead in the cemeteries a range of different types were present. Several theories were put forward to explain these differences, including the possibility that it reflects differences between urban and rural sites, or a change through time. Another possibility is that a range of domestic knives were in use, and placed as grave goods with the owner, whereas the Type 2 blades may have been ‘craft’ knives and not deposited widely in burials. Alternatively knives may have been specifically created for burial (Blakelock & McDonnell 2007). In both cases the knife could reflect the status of individual buried. However based on the small sample size of knives from cemeteries it was difficult to demonstrate any significant trends within the cemeteries (Blakelock & McDonnell 2007).

The suggestion put forward by McDonnell and Mack (Mack *et al.* 2000) that Early Medieval knives were good quality was confirmed in the review paper. The Type 2 knives were particularly excellent with cutting edges consisting of high-quality, high-carbon steel with few inclusions, These cutting edges were then heat-treated (Blakelock & McDonnell 2007). The welding techniques used also appeared to be excellent with few slag inclusions present in the welds and white weld lines, which would have resulted in a weld unlikely to fail (Blakelock & McDonnell 2007). The other types of knives were also well made, but did not utilise the same high-quality steels used in the Type 2s. There was an indication that knives in settlements were of better quality than those in the cemeteries, made using superior manufacturing and welding techniques and benefitting from enhanced heat-treatments (Blakelock & McDonnell 2007). This is mostly due to Type 2 knives being more common in settlements, but it could also reflect changes in technology through time or could reflect the difference between urban or rural sites

The review article also placed the data into the wider chronological framework and showed that over time the types of iron used differed, as did the quality of the metals used and the manufacturing techniques (Blakelock & McDonnell 2007). Roman artefacts were made using poor quality iron with few heat-treatments (Tylecote & Gilmour 1986; Swiss 2000), so there was a clear change from this to the Early Medieval cemetery knives (Blakelock & McDonnell 2007). Analysis of later 9th to 12th century knives from York (McDonnell 1992) revealed that there was a change in the preferred knife type from a Type 2 to a Type 1 in the late Saxon period. This change in preference was originally thought to have been due to regional differences between the sites, but this is unlikely as the pattern is repeated across England. It can be seen in the knives from Coppergate, York (McDonnell 1992), Winchester (Tylecote & Gilmour 1986: 38-39; Rulton 2003) and London (Wilthew 1987). There have been even fewer attempts to compare the results from English knives with those from the Continent (Scott 1991a: 99-149). In the medieval city of Novgorod, Russia the Type 1 knives are most common in the assemblage from the 9th century until the 12th century (Thompson *et al.* 1967: 73-74; Brisbane 1992: 73-75).

In addition to the above clear patterns in changing technology, the review revealed other smaller observations. There was an apparent increase in the use of phosphoric iron in Anglo-Scandinavian Coppergate, York. This might be due to Scandinavian influences in York, and relate to trade of the phosphoric iron with Scandinavia, but there was limited data so it was difficult to demonstrate any significant trends. The study also found knives from Lovedon Hill that had possibly been cremated on the pyre, and also knives from some inhumation graves that appeared to have been ritually ‘killed’. As before, with only a few examples, it was impossible in the review article to confirm these observations.

Overall the review paper demonstrated the paucity of archaeometallurgical investigations of iron objects, and particularly the gaps in the early medieval sampling strategy.

1.3 Research Aims

Archaeometallurgical studies are often affected by the samples available and this study was no different. This was also the case in the 1980s-1990s where samples derived from two primary contexts: rural early Saxon or Post-Roman cemeteries and the urban middle-late Saxon settlements. This was directly related to what was being excavated at the time, and what was provided to English Heritage for post-excavation work. The studies at the time took much from archaeology, but have given little back in return.

During this study, an attempt was made to fill in the gaps present in the review article. This included analysis of knives from middle-late Saxon rural settlements and religious or high status sites and early settlements. Even though, technically, early Saxon and Post-Roman sites are of a different nature. Post-Roman sites will be included in this study. Technology and trade is often not limited to cultural boundaries, for example there is evidence for imported Anglo-Saxon products and forms in the Post-Roman west (Hinton 2005: 40). In addition Post-Roman sites will also be used for comparison with data from Post-Roman sites present in the review paper. Many museums and excavation units were approached to identify sites and assemblages for analysis, but there was little response. It was particularly difficult to locate early settlements as there is a lack of large scale excavations of these sites that could provide assemblages large enough for analysis. In addition to this some early sites were excluded altogether, e.g. Mucking and West Heslerton, as the soil conditions at these sites resulted in poorly preserved knives.

The majority of the assemblages were chance finds by the author, usually from units or museums conducting post-excavation analysis or re-examining past excavation material. Therefore the overall aim of the study and the questions asked were determined to a certain extent by the nature of the samples provided. This was particularly the case with the Viking Dublin knives. This project started at the same time as a large scale study of the ironwork from Viking Dublin was being undertaken by Jennifer Mulrooney at the National Museum of Ireland. Therefore the opportunity was taken to examine knives from Viking Dublin. This led to the development of a new objective to the research, to investigate what influence if any the Vikings had on iron technology and knife manufacture in Europe.

The main aim of this research is to investigate the use of iron and steel in the construction of iron knives, and the blacksmithing techniques used, to gain an understanding of the early medieval iron economy in England and Europe. This research builds upon previous work and analyses knives from England and Scotland to investigate the differences in manufacturing techniques shown by the analysis of knives found in the early medieval rural cemeteries and urban settlements, and also investigates changes through time. Knives from early Saxon cemeteries were used to determine whether the materials and techniques used to manufacture a knife are affected by the status of the individual who subsequently owned it. Finally, knives from England, Scotland and Ireland were compared with other Viking knives across Europe in an attempt to record how the movement of Vikings and other cultural groups affected iron technology.

To accomplish these aims, knives from a full range of sites, spanning the early medieval period and across England, Scotland and Ireland were analysed. In addition knives from previous studies from across England and Europe were collected together to allow comparison. This analysis provided information about the knife’s role in society and answered questions about standardisation, specialisation, alloy types available and their use.

1.4 Research Objectives

The first objective of this research was to investigate the differences between knife manufacturing methods and quality of metals found in settlements and cemeteries in England which previous research had revealed. Previous research has suffered from potential bias because of the relatively small numbers of knives analysed, and also because of the types of sites examined, i.e. urban or rural and the date ranges. This was mostly due to the nature of early medieval archaeology in Britain in the 1980s-1990s but also influenced by the preservation of the ironwork itself. To investigate these patterns this study gathered samples from previous studies along with new samples from a range of sites previously unavailable, chosen to provide a more even coverage.

There are three hypotheses as to why there is such a difference between these site types.

The first is that there is a difference in the ironworking techniques used to make knives found in urban, rural and high-status sites. All the cemeteries previously analysed were from rural contexts while the settlements were mostly urban. Only one settlement previously analysed, Flixborough, was rural, but this is considered to be of high-status so this may not be representative (Loveluck 1998; Starley 1999). To test this hypothesis, knives from rural settlements contemporary, to the urban settlements at York and Hamwic were analysed.

The second hypothesis is that the differences in knives from settlements and cemeteries represent a change in manufacturing preference through time. All the analysed knives from cemeteries were dated to the early Saxon period when grave goods were deposited with the body, while the settlements were all later in date. To investigate this hypothesis, knives from early Saxon settlements contemporary with the early Saxon cemeteries were analysed, as were knives from graves securely dated to the middle Saxon period.

The third hypothesis is that the range of manufacturing types found in knives from cemeteries may indicate that they were being created specifically for burial. This hypothesis was investigated by examining the extent of wear on the knives from burials and comparing them with knives from contemporary settlements.

The second objective of this research project was to investigate whether the iron knife was a reflection of the status of the individual who owned and used it. Recent studies of early medieval pre-Christian cemeteries have shown that it is possible to use the grave goods present as a proxy for the social status of individuals buried (Härke 1989; Williams 2006; Williams & Sayer 2009). Archaeometallurgical studies of knives from large, well-dated inhumation cemeteries were used to determine how manufacturing techniques and metal quality correlate with the status of the individual as determined by other criteria. The comparison between grave goods and the manufacturing types of knives present would therefore provide archaeometallurgists with a possible criterion by which to determine how 'valuable' certain knives were, and possibly therefore the value of specific alloys or smithing techniques.

The third objective of this study was to examine how knife manufacture, alloy use and blacksmithing techniques changed through time. Knives from early, middle and late Saxon sites were examined and compared to a provide timeline of knife manufacturing techniques. In addition knives from the northern Anglo-Scandinavian Danelaw were compared to knives from the southern Saxon kingdoms to determine whether some of the patterns in knife manufacturing techniques seen relate to cultural differences. This study also attempts to determine whether different cultural groups utilised the same alloys in different ways.

The fourth objective of this study was to investigate knives from across Europe in an attempt to record if and how the movement of Vikings, and other cultural groups, affected iron technology. An investigation of changes in knife manufacture preferences in the Viking period was carried out, using an extensive study of knives from Viking Dublin, Ireland and a review of other studies of Viking knives in Europe. This study provides a detailed distribution of knife manufacture and use across Europe in the early medieval period. The Dublin knives provide an excellent comparison with the knives from Anglo-Scandinavian York as both sites are not only similar in settlement layout (i.e. workshops aligned to streets), and size, but also contemporary in date. This analysis in turn provides more information about the use of different iron alloys and therefore the trade of iron alloys across Europe will be investigated.

The final objective of this research project was to combine all the data gathered from the previous objectives, comparing it to our current knowledge of the early medieval ironworking economy. The life cycle of the knife was established by re-constructing the exact steps and decisions the blacksmith would have to make at each stage in the production process. It appears type 2 knife, with its excellent heat-treated cutting edge, was manufactured solely for use by craft workers. Part of this objective was also to investigate whether knife shape, manufacture and quality are linked to function. This will provide valuable information about craft specialisation and standardisation in the early medieval period.

Chapter 2: Early Medieval Background

2.1 Introduction

During the early medieval period (c. AD410-1100) the well-structured and urbanised settlements of the Roman period were replaced by small, early Saxon, rural settlements (c. AD410-650). In this period written sources are rare, and often unreliable. Most of our knowledge is derived from archaeological evidence (Scull 1993). In the past, archaeologists focussed primarily on cemeteries, as they provide secure contexts for dating and studying early medieval communities through the analysis of artefacts, but recently more settlement sites have been identified (Williams 2006: 4-5). In the middle Saxon period (c. AD650-850) urban, political and religious centres re-emerged (Campbell 2003). The late Saxon period (c. AD850-1100) brought further changes with Viking raids, but also changes in rural and urban settlements (Higham 2004: 310-311).

There has been much debate and controversy in the past about the so called 'Dark Ages', but it is now generally agreed that during the 5th century Germanic peoples migrated, whether peacefully or not, from the Continent and settled in England (Hamerow 1994; Arnold 1997: 21; Hamerow 1997). There is archaeological evidence for the apparent adoption of many aspects of Germanic culture and artefacts in Britain (Hamerow 1994). In addition, various isotope and DNA investigations have shown clear evidence for migration in this period (Privat & O'Connell 2002; Weale *et al.* 2003; Montgomery *et al.* 2005). The exact nature of this movement of people is not fully understood, with researchers debating whether it was a large scale migration into Britain (Scull 1993: 70-72) or if the population came to be dominated by a small warrior elite (Hamerow 1994: 162-164).

The initial impact of the Vikings was on Christian communities in the late 8th and 9th centuries (Forte *et al.* 2005: 54-58). Their raids affected the whole coastline of Western Europe. They also reached the Mediterranean, North Africa, and down the navigable rivers of Russia to the Black and Caspian Seas (Ulriksen 2004). From their homelands in Scandinavia they settled extensively in the British Isles, Normandy and parts of Russia, as well as islands such as Iceland and Greenland (Graham-Campbell 2001: 73-89).

Within this period there are many different cultural groups and technical terms. Many scholars use their own terms, and often the same phrase or word can be applied in different situations but for the same thing. To avoid misunderstanding the non-technical terms used in this research need defining. 'Anglo-Saxon' and 'Saxon' are used to refer to both people and the period between AD410-1066 in England. The south-west of Britain, was different from the rest of England and in this research is referred to as the post-Roman period, at least until it was integrated into the kingdom of Wessex during the 9th century (Hinton 2005: 152), Wales was integrated later in the 11th century (Hinton 2005: 141). In this research the term 'early medieval' is used to describe the period from c. AD400-1100 across Europe. 'Viking' on the other hand is more ambiguous, but for this research project the term 'Viking Age' is used to describe the period from the 8th to 11th century in north-west Europe. The terms laid out by Richards (2001: 269) are used for this research when describing the Danelaw in the North of England; 'Anglo-Scandinavian' is used to describe the cultural identity in the Danelaw during the 9th century, while the terms 'Viking' or 'Scandinavian' are used to describe people from elsewhere in north-west Europe.

This chapter is split into five main sections. Each discusses the archaeological evidence relevant to the first four objectives of this research. In each section a short description of what might be expected of knife technology is included. The first section looks at the nature and evidence of urban settlements compared to rural settlements from the same period. This section will also discuss the nature of status in this period. The second section plots the changes in settlements through time, and particularly the difference between Early Saxon, post-Roman and Middle to Late Saxon settlements. The third section describes the current state of Saxon cemetery analysis particularly looking at grave goods and how status can be determined. The fourth section looks at changes in settlements and society in the late Saxon period, following Viking raids and settlement. The final section expands this further to investigate changes in settlement and trade across Europe, and how this may have improved iron working techniques.

2.2 Different Types of Settlements

Prior to any discussion of early medieval sites it is necessary to define what is meant here by urban, rural and status. Reynolds (1977: ix) defined a 'town' or urban centre as a permanent settlement in which a significant proportion of the population live off non-agricultural occupation. Another way of defining an urban settlement is by noting certain characteristics such as a planned street system, market area, defences, mint, legal autonomy, relatively large and dense population, diverse economic base, plots and houses of urban type, social differentiation and complex religious organisation (Barlow & Biddle 1976: 4-8). However in the Saxon period many of these features are not recognisable due to a lack of documentary evidence and inadequate archaeological evidence (Faull 1984: 25). Archaeological excavations of urban sites can provide another way to define urban compared to rural, as urban sites are very different to their rural counterparts, with continuous deposition over a long period; closely packed pits suggest a lack of space, whereas in rural sites rubbish could be spread over large areas (Reynolds 1999: 161). Therefore during this research the term urban is used here for fairly organised or planned settlements often with clear street systems, pits, trade links and industry (Figure 2.1). These settlements were often located on water routes, presumably to facilitate trade, and housed many different industries (Barlow & Biddle 1976: 4-8; Palmer 2003). Outlying road systems centre on the urban settlement to allow contact and control over the town's hinterland (Palmer 2003).

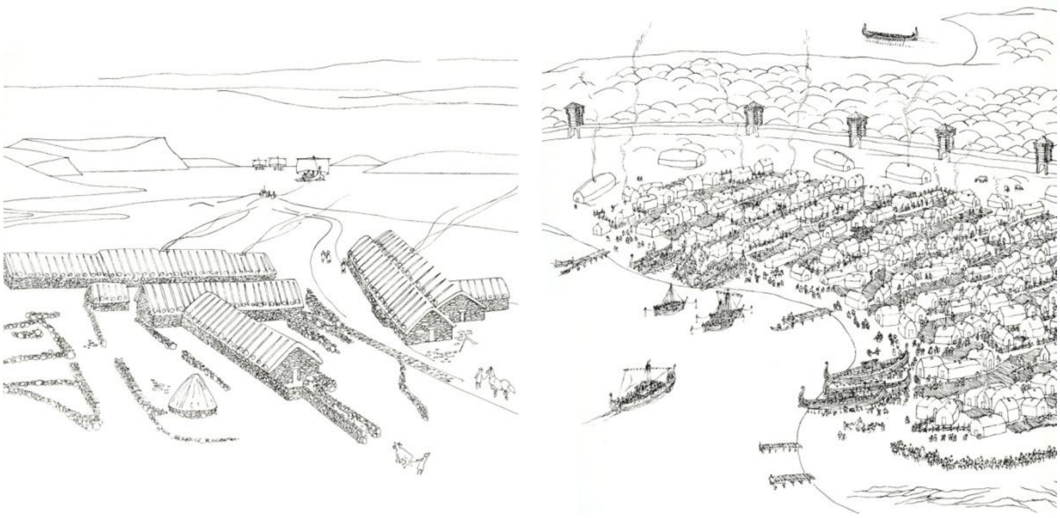


Figure 2.1: A rural settlement compared to an urban coastal settlement (Almgren 1966: 72, 39).

The definition of rural in the Oxford English Dictionary is 'characteristic of the countryside rather than the town' (OUP 2010). Settlements in the early Saxon period were nearly always 'in the countryside' and therefore are described here as rural. In the late Saxon period we see the start of the typical idealised rural parish (Reynolds 2003). Until recently it could be argued that each early medieval settlement was unique in character and that classifying them would be impossible, but as the number of large scale excavations grows, certain patterns are beginning to develop (Hamerow 2002: 53). Classification of settlements depends on the spatial relationships between household units and involves many individual components: buildings, pits, wells, paths, boundaries and/or central features (Hamerow 2002: 53). On this basis several types of rural settlement can be identified in Europe; row settlements along a track way, grouped settlement around a central feature, poly-focal settlements with multiple roads dividing many farmsteads and the isolated farmstead

(Hamerow 1995: 9; Hamerow 2002: 54). In Britain settlements appear to be more scattered until the 7th century (Hamerow 1995: 15).

The final consideration that must be made concerns the status of sites. Jørgensen (2003) has suggested that Danish settlements can be classified into several groups, which can also be applied to sites in the UK. These are introduced in order of status:

- Aristocratic (or ecclesiastical) with many buildings and high resource consumption.
- Early towns and emporia, large settlements possibly with royal mints.
- Small landing and trading places with evidence of craft activities and trade.
- Specialised production sites.
- Ordinary settlements with both agrarian and craft activity.
- Farms and villages with no craft activities.

These groups were created based on the distribution of metal finds, and metal working evidence, but this can artificially inflate the number of higher status and 'productive' sites as most are found during metal detecting surveys (Richards 2003).

Urban

There are no clear definitions of emporia or wic sites, and some researchers use the terms interchangeably (Ulmschneider & Pestell 2003: 1). The term 'wic' relates to the Germanic borrowing of the Latin 'vicus' for town while 'emporia' is closely tied to the Greek word 'emporion' which mean trading place (Pestell 2011: 557-558). Emporia are usually classed as trade centres or gateway communities (Hodges 1982: 50). The term wic is often associated with early trading sites which show unity with North Sea trading (Reynolds 1977: 19). Another definition is that emporia were royalty created exchange centres, whereas wics were production sites (Palmer 2003: 48-49). It is questionable how useful applying such definitions is to urban settlements as there may have been diversity in the terminology at the time (Pestell 2011: 557-558). No matter what label is assigned to these settlements, they played a significant role in both economic growth and political consolidation (Russo 1998: 137). So for the purpose of this research they will be classed as wics.

During the 7th century a few centres of trade and industry were founded in Britain. Hamwic, Ipswich, Lundenwic, Fordwich, Sandwich and Eorfowic (York) were trading settlements situated by water routes and were home to small industries producing a range of goods

(Williams 1984). Some of these settlements had planned street layouts, e.g. Hamwic and Ipswich, with clear small plots along the roads, each containing buildings with pits and middens (Figure 2.2; Andrews 1997; Reynolds 1999: 169). In some cases, for example York and Dublin, the roads and houses in these settlements were rebuilt multiple times, one on top of another (Ottaway 1992; Wallace 1992; Wallace 2001).

Figure 2.2: Reconstruction of the settlement at Jorvik, with each building gable end to the road on a narrow plot of land (Hall 2007: 114).

There is much debate as to when exactly the urban settlements developed (Hodges 1982: 69-71; Schofield & Vince 1994; Russo 1998; Anderton 1999; Newman 1999; Campbell 2003; Ulmschneider & Pestell 2003). It is clear that some of the urban settlements did start in the mid to late 7th century, but there is some evidence to suggest that a few started earlier (Hodges 1982: 69-71; Zaluckyj *et al.* 2001: 193). Bede, for example, mentions that London was a trading centre for many nations in AD 604 (Hodges 1982: 69) this is also supported by excavations in London (Blackmore *et al.* 1998; Brigham 2000: 182-183) and evidence for coin minting from 616 (Hinton 2005: 77). Ipswich was mass producing Ipswich-ware which reached its peak in the early 7th century, suggesting that it was active as an urban settlement during this period (Reynolds 1999: 169; Hinton 2005: 75, 90).

To defend against Viking attacks in the 8th century many urban settlements took refuge behind walls, sometimes relocating within existing Roman defences e.g. Lundenwic which relocated downstream to Lundenburh (Williams 1984). Where this was not possible, they moved and constructed entirely new towns, for example Southampton. These new sites are known as ‘burhs’ and were fortified towns or forts commissioned by the newly-founded royalty (Williams 1984; Haslam 1987). In addition to the relocation of existing towns, new markets and defensive sites were located on high ground and promontories (Reynolds 1999: 124).

The newly established urban settlements were a base for many different industries, although few have been studied in depth. The evidence has suggested that these industries were not carried out on a large scale, instead industries appear to be small scale, with dispersed production to serve the needs of local communities (Campbell 2003). Even so there is considerable evidence that the wics, minsters and royal estates were participating in long distance trade. In the 8th-9th century the Vikings disrupted settlements, but they also stimulated production and consumption within the Danelaw (Reynolds 1999; Hall 2001). The towns of York and Lincoln have provided a wealth of evidence for industry and commercial activity (Faull 1984; Bayley 1991; Vince 2001). In addition, the new systematic provision of fortified towns provided a framework of secure regional market centres throughout the English kingdom and across Europe (Hinton 2005: 75).

It would therefore be expected that in urban centres, where specialised craft working was taking place, knives would be of a superior quality to those found in rural settlements. In some crafts such as pottery production, i.e. Ipswich Ware, we already have evidence for standardisation in production (Blinkhorn 1999). It is therefore possible that the standardisation of knife types seen in the review paper (Blakelock & McDonnell 2007) is related to the fact that all the settlement knives analysed so far came from urban sites. Urban settlement with the large numbers of craft workers and merchants would become a centre for trading of not only goods but also ideas. Therefore it would be likely that new ideas about manufacturing technology and blacksmithing techniques would also be present in these settlements.

Rural

During the middle Saxon period in the 8th century, and possibly earlier, there was a widespread displacement of rural settlements which has been termed the 'mid Saxon shift' (Hamerow 1991). Rural settlements underwent other changes which can be dated to the 7th-8th century. The first important change is the appearance of planned settlements with complexes of enclosures (Hinton 1990: 27-39). Changes also occurred in the layout or management of the landscape with the development of hides in the late 7th century and kingdoms, shires and hundreds by the 10th century (Reynolds 1999: 71-73; Holman 2001: 4). Research has suggested that there were changes in the landscape, which may have been split into smaller portions of land, each containing a small rural settlement, sometimes supplying a central higher status site (Fabech 1999; Reynolds 2003). These changes to settlement patterns mark intensification in rural production as the settlements become fixed to their territories; which in turn is most likely related to the emergence of urban settlements (Reynolds 2003).

The 9th century marked the appearance of manorial estates with associated rural settlements (Reynolds 2003). The network of satellite settlements supplying a single estate is replaced by multiple small estates, which in the 12th century would become parishes run by nobles providing for central higher-status settlements. These settlements normally supported a royal estate, minster or superior church and a market (Reynolds 1999: 71-73). In this period organised villages begin to develop with associated churchyard cemeteries (Faull 1984; Reynolds 2003). Scandinavian influence within the Danelaw seemed to slow the progress of nucleated villages and communal farming, which is seen elsewhere in England at this time (Hooke 1988: 94-5). A number of former large, often ecclesiastical, estates were fragmented and passed into private ownership (Williams 1984; Richards 2001: 275).

In rural settlements evidence for industry and production sites is scarce (Hamerow 2002:189). In later Saxon rural settlements there is often evidence for industry, but on a smaller scale, although many settlements had smithing slag suggesting the presence of a smithy (Birch 2011). Even so a range of commodities from north-western Europe, are present in rural settlements (Hodges 1982: 104-129; Blinkhorn 1999; Hamerow 1999).

The rural blacksmith would be expected to create basic objects or tools, e.g. horseshoes, nails, or possibly repair objects imported to the site, but they may not have had the same skill base as those in the more specialised urban centres. In addition, the raw materials coming into the rural blacksmith may not have been the same quality as those imported into urban centres. It might therefore be expected that knives created in rural settlements would be poorer quality than in the urban settlements. Some knives may have been imported into rural settlements and these would most likely appear similar to those in urban sites.

Status

In Britain many rural settlements are identified or classified as ‘high status’ or ‘ecclesiastical’ based on one or two high status artefacts found, for example Wharram Percy (Stamper & Croft 2000: 196). These artefacts do not necessarily represent the wealth of the village, as they may represent items lost or deposited during an occasional ‘royal’ visit (Hinton 1990: 92). In these cases it could be argued that the sites are not ‘high status’ especially when compared with other sites such as Flixborough (Loveluck 1998), Yeavering (Frodsham &

O'Brien 2005) and Whithorn (Hill & Campbell 1997) which have far more evidence of this type, and are occasionally supported by written records (Hill 2001; Loveluck 2001). In addition it is difficult to determine the difference between monastic and secular estates, often complicated further when sites appear to change function over time, e.g. Flixborough (Reynolds 1999: 112; Loveluck 2001)

The status of urban settlements is difficult to determine. While some may have become political centres, others may not have been particularly high status, with poorer living conditions. There were obviously some wealthy individuals within these settlements, as attested by the high status burials at Hamwic (Hinton 2005: 75), but the crowded plots and industrial nature of these centres would have led to a very busy, noisy and unhealthy environment (Hinton 2005: 135).

In the 5th-6th centuries there is little evidence for social distinction in buildings and settlement layout, although it can clearly be seen in contemporary cemeteries (Reynolds 2003: 130). Social hierarchy seen in settlements appears to begin in the 7th-8th centuries, indicated by the need for enclosed spaces, and higher status structures (Reynolds 1999: 50). In this period there was also the introduction of the first large buildings, ‘great halls’ and ‘high status’ centres (Hamerow 2002: 97). Large halls were a clear indicator of and a high status symbol of power, for example in Beowulf King Hrothgar was noted to have a large hall to house his large war band (Figure 2.3; Raw 1992: 168). One explanation for the Middle Saxon shift in the 8th century is that it relates to the improved agricultural techniques that were needed to meet the demands of the new secular and ecclesiastical landlords as well as the towns (Newman 1999).

The emergence of secular estates, kingdoms and ecclesiastical centres may in part account for the increased archaeological evidence for crafts and industries (especially ironworking) associated with rural settlements as these estates were more intensively exploited. For example, in Ramsbury, which belonged to the West Saxon bishopric from AD909 to AD1058, iron was being smelted on a large scale (Haslam *et al.* 1980; Reynolds 1999: 155).

It would therefore be expected that knife production in high status settlements might be more specialised than in the rural settlements and possibly even the urban settlements. High quality materials or more skilled blacksmiths may have been sought by the social elite, and therefore better techniques might also be expected.

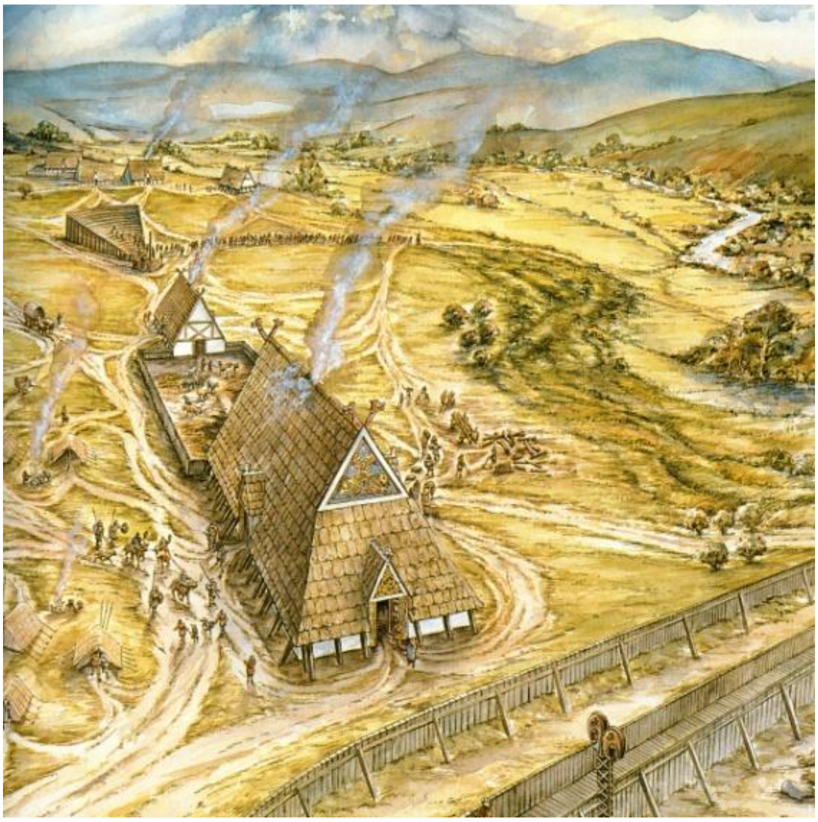


Figure 2.3: High Status settlement at Yeavering with large hall structure (Welch 1992: Plate 1)

2.3 Changes through time

Following the withdrawal of Roman control from Britain, major changes were seen in how and where people lived (Lucy 2000: 3-4). The archaeological evidence suggests that in the immediate post-Roman period the remains of Roman structures would have been clear to see, and people still inhabited some urban centres such as St Albans, Canterbury and Worcester and even some of the shore forts, i.e. Portchester Castle (Welch 1992: 104). In many cases the Roman remains of bath houses and town houses were being put to other uses, such as barns or industrial areas. In contrast there appears to be no desire to continue to occupy Roman villas, although some settlements occupied the same land (Welch 1992). By the end of the 6th century Southern England was pagan once more, although pockets of Christianity did survive (Stevenson 1992: 177).

During the 5th to 6th centuries rural settlements often only contained a few farmsteads with no evidence for defined boundaries or planned layouts (Hamerow 2002: 1-8). These settlements would shift location over the course of the 5th to 8th century (Hamerow 1991). This was a gradual process occurring as buildings fell out of use and were re-built on new sites (Hamerow 1993: 86-91). Excavations at the 5th to 7th century settlement at Mucking, Essex revealed that the settlement shifted over a large area with only a few sunken feature buildings standing at one time, thus suggesting only a few extended families were present (Hamerow 1993: 86-91). These settlements were mostly rural in nature, loosely structured, and were not constrained by individual property boundaries or limits to the settlement (Reynolds 2003: 103). Some contemporary settlements contradict this pattern, for example, West Heslerton in Yorkshire where boundaries were present from the beginning (Reynolds 2003). During the 6th-7th century there were power struggles between groups of warriors claiming territories. Kingship was a late 6th-7th century creation, although some historians have argued that it started earlier (Reynolds 1999: 49-50).

In the middle Saxon period there was a shift in the locations of many rural settlements and the development of urban centres. During this period settlements appear to be more planned with enclosed spaces indicating social hierarchy possibly linked to the new kingdoms that were forming (Reynolds 1999: 49-50). There were also changes in the way the landscape was managed (Reynolds 1999: 81). Another dramatic change in the middle Saxon period was the re-establishment of Christianity which started in 597AD (Bede *et al.* 1990: 74-75) and by the end of the 7th century the majority of England had been converted to Christianity (Hinton 2005: 57). Even so it is problematic to entirely rely on Bede for an unbiased view of the conversion, as it focused primarily on the rulers and their heirs and might not reflect the rest of the population (Stevenson 1992: 182).

By the end of the 10th-11th century all England was under Wessex rule supported by the military elite and church (Hinton 2005: 141). This included Cornwall which was integrated in the 9th century (Hinton 2005: 152). Landscapes before 10th century were characterised by large estates under royal or ecclesiastical ownership (Reynolds 1999: 81). Some changes in late Saxon Britain relate to the Viking raids, which started in the 8th century. These raids continued into the 9th century with many monasteries and urban settlements falling prey to them. This resulted in many urban settlements relocating behind walls (Hodges 1982; Reynolds 1999). The Viking raids continued until the Vikings finally settled the Danelaw area of northern and central England in the second half of the 9th century (Reynolds 1999; Campbell 2003). Settlements within the Danelaw saw considerable reorganisation in the 9th-10th centuries. The evidence suggests that, in the countryside, estates and ecclesiastical organisation were simply adopted by Scandinavians (Hadley 2001: 21; Richards 2001: 275). There was an expansion of urban activities and trading contacts in Danelaw and the foundation of new settlements in 10th century (Hadley 2001: 26; Vince 2001: 175).

Scandinavian invasion and conquest was only one of many political and cultural changes at the time, although it is a highly visible change. During this period there was also the division of landholdings, an increase in the political power of greater churches, new burhs developing, a re-organisation of land, changes in labour and agriculture and a change of focus to support royal mints (Higham 2004: 310-311)

There is negligible direct evidence for workshops and craft production in the 5th-6th century, apart from artefacts related to bone and antler working, or textile production. There is also some evidence for non-ferrous metalworking in this period with metalworking dies and tools found in graves (Bayley 1991). In addition most settlements did have evidence for iron smithing in the form of slag (McDonnell 1989a; Hamerow 2002: 173-176). Kent seems to have controlled the initial distribution of these prestigious imports once they had arrived in Britain (Huggett 1988). In post-Roman western Britain it is clear that not all glass and metal artefacts were made locally or imported from France into the West, there is evidence of imported Anglo-Saxon products and forms (Hinton 2005: 40). During the middle Saxon period there is lots of evidence for production sites in the urban settlements (MacGregor *et al.* 1999; Mainman & Rogers 2000), but in rural settlements the evidence for production sites remain scarce (Hamerow 2002: 189). In the middle Saxon period the evidence for both international and regional trade networks becomes clearer (Campbell 2003). The objects in 6th-7th century settlements suggest greater access to resources and dissemination of wealth than in the cemeteries. This is most likely due to a growing division between exceptionally wealthy and the poorer taxpayers (Hinton 2005: 74). The late 7th-9th metalwork shows very little regional variation, instead the material culture is standardised throughout England (Hinton 2005: 91). Large scale production and specialist workers concentrated on wics, churches and royal estates (Hinton 2005: 91). The regional and international trade within both urban and rural settlements continued to grow in the 9th century as did the evidence for industries (Reynolds 1999; Campbell 2003).

The early medieval period in Britain covers many different changes; in settlement pattern, kingdoms, religions, trade, burial and industry. It would therefore be very unlikely that blacksmithing techniques and knife manufacture did not also change during this time. It might be expected that blacksmithing skills would improve. As the population grew in size (Hinton 2005: 157) blacksmiths may have resorted to standardising knife production in much in the same way as ceramic production.

In post-Roman Devon and Cornwall it is simply unknown whether Anglo-Saxon influence was accepted and re-shaped or simply rejected (Hinton 2005: 89). There is little evidence for economic involvement with England, except with the metals industry where there was evidence for active trade (Hinton 2005: 152). There has not been enough research into this area of Britain, and therefore this study will compare knives from Early Saxon England and the post-Roman west (Hinton 2005: 89).

2.4 Cemeteries

The cemeteries in the early Saxon period in England were very different from the late Roman Christian cemeteries. These cemeteries were characterised by largely unfurnished burials with a west-east orientation which were located outside the city walls, often beside major roads (Lucy & Reynolds 2002b). In contrast during the early Anglo-Saxon period two burial rites occur; first inhumation burial furnished with grave goods and secondly cremations, which were also furnished (Lucy 2000: 1). There is little evidence for continuity between late Roman and early Saxon burial rites, although it is clear that approximately a quarter of all Saxon cemeteries have relationships with ancient monuments, particularly Bronze Age burial mounds (Williams 1997; Bradley & Williams 1998).

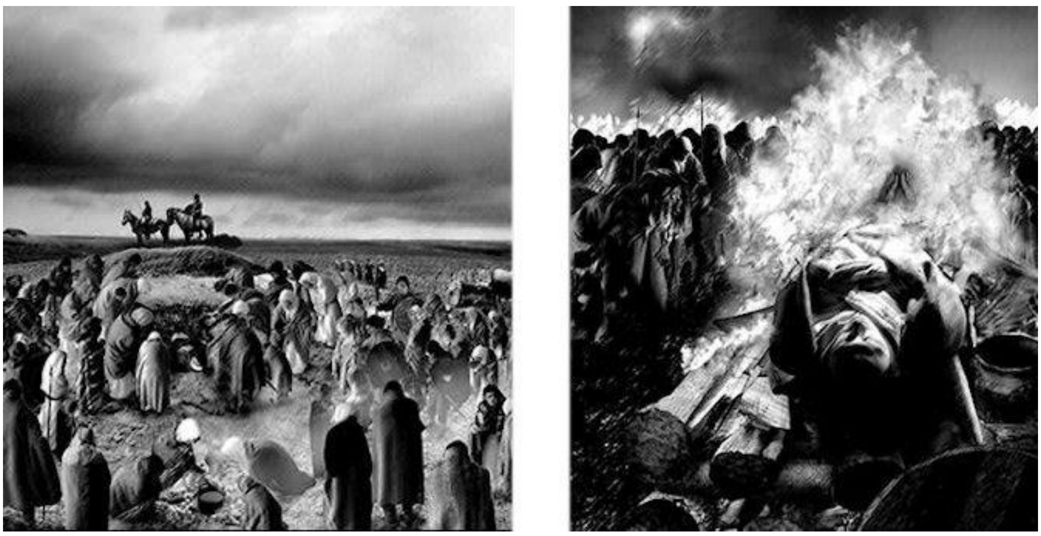


Figure 2.4: Reconstruction of an inhumation and cremation burial (Williams 2006: 198, 92)

The new 5th-6th century cemeteries varied greatly in orientation and were in rural locations. The most dramatic change to occur was the shift to furnished burial; weapons, food offerings and many of the deceased's possessions were placed in the grave with them (Lucy 2000: 63-64). The body, fully clothed, was laid out on its back, often on a bed of organic material, with the grave goods carefully positioned (Figure 2.4; Lucy & Reynolds 2002a; Petts 2009).

In addition to the continued inhumation burial, a new burial practice was re-introduced to some regions of England (Figure 2.4). This involved cremating the deceased on a funeral pyre, then collecting the cremated ashes and placing them in a pottery urn often along with some possessions, which was then deposited in a burial pit (Nielsen 2009). There is a large imbalance between inhumation and cremation burial rites, with far more inhumation than cremation cemeteries (Figure 2.5). In addition, mixed rite cemeteries were more common than cremation only cemeteries (Lucy 2000). There is no indication as to why some individuals were cremated while others were inhumed. Grave goods such as knives, miniature tweezers and shears, combs, beads and decorative metalwork were often found included in the urn, some of which appear to have been subjected to heat, presumably on the funeral pyre (Lucy 2000: 1-14). Some researchers have suggested that knives were placed into the urn after the cremation process as the knives showed no evidence of heat damage (Glasswell 2002: 51). It has been suggested that the cremation released the spirit of the deceased and symbolised fertility and regeneration. Another suggestion is that cremation was carried out to prevent the dead from harming the living (Richards 1992).

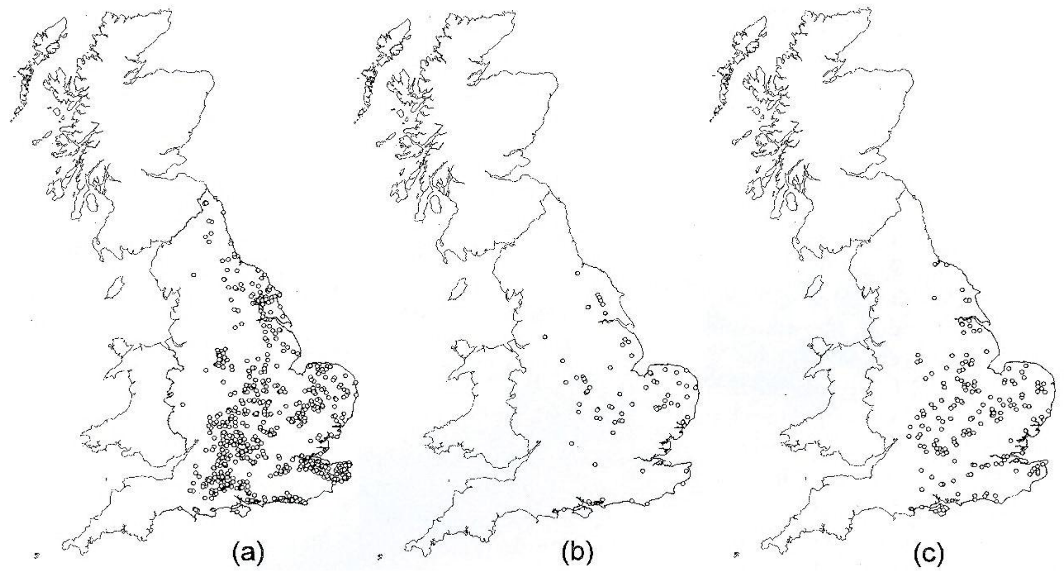


Figure 2.5: Distribution of inhumation cemeteries (a) and cremation cemeteries (b), and cemeteries with both rites present (c) across England. Constructed from a sample of Anglo-Saxon cemeteries dated to the 5th-6th century with at least ten graves. Mixed rite cemeteries contain substantial numbers (15%-85% cremation) of both rites (Williams 2002: 65).

During the 7th century, at the same time as the changes in settlement patterns, there were also changes occurring in burial practices. This period is usually termed the 'final phase' (Geake 1992; Lucy 2000; Geake 2002). Cemeteries that had been used for centuries were abandoned, coinciding with the introduction of Christianity (Astill 2009). There were changes in burial practice, including the abandonment of cremation in preference for inhumation

(Williams 2002). The most significant change was the absence of grave goods after the Church pronounced against pagan practices, although these changes did not occur overnight (Geake 1999). There is some evidence that the 'final phase' was taking place before Christianity was introduced, for example at Andover cemetery in Hampshire (Stoodley 2007). The practice of furnishing burials is usually thought to end in 720-730 (Geake 1999) but recent analysis has showed that it may have lingered until the late 7th century (Lucy & Reynolds 2002b; Astill 2009). During this 'final phase' the burial of knives became an alternative means of displaying status, with larger knives, 130-170mm long, possibly signifying adult masculinity (Härke 1992).

Analysis of Saxon cemeteries in the past has mainly focused on the grave goods rather than on putting the cemetery into a wider context, or examining the relationships between individual graves within the cemetery (Williams 2006: 4-5). Recent work has revealed some interesting patterns concerning different groups of individuals (Williams 2006: 4-5). Patterns in grave goods deposited have been noted by Härke (1992), and other studies have seen differences in the orientation and location within the cemetery. Children were often found to be aligned differently from adults, and in some cemeteries female graves were on a different orientation from males, or in a different area of the cemetery altogether (Lucy 2002). There is also some evidence that graves containing certain brooch types were kept spatially separate, perhaps relating to the presence of burials of immigrants as suggested by some isotope studies (Montgomery *et al.* 2005).

Most research has focused on using the grave goods present to identify the status of the individuals buried (Härke 1989; Williams & Sayer 2009). Identity and status cannot always be determined based on the way in which the person was buried, particularly since the grave goods present were placed by the mourners rather than the deceased (Williams 2006: 10). The graves excavated revealed the mourner's emphasis using material culture and there may be other aspects of the ritual that cannot be seen (Lucy 2000; Williams 2006: 10). For example, ritual feasting is seen in cremation burials, analysis of cremation urn contents has revealed the presence of animal remains, which presumably were also placed on the cremation pyre (Bond & Worley 2006). Even so, some grave goods such as swords, buckets, glass or copper alloy vessels and horse equipment are believed to be key signs of higher-status individuals. Arnold (1980) tried to calculate 'wealth' based on values assigned to artefact types depending on the time needed to create them, but this is impractical, and biased towards certain artefacts. Most studies now use a count of object types or the RAIC (Range of artefact identifiable categories) score that disregards multiple finds of the same type to indicate status (Malim *et al.* 1998: 301). Women are more often buried with larger numbers of grave goods, therefore a high status woman may have a higher RAIC score than a high-status male (Figure 2.6). Using this method graves with over 7+ (9+ for females) RAIC points indicate the highest status, lords and/or landowners. Those with 4-6 (4-8 for females) RAIC points usually indicate a lower-status individual, possibly someone that works the land or craft workers. Those with less than 2 RAIC points are the lowest status individuals, and any graves with no goods could indicate a slave (Malim *et al.* 1998: 301; Hinton 2005: 30).

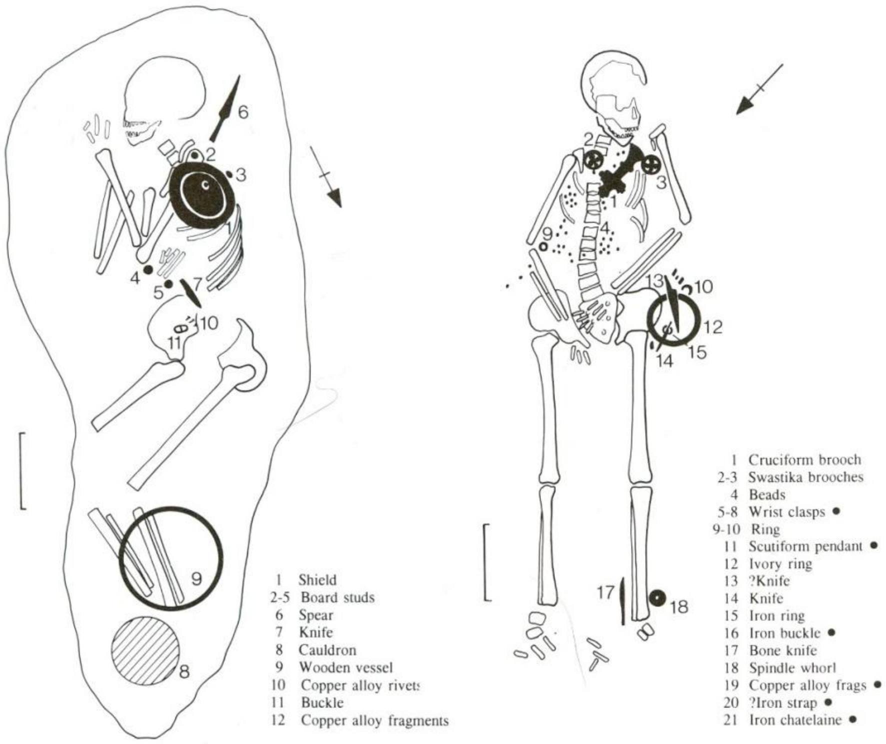


Figure 2.6: Grave goods with two high-status individuals, the left individual is a male with seven RAIC points while the female on the right has at least twelve RAIC points (Timby & Bartlett 1996: 138, 151).

Some grave goods, especially weapons, appear to have been deliberately damaged before burial (Lucy 2000: 95): for example a shield boss from Barrington Edix Hill, Cambridgeshire was pierced by a spear (Malim *et al.* 1998; Lucy 2000: 95). While some of these instances may be the result of actual warfare, others appear to be ‘ritual’ damage, perhaps as a way of ‘killing’ the weapon (Lucy 2000: 95). Alternatively the damage could have acted as a deterrent to grave robbers.

Since grave goods are generally accepted to be items that belonged to the individual, or items that the bereaved believed should be associated with them, it might be expected that the quality of the knife would reflect the status of the individual. Alternatively it has been suggested that some knives were made specifically for burial. This was tested during the review paper which showed that half of the knives in burials demonstrated some signs of wear, suggesting that they had been used prior to burial. Unfortunately, this was a very small sample and therefore more assemblages were needed to confirm this pattern of wear. If a knife showed evidence for wear this would suggest that it was used in life, and therefore it is possible that the manufacturing methods used to create the knife would relate to the status of the deceased, i.e. high quality knives with high status individuals. The knives with no evidence for wear could suggest that they were created for burial. There are two possible scenarios; the first is that cheaper 'token' knives were placed in graves, but at the other end of the scale high status individuals may have commissioned high quality knives specifically to take to the afterlife. Metalworking debris found at cemetery sites, like Spong Hill could point to manufacture of artefacts specifically for burials (Hinton 2005: 36). The review paper and subsequent cemetery analysis of grave goods has led to further questions about 'ritual killing' of knives and whether knives were placed on the pyre.

2.5 Late Saxon Britain

Throughout the early medieval period there was repeated contact with other cultural groups, be it through migration or conquest (Higham 2004: 310-311; Hinton 2005: 140). It is unknown to what extent this effected everyday life in Britain. By the mid 9th century the Vikings had captured York and settled in Northern England and in 878 the Danelaw was established. In response to this, during the 10th century, the individual kingdoms unified to oppose the Viking Danelaw (Richards 2001). If it was just the migration of a few elite individuals the impact would be smaller than a larger migration or conquest and the evidence suggests that the number of Vikings was probably in their hundreds rather than thousands (Holman 2001: 4).

There is no agreement between researchers as to the nature, extent and impact of the Scandinavian settlement in north-east England (Holman 2001: 4). The written evidence points to the Danelaw having larger penalties for breaking laws than the rest of England (Holman 2001: 4) but there is no documentary evidence to suggest that the Danes saw themselves as having a separate identity (Hadley 2001: 25). There was a clear mixing of Scandinavian and indigenous styles and forms in stone sculpture, coinage and jewellery, indicating the construction of new regional identities during the 10th century (Hadley 2001: 15; Higham 2004: 310-311, 304, 305). The metal artefacts found in settlements suggest that a range of different styles and types were possibly made in the same workshops. For example, there is evidence to suggest that Anglo-Saxon Winchester style jewellery was being produced within the Danelaw (Hadley 2001: 18-19; Kershaw 2008: 266). Other metal artefacts point to cultural interaction and development of Anglo-Scandinavian forms of jewellery, particularly clear in disc brooches with Scandinavian motifs (Leahy & Patterson 2001: 195) and strap ends (Thomas 2000: 241-244; Richards 2011: 54). This is supported further by evidence from bone, textile and leather workers in York, who adopted Scandinavian fashions but kept some of their own traditions (Cameron & Mould 2004: 465; Henry 2004: 455). The influence of Viking settlement can be seen through place names (Figure 2.7; Williams 1984; Richards 1991: 33, 2001: 275). In some areas of the Danelaw there is almost a complete replacement of English place names with ones of Scandinavian influence or origin (Figure 2.7; Williams 1984; Richards 1991: 33, 2001: 275). Place names may not always relate exactly to settlements and could have exaggerated reality (Higham 2004: 304) but metalwork styles often followed the same patterns as the place names (Leahy & Patterson 2001: 189).

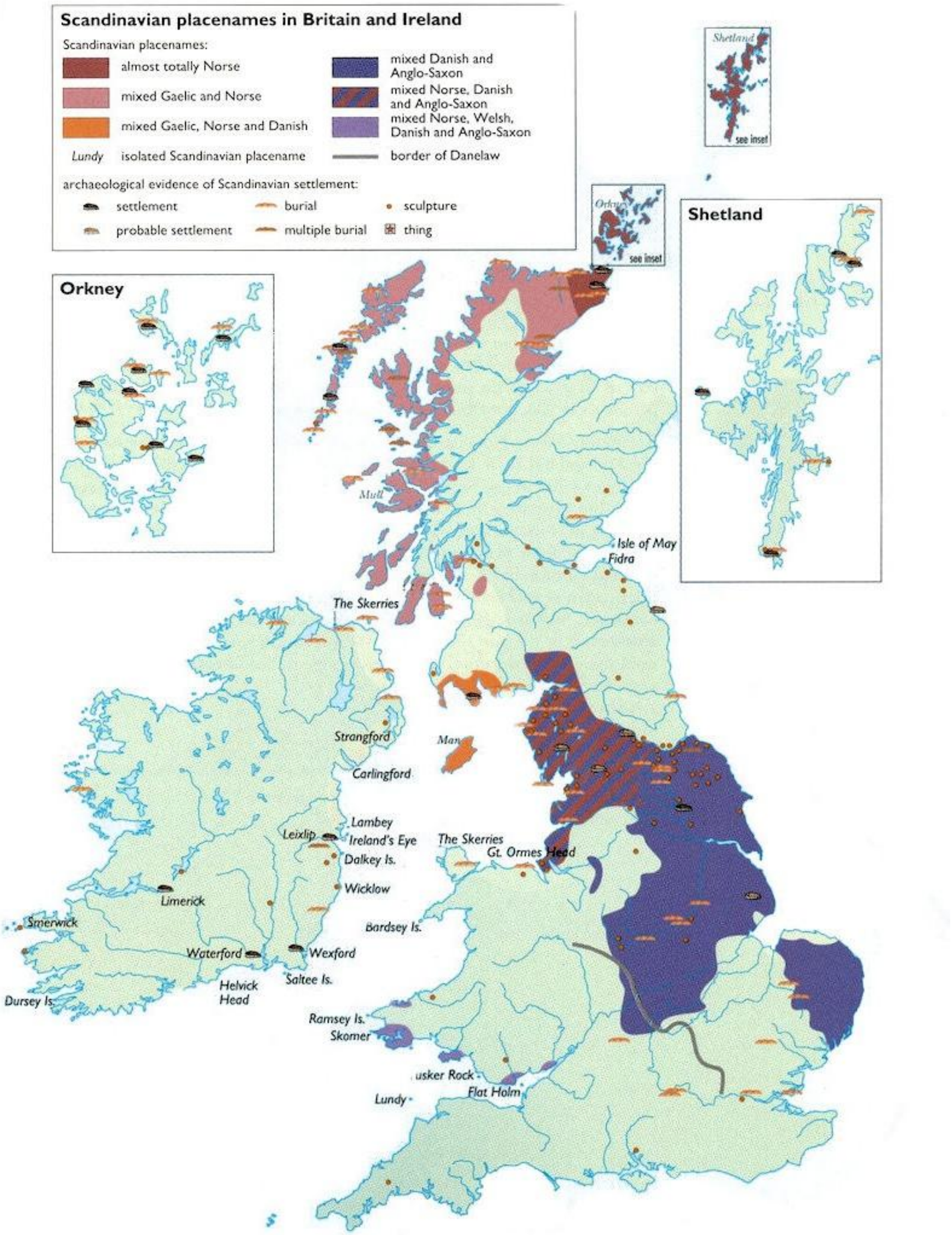


Figure 2.7: Map of the British Isles showing the distribution of Scandinavian place names and settlement evidence (Haywood 1995: 79).

The Battle of Hastings in 1066 officially marks the end of the 'Saxon' period, but many aspects of Anglo-Saxon life remained the same (Welch 1992: 12). The social framework of Norman Britain owes much to the late Saxon rural village settlements and social systems already in place between the 8th-10th centuries (Reynolds 1999: 57).

A cultural change in the Danelaw took place, but whether this was accompanied by a wholesale population change is another matter (Hinton 2005: 140). Therefore a more complex and sensitive modelling is required to evaluate the impact of the Scandinavian world in north-west England (Higham 2004: 310-311). The archaeological evidence suggests that contact between these groups had an influence on language, sculpture and art styles. It might therefore be expected that ideas about blacksmithing and iron working techniques may also have been passed on. There is evidence for other technological changes in this period, including Stamford Ware pottery which was wheel-thrown (Hinton 2005: 133; Richards 2011: 52-53). This was not a Viking technique, but was likely to have been brought to England through contact with the Danes, who had contact with the Rhineland and Low Countries where it was found (Hinton 2005: 133). Similarly there might also be differences in knives and blacksmithing techniques between the Anglo-Scandinavian Danelaw and Anglo-Saxon Britain. This research could show whether there were any changes in blacksmithing techniques, possibly influenced by the Scandinavian presence in the Danelaw, or whether native blacksmiths were just simply copying Viking styles while maintaining their own techniques.

2.6 Viking Europe

The Viking Age was a period of prosperity in Scandinavia with an influx of wealth from trading and raiding (Ulriksen 2004). During this period villages were founded and the first towns emerged. Elsewhere in Europe, Viking raids devastated ecclesiastical and urban settlements, before they settled in most of north-west Europe (Forte *et al.* 2005: 299-329). There have been many theories as to why the Vikings began to raid and colonise (Barrett 2008). The most commonly proposed theory was that there was a demand for land due to a growth in the population and the lack of good arable land. This might explain why the bulk of Viking expeditions and subsequent settlers came from Norway, where arable land was at a premium, although it is surprising that there was 80 years of raiding before any major settlements developed (Graham-Campbell & Batey 1998: 25). Another possible cause for the Viking expansion was that Scandinavian ship building techniques and sailing methods were perfected in the 8th century allowing raids to be carried out (Crumlin-Pedersen 1981; Barrett 2008). The most likely reason though is that there was an increase in trade during the 8th century with Arab traders penetrating into Europe, and the political stability in western Europe meant that there was treasure worth raiding (Callmer 1994).

Figure 2.8: Exotic artefacts found at Helgö. To the left is a crozier from Ireland which presumably was part of spoil from a Viking raid (Harbison 2004: 30). To the right is a Buddha figurine which has been dated to the 7th century and is originally from the Swat Valley (Gyllensvärd 2004: 11) and was presumably brought to the site via the Russian trade routes.

With the capability to build bigger and more sea-worthy ships came the ability to travel further and to trade (Crumlin-Pedersen 1981). The Vikings operated a far flung trade network from Greenland to Central Asia (Figures 2.8 and 2.9), although most trade was short distance, to and from small ports around the Scandinavia coast (Ulriksen 2004). There were a small number of international trading ports which attracted merchants from England, Frisia, Germany and occasionally further afield, with some Viking merchants reaching as far as Baghdad (Callmer 1994). The excavations throughout the Scandinavian homelands, Europe and the east have shown that the Vikings thrived through exploitation of trade routes, which is particularly notable at Helgö where artefacts from across the Viking known world were found (Figure 2.8; Gyllensvärd *et al.* 2004; Pushkina 2004). The north-south routes linked the east Mediterranean with the Baltic while the east-west routes were profitable for any merchant venturing to the markets of Volga Bulgars, who controlled the trade between Europe and the East (Hårdh 2007). The importance of trade with the east is represented by the large number of Arab silver coins recovered from Scandinavian hoards (Gaimster 2007). The temporal distribution of these coins starting in the 780s and increasing to a peak in the 950s with a sudden decline, suggests depletion in supplies thereafter (Callmer 1994). This corresponds to the decline of the Arab silver mines, which in turn also had a dramatic effect on Viking trade with the East (Woolf 1999; Hårdh 2007; Kruse 2007).

Figure 2.9: Viking trade routes across Eurasia, and beyond (Based on Graham-Campbell 2001: 88)

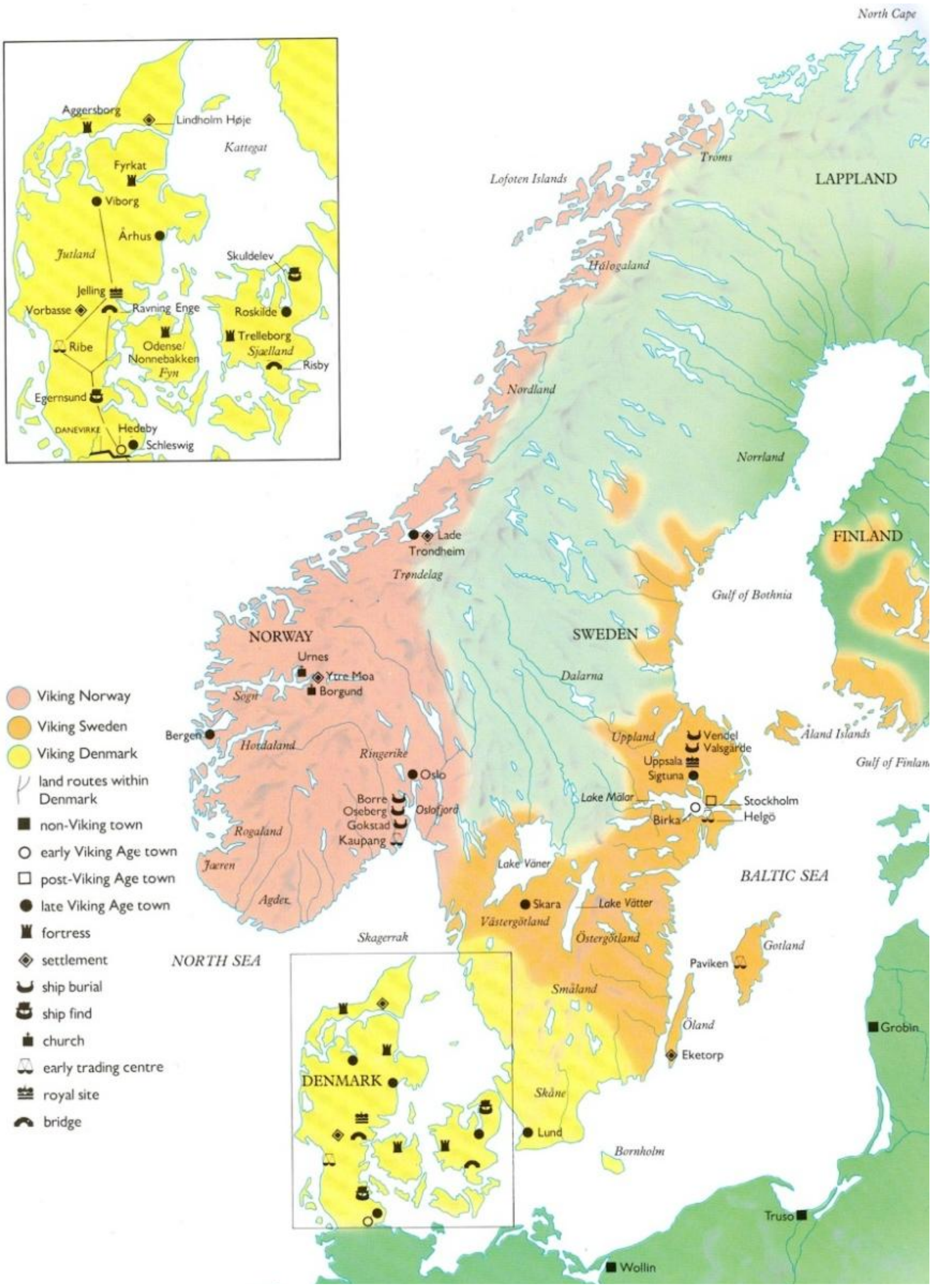


Figure 2.10: Viking Age Scandinavia (Graham-Campbell 2001: 11)

The Viking's homeland consisted of what are now mainly Denmark, Norway and Sweden (Figure 2.10). Many settlements in Scandinavia revolved around arable farming or animal husbandry in small villages, except in Norway where hunting and fishing made a significant contribution to the diet (Forte *et al.* 2005: 11). There are few fertile regions in Norway and Sweden, with the exception of the more fertile areas of Västergötland and Uppland (Hamerow 2002; Forte *et al.*

2005: 11-14), which led to a dispersed settlement pattern with isolated farms on the small areas of cultivable land (Martens 1992). The landscape in Denmark allowed for more agriculture to take place and by 700AD there were already signs of coordinated power being wielded in southern Scandinavia (Nasman 1999). The villages were small, and they shifted location every hundred years or so, only becoming permanent by the end of the Viking Age (Figure 2.11; Hamerow 2002: 104-106). Planned rural settlements were only widely adopted in the 8th century, at which time powerful landlords made best use of the land (Clarke & Ambrosiani 1991).

Figure 2.11: Reconstruction of three settlements in Scandinavia; the first is Vorbasse a rural settlement, Kaupang was a seasonal market settlement whereas Hedeby was a planned urban settlement (Konstam 2002: 37, 39, 42).

Towns were very slow to develop in Scandinavia, with few urban centres before the Viking Age (Clarke & Ambrosiani 1991: 51) although more recent excavations have revealed more small market and production centres (Sawyer 2003; Tulp 2003). The earliest urban settlements in Scandinavia were market places, often located in small inlets where craft industries were carried out in small un-standardised plots (Sawyer 2003). These settlements developed as temporary or seasonal sites for itinerant craftsmen and merchants. For example, Helgö in Sweden developed early in the 5th century, as a trading settlement but also an industrial centre with evidence for mass production. During excavations large quantities of silver, crucibles, moulds and metalworking tools were uncovered (Lamm 1991; Sawyer 2003; Grandin *et al.* 2008). Urban development was closely tied to royal power, often established by rulers to encourage, control and profit from trade (Callmer 1994). By the late 8th century more urban settlements were established. Some were re-located settlements, like Birka in Sweden which shifted from the established settlement at Helgö to a new location in the 8th century (Clarke & Ambrosiani 1991: 69-73; Callmer 1994). Other settlements such as Ribe in Denmark slowly developed from a small market place to a truly urban site with permanent residents as well as industries. Over time other settlements like Hedeby in North Germany were newly established (Figure 2.12) during the late 8th century (Ulriksen 2004; Wiechmann 2007). By the late 10th century these towns had become administrative and ecclesiastical centres (Jørgensen 2003).

In Ireland Viking coastal and inland raids via the navigable rivers began in 795, with more frequent raids in the 830s (Ó Corráin 2001). The Vikings began to establish long-phort 'ship bases' along the east coast which allowed them to winter in Ireland. These fortified camps, including the one built in Dublin, suggested they had ambitions beyond raiding, i.e. conquest and control (de-Paor 1976; Wallace 1992: 1-2). The Vikings were eventually drawn into Irish political life and Dublin developed as a trade centre for slaves, amongst other goods (Doherty 2001). By the 10th century Dublin had become a prosperous merchant and manufacturing town, along with other Viking settlements at Wexford, Waterford and Limerick. Despite the very few lasting territorial conquests or extensive settlements in Ireland, there was some interaction as seen in the Scandinavian art style of Irish pieces (Wallace 1981). Dublin continued to be an economic centre and a focus for trade with the English ports across the Irish Sea, even though the Hiberno-Norse Dubliners were pressured by the Irish provincial kings. Dublin also acted as a centre for warriors and ships that were used to raid England (Valante 2008: 111).

The Vikings in Dublin probably did not transform Irish society but, as in England, they were a catalyst for transformation (Doherty 2001: 35). Discovery of artefacts of Scandinavian style and materials in Dublin point to contacts with Vikings, this may reflect trade and intermarriage rather than settlement (Hall 2007: 125-126). Some researchers suggest that Dublin was founded by Scandinavians from Britain, whose numbers included both Anglo-Saxons and indigenous Irish, and this is reflected in the close connections between pottery types seen in Dublin and England (Barry 1987: 30-32). Even so it is clear that there was an intermix of Scandinavians and Irish cultures that made up the Hibero-Norse city of Dublin, with clear Irish & Scandinavian art styles seen in sculpture and metalworking (Ó Floinn 2001: 90-96). In addition, Nordic place names are clear indicators of some Scandinavian influence on Dublin and Ireland (Fellows-Jensen 2001: 107-113).

Further in the East the Rús, Vikings from Sweden, sailed up Russia's rivers to dominate lucrative trade routes in the East (Hårdh 2007). This expansion dominated by trade occurred more than a century before the outbreak of Viking raiding elsewhere. The Rús already had a significant presence in Slav and Baltic towns before AD700. By the 830s they had explored the Russian river system and had direct trade contacts with Arab traders and the Byzantines (Callmer 1994; Pushkina 2004). Ladoga, a gateway community linking the Baltic to Eastern Europe, and beyond, was founded around AD750 as a craft-working and trading settlement. Further up the river Volkhov, Novgorod was established in the 9th century and by the 10th century it experienced rapid urban growth due to the Scandinavian merchants (Brisbane 1992: 193-205; Pushkina 2004). Like many Viking towns the excavations of Novgorod revealed evidence for craft working, including blacksmithing and large number of iron knives, some of which were metallographically examined (Brisbane 1992). The Vikings, like elsewhere in the west, were absorbed by the people they conquered and began to adopt Slavic names and culture (Hall 2007: 96-101).

In England, and Ireland there is some evidence that the Scandinavians had an impact on place names, sculpture and metalworking. In most cases there appears to be a mixing of different cultures resulting in new Hibero-Norse art styles (Ó Floinn 2001: 90-96). The outward appearance of knives does not appear to change across Europe but it is unknown whether new 'Viking' blacksmiths techniques were adopted in Viking Dublin, if Scandinavian blacksmiths started up new businesses or whether the native blacksmiths simply continued using their own techniques. Therefore a comparison of knives from Scandinavian sites, Novgorod, England and Dublin should reveal whether the Vikings had an impact on blacksmithing ability.

2.7 Summary

This chapter has shown that the early medieval period was a time of constant change and flux, brought on by the movement of different cultural groups. In England the Roman urban settlements were abandoned and the people lived in small rural settlements. The way they buried their dead also changed with the return of cremation burials and fully furnished graves. Only in the middle Saxon period did urban settlements start to re-develop, and these acted as centres of trade and industry. The nature of rural settlements also changed during this time as they became more organised with clear boundaries. The acceptance of

Christianity resulted in the abandonment of many ‘pagan’ cemeteries and the associated furnished burial rite. The late Saxon period brought about new changes, as Viking raids intensified, urban settlements moving behind the safety of walls, but continuing to develop. The rural settlements started to develop into parishes, with clear boundaries in the landscape suggesting control over the resources available. The Vikings eventually settled in Britain particularly in the north of England, and also in Ireland establishing a new urban settlement at Dublin. In Europe the Vikings had extensive trading networks extending from Greenland, and Newfoundland, to the Middle East.

Chapter 3: Chaîne Opératoire of an Early Medieval Iron Knife

Gold is for the mistress, silver for the maid
Copper for the craftsman cunning at his trade
“Good!” said the Baron, sitting in his hall
“But iron, cold iron, is master of them all.”
Rudyard Kipling (1835-1936) in his poem ‘Cold Iron’

3.1 Introduction

The Chaîne Opératoire is used to describe a sequence of processes from the selection of naturally occurring raw materials, the processing and transformation of a cultural product to its final discard in the archaeological record (Schlanger 2005). The analysis of archaeological artefacts and the by-products retrieved from these processes makes it possible to reconstruct the dynamic links between these stages. This in turn can be used to address complex social, ecological and cognitive dimensions surrounding ancient technical activities (Schlanger 2005). Therefore a Chaîne Opératoire will be constructed for the manufacture, use and discard of an iron knife based on our current knowledge.

This chapter will discuss the whole life cycle of an iron knife (Figure 3.1) reviewing the evidence from previous archaeometallurgical studies of early medieval iron artefacts. The complete manufacturing cycle of an iron artefact can be divided into three distinct stages: smelting of the ore to produce the iron, the consolidation of the metal during primary smithing and secondary smithing of the stock iron into an artefact (McDonnell 1986). Therefore the first section will start with the production of iron during the smelting process. The second section will discuss the smithing process including both primary and secondary smithing. Next the manufacture of an iron knife will be considered. In this section the typology based on the shape of iron knives will be discussed as well as the use of different iron alloys and methods of constructing including smithing techniques, such as heat treatments, weld lines, non-ferrous inlays and pattern-welding. The materials used for finishing a knife, including the knife handle and scabbard will also be discussed. The final section will place all this information into early medieval context. It will discuss the archaeological evidence for iron smelting and smithing and introduce three models for the creation of iron artefacts in different settlements. It will investigate the role and status of the smithy in early medieval Europe. After which a full review of current research into knives will be presented, focusing on metallography but also discussing the use of knives in this period.

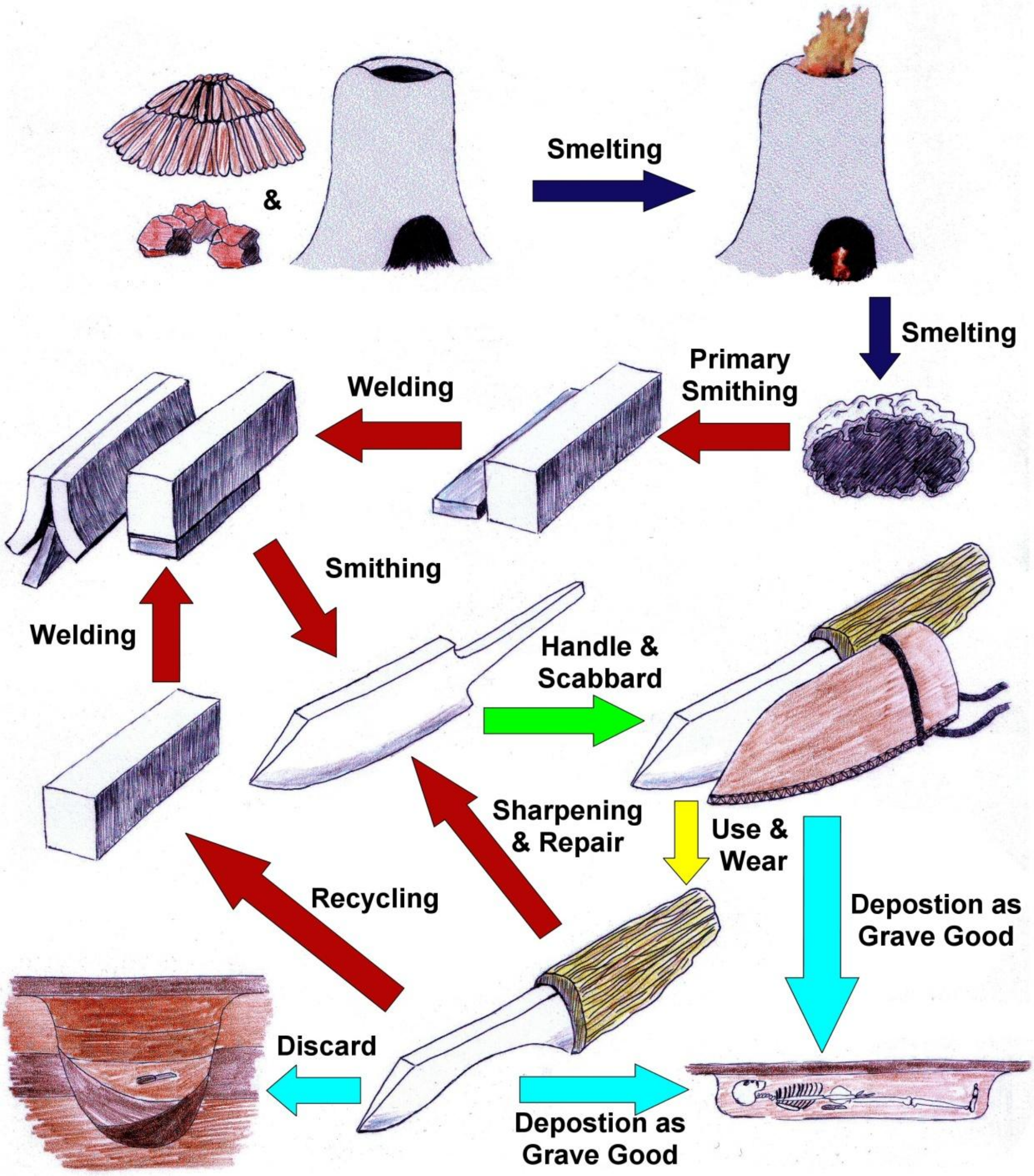


Figure 3.1: Chaîne Opératoire of an iron knife.

3.2 Iron Smelting: From Stone to Iron!

There are two basic methods for producing iron. The first is the direct method where iron metal is extracted from the ore in the solid state using a bloomery furnace (Buchwald & Wivel 1998). During this process the aim of firing ore and fuel in the furnace is to remove the unwanted gangue material as a slag, and encourage particles of solid iron to coalesce together to form a bloom (Buchwald

& Wivel 1998; Pleiner 2000: 131-136). Many reactions take place during iron smelting (Figure 3.2), but the main reaction is the reduction of iron oxide in the ore, using carbon monoxide resulting from fuel combustion, to produce metallic iron (Crew 1991; Hjärthner-Holdar *et al.* 1997; Pleiner 2000: 133). At the same time a slag forms during a reaction between iron oxide in the ore and silica present in both the ore and furnace lining (SiO_2); other impurities in the ore, fuel and furnace lining are often incorporated into the slag waste product (Paynter 2006).

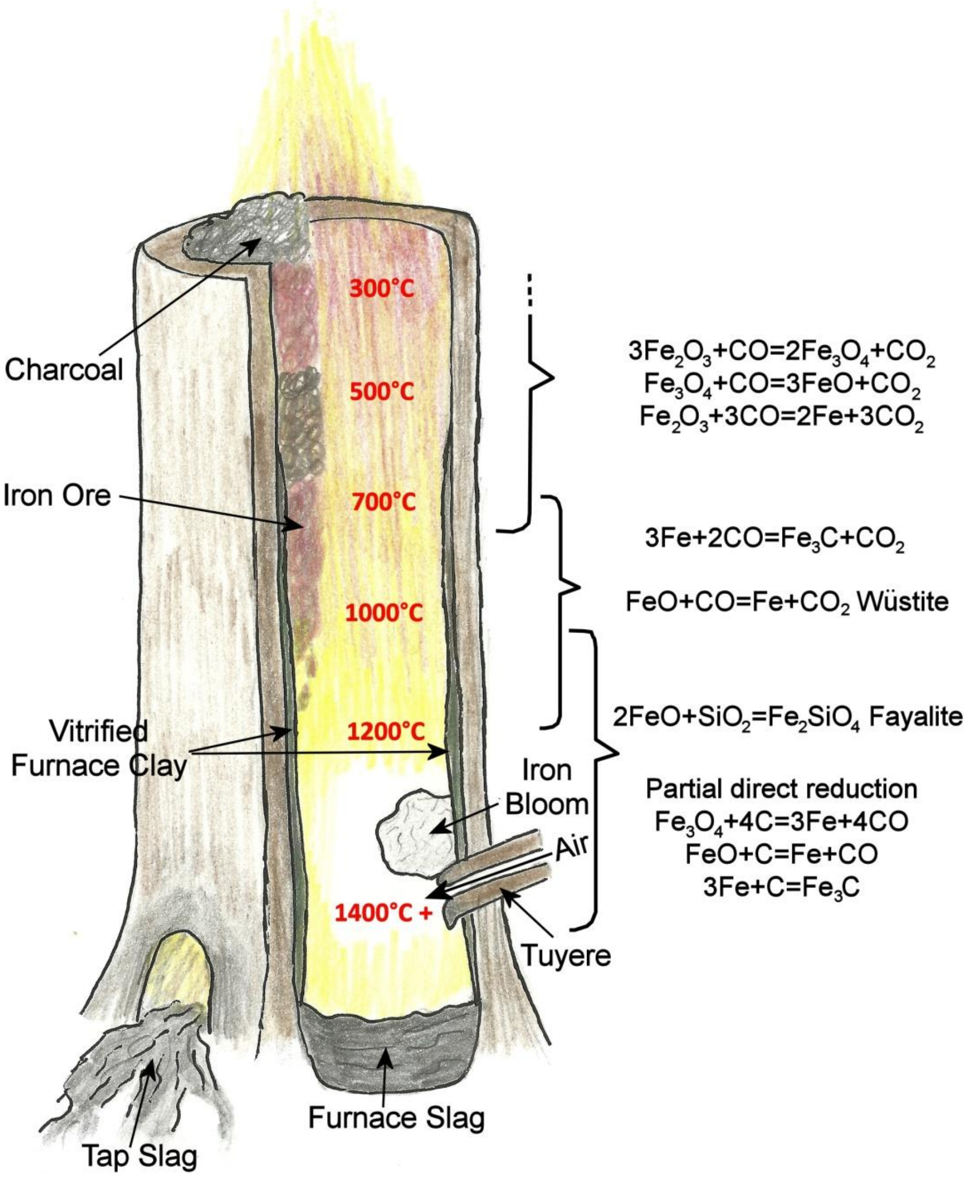


Figure 3.2: Theoretical model of a bloomery iron shaft furnace based on illustration by Pleiner (2000, 134, Fig. 33). The drawing shows various stages of the smelting process. Ranges of furnace temperatures, the formation of an iron bloom near tuyère level, the deposition of slag at the bottom of the furnace, the potential tapping of the slag, and melting of furnace wall and/or tuyère ceramic are indicated in the furnace itself. The chemical reactions taking place at the various locations and temperature zones of the furnace are indicated on the right.

The second method is the indirect process. During this process the iron is fully reduced and melted in a blast furnace, or high bloomery furnace. The resulting liquid iron, contains high proportions of carbon (between 2.1% to 4%) and is too brittle to be immediately worked further (Samuels 1999: 30). Therefore the cast iron produced needs to be refined, removing the excess carbon (Tylecote 1986; Samuels 1999: 30). There is no evidence to suggest that this method was carried out in Anglo-Saxon England.

Another method used to produce a high-carbon liquid steel involved re-melting bloomery iron in a container with carbon rich materials. This is well documented archaeologically in Sri Lanka, Turkmenistan and China and in Europe since the late Middle Ages (Craddock 1995). In India and Sri Lanka liquid steel was produced in a crucible in the 7th century, which resulted in high-quality high carbon steel with around 1% carbon and very few slag inclusions (Bachmann 1982; Craddock 1995: 275-283; Rehren & Papakhristu 2000).

A range of furnaces have been used to produce iron in antiquity (Tylecote 1986: 132-141,1992). The morphology of slag produced during smelting depends on the type of furnace used, which in turn varies both regionally and chronologically. It is dependent on the ore type available and used, the fuel available, and cultural traditions (Pleiner 2000: 141-194; Joosten 2004: 20-28; Rehren *et al.* 2007). Analysis of slag assemblages from across the world, and over time, has revealed that the majority of smelting slag is fairly homogenous in overall composition (Rehren *et al.* 2007). Even so, the final composition is a direct consequence of human decisions regarding furnace design, raw materials selected and charge recipe (Rehren *et al.* 2007). Apart from the obvious contribution from the iron ore gangue there is also a significant contribution from both the furnace clays and the fuel used, although opinions differ as to exactly how much they contribute (Høst-Madsen & Buchwald 1999; Thomas & Young 1999; Crew 2000; Paynter 2006).

Iron slag typically consists of four phases: fayalite, wüstite, metallic iron and a glassy matrix (Figure 3.3). On cooling from the liquid state, the silicate and any free iron oxide mineral in the slag crystallise. The iron silicate present in slag is fayalite (Fe_2SiO_4) which often appears as laths, although crystal development depends primarily on the cooling rate. Occasionally other elements can substitute with the iron oxide to form other phases (Bachmann 1982: 16-17). Wüstite (FeO) is a mineral form of insufficiently reduced iron oxide and has a dendritic appearance. The remainder of the liquid slag forms a glassy matrix between the fayalite, wüstite and other phases present and contains many of the compounds that are unable to substitute into these mineral phases (Bachmann 1982; Allen 1988; Buchwald & Wivel 1998). These different phases can also be identified in slag inclusions trapped in iron artefacts. Many researchers have suggested that it may be possible to provenance iron artefacts using these inclusions (Salter 1976; Hedges & Salter 1979; Buchwald & Wivel 1998; Dillmann & L'Heritier 2007; Blakelock *et al.* 2009).

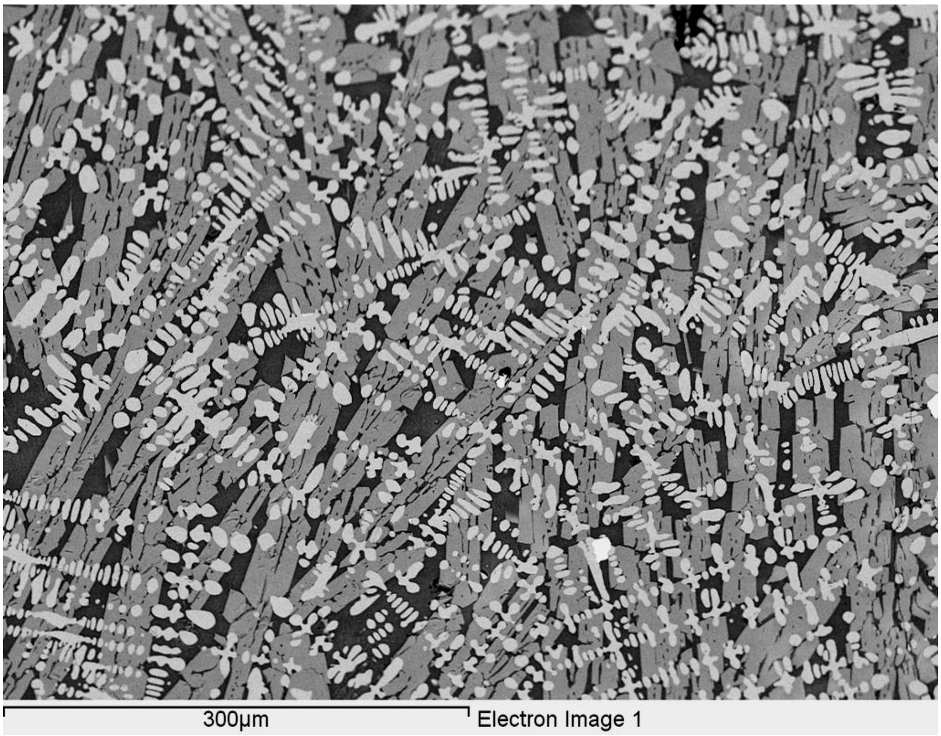


Figure 3.3: SEM backscatter image of tap slag from experimental iron smelting slag showing the different phases present in iron slag: metallic iron (white) dendritic wüstite (light grey) and fayalite (mid grey) in a glassy matrix (dark grey) (Blakelock et al. 2009; Fig 3).

3.3 Iron Smithing: From Bloom to Artefact

There are two types of smithing: primary and secondary (Figure 3.4). The first 'primary' smithing is required to refine and consolidate the bloom. This is carried out by hammering the bloom, often while still hot, to remove adhering slag or expel included slag and charcoal (Hedges & Salter 1979; McDonnell 1991; Serneels & Perret 2003). Primary smithing to create iron bars for trading was most likely carried out at the smelting site. Secondary smithing or 'forging' is the operation where the billet or bar is shaped into a finished product. This process is carried out by repeatedly heating the iron in a hearth and hammering it on an anvil, to give it shape and to increase hardness. During this process large amounts of metal is lost due to oxidisation, this forms a layer around the iron object which is removed during hammering, resulting in hammer scale (Dungworth & Wilkes 2007). Therefore a flux may have been added to help dissolve the oxide film and prevent further oxidation (McDonnell 1987e; Sim & Ridge 1998: 12; Serneels & Perret 2003). Discussions with Hector Cole (Cole *pers.comm*. 16/11/2010), a modern blacksmith who makes reconstruction swords and arrowheads, explained that some smithies do not use fluxes at all. Hector only uses fluxes when he is welding together pieces of steel.

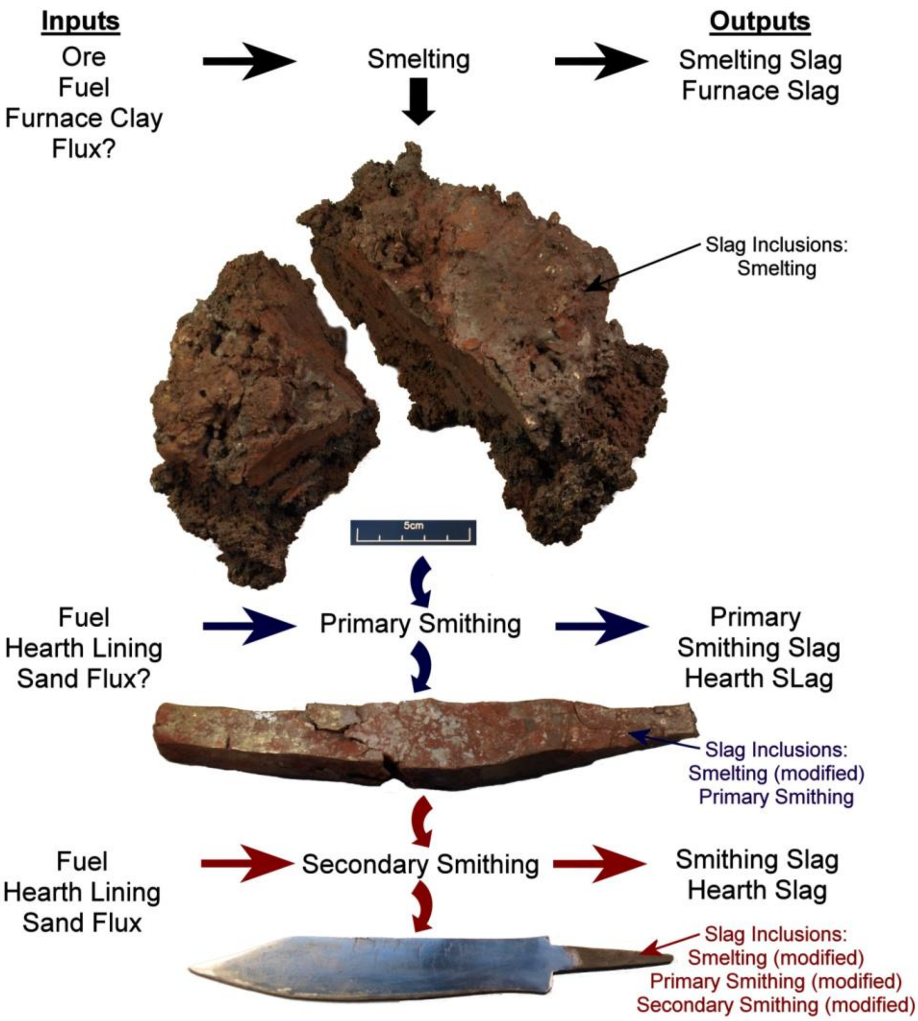


Figure 3.4: Detailed diagram showing the various stages of production from bloom to artefact. Below each stage is a description of the types of slag inclusions present, below that is the principle components involved in that stage that may affect the composition of the inclusions and then a description of the other slag types formed (based on Figure 1 in Blakelock et al. 2009). Photos are of the bloom, bar and knife produced during the experimental archaeometallurgy conference in 2010, courtesy of David Dungworth and Hector Cole. Note the curved cutting edge of the newly created knife.

The smith required a stock of iron which came in a variety of shapes and sizes including: bars, billets and strips (Tulp 2003). These were used to produce iron objects. Three basic types of iron alloy were available: ferritic iron which contained few alloying elements (less than 0.1%), phosphoric iron containing between 0.2 to 1% phosphorus, and steel which contains carbon as the main alloying element (McDonnell 1989a).

In antiquity three methods may have been used to produce steel, one directly from the smelting process by controlling the fuel to ore ratio, another was by carburisation of ferritic iron. The third method would be to produce liquid steel. Evidence from Hamwic suggests that high-quality high carbon-steels (homogeneous high carbon content >1% carbon) were being used during the middle to late Saxon period, although no residues from this production have been found there (Mack *et al.* 2000).

Another type of iron often present on many sites is piled iron which refers to iron which has alternating bands of different iron alloys (McDonnell 1989a). This banded appearance may result from the recycling of iron, but could also just have formed accidentally while the heterogeneous bloom was worked, by bending and forging into a strip (Tylecote 1986: 145).

3.4 Knife Chaîne Opératoire

In the past most studies of knives have been limited to typological studies. This allows archaeologists to group the knives, but does not reveal any details as to how the knives were constructed. Metallographic examination of iron knives however can reveal a great deal about the construction of knife, and can also provide information about how they were used.

Shaping the Knife

Iron knives come in a range of shapes and sizes, from the very small craft knife to much larger knives ideal for butchery. Occasionally knives with serrated edges have been found, e.g. at Coppergate in York (Ottaway 1992: 589) and Hamwic, St Mary's Stadium (Blakelock & McDonnell 2007) and these would have presumably had a specific function, possibly related to bone and antler working. Examples of pivoting and folding knives have been identified at a number of sites including York (Ottaway 1992: 586-8), Dublin and even in more rural locations like Burdale, Yorkshire. Again these knives were most likely required for some specialist purpose.

Knives may also have been used during battles. The seax (or scramaseaxe) is a single edged knife usually hilted in the same way as a double edged sword. Seaxes tend to be decorated using pattern welding, non-ferrous inlays, grooves and/or inscriptions. Although technically a knife, a seax is often more associated with weaponry rather than a tool therefore they will not be examined or discussed in detail in this research. Some seaxes appear to be too small or too highly decorated to have any function in battle and it is possible that they were a symbol of wealth and status (Gale 1989; Brooks 1991).

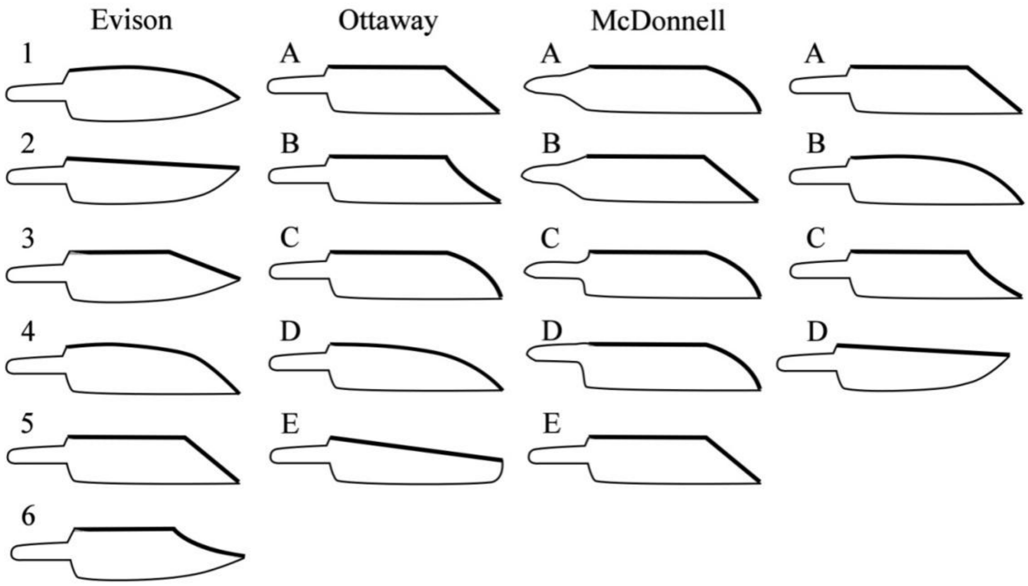


Figure 3.5: Four different archaeological knife typologies based on the shape of the blade. The simplified typology of knife forms at the far right is that used in the review paper, the Wharram Percy study and in this study. The primary difference between the knife types in McDonnell's typology is the different tang to blade interfaces.

The classification of knives is beset by the usual problem with the classification of objects that are individually handmade, which is that no two will be identical. So classification becomes a question of grouping simpler objects together. Three main typologies (Figure 3.5) were used to classify early medieval knives in Britain namely those devised by Evison, Ottaway and McDonnell. Evison's typology splits the knives into six separate groups based on whether the back is straight, curved or angled and if the cutting edge is straight or curved (Evison 1987: 113-117). Ottaway only uses the shape of the knife back, as this is unlikely to alter through wear or sharpening (Ottaway 1992: 558-574). McDonnell's typology, based on Ottaway's draft typology, relies heavily on the presence of a tang to blade interface without which classification is difficult if not impossible (McDonnell *et al.* 1991). Comparison between these different typologies (illustrated in figure 3.5) is difficult, as none of them can be easily matched or linked to each other. To complicate matters further, Evison's typology has most often been used to classify knives from early cemeteries while Ottaway's has been used on later settlement sites (Blakelock & McDonnell 2007). Therefore for the review article and the Wharram Percy research a new typology was created by the author that could be used to compare the three typologies and therefore compare the different site assemblages (Figure 3.5; Blakelock 2006; Blakelock & McDonnell 2007).

Manufacture, Alloy Use and Welding

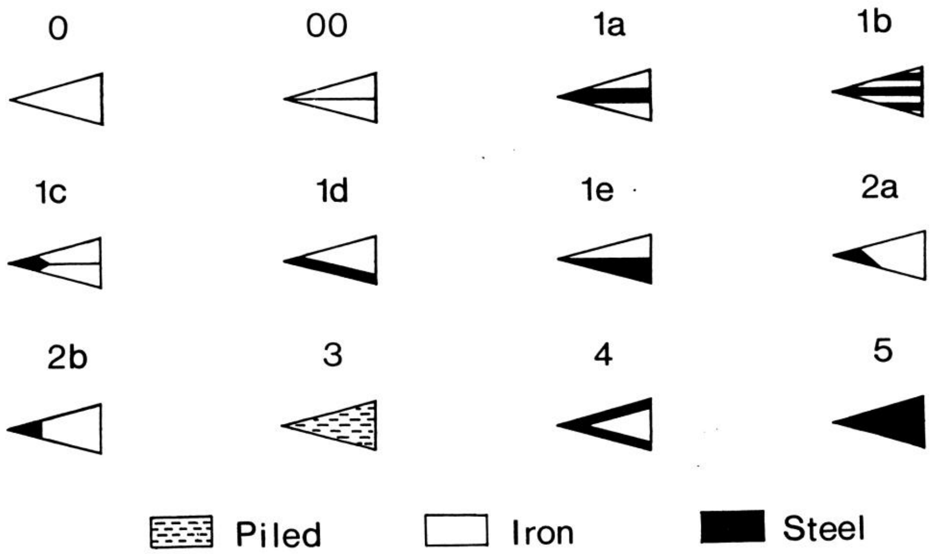


Figure 3.6: Tylecote and Gilmour's (1986: 6) original steel edged tool manufacturing typology.

Complex iron objects, such as knives, utilised different iron alloys to take advantage of the properties of each alloy. This resulted in the use of the hard and durable high carbon steels (0.7-1% carbon) for the cutting edge leaving the soft and flexible ferritic and phosphoric iron for the knife back. Analysis of knives by Tylecote and Gilmour in 1986 led to the development of a manufacturing typology with six main methods of creating an edged tool. Their original typology had many sub-classes including two different types of butt-welded knives and five different types of sandwich welds (Figure 3.6; Tylecote & Gilmour 1986).

Analysis since Tylecote's original study has allowed a simpler typology to be developed (Figure 3.7) but again there are some variants. In this research the type 0 knife is plain ferritic or phosphoric iron, in some cases low carbon steel will also be present. The type 1 knife has a steel cutting edge sandwiched between two flanks of ferritic, phosphoric, low carbon steel or occasionally piled iron. There are also some variations to the type 1 knife which can be seen in figure 3.7. One of the effects of sharpening is that the cutting edge can shift position (Figure 3.7). The main method of constructing a type 2 knife is by welding a piece of steel onto a knife back, which will usually be a flexible ferritic, phosphoric or piled iron. The cutting edge can be either butt welded flat to the back or scarf welded (Figure 3.7), another way to construct a type 2 knife is to carburise the iron to create a steel cutting edge. In this study a knife with only one iron flank beside a steel strip will be classified as a type 2 knife (Figure 3.7). The type 3 knife is constructed out of piled iron while the type 5 knife is a mid to high carbon steel. The type 4 knife has a core of ferritic, phosphoric or low carbon steel with a piece of steel wrapped around it.

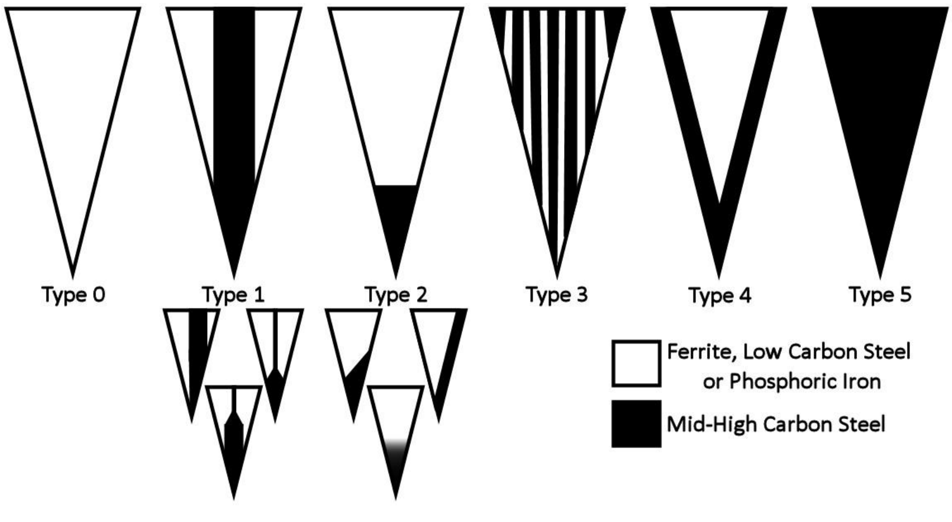


Figure 3.7: Simplified knife manufacturing typology based on blade cross sections (adapted from Tylecote and Gilmour 1986). Some of the variations on the type 1 and 2 blades are also shown below.

The majority of these methods of manufacture require the different iron alloys to be fire welded together. To weld pieces of iron together it is vital that the metal is heated to a temperature at which it is soft but not molten, c.1100˚C (Pleiner 2006: 53-54). Weld lines joining metals are often visible due to slag inclusions which get trapped during the welding. Some weld lines have a distinct white colour (Figure 3.8), which is due to arsenic and/or nickel enrichment (Tylecote &

Thomsen 1973; Castagnino 2007). There are many theories about these lines. One possibility is that a flux was being added during smithing to create a better quality weld. This study will provide an opportunity to investigate these theories.

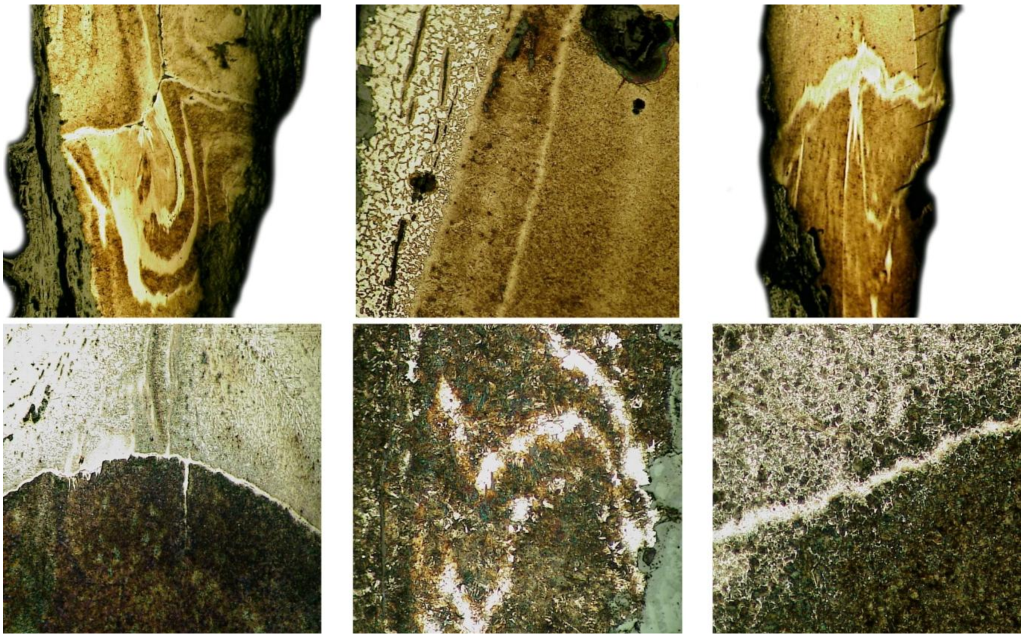


Figure 3.8: Various photos showing just some of the different types of white weld lines, seen in early medieval knives.

The deliberate manufacture of artefacts from strips of different irons, termed 'pattern welding' is regarded as the pinnacle of the smith's art (Anstee & Biek 1961; Gilmour 2007). There are two differences between pattern welded and piled knives. The first is that the size of the strips is smaller in piled knives and therefore less visible. The second is that the intention of pattern welding was to create an effect on the surface of the knife (Ottaway 1992: 481). These effects are created by forging, twisting and welding together strips of different metals including, low carbon ferrite, phosphoric iron and high carbon steels (Anstee & Biek 1961), these strips would then appear as light and dark bands which could be emphasised by etching or rust (Wilson 1981: 265-266). These patterns were mentioned in Beowulf for example "iron blade with its ill-boding patterns" (Heaney & Donoghue 2002: 39).

Another form of decoration is the inlay and use of non-ferrous metal; this can often be seen as distinct brighter areas on x-radiographs (Lang & Middleton 1997: 54-55; Fell *et al.* 2006). Grooves cut or indented into the knife back allow for non-ferrous metals to be inlaid, but may also have been decorative features in their own right or even functional. Other types of decoration include using non-ferrous staples on the back of the knife or stamping non-ferrous motifs into the blade, although this is mostly seen in later medieval knives.

Heat Treatments

To get the best out of a steel edge, it has to be heat-treated. The speed of cooling can control the formation of certain microstructures in the metal which therefore increases the hardness. The most common form of heat treatment is quenching, where the still hot object is plunged into a liquid to cool it rapidly and create an extremely hard martensite cutting edge (Tylecote 1990b; Scott 1991b: 31-32; Samuels 1999: 5-37). In modern smithies this is usually water, but other liquids such as oil, milk, urine and even blood would have been just as effective and may have been necessary for the ritual or 'secret recipe' aspect of the smith's work (Tylecote & Gilmour 1986: 17-18; Maddin 1987). Once quenched the metal, while harder, would also become brittle, so in many cases the object was then tempered (heating to 200-500°C). This would reduce some of the stress and brittleness, but also to some extent its hardness (Tylecote 1990b; Scott 1991b: 31-32; Samuels 1999: 5-37). Cold working could also have been used to increase the hardness of the iron (Swiss & McDonnell 2003).

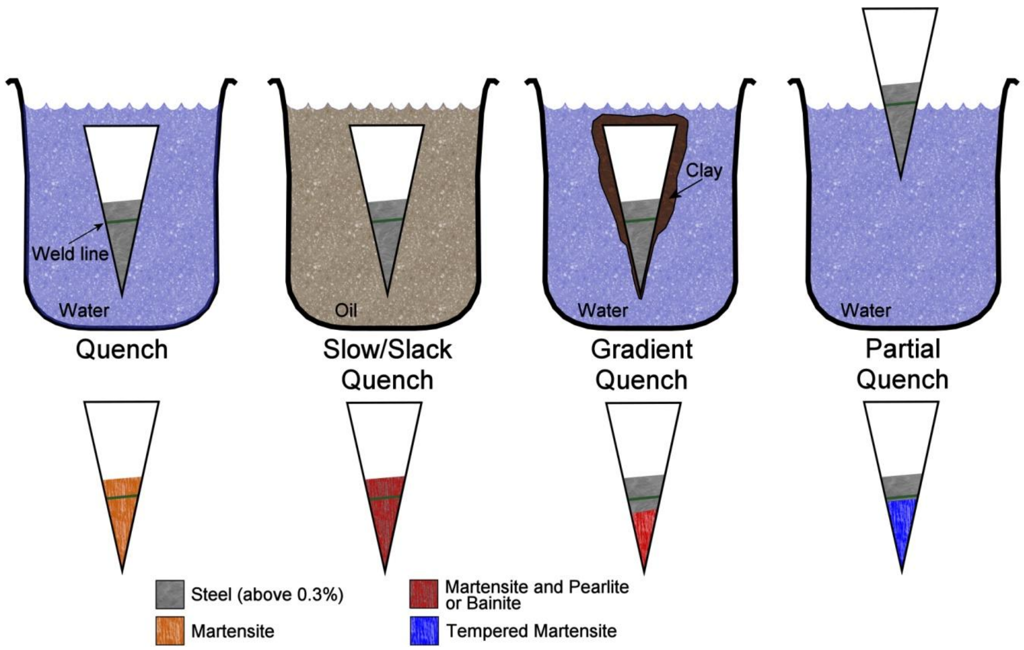


Figure 3.9: Diagram showing the 4 different methods of quenching and the microstructures present in the resulting blade.

There are at least four different ways to quench an iron artefact (Figure 3.9). Each will result in slightly different microstructures. The easiest way to quench an artefact is to completely plunge the entire object in a suitable liquid to cool it rapidly, transforming all steel almost simultaneously; depending on the carbon content present (Tylecote & Gilmour 1986: 17-18). Slow or 'slack' quenching is similar to above but uses a different liquid with lower thermal capacity than water (such as oil). This usually results in mixtures of hard martensite and the less hard phase such as bainite, achieving in one operation the same hardness as water quenching and tempering (Tylecote & Gilmour 1986: 17-18). The next heat treatment is known as gradient quenching. During this process the knife is protected by a layer of clay. This is thicker in areas where the slower cooling rates are desired, and thinnest (or non-existent) where the fastest cooling rates are required like near the cutting edge (Tylecote & Gilmour 1986: 17-18). This is the only method to obtain heat-treated cutting edges in all steel blades, but has not been identified in early medieval artefacts to date. The final method of quenching is done by heating the whole blade to a suitable hardening temperature at which point only the cutting edge is quenched. Once removed from the quenching bath a form of auto-tempering takes place due to the heat flow from the knife back into the quenched part of the blade, which tempers the martensite at the cutting edge (Tylecote & Gilmour 1986: 17-18).

Finishing Touches

Once the iron component of the knife was complete a handle would need to be added. Knife handles can be classified according to the method of attachment. The whittle-tang handled knives were most commonly used in the early medieval period, and are fixed into place by pushing the pointed end of the knife tang into the handle, possibly when hot. Alternatively wedges or glue could have been used to fix the handle to the knife tang. The scale-tang handle was attached to the knife tang using rivets and was only introduced in the 14th century (Cowgill *et al.* 1987: 25).

The evidence from mineralised organic residues on knife tangs have shown that knife handles were made of a variety of materials: wood, horn or bone (Figure 3.10; Cowgill *et al.* 1987). Studies of later medieval knives have revealed that wood, a cheap, readily available and easily worked material, was the most common option. The majority of wood species used were both hard and flexible, e.g. box, but some woods like oak are unsuitable for use as a handle as although they are hard, they can also be prone to longitudinal splitting (Cowgill *et al.*

1987). Many of the handles have knots along their lengths which may have been chosen deliberately for the elaborate grain pattern (Cowgill *et al.* 1987). The handles on whittle-tang knives are very seldom decorated and few techniques seem to have been employed to ornament them (Cowgill *et al.* 1987).

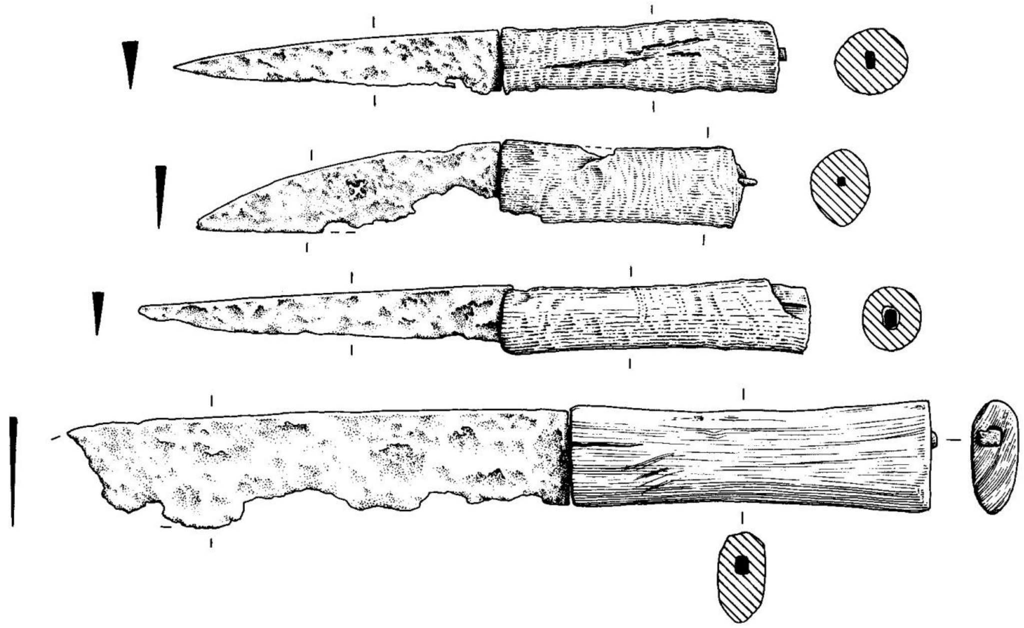


Figure 3.10: Knives from Medieval London with their tangs and handles still intact. The top two knives had iron tangs that were slightly longer than the handle. The next knifes' tang did not extend the entire length of the handle. The tip of the bottom tang has been bent over to hold the handle in place (Cowgill et al. 1987: 59-60). Not to scale.

Illustrations in later medieval manuscripts have shown that the majority of knives would have been carried in leather sheaths or scabbards either suspended from or attached to the belt (Cowgill *et al.* 1987: 52-55). This seems to have also been the practice in early medieval times as many scabbards had leather straps that could be attached to a belt, and the location of knives found in graves also supports this (Cowgill *et al.* 1987). The shape of the knife scabbards reflects their function. They are often asymmetrical, one side being more curved than the other to fit the cutting edge. The upper section which holds the handle is fairly standard size, with only the blade section varying (Cowgill *et al.* 1987: 52-55).

Knife Use, Wear and Repair

As an iron knife is used there should be some evidence for wear, damage and/or repairs. The cutting edge will begin to wear down and blunt which would lead to it being re-sharpened and this process can result in distortion of the original shape of the cutting edge (Figure 3.11). Ottaway has suggested that the way a knife was manufactured will affect how quickly the knife will be worn and how it will distort when sharpened; this can also apply to other objects (Ottaway 1992: 598-599). Instead the author argues that heat treatment will more likely affected the amount of wear, as knives with harder cutting edges would be less prone to wear, even so the type and amount of use will also affect the wear. This will be investigated during this research. Even so the shape at the cutting edge may not always be a clear indication of wear as new blades may have started with a curved cutting edge (Figure 3.4).

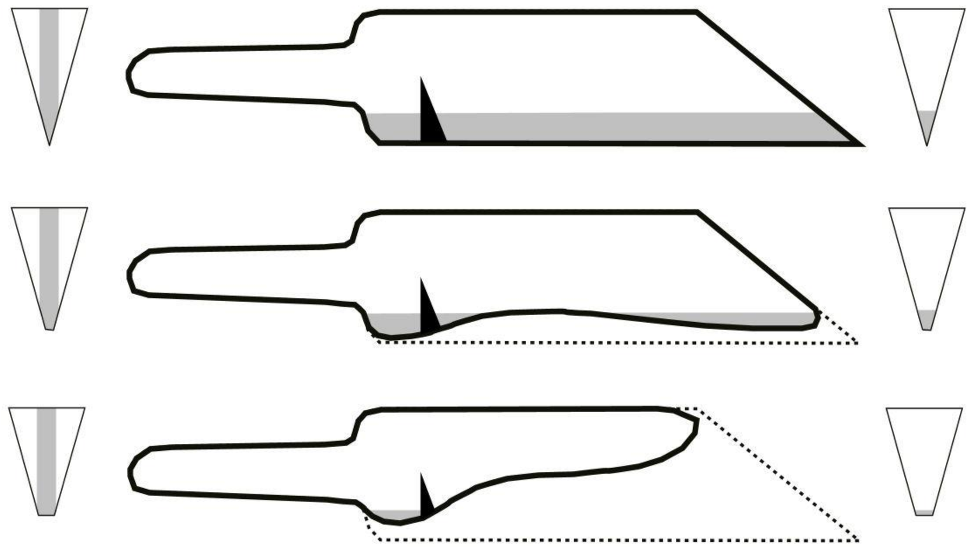


Figure 3.11: Angle-back knife with steel cutting edge butt-welded onto back (grey), with varying degrees of wear, based on the knives from Wharram Percy. The cutting edge of the middle knife is slightly worn with an S-shaped curve whereas the bottom knife has extensive wear. To the left of the knife the result of wear on a type 1 knife is shown, and the type 2 knife is shown on the right.

Other rarer microstructures can provide information about the use of an artefact. An example is neumann bands which are induced by shock. These have been identified in the Iron Age cart tyres from Ferrybridge (Swiss & McDonnell 2005), Roman knives from Carlisle (Swiss 2000), and an anvil from Coppergate, York (Ottaway 1992: 512-514).

When a knife has been completely worn down and is no longer of any use (bottom knife in figure 3.11) there is another option to consider, other than recycling or discard. The object could be repaired, by adding more metal to the object. This has been noted during analysis of knives from Hamwic (McDonnell 1987a,d; McDonnell *et al.* 1991) and Coppergate, York (McDonnell 1992).

It is possible that early medieval blacksmiths would have re-used metals when the opportunity arose, as they still do today (Woodward 1985). Archaeologists and historians in the past have suggested that iron and copper would have been too precious to be discarded and would have been recycled, which they claimed was confirmed by the relatively small quantities of metalwork found during excavations (Loveluck 2007: 150). Recent excavations, including those at Flixborough, appear to contradict this pattern as large quantities of iron were discovered suggesting that recycling may not have been as prominent an activity as previously suggested, especially in high status sites or sites producing their own iron (Loveluck 2007: 159). Recycling may have been more important in low status rural societies or settlements that were some distance from centres of iron production (Woodward 1985). Even so it is very unlikely that all objects made at rural sites were constructed from recycled iron scraps, and therefore recycled iron may have been used infrequently. It has been suggested that the piling affect seen in some iron is due to iron being recycled but another likely explanation is that the piling resulted accidentally while the heterogeneous bloom was forged into a bar (Tylecote 1986: 145).

3.5 Early Medieval Ironworking

This research primarily focuses on the blacksmithing production techniques and iron knives, but to place this within its context the evidence for smelting and smithing sites will be summarised here. Several ironworking models were proposed to summarise the production of iron objects in the early medieval period. The status of the early medieval smith is also briefly discussed in this section, although it is beyond the scope of this research to discuss this in detail. Finally the production of iron knives will be summarised.

Early Medieval Smelting Evidence

Generally two types of furnaces were used in the early medieval period, both were variations on the shaft furnace but had very different methods of slag removal. The first was a furnace where the slag was removed by tapping it through a hole at the furnace base when it was hot and fluid, resulting in tap slag

(Tylecote 1986: 156-159; Fulford & Allen 1992). The second type of furnace used was the slag-pit furnace where the slag was encouraged into a deep pit dug directly under the furnace (Tylecote 1986: 136; Voss 1993: 207).

Very few early medieval smelting sites have been identified in England. There is no evidence for early medieval iron smelting in the Weald or Forest of Dean which were centres for iron production in the preceding Roman period and following Medieval period (McDonnell 1989a; Hamerow 2002: 189; Birch 2011). Excavations of the few iron smelting sites discovered have revealed two group types based on slag morphology. The first group consists of slag similar to those present in other periods: tapped slag found at Flixborough, raked slag at Millbrook and furnace slag at Ramsbury (Haslam *et al.* 1980; McDonnell 1989a; Starley 1999). The slag in the second group has a distinct 'slag block' morphology similar to slag found in southern Scandinavia, North Germany and Poland (McDonnell 1989a; Voss 1993: 207). Examples of slag blocks have been found at Romsey (McDonnell 1988), Mucking and Little Totham (Hamerow 2002: 189). There is scant evidence for urban smelting in the early medieval period with very small amounts of smelting slag found at York and Stamford and even less evidence found at Hamwic (Ottaway 1992: 477-478; Rogers 1993: 1224-1228). Instead many of the iron smelting sites seem to be located away from the urban centres. Some like Ramsbury in Wiltshire, Flixborough in Lincolnshire and Cheddar in Somerset are located in royal centres possibly indicating control over this important commodity (Loveluck 1998; Hamerow 2002: 189). The small number of iron smelting sites found contradicts the relatively large quantities of Anglo-Saxon iron found, this supports Birch's assessment (Birch 2011) that archaeologists are looking in the wrong places. Smelting sites may have been located beyond the areas of habitation, perhaps much closer to the raw materials (Birch 2011).

Few smelting sites have been identified in Ireland, which could be because very few assemblages have been fully examined. The two main sites that have been analysed, Ballyvollen and Lisleagh, were associated with centres of political power (Scott 1991a: 99-100). Many more smelting sites have been found in Ireland over the last ten years (Young *pers.comm*. 16/03/2011).

The fall of the Roman Empire seems to have had a dramatic impact on the iron industry across Europe. Even so, while many iron industries collapsed altogether, a few large production centres continued to operate (Nørbach 1999). Our understanding and knowledge of ironworking across Europe in the 5th-7th century is still limited, although this knowledge is increasing rapidly due to new large scale regional research projects. There have been far too many smelting sites discovered to discuss them all in this chapter, instead some key sites will be mentioned. Evidence for early smelting in the 5th-7th century has been discovered in most countries, but in the later Viking period fewer are known (Voss 1993: 206; Nørbach 1999: 238; Pleiner 2000: 47-48). This could be due to the fact that, like in England, archaeologists on the continent are looking in the wrong places, as smelting sites in these later periods appear to focus on the raw materials (Nørbach 1999: 245).

Early Medieval Smithing Evidence

Most early medieval settlement sites have produced some evidence for smithing. This is to be expected since smithies would have been required to manufacture and repair iron artefacts used by all communities. There are different levels of smithies, from permanent 'full-time' workshops to forges where occasional smithing operations were carried out.

The evidence from the early medieval period in England is sparse as, although there is smithing slag very few smithy structures have been clearly identified (McDonnell 1989a; Stamper & Croft 2000: 155-166). A recent review of the smithy sites at Wharram Percy revealed that without the hammerscale it is practically impossible to establish the location of the smithy, although other evidence suggested that it was close by (McDonnell *et al.* Forthcoming). At Yarnton a small amount of hammerscale was found in two areas, but the lack of thick layers of charcoal and scale suggested that the actual smithy might have been further north (Salter 2004: 307-311). At Bloodmoor Hill another possible smithy was found, including some hammerscale, but again in small quantities (Cowgill 2009: 258). Even so smithing slag has been found at a range of urban sites including York, London and Stamford, but only at Hamwic has the smithy itself been identified (Ottaway 1987; Rogers 1993; Andrews 1997). Evidence for rural smithies has been found at a large number of settlements including West Stow, Baston Hall, West Heslerton, Catholme, Yarnton and Wharram Percy (West 1985a: 69; Starley 1995; Stamper & Croft 2000: 155-166; Hey 2004; Wallis *et al.* 2004: 52-53). Smithing slag has also been found associated with smelting sites such as Romsey, Ramsbury, Flixborough, Mucking and Little Totham although it is unknown whether this is primary, secondary or a combination (Haslam *et al.* 1980; McDonnell 1988; Starley 1999; Atkins *et al.* 2010: 60-62).

The evidence above suggests that practically every settlement had a smithy. Ireland was no different as the evidence there suggests that iron was being forged in virtually every village (Scott 1991a).

There is far more evidence for iron smithing in Europe in the early medieval period, but like Britain, very few actual smithy workshops have been identified. The exception is Snorup which not only had smelting furnaces but also the location of the smithy hearth and anvil was located using the large quantities of hammerscale and smithing slag (Voss 1993: 209; Birch 2011). Evidence for early 5^{th}-7^{th} century smithing is very limited. Later 9^{th}-11^{th} century smithing slag has been found throughout the continent in many settlements (Pleiner 2006), with large smithy workshops identified at Menzlin in Germany, Hedeby and Fyrkat in Denmark and the royal palace at Tilleda (Pleiner 2006).

Ironworking Models

There are three possible models for the production of iron objects in the early medieval period these were devised by McDonnell, the author and Rubinson during the review of the evidence at the Wharram Percy's smithy (Figure 3.12; McDonnell *et al.* Forthcoming). While it is possible that each of the models described below can be independent of the other models, it is equally likely that there could be a mixture of two or three models taking place at any one settlement. For example, some rarer iron alloys such as high-quality high carbon steel may have been imported into some smithy sites to create composite iron artefacts, even though the same site is smelting its own iron. In addition the same site may also be importing some artefacts from sites elsewhere. With each of the above models it is possible that both repairing and recycling of iron objects was also taking place producing evidence in the form of smithing slag. But this would also result in clear evidence in the microstructure of the objects when analysed.

Model 1: Self-sufficient Model. The whole process from collection of raw materials, to smelting to create iron and manufacture of an object is taking place entirely in the same settlement. The evidence for this model includes the presence of raw materials (e.g. ore, fuel and clay), the remains of a smelting furnace and the resulting smelting slag or on rare occasions the iron bloom. In addition, the evidence for the smithing of the artefact must also be present, including smithing hearth remains, smithing slag, stock iron, and/or partially complete iron objects.

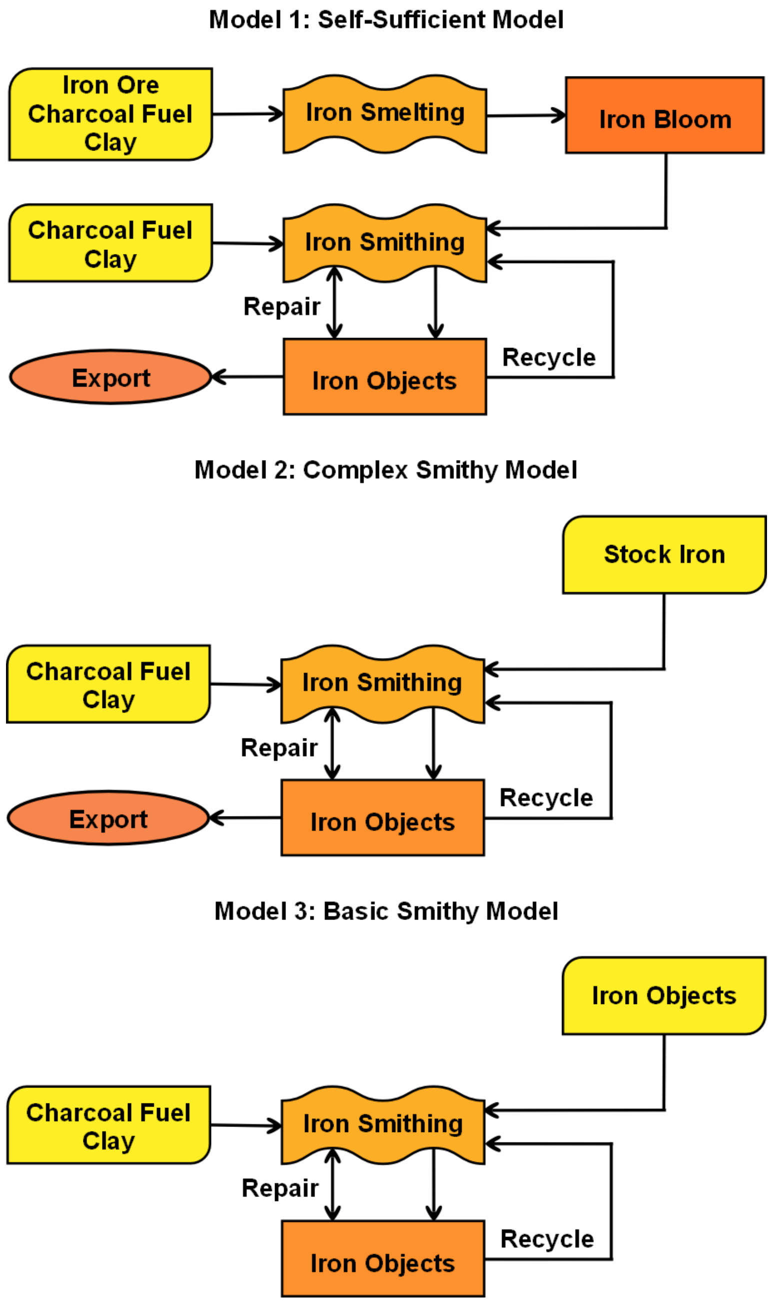


Figure 3.12: Diagrams of the three different ironworking landscape models.

Model 2: Complex Smithy Model. Imported stock iron in the form of bars, billets and strips was used to manufacture iron objects. The evidence for this model consists of smithing hearth remains and smithing slag, stock iron and partially complete artefacts. Within this model there are two possibilities. The first is that there is a permanent smithy based in the settlement; another possibility is that the smithy may have been itinerant. The best evidence to suggest a smithy based solely in the village would be the presence of a permanent smithy structure with hearth. Bars left at the site also support the presence of a permanent smithy as any itinerant smith would most likely take any stock iron with them when they moved to the next location. Very few smithies have actually been identified therefore the amount and concentration of smithing slag could be used to indicate the scale of manufacture and therefore how frequently the smith was working. In addition, the size of the consumer base would also be a good indicator to how often the smithy would be needed.

Model 3: Basic Smithy Model. Every iron artefact was being imported to the site from elsewhere. In this model there should be no evidence for smithing of new iron objects. For example, no partially complete objects or stock iron should be present on the site. There could still be some smithing slag as occasionally imported iron objects may have need to be repaired.

The archaeological evidence suggests that during the early medieval period there were a number of iron production centres, often located away from settlements. Some of these centres were found associated with royal or ecclesiastical estates suggesting a certain amount of control over this resource (Loveluck 1998; Hamerow 2002: 189). In stark contrast smithing slag is the most common ironworking residue found on early medieval settlement sites, suggesting that smithing was a craft carried out close to the consumer (McDonnell 1987e; Serneels & Perret 2003). Therefore stock iron was most likely traded between these iron making centres into the settlements.

Early Medieval Status of the Smithy

Although the social position occupied by the rural craft worker is poorly understood, a great deal of consideration has been given to the status of the early smith (Scott 1991a: 184). This is primarily because the ability to produce metal objects seems to be closely linked to political and military power (Hinton 2005: 54, 98-99). The blacksmith obviously was of great importance to early medieval society as many place names in Europe are associated with blacksmiths or their forges (Scott 1991a: 184).

Previous discussions have centred on whether the early medieval smith was ‘free’ or bound to a lord. It is unlikely to be this simple (Hinton 2000: 112-113). There is evidence to suggest that the status of a craft worker also depended upon his or her social status at birth (Faull & Moorhouse 1981: 771-773). For example in Irish literature the blacksmith was high-status often given magic and/or religious status, associated with many myths and legends (Figure 3.13), although sometimes they were seen by early Christians as a bad influence (Scott 1991a: 185-186). This unease of those with magical skills can be clearly seen in the isolated nature of the Tattershall Thorpe smith, buried on the edge of the kingdom and fens (Hinton 2000: 115; Hinton 2005: 70). There are many levels of blacksmith skill from the experienced, highly skilled weapon smith to the village smith who mainly constructed, or repaired, tools for agricultural activities. The majority of blacksmiths provided an important service to the community by manufacturing and repairing iron items used in the home or during work (Faull & Moorhouse 1981: 771-773). A tiny percentage of graves during the early medieval period contained tools. To date only one grave at Tattershall Thorpe belonged to a metal smith who was buried with scrap metal, garnets, glass and tools (Hinton 2000: 110-112). This therefore indicates that only a small proportion of the population probably carried out the craft (James 1991: 207).

Figure 3.13: Wood carving from a door frame of Hylestad church, Norway (Hall 2007: 47) and the Franks casket (photo by E. Blakelock), both show how smiths were generally held in high regard, as high status individuals, so much so that one Anglo-Saxon god was a blacksmith, and supplied armour to the other gods.

Another controversial issue is to what extent smiths were itinerant, or fixed in a particular settlement or bound to a lord. The Tattershall Thorpe smith was not buried with the full set of tools required, perhaps suggesting that he travelled light and the consumer was required to provide some materials (Hinton 2000: 112-113). Most materials such as metal and fuel could be readily supplied but others, like crucibles, which were also missing, may have been harder for a consumer to provide. The isolated nature of the burial of the Tattershall Thorpe smith may be an indicator that he was a stranger to the village and therefore itinerant (Hinton 2000: 115). Another possibility was that the smith was based in a workshop, but those who buried him did not know which tools to include in the grave. The presence of smiths in practically every settlement points to more permanent based smiths. Some establishments may have owned craft workshops and would have needed smiths to work permanently (Hinton 2005: 98-99). Commissioned itinerant metalworkers would not have been ideal, as there are records suggesting that some craft workers would leave the task incomplete (Hinton 2005: 142). In the story of Weland the smith the king Niðhad hamstrung Weland to force him to remain and forge items (Figure 3.13; Hinton 2005: 98-99). It is therefore likely that in this period a combination of itinerant metalworkers, smiths bound to lords and village smiths were present.

Early Medieval Knife Evidence

The data from the review article (Figure 3.5; Blakelock & McDonnell 2007) on the early medieval knives from England has shown that the majority of knives found in both cemeteries and settlements had curved backs (Form B). Angle-back knives (Form A) were also fairly well represented in both types of contexts, although more appear to occur in the later settlement sites. The vast majority of incurved (Form C) and straight-back knives (Form D) came from cemetery sites. The differences in knife forms seen in this study may be due to changes in knife preference over time but may also relate to the differences between settlements and cemeteries (Blakelock & McDonnell 2007). Another possibility is that the size and shape is linked to knife use as seen in some medieval illustrations (Figure 3.14). This will be investigated further during this study.

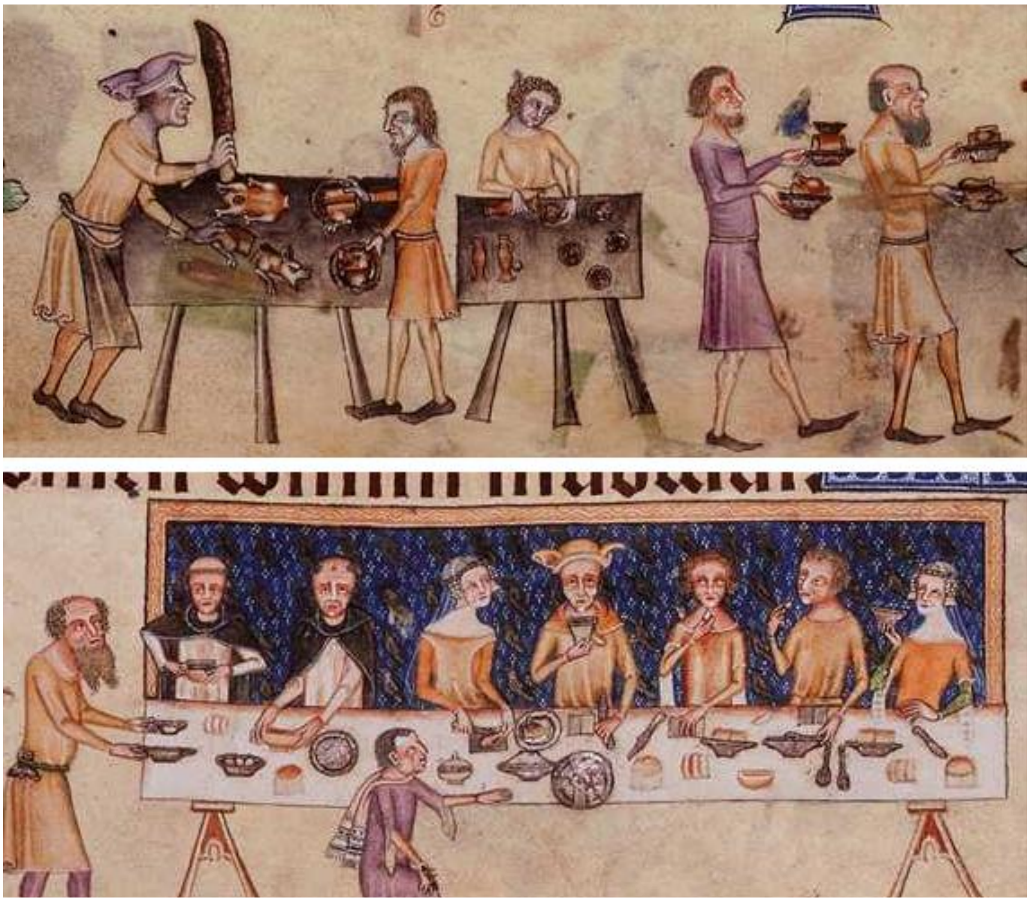


Figure 3.14: Knives seen in the medieval Luttrell Psalter (c.1325-1335) used during food preparation and at a banquet (British Library 2008).

As mentioned in chapter one, previous metallographic studies in the 1980-1990s revealed a number of trends but particularly that the knives from middle and late Saxon settlements, up to the 10th century, were predominately of type 2 manufacture (Figure 3.7; Blakelock & McDonnell 2007). This review also revealed that the early Saxon cemeteries had a much wider variation of manufacturing techniques, with many different manufacturing types present. However it is difficult, on the basis of a small sample, to demonstrate any significant trends. Further metallographic studies of knives from the full spectrum of early medieval sites are required before any of these patterns can be confirmed.

Comprehensive analysis of the Coppergate, York knives, sampled from a range of contexts and phases revealed that during the 10th century there appears to be a change in knife manufacture. After the 10th century the majority of knives analysed were of type 1 manufacture (McDonnell 1992; Blakelock & McDonnell 2007). This pattern has also been noted in Winchester (Tylecote 1990b; Rulton 2003) and medieval London (Cowgill *et al.* 1987: 62–74). On the other hand, in

Russia at Novgorod an entirely different trend is seen, here the prominent knife type in the 9th century is the type 1 which survives after the 12th century when it is replaced with type 2 knives (Thompson *et al.* 1967: 73-74; Brisbane 1992: 73-75).

The vast majority of knives from early medieval settlements and cemeteries had heat treated edges (Blakelock & McDonnell 2007). Over 70% of the knives from urban settlements such as Hamwic (McDonnell 1987a,d), Fishergate (Wiemer 1993) and Coppergate (McDonnell 1992) were heat treated. The different methods of heat-treating knives in the early medieval period will be investigated, as well as the frequency of heat-treatments.

In Europe relatively more metallographic studies of iron artefacts have been carried out and many of these were much larger projects with more samples (Tylecote & Gilmour 1986: 1-3). A particularly large study was undertaken by Kolchin on the material from Novgorod (Thompson *et al.* 1967: 73-74; Brisbane 1992: 73-75). For the past 70 years metallurgical examination of early iron implements have been undertaken in numerous countries, with studies of early medieval iron artefacts have been carried out in Ireland (Scott 1991a: 99-150,nd), Poland (Piaskowski 1961), Denmark (Lyngstrøm 2008), Bohemia (Hošek 2003) and Sweden (Tomtlund 1973; Lamm & Lundstrom 1978; Modin & Lagerquist 1978; Modin 1983; Lamm 1991). Unfortunately many of these studies were not carried out using all the techniques available during this study. Some studies were hampered by the lack of expensive scientific techniques (e.g. SEM-EDS chemical analysis), restricted access to the material, or the inability to section, while other researchers neglected to report important features such as heat-treatment of the knives.

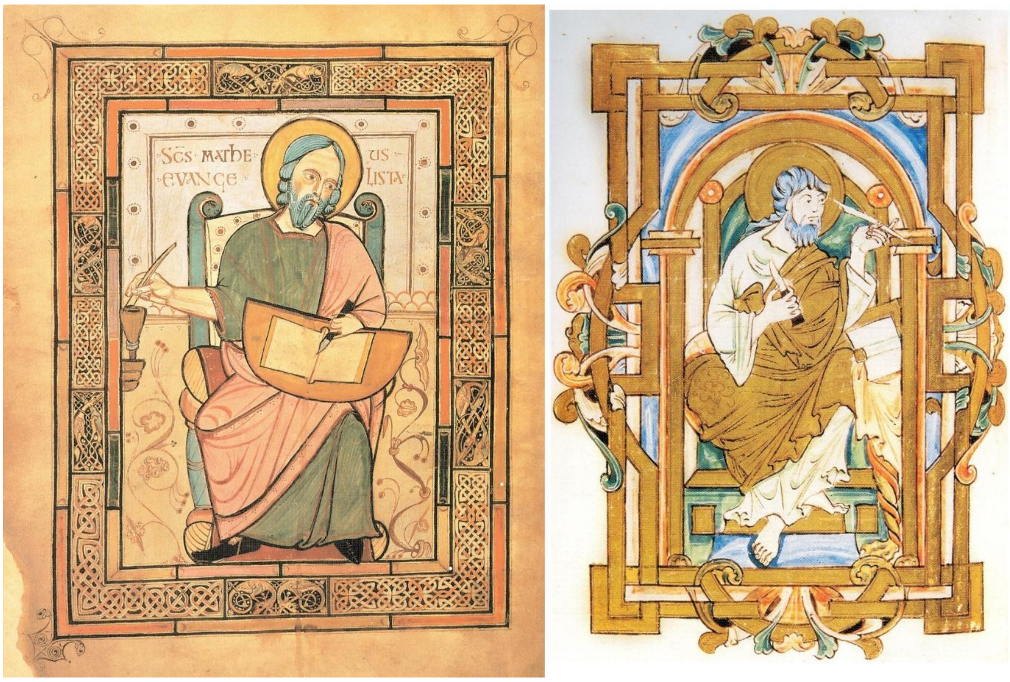


Figure 3.15: Anglo-Saxon knives seen in manuscripts; (left) the Barberini Gospels (Brown 2007: 66) and (right) the Eadui Codex (Brown 2007: 155).

The shape and size of the knife, especially the cutting edge and knife tip, would most likely determine its function. The handle length and materials used may also affect the function (Cowgill *et al.* 1987: 51). Historic illustrations such as manuscripts and sculpture can also provide clues as to how objects were used in everyday life (Cowgill *et al.* 1987: 57). Knives were often depicted in later medieval manuscripts (Figure 3.14), where a variety of activities are seen from everyday tasks such as eating and preparing food, to more specialised examples: craft working and other work related activities (Cowgill *et al.* 1987, 57). In comparison knives in Anglo-Saxon manuscripts are rare. Most examples are either related to the clergy, presumably to sharpen quills (Figure 3.15; Ohlgren 1992; Brown 2007). This is supported by a riddle in the Exeter Book manuscript which describes how a knife was used alongside the reed pen (Porter 1995: 93). Other examples show the use of knives during preparation, and consumption of food (Figure 3.16; Ohlgren 1992). Again a riddle in the Exeter manuscript describes using a knife to open oysters (Porter 1995: 107).

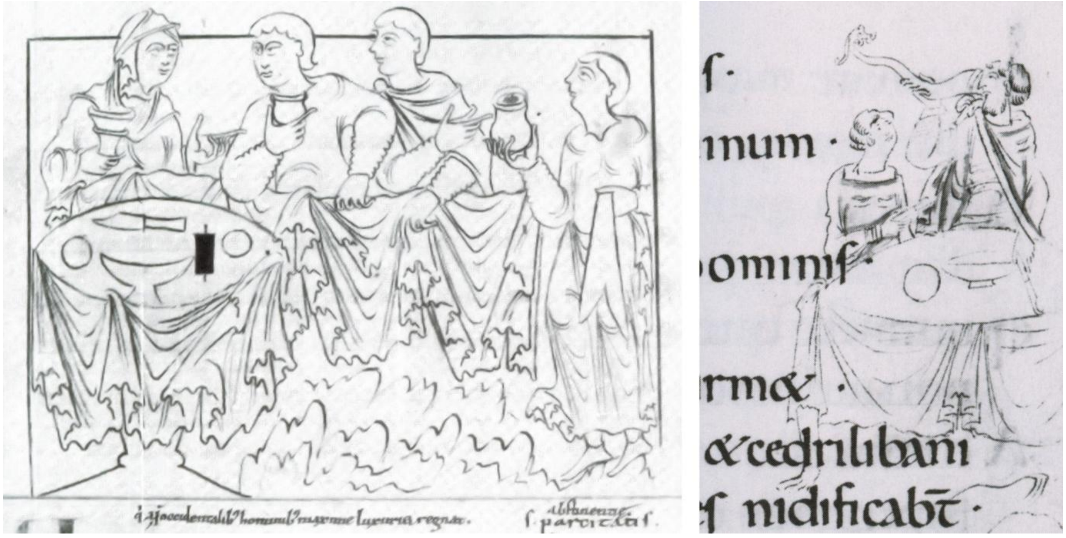


Figure 3.16: Shows knives in Anglo-Saxon manuscripts being used at the table in the Psychomachia of Prudentius, at the British Museum, dated to the 10th-11th century (Ohlgren 1992: 497) and also in the Bury Psalter, at the Vatican Bibloteca Apostolica, and is similar to the Harley Psalter dated to the 11th century, where a woman is passing a knife to the man next to her (Ohlgren 1992: 289).

3.6 Summary

This chapter has revealed that while many artefacts in the early medieval period are constructed from iron, there are relatively few smelting sites identified. The few large rural smelting sites mentioned are often associated with ecclesiastical sites like Romsey and Ramsbury, suggesting that some iron production may have been controlled by royalty or the church On the other hand practically every settlement, be it urban or rural, had evidence for blacksmithing. Different iron alloys were available to create complex iron artefacts, including iron knives. These iron alloys were most likely traded between these rural smelting centres and the large number of rural and urban smithies. Blacksmiths used a variety of different techniques while manufacturing knives, such as welding, heat-treatments such as quenching and tempering and forging to shape the knives. Previous studies of iron knives have revealed several patterns which will be explored further during this study.

Chapter 4: Methodology

4.1 Introduction

This chapter describes the analytical techniques performed during this PhD research. In many cases there are alternate techniques to those described here, but the methodology used depended on three major factors. The first is access to equipment and consumables, although during the course of this research some consumables did change. The second is suitability of a choice in the light of the research questions. The third factor was to create new data that would fit in with existing and current work elsewhere, in order to make it easily comparable. The same three factors apply to the choices of sample preparation and presentation of results.

The chapter is split into four different sections. The first section is the methodology for the x-radiograph studies (section 4.2). This was carried out on all samples prior to metallographic analysis to assess the condition of each assemblage, and therefore determine how viable it was for further analysis. X-radiograph analysis was also used in its own right to investigate the overall assemblage as it is impractical to metallographically examine all iron knives from a site (Fell *et al.* 2006; Blakelock & McDonnell 2007). The second section discusses the decisions around sample selection, from the perspective of both the assemblage and individual knife. To a certain extent this was predetermined due to willingness of site or museum directors (section 4.3). The third section describes in detail the sample preparation (section 4.4). The subsequent analysis undertaken for each archaeological sample and a brief introduction to metallographic analysis is included in section 4.5.

4.2 X-Radiograph Study

Taking X-radiographs

In most cases old x-radiographs were used, but in some cases new x-radiographs were taken when no x-radiographs were available. X-radiography was also undertaken if the knives have been in storage for a long period since the initial x-radiographs were carried out or if the x-radiographs were in poor condition.

New x-radiographs were taken using a HP Cabinet x-ray System (Faxitron series) with a working distance of 25cm. As the current is fixed at 3A, different exposures were achieved by changing the kV and exposure time. In the vast majority of cases to get the best contrast 120kV was used. Samples were exposed for 2 minutes, and occasionally 1 minute when the sample was badly corroded, this allowed the differences in density and amount of corrosion to be seen. Lead intensifying screens were used in the film cassettes to reduce the amount of scatter produced by the object itself during the x-ray process, but also from the floor and wall surfaces. The lead screen also intensifies the image by emitting electrons which contribute to the development of the film (Lang & Middleton 1997: 10-11).

Every x-radiograph was scanned and saved using an Agfa FS50B scanner with Radview Workstation software with a pixel pitch of 50 microns. The scanner with its associated software allowed for detailed enhancement and examination of the x-radiographs providing better quality data.

X-Radiograph Analysis

The corrosion layers present on the knives can often mask the form of the knife, therefore the x-radiographs were used to determine the original knife shape. As discussed in the previous chapter three very different typologies Evison, Ottaway and McDonnell have often been used during typological studies. For the review paper (Blakelock & McDonnell 2007) and subsequently this study a new simpler typology (Figure 4.1) was created, one based solely on the shape of the knife back (Blakelock 2006; Blakelock & McDonnell 2007). Specifically for this study another typology was created to work alongside the back shape types devised. It was used to examine the tang to blade interface, identifying distinct interfaces on both sides, one side only or blades with no interface (Figure 4.1). This allowed detailed classification of a knife to be determined using the two separate typologies, e.g. an angled-back knife with a distinct tang interface on both sides would be an A/1. The new original typology allows objects to be classified even if a significant proportion of the knife has broken.

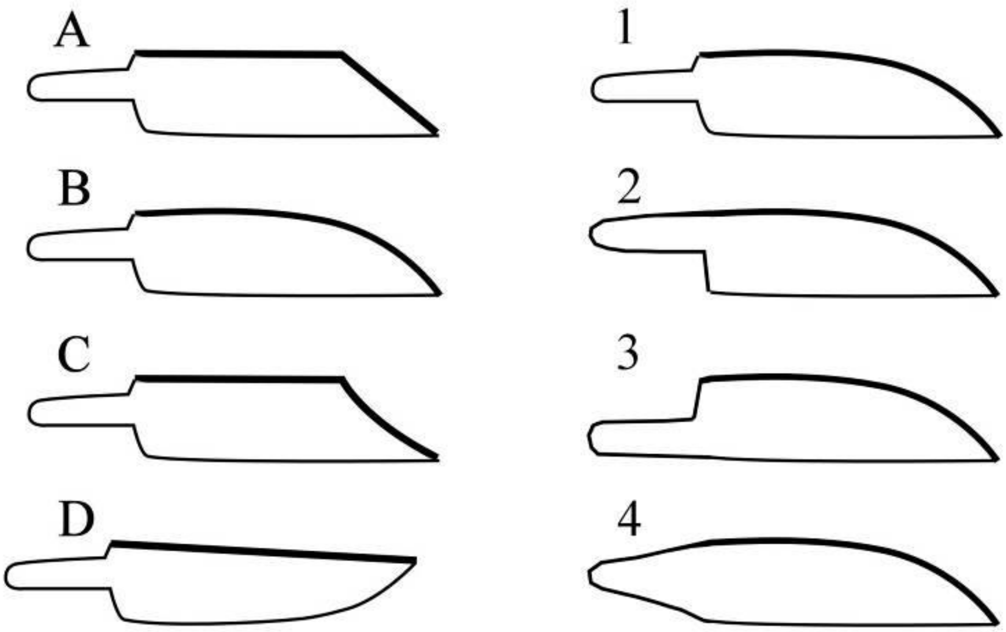


Figure 4.1: New knife typology based on the shape of the knife back alone. Also included is the simple knife typology for the tang interface.

X-radiographs of the knives were examined to identify manufacturing methods by noting the presence of weld lines and/or steel cutting edges. Weld lines occur as distinct lines on x-radiographs. Metallographic analysis of these weld lines revealed that in many cases the slag inclusions present in the weld acted as pathways for corrosion to take place (Figure 4.2).

During the analysis of the Hamwic (McDonnell 1987a,d) and Coppergate knives (McDonnell 1992) it became apparent that the high-quality steel edges had a characteristic x-radiographic image. This was also noted on x-radiographs by Fell and Starley (Starley 1996; Fell & Starley 1999). The 'spotted' appearance (Figure 4.2) was originally thought to be due to the presence of spheroidal slag inclusions, but the metallographic analysis during this research has revealed that it is most likely due to the corrosion found on tempered martensite or martensite cutting edges.

Using these features it is possible to identify a type 2 knife based on the presence of a weld line, with (or without) the 'spotted' appearance (i.e. figure 4.2 which is a good example of a type 2 knife which was clearly visible on the x-radiograph). Identification of other types of knives is more difficult. The type 1 and 5 knives can possibly be identified by the presence of steel with the absence of a weld line, although it is difficult to distinguish between them without metallographic analysis. Even though features seen in x-radiographs can be essential to the analysis of the assemblage as a whole, metallographic analysis is still required to confirm features. For example, an extremely good weld line will often by invisible on x-radiographs due to a lack of slag inclusions and/or a lack of corrosion penetration.

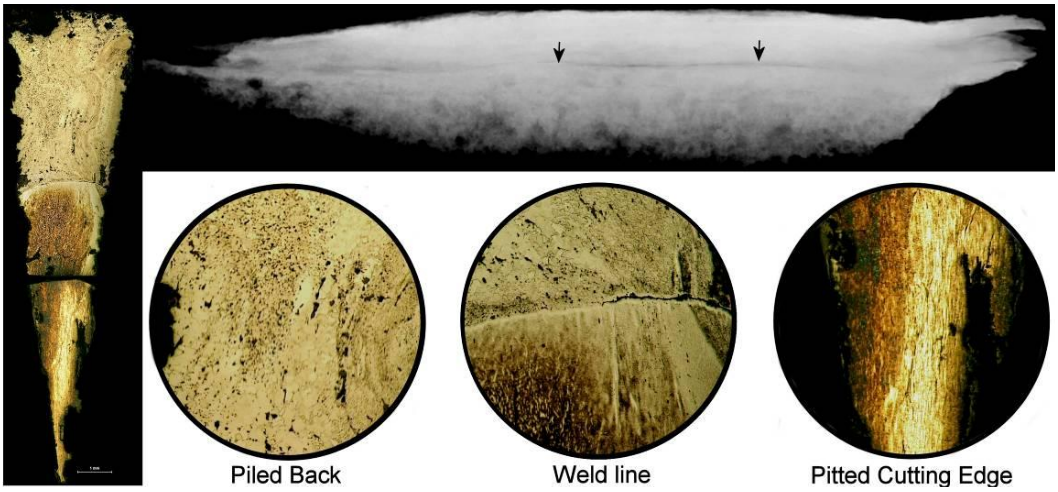


Figure 4.2: X-radiograph and corresponding metallographic section of knife 14241 (B/2 type) from Christchurch Place, Dublin. Note the 'spotted' texture indicative of heat-treated steel in the cutting edge (bottom strip) and a distinct weld line running along the blade (indicated by arrows). The x-radiograph also suggested a piled back.

The x-radiographs were also used to assess the amount of wear present in the knives therefore assisting in the interpretation of knife use. Ottaway (1992: 572-574) has suggested that the wear of knives depends on their method of construction. At Coppergate for example the type 1 'sandwich' knives frequently had an elongated S-shape (Figure 4.3) indicating they were heavily worn (Ottaway 1992: 572-574). Other studies have shown that this is not always the case as type 2 knives have also been found heavily worn (Blakelock 2007b).

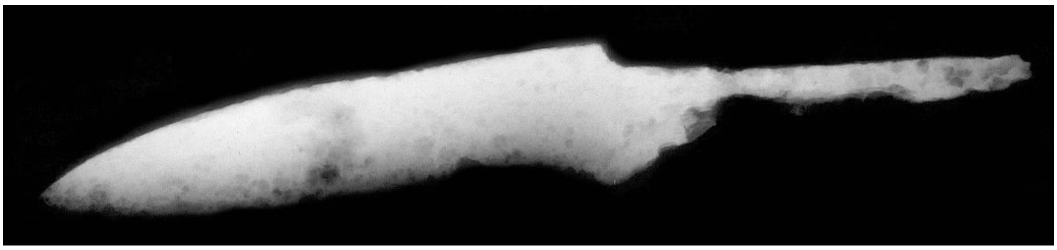


Figure 4.3: X-radiograph of knife 7695 (B/1 type) from Fishamble Street, Dublin showing the distinctive S-shape curved cutting edge indicating wear.

X-radiographs can also reveal other details about knives, which are often masked by the corrosion products. Transverse notches have been identified on a number of knives, most often at the shoulder. In other cases straight grooves in the knife backs are also found, and occasionally both grooves and notches are found on the same knife (Figure 4.4). Another form of decoration is the inlay and use of non-ferrous metal; this can often be seen as distinct brighter areas on x-radiographs (Figure 4.5). The final form of decoration is pattern welding, the pinnacle of the smith's art. This can clearly be seen in x-radiographs, not only through the many striations but also the differences in density between the different iron alloys used (Figure 4.6). Pivoting or folding knives can also be identified using x-radiographs, using both the shape and the presence of a rivet as an indication.

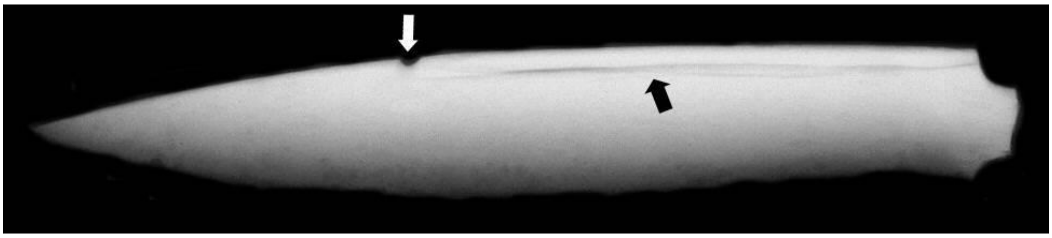


Figure 4.4: X-radiograph of knife 14725 (A/1 type) from Christchurch Place, Dublin. This is an example of a knife with both a notch (white arrow) and an indent (black arrow) in the back.

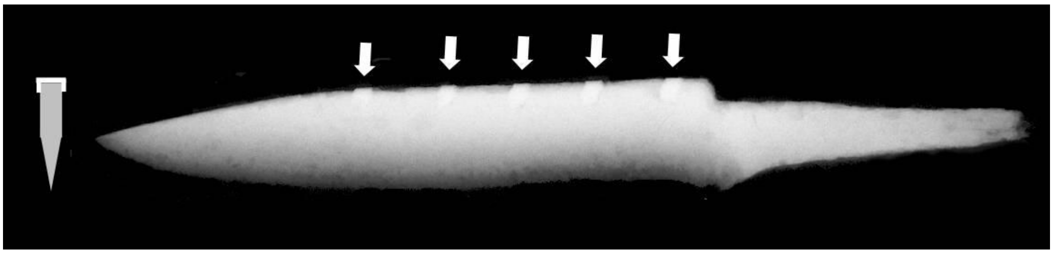


Figure 4.5: X-radiograph of knife 3840 (A/3 type) from Fishamble Street, Dublin showing the non-ferrous staples on the back of the knife. Also shown is a diagram (left) indicating how the knife may have been constructed, with the non-ferrous metal strip indicated by the white areas.

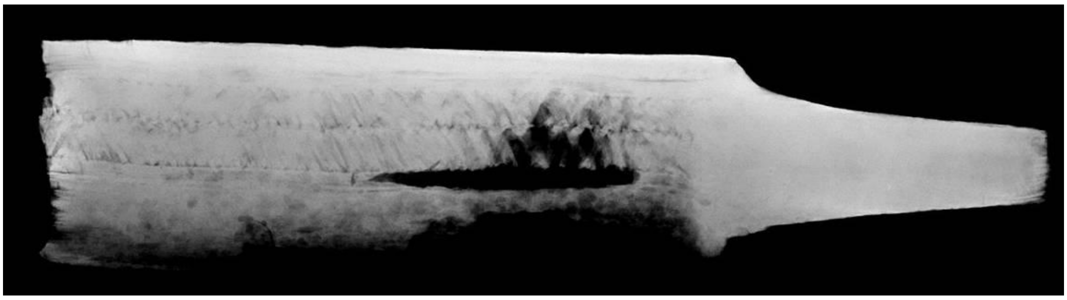


Figure 4.6: X-radiograph of knife 2475 (X/1 type) from Fishamble Street, Dublin showing pattern welding.

4.3 Sample Choice

Samples were sought from target sites across England, Scotland and also on the Continent. This research analysed new samples from the full spectrum of sites found in the early medieval period, especially those neglected by past studies. This includes early Saxon or Post-Roman settlements, inhumation and cremation cemeteries as well as more middle to later Saxon rural settlements. Over 500 knives from Viking Dublin were recovered during excavations in the 1960-80s, therefore a large scale analysis was carried out, to allow comparison with other contemporary knives like those from Anglo-Scandinavian York and Novgorod.

There were two main criteria used when choosing samples. The first was that samples had to be from securely dated contexts, the only exceptions being the more unusual objects such as the pivoting knife from Burdale and the pattern welded knife from Dublin, but in both these cases the sites themselves were fairly securely dated. The second criteria, based on their x-radiographs, was that samples had to have a significant proportion of metal surviving, to ensure there was metal available for metallographic analysis. When multiple samples that fulfilled both criteria were available, samples were taken from a range of archaeological typologies, and the x-radiographs were used to select those that displayed a range of different manufacturing techniques. This was to ensure that a representative sample of the whole assemblage was analysed.

4.4 Sample Preparation

Prior to removing sections from the samples, each knife was recorded: including knife dimensions, typology, wear and corrosion. In addition any mineralised organic remains were identified and recorded. Photographs of each knife were taken using a Sony digital camera. Mineralised organic remains were examined and recorded using a scanning electron microscope under low vacuum and using a low KV (15KV). Images were taken at various magnifications.

Figure 4.7: Photograph showing a knife after two half sections have been removed.

Sections from the knives were removed from across the blade cutting edge and knife back, where possible these were staggered to preserve the overall knife shape (Figure 4.7). Full sections were only taken if the knife was considered too badly corroded to attempt half sections, or if the knife broke during cutting. An Isomet Microslice slow speed wafering saw was used in the majority of cases, but sections from very fragile artefacts were removed using a vice to secure the knife and a jewellers piercing saw. The samples were either mounted using Fastech mounting solution (Wharram Percy and Burdale) or an epoxy resin (the remainder) and prepared by grinding on successively finer grinding paper before being polished to a 1-micron finish.

4.5 Sample Analysis

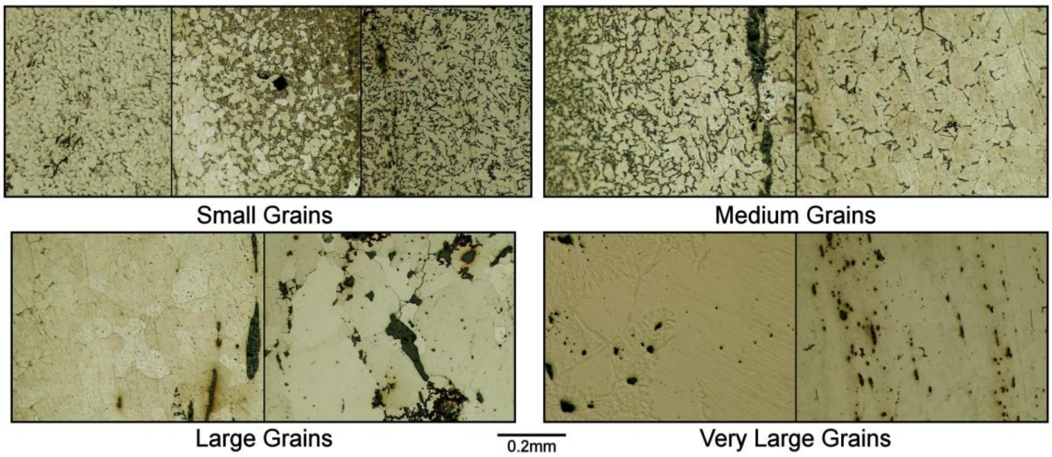


Figure 4.8: Figure showing the grain size categories: small (ASTM 6-8), medium (ASTM 4-5), large (ASTM 2-3) and very large (ASTM 1).

Metallographic examination was carried out using a Nikon Optiphot Reflected Light microscope with various objective lenses, ranging from x2.5 to x40. The microscope is fitted with a graticule eyepiece, which has 8 options of grain size for comparison at x10 objective magnification allowing the ferrite grain sizes to be estimated. Even with this graticule achieving consistent results is difficult therefore during this analysis the grain size will be grouped into four categories (Figure 4.8), small (ASTM 6-8), medium (ASTM 4-5), large (ASTM 2-3) and very large (ASTM 1, or bigger). Digital images were captured using a camera fitted to the Nikon microscope and Fire-I imaging software. The samples were then etched for approximately 5-10 seconds in a weak solution of acid (Nital, 4% nitric acid in alcohol) to reveal the microstructure of the metal. Vickers micro-hardness test was then used to determine the hardness of the different microstructures present in each sample. A load of 200g is applied (100g was used when analysing the Wharram Percy knives) and the indent measured. Multiple measurements were taken per knife, often between 16 and 21, these were distributed between different areas of each knife.

The Scanning Electron Microscope with Energy Dispersive X-Ray Analysis (SEM-EDX) was used to determine the elemental composition of the metal. Calibration was carried out using a cobalt standard. The spectra were collected at 20kV accelerating voltage and 2nA filament current for 100 seconds live time. The spectra were then quantified using the Oxford Instruments SEMQuant software. To allow for the heterogeneous nature of the metal an average of three or four analyses were carried out in each area of interest.

Slag Inclusion Distribution

Each sample was first examined in the as-polished state to investigate the distribution of slag inclusions and corrosion. Slag inclusions come in a range of shapes, sizes and vary in the number and types of phases present (Figure 4.9). The presence of slag inclusions are often noted during metallographic studies, but only recently have they become more important to archaeometallurgists. Even so they are rarely systematically recorded. The slag inclusions in this study will primarily be used to help identify different pieces of iron in the knife.

During this study the distribution and types of slag inclusions in each sample were noted. To make this process easier a figure showing the shapes and phases present was created (Figure 4.9). The shapes were split into five main types; rounded/spherical, elongated, sub-rounded, sub-angular and angular. Even so allocating shape to inclusions is not always very accurate as each individual researcher may view and allocate shapes differently, as it is not yet an exact science. Future studies and the use of microscope software packages may assist in this type of research. Inclusions with different phases present were also observed and noted. A range of inclusion types were identified during this analysis but three main groups were identified; single-phased with only the glassy phase present and two different types of multi-phased inclusions, although most usually consisted of fayalite in a glassy matrix, while the other type also included some retained FeO in the form of wüstite.

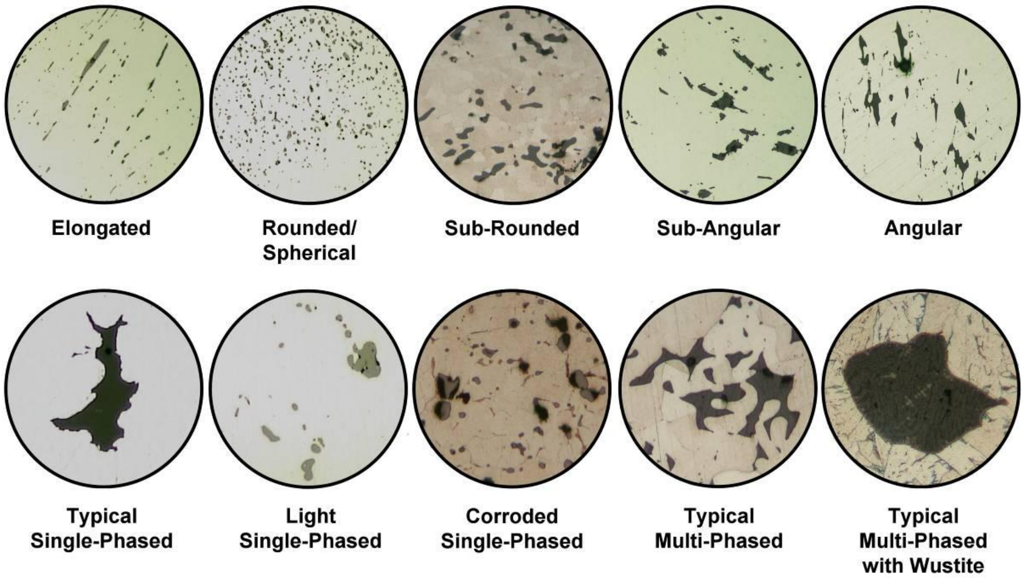


Figure 4.9: Different types of slag inclusions. The top row shows the different shapes identified while the bottom row shows the main phases present in inclusions.

There has been a lot of research recently into the use of slag inclusions as a provenance technique (Buchwald & Wivel 1998; Coustures *et al.* 2003; Dillmann & L'Heritier 2007; Blakelock *et al.* 2009). This technique is very time consuming, as each piece of different iron alloy would require at least 30 inclusions to be analysed using SEM-EDS. Since a single knife can be made of multiple pieces of iron it would take several hours to analyse each knife and additional time to process the data. This type of research is still at its infancy and, at this point in time, even if this data could be collected there is no consensus as to how the data should be utilised and applied. Other issues remain to be resolved, for example it is unknown what effect smithing has on the slag inclusions in iron. Therefore, bearing all this in mind it was felt that the analysis of slag inclusions to provenance the iron is beyond the scope of this PhD, but this could be a future avenue for research.

Metallographic Analysis

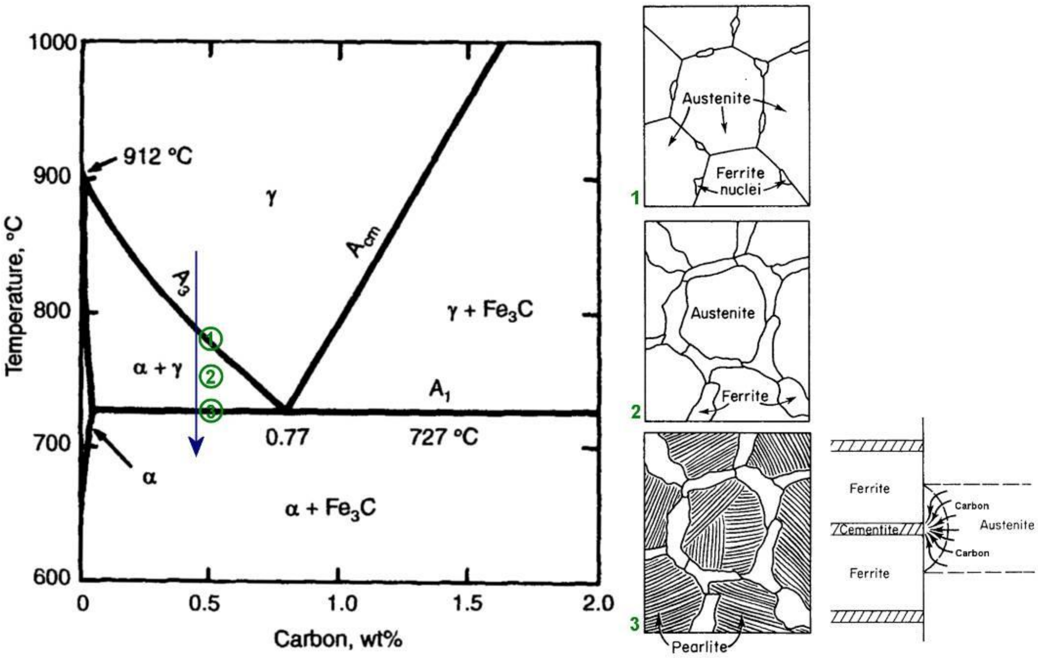


Figure 4.10: Iron-carbon diagram and a series of diagrams showing the formation of a mild-steel (Reed-Hill 1973: 691; Samuels 1999: 29).

Most archaeological iron is a low-mid carbon steel and consists predominately of grains of ferrite and pearlite, which are formed during the cooling of the iron from the austenite temperature. Ferrite is the first component to solidify and forms at ferrite nuclei. As the temperature of the iron falls below the eutectic line, the remaining austenite solidifies as plates of ferrite and carbon rich cementite (FeC_3), thus creating pearlite (Figure 4.10).

The iron carbon thermal diagram can be used in conjunction with the microstructures seen in archaeological samples to accurately determine the carbon content of mild steels. This is due to the nature of the thermal diagram which, when the lever rule is applied, allows the carbon content to be estimated based on the amount of pearlite, compared to ferrite. In the sample (Figure 4.11); 0% pearlite equals 0% carbon, 25% pearlite equals 0.2% carbon, 50% pearlite equals 0.4% carbon, 75% pearlite equals 0.6% and 100% pearlite is present at the eutectic point and therefore means 0.77% carbon. It is much harder to determine the exact carbon content of higher carbon steels, but the microstructure still provides a fairly good method of determining carbon content. In addition, it can also be difficult to distinguish between steels with more than 0.7% carbon and hypereutectoid steels up to 1.2%. This is because cementite in the hypereutectoid steels looks very similar to the grain boundary ferrite seen in 0.7% carbon steels. The only way to distinguish cementite from ferrite in these cases is by examining the corrosion products (Figure 4.12) as cementite is more corrosion resistant than ferrite and will remain in the iron (Knox 1963; Notis 2002). The amount of carbon present affects the hardness of the sample. Pure ferrite with no impurities is typically c. 100HV, the addition of carbon and the formation of pearlite raises the hardness to c.200-250HV. Cementite in the hyper eutectoid steels increases the hardness further, resulting in c. 250-300HV.

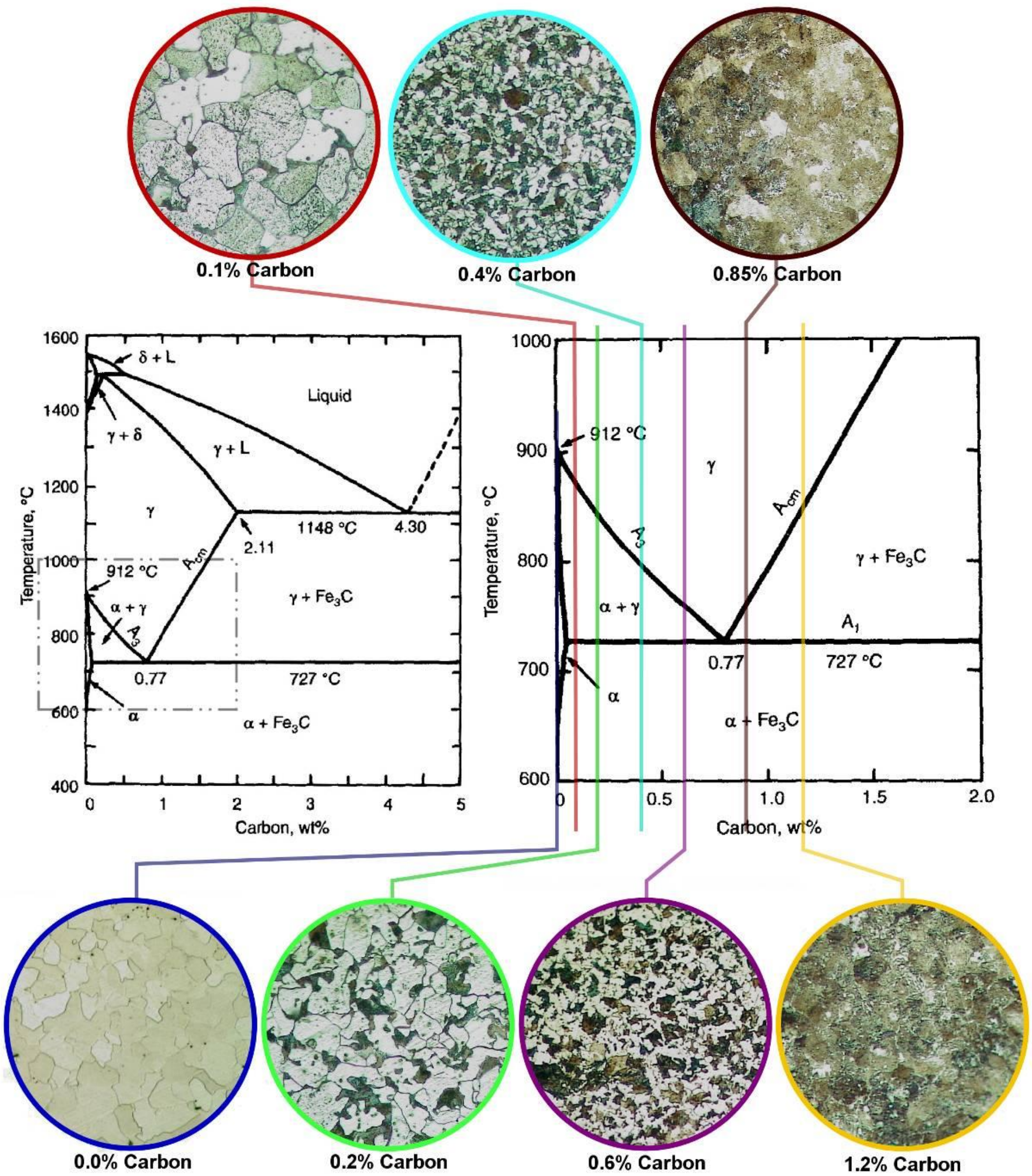


Figure 4.11: Iron-carbon diagram and the metallographic structures of iron after etching with nital with varying amounts of carbon (Samuels 1999: 29). Ferrite is the lighter phase while pearlite is the darker phase.

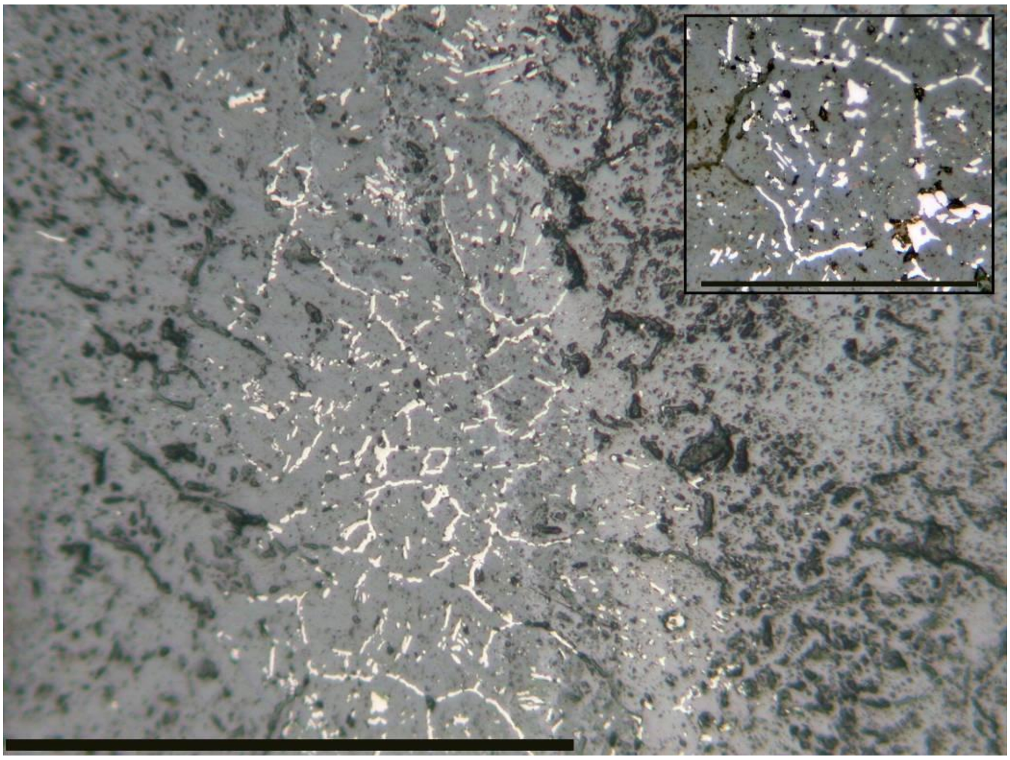


Figure 4.12: Remnant structures in the billet (2876.01) from Beth-Shemesh. Note the remaining metal located at the grain boundaries and within the grains indicating cementite, (plain polarised light, x200, scale bar equals 0.25mm). The inset picture shows a grain at a higher magnification also revealing the darker corrosion product of the cementite, (plain polarised light, x500, scale bar equals 0.1mm) Photo taken by E. Blakelock (Blakelock 2007a).

Phosphoric iron is a common iron alloy utilised during the Saxon period and has been identified by various researchers (McDonnell 1989a; Piaskowski 1989). The amount of phosphorus present in the iron ranges from 0.15% to values up to 2%. There are two main identifiers for phosphoric iron; the first is ghosting and the other is areas of ferrite with extremely large grains, greater that ASTM 2 (Figure 4:13). The exact reason for the ghosting effect is unknown. Phosphoric iron also has an elevated hardness when compared to ferritic iron, in the range of 150-300HV. For this research low phosphorus iron contains between 0.1%-0.3% phosphorus while phosphoric iron contains more than 0.3%.

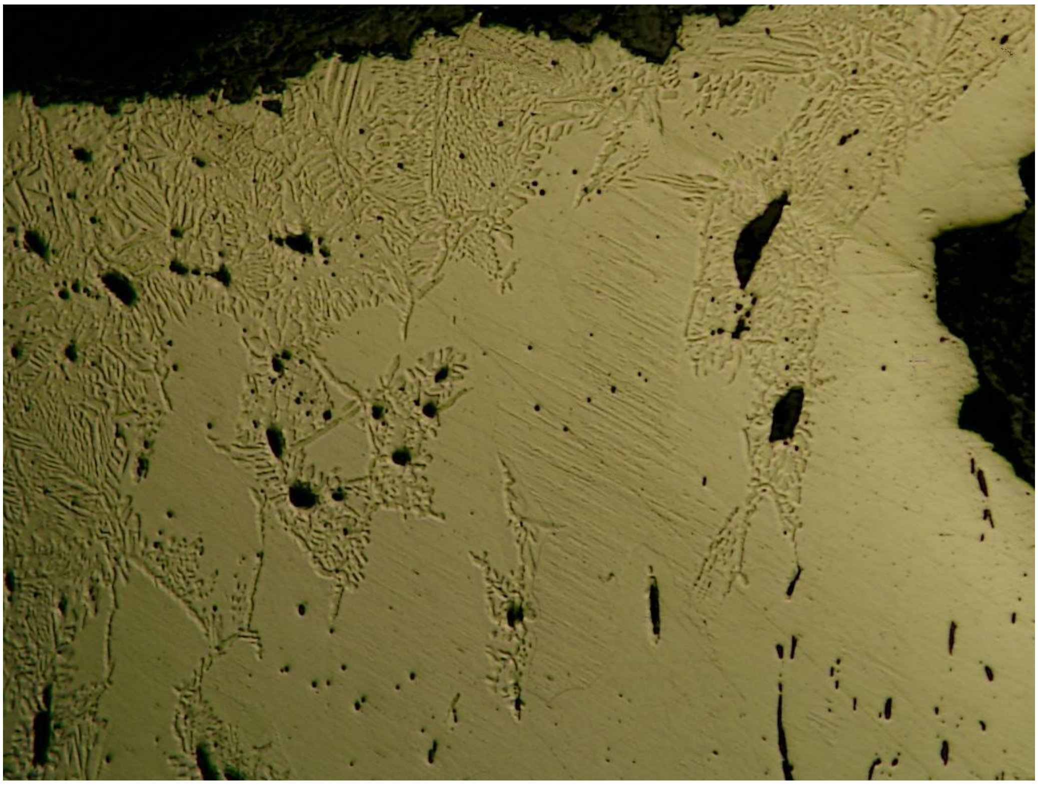


Figure 4.13: Knife 65 from Burdale with both ghosting and large grains indicating phosphoric iron, confirmed by SEM analysis.

A range of more unusual microstructures have been identified during previous research. Neumann bands are clear indicators for cold working, but they only occur after 30-40% reduction of the iron. Cold working iron will also increase the hardness with the greatest increase in hardness (73%) achieved after only 20% reduction, i.e. 110HV of stock iron to 190HV at 20% reduction (Samuels 1999; Swiss & McDonnell 2003: 141-142). The analysis of cremated knives from Lovedon Hill revealed nitride/carbide needles which may be similar to carbonitriding needles, formed when iron is heated at a temperature of 500˚C for 12 hours in an nitrogen atmosphere (Samuels 1999: 416-425), but further research is necessary. Spheriodisation, occurs if the metal is heated to 650˚C and kept at this temperature for at least 8 to 32 hours (Samuels 1999: 427-447) and has also been identified in a number of knives. Both these microstructures are a result from over-heating iron and therefore have a lower hardness.

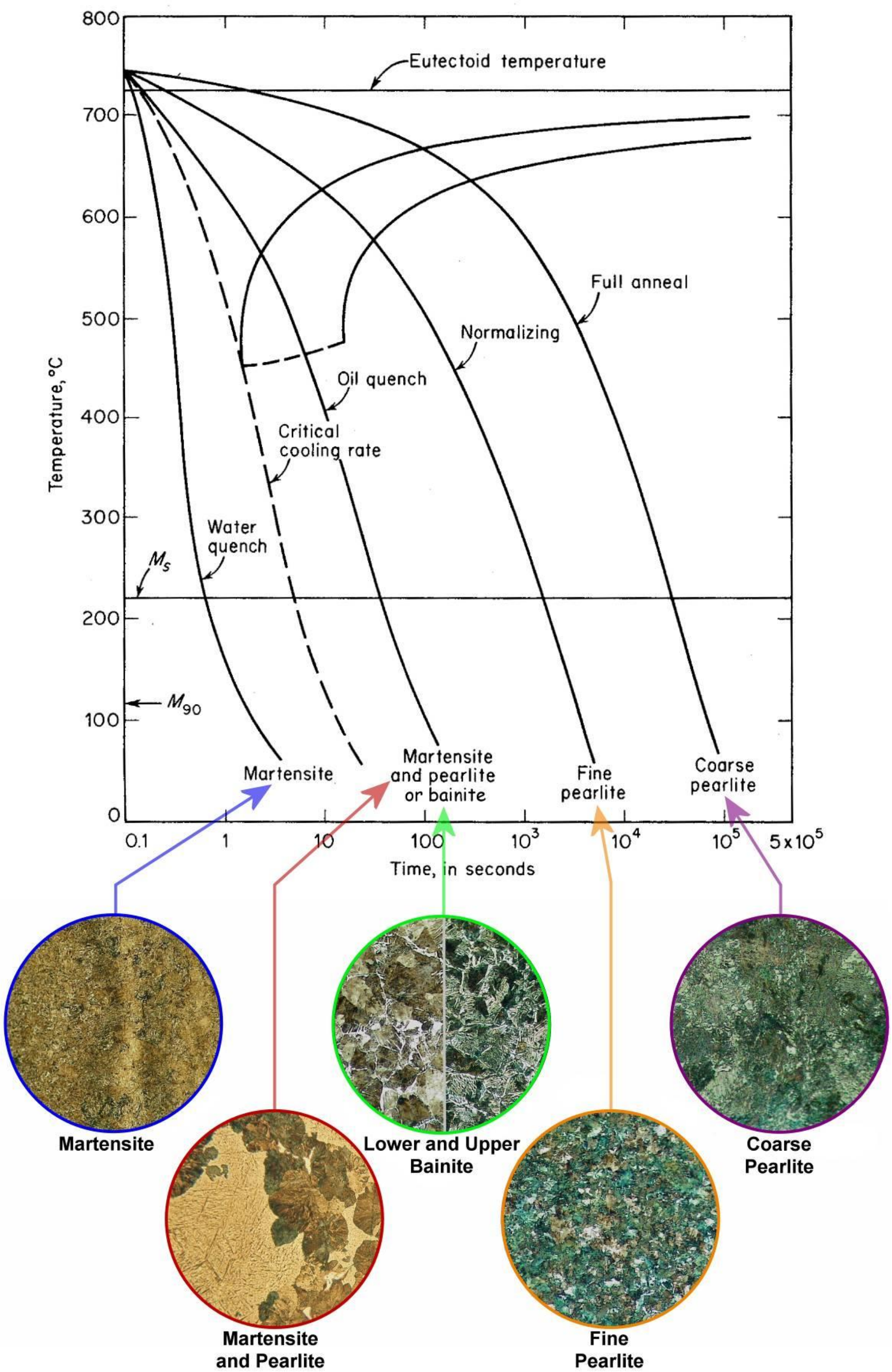


Figure 4.14: Diagram showing cooling rates and their resulting structures (Reed-Hill 1973: 704)

There are two factors that affect the microstructure resulting from heat-treatment. The first is the amount of carbon present in the sample, as steels with less that

0.3% carbon are practically impossible to quench to get the harder phase martensite. On the other hand a 0.8% carbon steel is ideal for heat-treatment at this percentage even a slow cooling will result in martensite. The other important factor is the speed at which the steel is cooled, which can be influenced by the quenching liquid. Oil, unlike water, has a much slower cool rate and will result in a structure of bainite or martensite with pearlite (Figure 4.14).

The main purpose of heat treatment is to enhance the hardness of the steel (Figure 4.15). There are two types of bainite, upper and lower, which form at different temperatures. Since both are the result of a slow quench they will be discussed as one microstructure. Bainite has a higher hardness than pearlite, ranging from 250HV up to 600HV, but the average tends to be c. 300-400HV. In most cases the desired microstructures are martensite and tempered martensite. These both have a very high hardness; martensite 700-1200HV and tempered martensite 500-700HV. It is impossible to accurately determine the amount of carbon present in these microstructures. Since the hardness of these structures is determined to some extent by the carbon, they can be used to suggest a mid or high carbon steel.

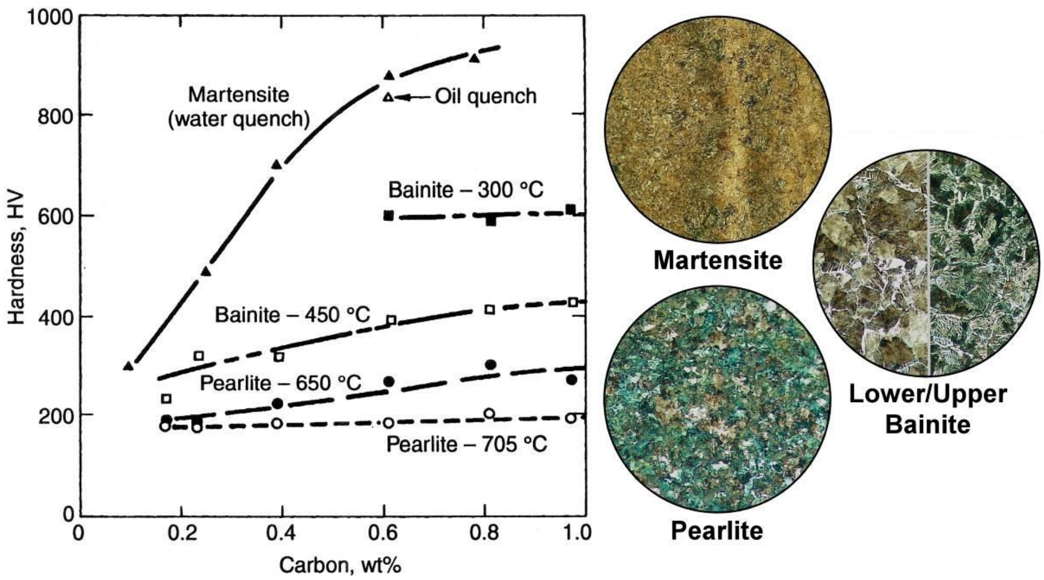


Figure 4.15: Diagram showing the hardness of various microstructures (Samuels 1999: 258).

Compositional Analysis

SEM-EDS analysis of the metal present in the knives is important for several reasons. The main reason is to establish whether phosphorus was present in the iron. Metallographic analysis is used to determine the number of pieces of iron present in the knife, each of these is analysed using the SEM to determine what elements are present. Other than phosphorus the elements detected include arsenic, nickel, copper and manganese.

The second reason for SEM analysis is to study the white weld lines which have been observed in many knives. These usual appear as yellow-white line identified using optical microscopy and are due to arsenic and/or nickel enrichment. Values up to 2.8% have been identified during analysis of other early iron artefacts, and it has been suggested that this effect is due to the accumulation of arsenic at the surface of a piece of iron during oxidation. This is then sealed during welding (Tylecote & Thomsen 1973). Another possibility is that an arsenic and/or nickel rich substance is being added during the welding process (Castagnino 2007).

Most studies have chemically analysed white weld lines using the spot analysis method but I observed that these resulted in very varied results. Therefore for this study a more systematic analysis of white weld lines was carried out using the line scan feature within the INCA software. Over thirty weld lines were examined by taking measurements at 10μm spacing running from the first piece of metal, across the weld line and then into the second piece of metal. In addition three measurements from both pieces of metal were taken, averaged and then included in the line graphs. Some weld lines were also examined at 5μm spacing to identify smaller changes in composition across the weld line. This analysis will determine whether all white weld lines are the same, and or whether there are any patterns in composition, i.e. more arsenic results in a smaller amount of nickel, or vice versa.

Chapter 5: Results

5.1 Introduction

This chapter presents the results from the x-radiograph and metallurgical studies of various sites (**Error! Reference source not found.**). The sites are split into 4 sections, in approximate chronological order. In each section the data collected during the PhD are presented followed by a summary of other relevant data. In this chapter various terms are used to describe the different iron alloys, the definitions of which are given in table 5.1 below. The knife shape and manufacturing typologies referred to in this chapter are available in the appendix volume on page 38 or can be seen below (Figure 5.1).

Iron Alloy	**Microstructure**	**Composition**
Ferritic iron	No pearlite or carbides	Few impurities
Low carbon steel	Ferrite with pearlite	0.1-0.3% carbon
Mid carbon steel	Ferrite and pearlite, and pearlite with ferrite	0.4%-0.6% carbon
High carbon steel	Pearlite, Pearlite with cementite,	0.7%-1% carbon
Low phosphorus iron	Large grains, ghosting and/or high hardness	0.1-0.3% phosphorus
Phosphoric iron	Large grains, ghosting and/or high hardness	0.3% or more phosphorus

Table 5.1: Terms used to describe iron alloys in the results chapter and their definitions.

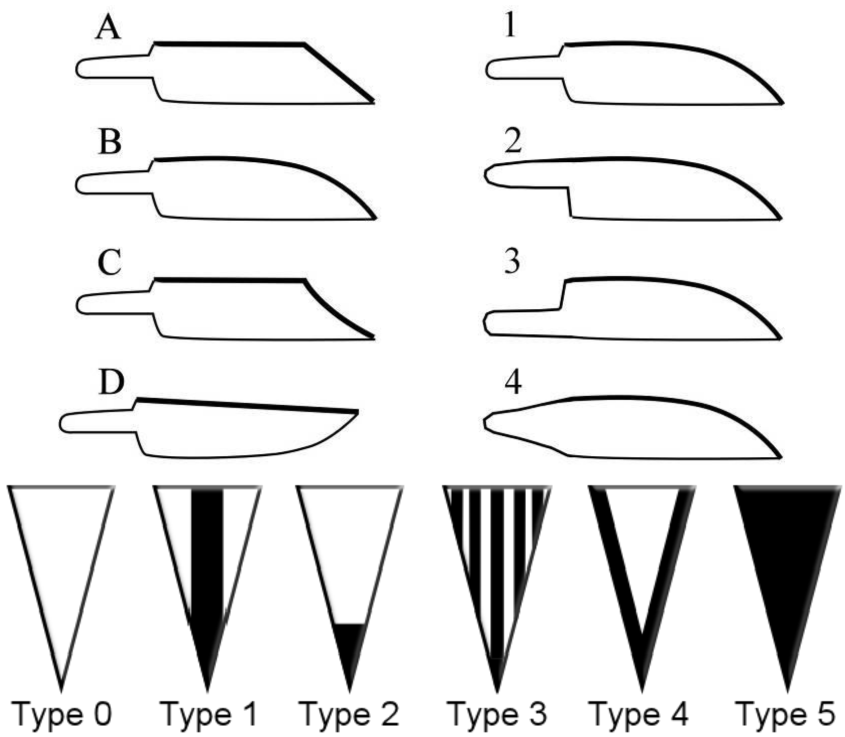


Figure 5.1: On the top is a figure showing the knife back shape and tang to blade interface typologies used in this research. On the bottom is a simplified manufacturing typology.

The first section (5.2) presents the results from the early settlements, which includes early Saxon West Stow and post-Roman Gwithian. The second section (5.3) includes all the early Saxon cemeteries that have been analysed, including Quarrington, Twyford and Collingbourne Ducis. The third section (5.4) groups all the middle-late Saxon settlements. This includes three rural settlements: Wharram Percy, Burdale and Sedgeford. The Wharram Percy assemblage has been re-analysed since (subsequent to an undergraduate dissertation (Blakelock 2006)) and three more knives included. This section also includes the results from the analysis of knives from Whithorn which was a high-status ecclesiastical site.

Figure 5.2: Map showing the location of sites mentioned in this chapter. Symbols with filled centres are those that were analysed during this study while those with white centres were analysed by others, but are also commented on. Red triangles indicate early settlements; purple stars indicate cemeteries; circles indicate middle to late Saxon and Viking settlements (green = rural, black = urban and blue = high status).

The fourth section (5.5) contains all the results from the analysis of the Viking Dublin knives. This section is split into five sub-sections: the first provides the background to Viking Dublin, the next includes the results from the x-radiograph study. After this section the metallographic analysis of knives at each site is reported. The next section summarises all the data from Viking Dublin. Finally there is a summary of pre-Viking and Viking Age knives analysed from other sites across Europe.

West Stow	Early Saxon Settlement
Gwithian	Post-Roman Settlement
Twyford	Saxon Cemetery
Collingbourne Ducis	Saxon Cemetery
Quarrington	Saxon Cemetery
Wharram Percy*	Middle to Late Saxon Rural Settlement
Burdale	Middle to Late Saxon Rural Settlement
Sedgeford	Middle to Late Saxon Rural Settlement
Whithorn	Middle to Late Saxon High Status Settlement
Dublin	Viking Urban Settlement

*Table 5.2: Table of sites analysed for this during this research. * The knives from Wharram Percy previously examined for a undergraduate dissertation were reviewed and more late Saxon knives were analysed.*

The final section of this chapter (5.6) describes the results from the systematic analysis of white weld lines in many knives. Line scans were carried out across weld lines in over 30 knives from a range of different sites. A summary of the results is provided, with some examples; the remaining weld lines information is included in the appendix.

5.2 Early Saxon Settlements

West Stow

The early Saxon settlement of West Stow, Suffolk is located on the north bank of the River Lark. It was excavated over five seasons between 1957-1961 (West 1985a: 9). There was evidence for seven post built structures and seventy sunken feature buildings, of various types (West 1985a: 111-113). The settlement at West Stow occupied the same site for 250 years, ending around 650AD (West 1985a: 146-152). There is evidence for small-scale smithing taking place at West Stow (West 1985a: 69).

In total, 77 knives were recovered during excavations at West Stow. The x-radiographs for all 77 knives were examined and the results for each knife are available in the appendix (Volume 2 table 4.1). For this PhD metallographic analysis was carried out on 15 knives, 6 of which were broken and the remaining knives complete. A list of the knives selected and their context is provided in table 5.3. In addition to the new knives sectioned and analysed, four knives discovered in the West Stow archive (out of the original five) from Tylecote's original study in 1986 (Tylecote & Gilmour 1986: 38-39) were re-examined.

Knife Number	Feature	Shape	Knife Number	Feature	Shape
72	Layer 2	X4	828	Layer 2	B3
86	Layer 2	B2	928	Layer 2	X2
100	Layer 2	B4	973	SFB 37	B1
330	Pit 44	A1	1135	Layer 2	B4
433	Layer 2	B1	1661	Unknown	C1
556	Unknown	B4	2191	SFB 65	X2
659	Layer 2	B1	2208	Layer 2	AX
794	Layer 2	D3			

Table 5.3: Samples selected from West Stow for analysis showing their small find numbers and features.

A combined survey using the excavation report diagrams (West 1985b), and x-radiographs of West Stow knives has shown that the most common knives deposited were curved-backed knives; this was followed by the angle-back and straight-backed knife (Table 5.4). Unfortunately seventeen of the knives were found broken and are therefore impossible to categorise (i.e. undiagnostic). The survey also revealed that the type of tang to blade interface varied, although the majority had a distinct tang to blade interface on both sides.

Number of Knives Examined	*Back Shape*					*Tang Interface*				
	A	*B*	*C*	*D*	*X*	*1*	*2*	*3*	*4*	*X*
77	16	27	3	14	17	31	15	17	6	8

Table 5.4: A table showing the archaeological typologies of the knives from West Stow. Note: X indicates where a knife was un-diagnostic or un-classifiable.

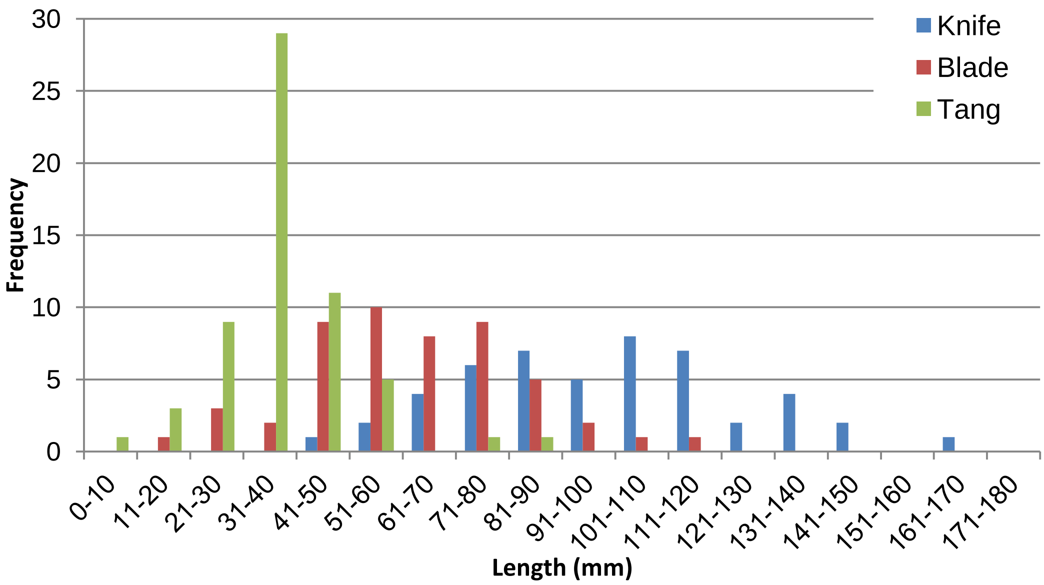


Figure 5.3: Histogram of knife sizes. This graph excludes some knives that appear to have been broken in antiquity.

The full measurements of all the West Stow knives are available in the appendix (Table 4.1). Many of the knives appear to have either broken blades or tangs and most of these were therefore ignored (Figure 5.3). The complete, or near complete, knives from West Stow ranged in size from 50mm to 170mm in length, with the average length being 94mm. The length of the knife blade also varied widely, from 20mm to 120mm, as did the tangs which varied in length from 8mm to 110mm. The small sample size and poor condition of many of the knives makes a detailed examination impossible. Determining the amount of wear present was hampered by the fragmented nature of many of the knives, but even so 41 knives showed clear evidence for wear, and six of these had significant wear (Table 5.5).

Wear Pattern				
None	*Slight*	*Moderate*	*Heavy*	*Unknown*
22	22	13	6	14

Table 5.5: A table showing the amount of wear in the knives from West Stow.

Summary of Knives

72 - *Type 3 piled knife consisting of low carbon steel (Average 169HV$_{0.2}$, Range 148-183HV$_{0.2}$), ferritic and phosphoric iron (Average 183HV$_{0.2}$, Range 148-192HV$_{0.2}$, 0.3%-0.6% P).*

86 -*Type 0 knife with phosphoric iron. Large grains at the cutting edge and knife back (Average 169HV$_{0.2}$, Range 127-221HV$_{0.2}$, 0.4%-0.5% P) with smaller grains in between (Average 188HV$_{0.2}$, Range 161-201HV$_{0.2}$, 0.2-0.3% P).*

100 - *Type 2 knife with a piled ferritic and phosphorus iron back (Average 224HV$_{0.2}$, Range 132-340HV$_{0.2}$, up to 0.3% P) separated from the heat-treated steel cutting edge (549HV$_{0.2}$, Average 498HV$_{0.2}$, Range 412-593HV$_{0.2}$) by a white weld line (0.5%-0.6% As, 0.1%-1.2% Ni). A second weld line suggests that this knife was repaired.*

330 - *Type 5 knife with a tempered martensite and bainite microstructure (Average 549HV$_{0.2}$, Range 362-549HV$_{0.2}$). Also present were bands, resistant to the etchant, which were enriched in arsenic (0.5%) and nickel (0.6%).*

433 - *Type 1 knife with a heat-treated steel core* (453*HV$_{0.2}$, Average 330HV$_{0.2}$, Range 321-509HV$_{0.2}$*) *sandwiched between two pieces of low phosphorus iron (Average 180HV$_{0.2}$, Range 114-321HV$_{0.2}$, up to 0.2% P).*

556 - *Type 0 knife with homogenous low phosphorus iron throughout (Average 205HV$_{0.2}$, Range 183-257HV$_{0.2}$, up to 0.3% P)*

659 - *Type 2 knife with a high carbon steel cutting edge (154HV$_{0.2}$, Average 165HV$_{0.2}$, Range 107-244HV$_{0.2}$) separated with a white weld line (up to 0.1% As, 0.6%-0.9% Ni) from a piled iron and low carbon steel back (Average 140HV$_{0.2}$, Range 137-148HV$_{0.2}$).*

794 - *Type 1 knife with a heat-treated bainitic steel core (303HV$_{0.2}$, Average 297HV$_{0.2}$, Range 271-340HV$_{0.2}$) between two ferritic iron flanks (Average 203HV$_{0.2}$, Range 171-232HV$_{0.2}$).*

828 - *Type 2 knife with a high carbon steel cutting edge (271HV$_{0.2}$, Average 245HV$_{0.2}$, Range 210-271HV$_{0.2}$) and a white weld line (0.6% As, 2.4% Ni) that separated this from the knife back. The knife back was made of two pieces of iron; phosphoric iron (Average 164HV$_{0.2}$, Range 148-175HV$_{0.2}$, 0.4%-0.6% P) and the other was a low carbon steel (Average 171HV$_{0.2}$, Range 152-201HV$_{0.2}$, 0.2-0.3% P).*

928 - *Type 0 knife with ferritic and low phosphorus iron* (168*HV$_{0.2}$, Average 148HV$_{0.2}$, Range 107-175HV$_{0.2}$, up to 0.3% P*).

973 - *Type 3 piled iron knife, with at least three pieces of iron separated by white weld lines (0.3%-0.6% As, 0.1%-0.2% Ni). The cutting edge was a low carbon* *steel* (*175HV$_{0.2}$, Average 165HV$_{0.2}$, Range 148-175HV$_{0.2}$*)*, the centre was a mid carbon steel* (*Average 201HV$_{0.2}$, Range 183-232HV$_{0.2}$*) *and the knife back was ferritic* (*Average 151HV$_{0.2}$, Range 132-161HV$_{0.2}$*)*.*

1135 - *Type 2 knife with a heat-treated cutting edge* (473*HV$_{0.2}$, Average 502HV$_{0.2}$, Range 473-509HV$_{0.2}$*)*, separated by a white weld line (0.4%-0.5% As, 0.1%-0.2% Ni) from a piled low carbon* (0-0.2% carbon, *Average 195HV$_{0.2}$, Range 168-238HV$_{0.2}$*) *and ferritic/phosphoric iron back* (*Average 147HV$_{0.2}$, Range 118-168HV$_{0.2}$, up to 0.3% P*)*.*

1661 - *Type 4 knife with a ferritic core* (*Average 117HV$_{0.2}$, Range 103-132HV$_{0.2}$*) *surrounded by a mid to high carbon steel* (201*HV$_{0.2}$, Average 221HV$_{0.2}$, Range 201-244HV$_{0.2}$*)*. Separating the two pieces of metal was a white weld line (0.2 As, 0.2% Ni).*

2191 - *Type 2 knife with a high carbon steel cutting edge* (386*HV$_{0.2}$, Average 307HV$_{0.2}$, Range 286-386HV$_{0.2}$*) and *a heterogeneous ferritic and low phosphorus iron back* (*Average 159HV$_{0.2}$, Range 123-205HV$_{0.2}$, up to 0.3% P*)*. The absence of a weld line suggests that it may have been carburised.*

2208 - *Type 2 knife with a heat-treated high carbon steel cutting edge* (*549HV$_{0.2}$, Average 469HV$_{0.2}$, Range 374-549HV$_{0.2}$*)*, separated by a white weld line(0.1%-0.2% As) from the knife back. The knife back consisted of two pieces of iron; phosphoric iron* (*Average 170HV$_{0.2}$, Range 152-201HV$_{0.2}$, 0.2%-0.4% P*) *and low carbon steel* (*Average 139HV$_{0.2}$, Range 137-140HV$_{0.2}$*)*.*

The metallographic analysis of twenty knives from West Stow revealed that the majority were either simple type 0 knives or type 2 knives (Figure 5.4 and Table 5.6). There were also three of type 1, three type 3 knives and one type 4 and type 5. Only five knives had a high-carbon steel and heat-treated cutting edge. The others had either a pearlite, low carbon steel or phosphoric iron cutting edge. Most of these would have been too low in carbon to heat-treat. The majority of the knife backs were ferritic or phosphoric iron, but there was also a high percentage (35%) of piled iron backs.

Analysis of the x-radiographs from the twenty-one remaining knives revealed up to eleven type 2 butt-welded knives and possibly nine knives which have been heat-treated. This suggests that, unlike middle and late Saxon settlements in England, the knives at West Stow were manufactured using a range of techniques.

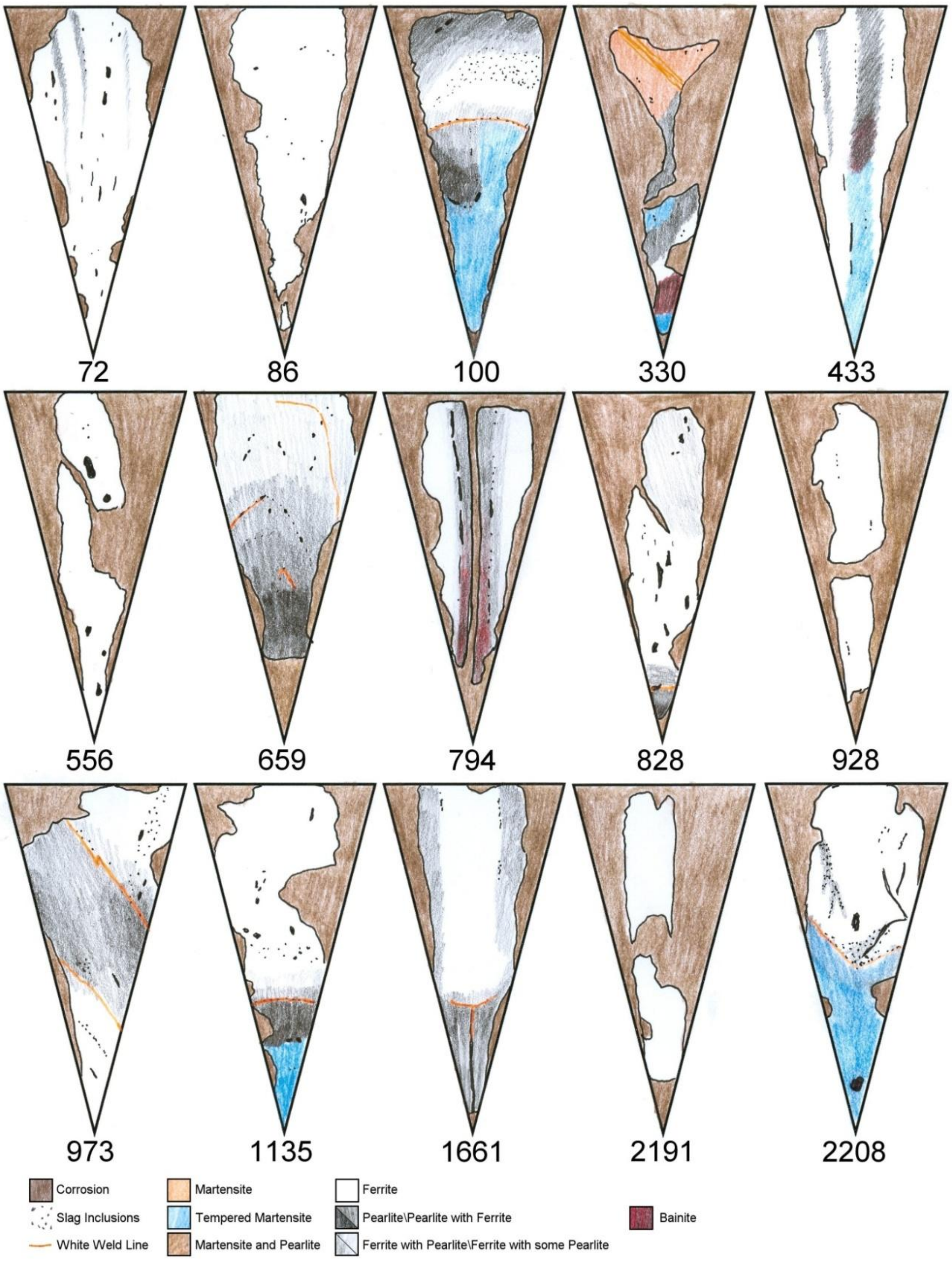


Figure 5.4: Diagrams of the knives from West Stow.

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
72	Slight	3	Phosphoric iron/ Ferrite with pearlite	183	148-192	Phosphoric iron/ Ferrite with pearlite	170	148-192		
86	Slight	0	Phosphoric iron	221	127-221	Phosphoric iron	184	161-201		
100	None	2	Tempered martensite	549	412-593	Piled Ferritic/Phosphoric iron	224	132-340	Yes	White weld line
330	Heavy	5	Tempered martensite	549	362-549	Martensite with ferrite/ Pearlite with ferrite	466	183-841	Yes	
433	Slight	1	Tempered martensite	453	321-509	Ferrite	239	114-441	Yes	
556	None	0	Ferritic/Phosphoric iron	257	183-257	Ferrite with carbides	205	183-257		
659	Slight	2	Pearlite	165	107-244	Ferrite	140	137-148		
794	Heavy	1	Bainite/Pearlite	303	271-340	Ferrite	203	171-232	Slow	White weld line
828	Some	2	Pearlite	271	210-271	Phosphoric iron	167	148-201		White weld line
928	Some	0	Piled Ferritic/Phosphoric iron	168	107-175	Ferritic/Phosphoric iron	148	107-175		
973	Slight	3	Ferrite with pearlite	175	148-175	Piled Ferrite/Ferrite and pearlite	186	132-232		White weld line
1135	Some	2	Tempered martensite	473	473-509	Piled Ferritic/Phosphoric iron	160	118-238	Yes	White weld line
1661	Slight	4	Pearlite	201	201-244	Ferrite	117	103-132		
2191	Slight	3	Pearlite	386	232-386	Ferrite	159	123-205		
2208	None	2	Tempered martensite	549	374-549	Piled Ferritic/Phosphoric iron	163	137-201	Yes	White weld line
716210		2	Pearlite with ferrite			Piled Ferritic/Phosphoric iron				
716216		0	Ferrite	216	148-244	Ferrite	189	148-244		
716232		0	Ferrite	137	135-168	Phosphoric iron	182	137-221		White weld line
716248		0	Ferrite	188	164-188	Ferrite with pearlite	216	148-321		
716300		1	Ferrite with pearlite	221	221-490	Piled Ferritic/Phosphoric iron/ Ferrite with pearlite	282	183-441		

Table 5.6: Summary of the fifteen knives analysed from West Stow, plus the data for the four knives re-analysed. Knife 716210 is also included although this could not be found, so the data is from Tylecote & Gilmour (1986). This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges.

Gwithian

The post-Roman excavations at Gwithian revealed a localised sequence dated from the 5th to 8th centuries. The site consisted of a series of cellular stone-lined buildings. Evidence for industry and crafts such as small-scale iron-working, the working of animal bone, salt-making and fishing was uncovered (Nowakowski *et al.* 2008). In addition to the local ceramic types found a range of foreign imports were also found, from as far as the eastern Mediterranean, north Africa and south-west France (Campbell 2007: 4; Nowakowski 2007a,b). This indicates that while the settlement was small it may have acted as a trade post or market, with access to an extensive trade network.

In total 15 knives were recovered during excavations at Gwithian. The x-radiographs for all 15 knives were examined and the results for each knife are available in the appendix (Volume 2 table 5.1). For this PhD research metallographic analysis was carried out on 4 knives. A list of the knives selected, their context details and phase is provided in table 5.7.

Object	Number	Context	Phase	Shape
Knife	GM/M/19	2238	2-4	A2
	GM/M/37	2232	2-4	B2
	GM/M/53	2202	3-4	B1
	GM/M/61	2002/3	3-4	B2

Table 5.7: Samples selected for analysis from Gwithian showing their small find numbers, context details, phase and date.

The x-radiograph analysis of knives from Gwithian has shown that the most common knives deposited were curved-backed knives; this was closely followed by the angle-back knife (Table 5.8). Many of the knives found were broken and therefore un-diagnostic. The survey also revealed that the type of tang to blade interface varied, although the majority had a distinct tang to blade interface on one side only.

Number of Knives Examined	***Back Shape***					***Tang Interface***				
	A	***B***	***C***	***D***	***X***	***1***	***2***	***3***	***4***	***X***
14	1	7	0	1	5	2	6	1	1	4

Table 5.8: A table showing the archaeological typologies of the knives from Gwithian. Note: X indicates where a knife was un-diagnostic or un-classifiable.

The full measurements of all the Gwithian knives are available in the appendix (Table 5.1). Many of the knives appear to have either broken blades or tangs and most of these were therefore ignored in the following analysis. The complete, or near complete, knives from Gwithian ranged in size from 50mm to 80mm in length, with the average length 61mm. The length of the knife blade also varied dramatically from 38mm to 53mm, as did the tangs which varied in length from 10mm to 66mm. The small sample size and poor condition of many of the knives makes a detailed examination of lengths and widths impossible. Determining the amount of wear present was hampered by the fragmented nature of many of the knives, but even so 6 knives showed clear evidence for wear, and one knife (53) had significant wear (Table 5.9).

Wear Pattern				
None	***Slight***	***Moderate***	***Heavy***	***Unknown***
2	2	3	1	6

Table 5.9: A table showing the amount of wear in the knives from Gwithian.

Summary of Knives

GM/M/19 **-** *Type 3 piled knife with low carbon steel (Average 330HV$_{0.2}$, Range 238-386HV$_{0.2}$ and phosphoric iron (Average 339HV$_{0.2}$, Range 257-441HV$_{0.2}$, 0.3%-0.5% P). Low carbon steel at the cutting edge may indicate that it was meant to be a type 2 knife, possibly carburised.*

GM/M/37 **-** *Type 2 knife with a high carbon bainite cutting edge (457HV$_{0.2}$, Average 407HV$_{0.2}$, Range 362-457HV$_{0.2}$) with a back of piled ferrite (Average 251HV$_{0.2}$, Range 244-264HV$_{0.2}$) and low phosphorus iron (Average 206HV$_{0.2}$, Range 179-244HV$_{0.2}$, up to 0.1% P).*

GM/M/53 **-** *Type 0 knife with heterogeneous ferritic iron and low carbon steel throughout. The cutting edge had elongated grains, possible evidence of cold working (Average 286HV$_{0.2}$, Range 232-386HV$_{0.2}$) while further to the back some pearlite was present in areas (Average 274HV$_{0.2}$, Range 215-340HV$_{0.2}$, 0.1%-0.4% P).*

GM/M/61 **-** *Type 0 heterogeneous knife which consists of ferritic iron and low carbon steel (Average 248HV$_{0.2}$, Range 201-278HV$_{0.2}$) and low phosphorus iron (Average 250HV$_{0.2}$, Range 210-303HV$_{0.2}$, 0.1%-0.4% P).*

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
19	None	3	Ferrite with some pearlite	386	238-386	Ferrite/Phosphoric Iron	330	257-441		
37	Some	2	Pearlite/Bainite	457	362-457	Ferrite/Phosphoric Iron	248	179-321	Slow	
53	Heavy	0	Ferrite with some pearlite	232	232-386	Ferrite with some pearlite	271	215-340		
61	Some	0	Ferrite/Phosphoric Iron	232	201-278	Ferrite/Phosphoric Iron	251	210-303		

Table 5.10: Summary of the four knives analysed from Gwithian. This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges).

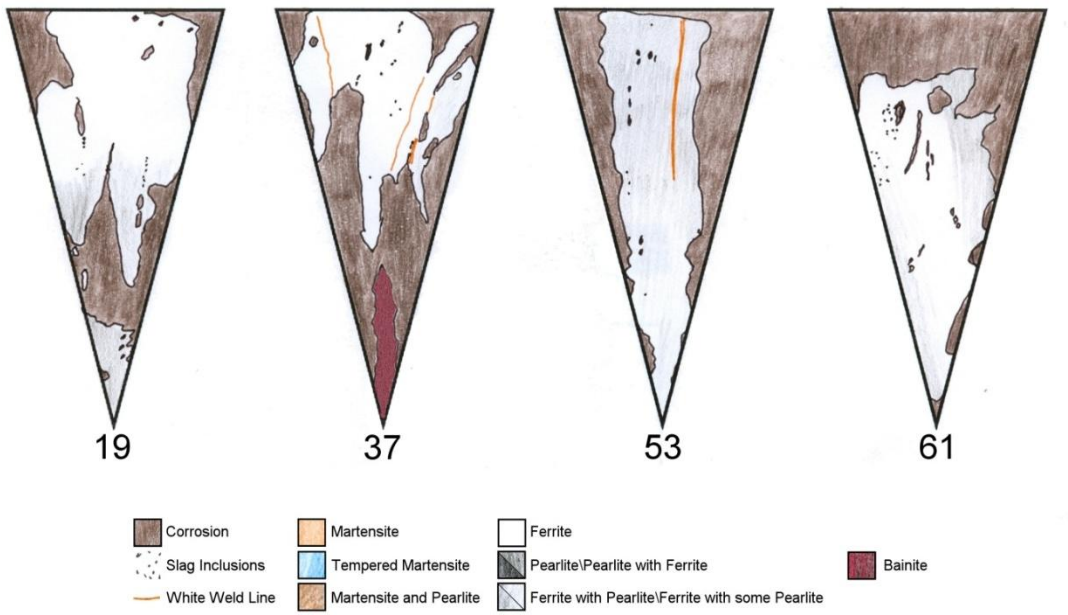


Figure 5.5: Diagrams of the knives from Gwithian.

The metallographic analysis of four knives from Gwithian revealed that the majority were either simple type 0 knives or type 2 knives (Figure 5.5 and Table 5.10). Only one knife had a high carbon steel cutting edge. This cutting edge was not cooled fast enough to create the hard but tough tempered martensite, but had been cooled quickly to form bainite. The other had low carbon steel or phosphoric iron cutting edges, which would have been too low in carbon to heat-treat. The majority of the knife backs were ferritic or phosphoric iron.

The x-radiographs of the other remaining knives revealed another two possible type 2 butt-welded knives and up to four knives which have been heat-treated. This suggests that unlike knives from middle and late Saxon settlements in England the knives at Gwithian were manufactured using a range of techniques.

All four knives from Gwithian had unusually high arsenic and copper contents. They all had traces of nickel present, with the exception of knife 19 which had no nickel. The majority of the knives had between 0.1%-0.5% arsenic and copper, but one knife had large quantities of arsenic and copper (0.4-1.2%).

Additional Early settlement knives

There have been very few studies of knives from early Saxon settlements but this section will summarise the results from this work. The only assemblage that can be compared with West Stow and Gwithian is the knife assemblage from Poundbury (Volume 2 table 1.1), analysed by Tylecote (Tylecote & Gilmour 1986: 38; Tylecote 1987). The Poundbury knives were dated from the post-Roman to early Saxon period. The vast majority of the knives were made by butt-welding a heat-treated tempered martensite cutting edge on to a back of ferritic or low carbon steel. The remaining knives were a range of types including a type 1 sandwich weld, a plain low carbon steel type 0 and a piled type 3 knife.

Over half of the knives from Poundbury had been heat-treated, and a further two had a high enough carbon content to have been treated but had not been. The majority of the knives had ferritic or low carbon steel backs. During Tylecote's examination, compositional analysis using an SEM or XRF was not carried out and therefore it is impossible to know whether phosphorus was present, although the relative high hardness of some of the microstructures suggests that phosphorus might have been present.

5.3 Early Cemeteries

Quarrington

The early Saxon cemetery at Quarrington, Lincolnshire is a small inhumation cemetery located near to Sleaford. The location of the burials was probably influenced by a Bronze Age ditch present at the site. Unfortunately many of the graves were shallow and therefore may have been disturbed, even so fifteen graves were identified, although more may be located beyond the excavated area. The number and range of grave goods present was modest, particularly in the female graves, but the grave goods present date the cemetery between the late 5th to late 6th century. It is likely that some grave goods are under-represented, i.e. female non-ferrous brooches, due to the known heavy incidence of metal detecting at the site. The analysis of the skeletons suggested a rural community with evidence for disease and hard physical labour (Dickenson 2004).

Knife Number	Grave	Sex	Age	RAIC	Shape
5	Grave 5	Unknown	11-15	1	B1
9	Grave 1	Male	26-35	3	A3
11	Grave 4	Male	26-35	3	D4
17	Grave 7	Male	26-35	5	B3
222					B1
230	Grave 12	Male	20+	2	B3

Table 5.11: Samples from Quarrington selected for analysis showing their small find numbers and feature.

In total 11 knives were recovered during excavations at Quarrington. The x-radiographs for all 11 knives were examined and the results for each knife are available in the appendix (Volume 2 table 6.1). For this PhD metallographic analysis was carried out on 6 knives, mostly from male graves. This was partially due to the poor condition of some knives, but was also done to reduce the influence that under representation of female grave goods would have. A list of the knives selected and the grave details is provided in table 5.11.

The x-radiograph analysis of the knives from Quarrington has shown that the most common knives deposited were curved-backed knives; this was followed by the straight-backed knife (Table 5.12). The survey also revealed that there were roughly similar numbers of knives with a distinct tang to blade interface on both sides, no distinct tang interface or a distinct tang interface on the knife back.

Number of Knives Examined	Back Shape					Tang Interface				
	A	B	C	D	X	1	2	3	4	X
11	1	7	0	3	0	4	0	4	3	0

Table 5.12: A table showing the archaeological typologies of the knives from Quarrington. Note: X indicates where a knife was un-diagnostic or un-classifiable.

The full measurements of all the Quarrington knives are available in the appendix (Volume 2 table 6.1). Many of the knives appear to have either broken blades or tangs. The small sample size and poor condition of many of the knives makes a detailed examination of knife, blade and tang lengths impossible. Determining the amount of wear present was also hampered by the fragmented nature of many of the knives, but even so six knives showed clear evidence for wear, although none were heavily worn (Table 5.13).

Wear Pattern				
None	Slight	Moderate	Heavy	Unknown
4	3	3	0	1

Table 5.13: A table showing the amount of wear in the knives from Quarrington.

Summary of Knives

5 - *Type 0 heterogeneous iron knife with low carbon steel near the cutting edge (154HV$_{0.2}$, Average 164HV$_{0.2}$, Range 154-183HV$_{0.2}$) and ferritic iron at the back (Average 164HV$_{0.2}$, Range 148-175HV$_{0.2}$).*

9 - *Type 2 knife with a mid to high carbon steel cutting edge (271HV$_{0.2}$, Average 212HV$_{0.2}$, Range 161-271HV$_{0.2}$) welded onto a back consisting of ferritic iron (Average 171HV$_{0.2}$, Range 148-175HV$_{0.2}$).*

11 - *Type 1 knife with a heat-treated tempered martensite core (549HV$_{0.2}$, Average 357HV$_{0.2}$, Range 271-549HV$_{0.2}$) sandwiched between two pieces of ferritic iron (Average 215HV$_{0.2}$, Range 154-257HV$_{0.2}$).*

17 - *Type 5 all steel knife, which has a mid carbon steel cutting edge (183HV$_{0.2}$) mid to low carbon steel throughout (Average 181HV$_{0.2}$, Range 148-210HV$_{0.2}$).*

222 - *Type 0 homogeneous iron knife with phosphoric iron throughout (175HV$_{0.2}$, Average 172HV$_{0.2}$, Range 143-201HV$_{0.2}$, 0.2%-0.6% phosphorus).*

230 - *This knife was unclassifiable due to the bad corrosion, although the back was a low carbon steel (Average 173HV$_{0.2}$, Range 161-183HV$_{0.2}$).*

The metallographic analysis of six knives from Quarrington revealed a range of different knife types (Table 5.14 and Figure 5.6) although slightly more type 0 knives were identified. One knife (230) was so badly corroded identification was impossible. Only one knife had a heat-treated cutting edge (11), although another had a mid to high carbon steel cutting edge (9). The others had either a low carbon steel or phosphoric iron cutting edge, which would have been too low in carbon to heat-treat. The majority of the knife backs were ferritic or phosphoric iron.

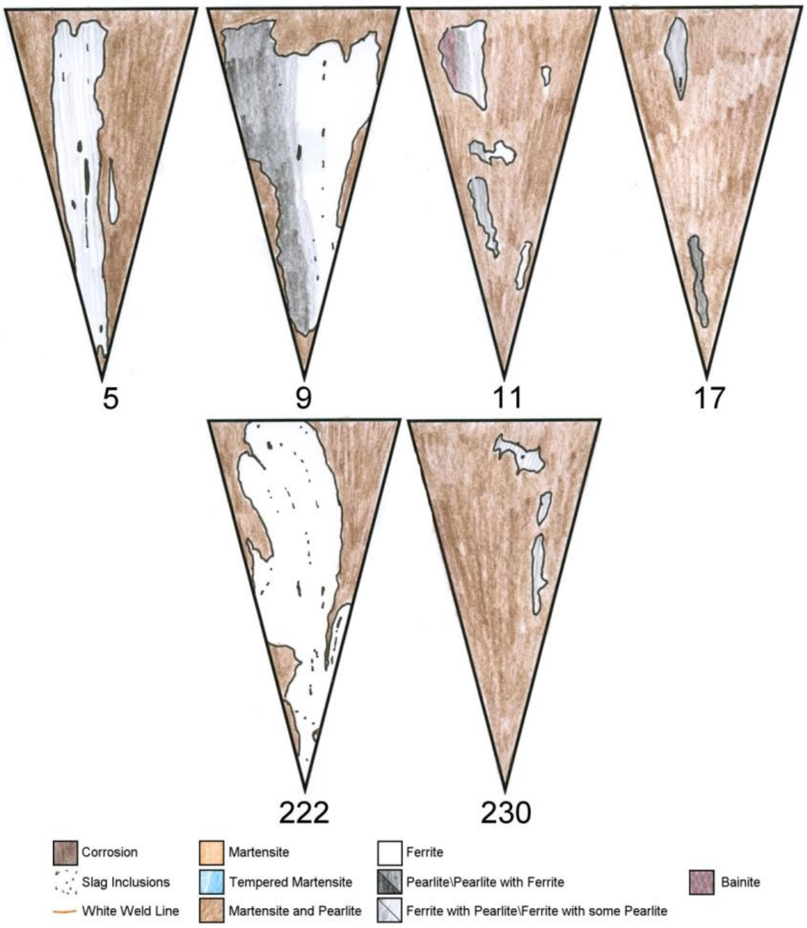


Figure 5.6: Diagrams of the knives from Quarrington.

Analysis of the remaining knives that were x-rayed revealed another two possible type 2 butt-welded knives and up to three more knives which have been heat-treated. This suggests that unlike other middle and late Saxon settlements in England the knives at Quarrington were manufactured using a range of techniques.

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
5	Some	0	Ferrite with pearlite	154	154-183	Ferritic iron	164	154-183	No	
9	Slight	2	Pearlite with ferrite	271	161-271	Ferrite with pearlite/Ferritic iron	171	132-271	No	
11	Some	1	Tempered Martensite	549	271-549	Ferritic iron	215	154-257	Yes	White weld line
17	Unknown	5	Ferrite and pearlite	183	148-210	Ferrite and pearlite	181	148-210	No	
222	Some	0	Phosphoric iron	175	143-201	Phosphoric iron	172	143-210	No	
230	Unknown	?	Ferrite and pearlite	168	161-183	Ferrite and pearlite	173	161-183	No	

Table 5.14: Summary of the six knives analysed from Quarrington. This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges.

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
100	None	0	Ferrite with pearlite	143	143-175	Pearlite and ferrite/Ferrite with pearlite	177	143-232	No	
103	None	2	Tempered Martensite	509	168-509	Ferrite with some pearlite	163	132-232	Yes	White weld line
110	Slight	2	Tempered Martensite	441	271-473	Phosphoric iron	159	143-183	Yes	White weld line
116	Some	1	Ferrite with pearlite	168	154-221	Ferritic/Phosphoric iron	159	148-168	No	
127	Slight	2	Tempered Martensite	644	303-644	Ferrite with pearlite/Pearlite with ferrite	216	154-412	Yes	Carburised

Table 5.15: Summary of the five knives analysed from Twyford. This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges.

Twyford

Excavations in 2007 uncovered an Anglo-Saxon cemetery at Twyford, near Winchester in Hampshire. The excavation revealed 18 graves dated between the 6^{th} and early 8^{th} century, but this represents only a small proportion of the original cemetery. Ten of the graves contained identifiable grave goods, with a beaded necklace found at the neck of a female, shield bosses in male graves, with knives and buckles found in both male and female graves. The osteoarchaeological evidence points to a local, rural population, enjoying a fair standard of living, reasonably good health and little competition for resources (Dinwiddy Forthcoming).

Knife Number	Grave	Sex	Age	RAIC	Date	Shape
100	1006	Female	35-45	4	6^{th}-7^{th}	A3
103	1006	Female	35-45	4	6^{th}-7^{th}	B1
110	1062	Female	30-40	5	7^{th}	B1
116	1075	Male	45+	2	6^{th}-7^{th}	B3
127	1143	Female?	45-60	1	6^{th}-7^{th}	B1

Table 5.16: Samples selected for analysis from Twyford showing their small find numbers and feature.

In total only 5 knives were recovered during excavations at Twyford, mostly from female graves. All of these knives were examined metallographically for this PhD (Table 5.16), the x-radiography results for each knife is available in the appendix (Volume 2 table 7.1).

Number of Knives Examined	***Back Shape***					***Tang Interface***				
	A	***B***	***C***	***D***	***X***	***1***	***2***	***3***	***4***	***X***
5	1	4	0	0	0	3	0	2	0	0

Table 5.17: A table showing the archaeological typologies of the knives from Twyford. Note: X indicates where a knife was un-diagnostic or un-classifiable.

The x-radiograph analysis of knives from Twyford has shown that the most common knives deposited were curved-backed knives with one angle-backed knife (Table 5.17). The survey also revealed that the majority of knives had either a distinct tang to blade interface on both sides or a distinct tang interface on the knife back.

Wear Pattern				
None	***Slight***	***Moderate***	***Heavy***	***Unknown***
2	2	1	0	0

Table 5.18: A table showing the amount of wear in the knives from Twyford.

The full measurements of all the Twyford knives are available in the appendix (Volume 2 table 7.1). The knives were in good condition but the small sample size makes a detailed examination of knife, blade and tang lengths difficult. Examination of the knives revealed that three of the knives showed clear evidence for wear, although none were heavily worn (Table 5.18).

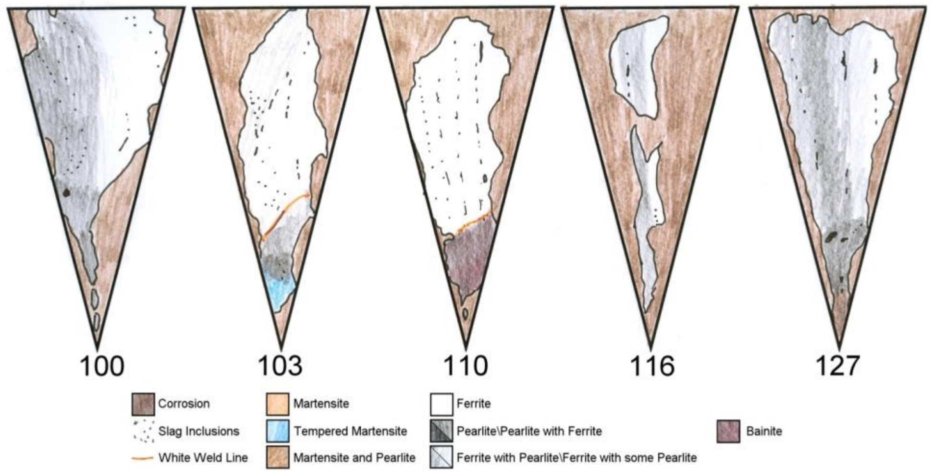


Figure 5.7: Diagrams of the knives from Twyford.

Summary of Knives

100 - *Type 0 heterogeneous iron knife with ferritic iron near the cutting edge (143HV$_{0.2}$, Average 160HV$_{0.2}$, Range 143-175HV$_{0.2}$) and mid to low carbon steel at the back (Average 177HV$_{0.2}$, Range 143-232HV$_{0.2}$).*

103 - *Type 2 knife with a heat-treated tempered martensite cutting edge (509HV$_{0.2}$, Average 289HV$_{0.2}$, Range 168-509HV$_{0.2}$) welded onto a back made of two pieces of iron; a piece of ferritic iron (Average 178HV$_{0.2}$, Range 148-221HV$_{0.2}$) and a low carbon steel (Average 193HV$_{0.2}$, Range 132-232HV$_{0.2}$). A white weld line separated the cutting edge from the back (up to 0.3% As, up to 0.2% Cu).*

110 - *Type 2 knife with a heat-treated tempered martensite cutting edge (441HV$_{0.2}$, Average 387HV$_{0.2}$, Range 271-473HV$_{0.2}$) scarf-welded onto a back consisting of low phosphorus iron (Average 159HV$_{0.2}$, Range 143-183HV$_{0.2}$,* up to 0.3% P*). A white weld line separated the cutting edge from the back (0.8%-1.8% As, 0.9%-1.6% Ni).*

116 - *Type 1 knife with a low carbon steel core (168HV$_{0.2}$, Average 186HV$_{0.2}$, Range 154-221HV$_{0.2}$) sandwiched between low phosphorus iron (Average 159HV$_{0.2}$, Range 148-168HV$_{0.2}$,* up to 0.2% P*).*

***127 -** Type 2 knife with a heat-treated cutting edge of tempered martensite (644$HV_{0.2}$, Average 452$HV_{0.2}$, Range 303-644$HV_{0.2}$) welded onto a piled iron back consisting of low-mid carbon steels (Average 216$HV_{0.2}$, Range 154-412$HV_{0.2}$).*

The metallographic analysis of all the knives from Twyford was carried out. This revealed that the majority were type 2 knives, although there was also a type 0 and type 1 knife present (Table 5.15 and Figure 5.7). All three of the type 2 knives had a high-carbon steel and heat-treated cutting edge. The others were low carbon steel cutting edges, which would have been too low in carbon to heat-treat. The majority of the knife backs were low carbon steels or phosphoric iron.

Collingbourne Ducis

Collingbourne Ducis is a Saxon cemetery which spans from the early Saxon period into the 'final phase' and therefore includes burials dated to the 7th century. It is located in South Wiltshire, and was associated with a nearby rural settlement (Pine 2001). In total 114 inhumation graves were found in the cemetery and 23 possible cremations were also found making this a possible 'mixed rite' cemetery. The grave goods found were fairly typical of other cemeteries in the region, with a range of weapons, knives, buckles and jewellery. The majority of 7th century 'final phase' burials were separated from the main cemetery by a hollow ditch (Stoodley & Schuster 2009).

In total 55 knives were recovered during excavations at Collingbourne Ducis, although none were found associated with the cremation burials. The x-radiographs for only 51 of these knives were examined and the results for each knife are available in the appendix (Volume 2 table 8.1). Metallographic analysis was carried out on 25 knives from Collingbourne Ducis for this PhD research. Of these 15 were from 6th-early 7th century contexts while the remaining 10 were from securely dated 7th century contexts (Table 5.19).

Knife Number	Grave	Sex	Age	RAIC	Date	Shape
12	61	Female	45-55	6	Early 6th	B1
18	59	Male	50+	5	Early 6th	A1
39	42	Unknown	1-3	4	6th	B1
44	52	Male	45+	2	6th	B3
96	43	Female	24-29	2		D2
116	68	Female	30-40	3		D3
118	83	Male	24-29	4	6th	D1
123	66	Female	25-40	1		B1
124	82	Male	24-29	3	Early 6th	B4
175	74	Female	30-35	4	Early 6th	B1
177	69	Female	30-45	7	6th	XX
190	77	Male	45-50	5	6th	C3
196	71	Unknown	1-2	1	Late 6th/ Early 7th	B2
217	38	Female	25-35	12	E 6th	X2
263	76	Male	50+	2	E 6th	D1
128	91	Male	45+	3	7th	B1
252	104	Female?	12-14	2	7th	A3
257	106	Male	45+	2	7th	A1
260	108	Male	50+	3	7th	B3
266	110	Female	40-50	4	7th	B3
271	107	Male	24-29	2	7th	B1
272	102	Female	35-40	1	7th	AX
280	109	Male	30-40	3	7th	B3
282	101	Male	35-40	5	7th	B1
285	97	Female	25-35	1	7th	B4

Table 5.19: Samples selected for analysis from Collingbourne Ducis showing their small find numbers and feature.

The x-radiograph analysis of knives from Collingbourne Ducis has shown that the most common knives deposited were curved-backed (Table 5.20). There were also a small number of angle-backed, straight-backed and a few incurved-backed knives. The survey also revealed that the preferred type of tang to blade interface was distinct on both sides followed by knives with a distinct tang interface on the knife back.

Number of Knives Examined	***Back Shape***					***Tang Interface***				
	A	***B***	***C***	***D***	***X***	***1***	***2***	***3***	***4***	***X***
51	8	28	2	7	6	25	6	11	4	5

Table 5.20: A table showing the archaeological typologies of the knives from Collingbourne Ducis. Note: X indicates where a knife was un-diagnostic or un-classifiable.

The full measurements of all the Collingbourne Ducis knives are available in the appendix (Volume 2 table 8.1). Some of the knives appear to have either broken blades or tangs and most of these were therefore ignored in the following analysis (Figure 5.8). The complete, or near complete, knives from Collingbourne ranged in size from 55mm to 225mm in length, with the average length 128mm. The length of the knife blade also varied dramatically from 40mm to 164mm, as did the tangs which varied in length from 15mm to 67mm. Analysis of the amount of wear present revealed that more than 70% of the assemblage, 36 knives, showed some evidence for wear. Of these 16 were worn down so that the cutting edge was curved and two were heavily worn (Table 5.21). This suggests that at least 35% of the assemblage had been used in life before burial.

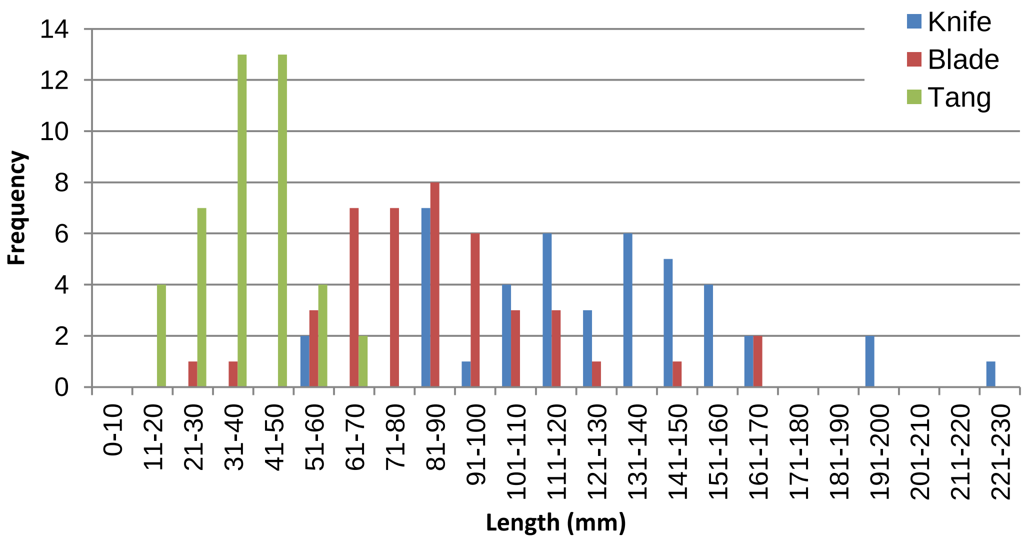


Figure 5.8: Histogram of knife sizes at Collingbourne Ducis. This graph excludes some knives that appear to have been broken in antiquity.

Wear Pattern				
None	***Slight***	***Moderate***	***Heavy***	***Unknown***
8	18	16	2	7

5.21: A table showing the amount of wear in the knives from Collingbourne Ducis.

Summary of Knives

12 - *Type 0 heterogeneous iron knife with low phosphorus iron near the cutting edge (132HV$_{0.2}$, Average 130HV$_{0.2}$, Range 110-143HV$_{0.2}$) and low carbon steel in the back (Average 124HV$_{0.2}$, Range 100-143HV$_{0.2}$).*

18 - *Type 0 heterogeneous iron knife with low carbon steel near the cutting edge and throughout the knife (240HV$_{0.2}$, Average 204HV$_{0.2}$, Range 161-271HV$_{0.2}$)*

39 - *Type 2 knife with a heat-treated martensite cutting edge (473HV$_{0.2}$, Average 505HV$_{0.2}$, Range 441-549HV$_{0.2}$) welded onto a back consisting of low phosphorus iron (Average 124HV$_{0.2}$, Range 100-137HV$_{0.2}$,* 0.1%-0.2% P*). A white weld line separated the cutting edge from the back (0.7%-1.0% As, 0.1%-0.2% Ni).*

44 *- Type 3 piled knife with bands of high, mid and low carbon steels* (*Average 226HV$_{0.2}$, Range 132-593HV$_{0.2}$*)*. The cutting edge was a ferritic iron* (*192HV$_{0.2}$*).

96 *- Type 3 piled knife which consisted of two phases; a ferritic iron* (*Average 152HV$_{0.2}$, Range 103-201HV$_{0.2}$) and bands of tempered martensite which formed the cutting edge (593HV$_{0.2}$, Average 510HV$_{0.2}$, Range 412-644HV$_{0.2}$).*

116 *- Type 2 knife with a heat-treated martensite cutting edge* (473*HV$_{0.2}$, Average 396HV$_{0.2}$, Range 210-473HV$_{0.2}$*) *welded onto a back made of two pieces of iron; pieces of ferritic iron and low carbon steel (Average 195HV$_{0.2}$, Range 183-221HV$_{0.2}$) and a piece of low phosphorus iron* (*Average 155HV$_{0.2}$, Range 143-168HV$_{0.2}$*, up to 0.1% P)*.*

118 *- Type 5 knife slowly heat-treated all steel knife. This knife has a bainite cutting edge* (*321HV$_{0.2}$, Average 347HV$_{0.2}$, Range 286-386HV$_{0.2}$*)*, and a bainite with ferrite back* (*Average 337HV$_{0.2}$, Range 192-473HV$_{0.2}$*, up to 0.2% As*). Arsenic was present throughout as were many white bands (0.2%-0.3% As, up to 0.2% Ni, 0.9%-1.5% Cu).*

123 *- An unusual type 1 knife with a small piece of phosphoric iron* (*257HV$_{0.2}$, Average 230HV$_{0.2}$, Range 192-257HV$_{0.2}$*, 0.4%-0.7% P) *sandwiched between two larger pieces of heat-treated tempered martensite and bainite ((Average 379HV$_{0.2}$, Range 168-593HV$_{0.2}$) forming a upside down Y shape weld. To either side of these pieces, joining near the back, of iron there were two white weld lines (0.3%-1.2% As, up to 0.2%).*

124 *- Type 0 knife made from two pieces of low phosphorus iron (192HV$_{0.2}$, Average 183HV$_{0.2}$, Range 161-210HV$_{0.2}$* 0.2%-0.4% P*).*

175 *- Type 5 all steel knife, with a mid carbon steel cutting edge* (*286HV$_{0.2}$, Average 234HV$_{0.2}$, Range 154-362HV$_{0.2}$*) *and a mid to low carbon steel back. Arsenic was present throughout the knife (0.1%-0.4%)*

177 *- Type 0 heterogeneous iron knife with ferritic iron near the cutting edge (*303*HV$_{0.2}$, Average 239HV$_{0.2}$, Range 201-303HV$_{0.2}$) and low carbon steel and ferritic iron at the back (Average 198HV$_{0.2}$, Range 161-244HV$_{0.2}$).*

190 *- Type 5 all steel knife, with a mid carbon steel cutting edge* (*303HV$_{0.2}$, Average 278HV$_{0.2}$, Range 244-321HV$_{0.2}$*) *and a mid-low carbon steel back, which was heat-treated in areas (Average 334HV$_{0.2}$, Range 175-412HV$_{0.2}$*).

196 *- Type 0 heterogeneous iron knife with low carbon steel near the cutting edge (137HV$_{0.2}$, Average 147HV$_{0.2}$, Range 132-168HV$_{0.2}$) and low phosphorus iron at the back (Average 105HV$_{0.2}$, Range 100-110HV$_{0.2}$*, up to 0.4% P*).*

217 - *Type 5 all steel knife, which has been heat-treated resulting in a tempered martensite cutting edge (593$HV_{0.2}$, Average 480$HV_{0.2}$, Range 286-644$HV_{0.2}$) which transformed into bainite and pearlite towards the back.*

263 – *Badly sharpened type 1 knife with a mid carbon steel core (Average 135$HV_{0.2}$, Range 123-154$HV_{0.2}$) sandwiched between a piece of ferritic iron which formed the cutting edge (161$HV_{0.2}$, Average 145$HV_{0.2}$, Range 123-161$HV_{0.2}$) and low carbon steel (Average 135$HV_{0.2}$, Range 123-154$HV_{0.2}$). At the back of the knife there was a piece of low phosphorus iron (Average 135$HV_{0.2}$, Range 123-154$HV_{0.2}$, up to 0.2% P)*

128 - *Type 2 knife with a high carbon steel cutting edge (*321*$HV_{0.2}$, Average 291$HV_{0.2}$, Range 221-340$HV_{0.2}$) welded onto a back consisting of phosphoric iron (Average 180$HV_{0.2}$, Range 143-221$HV_{0.2}$,* up to 0.6% P*). This knife was most likely carburised.*

252 - *Type 2 knife with a heat-treated tempered martensite cutting edge (549$HV_{0.2}$, Average 495$HV_{0.2}$, Range 154-549$HV_{0.2}$) welded onto a back consisting of heterogeneous mid-high carbon steel (Average 166$HV_{0.1}$, Range 132-201$HV_{0.1}$). A white weld line separated the cutting edge from the back (up to 0.1% As, up to 0.3% Ni, 0.1%-0.2% Cu).*

257 - *Type 2 knife with a heat-treated tempered martensite cutting edge (644$HV_{0.2}$, Average 412$HV_{0.2}$, Range 303-644$HV_{0.2}$) welded onto a back consisting of two pieces of iron; a low carbon steel with phosphorus (Average 191$HV_{0.2}$, Range 161-232$HV_{0.2}$,* 0.3%-0.4% P*) and the other a low carbon steel (Average 140$HV_{0.2}$, Range 123-161$HV_{0.2}$). A white weld line separated the cutting edge from the back (0.1%-0.2% As, up to 0.2% Ni).*

260 - *Type 2 knife with a slow heat-treated martensite with pearlite cutting edge* (509*$HV_{0.2}$, Average 339$HV_{0.2}$, Range 340-509$HV_{0.2}$) welded onto a back consisting of heterogeneous ferritic iron and low carbon steel (Average 158$HV_{0.2}$, Range 143-175$HV_{0.2}$). A white weld line separated the cutting edge from the back (0.2%-1.2% As, up to 1.3% Ni).*

266 - *Type 2 knife with a heat-treated martensite cutting edge* (*841$HV_{0.2}$, Average 693$HV_{0.2}$, Range 412-841$HV_{0.2}$) welded onto a back consisting of heterogeneous ferritic iron and low carbon steel (Average 129$HV_{0.2}$, Range 114-148$HV_{0.2}$). A white weld line separated the cutting edge from the back (0.1% As, 0.4% Ni).*

271 - *Type 1 knife with a heat-treated tempered martensite core (593$HV_{0.2}$, Average 649$HV_{0.2}$, Range 232-701$HV_{0.2}$) sandwiched between two pieces of iron; one phosphoric (Average 178$HV_{0.2}$, Range 148-201$HV_{0.2}$) while the other was ferritic (Average 257$HV_{0.2}$, Range 148-386$HV_{0.2}$).*

272 - *Type 2 knife with a slow heat-treated cutting edge of bainite ($303HV_{0.2}$, Average $309HV_{0.2}$, Range 161-$321HV_{0.2}$) welded onto a back consisting of heterogeneous low carbon steel (Average $218HV_{0.2}$, Range 201-$244HV_{0.2}$) and phosphoric iron (Average $140HV_{0.2}$, Range 123-$148HV_{0.2}$,* up to 0.3% P*).*
280 - *Type 0 knife made from mid to low carbon steel and low phosphorus iron ($154HV_{0.2}$, Average $168HV_{0.2}$, Range 154-$192HV_{0.2}$* 0.1%-0.3% P*).*
282 - *Type 2 knife with a heat-treated martensite cutting edge* (*$701HV_{0.2}$, Average $629HV_{0.2}$, Range 441-$701HV_{0.2}$) welded onto a back consisting of heterogeneous mid-high carbon steel (Average $210HV_{0.2}$, Range 154-$271HV_{0.2}$). A white weld line separated the cutting edge from the back (0.7%-1.1% As, 0.1%-0.2% Ni), and these carried on into the knife back.*
285 - *Type 3 piled knife with bands of ferritic iron, phosphoric iron and low carbon steels* (*$143HV_{0.2}$, Average $148HV_{0.2}$, Range 118-$183HV_{0.2}$*).

The metallographic analysis of twenty five knives from Collingbourne Ducis was carried out. This revealed distinct differences between the two groups: fifteen 6th century knives and the later 7th century knives. The 6th century knives were constructed using a range of different manufacturing techniques (Table 5.22 and Figure 5.9). The highest proportion of knives were plain iron type 0 knives or all steel type 5 knives. Eight out of the fifteen knives were heat-treated. Knife 123 was very unusual in construction as it appeared to be a reverse type 1 knife with a phosphoric iron core sandwiched between two pieces of heat-treated steel. The majority of the knife backs were low carbon steels or phosphoric iron.

The 7th century knives on the other hand were mostly type 2 knives (Table 5.22 and Figure 5.10). The rest of the group consisted of one type 0, type 1 and type 3. Six out of the ten knives had been heat-treated. As in the earlier dated knives, the majority of the knife backs were low carbon steels or phosphoric iron.

The x-rays of the remaining knives revealed up to another fourteen butt welded knives, of which eleven of these may have had a steel cutting edge. Nine knives also had the spotted texture suggesting a heat-treated steel cutting edge; therefore possibly type 1, 4 or 5 knives. Only two knives had neither weld lines nor evidence for steel and these may have been type 0 or 3 knives.

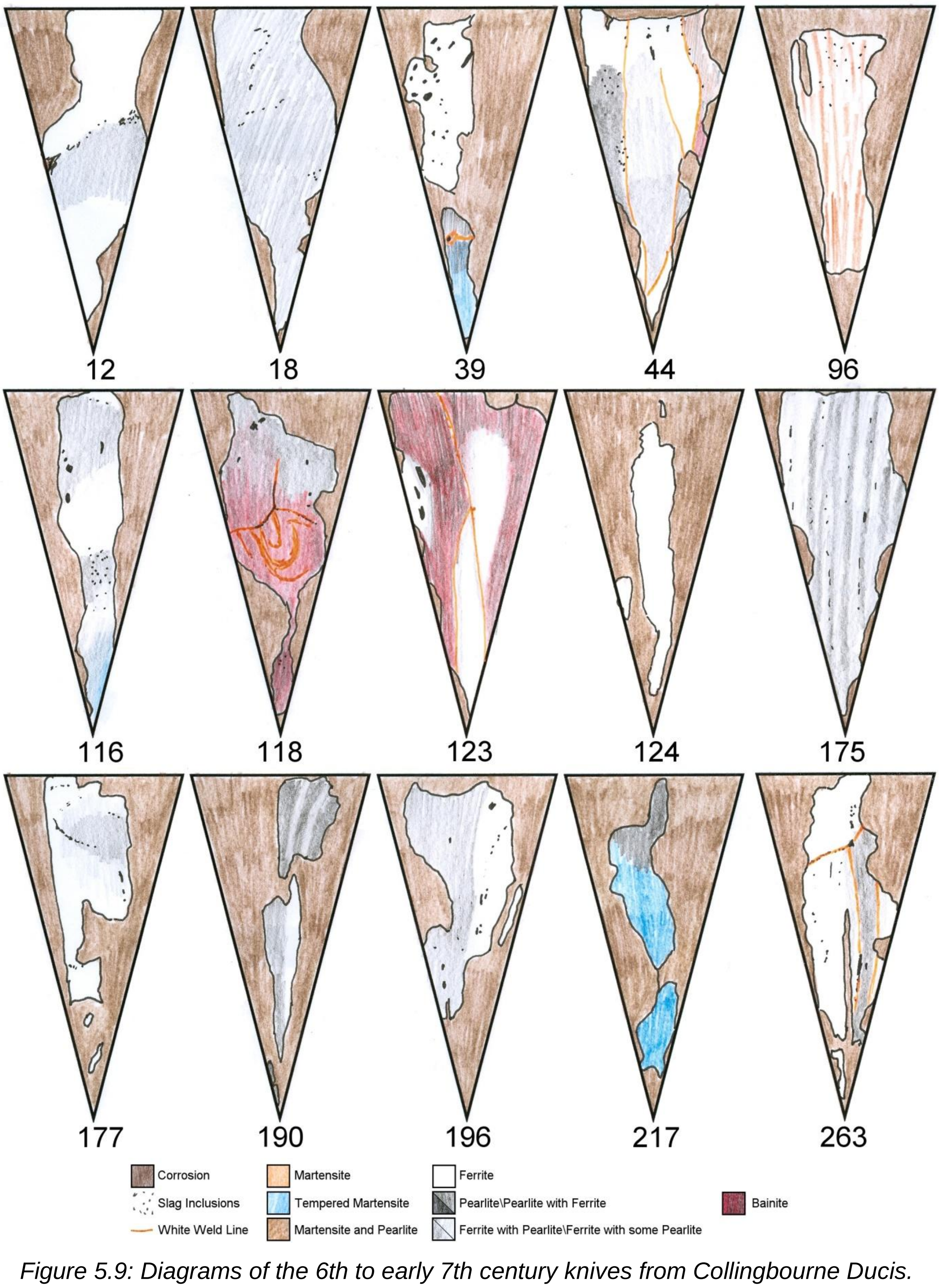


Figure 5.9: Diagrams of the 6th to early 7th century knives from Collingbourne Ducis.

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
12	Some	0	Phosphoric Iron	132	100-143	Phosphoric Iron/Ferrite with pearlite	132	100-143	No	
18	Some	0	Ferrite with pearlite	240	161-271	Ferrite with pearlite	204	161-271	No	
39	Some	2	Tempered Martensite	473	441-549	Phosphoric Iron	124	100-137	Yes	White weld line
44	Some	3	Ferrite/Ferrite with Pearlite/Bainite	192	132-593	Ferrite/Phosphoric Iron/Ferrite with Pearlite	226	132-593	Yes	
96	Some	3	Tempered Martensite	593	412-644	Ferrite	331	103-201	Yes	
116	None	2	Tempered Martensite	473	210-473	Ferrite with pearlite/Ferrite	178	143-221	Yes	
118	Slight	5	Bainite	321	286-473	Bainite with ferrite/Phosphoric iron	337	192-473	Yes	White weld line
123	Some	1	Phosphoric Iron	257	192-257	Bainite/Tempered Martensite	379	168-593	Yes	Reverse type 1 White weld line
124	None	0	Phosphoric iron	192	161-210	Phosphoric iron	183	161-210	No	
175	Slight	5	Phosphoric iron/ Pearlite with ferrite	286	154-362	Phosphoric iron with pearlite bands	234	154-362	No	
177	Slight	0	Ferritic iron	303	161-303	Ferritic Iron/ Ferrite with pearlite	216	161-303	No	
190	Unknown	5	Pearlite with ferrite	303	175-412	Pearlite/Bainite	280	175-412	Yes	
196	Slight	0	Ferrite with pearlite	137	100-168	Ferrite with pearlite	131	100-168	No	
217	None	5	Tempered Martensite	593	286-644	Tempered Martensite	480	286-644	Yes	
263	Unknown	1	Pearlite with ferrite	161	161-192	Ferrite with pearlite/Phosphoric Iron	149	123-183	No	
128	Slight	2	Pearlite with ferrite	321	221-340	Phosphoric Iron	180	143-221	No	Carburised
252	Slight	2	Tempered Martensite	549	154-549	Pearlite with ferrite	166	132-201	Yes	White weld line
257	Slight	2	Tempered Martensite	644	303-644	Phosphoric Iron/Ferrite with pearlite	166	123-232	Yes	White weld line
260	Some	2	Tempered Martensite with pearlite	509	340-509	Ferrite with pearlite	158	143-175	Yes	White weld line
266	None	2	Martensite/Tempered Martensite	841	412-841	Ferrite with pearlite	129	114-148	Yes	White weld line
271	None	1	Tempered Martensite	593	232-701	Phosphoric Iron/Ferrite with pearlite	217	148-386	Yes	
272	Slight	2	Bainite/Pearlite	303	161-321	Phosphoric Iron/Pearlite with ferrite	172	123-244	No	White weld line
280	None	0	Pearlite with ferrite	154	154-192	Ferrite with pearlite	168	154-192	No	
282	Slight	2	Tempered Martensite with pearlite	701	441-701	Ferrite with pearlite	210	155-271	Yes	White weld line
285	None	3	Phosphoric iron	143	118-183	Ferrite/Ferrite with pearlite	148	118-183	No	

Table 5.22: Summary of the twenty-five knives analysed from Collingbourne Ducis. This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges.

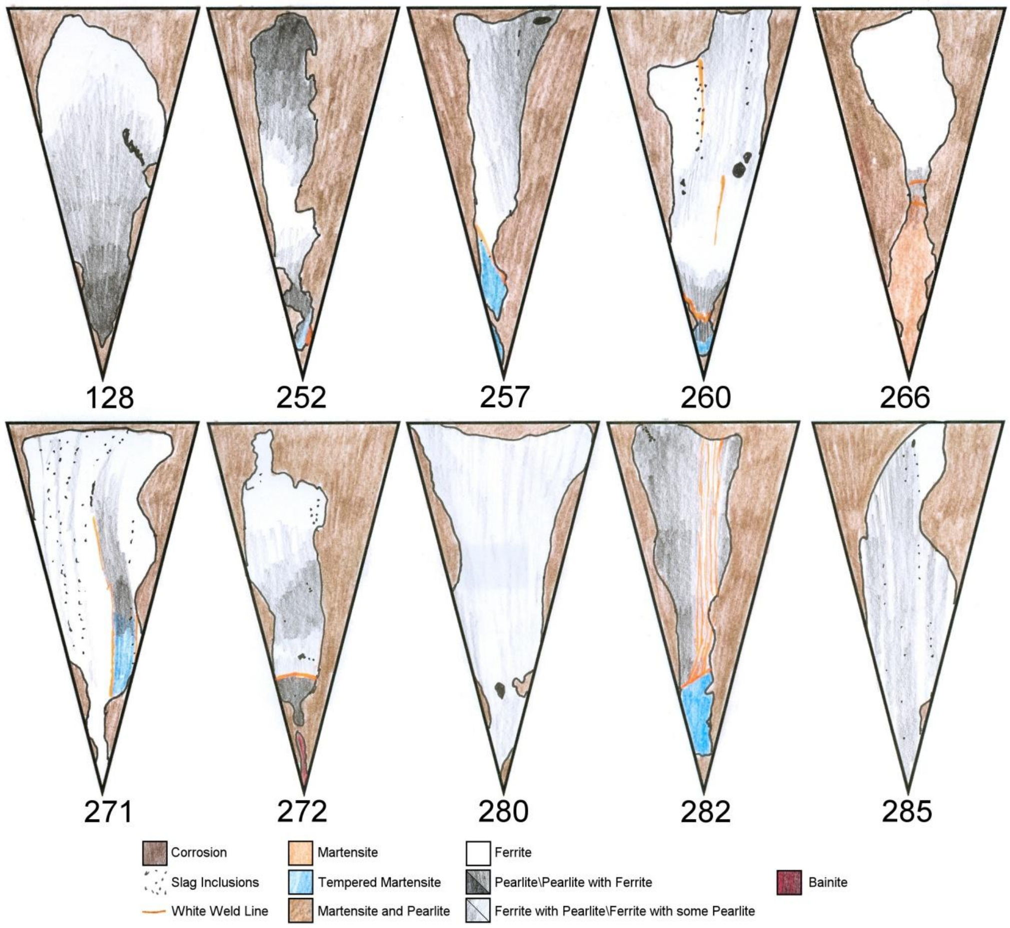


Figure 5.10: Diagrams of the 7th century knives from Collingbourne Ducis.

Summary/Review of other Early Cemeteries

The majority of the other knives from early cemeteries were reported in the review paper (Blakelock & McDonnell 2007). This revealed that generally there was a range of manufacturing types being deposited in graves. The exception is Lovedon Hill (McDonnell 1989c) where only type 1 and 5 knives were identified, but this could be due to the small sample size. Since the review paper, David Starley (Starley 2009b) has analysed knives from the 5th-7th century cemetery at Wasperton. Like the other cemeteries, this revealed a range of different knives; most of them type 2 butt-welded or piled type 3 knives.

The previous analysis has revealed that less than half (25 of 51) of the knives from the cemeteries were heat-treated, although only two other knives had a high enough carbon content to be treated (Volume 2 tables 1.2-1.6). Within the cemetery knives six were over heated, possibly evidence that some knives were destroyed before burial, possibly part of the ritual. The majority of the knife backs were low carbon steel (16 of 51), ferritic iron (11 of 51), phosphoric iron (10 of 51) or piled ferritic and phosphoric iron (6 of 51).

5.4 Middle to Late Saxon Rural & Ecclesiastical Sites

Wharram Percy

The deserted medieval village of Wharram Percy had evidence for continuous occupation from the Bronze Age to the medieval period. Archaeological evidence in the 1950s to 1990s revealed the presence of a number of timber buildings as well as a smithy. Radiocarbon dates from four samples from features associated with the smithy all fall within the calibrated date range of AD600-1010. Some finds from Wharram Percy may point to high status occupation and a possible monastic link: including Tating-Type ware, a sceat and non-ferrous metalworking remains (Stamper & Croft 2000: 195-200). But these types of finds are found on many middle Saxon sites, and the other evidence from the smithy site, i.e. poor quality knives and raw materials, points to the settlement being rural and low status (McDonnell *et al.* Forthcoming).

Number	Context	Phase	Date	Shape
134	44/139	2-3	7^{th}-8^{th}	D1
159	85/29/4	3	7^{th}-8^{th}	AX
176	85/29/6	3	7^{th}-8^{th}	D1
237	85/104	2	7^{th}-8^{th}	A1
278	81/39/9	2	7^{th}-8^{th}	BX
307	85/148	2	7^{th}-8^{th}	A1
308	85/104/6	2	7^{th}-8^{th}	XX
442	59/40/8	3	7^{th}-8^{th}	A1
472	59/127/22	3	7^{th}-8^{th}	AX
502	59/150/16	2	7^{th}-8^{th}	A2
110	85/10/1	4	9^{th}-10^{th}	X1
113	85/10/23	4	9^{th}-10^{th}	XX
126	85/10/8	4	9^{th}-10^{th}	B1

Table 5.23: Samples selected from Wharram Percy for analysis showing their small find numbers, context details and phase.

Forty-four knives were recovered during excavations at the South and North Manors at Wharram Percy. Of these, nineteen knives were dated to the early medieval period. Ten knives were examined for an undergraduate dissertation (Blakelock 2006) and these were re-examined. A further three knives were sectioned for this PhD bringing the total examined knives to thirteen, from phases ranging from the 7th to the 10th century (Table 5.23 & Figure 5.10).

Number of Knives Examined	***Back Shape***					***Tang Interface***				
	A	***B***	***C***	***D***	***X***	***1***	***2***	***3***	***4***	***X***
16	7	6	0	0	6	7	0	3	1	8

Table 5.24: A table showing the archaeological typologies of the knives from Wharram Percy. Note: X indicates where a knife was un-diagnostic or un-classifiable.

The knives from Wharram Percy had roughly equal numbers of angle-backed knives and curved knives (Table 5.24). Many were broken and therefore difficult to classify. The majority of knives had distinct tang to blade interfaces on both sides.

Summary of Knives

134 - *Type 3 piled knife with bands of mid and low carbon steels (Average 175HV$_{0.1}$, Range 157-229HV$_{0.1}$) and low phosphorus iron (Average 186HV$_{0.1}$, Range 143-216HV$_{0.1}$,* up to 0.4% P*). The cutting edge was a low carbon steel (188HV$_{0.1}$).*

159 - *Type 2 knife with a heat-treated tempered martensite cutting edge (450HV$_{0.1}$, Average 524HV$_{0.1}$, Range 450-585HV$_{0.1}$) welded onto a piled iron back, with a clear white weld line. Multiple white weld lines were present in the cutting edge (up to 0.6% As, up to 0.2% Ni, up to 0.3% Cu). The knife back consisted of low phosphorus iron (0.2%) and phosphoric iron (Average 200HV$_{0.1}$, Range 151-219HV$_{0.1}$,* 0.5%-0.6% P*).*

176 - *Type 2 knife with a low carbon steel cutting edge (120HV$_{0.1}$, Average 121HV$_{0.1}$, Range 117-125HV$_{0.1}$) welded onto a back consisting of phosphoric iron (Average 197HV$_{0.1}$, Range 167-220HV$_{0.1}$,* 0.4%-0.6% P*).*

237 - *Type 2 knife with a mid to high carbon steel cutting edge (214HV$_{0.1}$, Average 176HV$_{0.1}$, Range 147-214HV$_{0.1}$) welded onto a back consisting of piled ferritic iron and low carbon steel (Average 123HV$_{0.1}$, Range 93-141HV$_{0.1}$).*

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
134	Heavy	3	Ferritic/phosphoric iron	188	172-188	Ferritic/phosphoric iron	175	143-229	No	
159	None	2	Tempered martensite	450	450-585	Ferritic/phosphoric iron	200	151-219	Yes	White Bands
176	Some	2	Ferrite with pearlite	120	117-125	Phosphoric iron	197	167-220	No	
237	Some	2	Pearlite with ferrite	214	147-214	Ferrite	123	93-141	No	
278	Heavy	2	Ferrite cutting edge Fine pearlite or bainite	183 347	138-183 266-524	Ferrite with pearlite	139	131-203	No	Repair White weld line
307	Heavy	0	Ferritic/phosphoric iron	150	152-212	Ferritic/phosphoric iron	187	152-212	No	Repair
308	Heavy	2	Pearlite	207	193-236	Ferrite	162	125-199	No	Repair
442	Heavy	3	Pearlite	319	130-319	Ferrite with pearlite/ phosphoric iron	150	128-258	No	
472	Some	2	Pearlite	333	131-333	Phosphoric iron	191	166-213	No	
502	Some	2	Pearlite	217	185-264	Ferrite with pearlite	120	85-138	No	Repair White weld line
110	Heavy	2	Phosphoric iron (repair) Pearlite	249 299	196-249 279-380	Phosphoric iron	151	112-187	No	Repair White weld line
113	Some	3	Ferrite with pearlite	182	156-205	Piled ferrite with pearlite/ phosphoric iron	181	156-205	No	
126	Some	2	Pearlite	285	247-285	Piled ferritic iron/ ferrite with pearlite	232	194-266	No	

Table 5.25: Summary of the thirteen knives from Wharram Percy analysed. This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges).

278 - *Type 2 knife which originally had a slow heat-treated bainite cutting edge (Average 347*$HV_{0.1}$*, Range 266-524*$HV_{0.1}$*) scarf-welded onto a back consisting of three pieces of iron; two pieces of ferritic iron (Average 144*$HV_{0.1}$*, Range 131-170*$HV_{0.1}$*) with a core of mid carbon steel (Average 176*$HV_{0.1}$*, Range 137-203*$HV_{0.1}$*). A white weld line separated the cutting edge from the back (up to 0.1% Ni). There was a later repair to the knife, resulting in a low carbon steel cutting edge (183*$HV_{0.1}$*, Average 155*$HV_{0.1}$*, Range 138-183*$HV_{0.1}$*).*

307 - *Type 0 heterogeneous iron knife with low carbon steel near the cutting edge (150*$HV_{0.1}$*) and ferritic or low phosphorus iron at the back (Average 187*$HV_{0.1}$*, Range 152-212*$HV_{0.1}$*,* up to 0.3% P*).*

308 - *Type 2 knife with a high carbon cutting edge (207*$HV_{0.1}$*, Average 211*$HV_{0.1}$*, Range 193-236*$HV_{0.1}$*) welded onto a back made of two pieces of iron; one piece was a ferritic iron (Average 162*$HV_{0.1}$*, Range 128-199*$HV_{0.1}$*) while the other was a low carbon steel (Average 162*$HV_{0.1}$*, Range 152-170*$HV_{0.1}$*).*

442 - *Type 3 piled knife with bands of mid and low carbon steel, ferritic and phosphoric iron* (*Average 150*$HV_{0.1}$*, Range 128-258*$HV_{0.1}$). *The cutting edge was a high carbon steel (319*$HV_{0.1}$*, Average 247*$HV_{0.1}$*, Range 130-319*$HV_{0.1}$).

472 - *Type 2 knife with a high carbon steel cutting edge (333*$HV_{0.1}$*, Average 187*$HV_{0.1}$*, Range 131-333*$HV_{0.1}$*) welded onto a back consisting of two pieces of phosphoric iron (Average 191*$HV_{0.1}$*, Range 166-213*$HV_{0.1}$, 0.3%-0.6% P*).*

502 - *Type 2 knife with a high carbon steel cutting edge (217*$HV_{0.1}$*, Average 223*$HV_{0.1}$*, Range 185-264*$HV_{0.1}$*) scarf-welded onto a back consisting of three pieces of iron; low carbon steel (Average 132*$HV_{0.1}$*, Range 126-138*$HV_{0.1}$*), mid to high carbon steel (Average 234*$HV_{0.1}$*, Range 197-260*$HV_{0.1}$*) and low phosphorus iron (Average 112*$HV_{0.1}$*, Range 85-131*$HV_{0.1}$, up to 0.1% P*). A white weld line separated the cutting edge from the back (0.8%-1.5% As, 0.1%-0.3% Ni).*

110 - *Type 2 knife which originally had a high-quality high carbon steel cutting edge (Average 299*$HV_{0.1}$*, Range 279-380*$HV_{0.1}$*) welded onto a piled iron back, with a clear white weld line. The knife back consisted of ferritic, low-mid carbon steels (Average 151*$HV_{0.1}$*, Range 112-187*$HV_{0.1}$*). A piece of low phosphorus iron had been welded onto the cutting edge to repair the knife (Average 249*$HV_{0.1}$*, Range 196-249*$HV_{0.1}$, up to 0.2% P*).*

113 - *Type 3 piled knife with bands of high and low carbon steels and phosphoric iron* (*Average 181*$HV_{0.1}$*, Range 156-205*$HV_{0.1}$, up to 0.2% P)*. The cutting edge was a phosphoric iron* (*182*$HV_{0.1}$).

126 - *Type 2 knife with a high carbon steel cutting edge (285*$HV_{0.1}$*, Average 285*$HV_{0.1}$*, Range 247-285*$HV_{0.1}$*) welded onto a piled iron back, with a clear white* *weld line. The knife back consisted of phosphoric and ferritic iron as well as low to mid carbon steels (Average 232HV$_{0.1}$, Range 194-266HV$_{0.1}$,* up to 0.6% P*).*

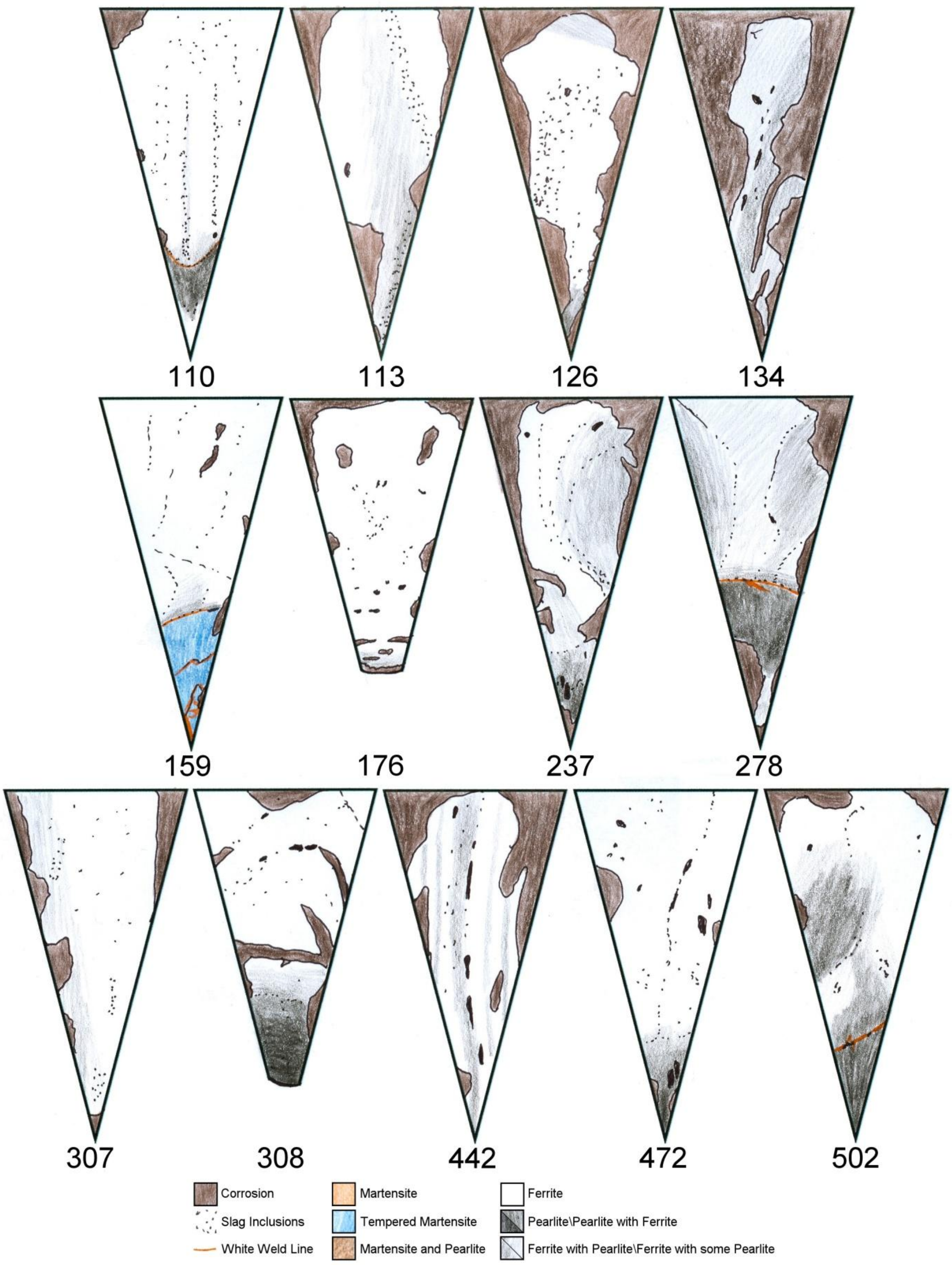


Figure 5.11: Diagrams of the knives from Wharram Percy.

Metallurgical analysis revealed that nine out of the thirteen Wharram Percy knives were butt-welded type 2 knives (Table 5.25 and Figure 5.11). There were also three type 3 knives and a single type 0 knife. Some of the knives with considerable wear (e.g. 134 and 442) may originally have been type 2 knives, but through excessive use, including re-sharpening and heavy wear, may have worn through their steel cutting edges.

A full range of materials were being utilised for the knife backs including; ferritic iron, low carbon steels and phosphoric iron. The majority of the knife backs from Wharram Percy consisted of more than one piece of iron, although it is impossible to determine whether the piled iron backs were deliberate or accidental. Only one knife showed evidence for heat treatment as it clearly had a tempered martensite cutting edge. Six of the knives had high carbon structures which consisted of pearlite, while the fine pearlite and bainite structures in some knives suggest that they were cooled quickly.

Burdale

During the 1990s intensive prospection by metal detectorists led to the discovery of many new Anglian and Anglo-Scandinavian settlements. Burdale is just such a site, identified on the Yorkshire Wolds, in a valley-bottom where Anglian settlement features were identifiable from crop marks. Excavations in Burdale during 2006-2007 in two different areas, revealed a multi-phase Anglian farmstead. Traces of sunken buildings and refuse pits were excavated and there was evidence for the development of a number of enclosures. Preliminary dating places the settlement in the 8th and 9th centuries (Richards 2007).

Knife Number	X-Ray Number	Year	Context	Shape
4 (Pivoting Knife)	6633	2006	1000	AX
200	6634	2006	6194	X3
204	6633	2006	6197	B1
208	6633	2006	I SE 8786 6196	X3
218	6633	2006	E SE 8787 6196	B1
64	6759	2007	1004	B4
65	6759	2007	1004	B3
67	6759	2007		A3
69	6759	2007	1019	D3
70	6759	2007	1050	B1
75	6760	2007	1157	A1
76	6760	2007	1179	X3
113	6760	2007	1018	X1
244	6779	2007	1472	A1

Table 5.26: Samples selected from Burdale for analysis showing their small find numbers, year of excavation, context details and x-radiograph numbers.

In total 30 knives were recovered during excavations at Burdale, including a pivoting knife. The majority (19) came from the excavations carried out in 2007 while the remainder were found in 2006. The x-radiographs for all 30 knives were examined. The results for each knife are available in the appendix (Volume 2 table 10.1). For this PhD metallographic analysis was carried out on 13 knives and the pivoting knife. A list of the knives selected and the context details is provided in table 5.26.

The x-radiograph analysis of the knives from Burdale has shown that the most common knives deposited were curved-backed knives; this was closely followed by the angle-back knife (Table 5.27 and Figure 5.12). Unfortunately many of the knives were found broken therefore many were un-diagnostic. The survey also revealed that the type of tang to blade interface was varied although the majority had a distinct tang to blade interface on one side only. There was a difference in knife shape between the two sites with a significant number of angle-backed knives recovered during the 2007 excavation. This may reflect a slight difference in date or possibly a difference in activities across the settlement.

Burdale	***Number of Knives Examined***	***Back Shape***					***Tang Interface***				
		A	***B***	***C***	***D***	***X***	***1***	***2***	***3***	***4***	***X***
2006	*10*	*0*	*5*	*0*	*0*	*5*	*2*	*1*	*5*	*2*	*0*
2007	*19*	*7*	*4*	*0*	*2*	*6*	*7*	*3*	*5*	*2*	*2*
Total	*29*	*7*	*9*	*0*	*2*	*11*	*9*	*4*	*10*	*4*	*2*

Table 5.27: A table showing the archaeological typologies of the knives from Burdale. Note: X indicates where a knife was un-diagnostic or un-classifiable. This table excludes the pivoting knife (4) which will be discussed separately.

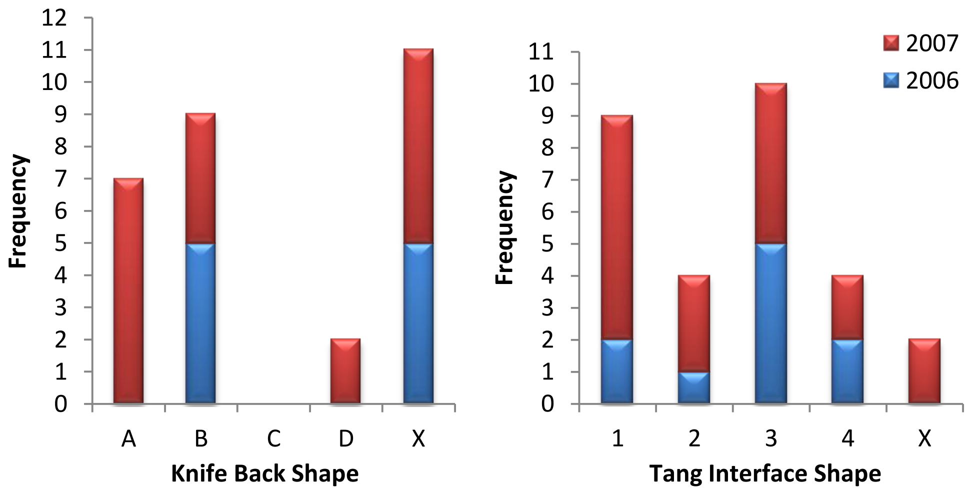


Figure 5.12: Histogram of knife typology

The full measurements from all knives from Burdale are available in the appendix (Volume 2 table 10.1). Ten knives appear to have either broken blades or tangs therefore these were ignored in the following analysis, along with the pivoting knife (Figure 5.13). The complete, or near complete, knives from Burdale ranged in size from 64mm to 148mm in length, with the average length 102mm. The length of the knife blade also varied widely from 32mm to 110mm, whereas the tangs were a more consistent in length from 17mm to 55mm. There appeared to be a direct relationship between the blade length and the tang length as blades in the majority of knives were twice as long as the tang. Even so caution must be used as the tangs are often the first thing broken during deposition and they may therefore have originally been much longer.

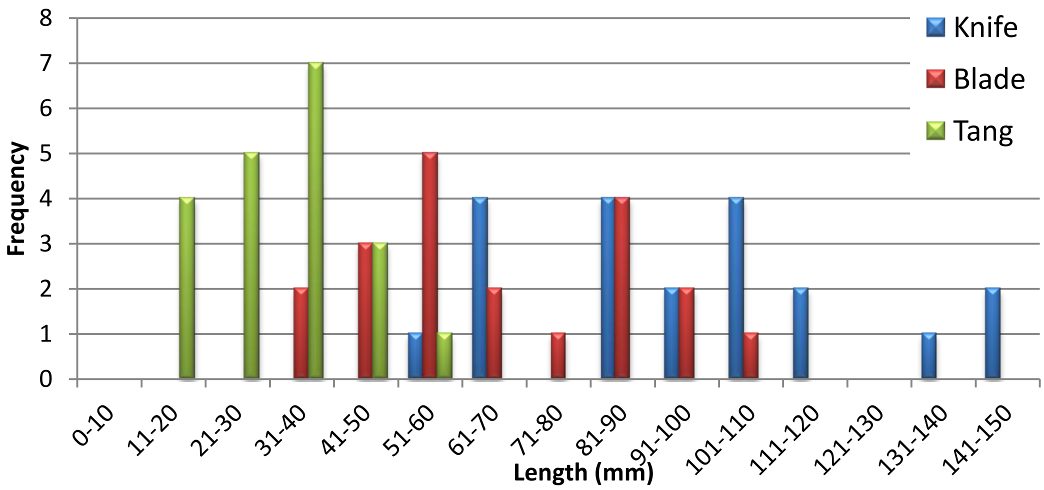


Figure 5.13: Histogram of knife sizes. This graph excludes some knives that appear to have been broken in antiquity.

The x-radiograph survey of the 29 knives revealed that 22 showed signs of some wear. The majority of which showed either an S-shaped curve (13) or slight (8) evidence of wear. Only one of the knives from Burdale showed signs of heavy wear (Table 5.28).

	Wear Pattern				
Burdale Site	*None*	*Slight*	*Moderate*	*Heavy*	*Unknown*
2006	*0*	*0*	*8*	*0*	*2*
2007	*1*	*8*	*5*	*1*	*4*
Total	*1*	*8*	*13*	*1*	*6*

Table 5.28: A table showing the amount of wear in the knives from each site.

The Burdale assemblage of knives was particularly unusual as five of the knives recovered from the 2007 excavations were bent (Figure 5.14). This type of damage could not occur naturally during deposition and therefore must have occurred during the knives life or just before deposition. Perhaps this act represents ritual destruction prior to discard.

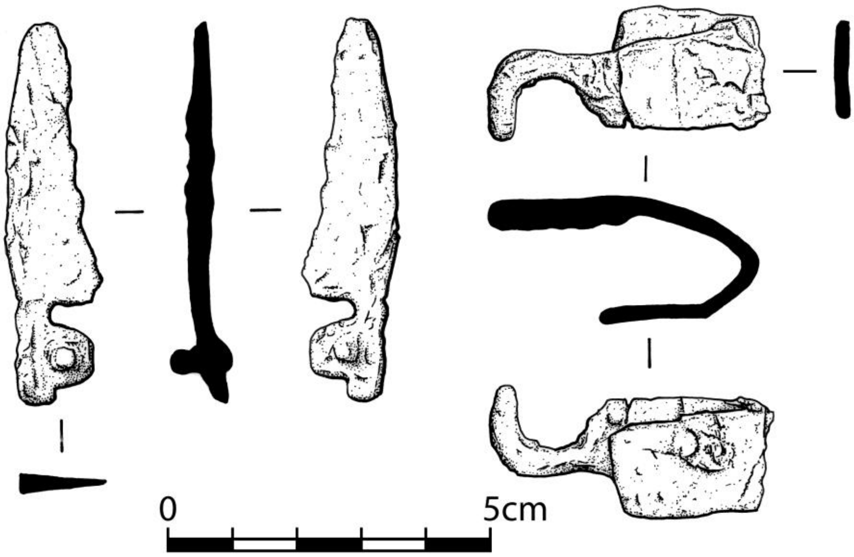


Figure 5.14: Sketches of two knives from Burdale. Left) is the broken pivoting knife and right) is an example of a bent knife (Illustration by Daniel Bashford).

Summary of Knives

64 - *Type 2 knife with a martensite to tempered martensite cutting edge (701HV$_{0.2}$, Average 490HV$_{0.2}$, Range 362-701HV$_{0.2}$) separated by a white weld line (0.2%-0.3% As, up to 2.4% Ni). The knife back consisted of low carbon steel (Average 162HV$_{0.2}$, Range 137-187HV$_{0.2}$) and phosphoric iron (Average 139HV$_{0.2}$, Range 132-148HV$_{0.2}$, 0.2%-0.3% P).*

65 - *Type 2 knife with an unusual repaired cutting edge of low phosphorus iron (210HV$_{0.2}$, Range 183-232HV$_{0.2}$, 0.2%-0.3% P) attached to tempered martensite (Average 578HV$_{0.2}$, Range 362-766HV$_{0.2}$). The knife back was phosphoric iron (Average 209HV$_{0.2}$, Range 161-244HV$_{0.2}$, 0.4%-1.0% P)*

67 - *Type 2 knife with a tempered martensite cutting edge (549HV$_{0.2}$, Range 441-549HV$_{0.2}$) separated from the knife back by a white weld line (0.6%-2.0% As, up to 0.3% Ni). The knife back consisted of two pieces of metal a low carbon steel (Average 111HV$_{0.2}$, Range 103-127HV$_{0.2}$) and ferritic iron (Average 108HV$_{0.2}$, Range 91-137HV$_{0.2}$).*

69 - *Type 2 knife with a tempered martensite cutting edge (257HV$_{0.2}$, Average 377HV$_{0.2}$, Range 257-457HV$_{0.2}$) again separated from the back by a white weld* *line (0.2%-0.4% As, up to 0.1% Ni).The knife back was piled with ferrite bands (Average 187$HV_{0.2}$, Range 183-187$HV_{0.2}$) in a predominately mid to high carbon back (Average 230$HV_{0.2}$, Range 210-264$HV_{0.2}$).*

70 - *Type 2 knife with a white weld line (0.9% As, 1.8% Ni) separating the tempered martensite cutting edge (732$HV_{0.2}$, Range 473-766$HV_{0.2}$) from the ferritic iron back (Average 138$HV_{0.2}$, Range 118-161$HV_{0.2}$).*

75 - *Type 2 knife with a high carbon steel cutting edge (549$HV_{0.2}$, Range 340-549$HV_{0.2}$). The knife back was constructed of two pieces of ferritic iron (Average 159$HV_{0.2}$, Range 103-210$HV_{0.2}$). and low carbon steel (Average 208$HV_{0.2}$, Range 161-271$HV_{0.2}$). There is no evidence that the knife was bent while cold, instead it appears that it was slightly annealed.*

76 - *Type 2 knife with a pearlite cutting edge (Average 272$HV_{0.2}$, Range 244-321$HV_{0.2}$) while the back was a ferritic iron (Average 184$HV_{0.2}$, Range 137-221$HV_{0.2}$).*

113 - *Type 3 piled knife with bands of ferrite* (*168$HV_{0.2}$, Average 163$HV_{0.2}$, Range 158-168$HV_{0.2}$*) *and low carbon steel* (*Average 148$HV_{0.2}$, Range 116-176$HV_{0.2}$*). *Neumann bands in the back of the knife suggest it was most likely bent while cold.*

200 - *Type 2 knife which had a white weld line (0.1%-0.4% As, up to 0.3% Ni) that separated the tempered martensite cutting edge* (*671$HV_{0.2}$, Average 555$HV_{0.2}$, Range 386-701$HV_{0.2}$*) *from the ferritic back* (*Average 140$HV_{0.2}$, Range 94-168$HV_{0.2}$*).

204 - *Type 2 knife with a heat-treated lightly tempered cutting edge (441$HV_{0.2}$, Average 369$HV_{0.2}$, Range 303-441$HV_{0.2}$). This cutting edge was separate from the back by a white weld line (0.2%-1.3% As, up to 0.1% Ni). The knife back was constructed of two pieces of iron; mid-high carbon steel (Average 172$HV_{0.2}$, Range 140-183$HV_{0.2}$) around a low phosphorus iron (Average 178$HV_{0.2}$, Range 143-215$HV_{0.2}$, 0.1%-0.3% P).*

208 - *Type 3 piled knife with bands of low carbon steel* (*286$HV_{0.2}$, Average 380$HV_{0.2}$, Range 196-441$HV_{0.2}$*) *and phosphoric iron (Average 341$HV_{0.2}$, Range 232-412$HV_{0.2}$, 0.2%-0.4% P).*

218 - *Type 4 knife with a phosphoric iron core* (*Average 233$HV_{0.2}$, Range 148-303$HV_{0.2}$, 0.2%-0.4% P)* with *tempered martensite* (*549$HV_{0.2}$, Average 529$HV_{0.2}$, Range 232-549$HV_{0.2}$*) *and high carbon steel wrapped around.*

244 - *Type 2 knife with a tempered martensite cutting edge* (*766$HV_{0.2}$*, *Average 651$HV_{0.2}$, Range 441-927$HV_{0.2}$*) *with a white weld line (0.4%-0.6% As, 0.1-0.4%*

Ni) separating this from the piled ferritic/phosphoric iron back (Average 181$HV_{0.2}$, Range 148-210$HV_{0.2}$).

The vast majority of knives from Burdale (10 out of 13) are type 2 butt-welded knives, directly comparable to other middle Saxon sites, e.g. Wharram Percy, Hamwic and York (Table 5.29 and Figure 5.15). The remaining knives consist of two piled knives (type 3) and a type 4 knife with steel wrapped around an iron core. Most of the type 2 knives (7 out of the 10) and the single type 4 knife had been heat treated to create a harder cutting edge. The backs of many knives consisted of more than one piece, and type, of iron alloy. There does not appear to be any difference between the technologies used to manufacture the knives in the two excavation areas.

The x-radiographs of the remaining sixteen knives, that were not sectioned, suggested that there are as many as ten butt-welded knives and eight knives were identified as possibly having steel cutting edges. Out of these knives five were identified as type 2 butt-welded knives with steel. This leaves up to two knives that could be type 1 ‘sandwich type’ knives or homogenous steel knives.

Analysis of the assemblage revealed pivoting knife (knife 4) from the 2006 Burdale excavations (Figure 5.14 and Figure 5.15). This knife had broken just beyond the pivoting pin. The x-radiograph revealed a clear groove in the back of the knife, similar to those seen at York. Very few, if any, pivoting knives have been examined in the past therefore the opportunity was taken to metallographically examine this one. The pivoting knife was a fairly typical type 2 knife but with a bainitic cutting edge (486$HV_{0.2}$, Average 438$HV_{0.2}$, Range 386-486$HV_{0.2}$) suggesting that it was quenched slowly. A white weld line (0.2%-1.1% As, up to 0.2% Ni) separated this from the back which consisted of three pieces of iron; low carbon steel (Average 129$HV_{0.2}$, Range 107-143$HV_{0.2}$) and two pieces of mid carbon steel (Average 186$HV_{0.2}$, Range 148-210$HV_{0.2}$). The knife back most likely ran the full length of the knife. The pivoting pin was made of a similar piled iron alloy to the back and was pushed through a hole premade in the knife.

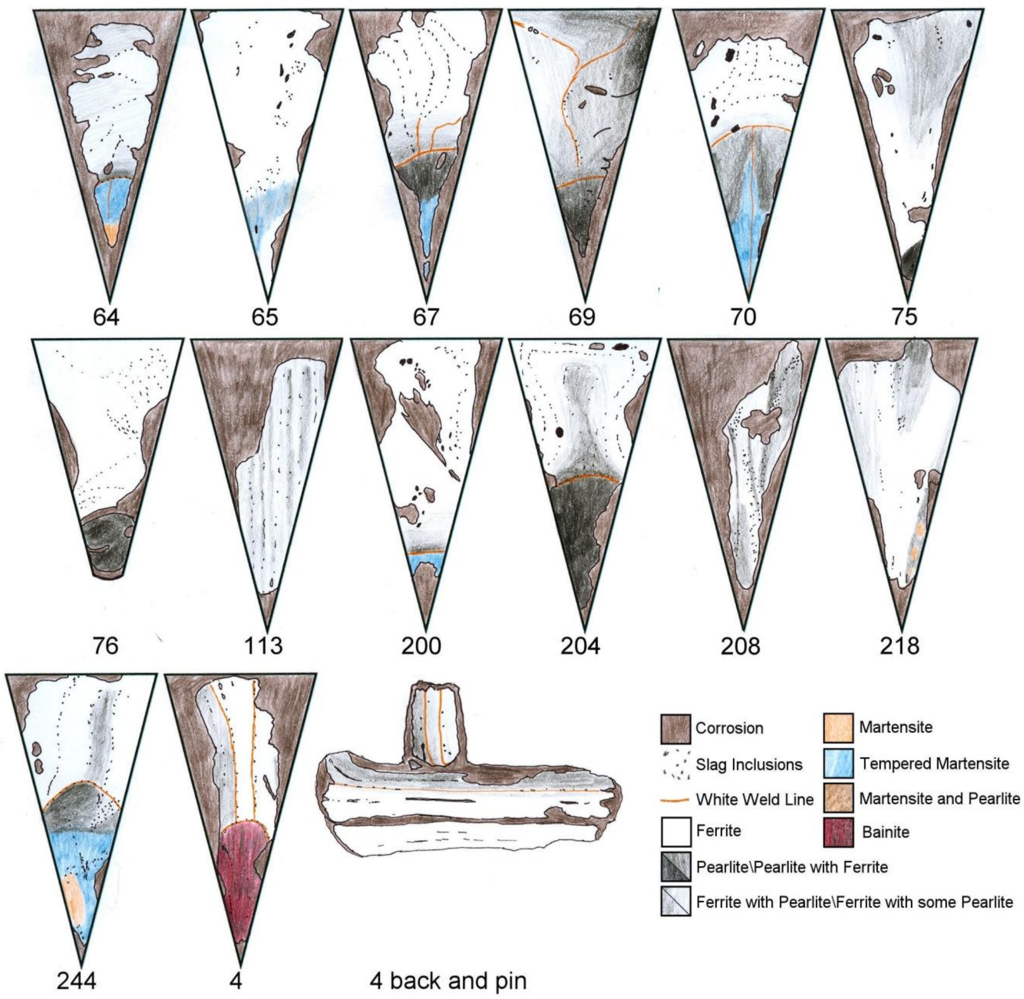


Figure 5.15: Diagrams of the knives from Burdale.

At other early medieval sites such as Coppergate (Ottaway 1992: 579-582) and Dublin (Ottaway 1992: 579-582; Blakelock 2007b) a number of different features are present in the knives; Burdale was no different. One knife had a possible transversal notch but two, possibly three, knives had indents in the back. The majority of knives from Burdale with notches and/or indents were angle-backed; this was also noted at Coppergate, York (Ottaway 1992: 579-582) and Dublin (Blakelock 2007b). None of the knives had any obvious form of decoration, e.g. pattern welding or non-ferrous inlays.

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
4	Some	2	Bainite	486	386-486	Ferrite with some pearlite	158	107-201	Slow	White weld line
64	Very	2	Tempered Martensite	701	362-701	Ferrite with pearlite/ phosphoric iron	130	91-187	Yes	White weld line
65	Slight	2	Phosphoric iron	210	183-210	Phosphoric iron	209	161-244		Repair
67	Slight	2	Tempered Martensite	549	441-549	Ferrite with some pearlite	109	91-137	Yes	White weld line
69	Some	2	Pearlite	257	257-457	Piled Ferrite and pearlite/ pearlite	212	183-264		White weld line
70	Slight	2	Tempered Martensite	732	473-766	Ferrite	138	118-161	Yes	White weld line
75	Some	2	Tempered Martensite	549	340-549	Ferrite with pearlite/ phosphoric iron	191	103-271	Yes	
76	Some	2	Pearlite	272	244-321	Ferrite	184	137-221		
113	Some	3	Ferrite with pearlite	168	116-176	Ferrite with pearlite	148	116-176		
200	Some	2	Tempered Martensite	671	386-701	Ferritic/phosphoric iron	140	94-168	Yes	White weld line
204	Some	2	Tempered Martensite	441	303-441	Ferrite with pearlite/ phosphoric iron	175	140-215	Slow	White weld line
208	Slight	3	Ferrite with pearlite	286	196-412	Ferrite with pearlite/ phosphoric iron	294	196-412		
218	Some	4	Tempered Martensite	549	232-549	Phosphoric iron	233	148-303	Yes	
244	Slight	2	Tempered Martensite	766	441-927	Ferrite with pearlite (carbides)/ phosphoric iron	181	148-210	Yes	White weld line

Table 5.29: Summary of the thirteen knives analysed. This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges).

Sedgeford

The excavations at Sedgeford are still being carried out by the Sedgeford Historical and Archaeological Research Project which has revealed a continuous occupation in this rural settlement in north-west Norfolk. The main focus of the project has been the large scale excavation of Boneyard Field which has revealed a late Saxon cemetery. The recent excavations have now expanded into the adjacent field to locate the middle to late Saxon settlement. Both sites have produced large numbers of middle and late Saxon features and the artefacts present suggest that Sedgeford was a fairly typical rural site (Cabot *et al.* 2004). Smithing slag has been identified at Sedgeford, but in addition to this smelting slag has also been found. This suggests that the settlement was to some extent self-sufficient.

Number	Site	Context	Phase	Shape
40	BYD/RDM	45	Middle Saxon	X1
120	BYD/RDM	1200	Middle Saxon	X2
1513	BYD/RDM	8701	Middle Saxon	B4
2318	CNE	302	Middle Saxon	XX
45	BYD/RDM	65	Middle/Late Saxon	BX
108	BYD/RDM	1139	Middle/Late Saxon?	D1
116	BYD/RDM	1132	Middle/Late Saxon	B2
666	BYD/RDM	7015	Middle/Late Saxon?	B3
705	BYD/RDM	7091	Middle/Late Saxon?	BX
747	BYD/RDM	7091	Middle/Late Saxon?	A1
1178	BYD/RDM	0	Middle/Late Saxon?	B1
3138	BYD/RDM	1084	Middle/Late Saxon?	D1
3140	BYD/RDM	65	Middle/Late Saxon	B3
3141	BYD/RDM	2	Middle/Late Saxon?	D3
8	BYD/RDM	1047	Late Saxon?	BX
115	BYD/RDM	1185 (1180)	Late Saxon?	B2
128	BYD/RDM	1189 (1180)	Late Saxon?	B3
188	BYD/RDM	1180	Late Saxon?	B2
337	BYD/RDM	1419	Late Saxon	B3
344	BYD/RDM	1663	Late Saxon	D3
429	BYD/RDM	1573	Late Saxon	BX
1378	BYD/RDM	8555	Late Saxon	B1
1384	BYD/RDM	8543	Late Saxon	X3
2304	CNE	303	Late Saxon	B3
2309	CNE	310	Late Saxon	DX
2401	CNE	404	Late Saxon	A3
3031	CNE	0	Late Saxon?	B1
3066	CNE	10134	Late Saxon?	B1
3136	BYD/RDM	1056	Late Saxon?	B1

Table 5.30: Samples selected for analysis from Sedgeford showing their small find numbers, context details, phase and date.

In total 52 knives have been recovered so far during excavations at Sedgeford. The x-radiographs for all knives were examined and the results for each knife are available in the appendix (Volume 2 table 11.1). A full list of knives analysed for this PhD, their contexts and site phase have been included in table 5.30.

The x-radiograph analysis of knives from Sedgeford has shown that the most common knives deposited were curved-backed knives (Table 5.31). The survey also revealed that the type of tang to blade interface varied, although the majority had a distinct tang to blade interface on one side only.

Number of Knives Examined	***Back Shape***					***Tang Interface***				
	A	***B***	***C***	***D***	***X***	***1***	***2***	***3***	***4***	***X***
49	5	24	0	8	12	11	5	15	2	16

Table 5.31: A table showing the archaeological typologies of the knives from Sedgeford. Note: X indicates where a knife was un-diagnostic or un-classifiable.

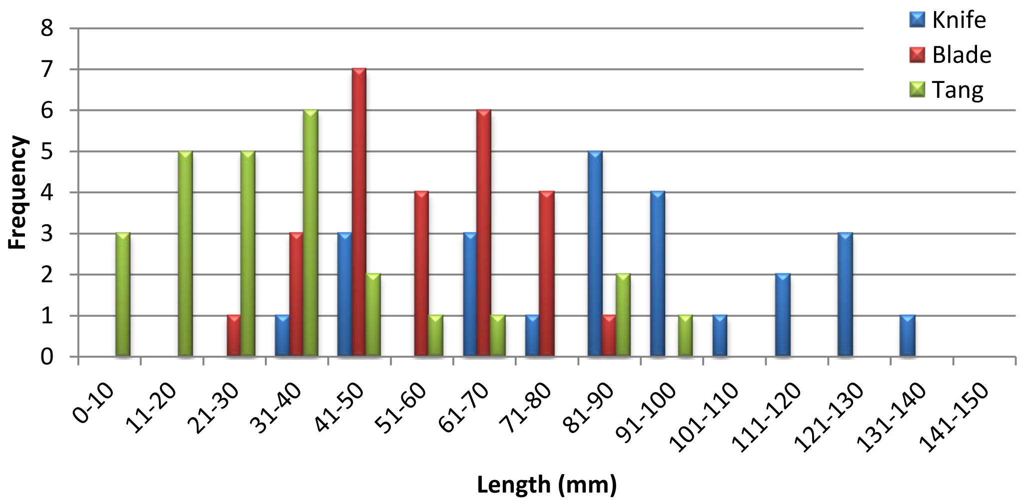


Figure 5.16: Histogram of knife sizes at Sedgeford. This graph excludes some knives that appear to have been broken in antiquity.

The full measurements of all the Sedgeford knives are available in the appendix (Volume 2 table 11.1). Many of the knives appear to have either broken blades or tangs and most of these were therefore ignored in the following analysis (Figure 5.16). The complete, or near complete, knives from Sedgeford ranged in size from 40mm to 158mm in length, with the average length 92mm. The length of the knife blade also varied dramatically from 86mm to 22mm, as did the tangs which varied in length from 8mm to 113mm. Determining the amount of wear present was hampered by the fragmented nature of some of the knives, but even so twenty knives showed clear evidence for wear, and two knives (2304 and 3139) had significant wear (Table 5.32).

Wear Pattern				
None	***Slight***	***Moderate***	***Heavy***	***Unknown***
29	11	7	2	6

Table 5.32: A table showing the amount of wear in the knives from Sedgeford.

Summary of Knives

40 - *Type 0 heterogeneous iron knife with low carbon steel near the cutting edge (137$HV_{0.2}$, Average 155$HV_{0.2}$, Range 123-192$HV_{0.2}$) and ferritic and low phosphorus iron at the back (Average 154$HV_{0.2}$, Range 123-192$HV_{0.2}$, up to 0.3% P).*

120 - *Type 3 piled knife with bands of mid and low carbon steels* (*Average 171$HV_{0.2}$, Range 132-271$HV_{0.2}$*) *and phosphoric iron* (*Average 177$HV_{0.2}$, Range 168-192$HV_{0.2}$, 0.1%-0.7% P*)*. The cutting edge was a low carbon steel* (*137$HV_{0.2}$, Average 156$HV_{0.2}$, Range 137-175$HV_{0.2}$*).

1513 - *Type 2 knife with a heat-treated tempered martensite cutting edge (549$HV_{0.2}$, Average 525$HV_{0.2}$, Range 192-549$HV_{0.2}$) welded onto a back consisting of two pieces of iron; low carbon steel (Average 187$HV_{0.2}$, Range 175-210$HV_{0.2}$), and ferritic iron (Average 155$HV_{0.2}$, Range 137-175$HV_{0.2}$). White weld lines separated the cutting edge from the back, as well as the three pieces of metal in the knife back (up to 0.2% As, 1.3%-1.8% Ni).*

2318 - *Type 2 knife with a high carbon steel cutting edge (201$HV_{0.2}$, Average 245$HV_{0.2}$, Range 201-286$HV_{0.2}$) welded onto a back consisting of two pieces of iron; low carbon steel (Average 227$HV_{0.2}$, Range 221-244$HV_{0.2}$), and phosphoric iron (Average 212$HV_{0.2}$, Range 192-257$HV_{0.2}$,* 0.3%-0.4% P*).*

45 - *Type 2 knife with a low carbon steel cutting edge (154$HV_{0.2}$, Average 157$HV_{0.2}$, Range 154-168$HV_{0.2}$) welded onto a back consisting of phosphoric iron (Average 192$HV_{0.2}$, Range 148-221$HV_{0.2}$,* 0.2%-0.6% P*).*

108 - *Type 2 knife with a high carbon steel cutting edge (362$HV_{0.2}$, Average 368$HV_{0.2}$, Range 321-441$HV_{0.2}$) welded onto a back consisting of ferritic iron (Average 152$HV_{0.2}$, Range 97-244$HV_{0.2}$). A white weld line separated the cutting edge from the back (0.1%-0.2% As, up to 0.1% Ni and Cu).*

116 - *Type 2 knife with a high carbon steel cutting edge (257$HV_{0.2}$, Average 270$HV_{0.2}$, Range 257-321$HV_{0.2}$) welded onto an iron back, separated by a clear* *white weld line. The knife back consisted of piled low and mid carbon steel (Average 159HV$_{0.2}$, Range 132-201HV$_{0.2}$).*

666 - *Type 0 homogenous iron knife with low carbon steel near the cutting edge (183HV$_{0.2}$, Average 154HV$_{0.2}$, Range 118-201HV$_{0.2}$) and ferritic iron at the back (Average 122HV$_{0.2}$, Range 107-148HV$_{0.2}$).*

705 - *Type 2 knife with a heat-treated tempered martensite cutting edge (549HV$_{0.2}$, Average 468HV$_{0.2}$, Range 386-549HV$_{0.2}$) welded onto a back consisting of two pieces of iron; ferritic iron (Average 145HV$_{0.2}$, Range 107-192HV$_{0.2}$) and low carbon steel (Average 167HV$_{0.2}$, Range 148-192HV$_{0.2}$). A white weld line separated the cutting edge from the back (up to 0.4% As, 0.3%-0.8% Ni, 0.1% Cu).*

747 - *Type 1 knife with a small piece of heat-treated tempered martensite steel (549HV$_{0.2}$, Average 385HV$_{0.2}$, Range 244-549HV$_{0.2}$) sandwiched between two larger pieces of low carbon steel and phosphoric iron (Average 170HV$_{0.2}$, Range 137-221HV$_{0.2}$,* 0.1%-0.6% P*) forming an upside down Y shape weld.*

1178 - *Type 5, all steel knife, which has been heat-treated resulting in a martensite cutting edge (509HV$_{0.2}$, Average 501HV$_{0.2}$, Range 386-644HV$_{0.2}$) but bainite and pearlite in the knife back (Average 339HV$_{0.2}$, Range 183-473HV$_{0.2}$).*

3138 - *Type 1 knife with a heat-treated tempered martensite cutting edge (644HV$_{0.2}$, Average 537HV$_{0.2}$, Range 340-644HV$_{0.2}$) scarf-welded onto a back consisting of low phosphorus iron (Average 211HV$_{0.2}$, Range 175-244HV$_{0.2}$,* 0.1%-0.4% P*) and also large quantities of arsenic (0.1%-0.6%). A white weld line separated the cutting edge from the back (0.4%-0.6% As, 0.2%-0.9% Ni).*

3140 - *Type 0 heterogeneous iron knife with phosphoric iron near the cutting edge (175HV$_{0.2}$, Average 199HV$_{0.2}$, Range 175-232HV$_{0.2,}$* 0.4%-0.6% P*) and low carbon steel at the back (Average 226HV$_{0.2}$, Range 192-286HV$_{0.2}$).*

3141 - *Type 1 knife with a small piece of heat-treated martensite steel (766HV$_{0.2}$, Average 623HV$_{0.2}$, Range 386-766HV$_{0.2}$) sandwiched between two larger pieces of phosphoric iron (Average 192HV$_{0.2}$, Range 168-221HV$_{0.2}$,* 0.2%-0.5% P*) forming an upside down Y shape weld showing as white weld lines (0.1%-0.3% As, 0.2%-1.6% Ni).*

8 - *Type 2 knife with a heat-treated tempered martensite cutting edge (509HV$_{0.2}$, Average 469HV$_{0.2}$, Range 271-509HV$_{0.2}$) welded onto a piled iron back, with a clear white weld line. The knife back consisted of ferritic and low carbon steel (Average 177HV$_{0.2}$, Range 137-232HV$_{0.2}$).*

115 - *Type 2 knife with a heat-treated tempered martensite cutting edge (509HV$_{0.2}$, Average 476HV$_{0.2}$, Range 362-509HV$_{0.2}$) welded onto a back made of* three pieces of iron; low carbon steel (Average 291$HV_{0.2}$, Range 232-321$HV_{0.2}$), mid carbon steel (Average 274$HV_{0.2}$, Range 244-303$HV_{0.2}$) and phosphoric iron (Average 198$HV_{0.2}$, Range 168-221$HV_{0.2}$, 0.3%-0.4% P). White weld lines separated the cutting edge from the back, as well as the three pieces of metal in the knife back (0.6%-0.9% As, 0.3%-0.5% Ni, 0.1%-0.2% Cu).

128 - Type 1 knife with a heat-treated tempered martensite core (509$HV_{0.2}$, Average 543$HV_{0.2}$, Range 303-701$HV_{0.2}$) sandwiched between two pieces of piled iron. This consisted of phosphoric iron (Average 217$HV_{0.2}$, Range 210-221$HV_{0.2}$, 0.1%-0.7% P) and heat-treated mid-high carbon steel (Average 331$HV_{0.2}$, Range 286-386$HV_{0.2}$). To either side of these pieces there was a white weld line (0.1% As, 0.1% Ni).

188 - Type 2 knife with a heat-treated martensite cutting edge (509$HV_{0.2}$, Average 610$HV_{0.2}$, Range 257-644$HV_{0.2}$) welded onto a back consisting of phosphoric iron (Average 196$HV_{0.2}$, Range 175-210$HV_{0.2}$, 0.2%-0.8% P). A white weld line separated the cutting edge from the back (0.6%-0.7% As, up to 0.4% Ni).

337 - Unusual reverse type 2 knife with a phosphoric iron cutting edge (161$HV_{0.2}$, Average 169$HV_{0.2}$, Range 148-201$HV_{0.2}$, 0.3%-0.6% P) welded onto a pearlite back (Average 340$HV_{0.2}$, Range 303-412$HV_{0.2}$).

344 - Type 0 knife consisting of phosphoric iron (132$HV_{0.2}$, Average 163$HV_{0.2}$, Range 132-192$HV_{0.2}$, 0.2%-0.6% P), with a low carbon steel area on one side (Average 179$HV_{0.2}$, Range 161-232$HV_{0.2}$).

429 - Type 2 knife with a high carbon steel cutting edge (321$HV_{0.2}$, Average 330$HV_{0.2}$, Range 271-386$HV_{0.2}$) welded onto a back consisting of ferritic iron (Average 188$HV_{0.2}$, Range 148-221$HV_{0.2}$). A white weld line separated the cutting edge from the back (up to 0.2% As, up to 0.1% Ni).

1378 - Type 2 knife with a heat-treated tempered martensite cutting edge (509$HV_{0.2}$, Average 495$HV_{0.2}$, Range 342-644$HV_{0.2}$) welded onto a back consisting of phosphoric iron (Average 231$HV_{0.2}$, Range 148-386$HV_{0.2}$, 0.2%-0.4% P). A white weld line separated the cutting edge from the back (0.1% As).

1384 - Type 0 knife consisting of low carbon steel at the cutting edge (143$HV_{0.2}$, Average 149$HV_{0.2}$, Range 127-175$HV_{0.2}$).

2304 - Type 0 heterogeneous iron knife with low phosphorus iron near the cutting edge (168$HV_{0.2}$, Average 141$HV_{0.2}$, Range 114-168$HV_{0.2}$, 0.1%-0.3% P) and low carbon steel at the back (Average 156$HV_{0.2}$, Range 132-210$HV_{0.2}$, 0.1%-0.3% P).

2309 - Type 1 knife with a heat-treated tempered martensite core (701$HV_{0.2}$, Average 614$HV_{0.2}$, Range 473-701$HV_{0.2}$) sandwiched between two pieces of phosphoric iron (Average 216$HV_{0.2}$, Range 154-271$HV_{0.2}$, 0.3%-0.5% P).

2401 - *Type 1 knife with a heat-treated tempered martensite core (644*$HV_{0.2}$*, Average 442*$HV_{0.2}$*, Range 286-644*$HV_{0.2}$*) sandwiched between two pieces of ferritic iron (Average 168*$HV_{0.2}$*, Range 107-303*$HV_{0.2}$, up to 0.1% P*).*

3031 - *Type 3 piled knife with two main components the first is a low carbon steel* (*110*$HV_{0.2}$*, Average 130*$HV_{0.2}$*, Range 110-168*$HV_{0.2}$) *the other was ferritic iron* (*Average 121*$HV_{0.2}$*, Range 90-127*$HV_{0.2}$).

3066 - *Type 2 knife with a slow heat-treated cutting edge of martensite with pearlite (441*$HV_{0.2}$*, Average 528*$HV_{0.2}$*, Range 201-593*$HV_{0.2}$*) welded onto a back consisting of ferritic iron (Average 133*$HV_{0.2}$*, Range 107-175*$HV_{0.2}$, up to 0.1% P*).*

3136 - *Type 1 knife with a heat-treated tempered martensite core (593*$HV_{0.2}$*, Average 388*$HV_{0.2}$*, Range 168-593*$HV_{0.2}$*) sandwiched between two pieces of low phosphorus iron (Average 217*$HV_{0.2}$*, Range 148-362*$HV_{0.2}$, 0.1%-0.2% P*). To either side of these pieces of iron there was a white weld line.*

The metallographic analysis of twenty-nine knives from Sedgeford revealed that the majority were type 2 knives (Table 5.33 and Figure 5.17). Although there were also large numbers of type 0 and 1 knives. Thirteen of the twenty-nine knives analysed were heat-treated. Four knives from the middle to late Saxon period and one from the late Saxon period could have been heat-treated as there was enough carbon present, but they were not. The remaining knives had low carbon steel or phosphoric iron cutting edges, which were too low in carbon to heat-treat. The majority of the knife backs were phosphoric iron, and the remaining were carbon steels.

The x-radiographs of the other remaining knives revealed another nine possible type 2 butt-welded knives and up to eleven knives which have been heat-treated. This suggests that, like other middle and late Saxon settlement in England the knives at Sedgeford were mostly just the standard type 2 manufacture.

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
40	None	0	Ferrite with pearlite	137	123-192	Ferrite with pearlite/Phosphoric iron/ Ferritic iron	154	123-192		White weld line
120	None	3	Ferrite with pearlite	137	137-175	Piled ferrite and pearlite/Phosphoric iron	171	132-271		
1513	Some	2	Tempered Martensite	549	192-549	Ferrite with pearlite/Phosphoric iron	171	137-210	Yes	White weld line
2318	None	2	Pearlite with ferrite	201	201-286	Ferrite with pearlite/Phosphoric iron	226	192-257		Carburised
45	Non	2	Ferrite with pearlite	154	154-168	Phosphoric iron	192	148-221		
108	Some	2	Pearlite	362	321-441	Ferrite	152	97-244	Yes	White weld line
116	None	2	Pearlite with ferrite	257	257-321	Piled ferrite with pearlite/Pearlite with ferrite	159	132-201		
666	None	0	Ferrite with some pearlite	183	107-201	Ferrite	138	107-201		White weld line
705	Slight	2	Tempered Martensite	549	386-549	Ferrite/Ferrite with pearlite	155	107-192	Yes	
747	Slight	1	Tempered Martensite	549	244-549	Ferrite with Pearlite/Phosphoric iron	170	137-221		White weld line
1178	None	5	Tempered Martensite	509	386-644	Bainite/Pearlite	339	183-473	Yes	
3138	Slight	2	Martensite with pearlite	644	340-644	Phosphoric iron	211	175-244	Yes	White weld line
3140	None	0	Ferrite/Phosphoric	175	175-286	Ferrite with pearlite	208	175-286		White weld line
3141	None	1	Tempered Martensite	766	386-766	Phosphoric iron	192	168-221	Yes	
8	Slight	2	Tempered Martensite	509	271-509	Ferritic/Phosphoric iron	177	137-232	Yes	
115	None	2	Tempered Martensite	509	362-509	Pearlite/Phosphoric iron	251	168-321	Yes	White weld line
128	Some	1	Tempered Martensite	509	303-701	Bainite/Phosphoric iron	329	210-386	Yes	White weld line
188	None	2	Tempered Martensite	509	257-644	Phosphoric iron	196	175-210	Yes	White weld line
337	Slight	2	Phosphoric	161	148-201	Pearlite with ferrite	340	303-412		Reverse Type 2
344	None	0	Phosphoric iron/Ferrite with pearlite	132	132-232	Phosphoric iron/Ferrite with pearlite	179	132-232		
429	None	2	Pearlite	321	271-386	Pearlite with ferrite/Ferrite	188	148-221		White weld line
1378	None	2	Tempered Martensite	509	342-644	Phosphoric iron	231	148-386	Yes	White weld line
1384	None	0	Ferrite with some pearlite	143	127-175	Ferrite with some pearlite	149	127-175		
2304	Heavy	0	Phosphoric iron	168	114-168	Ferrite with pearlite	156	132-210		
2309	Slight	1	Tempered Martensite	701	473-701	Phosphoric iron	216	154-271	Yes	
2401	Slight	1	Tempered Martensite	644	412-644	Ferrite	168	107-303	Yes	
3031	Some	3	Ferrite with pearlite	110	90-168	Ferrite	121	90-168		
3066	None	2	Tempered martensite with pearlite	441	201-593	Ferrite	133	107-175	Yes	
3136	None	1	Tempered martensite	593	386-593	Ferrite/Phosphoric iron	217	148-362	Yes	

Table 5.33: Summary of the twenty-nine middle to late Saxon knives analysed. This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges).

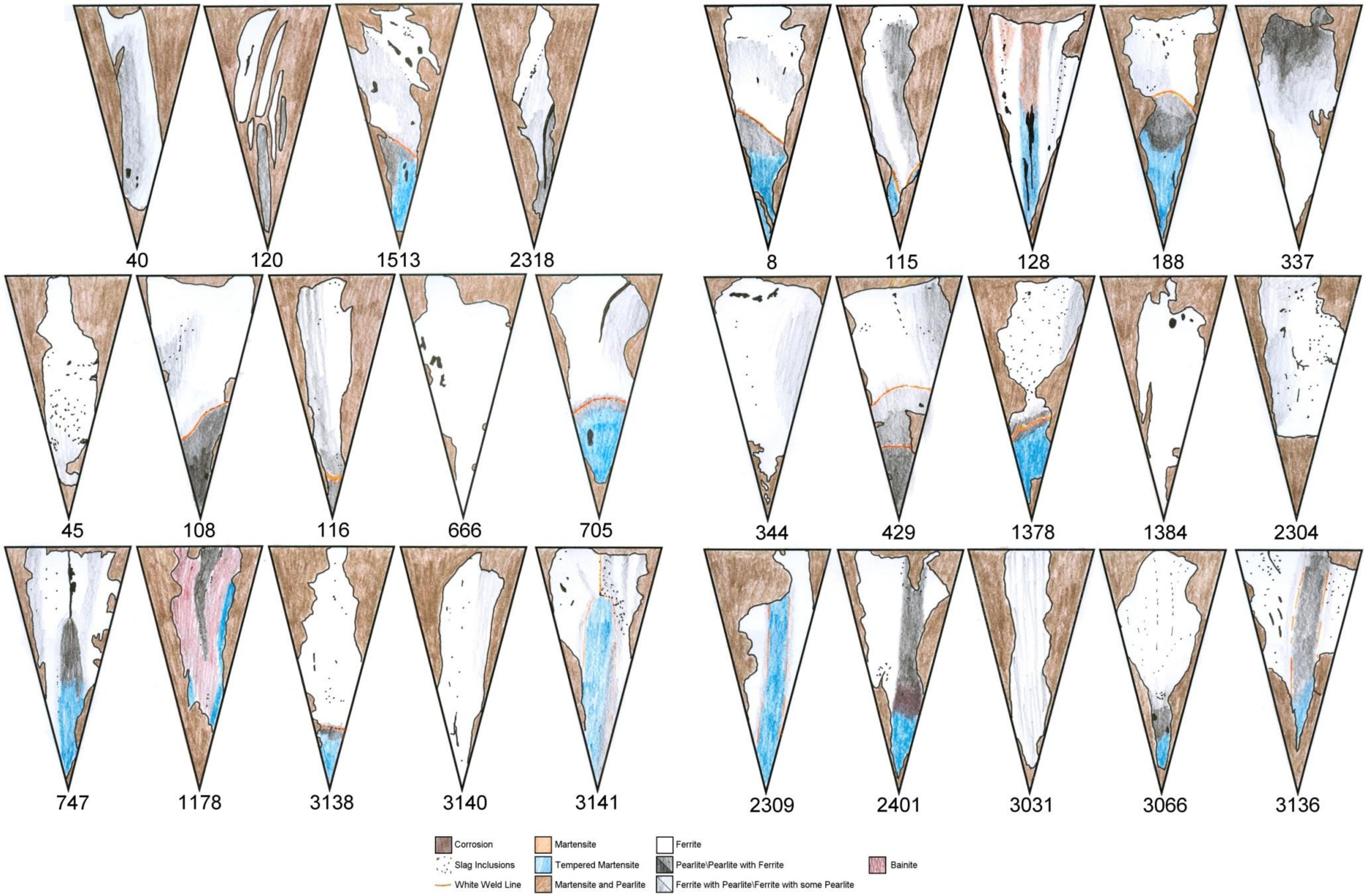


Figure 5.17: Diagrams of the middle to late Saxon knives from Sedgeford.

Whithorn

The ecclesiastical settlement at Whithorn is one of only a few sites mentioned by *Bede's Ecclesiastical History* (Bede *et al.* 1990: 148) which suggests a founding date in the 5th century although the excavations between 1984 to 1991 revealed that it was more likely established in the 6th century (Hill 2001: 47-48). Archaeological deposits were recovered, organised into several phases. Phase 1 is from the 6th century AD to AD730 when the settlement was first established. Phase 2 (730-845AD) covers the period when the minster was constructed, and while there were other Anglian settlements nearby there was very little evidence for trade and contact beyond Northumbria (Hill & Campbell 1997: 47-48). During phase 3 (845-1000AD) there was a dramatic change in material culture indicating trade and by phase 4 (1000-1250AD) the archaeological evidence points to major expansion, with the construction of the cathedral. During this period there appears to have been a displacement of the Anglian settlers and an increase in Irish contacts, suggesting a Hibero-Norse or Irish community (Hill & Campbell 1997).

Knife Number	Context	Period	Shape
13737	14763	6th century to 730	D2
14373	14475	6th century to 730	A1
4542	5358	730-845	BX
10070	7297	730-845	A1
84293	84008	730-845	B1
1744	570	845-1000	X2
11202	13046	845-1000	B1
12524	11901	845-1000	X3
84343	85052	845-1000	B1
813	540	1000-1250	B1
1537	1104	1000-1250	D2
1935	1065	1000-1250	B1
11988	11755	1000-1250	B2
14622	15144	1000-1250	X1
84270	82013	1000-1250	B1
84298	84070	1000-1250	B1

Table 5.34: Samples selected from Whithorn for analysis showing their small find numbers, context number and date.

In total ninety knives were recovered during excavations at Whithorn, including eight pivoting or swivel knives. Almost half of them (41) came from phases dated between 6th to 13th centuries. The remaining were from contexts dating between the 13th and 16th century. The x-radiographs for the forty-one knives dated to the 6th-13th century were examined. The results for each knife are available in the appendix (Volume 2 table 12.1). For this PhD metallographic analysis was carried out on sixteen knives. A list of the knives selected and the context details is provided in table 5.34.

The x-radiograph analysis of knives from Whithorn has shown that the most common knives deposited were curved-backed knives (Table 5.35 and Figure 5.18). Many of the knives were found broken and therefore un-diagnostic. The survey also revealed that the type of tang to blade interface was varied although the majority had a distinct tang to blade interface on both sides. There was little difference between knife shape across time, although there were slightly more angle-backed knives in the earlier periods.

Period Site	***Number of Knives Examined***	***Back Shape***					***Tang Interface***				
		A	***B***	***C***	***D***	***X***	***1***	***2***	***3***	***4***	***X***
6th-8th Century	11	3	5	0	1	2	1	3	1	1	5
8th-10th Century	16	2	8	0	0	6	5	1	1	2	7
11th-13th Century	14	0	8	0	1	5	7	2	1	0	4
Total	41	*5*	*21*	*0*	*2*	*13*	13	6	3	3	16

Table 5.35: A table showing the archaeological typologies of the knives from Whithorn. Note: X indicates where a knife was un-diagnostic or un-classifiable. This table excludes all the pivoting knives which will be discussed separately.

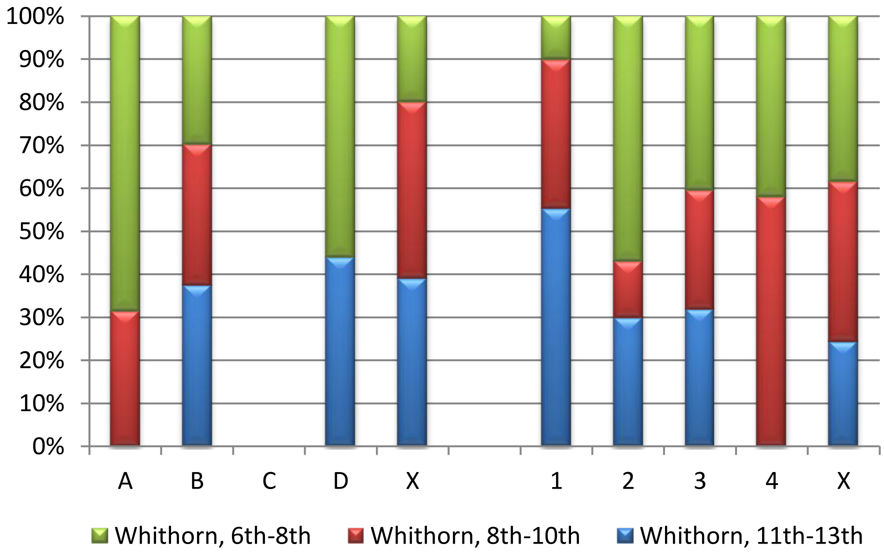
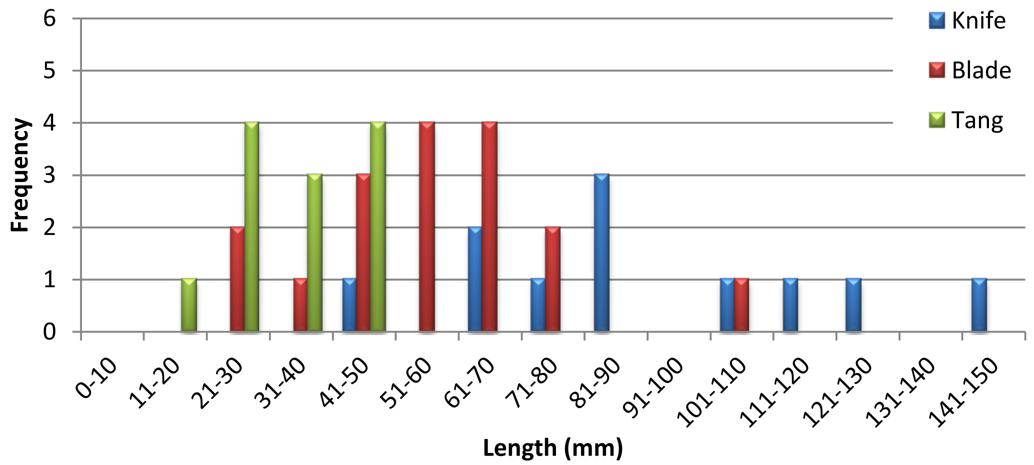


Figure 5.18: Bar chart showing the percentage of the different knife typologies, both shape and tang interface, found at Whithorn, across each Period



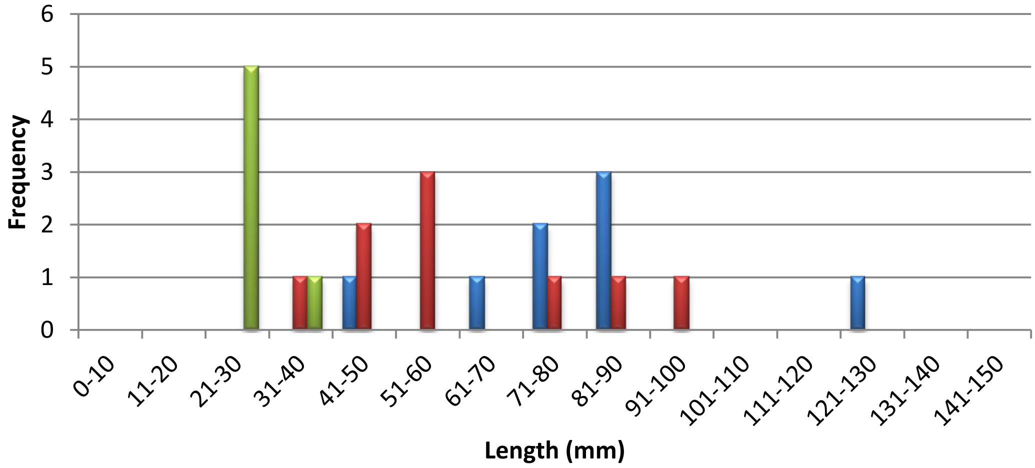


Figure 5.19: Histogram of knife sizes at Whithorn top) 6th-10th century and bottom) 11th-13th century. This graph excludes some knives that appear to have been broken in antiquity or during deposition.

The full measurements for all forty-one knives analysed from Whithorn are available in the appendix (Volume 2 table 12.1). Fifteen knives appear to have either broken blades or tangs therefore these were ignored in the following analysis, along with the three pivoting knife (Figure 5.19). The complete, or near complete, knives from Whithorn dating between the 6^{th}-10^{th} century ranged in size from 48mm to 142mm in length, with the average length 72mm. The length of the knife blade also varied dramatically from 25mm to 102mm, whereas the tangs were a more consistent in length from 18mm to 50mm. The later period knives ranged in size from 42mm to 128mm in length, with an average length 75mm. As before the blade length also varied dramatically from 40mm to 92mm, whereas the tangs were again a more consistent in length from 26mm to 36mm.

In the Whithorn assemblage there seemed to be a relationship between the blade length and the tang length as blades in the majority of knives were twice as long as the tang. Even so caution must be used as the tangs are often the first thing broken during deposition and they may originally have been much longer. Fifteen knives had broken tangs or blades, this most likely occurred during deposition, but in some cases the damage may have occurred during use.

The x-radiograph survey of the forty-one knives revealed that sixteen showed signs of some wear (Table 5.36). The majority of which showed either an s-shaped curve (5) or slight (9) evidence of wear. Only two of the knives from Whithorn showed signs of heavy wear. There is slightly more wear on the later knives with the s-shaped curved knives and both heavily worn knives coming from later contexts.

Period	***Wear Pattern***				
	None	*Slight*	*Moderate*	*Heavy*	*Unknown*
6^{th}-8^{th} Century	*4*	*3*	*0*	*0*	*4*
8^{th}-10^{th} Century	*4*	*3*	*2*	*1*	*6*
11^{th}-13^{th} Century	*2*	*3*	*3*	*1*	*5*
Total	*10*	*9*	*5*	*2*	*15*

Table 5.36: A table showing the amount of wear in the knives from each phase at Whithorn.

Summary of Knives

13737 - *Type 2 knife with a pearlite cutting edge* (210$HV_{0.2}$, *Average* $260HV_{0.2}$, *Range* $210\text{-}340HV_{0.2}$) *separated by a clear white weld line (0.2%-1.1% As, up to 0.1%Ni) from a ferritic iron back* (*Average* $215HV_{0.2}$, *Range* $127\text{-}321HV_{0.2}$).

14373 - *Type 0 knife with a heterogeneous low phosphorus iron and low carbon steel* (*141*$HV_{0.2}$, *Average* $169HV_{0.2}$, *Range* $148\text{-}221HV_{0.2}$).

4542 - *Type 0 knife consisting of ferritic and low carbon steel* (*201*$HV_{0.2}$, *Average* $217HV_{0.2}$, *Range* $183\text{-}257HV_{0.2}$). *There were some vertical white weld lines (0.3%-1.2% As, up to 0.1% Ni)*.

10070 - *Type 2 knife consisted of a piled high carbon steel knife back (Average* $201HV_{0.2}$, *Range* $132\text{-}271HV_{0.2}$) *separated by a white weld line (0.5%-1.6% As, up to 0.2% Ni), with a unusual cutting edge made of two pieces of iron: one high carbon steel* (321$HV_{0.2}$, *Average* $322HV_{0.2}$, *Range* $271\text{-}412HV_{0.2}$) *and the other ferritic* (*Average* $182HV_{0.2}$, *Range* $161\text{-}215HV_{0.2}$) .

84293 - *Type 0 knife consisting of heterogeneous ferritic* (201$HV_{0.2}$, *Average* $197HV_{0.2}$, *Range* $175\text{-}244HV_{0.2}$) *and low phosphorus iron* (*Average* $171HV_{0.2}$, *Range* $157\text{-}197HV_{0.2}$).

1744 - *Type 3 piled knife constructed from at least two pieces of phosphoric iron* (*148*$HV_{0.2}$, *Average* $183HV_{0.2}$, *Range* $137\text{-}232HV_{0.2}$, 0.2%-0.4% P).

11202 - *Type 0 knife with a heterogeneous low phosphoric iron* (*168HV$_{0.2}$, Average 153HV$_{0.2}$, Range 137-168HV$_{0.2}$*, up to 0.3%) *and mid carbon steel* (*Average 180HV$_{0.2}$, Range 154-244HV$_{0.2}$*).

12524 - *Type 2 knife with a bainitic cutting edge* line (*399HV$_{0.2}$, Average 313HV$_{0.2}$, Range 183-473HV$_{0.2}$*) *suggesting it was slowly quenched. This was welded to a low phosphorus iron back (Average 158HV$_{0.2}$, Range 125-183HV$_{0.2}$*, up to 0.2% P)*. The cutting edge and back were separated by a white weld line (0.2%-0.5% As, 0.1%-0.3% Ni)*.

84343 - *Type 2 knife with a tempered martensite cutting edge* (*412HV$_{0.2}$, Average 412HV$_{0.2}$, Range 286-618HV$_{0.2}$*)*, separated from the piled iron back* (*Average 147HV$_{0.2}$, Range 118-210HV$_{0.2}$*) *by a white weld line (0.3% As).*

813 - *Type 1 knife with a piece of martensite heat-treated steel (841HV$_{0.2}$, Average 586HV$_{0.2}$, Range 441-841HV$_{0.2}$) sandwiched between two pieces of phosphoric iron (Average 130HV$_{0.2}$, Range 93-158HV$_{0.2}$, 0.2%-0.4% P). White weld lines separated the three pieces of iron (0.3-0.5% As,0.5% Ni).*

1537 - *Type 3 piled iron knife of low phosphorus iron (137HV$_{0.2}$, Average 145HV$_{0.2}$, Range 137-171HV$_{0.2}$*, up to 0.3% P) *and low carbon steel* (*Average 186HV$_{0.2}$, Range 168-210HV$_{0.2}$*).

1935 - *Type 0 knife with ferritic iron throughout* (123*HV$_{0.2}$, Average 130HV$_{0.2}$, Range 107-154HV$_{0.2}$*).

11988 - *Type 5 knife mid-high carbon steel which had not been heat-treated* (183*HV$_{0.2}$, Average 186HV$_{0.2}$, Range 154-221HV$_{0.2}$*).

14622 - *Type 1 knife with a piece of high carbon steel* (264*HV$_{0.2}$, Average 279HV$_{0.2}$, Range 221-303HV$_{0.2}$*) *sandwiched between two flanks of phosphoric iron* (*Average 210HV$_{0.2}$, Range 192-232HV$_{0.2}$, 0.7%-1.1% P). White weld lines separate the three pieces of iron (0.3-0.4% As,0.4%-1.1% Ni).*

84270 - *Type 5 knife mid to high carbon steel, quenched and then over tempered* (*386HV$_{0.2}$, Average 416HV$_{0.2}$, Range 321-528HV$_{0.2}$*)*. Some vertical white weld lines were present.*

84298 - *Type 1 knife with a piece of heat-treated high carbon steel (*644*HV$_{0.2}$, Average 557HV$_{0.2}$, Range 257-701HV$_{0.2}$*) *sandwiched between two flanks of ferritic iron* (*Average 121HV$_{0.2}$, Range 110-180HV$_{0.2}$*)*. White weld lines separate the three pieces of iron (0.5-0.6% As).*

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
13737	None	2	Pearlite	210	210-340	Ferritic	215	127-321		White weld line
14373	Slight	0	Ferrite with carbides	161	148-221	Ferrite with Pearlite	169	148-221		
4542	None	0	Ferrite with carbides	201	183-257	Ferrite with Pearlite	217	183-257		Overheated
10070	Slight	2	Pearlite with ferrite	321	271-412	Piled Ferrite with carbides/ pearlite	201	132-271		White weld line
84293	Some	0	Ferrite with carbides	201	157-244	Ferritic/ Phosphoric Iron	190	157-244		
1744	Unknown	3	Piled Phosphoric/ Ferrite with carbides	148	137-232	Piled Phosphoric/ Ferrite with carbides	183	137-232		
11202	Slight	0	Ferrite with carbides	168	137-168	Pearlite with ferrite	167	137-244		
12524	Unknown	2	Bainite	399	183-473	Phosphoric iron	158	125-183	Yes	White weld line
84343	Heavy	2	Tempered Martensite	412	286-618	Ferritic/Phosphoric Iron	147	118-210	Yes	White weld line
813	Slight	1	Martensite	841	441-841	Phosphoric Iron	130	93-158	Yes	White weld line
1537	None	3	Piled Phosphoric/ Ferrite with carbides	137	137-210	Piled Phosphoric/ Ferrite with carbides	158	137-210		
1935	Slight	0	Ferrite with carbides	123	107-154	Ferrite with carbides	130	107-154		
11988	None	5	Pearlite with ferrite	183	154-221	Pearlite with ferrite	186	154-221		
14622	Some	1	Pearlite	264	221-303	Phosphoric Iron	210	192-232		White weld line
84270	Some	5	Tempered Martensite	386	321-528	Tempered Martensite	416	321-528	Yes	
84298	Some	1	Tempered Martensite	644	257-701	Ferritic Iron	121	110-180	Yes	White weld line

Table 5.37: Summary of the sixteen knives analysed. This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges).

The vast majority of knives from early phases at Whithorn were either type 2 butt-welded knives or type 0 plain ferritic or phosphoric iron (Table 5.37, Figure 5.20 and Figure 5.21). The remaining knives from this period were piled knives (type 3). The x-radiographs of the remaining eighteen knives dated between the 6th-10th centuries, suggested that there are as many as six additional butt-welded knives and nine knives were identified as having steel cutting edges. Out of these only four knives were identified as type 2 butt-welded knives with steel.

In the 11th century there is a dramatic shift from the presence of type 0 and 2 knives to an assemblage of type 1 knives, with the introduction of the all steel type 5 knife (Table 5.37, Figure 5.20 and Figure 5.21).The x-ray analysis of the remaining six knives revealed only three with identifiable structures. There was one which had a clear weld line, one with just the spotted texture suggesting a steel cutting edge and another knife that had both a weld and the spotted steel.

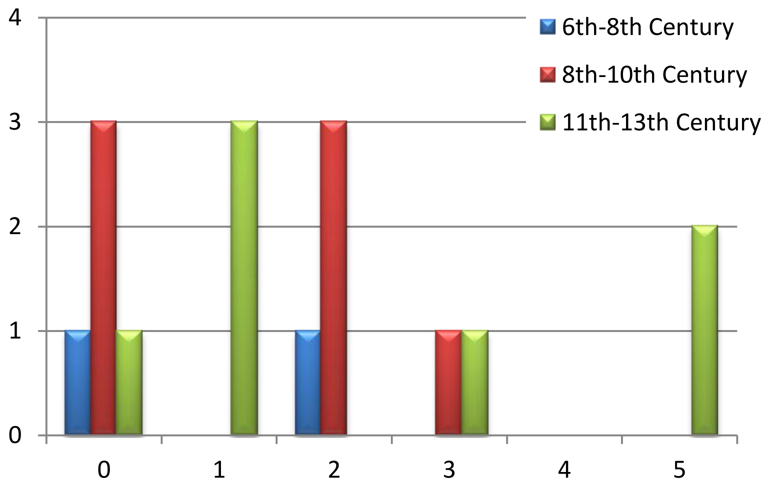


Figure 5.20: Bar chart showing the distribution of the different knife types over time. Note the dramatic change in preference from type 2 to type 2 in the 11th century.

The analysis of the knives from Whithorn revealed a marked absence of heat-treatments. None of the 6th-8th century knives were heat-treated, even though both had the potential to be treated. Analysis of the phase 2 knives from Whithorn also revealed no heat-treated knives. It was only in phase 3 that two, of the four knives, were heat-treated, one to produce the hard, but durable, tempered martensite while another had been cooled more slowly resulting in bainite. Instead the vast majority of the knives from phase 1 and 2 had a microstructure of ferrite with carbides, which suggested a different method of smithing. The evidence suggests that the heat of the smithing hearth was not enough to allow the iron to form austenite, as a consequence carbides formed at the grain boundaries. This also then affected the amount of time that the iron could be forged before being placed back into the hearth, evidenced by the small grains seen. The cracks also seen in some of these knives were evidence that they had been submitted to stress, suggesting that they had been cold worked, possibly as the knife cooled. Overall the evidence suggests a low skilled smithy, perhaps the work of an apprentice. But considering that the majority of knives were similar, across multiple phases suggests that the smithy itself was of a low standard.

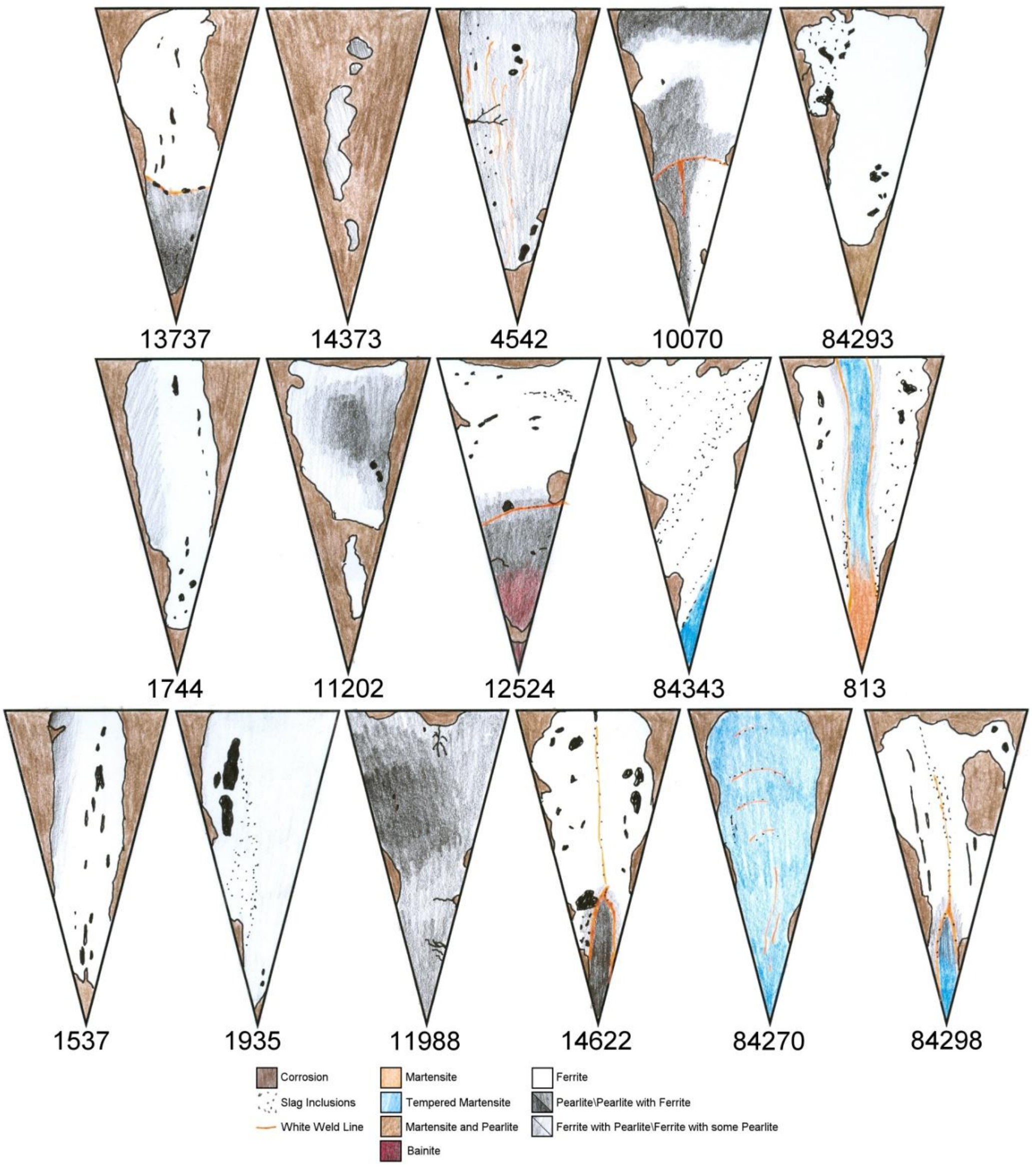


Figure 5.21: Sketches of the knives analysed from Whithorn.

The 11th-13th century knives were equally badly heat-treated. Only three of the seven knives analysed were heat-treated, the rest showed traits similar to the knives from earlier phases. Two of the sandwich weld knives had excellent cutting edges, one being a typical tempered martensite while the other was a martensite. The remaining heat-treated knife was a type 5 all steel knife which was tempered martensite throughout the knife. These three knives were similar to knives from Viking Dublin and York.

Summary/Review of Middle to Late Saxon settlements

This sub-section will summarise other studies carried out on middle to late settlement knives. These primarily focused on excavations carried out at the time, which happened to be urban sites, The assemblages from urban Saxon Hamwic and York have been previously reviewed (Volume 2 table 1.7 and 1.11; Blakelock & McDonnell 2007), but for this study later Anglo-Scandinavian knives from York, Anglo-Scandinavian knives from Lurk Lane, Beverley and Anglo-Norman Winchester will also be included (Volume 2 table 1.8 and 1.9; Tylecote & Gilmour 1986: 38-39; McDonnell 1992).

Analysis of the knives dated between the 7th-early 10th century from Hamwic and York revealed that the majority were type 2. After this time there is a dramatic change as the type 1, sandwich knife, predominates in the 10th to 12th century assemblages at York, Beverley and Winchester.

At Hamwic the majority of the knives had been heat-treated resulting in a tempered martensite cutting edge. The remaining knife could have been heat-treated as it had enough carbon but had not been. This was similar to the knives from York which were mostly heat-treated (15 of 18) until the early 10th century after which few were treated (12 of 30). At Winchester there was a similar pattern as all three of the 9th-10th century knives were treated, but only half of the later 10th-12th century knives were treated (6 of 12). At Beverley the majority of the knives were heat-treated (4 out of 5).

The knives from Hamwic and some from Winchester had predominately ferritic iron backs, although SEM analysis was not carried out during Tylecote's study of the Winchester knives and therefore phosphorus was not detected. The knives from York had a range of different iron alloys used in their construction, but before the 10th century most were ferritic iron (8 of 18), with a similar number of phosphoric (4 of 18) and piled iron (5 of 18). In the later period piled (13 of 30) and then ferritic iron (10 of 30) dominated the assemblage with some phosphoric iron (4 of 30) and low carbon steel (2 of 30). Beverley also had a range of iron alloys from piled iron, to phosphoric iron and ferritic iron.

In addition to the urban assemblages above, the knives from the middle-late Saxon high-status and ecclesiastical settlement at Flixborough (Volume 2 table 1.10), analysed by David Starley, were examined (Starley 1999). A similar pattern to Hamwic was seen in the knives from Flixborough as the majority were type 2 (11 of 14), and most of these were heat-treated (12 of 14). A range of different iron alloys were used to construct the knife backs.

5.5 Viking Dublin & Europe

Viking Dublin Background

Excavations were carried out in the 1960-1980s across Dublin, Ireland. These have shown that, from the early 10th century, Dublin was a planned town divided into plots and enclosed within an earth embankment (Wallace 1981). Several years of excavations in the Fishamble Street and Wood Quay area have yielded an increasing amount of material of recognisably Anglo-Saxon origin, with a relatively diminished amount of Scandinavian artefacts, and other finds originating from north-west Europe. The habitation layers in Dublin date from the early 10th century, possibly relating to the settlement established by Scandinavians in about AD917 (de-Paor 1976; Wallace 1981; Wallace & Floinn 1988). Not all early medieval crafts would have left archaeological evidence, even so the excavations revealed that a variety of crafts were taking place, from the wood working, to metalworking, comb making and leatherworking. The excavations also revealed that many of these crafts were occurring in specific areas of Viking Dublin (Wallace & Floinn 1988; Ryan 1991).The sites are summarised below since the Dublin excavation reports are difficult to obtain and this data will be drawn on further in chapter 7.

Fishamble Street consists of multiple sites (E141, E148, E172 and E190). During excavations evidence for the earth bank which surrounded the settlement were found. Also uncovered were fourteen plots for tenants with thirteen successive building levels. The archaeological evidence suggests the presence of coopers, shipwrights and general woodworkers along with an amber worker (Ríordáin 1976a,b; Wallace & Floinn 1988).

Christchurch Place (E122) is situated in the centre of the medieval city of Dublin, and produced evidence of intensive occupation spanning a period from as early as the mid-tenth century to the late 13th-early 14th centuries. The excavations revealed seven successive houses on the same plot over a period of 200 years. In this area antler waste as well as single and double sided decorated combs were discovered, suggesting that bone comb manufacture was taking place. An area of metalworking was also recovered from the 11th and 12th century layers contemporary with the knives (Ríordáin 1974; Wallace & Floinn 1988).

Excavations at **Wine Tavern Street and St John's Lane** (E173 and E81), adjacent to Wood Quay, revealed 10th-11th century post and wattle structures. In the 9th and 10th century contexts there was much evidence for metalworking including strands of bronze and gold wire. In addition in the 11th century deposits, many wooden bowls, platters and barrel staves, some unfinished were discovered, suggesting the presence of wood-turners and coopers in this area (Ríordáin 1970c; Wallace & Floinn 1988).

High Street (E71) runs parallel to the River Liffey, here post and wattle structures were identified. Like at Christchurch Place there was evidence for bone and antler working, especially comb manufacture, dating from the 11th to 13th century. In addition finds of crucible-fragments, slag and vitreous material, in association with a workshop-hearth and some trial pieces suggested the presence of a metalworking area (Ríordáin 1970a,b). While not far away at the other High Street excavation site E43 evidence of leather working and weaving was also recovered (Ríordáin 1970a; Wallace & Floinn 1988).

Wood Quay (E132) is located next to Fishamble Street and also had evidence for woodworking (Wallace & Floinn 1988). The majority of contexts at this site were dated to the 12th and 13th century and therefore only the x-radiographs were examined.

X-Radiograph Analysis

In total 535 knives were examined from across the five sites. Due to the nature of the excavation not all of these can be securely dated to the Viking Period, although most are believed to date to this period. Therefore the numbers of knives shown during the x-radiography analysis here should only be used qualitatively.

The survey of the knives from Viking Dublin has shown that the most common knives deposited were curved-backed knives; these were closely followed by the angle-back knife (Table 5.38). There were very few incurved knives identified. This pattern is very similar to that at Coppergate, York where the majority of knives were curved-backed, with some angle-backed knives and very few straight or incurved knives were identified. There were also some clear differences in knife shapes between the five different sites. For example at Fishamble Street the knives were predominately curved-backed, with quite a few angle-backed knives and fewer still straight backed knives, but at Christchurch Place there were roughly equal numbers of curved-knives and straight-backed knives, and fewer angle-backed knives. A similar pattern is seen at High Street where very few angle-backed knives were identified. This may suggest that the knife shape is closely linked to the function of the knife.

Site	Number of Knives Examined	Back Shape					Tang Interface				
		A	B	C	D	X	1	2	3	4	X
Fishamble Street	187	46	61	5	28	47	64	37	44	10	32
Christchurch Place	158	20	45	5	41	47	52	8	49	13	36
Winetavern Street	56	9	22	1	10	14	22	7	12	4	11
High Street	70	6	31	1	18	14	42	4	13	2	9
Wood Quay	64	5	32	2	11	14	32	4	12	1	15

Table 5.38: A table showing the archaeological typologies of the knives from each site in Dublin. Note: X indicates where a knife was un-diagnostic or un-classifiable.

The survey also revealed that the type of tang to blade interface was dependant on the site they were from (Table 5.38). At Wine Tavern Street, High Street and Wood Quay the majority of knives had a tang to blade interface that was distinct on both sides (type 1). There were very few knives that had no distinct interfaces (type 4). At Fishamble Street there appeared to be roughly equal number of type 1 and type 2 interfaces. Again in stark contrast, Christchurch Place varied from all these sites as there were roughly equal numbers of knives with distinct junctions on both sides (type 1) and those that had a distinct shoulder on the back of the knife (type 3). Again this may be an indication about knife function.

The analysis of the features in the x-rays suggests that there are as many as 182 butt-welded knives (Table 5.39). In total there were 362 knives identified as having steel cutting edges. Out of these knives only 133 were clearly identified as type 2 butt-welded knives with steel. This leaves as many as 229 knives that could be type 1 'sandwich type' knives or homogenous steel knives. It also leaves a possible 49 knives type 2 knives with no steel cutting edge. In these cases they may have used another type of alloy, the slightly harder phosphoric iron or a poorer quality low carbon steel instead.

Site	***Weld Line***	***'Spotted' Steel***	***Weld and Steel***
Fishamble Street	49	133	43
Christchurch Place	50	105	41
Winetavern Street	24	38	17
High Street	22	46	15
Wood Quay	26	41	17

Table 5.39: A table showing the features present and the amount of wear in the knives from each site in Dublin.

Out of the 535 knives examined, at least 275 showed signs of some wear (Table 5.40). The majority of which, showed either an S-shaped curve (139) or slight (92) evidence of wear. The remainder had heavy wear, some even had the cutting edge heavily worn into the back of the knife, or had even resulted in a distortion of the original shape. The frequency of wear, along with other features present, suggests that the type 1 'sandwich type' knife is predominate. But unlike at Coppergate, York some of the knives with butt-welds also showed sign of wear; this means that wear alone cannot be an indicator of knife manufacturing type.

Site	***Wear Pattern***				
	None	***Slight***	***Moderate***	***Heavy***	***Unknown***
Fishamble Street	*52*	*42*	*41*	*26*	*26*
Christchurch Place	*67*	*22*	*37*	*8*	*23*
Winetavern Street	*16*	*7*	*17*	*3*	*6*
High Street	*27*	*11*	*21*	*2*	*9*
Wood Quay	*19*	*10*	*23*	*5*	*7*

Table 5.40: A table showing the amount of wear in the knives from each site in Dublin.

The distribution of other features seen in the x-radiographs were also examined (Table 5.41). In total 21 knives with notches were identified, one knife had two notches present. These knives were distributed across Dublin, with the exception of High Street where none were present. Knives with indents in the back were present at Fishamble Street, Christchurch Place and Wood Quay. The vast majority of knives with notches were angle-backed, this was also noted at Coppergate, York (Ottaway 1992: 579-582). Two pattern welded knives were also found in Dublin, both were broken. These were both very different in appearance (Figure 5.22 and Figure 5.23)

Site	**Notches**	**Indents**	**Pattern Welded**
Fishamble Street	*10*	*4*	*1*
Christchurch Place	*5*	*5*	*1*
Winetavern Street	*1*		
High Street			
Wood Quay	*5*	*1*	

Table 5.41: A table showing the other features in the knives from each site in Dublin.

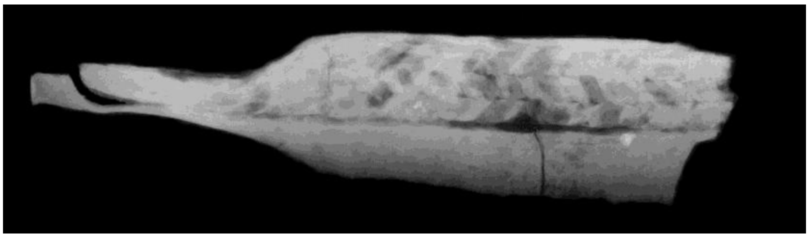


Figure 5.22: X-radiograph of knife 6140 from Christ Church Place, Dublin showing pattern welding.

The use of non-ferrous metal in the Dublin knives was mostly restricted to the hilt band at the tang to blade interface (Figure 5.23) with ten knives identified across Dublin. There was no evidence for twisted wire inlays of non-ferrous metal but knife 3840 had 5 patches of brighter material evenly spaced along the back of the knife (Figure 4.5). These are most likely non-ferrous metal strips attached to either side and wrapped around the back, creating a small ridge. There were two possible pivoting or folding knives identified from Dublin. The first knife 859 from Fishamble Street, had two pins, and a shape similar to pivoting knives found at Coppergate, York (Ottaway 1992: 586-588). The other knife 1026, from Christchurch Place had one non-ferrous pivot or pin.

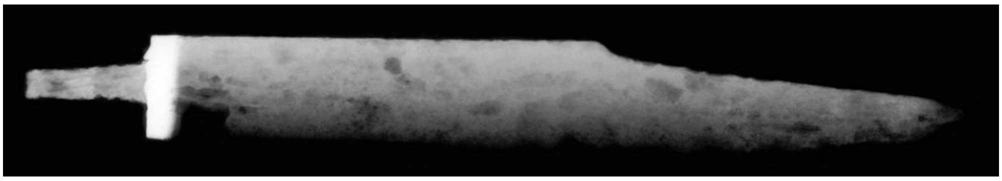


Figure 5.23: X-radiograph of knife 3081 from Wine Tavern Street, Dublin showing the non-ferrous tang to blade interface.

Metallographic Analysis

Fishamble Street

In total eleven knives were sampled from Fishamble Street (Table 5.42, Table 5.43 and Figure 5.24). Most of these knives dated to the 10^{th} to mid 11^{th} century. Also included in the analysis was the pattern welded knife from Fishamble Street (2475) which unfortunately came from an un-stratified context, although it was associated with other 11^{th} century finds.

Area	Knife Number	Date	Shape
190	2555	1025-1040	A3
190	2696	1000-1020	B1
190	2743	1000-1020	A1
190	2758	990-1010	B1
190	4485	1000-1020	B1
190	7306		X1
172	10627	Mid-late 10thC	B2
172	10964	Early 10thC	B1
172	13190	Mid 10thC	A1
172	2041	Mid 11th	B1
172	16082	Early 10th	B1

Table 5.42: Samples selected from Fishable Street for analysis showing their small find numbers and date. This table excludes pattern welded knife 2475.

Summary of Knives

2555 - *Type 5 all steel knife with martensite with varying amounts of pearlite (509$HV_{0.2}$, Average 573$HV_{0.2}$, Range 294-975$HV_{0.2}$). There were vertical white weld lines (0.1%-0.2% As, up to 0.3% Ni).*

2696 - *Type 2 knife with a heat-treated martensite high-carbon steel cutting edge* (*1144$HV_{0.2}$, Average 1086$HV_{0.2}$, Range 1027-1144$HV_{0.2}$*), *separated by a white weld line (up to 0.2% As) from the piled low to high carbon steel* (*Average 245$HV_{0.2}$, Range 143-286$HV_{0.2}$*).

2743 - *Type 2 knife with a heat-treated martensite steel cutting edge* (*1144$HV_{0.2}$, Average 992$HV_{0.2}$, Range 841-11441$HV_{0.2}$*), *with a white weld line (0.1%-0.2%*

As, up to 0.2% Cu) separating it from the knife back. The back consisted of three pieces of iron; ferritic iron and low carbon steel (*Average 224* $HV_{0.2}$, *Range 120-509* $HV_{0.2}$).

2758 - *Type 3 piled knife with two main components the first is a low carbon steel* (*232* $HV_{0.2}$, *Average 183* $HV_{0.2}$, *Range 143-232* $HV_{0.2}$) *the other was ferritic iron* (*Average 124* $HV_{0.2}$, *Range 97-148* $HV_{0.2}$). *Needles were seen in the cutting edge.*

4485 - *Type 5 all steel knife, the martensite microstructure suggested that it had been heat-treated* (*1283* $HV_{0.2}$, *Average 775* $HV_{0.2}$, *Range 161-1283* $HV_{0.2}$)*, but carefully quenched to result in martensite and pearlite at the back of the knife.*

7306 - *Type 2 knife with a heat-treated martensite steel cutting edge* (*927* $HV_{0.2}$, *Average 906* $HV_{0.2}$, *Range 644-1027* $HV_{0.2}$) *welded onto a phosphoric iron back* (*Average 328* $HV_{0.2}$, *Range 271-426* $HV_{0.2}$)*.*

10627 - *Type 3 piled knife with bands of high, mid and low carbon steels* (*Average 242* $HV_{0.2}$, *Range 154-386* $HV_{0.2}$)*. The cutting edge was a high carbon steel* (*386* $HV_{0.2}$).

10964 - *Type 2 knife with a heat-treated martensite steel strip*(*1283* $HV_{0.2}$, *Average 868* $HV_{0.2}$, *Range 412-1283* $HV_{0.2}$) *and a piled iron back*, *separated by a white weld line (up to 0.2% Ni, 0.2% Cu). The back consisted of bands of iron; ferritic iron and low-mid carbon steel* (*Average 210* $HV_{0.2}$, *Range 132-303* $HV_{0.2}$)*.*

13190 - *Type 2 knife with a heat-treated martensite high carbon steel cutting edge* (*1027* $HV_{0.2}$, *Average 1040* $HV_{0.2}$, *Range 644-1283* $HV_{0.2}$)*. This was separated from the ferritic and low phosphorus iron back* (*Average 178* $HV_{0.2}$, *Range 148-221* $HV_{0.2}$, up to 0.2% P) *by a white weld line (0.2%-3.5% As, up to 0.3% Ni).*

2041 - *Type 1 knife with a tempered martensite heat-treated steel core* (644 $HV_{0.2}$, Average 600 $HV_{0.2}$, Range 441-766 $HV_{0.2}$) *sandwiched between two pieces of low phosphorus iron* (Average 385 $HV_{0.2}$, Range 303-570 $HV_{0.2}$, up to 0.2% P)*. White weld lines separate each piece of metal (0.2% As).*

16082 - *Type 2 knife with a tempered martensite cutting edge* (644 $HV_{0.2}$, Average 510 $HV_{0.2}$, Range 271-701 $HV_{0.2}$) *butt-welded on to a low phosphorus iron* (Average 261 $HV_{0.2}$, Range 192-321 $HV_{0.2}$, up to 0.2% P).

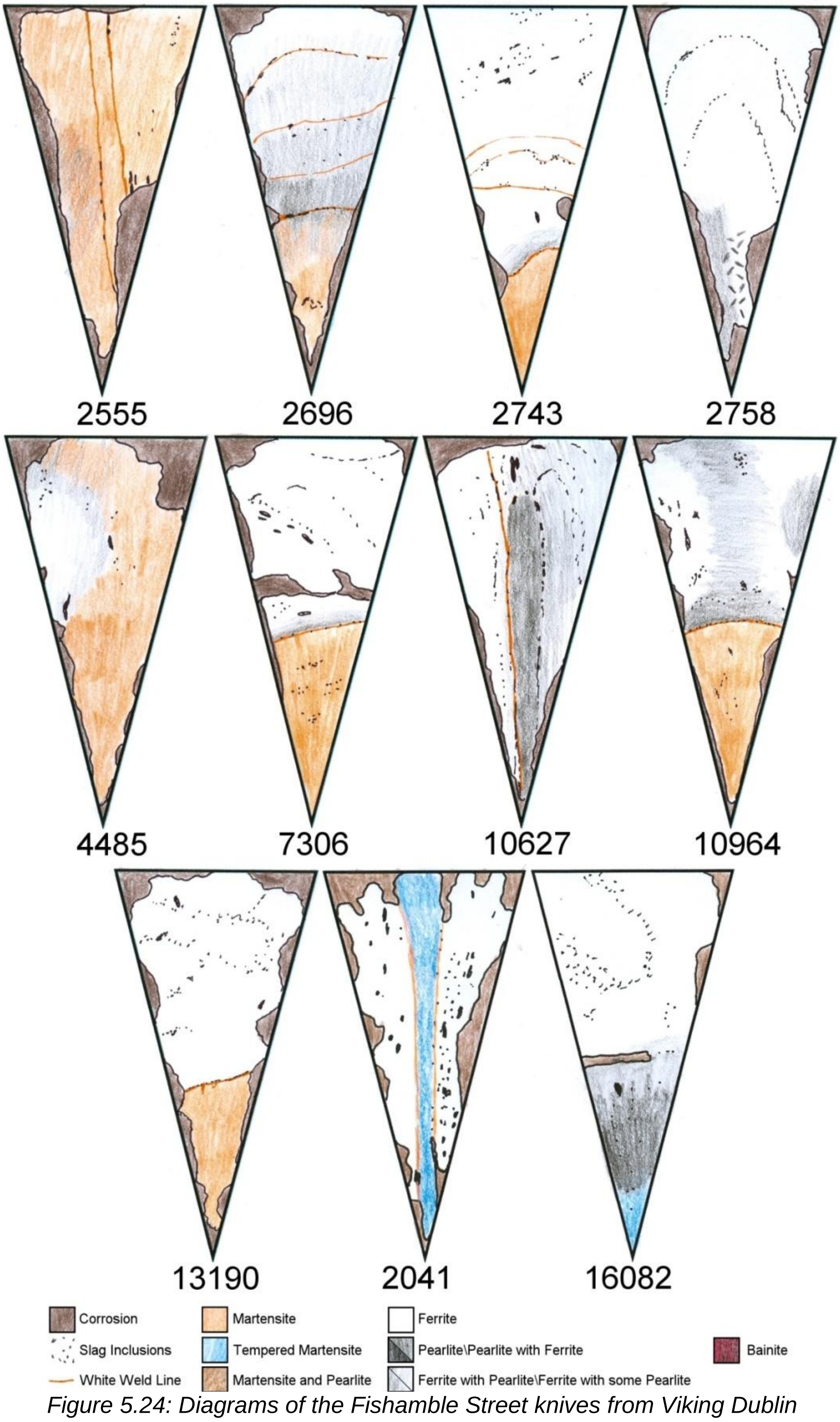


Figure 5.24: Diagrams of the Fishamble Street knives from Viking Dublin

Figure 5.25: Photograph and x-radiograph of pattern-welded knife 2475.

During this study it was possible to metallurgically examine pattern welded knife 2475 (Figure 5.26). This revealed that it was constructed from at least eight pieces of iron, although the pieces used to construct the pattern welded strip are similar and may therefore have been made using the same piece of deliberately piled bar iron. Even so the construction of just one of these piled iron bars, used in the pattern welded strip, would have required at least four, possibly five, different iron alloys. This therefore takes the total of iron bars or strips used to around eight or nine.

The construction of the Dublin knife is very different to the pattern-welded knife from Coppergate, York (Figure 5.26), which was examined in 1987 (McDonnell 1987b,1992). The York knife had a central strip of steel with three bars to either side. The range of iron alloys used was similar in both knives, with heat-treated steel in the cutting edge, and high-carbon steel stripes separated by stripes of phosphoric and ferritic iron. In both cases a piece of iron was added to the back of the knife, constructed of high-carbon steel. The Dublin knife back had been heat-treated while the Coppergate knife had only been lightly heat-treated in areas.

Like the knife from Coppergate, York the Dublin pattern welded knife was bent at the tip. This most likely occurred at the same time as the knife was broken. The metallurgical evidence suggests that the knife had been heated, reducing the hardness and so possibly allowing the knife to be broken. Many of the pattern welded knives found appear to have been broken in antiquity which would be difficult considering the quality of the knives themselves. This could therefore suggest some form of 'ritual' deposition of these high status objects? The evidence certainly suggests that these knives were not broken during use but had been exposed to heat (will be discussed further in chapter 7).

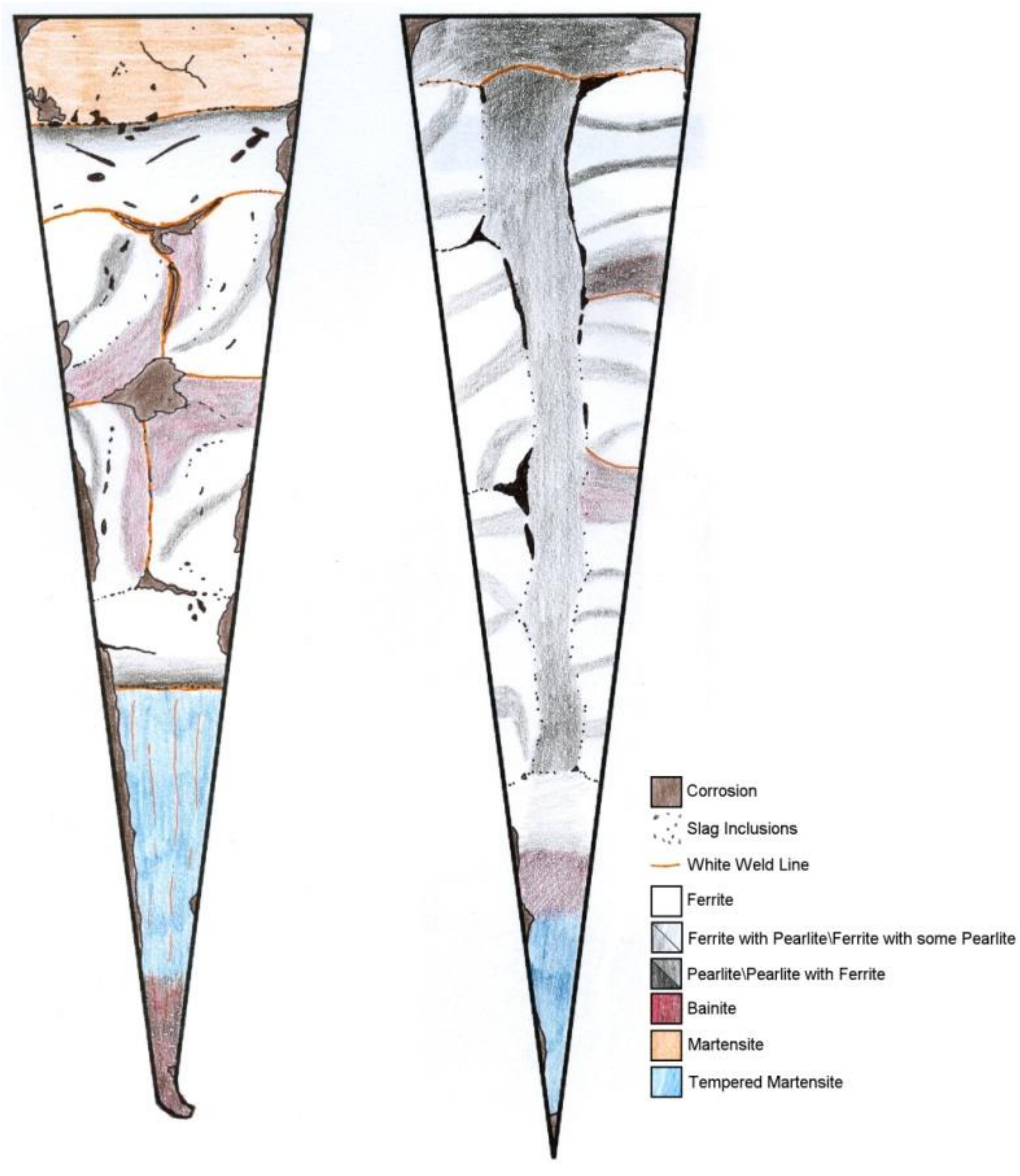


Figure 5.26: Diagram of the pattern welded knife from Dublin compared to the knife from Coppergate, York.

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
2555	Slight	5	Martensite with pearlite	509	441-975	Martensite with pearlite	573	294-766	Yes	White weld line
2696	Some	2	Martensite	1144	1027-1144	Ferrite with pearlite	245	143-286	Yes	
2743	Slight	2	Martensite	1144	841-1144	Ferrite with some pearlite	224	120-509	Yes	White weld line
2758	Slight	0	Ferrite with pearlite (needles)	232	143-232	Ferrite	124	97-148		
4485	None	5	Martensite	1283	509-1283	Martensite with pearlite	775	161-1283	Yes	
7306	None	2	Martensite	927	644-1027	Phosphoric Iron	328	271-426	Yes	White weld line
10627	Some	3	Pearlite with some ferrite	386	303-386	Pearlite with ferrite	242	154-386		White weld line
10964	None	2	Martensite	1283	412-1283	Ferrite and pearlite	210	132-303	Yes	White weld line
13190	Slight	2	Martensite	1027	644-1283	Ferrite/ Phosphoric Iron	178	148-221	Yes	White weld line
2041	Some	1	Tempered Martensite	644	441-766	Phosphoric Iron	385	303-570	Yes	White weld line
16082	None	2	Tempered Martensite	644	271-701	Phosphoric Iron	261	192-321	Yes	

Table 5.43: Summary of the eleven knives analysed from Fishamble Street. This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges).

Christ Church Place

In total eighteen knives were sampled from Christchurch Place (Table 5.44, Table 5.45 and Figure 5.27).

Area	Knife Number	Date	Shape
122	1047	c1100	B1
122	6255	c1100	A1
122	8891	c1000	A1
122	11635	c1200	B1
122	12055	c1080-1100	B1
122	12320	c1080-1100	A1
122	12477	c1080-1100	B3
122	12499	c1080-1100	A1
122	12677	c1080-1100	B3
122	13135	c1080-1100	D3
122	14241	c1080 - 1100	A2
122	14491	c1080 - 1100	B1
122	15910	c1050	X3
122	16514	c1050	A1
122	16557	1005-1010	B1
122	16808	11th	X1
122	16826a	11th	X1
122	16826b	11th	B2

Table 5.44: Samples selected from Christchurch Place for analysis showing their small find numbers and date.

Summary of Knives

1047 - *Type 2 knife with a heat-treated martensite, slightly tempered, cutting edge (549$HV_{0.2}$, Average 613$HV_{0.2}$, Range 549-766$HV_{0.2}$) welded onto a back consisting of ferritic iron (Average 152$HV_{0.2}$, Range 88-257$HV_{0.2}$). A white weld line separated the cutting edge from the back (up to 0.2% As, up to 0.2% Ni).*

6255 - *Type 5 knife constructed of steel. The cutting edge had been heat-treated resulting in martensite with ferrite (509$HV_{0.2}$, Average 577$HV_{0.2}$, Range 509-644$HV_{0.2}$) while the back was mid to high carbon steel (Average 311$HV_{0.2}$, Range 210-412$HV_{0.2}$).*

8891 - *Type 2 knife with a heat-treated tempered martensite cutting edge (473$HV_{0.2}$, Average 466$HV_{0.2}$, Range 386-509$HV_{0.2}$) welded on to a low phosphorus iron (Average 255$HV_{0.2}$, Range 175-386$HV_{0.2}$,* up to 0.3% P*). A white weld line separated the cutting edge from the back (0.3%-1.9% As, up to 0.2% Ni).*

11635 - *Type 2 knife with a heat-treated martensite cutting edge (1027$HV_{0.2}$, Average 922$HV_{0.2}$, Range 701-1027$HV_{0.2}$) welded onto a back consisting of two* *pieces of low phosphorus iron (Average 332HV$_{0.2}$, Range 148-549HV$_{0.2}$,* up to 0.4% P*). A white weld line separated the cutting edge from the back (2.3%-2.5% As,* up to 0.2% *Ni).*

***12055 -** Type 1 knife with a small piece of heat-treated martensite steel (1288HV$_{0.2}$, Average 1089HV$_{0.2}$, Range 946-1288HV$_{0.2}$) sandwiched between two larger pieces of low phosphorus iron (Average 186HV$_{0.2}$, Range 123-254HV$_{0.2}$,* up to 0.3% P*) forming a upside down Y shape weld. To either side of these pieces of iron there were two white weld lines, joining near the back (up to 0.3% As, up to 0.2% Ni).*

***12320 -** Type 1 knife with a heat-treated tempered martensite core (1047HV$_{0.2}$, Average 838HV$_{0.2}$, Range 644-1047HV$_{0.2}$) sandwiched between two pieces of phosphoric iron (Average 235HV$_{0.2}$, Range 175-286HV$_{0.2}$,* 0.3%-0.4% P*). To either side of these pieces of iron there were two white weld lines (up to 0.2% As).*

***12477 -** Type 1 knife with a small piece of heat-treated martensite steel (644HV$_{0.2}$, Average 456HV$_{0.2}$, Range 412-644HV$_{0.2}$) sandwiched between two larger pieces of ferritic and low phosphorus iron (Average 205HV$_{0.2}$, Range 168-271HV$_{0.2}$,* up to 0.2% P*) forming a upside down Y shape weld. To either side of these pieces of iron there were two white weld lines, joining near the back (0.6%-1.1% As).*

***12499 -** Type 5 knife constructed of steel. The cutting edge had been heat-treated resulting in martensite (927HV$_{0.2}$, Average 978HV$_{0.2}$, Range 766-1144HV$_{0.2}$) while the back was mid to high carbon steel (Average 201HV$_{0.2}$, Range 148-271HV$_{0.2}$), some of which had also been heat-treated (Average 656HV$_{0.2}$, Range 386-1027HV$_{0.2}$).*

***12677-** Type 2 knife with a heat-treated martensite cutting edge (1027HV$_{0.2}$, Average 876HV$_{0.2}$, Range 593-1027HV$_{0.2}$) welded onto a back consisting of phosphoric iron (Average 258HV$_{0.2}$, Range 210-399HV$_{0.2}$,* 0.3%-0.6% P*). A white weld line separated the cutting edge from the back (0.2%-0.4% As,* 0.1%-0.6% P*, up to 0.2% Ni).*

***13135 -** Type 1 knife with a heat-treated martensite core (701HV$_{0.2}$, Average 530HV$_{0.2}$, Range 232-701HV$_{0.2}$) sandwiched between two different pieces of piled ferritic and phosphoric iron (Average 254HV$_{0.2}$, Range 183-340HV$_{0.2}$,* up to 0.5% P*). To either side of these pieces of iron there was a white weld line.*

***14241 -** Type 2 knife with a heat-treated tempered martensite cutting edge (457HV$_{0.2}$, Average 475HV$_{0.2}$, Range 321-644HV$_{0.2}$) welded onto a back* *consisting of ferritic iron (Average 177HV$_{0.2}$, Range 123-257HV$_{0.2}$,). A white weld line separated the cutting edge from the back (0.3%-0.8% As).*

14491 - *Type 2 knife with a heat-treated martensite cutting edge (1288HV$_{0.2}$, Average 1189HV$_{0.2}$, Range 1097-1288HV$_{0.2}$) welded onto a back consisting of piled ferritic iron and low carbon steel (Average 201HV$_{0.2}$, Range 160-274HV$_{0.2}$). A white weld line separated the cutting edge from the back (0.3%-0.8% As, 0.1%-0.2% Cu, up to 0.2% Ni).*

15910 - *Type 2 knife with a heat-treated martensite cutting edge (509HV$_{0.2}$, Average 664HV$_{0.2}$, Range 509-927HV$_{0.2}$) welded onto a back consisting of two pieces of iron; the first was a ferritic iron (Average 308HV$_{0.2}$, Range 192-528HV$_{0.2}$) while the other piece was a mid-high carbon steel. A white weld line separated the cutting edge from the back (0.2%-0.4% As, up to 0.2% Ni).*

16514 - *Type 1 knife with a heat-treated martensite core (1144HV$_{0.2}$, Average 951HV$_{0.2}$, Range 644-1211HV$_{0.2}$) sandwiched between two pieces of phosphoric iron (Average 260HV$_{0.2}$, Range 221-362HV$_{0.2}$,* 0.2%-0.4% P*).*

16557 - *Type 2 heat-treated knife with a tempered martensite cutting edge* (441*HV$_{0.2}$, Average 417HV$_{0.2}$, Range 257-593HV$_{0.2}$*) *separated from the piled iron back by a white weld line. The back comprised of low carbon steel and high carbon steel, some of which was heat-treated to form bainite* (*Average 360HV$_{0.2}$, Range 192-589HV$_{0.2}$*)*.*

16808 - *Type 1 knife with a heat-treated martensite core (1027HV$_{0.2}$, Average 965HV$_{0.2}$, Range 412-1027HV$_{0.2}$*) *with high quantities of arsenic (0.3%-0.9% As) sandwiched between piled low carbon iron (Average 519HV$_{0.2}$, Range 3HV$_{0.2}$,* up to 0.2% P*). To either side of these pieces of iron there was a white weld line.*

16826a - *Type 5 knife slowly heat-treated all steel knife. This knife has a bainite cutting edge with martensite in areas (362HV$_{0.2}$, Average 681HV$_{0.2}$, Range 362-1144HV$_{0.2}$), and a pearlite with martensite back and arsenic was present throughout (Average 713HV$_{0.2}$, Range 330-1144HV$_{0.2}$,* 0.3%-0.4% As*). Many white bands were also identified (0.6%-0.7% As, 0.1% Ni).*

16826b - *Type 1 knife with a heat-treated martensite core (1144HV$_{0.2}$, Average 1018HV$_{0.2}$, Range 766-1144HV$_{0.2}$) sandwiched between two different pieces of phosphoric iron (Average 392HV$_{0.2}$, Range 321-441HV$_{0.2}$,* 0.6%-0.8% P*). To either side of these pieces of iron there was a white weld line (0.1%-0.3% As, 0.2%-0.4% Ni).*

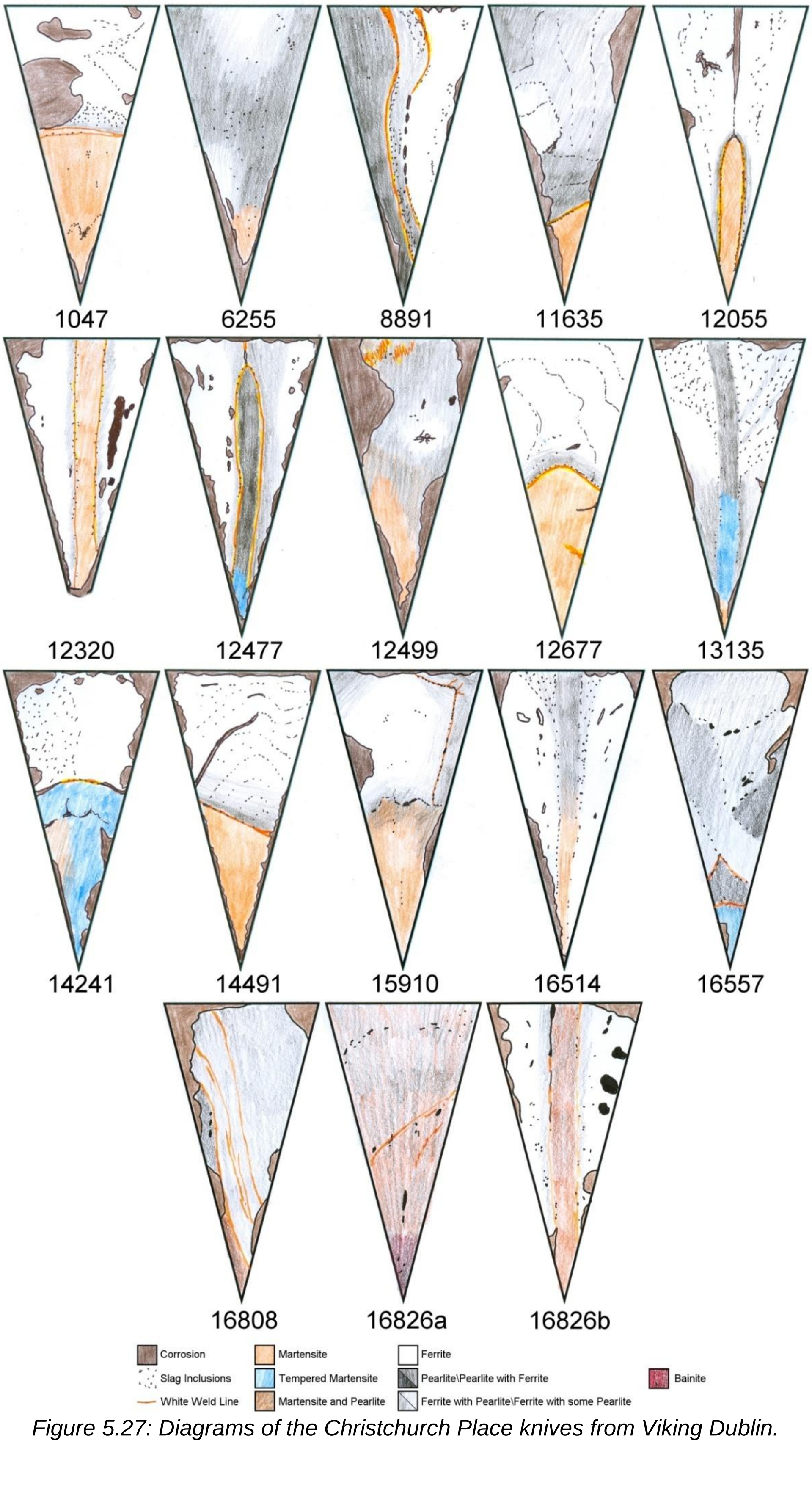


Figure 5.27: Diagrams of the Christchurch Place knives from Viking Dublin.

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
1047	None	2	Martensite	549	549-766	Ferrite	152	88-257	Yes	White weld line
6255	None	5	Martensite with ferrite	509	509-644	Pearlite with ferrite	311	210-412	Yes	
8891	Some	2	Tempered Martensite	473	386-509	Phosphoric Iron	255	175-386		White weld line
11635	Slight	2	Martensite	1027	701-1027	Ferrite with pearlite/Phosphoric Iron	332	148-549	Yes	White weld line
12055	Slight	1	Martensite	1288	946-1288	Phosphoric Iron	186	123-254	Yes	White weld line
12320	Some	1	Martensite	1047	644-1047	Phosphoric Iron	235	175-286	Yes	White weld line
12477	Slight	1	Martensite with ferrite	644	412-644	Ferrite/ Phosphoric Iron	205	168-271	Yes	White weld line
12499	Some	5	Martensite	927	766-1144	Pearlite with ferrite	283	148-509	Yes	
12677	None	2	Martensite	1027	593-1027	Phosphoric Iron	258	210-399	Yes	White weld line
13135	None	1	Martensite	701	232-701	Piled phosphoric Iron	252	183-340	Yes	
14241	None	2	Tempered Martensite	457	321-644	Ferrite	177	123-257	Yes	White weld line
14491	Some	2	Martensite	1288	1097-1288	Ferrite with pearlite	201	160-274	Yes	White weld line
15910	Some	2	Martensite	509	509-927	Ferrite with some pearlite	308	192-528	Yes	
16514	Some	1	Martensite	1144	644-1211	Phosphoric Iron	260	221-362	Yes	
16557	Slight	2	Tempered Martensite	441	257-593	Piled ferrite/ferrite with pearlite/pearlite	360	192-589	Yes	White weld line
16808	Some	1	Martensite	1027	412-1027	Piled ferrite with pearlite	519	386-701	Yes	White weld line
16826a	Slight	5	Bainite	362	362-1144	Martensite with Pearlite	713	330-1144	Yes	White weld line
16826b	Slight	1	Martensite	1144	766-1144	Phosphoric Iron	392	321-441	Yes	White weld line

Table 5.45: Summary of the eighteen knives analysed from Christchurch Place. This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges).

Winetavern Street & John’s Lane

In total six knives were sampled, four from Winetavern Street and two from John’s Lane (Table 5.46, Table 5.48 and Figure 5.28).

Site	Area	Knife Number	Date	Shape
Winetavern Street	81	323	11th	D1
Winetavern Street	81	589	c1200	D1
Winetavern Street	81	3971	Mid-late 11th	B1
Winetavern Street	81	4974	Early 11th	D1
John's Lane	173	604	11th	A3
John's Lane	173	4437	11th	A1

Table 5.46: Samples from Winetavern Street and John’s Lane selected for analysis showing their small find numbers and date.

Summary of Knives

323 - *Type 2 knife with a heat-treated martensite cutting edge (1144$HV_{0.2}$, Average 1077$HV_{0.2}$, Range 927-1144$HV_{0.2}$) welded onto a back made of three pieces of iron; two pieces of ferritic iron (Average 288$HV_{0.2}$, Range 221-386$HV_{0.2}$) with a core of mid carbon steel (Average 402$HV_{0.2}$, Range 362-473$HV_{0.2}$). A white weld line separated the cutting edge from the back (0.3% As, 0.1% Cu).*

589 - *Type 0 heterogeneous iron knife with ferritic iron near the cutting edge (161$HV_{0.2}$, Average 205$HV_{0.2}$, Range 161-303$HV_{0.2}$) and mid-high carbon steel at the back, that had been heat-treated to form martensite and bainite (Average 504$HV_{0.2}$, Range 192-1027$HV_{0.2}$).*

3971 - *Type 1 knife with a heat-treated tempered martensite core (509$HV_{0.2}$, Average 556$HV_{0.2}$, Range 232-841$HV_{0.2}$) sandwiched between two pieces of phosphoric iron (Average 302$HV_{0.2}$, Range 257-340$HV_{0.2}$,* 0.4%-0.6% P*). To either side of these pieces of iron there was a white weld line (0.3% As, 0.2%-0.3% Ni, 0.2% Cu).*

4974 - *Type 1 knife with a slowly heat-treated bainite core (593$HV_{0.2}$, Average 339$HV_{0.2}$, Range 286-593$HV_{0.2}$) sandwiched between two pieces of phosphoric iron (Average 362$HV_{0.2}$, Range 303-412$HV_{0.2}$,* 0.4%-0.7% P*). To either side of these pieces of iron there was a white weld line (0.5% As, 0.1% Ni).*

604 - *Type 2 knife with a slow heat-treated cutting edge of bainite (509$HV_{0.2}$, Average 381$HV_{0.2}$, Range 286-509$HV_{0.2}$) welded onto a piled iron back, with a clear white weld line (0.2%-0.4% As, 0.2%-0.4% Ni, up to 0.2% Cu).The knife back consisted of ferritic, low-mid carbon steels (Average 244$HV_{0.2}$, Range 161-386$HV_{0.2}$).*

4437 *- Type 5 low carbon steel knife, with a slowly heat-treated bainitic cutting edge (490*$HV_{0.2}$*, Average 464*$HV_{0.2}$*, Range 321-593*$HV_{0.2}$, 0.1%-0.7% P*), and slightly higher carbon content at the back (Average 388*$HV_{0.2}$*, Range 321-412*$HV_{0.2}$, 0.1%-0.3% P*). Multiple white lines were visible in the back of the knife (up to 0.2% As, 0.1%-0.2% Ni).*

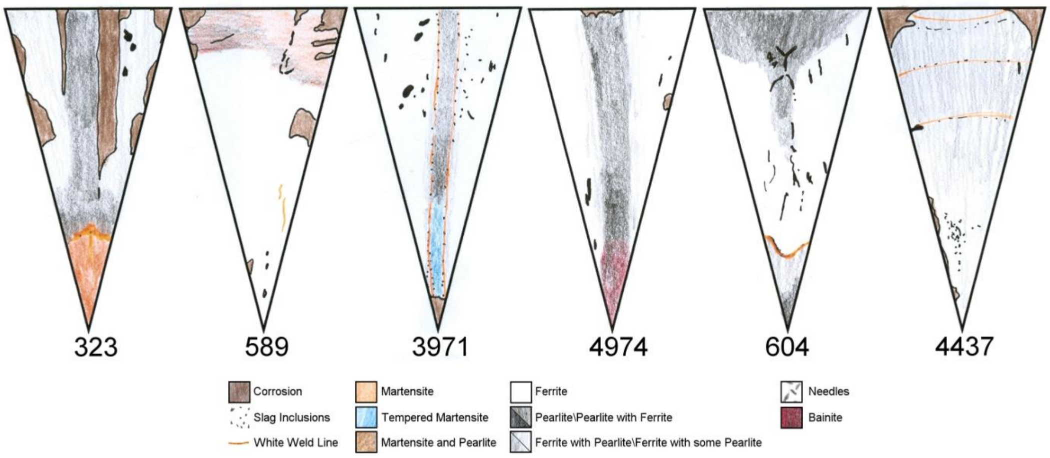


Figure 5.28: Diagrams of the Winetavern Street and John's Lane knives from Viking Dublin

High Street

In total five knives were sampled from High Street (Table 5.47, Table 5.49 and Figure 5.29).

Area	Knife Number	Date	Shape
43	1114	11th-12th	B1
43	1708	11th-12th	B1
71	10012	11th-12th	D2
71	10069	11th-12th	B3
71	10369	11th-12th	D1

Table 5.47: Samples selected from High Street for analysis showing their small find numbers and date.

Summary of Knives

1114 *- Type 5 all steel knife, which had been heat-treated resulting in a martensite cutting edge (1144*$HV_{0.2}$*, Average 1022*$HV_{0.2}$*, Range 644-1144*$HV_{0.2}$*) but pearlite in the knife back (Average 697*$HV_{0.2}$*, Range 473-1027*$HV_{0.2}$, up to 0.1% P*). There was also some phosphoric iron in the knife back (Average 304*$HV_{0.2}$*, Range 257-362*$HV_{0.2}$, 0.3%-0.4% P*). Multiple white lines were visible in the cutting edge of the knife (1.3%-1.5% As).*

1708 - *Type 2 knife with a heat-treated martensite cutting edge (1283$HV_{0.2}$, Average 1230$HV_{0.2}$, Range 1144-1283$HV_{0.2}$) scarf-welded onto a back consisting of phosphoric iron (Average 377$HV_{0.2}$, Range 321-441$HV_{0.2}$,* 0.3%-0.7% P*).*

10012 - *Type 2 knife with a heat-treated cutting edge of martensite (841$HV_{0.2}$, Average 1041$HV_{0.2}$, Range 412-1283$HV_{0.2}$) welded onto a piled iron back. The knife back consisted of low phosphorus iron and mid-carbon steel (Average 321$HV_{0.2}$, Range 183-593$HV_{0.2}$,* up to 0.3% P*).*

10069 - *Type 0 knife made from two pieces of iron; one a ferritic iron (321$HV_{0.2}$, Average 322$HV_{0.2}$, Range 244-441$HV_{0.2}$) while the other was a phosphoric iron (Average 372$HV_{0.2}$, Range 183-509$HV_{0.2}$,* 0.3%-0.4% P*).*

10369 - *Type 1 knife with a heat-treated tempered martensite core (473$HV_{0.2}$, Average 429$HV_{0.2}$, Range 192-549$HV_{0.2}$) sandwiched between two different pieces of piled ferritic iron (Average 171$HV_{0.2}$, Range 127-210$HV_{0.2}$). To either side of these pieces of iron there was a white weld line (0.2%-0.4% P, up to 0.2% Ni).*

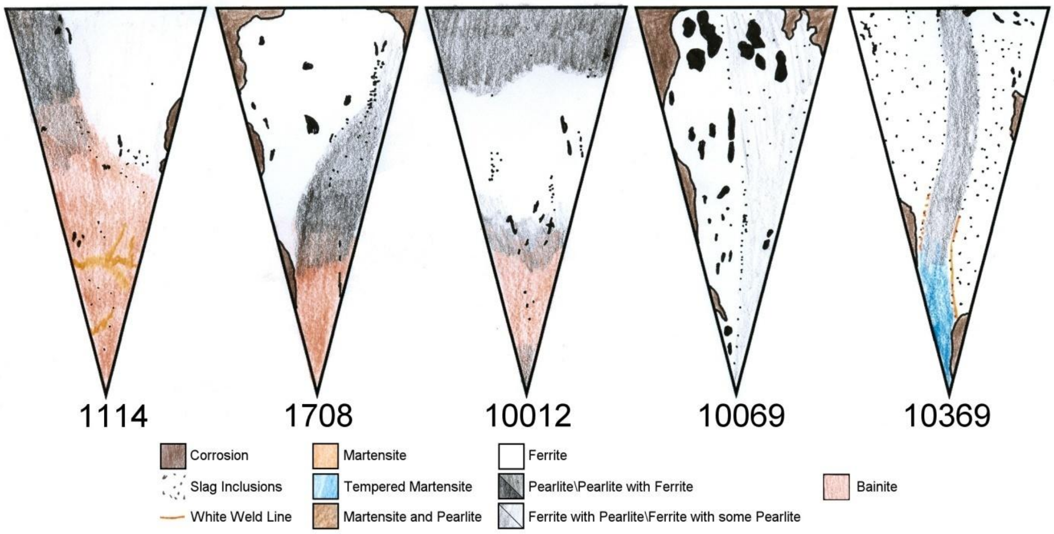


Figure 5.29: Diagrams of the High Street knives from Viking Dublin

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
323	Slight	2	Martensite	1144	927-1144	Piled Ferrite/Pearlite with Ferrite	334	221-473	Yes	White weld line
589	Slight	0	Ferrite	161	161-303	Piled ferrite/Martensite	504	192-1027	Yes	White Bands
3971	Some	1	Tempered Martensite	509	232-841	Phosphoric Iron	302	257-340	Yes	White weld line
4974	Some	1	Bainite	593	286-593	Phosphoric Iron	362	303-412	Slow	White weld line
604	Slight	2	Bainite	509	286-509	Piled Ferrite/Pearlite with Ferrite	244	161-386	Slow	White weld line
4437	Slight	5	Bainite	490	321-593	Phosphoric Iron	388	321-412	Yes	White Bands

Table 5.48: Summary of the six knives analysed from Winetavern Street and John's Lane. This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges).

Knife No	Wear	Type	Cutting Edge			Back			Heat Treated	Other Details
			Microstructure	HV	HV Range	Microstructure	Avg HV	HV Range		
1114	Some	5	Martensite	1144	644-1144	Pearlite/Phosphoric Iron	633	257-1144	Yes	White Bands
1708	Some	2	Martensite	1283	1144-1283	Phosphoric Iron	377	321-441	Yes	
10012	Some	2	Martensite	841	412-1283	Ferritic Iron	321	183-593	Yes	
10069	Lots	0	Ferrite/Phosphoric Iron	321	244-441	Phosphoric Iron	372	183-509		
10369	Slight	1	Tempered Martensite	473	192-549	Piled Ferritic Iron	171	127-210	Yes	White Bands

Table 5.49: Summary of the five knives analysed from High Street. This includes the archaeological typologies assigned to the knives. It also shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values and hardness ranges).

Viking Dublin Summary

Two previous studies of the knives from Dublin have been carried out. Brian Scott undertook a small project, analysing four knives from the Viking period, two from the late 12th century and two from later medieval contexts (Volume 2 table 11.12; Scott nd). The second larger research project was carried out by Mark Hall for a PhD (Hall 1992), but this research has not been published. Reading the results section of his PhD thesis serious doubts were raised about the sampling strategy, as samples were taken at the knife tip which would result in non-representative sections. In addition some of the microstructure identification did not correlate with the hardness values seen and there is not enough raw data to re-construct the knife data. This research will therefore not be used during comparisons.

Figure 5.30: Distribution of knife manufacturing types across Dublin.

When the results from Scott's analysis are combined with this study the evidence shows a range of manufacturing types identified in Viking Dublin (Figure 5.30). The vast majority of knives (18 out of 44) are type 2 butt-welded knives. Type 1 knives were also abundant (13 out of 44) in the assemblage. The remaining knives consist of five plain iron knives (type 0), seven type 5 all steel knives and a single type 3 knife. There were some clear differences between the sites, the majority of Fishamble Street knives where type 2's (6 out of 11) whereas at Christchurch Place there were equal numbers of type 1 and 2 knives. At Winetavern Street, John's Lane and High Street there were a roughly equal numbers of type 0 (plain iron), type 1 and 2 knives.

Most of the type knives from Dublin (35 out of the 44) had been heat treated to create a harder cutting edge. The vast majority of these were martensite (23/44);

some were martensite with ferrite or pearlite (4/44) or were tempered martensite (6/44). The backs of some of the knives consisted of more than one piece, and type, of iron alloy. The most common alloy used to create the knives backs or flanks was phosphoric iron (15 out of 44) or ferrite with pearlite (11 out of 44). SEM-EDS analysis revealed the presence of arsenic in the metal (between 0.2-1.5%) in many samples (26 of 40), mostly in cutting edges (20 of 40) but also in knife backs (18 of 40). This may explain why there were so many white weld lines in the Dublin samples compared to other assemblages and may be linked to the iron ores used but more analysis is required to confirm this pattern.

Summary/Review of other European Settlements

For comparison with Viking Dublin, more metallographic studies of knives from Ireland were sought. Brian Scott also examined six early Christian, pre-Viking knives which revealed a range of different types of manufacturing methods (Volume 2 table 1.12). It also showed that the majority were heat-treated resulting in martensite cutting edges (Scott 1991a).

Thirteen knives were examined from the 5th-9th century pre-Viking site of Helgö, Sweden which revealed a range of manufacturing methods (Volume 2 table 1.14). Many of these knives were heat-treated with tempered martensite cutting edges and ferritic iron backs. No chemical analysis was carried out on these knives so it is unknown how many of them had phosphorus present in the iron (Tomtlund 1973).

There have been very few extensive studies of Viking knives in Europe. A small sample of knives from 9th-11th century Iceland revealed an assemblage of mostly type 1, sandwich knives with the exception of one type 5 knife. Only half of the knives were heat-treated tempered martensite and the backs were predominately ferritic iron (Volume 2 table 1.13; Sigurðardóttir 1999). The remaining studies of Viking knives have focused on the manufacturing methods and have ignored the different types of iron alloys used to create them or the heat-treatments applied. The study of knives from Novgorod revealed that in the 9th to 11th century the knives were constructed using the sandwich, type 1, method (Thompson *et al.* 1967). This pattern was also noted in the knives sampled from Denmark (Lyngstrøm 2008).

5.6 White Weld Line Analysis Results

Visual examination of the many white weld lines seen in early medieval knives revealed two different types of line: a solid white line and a slightly faded yellow line. This is the first instance where such a difference has been noted. The solid white line was often slightly raised and therefore visible prior to etching (Figure 5.31), on the other hand the yellow weld line was slightly faded, diffusing into the metal (Figure 5.32 and 5.34). Occasionally multiple white weld lines were seen, again not previously noted by other researchers, and in some cases the weld lines were not necessarily associated with slag inclusions (Figure 5.33). This suggests that not all white lines occur at the weld line. Some of the white lines also appear to expand beyond the weld lines (Figure 5.31).

Weld Line Type	Arsenic			Nickel			Copper		
	Avg	Range	StDev	Avg	Range	StDev	Avg	Range	StDev
Solid White*	1.1%	0.4%-2.5%	0.9%	0.4%	0.3%-1.0%	0.3%	0.2%	0.1%-0.4%	0.1%
Faded Yellow	0.7%	0.1%-2.8%	0.7%	0.6%	0.2%-2.0%	0.5%	0.2%	0.1%-0.4%	0.1%

*Table 5.50: Table of results showing the data from the weld line analysis, including the average, range and standard deviation for each arsenic, nickel and copper for both types of weld line. *This excludes the unusual copper rich weld lines in the Collingbourne Ducis knife 118.*

The compositional analysis taking multiple readings across the weld line by SEM-EDS revealed that there were no specific trends to explain the difference between the two types of weld line (Table 5.50). In general it seems solid white weld lines tend to have more arsenic present while the faded yellow lines have slightly more nickel. Some of the white weld lines were very different, e.g. Collingbourne Ducis 118 and Wharram Percy 159 which had relatively small quantities of arsenic (0.1%-0.4%) and nickel (0.1%) but were enriched in copper (0.4%-5.2%) and occasionally phosphorus (0.1%-0.4%). The analysis also revealed that in most cases small and sometimes large quantities of arsenic, nickel and copper were present in at least one, if not both, pieces of iron either side of the line. This perhaps suggests that the weld lines are related to the composition of the metal used, and may in turn be linked to the ores chosen. This theory needs to be tested further, and more data needs to be collected from objects without white weld lines.

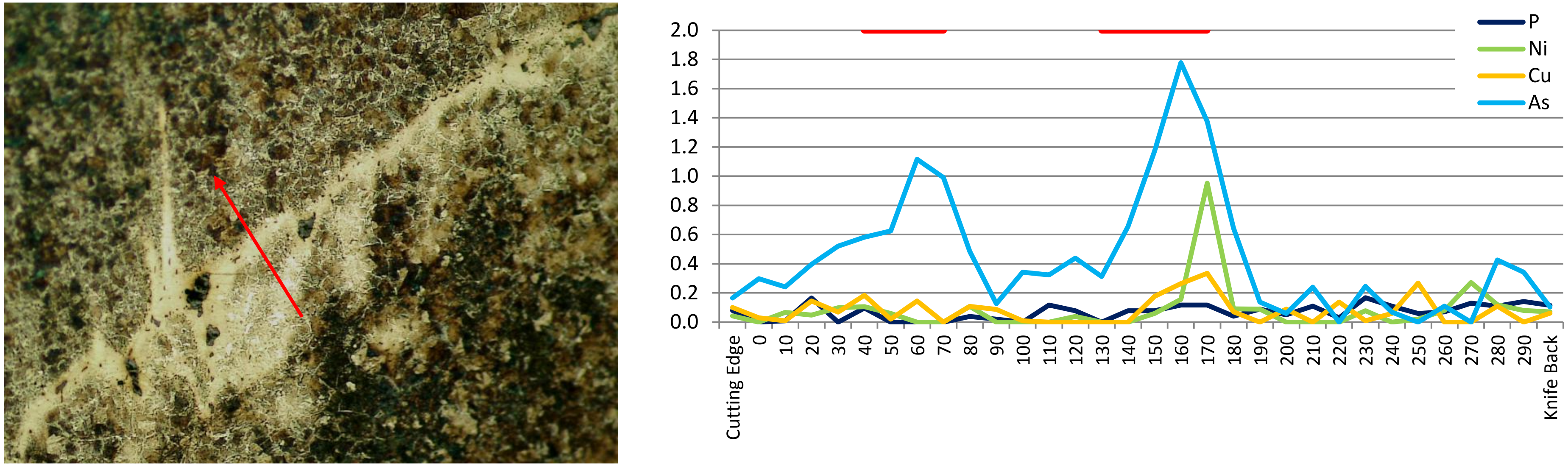


Figure 5.31: Solid white weld line in knife 502 from Wharram Percy, with some diffusion beyond the weld. Values below the 0.1% detection limit of the SEM-EDS may not be reliable.

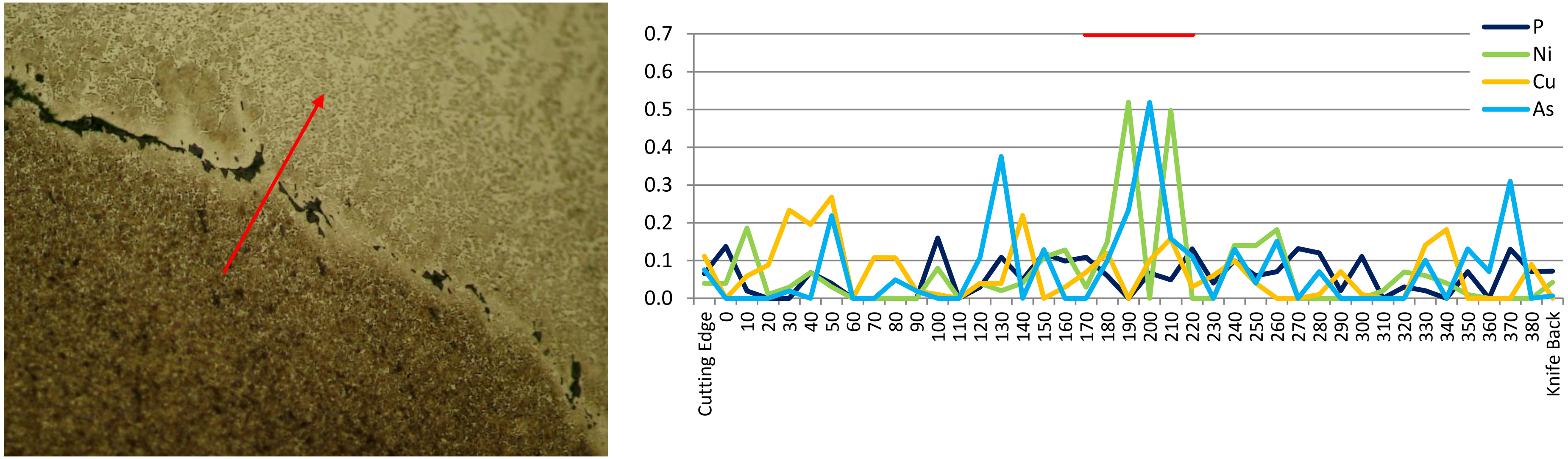
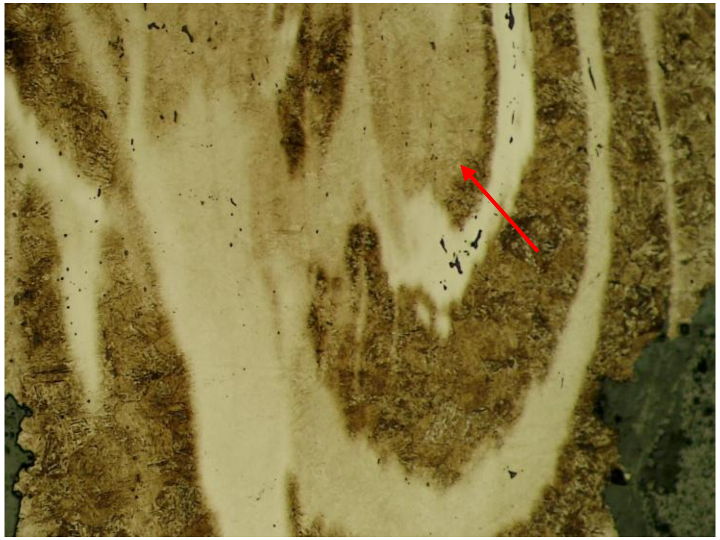


Figure 5.32: Faded yellow weld line in knife 8 from Sedgeford. Values below the 0.1% detection limit of the SEM-EDS may not be reliable.



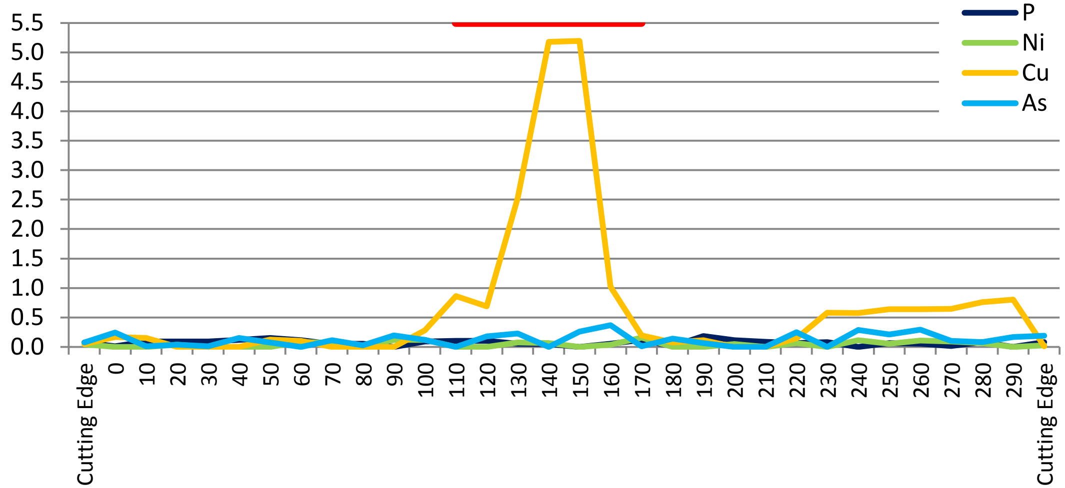
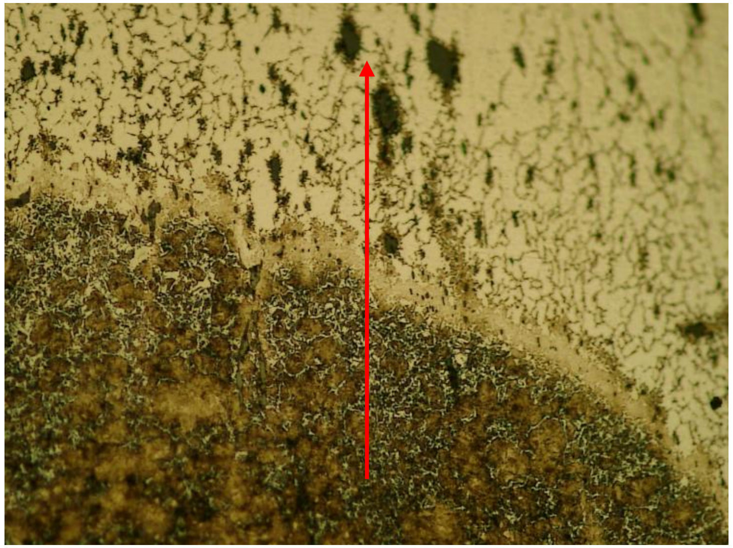


Figure 5.33: Multiple solid white lines in knife 118 from Collingbourne Ducis, none associated with the weld line, enriched in copper. Values below the 0.1% detection limit of the SEM-EDS may not be reliable.



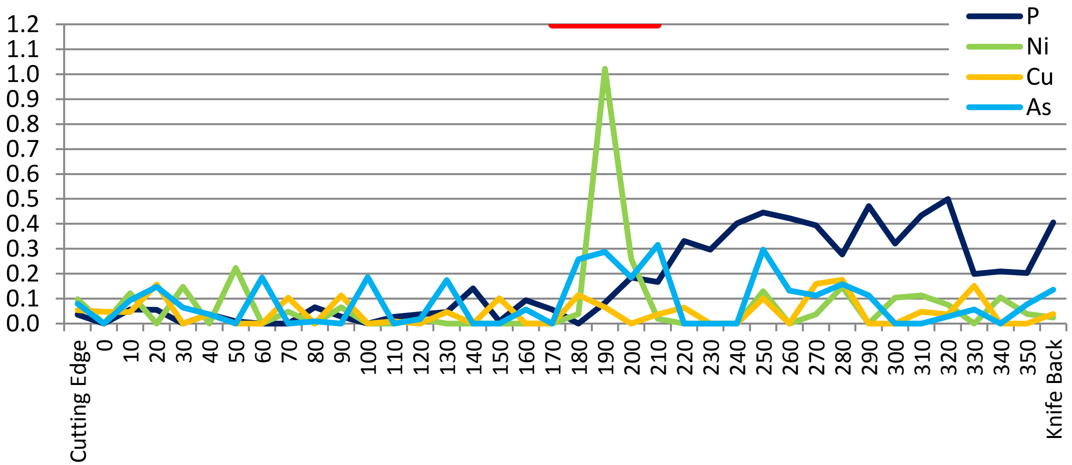


Figure 5.34: Faded yellow white line in knife 188 from Sedgeford. Values below the 0.1% detection limit of the SEM-EDS may not be reliable.

The SEM-EDS analysis using line scans revealed clear changes in composition across the white weld lines, and in the metal to either side therefore confirming previous observations by the author. The full results from the analysis of over 30 weld lines are available in the appendix. There was no clear pattern to the changes in composition. In most cases when there is an increase in arsenic in the weld line there is also an increase in nickel and/or copper. This is not always the case as sometimes the arsenic peak inversely correlated with the nickel (Figure 5.32) but this seems to only occur with the faded yellow lines. Occasionally the biggest changes in composition occur beyond the weld line, and again there does not seem to be any pattern to this observation. This research has clearly shown that single spot analysis of white weld lines should not be relied upon. Instead averages of several points, areas or a line scan should be carried out. However further research is required to determine which of these techniques provides the best results.

Chapter 6: Knife Manufacture and Early Medieval Society

6.1 Introduction

This chapter discusses the cultural implications of the analytical results, primarily focusing on the first four research objectives. The first objective was to investigate the differences in manufacturing techniques and methods first identified in the review paper by Blakelock and McDonnell (2007). In that paper three main hypotheses were put forward to explain the observed differences, and these are explored further in this chapter. The first hypothesis was that the differences between the knives from settlements and cemeteries reflect the nature and the status of the sites. The first section (6.2) will therefore compare the knives from rural sites and higher status ecclesiastical sites with those from urban contexts to determine if the nature of settlements influence iron manufacturing techniques. The next section (6.3) investigates the second hypothesis: that there was a change in manufacturing techniques though time. To assess this, knives from early settlements will be compared to those from contemporary early cemeteries and from the later middle to late Saxon settlements (urban, rural and ecclesiastical). This section will also attempt to narrow down a date for any changes in manufacture using knives from precisely dated graves from cemeteries. The final hypothesis is that knives were created for burial. This is partially discussed in section 6.3, but is also investigates in section 6.4.

The second research objective of this project was to determine whether the status of the knives' owner is reflected in the knife manufacture, in terms of quality. In section 6.4 this question will be investigated using the knife manufacturing methods, heat-treatments and alloys used, as well as the wear present; they will all be compared to the sex, age and status of the individual buried to determine whether any patterns emerge. In addition the possible evidence for the ritual killing of knives will also be discussed in tandem with the issue of the cremation of knives.

The third objective was to compare knives through time in an attempt to determine what, if any, impact the Vikings had on the ironworking industries in England. Section 6.5 thus compares knives from England chronologically, into the late Saxon period and up to c. 11th century. Then knives from different regions, assumed to represent different cultural groups, are discussed (section 6.6), including the Anglo-Scandinavian Danelaw and Anglo-Saxon Wessex.

The fourth objective of this research was to investigate knives from across Europe in an attempt to provide an overview of Viking knife manufacture and plot the transference of ideas and technology. This will be achieved by comparing the new results from Viking Dublin (Hiberno-Norse) with knife studies from other parts of Viking Europe (section 6.7).

6.2 Rural vs High Status Ecclesiastical vs Urban

This section discusses the knives from rural settlements such as Wharram Percy, Burdale and Sedgeford, and compares them to the urban knives from Hamwic as well as those from the Fishergate and Coppergate sites in York. Knives in rural settlements might be expected to be of poorer quality to those made in urban settlements with its specialised craft workers. The availability of iron alloys might also have been limited in rural settlements, which may have relied on the recycling of iron. On the other hand the urban smiths would have had access to a wider trade network and access to supplies of better quality iron. In addition, knives from ecclesiastical Whithorn are added to those from high status and ecclesiastical Flixborough, and will be compared to both urban and rural knives. Like urban settlements the high status settlements may have had access to more talented or specialised blacksmiths and better quality iron alloys. All these knives are also compared to those from early rural cemeteries to investigate the first hypothesis, that the differences seen in the cemeteries represent knives in rural and urban settlements which have been constructed differently.

In order to compare the assemblages the shape of the knife backs at the different sites will be examined and the manufacturing methods of knives from rural, urban and ecclesiastical sites will be compared. The differences in alloys and heat-treatments at the cutting edge and knife backs will also be compared.

Knife Shape

There have been many excavations of middle Saxon urban, rural and high status settlements and most of the more recent ones have been published, particularly those of rural sites, while some of the older excavations have still not been fully reported. Unfortunately even those sites that have been fully published rarely illustrate every knife found. This makes the analysis of the full assemblage difficult or even impossible when there has been no opportunity to re-examine the finds.

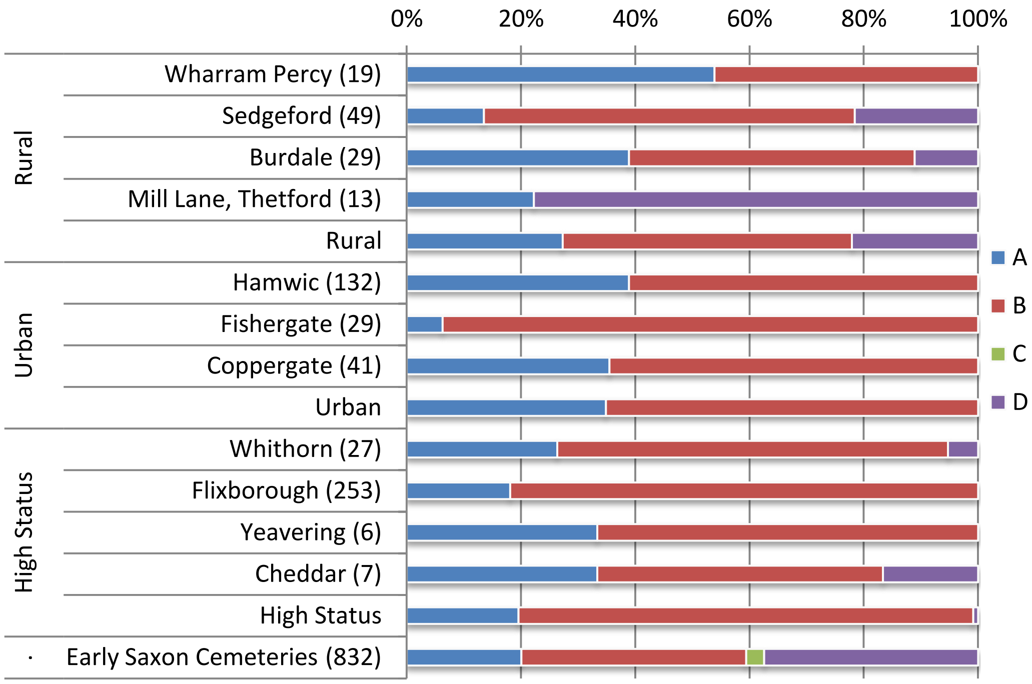


Figure 6.1: Stacked bar chart showing the frequency of knife back shapes for each middle to late Saxon knife assemblage. The data used in this of figure is in table 2.1 in Volume 2 (Rahtz & Hirst 1979; McDonnell et al. 1991; Ottaway 1992; Rogers 1993; Stamper & Croft 2000; Rahtz & Watts 2004; Wallis et al. 2004; Frodsham & O'Brien 2005; Evans et al. 2009).The number in brackets (in all the stacked bar charts) indicates the total number of knives. The knife shape typology is in the appendix volume on page 38.

The analysis of the knife shapes using the typology presented in the methodology (Figure 4.1) revealed that the majority had curved backs. There were slight differences between the groups with more straight backed knives in rural settlements and more angle-backed knives in the urban settlements (Figure 6.1). These differences were statistically significant, with the largest difference being the proportion of straight-backed knives (Chi-square value 36.93, degrees of freedom 2 and probability 0.0). This may represent different uses of the knives in urban settlements compared to rural ones. When compared with knives from early cemeteries it is clear that there are some dramatic differences. The incurved backs only occur in the cemeteries where there were also a higher proportion of straight backed knives. The Chi-square test revealed that again there was a statistically significant difference, particularly when considering the straight backed knives (Chi-square value 226.57, degrees of freedom 9 and probability 0.0).

Knife Manufacture Methods

When the manufacturing types for rural and urban sites are compared very few differences are present (Table 6.1 and Figure 6.2). Both site types had a high proportion of type 2 knives although the rural sites also had poorer quality type 0 and 3 knives present. The Chi-square test confirmed that there was a statistical similarity between urban and rural knives (Chi-square value 6.87, degrees of freedom 5 and probability 0.23). The knives from both high status sites were different; Flixborough revealed a pattern similar to the urban sites while the Whithorn knives had manufacturing type more similar to those in early Saxon cemeteries. This pattern may relate to the isolated nature of the ecclesiastical site at Whithorn, which seemed to have little contact beyond Northumbria (Hill & Campbell 1997: 47-48). Even so the Chi-square test result reveals an even closer link between the different sites when the high status knives are included with the rural and urban ones (Chi-square value 18.79, degrees of freedom 10 and probability 0.04). This suggests that manufacturing methods in the middle Saxon period were similar in urban, rural and most high status settlements.

The Chi-square test showed a clear statistical difference between the knives from cemeteries and those from the urban settlements (Chi-square value 17.54, degrees of freedom 5 and probability 0.0) as noted by Blakelock and McDonnell previously (2007). This wider analysis project has shown that the vast majority of middle to late Saxon knives, be they urban, rural or ecclesiastical were type 2, unlike the cemetery knives (Figure 6.2). This is confirmed by the Chi-square test which revealed a weak relationship between rural settlements and the cemeteries (Chi-square value 22.85, degrees of freedom 5 and probability 0.0).

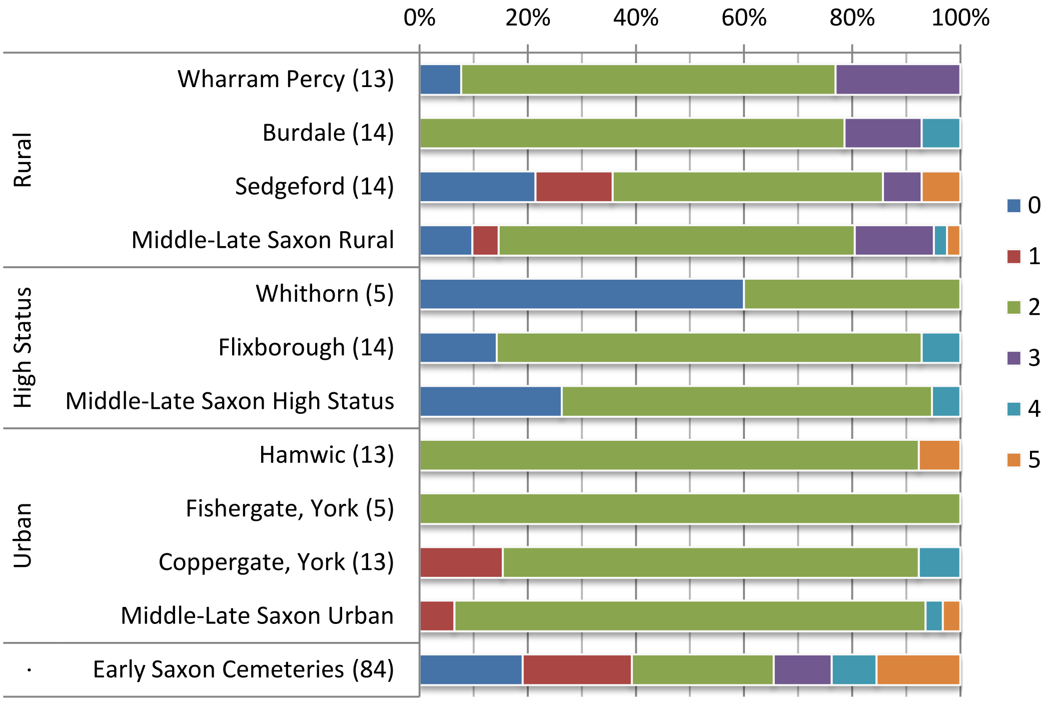


Figure 6.2: Stacked bar chart showing the frequency of different knife manufacturing methods in rural, urban and high status settlements, compared to early Saxon cemeteries. The data for this graph is from table 6.1. The manufacturing typology is in the appendix volume on page 38.

Analysis of the rural knives revealed a large number of white weld lines (20 in 41, 49%), whereas the previous analysis (Blakelock & McDonnell 2007) had revealed relatively few in urban settlements (5 in 32 knives, 16%). In the higher status settlements there was an even higher proportion of white weld lines (12 in 19, 63%). This suggests that these weld lines are more likely linked to settlements in rural locations and therefore to the iron alloys available there, rather than being an indicator of high-quality welding techniques using a flux. This again points to a link between ores and weld lines, the majority of Saxon smithies presumably used bog iron ores which were readily available but tend to contain many impurities.

Sites		Manufacturing Typology and Cutting Edge Data							Manufacturing Typology and Knife Back Data						
		0	1	2	3	4	5	Overall	0	1	2	3	4	5	Overall
Wharram Percy 7^{th}-10^{th}	Number	1		9	3			**13**	1		9	3			**13**
	Avg HV	187		252	224			**241**	187		168	169			**170**
	Range HV	187		121-524	175-314			**121-524**	187		120-232	150-181			**120-232**
Burdale 7^{th}-9^{th}	Number			11	2	1		**14**			11	2	1		**14**
	Avg HV			512	227	549		**474**			166	221	233		**179**
	Range HV			210-766	168-286	549		**168-766**			109-212	148-294	233		**109-294**
Sedgeford 7^{th}-9^{th}	Number	3	2	7	1		1	**14**	3	2	7	1		1	**14**
	Avg HV	165	658	388	137		509	**370**	167	181	181	171		339	**189**
	Range HV	137-183	549-766	154-644	137		509	**136-766**	138-208	170-192	152-226	171		339	**138-339**
Middle to Late Saxon Rural	**Number**	**4**	**2**	**27**	**6**	**1**	**1**	**41**	**4**	**2**	**27**	**6**	**1**	**1**	**41**
	Avg HV	**171**	**658**	**393**	**211**	**549**	**509**	**364**	**172**	**181**	**171**	**187**	**233**	**339**	**179**
	Range HV	**137-187**	**549-766**	**121-766**	**137-314**	**549**	**509**	**121-766**	**138-208**	**170-192**	**120-232**	**148-294**	**233**	**339**	**109-339**
Whithorn 6^{th}-late 9th	Number	3		2				**5**	3		2				**5**
	Avg HV	188		266				**219**	192		208				**198**
	Range HV	161-201		210-321				**161-321**	169-217		201-215				**169-217**
Flixborough[3] 7^{th} -10^{th}	Number	2		11		1		**14**	2		11		1		**14**
	Avg HV	204		556		479		**500**	191		161		195		**168**
	Range HV	139-268		379-650		479		**139-650**	139-242		124-203		195		**124-242**
Middle to Late Saxon High Status	**Number**	**5**		**13**		**1**		**19**	**5**		**13**		**1**		**19**
	Avg HV	**194**		**511**		**479**		**426**	**191**		**168**		**195**		**176**
	Range HV	**123-268**		**210-650**		**479**		**139-650**	**139-242**		**124-215**		**195**		**124-242**
Six Dials, Hamwic[4] 8^{th}-9^{th}	Number			12			1	**13**		2	10		1		**13**
	Avg HV			430			607	**444**		176	225		89		**207**
	Range HV			153-813			572-642	**153-813**		153-199	133-707		89		
Fishergate, York[5] 8^{th}-9^{th}	Number			5				**5**		2	27		1	1	**31**
	Avg HV			445				**445**		176	191		89	607	**200**
	Range HV			314-630				**314-630**		153-199	101-707		89	607	**89-707**
Coppergate, York[6] 9^{th}-10^{th}	Number		2	10		1		**13**		2	10		1		**13**
	Avg HV		503	515		309		**497**		176	225		89		**207**
	Range HV		476-530	270-847		309		**244-927**		153-199	133-707		89		
Middle to Late Saxon Urban	**Number**		**2**	**27**		**1**	**1**	**31**		**2**	**27**		**1**	**1**	**31**
	Avg HV		**503**	**464**		**309**	**607**	**466**		**176**	**191**		**89**	**607**	**200**
	Range HV		**476-530**	**153-847**		**309**	**607**	**153-847**		**153-199**	**101-707**		**89**	**607**	**89-707**
Early to Middle Saxon Cemetery Total	**Number**	**16**	**17**	**22**	**9**	**7**	**13**	**84**	**16**	**17**	**22**	**9**	**7**	**13**	**84**
	Avg HV	**172**	**316**	**560**	**215**	**513**	**267**	**350**	**167**	**195**	**185**	**185**	**192**	**242**	**193**
	Range HV	**130-303**	**100-724**	**238-1000**	**143-593**	**388-775**	**116-593**	**100-1000**	**130-216**	**149-379**	**124-316**	**148-331**	**150-282**	**104-480**	**124-480**

Table 6.1: Table showing the number, average hardness and hardness range for the cutting edge and backs of knives from various rural, urban and high status sites. Data from this thesis except for Flixborough (Starley 1999,2009a), Hamwic (McDonnell 1987a,d), Fishergate (Wiemer 1993) and Coppergate (McDonnell 1992).

Cutting Edge Heat-treatment and Alloys

The main difference between urban and rural knives was that there were fewer, or poorer quality heat-treatments in the knives from rural settlements as compared to those seen in the urban settlements. Fewer than 50% of the rural knives were heat-treated, but this figure rose to over 70% in the urban settlements (Figure 6.3). The high status settlements differed from each other; the knives from Flixborough were very good quality with twelve out of fourteen treated, but the Whithorn knives were much poorer quality, with no heat-treated knives, again possibly influenced by its isolation. These differences in heat-treatments were reflected in the average hardness of the type 2 knives which were not very hard in the rural settlements when compared to other settlements (Table 6.1).

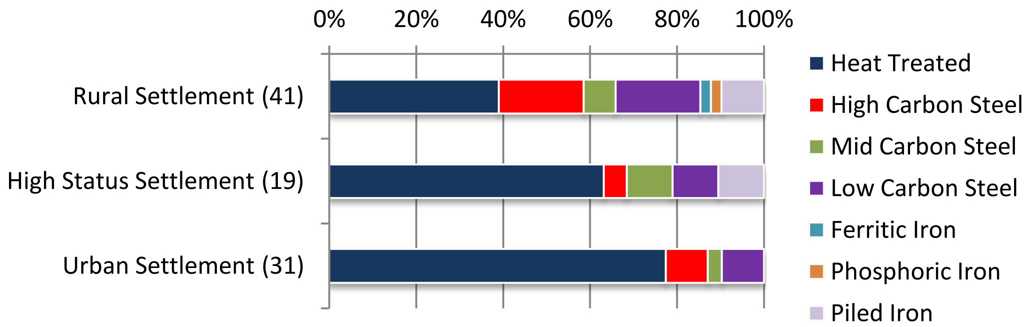


Figure 6.3: Stacked bar chart showing heat-treatments applied and alloys used in the knife cutting edges in the different site types in the middle to late Saxon settlements. The data used in this figure is given in table 2.2 in Volume 2.

The remainder of cutting edges that were not heat-treated, revealed a similar trend. In the urban settlements all of the cutting edges were steel although a small proportion of these (10%) had a low carbon content and could not therefore have been heat-treated. In the rural and high status settlements the higher proportion of type 0 and 3 knives meant that a higher proportion of cutting edges were not steel, and in these cases ferritic, phosphoric or piled iron was used. Occasionally repairs to knives in the rural settlements resulted in phosphoric iron being used as a cutting edge, e.g. knife 278 at Wharram Percy. The amount of steel present in the rural and high status settlements was similar, as was the proportion of knives that could technically be heat-treated.

There are two possible explanations for the lack of heat-treatments in the rural settlements. The first and most likely explanation is that the blades had never been hardened, as suggested by the reduced proportion of heat-treated knives at Burdale and Sedgeford, and the lack of heat-treated blades at Wharram Percy. This indicates that the rural smith, although using a good range of materials, may have lacked the ability to carry out the same range of ironworking techniques used by smiths in urban centres. If this was the case, some if not all the heat-treated knives were being imported into these site. Another possibility is that the knives had reached the end of their lives and were exposed to excessive heat for extended periods to remove the hardness in preparation for recycling, this is supported by the larger number of bent knives seen in rural settlements.

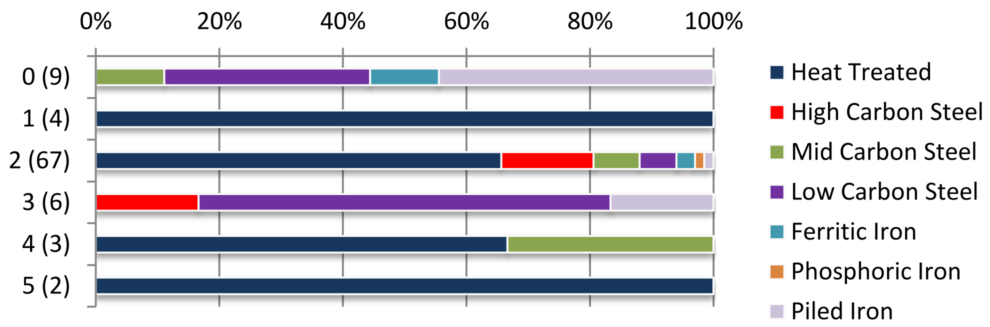


Figure 6.4: Stacked bar chart showing cutting edge heat-treatments and alloys for each knife manufacturing type in the middle to late Saxon settlements. The data used in this figure is in table 2.7 in Volume 2. The manufacturing typology is in the appendix volume on page 38.

At Flixborough, another contemporary rural but high status settlement, the quality and number of heat-treated knives was much higher, being more comparable to the urban sites (Figure 6.3). This is most likely due to the high status of this site, suggesting it had better access to imported goods or to more highly skilled smiths. This may not have always been the case with ecclesiastical sites as the unusual treatments at Whithorn resulted in a high proportion of over-heated, spherioised carbides and extremely small grained microstructure suggested an entirely different and less skilful smithing technique. The microstructures suggested that the iron had been heated many times, but never enough to reach a temperature that would allow the grains to normalise (i.e. not above the austenite temperature of 700°C). The temperature reached would not have been enough to allow the smith to forge the artefact efficiently and the knife would have been heated and re-heated many times, resulting in a loss of carbon content. Very few imported finds at Whithorn suggests that, up to AD845, the settlement was isolated with little contact with other settlements (Hill & Campbell 1997: 47-48). This is supported both by the unusual smithing techniques mentioned above, but also by the manufacturing methods, which appear to be more like those in early Saxon cemeteries than the other middle to late Saxon settlements.

When individual knife types are identified it is clear that all the type 1 knives were heat-treated (Figure 6.4). The majority of type 2, 4 and 5 knives were also heat-treated, and those that were not were found at rural settlement sites. As would be expected, all the type 0 and 3 knives were not heat-treated, and these mostly consisted of piled iron, low carbon steels or phosphoric irons.

Knife Back Alloys

The alloys used to construct the knife backs in urban, rural and high status sites showed some differences. The analysis revealed that phosphoric iron was more frequent in rural sites along with piled iron (Figure 6.5). There was slightly more steel and ferrite available in the high status sites, but even so the majority were piled iron, similar to the rural settlements. The urban settlements had a much higher proportion of ferritic iron, possibly suggesting that ferrite was preferentially chosen for the knife backs and/or was more available.

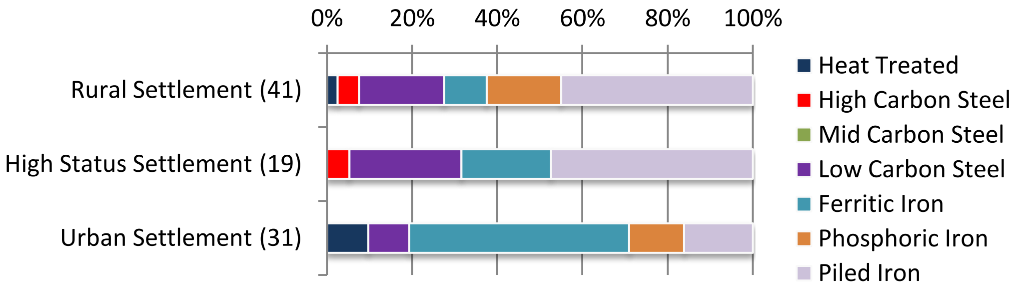


Figure 6.5: Stacked bar chart showing alloys used to construct knife backs in rural, high status and urban middle to late Saxon settlements. The data used in this figure is in table 2.2 in Volume 2.

This may suggest some degree of choice of alloys, especially since pure ferritic iron may have been less common than phosphoric iron which was produced by smelting readily available bog ore (Rubinson 2009: 138). In addition to the increase in phosphoric iron, the high frequency of piled iron backs found in rural settlements may be evidence for recycling of iron alloys.

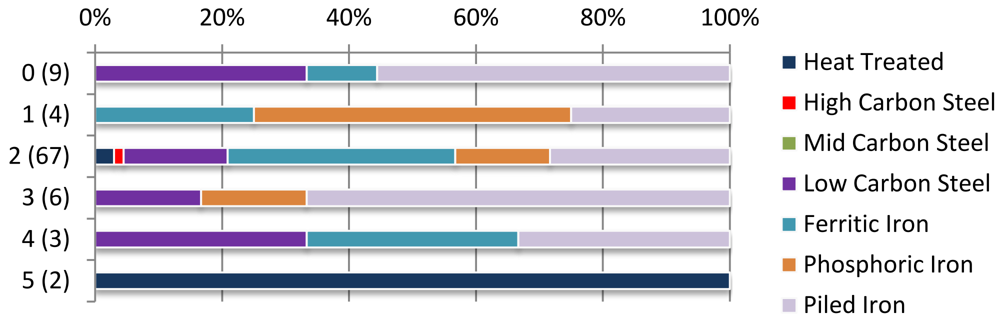


Figure 6.6: Stacked bar chart showing knife back alloys for each knife manufacturing type in the middle to late Saxon settlements. The data used in this figure is in table 2.7 in Volume 2. The manufacturing typology is in the appendix volume on page 38.

Piled iron was seen in nearly all knife types (Figure 6.6), but was more widely used in the rural settlements whereas in the urban settlements piled iron was only seen in the type 2 knives (Table 2.7 in Volume 2). Ferritic iron was primarily used in the better quality type 1, 2 and 4 knives, rather than in the type 0 and 3 knives.

Wear, Recycling and Repair

Most of the knives from Wharram Percy, Burdale and Sedgeford showed some signs of wear and many of those from Wharram Percy were heavily worn. To a certain extent the amount of wear present is related to the iron alloy used, any heat-treatments carried out and what the knife is used for; this will be discussed in chapter 7, section 7. Even so, a higher proportion of knives at the rural sites showed signs of heavy wear than those from Coppergate, York. In the rural settlements nine knives (9%) showed significant wear, and another forty-five showed some wear (46%) whereas only four in seventy-nine, (5%) in Coppergate, York showed sign of significant wear (Ottaway 1987,1992).

At Wharram Percy four knives were clearly repaired while at Burdale two knives showed signs that they had been repaired. On the other hand none of the knives from Sedgeford showed signs of repair. Even so there is a much higher proportion of repairs in the rural settlements than seen at York and Hamwic where only one knife from each site had evidence for repair, perhaps due to the overall good quality. The repairs carried out in the urban settlements used good quality metals and were heat-treated to get the best out of the new cutting edge. On the other hand the repairs in the rural settlements were poor quality. Often low carbon steel or in some cases phosphoric iron was used, in some cases the repairs were so poor it would have been better to continue sharpening the knife rather than repair it (e.g. knife 278 from Wharram Percy).

During excavations in York and Hamwic a few bent knives were recovered, but at Burdale five (13%) of the knives were bent and at Wharram Percy two (12%) knives were found bent. This type of damage could not occur naturally during burial and is unlikely to occur during normal use. Perhaps bending represents ritual destruction prior to discard. More likely, it is additional evidence for recycling at rural sites as bending a knife was possibly a method for determining the properties of the metal and therefore allowing the smith to determine the alloys present.

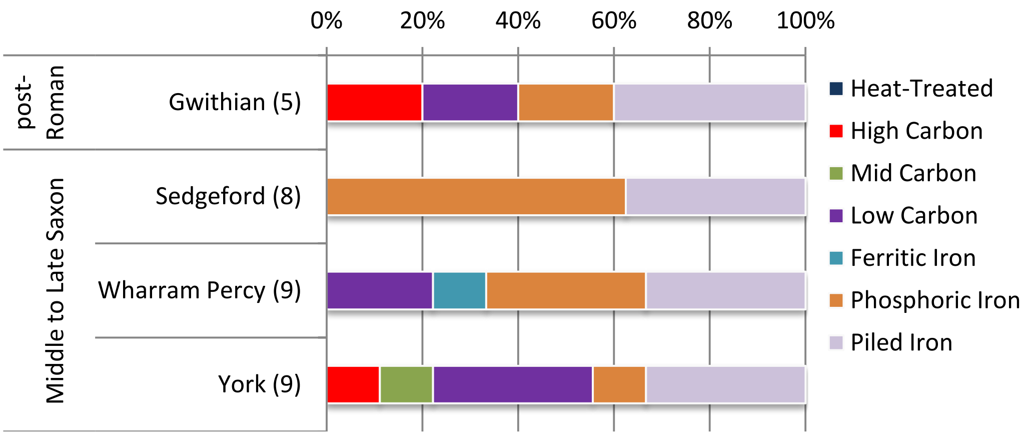


Figure 6.7: Stacked bar chart showing iron alloys present in the stock iron (billets, bars and strips) available in middle Saxon settlements. The data used in this figure is in table 2.13 in Volume 2.

Piled iron constituted over 40% of the rural assemblage. The presence of large quantities of piled iron in rural knives in addition to the frequent poorer quality (type 0 and 3) manufacturing types suggests that at least some of the knives from rural sites were constructed using recycled iron. This is not unexpected at rural sites which may not have had access to the better quality iron alloys available in the urban settlements, and may have needed to conserve iron (Woodward 1985). Metallographic analysis of bars and strips of iron from Wharram Percy showed there were no high-quality high carbon steel bars, such as those found in York (Figure 6.7; McDonnell *et al.* Forthcoming), suggesting that the smithy may not have had easy access to the full range of iron alloys (Blakelock 2009; McDonnell *et al.* Forthcoming). Supported by the fact that the majority of the Wharram Percy and Burdale knives were constructed using piled iron and lower carbon steels, and that some iron alloys were used in unconventional ways, there were a large number of steel cutting edges which had been repaired using either low carbon steels or phosphoric iron.

6.3 Early Saxon Settlements vs Early Saxon Cemeteries

The results above have shown that there are clear similarities between urban, rural and high-status sites in terms of manufacturing methods, but still a marked difference compared to early cemeteries. Therefore the first hypothesis can be rejected. The second hypothesis is that the knives reflect changes through time; from the early period into the middle Saxon period. If there was a change in knife manufacturing techniques through time there will be a marked difference in the manufacturing types of the knives found in early settlements compared to middle-late settlements. If the knives do represent a change in technology through time the range of types of knives in the cemeteries should be similar to those in the contemporary settlements. In addition the assemblages from post-Roman Gwithian will be included and compared in this analysis to determine whether any distinct differences exist in the post-Roman south-west and Anglo-Saxon England. Previously the only early settlement to be examined was post-Roman Poundbury and this revealed a pattern similar to the middle Saxon settlements, although it was a small sample size. Therefore new knives from the early Saxon settlement of West Stow and post-Roman Gwithian were sampled. In addition to these, more cemetery knives were also sampled; including those from the early cemetery at Quarrington and knives from later cemeteries like those at Twyford and Collingbourne Ducis.

To compare early cemeteries and settlements the first task was to analyse the shape of the knife backs, after which the manufacturing methods in the settlement knives were compared to those from the cemeteries. The differences in alloys and heat-treatments at the cutting edge and knife backs were also investigated.

Knife Shape

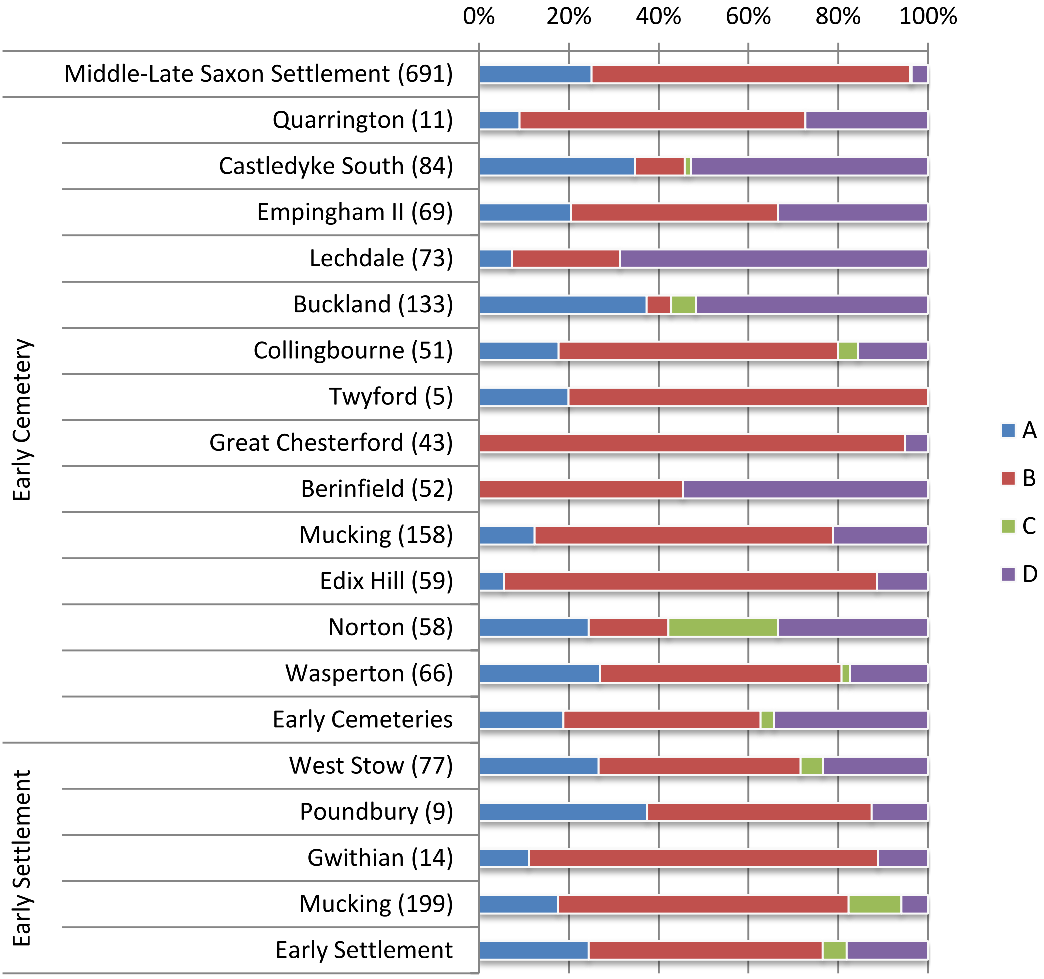


Figure 6.8: Stacked bar chart showing the frequency of different knife shapes in early Saxon cemeteries and settlements, compared to middle to late Saxon settlements. The data used in this figure comes from table 2.1 in Volume 2 (West 1985a,b; Evison 1987; Green et al. 1987; Sherlock & Welch 1992; Clark & Hamerow 1993; Evison 1994; Boyle 1995; Starley 1996; Timby & Bartlett 1996; Boyle 1998; Drinkall et al. 1998; Malim et al. 1998; Carver et al. 2009). The knife shape typology is in the appendix volume on page 38.

Many early cemetery publications often provide a full catalogue of the grave goods present. It was therefore possible to include more assemblages during the comparison of knife shapes and wear. On the other hand very few early Saxon settlements have been published with illustrations of all the knives, and therefore only Mucking was available for comparison. Again the basic typology in the methodology (Figure 4.1) was used during this analysis.

This analysis resulted in a clear difference in knife shape between early cemeteries and middle to late Saxon settlements, as noted before in the previous section (Figure 6.8). There was a much lower proportion of curved backed knives in the cemeteries, with higher numbers of straight and incurved backs. Examination and comparison between the early Saxon cemeteries and settlements, on the other hand, revealed many similarities in knife shape with higher proportions of straight and incurved knives present. The Chi Square test revealed that the knife shapes in the contemporary cemetery and settlement assemblages were not related, perhaps an indicator that some knives were chosen for burial (Chi-square value 10.63, degrees of freedom 3 and probability 0.01). There was a greater statistically significant difference in the later middle to late Saxon settlement knives compared to the early settlement knives (Chi-square value 52.45, degrees of freedom 3 and probability 0.00).

Changes of knife shape through time has been previously suggested by Evison (1987: 113-116) during the analysis of the Buckland, Dover knives. This was based on the grave dates obtained through examination of other grave goods present. Evison's analysis revealed clear differences with the curved-backed knives only occurring in later 7th century graves, with no straight backed knives identified and few angle-backed knives (Evison 1987: 113-116) but this was based on a very small sample size. The above analysis points to a change in shape preference through time, but the author would argue that the use of particular knife shapes to date a knife should be avoided. This research has clearly shown that most knife shapes are present throughout the early medieval period. Even the incurved knife which are rare in middle Saxon settlements, are present in later Anglo-Scandinavian and Viking contexts, e.g. York and Dublin. Instead shape may be more likely related to knife function, and this will be discussed in chapter 7 (Section 4, 7 and 8).

Knife Manufacturing Methods

When construction methods were compared, there was a clear difference between early cemeteries and settlements and the later middle to late Saxon settlements. The knives from the early settlements showed a variety of different construction techniques (Figure 6.9). This is similar to the cemeteries which all revealed a range of different techniques. The Chi-square test confirmed these similarities as when cemetery knives were compared to the middle to late Saxon settlement knives there was a statistical difference (Chi-square value 37.42, degrees of freedom 5 and probability 0.00) but when the early settlements were compared to the cemeteries there was a clear relationship (Chi-square value

6.47, degrees of freedom 5 and probability 0.26). This analysis has therefore shown that there is a clear relationship between early settlement and cemetery knives, and that the change in manufacturing style occurs through time. Analysis also revealed that there were some similarities between the early settlements and the later settlements, although these were not statistically significant in the Chi-square test (Chi-square value 13.87, degrees of freedom 5 and probability 0.02).

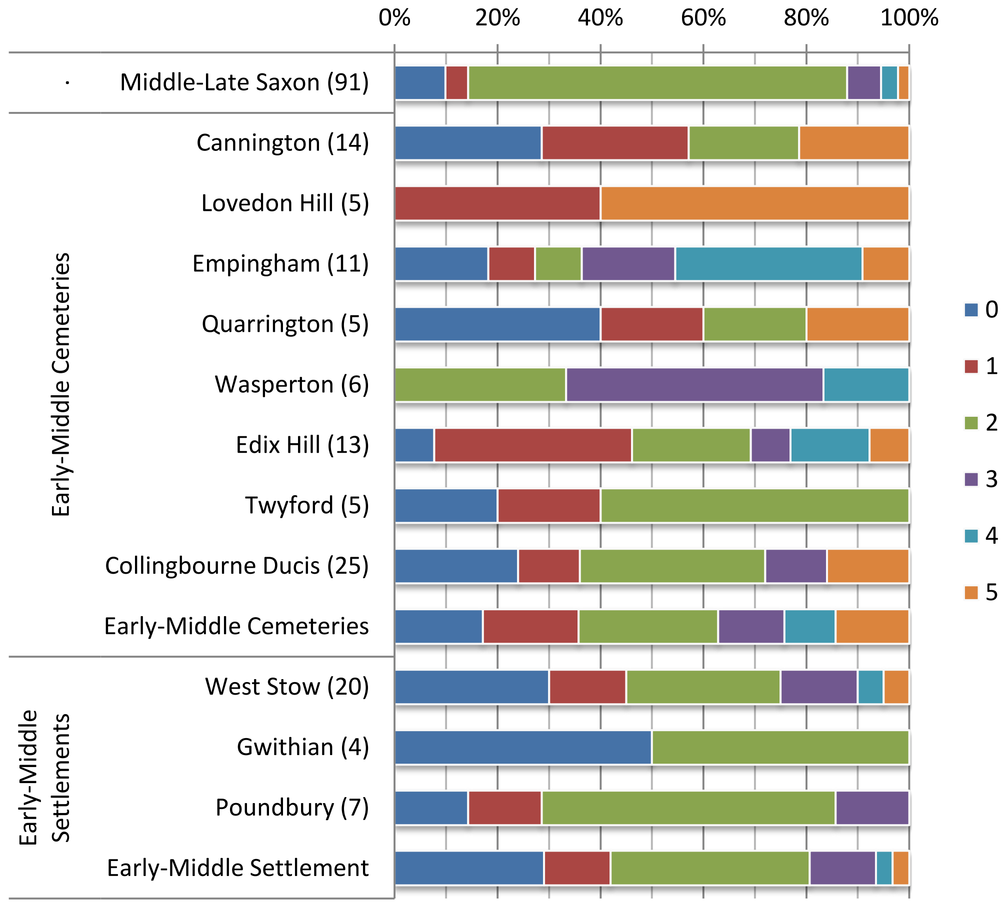


Figure 6.9: Stacked bar chart showing the distribution of knife manufacturing methods in early settlements and cemeteries, compared to middle to late Saxon settlements. The data for this chart is in table 6.2. The manufacturing typology is in the appendix volume on page 38.

There were roughly equal numbers of white weld lines in the early settlements (11 in 31 knives, 35%) as in the later middle to late Saxon settlements (42 in 118 knives, 36%). This was dramatically different from the cemeteries where very few knives had white weld lines (5 in 43, 12%).

Sites		Manufacturing Typology and Cutting Edge Data							Manufacturing Typology and Knife Back Data						
		0	1	2	3	4	5	Overall	0	1	2	3	4	5	Overall
West Stow 5th-7th	Number	6	3	6	3	1	1	20	6	3	6	3	1	1	20
	Avg HV	198	326	401	248	201	549	303	187	241	171	172	117	466	199
	Range HV	137-257	221-453	165-549	175-386	201	549	137-549	148-216	203-282	140-224	159-186	117	466	117-466
Gwithian, Cornwall 5th-7th	Number	2		2				4	2		2				4
	Avg HV	422		232				327	289		261				275
	Range HV	386-457		232				232-457	248-330		251-271				248-330
Poundbury, Dorset 5th-7th	Number	1	1	4	1			7	1	1	4	1			7
	Avg HV	210	245	505	214			384	105	185	171	214			170
	Range HV	210	245	330-615	214			210-615	105	185	160-186	214			105- 214
Early to Middle Settlements	**Number**	**9**	**4**	**12**	**4**	**1**	**1**	**31**	**9**	**4**	**12**	**4**	**1**	**1**	**31**
	Avg HV	**249**	**306**	**408**	**240**	**201**	**549**	**325**	**201**	**227**	**186**	**182**	**117**	**466**	**202**
	Range HV	**137-457**	**221-453**	**165-615**	**175-386**	**201**	**549**	**137-615**	**105-330**	**185-282**	**140-271**	**159-214**	**117**	**466**	**105-466**
Cannington 4th-6th	Number	4	4	3			3	14	4	4	3			3	14
	Avg HV	145	260	866			218	348	150	208	208			248	200
	Range HV	130-171	182-400	672-1000			194-257	148-1000	130-180	174-238	178-260			199-274	130-274
Lovedon Hill 5th-7th	Number		2				3	5		2				3	5
	Avg HV		442				218	308		186				207	199
	Range HV		160-724				116-299	116-724		156-215				104-302	104-302
Empingham 5th-7th	Number	2	1	1	2	4	1	11	2	1	1	2	4	1	11
	Avg HV	195	213	258	189	592	475	371	192	213	197	198	191	267	202
	Range HV	182-208	213	258	181-196	433-775	475	181-775	176-208	213	197	166-230	154-214	267	154-267
Quarrington 5th-7th	Number	2	1	1			1	5	2	1	1			1	5
	Avg HV	165	549	271			183	266.6	168	215	171			181	181
	Range HV	154-175	549	271			183	154-549	164-172	215	171			181	164-215
Wasperton 5th-7th	Number			2	3	1		6			2	3	1		6
	Avg HV			420	210	445		319.1667			170	189	282		198
	Range HV			238-602	144-285	445		144-602			162-178	156-216	282		156-282
Edix Hill 6th-7th	Number	1	5	3	1	2	1	13	1	5	3	1	2	1	13
	Avg HV	144	302	649		388		337	144	155	242		150		150
	Range HV	144	100-586	312-824		388		100-824	144	155	168-316		150		144-316
Twyford 6th-7th	Number	1	1	3				5	1	1	3				5
	Avg HV	143	168	531				381	177	159	179				175
	Range HV	143	168	441-644				143-644	177	159	159-216				159-216
Collingbourne Ducis 6th-7th	Number	6	3	9	3		4	25	6	3	9	3		4	25
	Avg HV	193	337	535	309		376	377	172	248	165	235		333	212
	Range HV	132-303	161-593	303-841	143-593		286-593	132-593	131-216	149-379	124-210	148-331		234-480	131-379
Early to Middle Cemeteries	**Number**	**16**	**17**	**22**	**9**	**7**	**13**	**84**	**16**	**17**	**22**	**9**	**7**	**13**	**84**
	Avg HV	**172**	**316**	**560**	**215**	**513**	**267**	**350**	**167**	**195**	**185**	**185**	**192**	**242**	**193**
	Range HV	**130-303**	**100-724**	**238-1000**	**143-593**	**388-775**	**116-593**	**100-1000**	**130-216**	**149-379**	**124-316**	**148-331**	**150-282**	**104-480**	**124-480**
Middle to Late Saxon Settlements	**Number**	**9**	**4**	**67**	**6**	**3**	**2**	**91**	**9**	**4**	**67**	**6**	**3**	**2**	**91**
	Avg HV	**184**	**581**	**445**	**211**	**446**	**558**	**412**	**183**	**179**	**179**	**187**	**172**	**473**	**186**
	Range HV	**123-268**	**476-766**	**121-847**	**137-314**	**309-549**	**509-607**	**121-847**	**138-242**	**153-707**	**101-707**	**148-294**	**89-233**	**339-607**	**89-707**

Table 6.2: Table showing the number, average hardness and hardness range for the cutting edge and knife backs of knives from Early cemeteries and settlements, and the total for middle to late Saxon settlements. Data from this thesis except Poundbury (Tylecote 1987), Cannington (McDonnell 1989b), Lovedon Hill (McDonnell 1989c), Empingham (Timby & Bartlett 1996), Wasperton (Starley 2009b) and Edix Hill (Gilmour & Salter 1998).

Cutting Edge Heat-treatment and Alloys

There were fewer heat-treatments in the early knives compared to the middle to late Saxon knives. This was particularly clear when comparing the two sets of settlement knives (33% compared to 58%; Figure 6.10). The analysis did reveal that the cemetery knives were more often heat-treated than the early medieval settlement knives, which can be clearly seen figure 6.10. But if all those early knives that had high-carbon steel cutting edges were heat-treated there would have been roughly equal proportions of heat-treatments in the two graphs. This suggests that the knives in the cemeteries were better made, with more heat-treatments and better quality steel, and so were most likely constructed by more skilled blacksmiths.

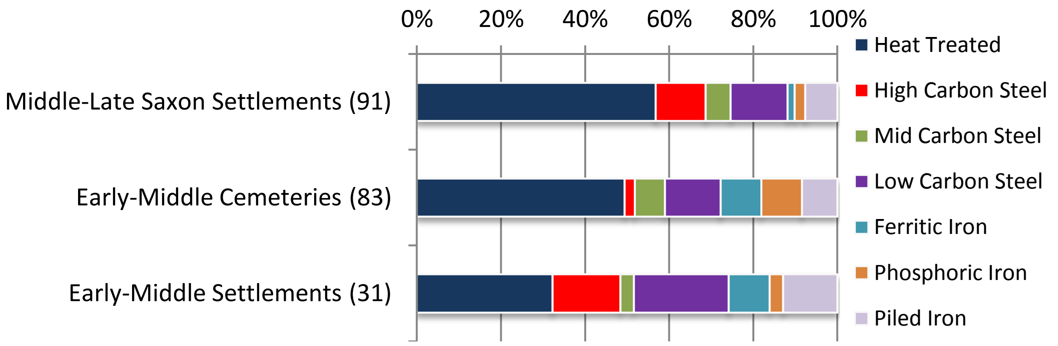


Figure 6.10: Stacked bar chart showing alloys used to construct knife cutting edges in the early cemetery knives, compared to middle to late Saxon or early settlements. The data used in this figure is in table 2.3 in Volume 2.

The remaining alloys were very similar between the early settlements and cemeteries with ferritic, phosphoric and piled iron making up 25%-30% of cutting edges (Figure 6.10). Phosphoric iron seems to have been less common in the early settlements, with a similar frequency to the middle to late Saxon settlements. However, this may just represent a bias due to the relatively small sample size. There was also a higher proportion of low carbon steel in the early settlements.

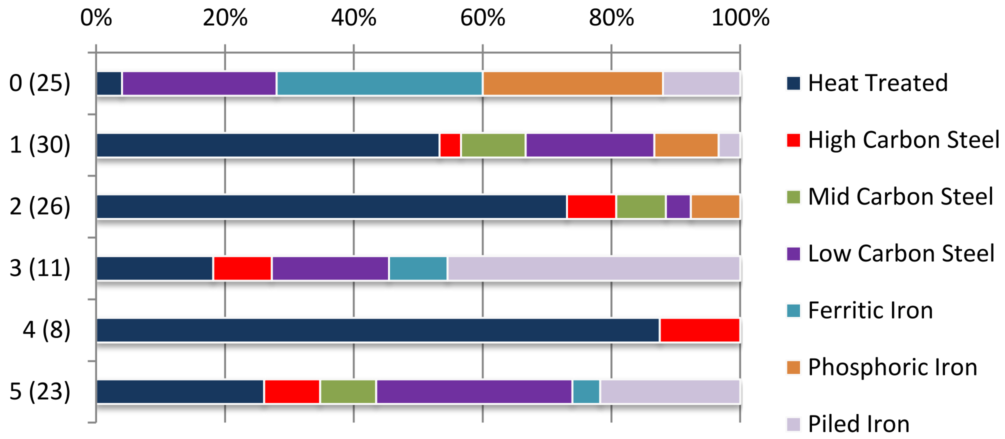


Figure 6.11: Stacked bar chart showing knife cutting edge alloys for each knife manufacturing type in the early settlements. The data used in this figure is in table 2.7 in Volume 2. The manufacturing typology is in the appendix volume on page 38.

When individual knife manufacturing types are considered it is clear that the majority of heat-treatments carried out in the early period are on the better quality knives, type 1, 2 and 4 (Figure 6.11). Even some of the knives with heterogeneous or piled iron were occasionally heat-treated in this period, particularly in the cemeteries (Table 2.7 in Volume 2).

Knife Back Alloys

The alloys used to construct the knife backs were similar in the early and the middle to late Saxon settlements (Figure 6.12). The cemetery knives had fewer examples of ferritic and piled iron than the settlements but the cemeteries had slightly more low carbon steel.

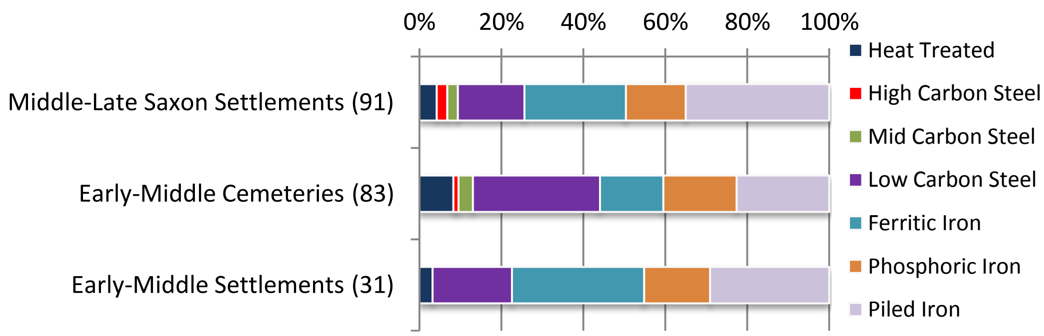


Figure 6.12: Stacked bar chart showing alloys used to construct knife backs in the early Saxon cemetery knives, compared to middle to late Saxon or early Saxon settlements. The data used in this figure is in table 2.3 in Volume 2.

As in the middle to late Saxon period, piled iron was commonly used in the early period for many of the manufacturing methods. The exception was the type 4 knives, where mainly phosphoric or ferritic iron was used (Figure 6.13).

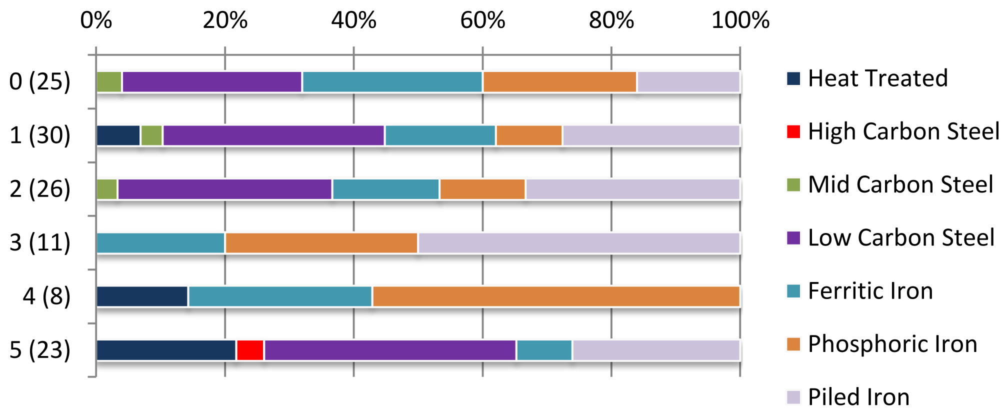


Figure 6.13: Stacked bar chart showing knife back alloys for each knife manufacturing type in the early settlements. The data used in this figure is in table 2.7 in Volume 2. The manufacturing typology is in the appendix volume on page 38.

Wear, Recycling and Repair

As many of the cemetery knives were illustrated, it was possible to analyse the amount of wear on them, but this was only possible for the few early settlement knives that were illustrated in the published excavation reports (Figure 6.14). The wear in the early and middle to late settlements was very similar (Figure 6.14). In the cemeteries there were similar proportions of knives with no wear, but the highest proportion of the knives were suffering from slight wear and the distinctive s-curved shape. There were very few cemetery knives with heavy wear.

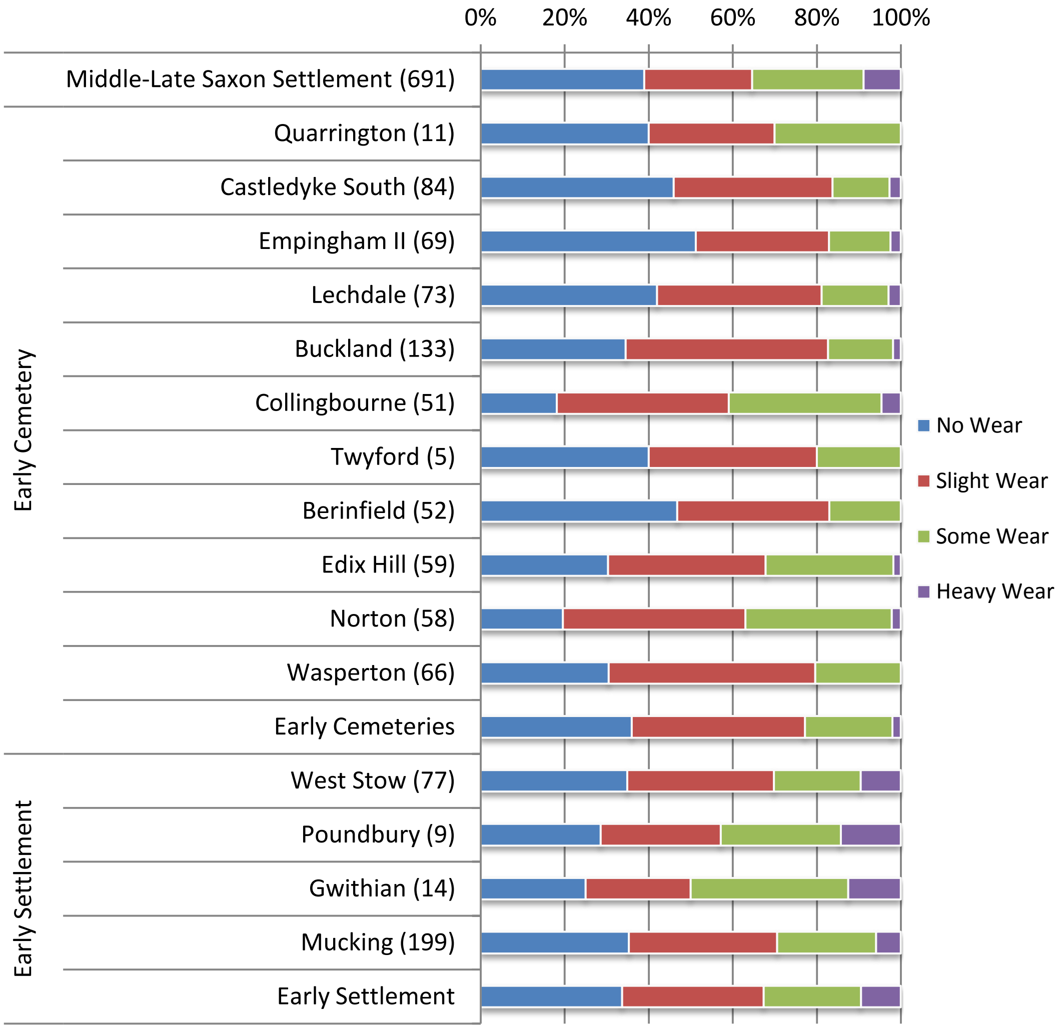


Figure 6.14: Stacked bar chart showing the distribution of wear in early cemeteries and settlements compared to those from middle to late Saxon settlements. The data is available in table 2.1 in Volume 2.

This analysis has shown that less piled iron was used in the early period settlements than the middle to late settlements, with even smaller quantities in the cemeteries. This, in addition to larger quantities of low carbon steel, suggests that cemetery knives were made out of better quality iron. The analysis of the early knives revealed very few repairs; this is probably due to the range of types seen. Repairs were generally only carried out on type 2 knives in the middle to late Saxon settlements and the absence of good quality type 2s in the early Saxon cemeteries and settlements most likely explains the absence of repairs.

Changes in the 7^{th} Century

The above analysis has shown that a change in manufacturing methods occurred sometime between the early Saxon period and the middle Saxon period. The move to standardised knives throughout the country in this period suggests significant changes in technology and organisation of blacksmiths. It is very rare to be able to associate changes in technology with a specific date or even period, especially when many sites span multiple centuries and have many poorly-stratified insecure contexts. An exception to this pattern are early Saxon graves, as some can be dated to specific centuries based on the grave goods present, or via associated evidence e.g. radiocarbon dating (Lucy 2000: 16-64; Lucy & Reynolds 2002b).

To determine a specific time frame for these manufacturing changes in knives graves that have been securely dated to the 7^{th} century were separated from the other early Saxon cemetery knives. Both sets of data were then re-analysed to see if a distinct change could be observed. Because it is very difficult to precisely date artefacts in early medieval settlements and cemeteries, it is not always possible to identify all 7^{th} century knives so there may be some later knives within the early Saxon contexts group identified here.

The most striking difference is that the vast majority of the 7^{th} century knives from cemeteries were type 2s (Figure 6.15) though overall there was a wide range of types in the early cemeteries. The distribution of types in the 7^{th} century knives from cemeteries was very similar to the middle Saxon settlements, and when the Chi-square test was applied it showed that there was a statistically significant relationship (Chi-square value 1.07, degrees of freedom 5 and probability 0.96). The Chi-square test was applied again to ensure that there was a statistical difference in the manufacturing types of knives in the early cemetery knives compared to the 7^{th} century cemetery knives; this resulted in a clear difference (Chi-square value 17.97, degrees of freedom 5 and probability 0.0). Therefore it can be argued that there was a dramatic change in manufacturing methods in the 7^{th} century.

Sites		Manufacturing Typology and Cutting Edge Data							Manufacturing Typology and Knife Back Data						
		0	**1**	**2**	**3**	**4**	**5**	**Overall**	**0**	**1**	**2**	**3**	**4**	**5**	**Overall**
Early-Middle Settlements	Number	9	4	12	4	1	1	**31**	9	4	12	4	1	1	**31**
	Avg HV	249	306	408	240	201	549	**325**	201	227	186	182	117	466	**202**
	Range HV	137-457	221-453	165-615	175-386	201	549	**137-615**	105-330	185-282	140-271	159-214	117	466	**105-466**
Early Cemeteries	Number	15	16	13	8	7	13	**72**	15	16	13	8	7	13	**72**
	Avg HV	209	312	500	209	513	252	**322**	201	181	206	159	192	221	**196**
	Range HV	130-303	100-724	238-1000	144-593	388-775	116-593	**100-1000**	130-216	149-379	124-316	156-331	150-282	104-480	**124-480**
7th Century Middle Saxon Cemeteries	Number	1	1	9	1			**12**	1	1	9	1			**12**
	Avg HV	154	593	597	143			**522**	168	217	178	148			**178**
	Range HV	154	593	303-1000	143			**143-1000**	168	217	129-260	148			**129-260**
Middle to Late Saxon Settlements	Number	14	11	76	9	3	4	**117**	14	11	76	9	3	4	**117**
	Avg HV	171	593	442	184	446	422	**403**	173	191	181	176	172	387	**188**
	Range HV	123-268	264-841	121-847	110-314	309-549	183-607	**121-847**	130-242	121-329	101-707	121-294	89-233	183-607	**89-707**

Table 6.3: Table showing the number, average hardness and hardness range for the cutting edge and knife backs of knives from early cemeteries and settlements, and the total for middle to late Saxon settlements.

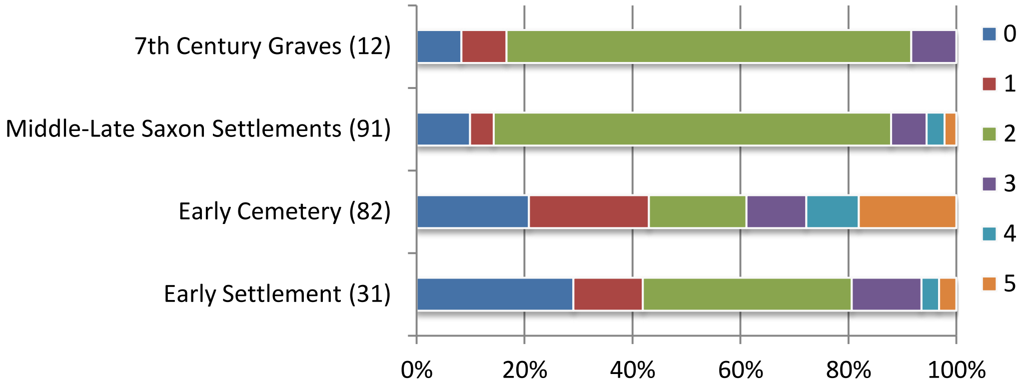


Figure 6.15: Stacked bar chart showing the distribution of knife manufacturing methods in the 7th century graves compared to early Saxon cemeteries and settlements, and middle to late Saxon settlements. The data is available in table 6.3. The manufacturing typology is in the appendix volume on page 38.

After excluding the 7th century knives from the analysis it is clear there are still some differences between the early cemeteries and settlements; for example in the settlements there now appears to be a higher proportion of type 0 and 2 knives. Comparison, using the Chi-square test was made between the early cemetery knives (excluding the 7th century knives) and the contemporary settlement knives which revealed a poorer relationship although it is still statistically significant (Chi-square value 10.15, degrees of freedom 5 and probability 0.07) when compared to the result when 7th century knives were included (probability 0.26). The analysis of the cutting edge heat-treatments and alloys (Figure 6.16) revealed that there were still more heat-treatments carried out on the cemetery knives than on the knives from settlements but generally the alloys used remained similar.

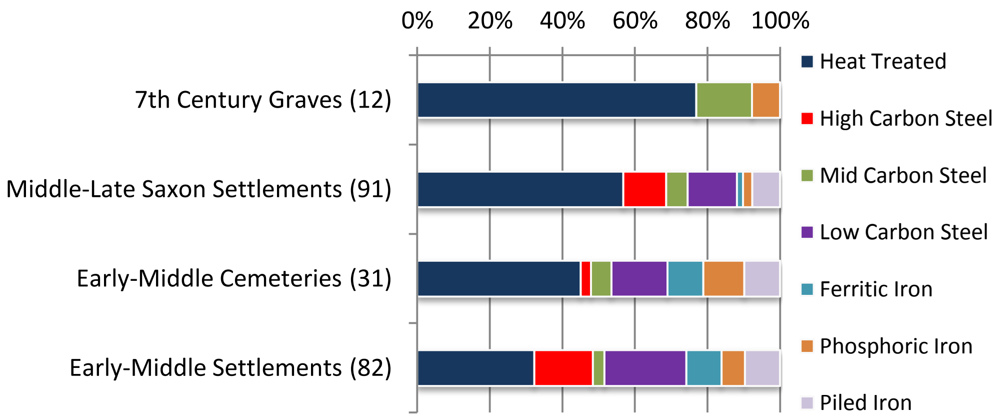


Figure 6.16: Stacked bar chart showing the distribution of iron alloys and heat-treatments used in the cutting edges of 7th Century graves compared to early Saxon cemeteries and settlements, and middle to late Saxon settlements. The data is available in table 2.3 in Volume 2.

There is also a difference when 7th century cemetery knives are compared with those from middle to late Saxon settlements. Unlike in early cemeteries, there were more heat-treatments in the middle Saxon cemetery knives, although this may be skewed by the relatively smaller number of knives. The quality of the steels in the knife backs in the cemeteries seems to increase in the 7th century with a higher proportion of low carbon steel being used (Figure 6.17), but this again may be affected by the small number of 7th century knives.

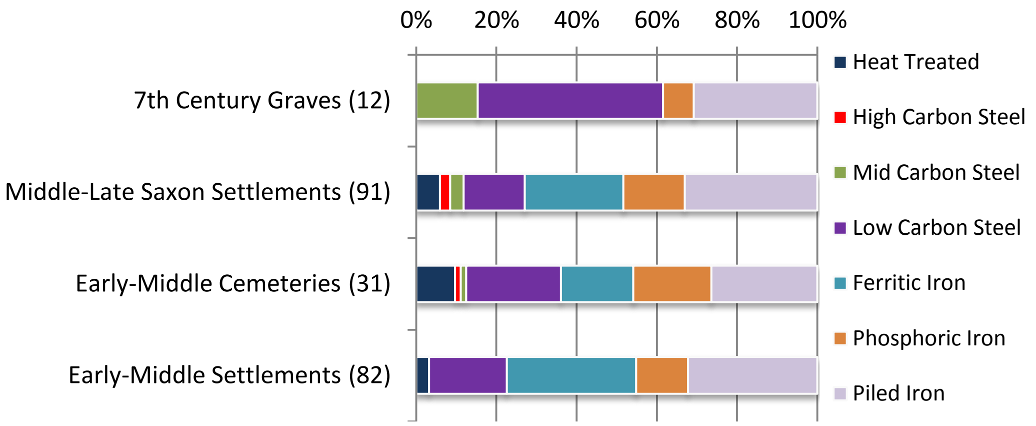


Figure 6.17: Stacked bar chart showing the distribution of iron alloys and heat-treatments used in the knife backs of 7th Century graves compared to early Saxon cemeteries and settlements, and middle to late Saxon settlements. The data is available in table 2.3 in Volume 2.

During the 7th century trading and industrial urban settlements were starting to re-appear, e.g. Ipswich and Lundenwic (Hodges 1982: 69-71; Zaluckyj *et al.* 2001: 193; Hinton 2005: 75-77), possibly around the same time as there were changes in knife manufacture. The sudden standardisation of knives could have been influenced by the specialised blacksmiths present in these urban settlements. These new settlements were mainly ports which would also have allowed new ideas, innovations and technologies to diffuse into the country, and perhaps develop in these settlements. As seen in the previous section, standardisation was not limited to the urban settlements but it is also seen in rural and high status settlements suggesting that if these urban settlements started the process of change, it had a huge effect country-wide.

The 7th century was also a time of change in status and control. Kingdoms began to emerge and with them came organisation and control of the landscape. The landscape was split into hundreds with enough resources, e.g. water, woodland etc, and land to support 100 families; these would eventually turn into planned rural parishes (Reynolds 1999: 69; Reynolds 2003). This new system of landscape control can be inferred as having had an impact on the iron industry as large scale specialist smelting sites developed, e.g. Ramsbury and Romsey (Haslam *et al.* 1980; McDonnell 1988). Access to certain iron alloys may have been restricted, which could explain the presence of high quality, high carbon steel in the urban settlements in contrast to the more frequent piled iron in the rural settlements.

6.4 Cemeteries Analysis

The previous analysis of knives from early Saxon settlements compared to those from cemeteries revealed some differences, although not as clear. Therefore analysis of knives within cemeteries was carried out and is discussed in this section. This analysis compared the knives against the deceased individual's age, sex and relative status, based on the number of grave goods in the grave (RAIC score). This analysis does not include the knives from the 7th century as these have been shown to be different from the earlier cemetery knives, with higher proportions of type 2 knives; in addition this group is too small to analyse on its own right.

The generally accepted opinion is that grave goods are items that belonged to the individual buried, or items that the bereaved believed should be associated with them after death (Lucy 2000: 83-95; King 2004). It is therefore likely that knives in burials are those that were used in life by the individual buried. If this is the case it would be expected that the wear seen in the knives would increase as the age of the deceased increases. It might also be expected that the quality of the knife would reflect the individual's status.

There are other theories to consider, such as the possibility that knives were created for burial. The wear patterns seen in the cemetery knives suggests it is unlikely that all knives were constructed to go in the grave, but if some knives were made for burial it might be possible to identify two distinct patterns within the assemblage. The 'made for burial' knives would be cheap, possibly token knives, which may not have had a functional purpose but were there to represent the knife needed in the afterlife. Another possibility is that knives were made to reflect the status of the individual, with some knives clearly better quality than others. In some cases knives may have been made specifically to order using unusual manufacturing techniques.

Another possibility to consider is that poorer family groups may have felt it was necessary to keep the knife from the grave, particularly if the knife was of good quality, with a good cutting edge. In these cases either the knife was not placed in the grave or a cheaper substitute may have been placed in the grave, possibly made of recycled piled iron. Alternatively a knife constructed of another material, possibly even organic, may have been substituted. This would unfortunately leave no trace and it is difficult to find evidence to suggest that this practice may have taken place. It is also possible that some individuals may not have owned their own knives.

Knife Manufacturing Methods

When the manufacturing methods are examined and compared to the sex of the individual buried it was clear that there was a fairly even distribution of types present in female graves (Figure 6.18). The males on the other hand had a higher proportion of type 1, 2 and 5 knives. These are all knives that would have had the potential of high quality steel cutting edges and therefore indicative of knives used for craft activities; this applies particularly to type 2 knives.

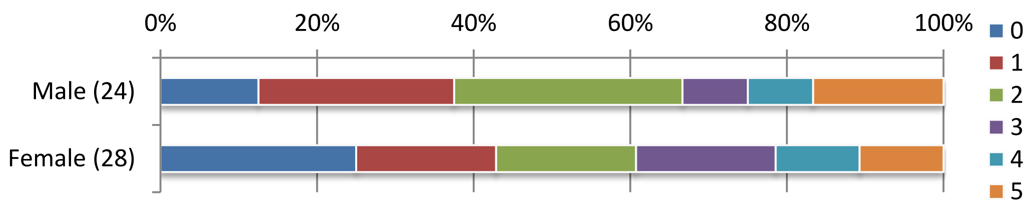


Figure 6.18: Stacked bar chart showing the distribution of different knife manufacturing types in female and male graves. The data is available in table 2.10 in Volume 2. The manufacturing typology is in the appendix volume on page 38.

When these knives are then separated into age groups, and the knives from the under 15 un-sexed graves were included, several patterns can be seen (Figure 6.19). The most noticeable was that all steel type 5 knives were only deposited with individuals over 20 years of age, and mostly between the ages of 20-40. The type 1 knife was also restricted to those over 20 years of age. The cheaper knives, e.g. type 0 plain iron knives, were more often found in the under 15s graves, although the small sample size biases this result.

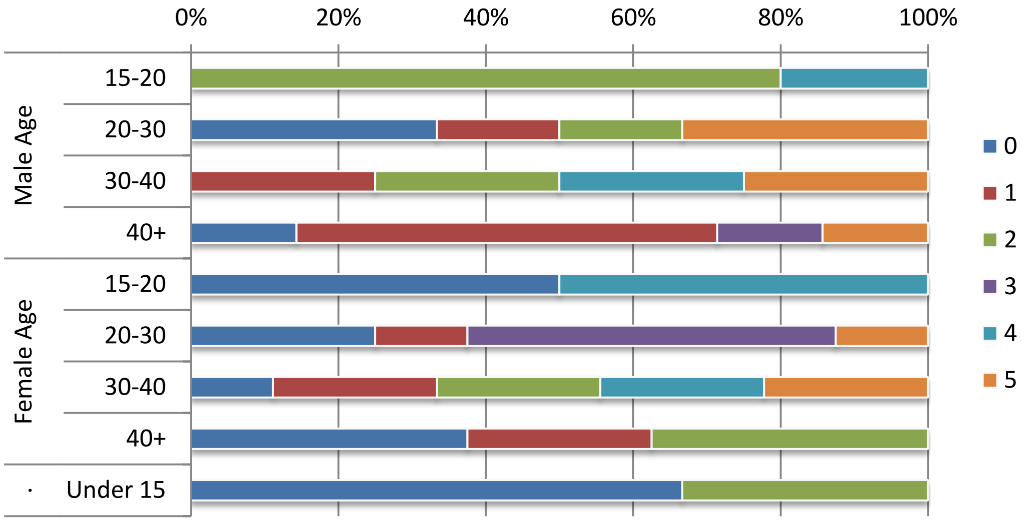


Figure 6.19: Stacked bar chart showing the knife manufacturing methods distribution according to sex and age. The data is available in table 2.10 in Volume 2. The manufacturing typology is in the appendix volume on page 38.

Males between 15 to 20 years of age often had type 2 knives, associated with craft workers (Figure 6.19), whereas women only seemed to have type 2 knives after the age of 30. This pattern was repeated when the status of individuals was examined. The majority of lower status male graves had type 2 knives. In women's graves type 2 knives formed a high proportion of the knives found in middle status graves but not in lower status women graves (Figure 6.20. Unsurprisingly the number of better quality knives, type 4 and 5, increased as the status of the individual increased. The absence of type 0 knives in the lower status male burials, and the presence of piled iron type 3 knives in the higher status female graves, suggest that knives may not always represent the status of the individual, though perhaps this is an example of richer families passing on their good quality knives as an inheritance, while a cheaper knife is included in the grave.

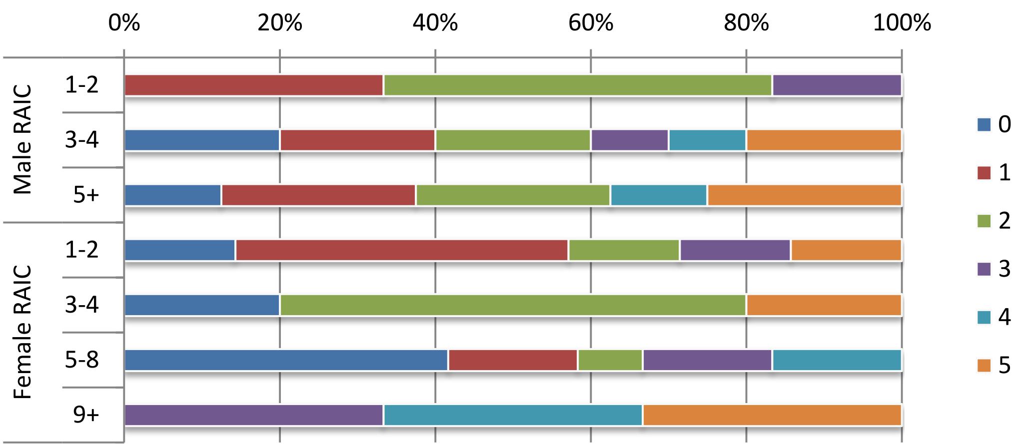


Figure 6.20: Stacked bar chart showing the knife manufacturing methods distribution according to sex and the number of other grave goods. Note that females often have more grave goods than males and therefore another range was added. The data is available in table 2.10 in Volume 2. The manufacturing typology is in the appendix volume on page 38.

Two cemetery knives (Edix Hill 547.1 and Collingbourne Ducis 123) were most likely created specifically for burial as they were constructed using the sandwich weld manufacturing technique (type 1) but both used the opposite to expected iron alloys (a phosphoric iron cutting edge but a steel sheath). These knives would technically have been usable but would have worn quickly and are therefore not practical to use, as they had low hardness cutting edges. Instead it is more likely that they were intended to be decorative. Polishing and etching of these knives would have resulted in a unique appearance, with a darker back and a shiny white cutting edge. These were both found associated with women between the ages of 25 to 40 years. Surprisingly though, they were not with high status individuals; instead one was the only grave good (RAIC 1) in the grave while the other grave had a range of artefacts including the knife (RAIC 5).

Cutting Edge Heat-treatment and Alloys

When the cutting edges of the knives in male and female graves are compared it becomes clear that many of the knives in male graves were heat-treated to make them harder (Figure 6.21). In addition steel occurs more often in the knives present in male graves than in the knives that are associated with females. The cutting edges in the knives in female graves were mostly piled or phosphoric iron.

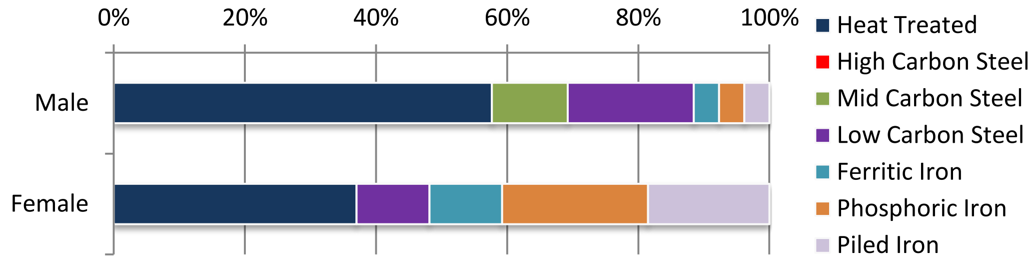


Figure 6.21: Stacked bar chart showing the distribution of different heat treatments and alloys used in the cutting edges of female and male graves. The data is available in table 2.4 in Volume 2.

When age is considered it is clear that the knives in graves belonging to the under 15s or over 50s were least likely to be heat-treated (Figure 6.22). This most likely relates to the high number of poorer quality plain type 0 knives in both of these are groups. The highest proportion of heat-treated knives occurred with males between 15 and 40, and in graves of females over the age of 30. This pattern also corresponds tightly with the type 2 and 1 knives.

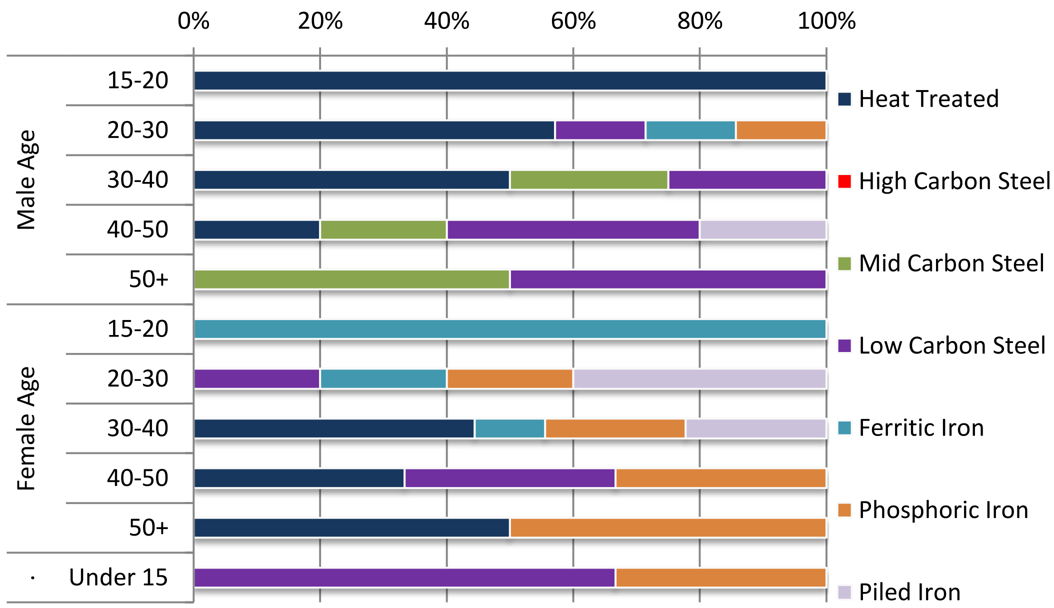


Figure 6.22: Stacked bar chart showing the distribution of different heat treatments and alloys used in the cutting edges according to sex and age. The data is available in table 2.4 in Volume 2.

When status is used to compare the knives, it becomes clear that proportion of heat-treatments in knives in male graves remained similar even as the status of the male increased (Figure 6.23). On the other hand the number of heat-treated knives in female graves varied greatly, although the majority occured in the highest status graves. The remainder of the knives found in male graves were mostly mid to low carbon steels, although piled and phosphoric iron was found at the cutting edge of some higher status knives. The amount of piled iron used in the knives in the cutting edge also increased as the female status increased.

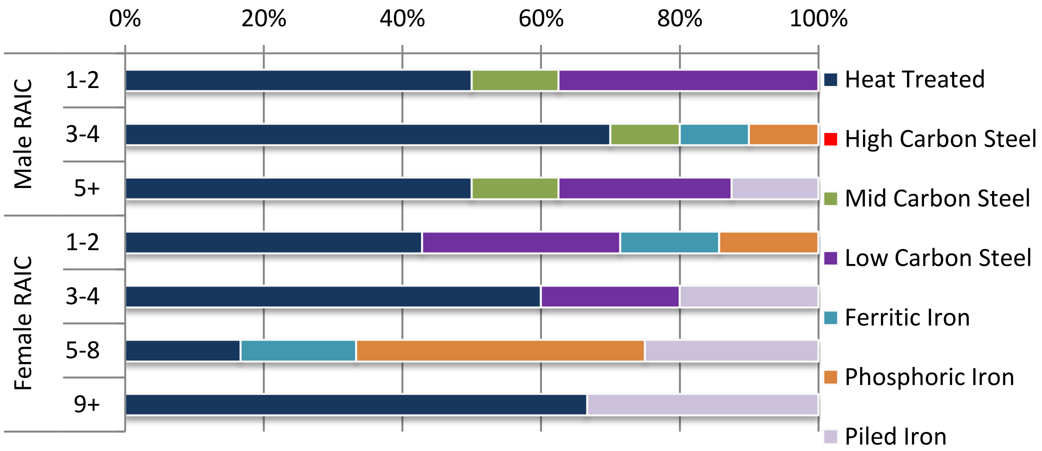


Figure 6.23: Stacked bar chart showing the distribution of different heat treatments and alloys used in the cutting edges according to sex and the number of other grave goods. Note that females often have more grave goods than males and therefore another range was added. The data is available in table 2.4 in Volume 2.

Knife Back Alloys

The distribution of iron alloys in the knife backs was similar in male and female grave knives (Figure 6.24). The only exception was the presence of mid carbon steel in the knives found in female graves which was absent from male grave knives.

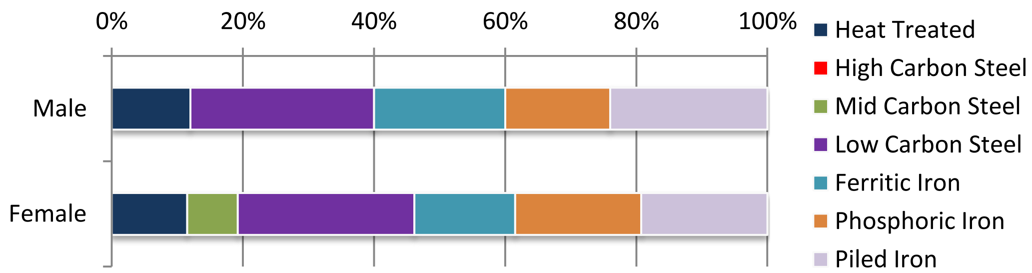


Figure 6.24: Stacked bar chart showing the distribution of different heat treatments and alloys used in the knife backs of female and male graves. The data is available in table 2.4 in Volume 2.

There do not appear to be any clear differences in the iron alloy used in the knife backs when compared with age at death (Figure 6.25). There was some evidence to suggest that the frequency of piled iron backs increased as the age of the individual increased, with ferrite more often associated with younger individuals. The iron used to create the knife backs in the knives belonging to the under 15s was predominately low carbon steel or piled iron. There seemed to be no particular pattern to the use of phosphoric iron.

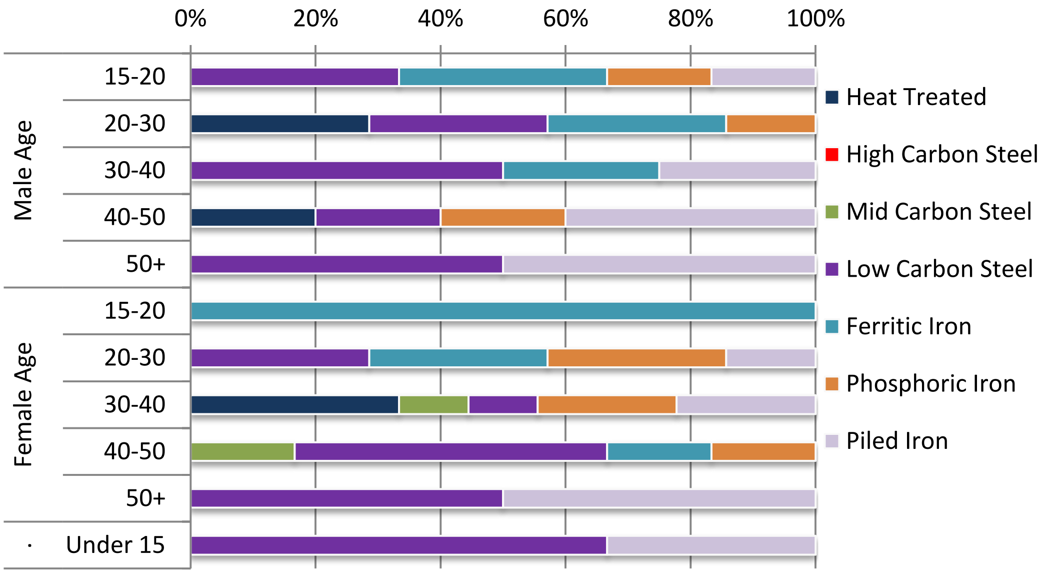


Figure 6.25: Stacked bar chart showing the distribution of different heat treatments and alloys used in the knife backs according to sex and age. The data is available in table 2.4 in Volume 2.

As before, the proportion of knives with piled iron backs appears to decrease as the status of the males increase (Figure 6.26). This, surprisingly, is completely opposite to the female knives, where more piled iron is seen in the knife backs of the high status individuals, although the number of heat-treated and steel backs also increases. In the higher status male knives the majority of backs consist of ferritic iron.

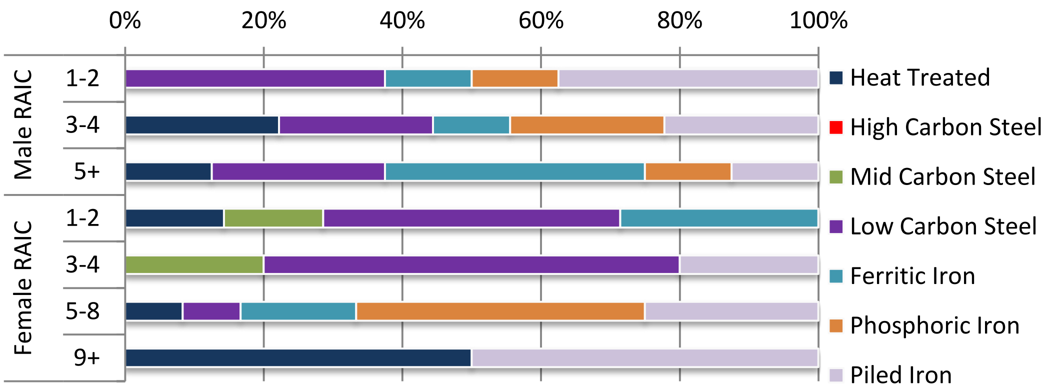


Figure 6.26: Stacked bar chart showing the distribution of different heat treatments and alloys used in the knife backs according to sex and the number of other grave goods. Note that females often have more grave goods than males and therefore another range was added. The data is available in table 2.4 in Volume 2.

Knife use and wear

If all the knives placed in graves were those used in life, you would expect to see a distribution of wear patterns, with the knives associated with the oldest individuals being more worn than those with the youngest. This pattern would not take into account the occasional inheritance of artefacts which has clearly been shown to occur in this period (Huggett 1988; King 2004), so there may be some exceptions to this pattern. Examination of a small sample of knives from cemeteries, i.e. those analysed during this study, has shown that no clear relation between wear and age exists (Figure 6.27). Instead the amount of wear is fairly similar for all age groups, and therefore suggests that some knives were hardly ever used, while others were used extensively.

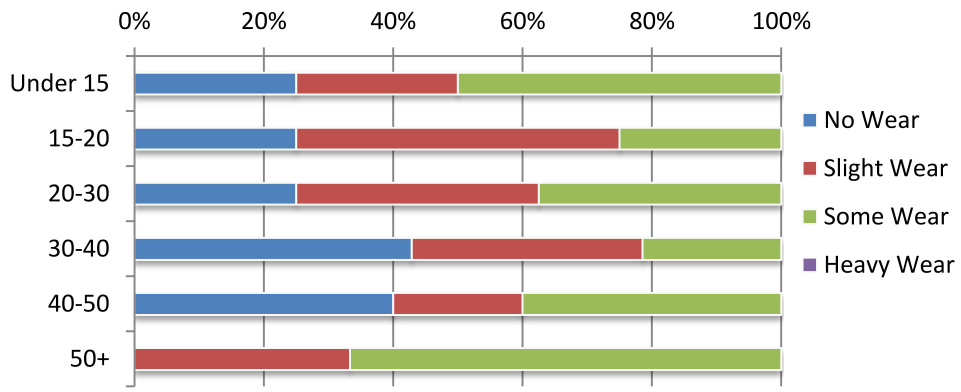


Figure 6.27: Stacked bar chart showing the distribution of wear on each knife by age. Graves with individuals of unknown age are not included. The data is available in table 2.11 in Volume 2.

If one assumes only the wealthy could afford to create a knife for burial, one might expect that individuals of higher status would have knives showing little wear. This was supported by the relatively large number of higher status graves with knives showing no evidence for wear (8 out of 19), whereas fewer knives with no wear were placed in poorer graves (4 out of 19). In addition, poorer individuals might use their knives for longer before allowing them to be deposited in the grave, resulting in an increase in wear as the status of the individual decreases. This trend was apparent in the knives from male graves, with the only heavily worn knife belonging to a low status male and half of the knives from high status graves showing no trace of wear (Figure 6.28). There was no similar trend in the knives from female graves.

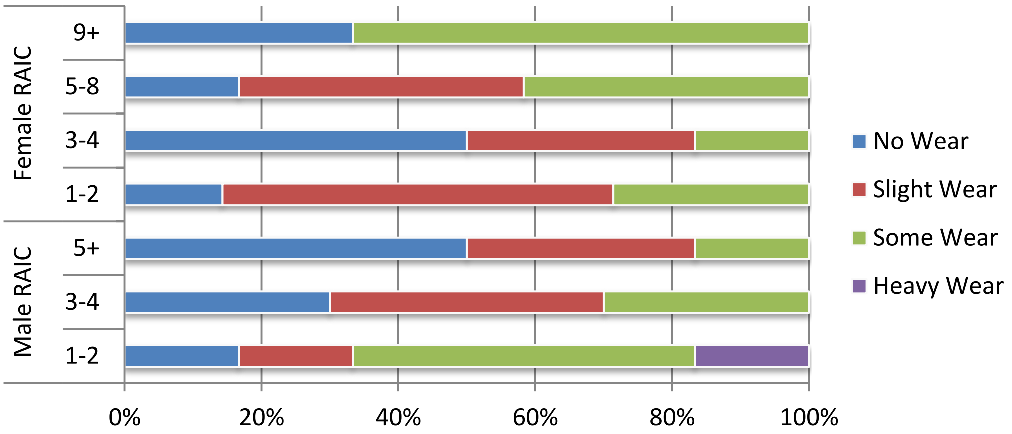


Figure 6.28: Stacked bar chart showing the distribution of wear on each knife according to sex and the number of other grave goods. Note that females often have more grave goods than males and therefore another range was added. The data is available in table 2.11 in Volume 2.

Knives in the Ritual of Burial

Several knives from graves show spheriodisation and other microstructures suggesting that they had been heated for extended periods. Spheroidisation occurs if the metal is heated to *c*700˚C and kept at this temperature for 8 to 32 hours (Samuels 1999: 117). This results in a very soft cutting edge which would have been prone to extensive wear. There are two theories that may explain these microstructures. The first is that they were the result of house fires or similar accidents (Rogers 1993: 1303) and the second theory is that the knives were ritually 'killed' (Lucy 2000: 95).

To investigate whether a house fire could result in this microstructure, iron from the reconstructed West Stow house which was burnt down recently was examined. While the outside of the iron objects analysed showed some evidence for burning, i.e. oxidised surfaces, the microstructural analysis revealed only some decarburisation at the surface. There was no spheriodisation or other microstructures so they cannot have been exposed to excessive temperatures for long periods. Modern metals that have been used to make the replica objects, often contain traces of impurities such as manganese, titanium, molybdenum, tungsten, chromium and nickel which can affect the properties of the iron; but these are unlikely to have affected the results (Samuels 1999: 34). Instead this analysis suggests that Anglo-Saxon house fires may not have reached high enough temperatures, or these temperatures may not have lasted for long enough, to physically affect the microstructure, although this would vary depending on the location of the object in the house. Thatch will burn at temperatures well in excess of 1100°C and thatch fires are almost impossible to put out, resulting in the roof collapsing as the rafters and joists are incinerated (Angold & Sanders 2007). This means that any artefacts placed higher in the roof space are more likely to have been affected by a fire.

Site	Knife	Manufacturing Type	Sex	Age	Status
Cannington	5	1	Unknown	Unknown	Unknown
Empingham	119A/2	1	Male	30-50	5
Empingham	90/5	2	Female	30-40	6
Empingham	50/11	3	Female	17-25	10

Table 6.4: Table of knives suffering from damage from overheating, and the sex, age and status of the individual they were buried with.

The second theory is that overheated knives were intentionally destroyed before burial. This practice has been seen with other artefacts, including broken shield bosses and swords. While some of these instances may be the result of warfare, others appear to be 'ritual' damage, perhaps as a way of 'killing' the weapon (Lucy 2000: 94-95). In these cases the damage is more obvious, but the overheating of knives would have been an excellent method for damaging or 'destroying' a knife. The majority of the knives suffering from heat damage were associated with higher status graves (Table 6.4). This, like the spearheads from Wasperton where metallographic analysis also revealed damage due to overheating (Starley 2009b), strongly supports the theory that these knives were ritually 'killed' prior to burial. Alternatively it could have been a deterrent against grave robbers. At this time there is too little data to determine whether these knives were accidentally damaged or deliberately 'killed', further research and experiments are necessary.

Another entirely different debate relates to the cremation of knives as Glasswell (2002: 51) has argued against placing iron artefacts on a cremation pyre on metallurgical grounds, as there is no evidence that iron from cremations has been 'burnt' i.e. partially oxidised. Experiments carried out on pyre cremations and the material from excavations at Spong Hill indicate that temperatures over 1000˚C were attained, and kept, although the temperature varied depending on the location within the pyre (McKinley 1994: 84; McKinley 1997). These temperatures would not necessarily leave visible traces on the surface of the knife, however their metallographic examination should reveal whether they had been exposed to excessive heat. Other work on knives from Lovedon Hill, which were mostly from cremation urns, showed the majority had overheated microstructures or nitride/carbide needles (McDonnell 1989c). It is difficult, on the basis of this small sample, to demonstrate significant trends, but it should be noted that the ‘carbo-nitride needles’ and annealed structure in these three knives suggests that they were placed on the cremation pyre. Further research is needed, on the metallographic structures of knives from other cremations burials, and of ironwork included in cremation experiments. This should confirm the structure to be expected if knives were placed on the cremation pyre.

6.5 Changes in Iron Technology in England through Time

The second aim of this research was to compare knives through time to determine what if any contact with cultural groups like the Vikings had on the pre-existing English iron industry. This section maps changes in manufacture, alloy use and heat treatments in England through the whole early medieval period, from the 5th century to the 12th century.

It has already been shown that knife manufacturing technology changed in the 7th century (Section 6.3) but previous work has suggested that there was further change in manufacturing techniques between the 9th and 11th century (Blakelock & McDonnell 2007). To test this second period of change, knives from the 9th to 12th century were examined, including examples from rural Sedgeford and ecclesiastical Whithorn. These were compared with knives from Coppergate (McDonnell 1992) and Beverley (McDonnell 1987c), and also knives from Winchester (Tylecote & Gilmour 1986). The archaeological evidence suggests that the Scandinavians had little impact on most aspects of Anglo-Saxon Britain. The exception was the metalworking and sculpture industries where Scandinavian motifs mingled with Anglo-Saxon designs. Therefore this section will investigate whether differences in ironworking techniques or manufacturing methods can be detected. If the Scandinavians had an impact it might be expected that the knives from the Viking Danelaw would be different from those is Anglo-Saxon Britain (or in this study Winchester, in Saxon Wessex).

As in the previous sections, the knife shape was examined and then the manufacturing techniques were compared. Finally the heat-treatments and alloys used in the cutting edges and knife backs were examined, as well as the evidence for wear and repair through time.

Knife Shape

Very few securely dated 9th-11th century knives have been found and published, and few of these are illustrated so comparison of knife shapes is more difficult (Ottaway 1987). At Coppergate the knives were examined by Patrick Ottaway, and the knife back shapes were plotted through time (Ottaway 1992: 584). The only other knives from the late Saxon period available for comparison were those from Sedgeford and Whithorn, but many of these could not be precisely dated so they have been grouped together with the other middle-late Saxon knives. Figure 6.29 shows that the shape of the knife back does not vary much after the middle Saxon period when the majority of knives had a curved back while the remainder were mostly angle-backed.

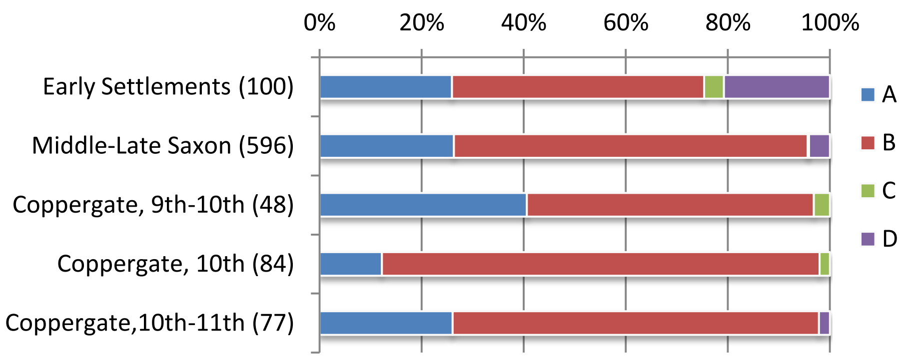


Figure 6.29: Stacked bar chart showing the distribution graph of knife back shapes of Early and middle Saxon knives compared to later knives from Coppergate in York (Ottaway 1992: 584). The data for this graph is in table 2.1 in Volume 2. The knife shape typology is in the appendix volume on page 38.

Knife Manufacturing Methods

The discussion above (section 6.3) has identified a change in manufacturing techniques in the 7th century. There is a slightly higher proportion of the poorer quality type 0 and 3 knives in the rural settlements, or in cases where the settlement was very isolated. By the 10th century another change in manufacturing types was noted (Figure 6.30 and Table 6.5). Type 1 knives became more common and on some sites became more common than the type 2 knives. This has been confirmed by the Chi-square test which revealed a clear statistical difference between middle Saxon and late Saxon knives (Chi-square value 42.98, degrees of freedom 5 and probability 0.00). This change was originally believed to relate to regional differences, but this new analysis has clearly shown that these changes occurred not only in areas of the Danelaw (York, Sedgeford and Whithorn), but also those in Anglo-Saxon Wessex (Winchester).

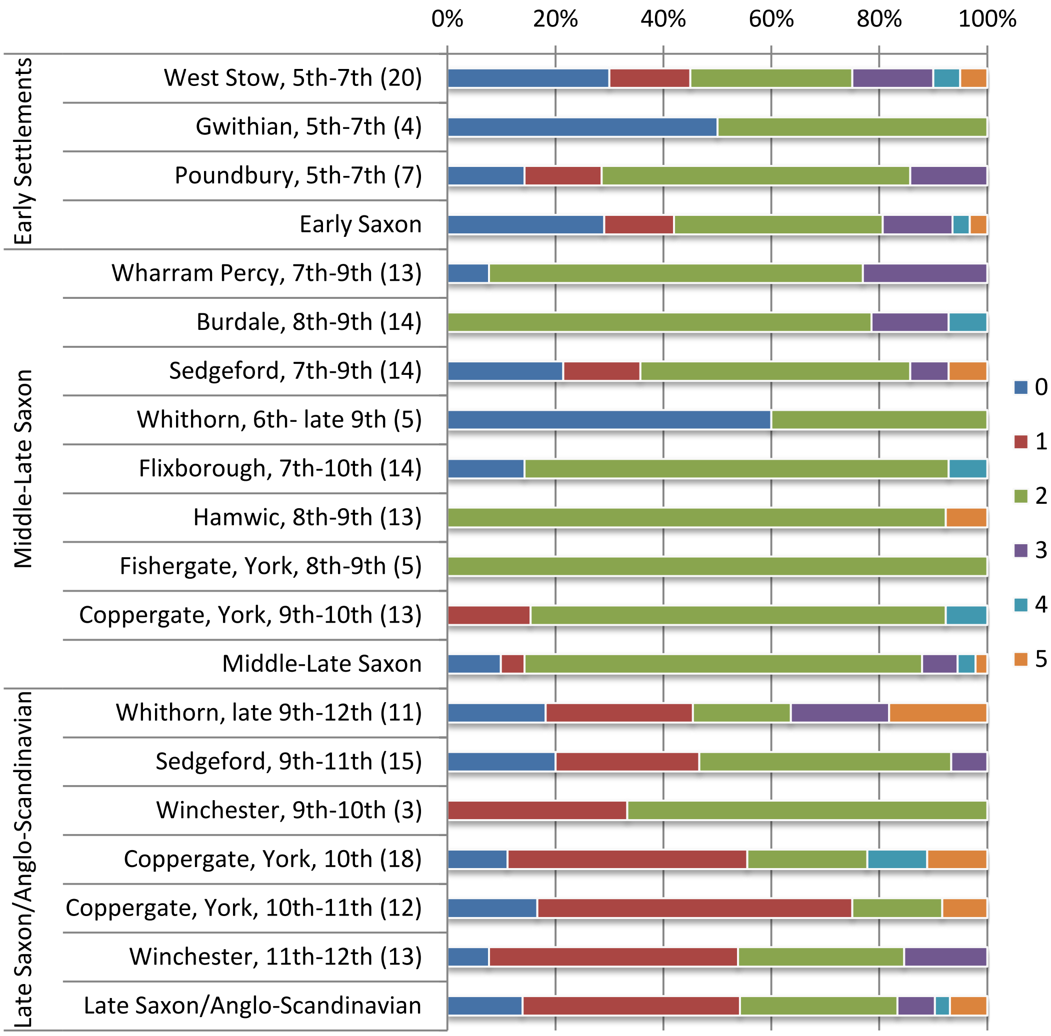


Figure 6.30: Stacked bar chart showing the distribution of different knife manufacturing techniques in early, middle and late Saxon Britain. The data for this chart is in table 6.1, 6.2 and 6.5. The manufacturing typology is in the appendix volume on page 38.

Cutting Edges

The number of heat-treated knives increased through time. Heat-treatments were most frequent after the 10th century, although this was only a slight increase on the proportion of heat-treatments in the middle Saxon period (Figure 6.31). The unusual smithing technique seen at Whithorn, resulting in a high proportion of spherioised and overheated microstructures in the cutting edges, continues beyond the period of apparent 'isolation' (AD 845), but to a lesser extent.

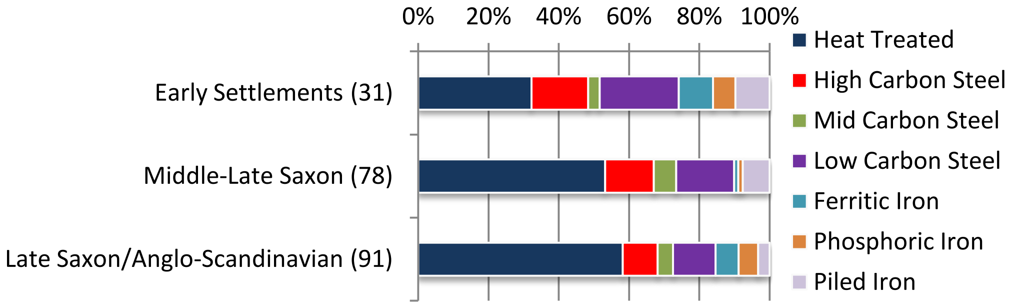


Figure 6.31: Stacked bar chart showing the alloys used to construct the knife cutting edges through time. The data used in this figure is in table 2.2 in Volume 2.

The amount of mid to high carbon steel present remained roughly constant over time. The remaining iron alloys in the cutting edges varied, although less piled iron was being used in later centuries. When the individual manufacturing types in the late Saxon period are examined, it is clear that the vast majority are type 2s (80%) and most of the type 1s had been heat-treated (Figure 6.32). This resulted in much higher average hardness for these knife types (Table 6.5). The exception was in the late Saxon rural settlements were fewer knives were heat-treated, even though they were made of mid to high carbon steels. This was a similar pattern to that found in the middle Saxon settlements. Surprisingly, fewer type 4 and 5 knives were heat-treated although they were often constructed from high carbon steel. This did not influence the average hardness of the type 5 knives, as those that were heat-treated usually had a very high hardness which raises the overall average (Table 6.5).

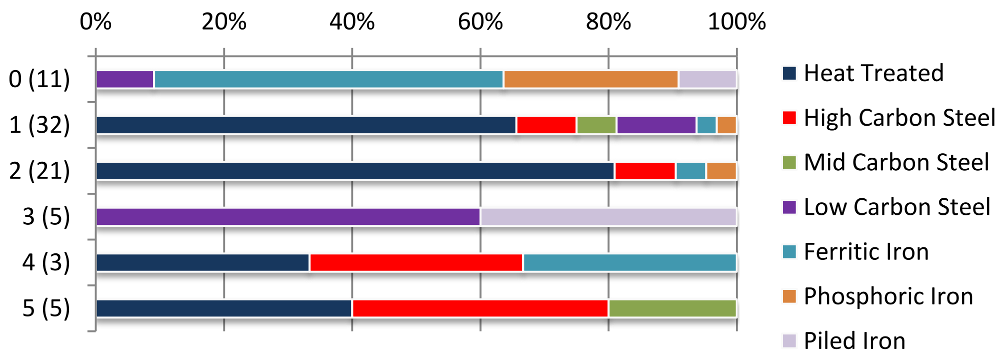


Figure 6.32: Stacked bar chart showing the cutting edge heat-treatments and alloys for each knife manufacturing type in the late Saxon settlements. The data used in this figure is in table 2.7 in Volume 2.

Sites		Manufacturing Typology and Cutting Edge Data							Manufacturing Typology and Knife Back Data						
		0	1	2	3	4	5	Overall	0	1	2	3	4	5	Overall
Early to Middle Settlements	Number	**9**	**4**	**12**	**4**	**1**	**1**	**31**	**9**	**4**	**12**	**4**	**1**	**1**	**31**
	Avg HV	**249**	**306**	**408**	**240**	**201**	**549**	**325**	**201**	**227**	**186**	**182**	**117**	**466**	**202**
	Range HV	**137-457**	**221-453**	**165-615**	**175-386**	**201**	**549**	**137-615**	**105-330**	**185-282**	**140-271**	**159-214**	**117**	**466**	**105-466**
Middle to Late Saxon Settlements	Number	**9**	**4**	**67**	**6**	**3**	**2**	**91**	**9**	**4**	**67**	**6**	**3**	**2**	**91**
	Avg HV	**184**	**581**	**445**	**211**	**446**	**558**	**412**	**183**	**179**	**179**	**187**	**172**	**473**	**186**
	Range HV	**123-268**	**476-766**	**121-847**	**137-314**	**309-549**	**509-607**	**121-847**	**138-242**	**153-707**	**101-707**	**148-294**	**89-233**	**339-607**	**89-707**
Sedgeford 9th-11th	Number	3	4	7	1			**15**	3	4	7	1			**15**
	Avg HV	148	612	423	110			**397**	161	233	217	121			**203**
	Range HV	132-168	509-701	161-509	110			**132-701**	149-179	168-329	133-340	121			**121-340**
Whithorn Late 9th-12th	Number	2	3	2	2		2	**11**	2	3	2	2		2	**11**
	Avg HV	146	583	406	143		285	**337**	149	154	153	171		301	**183**
	Range HV	123-168	264-841	399-412	137-148		183-386	**123-841**	130-167	121-210	147-158	158-183		186-416	**121-416**
Coppergate, York 10th	Number	2	8	4		2	2	**18**	2	8	4		2	2	**18**
	Avg HV	204	467	548		252	407	**425**	197	215	193		173	221	**204**
	Range HV	178-230	157-813	156-689		206-297	394-420	**156-813**	178-215	144-348	160-243		145-200	221	**144-348**
Coppergate, York 10th-11th	Number	2	7	2			1	**12**	2	7	2			1	**12**
	Avg HV	149	283	473			195	**285**	160	151	207			273	**172**
	Range HV	136-160	155-554	420-525			195	**136-554**	136-183	95-180	190-273			273	**95-273**
Lurk Lane, Beverley 9th-12th	Number	1	3			1		**5**	1	3			1		**5**
	Avg HV	187	786			592		**627**	165	200			183		**190**
	Range HV	187	627-907			592		**187-907**	165	164-251			183		**164-251**
Winchester 9th-10th	Number		1	2				**3**		1	2				**3**
	Avg HV		533	538				**536**		219	120				**153**
	Range HV		533	439-636				**439-636**		219	113-127				**113-219**
Winchester 11th-12th	Number	1	6	4	2			**13**	1	6	4	2			**13**
	Avg HV	113	429	404	121			**349**	113	220	111	121			**163**
	Range HV	113	290-633	102-551	99-143			**99-633**	113	165-262	95-117	99-143			**95-262**
Late Saxon/Viking Settlements	**Number**	**11**	**32**	**21**	**5**	**3**	**5**	**77**	**11**	**32**	**21**	**5**	**3**	**5**	**77**
	Avg HV	**158**	**481**	**457**	**128**	**365**	**316**	**390**	**161**	**197**	**176**	**141**	**176**	**263**	**186**
	Range HV	**113-230**	**155-907**	**161-689**	**99-148**	**206-592**	**183-420**	**99-907**	**113-215**	**95-348**	**95-340**	**99-183**	**145-200**	**186-416**	**95-416**

Table 6.5: Table showing the number, average hardness and hardness range for the cutting edge and knife backs of knives from Early cemeteries and settlements, and the total for Middle-Late Saxon settlements. Data from this thesis except for Coppergate (McDonnell 1992), Lurk Lane (McDonnell 1987c) and Winchester (Tylecote & Gilmour 1986; Tylecote 1990b).

Knife Backs

The analysis of the knives from Winchester did not include SEM-EDS analysis and therefore phosphoric iron was not detected. This may explain the relative increase in ferritic iron present in figure 6.33. In addition piled iron was not noted during the analysis of these knives. Even so, the knife back alloys did not seem to change through time with similar amounts of piled and ferritic iron (Figure 6.33). More of the late Saxon and Anglo-Scandinavian knives had knife backs that consisted of mid to high carbon steel, but this is most likely due to the more frequent type 5, all steel knives.

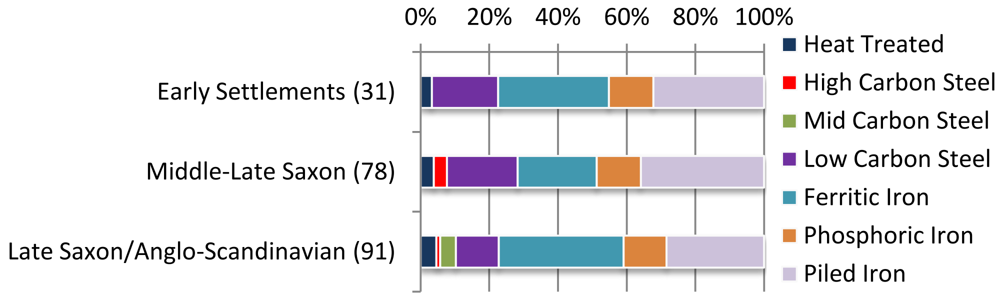


Figure 6.33: Stacked bar chart showing the alloys used to construct the knife backs through time. The data used in this figure is in table 2.2 in Volume 2.

When the iron alloys used in the knife backs were plotted by the individual manufacturing types it is clear that piled iron was used in most knife types, similar to other periods (Figure 6.34). The exception was the type 4 knives which most often had a ferritic iron core, although low carbon steel was also used occasionally. Another exception was the type 5 knife which was predominately heat-treated steel. Phosphoric iron and ferritic iron was mostly used in type 0, 1 and 2 knives.

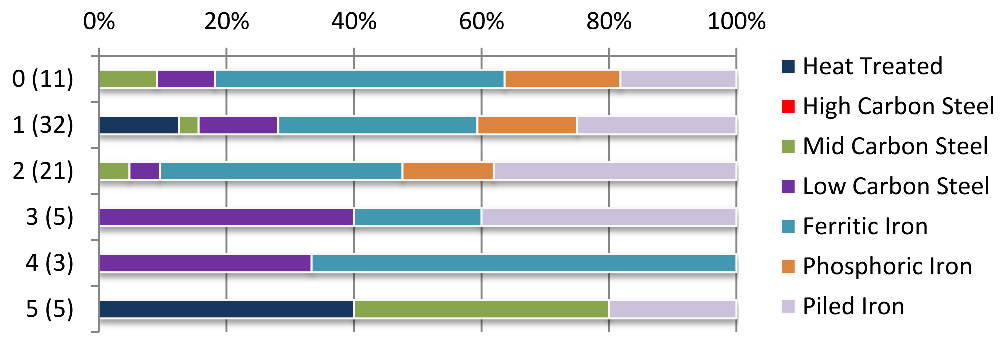


Figure 6.34: Stacked bar chart showing the knife back heat-treatments and alloys for each knife manufacturing type from late Saxon settlements. The data used in this figure is in table 2.7 in Volume 2. The manufacturing typology is in the appendix volume on page 38.

Wear, Recycling and Repair

As few of the published 9th-11th century knives are illustrated it is difficult to determine whether wear increases through time. Metallographic examination has shown that during the later period fewer repairs were being carried out, and then only in the urban centres. This suggests that knives were more likely to be discarded once they were badly worn, perhaps pointing to cheaper more plentiful knives. There was also a reduction in piled iron which suggests that recycling became less common (even considering that piled iron was not identified in the Winchester knives). This all suggests that a better range of iron alloys and skilled workers were more available in urban centres.

6.6 The Vikings' Influence on Ironworking

This final section examines Viking knives, from Britain and Ireland as well as further afield, to determine whether contact with the Vikings influenced pre-existing ironworking techniques. If ironworking techniques were being developed and introduced by Scandinavian settlers it would be expected that knives in pre-Viking Scandinavian might be similar to those in the later periods in England. Another possibility is that the change in techniques was transmitted due to contact with Viking merchants, and their large trading network, in this case it would be expected that there would be changes across Europe at roughly the same time. The final possibility is that the Scandinavians had no impact on ironworking techniques in Britain and Ireland, and instead the indigenous craftworks kept their own techniques and developed methods independently.

The shapes of knives from Dublin are compared to those from Coppergate in York. The knife manufacturing methods are then compared to determine whether the changes noted above in the 10th century were due to 'Viking' influences or techniques. Finally, the heat-treatments and iron alloys used in various different assemblages are compared.

Shape

As mentioned in the results (Chapter 5) the nature of the excavation reports, and the excavators' notes of the Dublin excavations make it very difficult to precisely date the Dublin knives. Virtually everything on these Dublin sites is 10th or 11th century. The first Dublin settlement was further east and is being found in more recent small scale excavations (Bayley *pers.comm*. 16/11/2010). Even so there was a clear difference in the knife shapes between Viking Dublin and Anglo-Scandinavian Coppergate (Figure 6.35). There were considerable numbers of straight backed knives in the Dublin whereas hardly any were found in York.

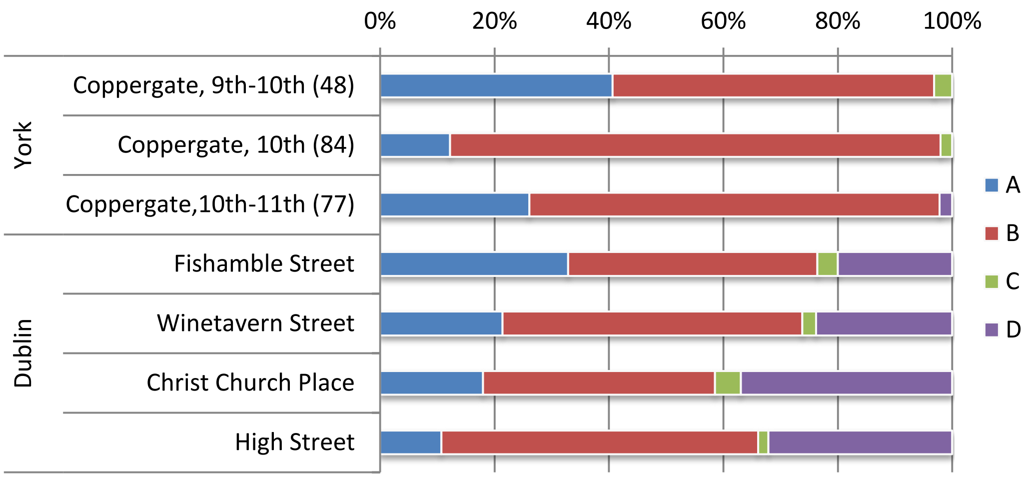


Figure 6.35: Stacked bar chart showing the distribution of knife shapes in Anglo-Scandinavian York (Ottaway 1992) compared to the different excavated areas from Viking Dublin. The data for this chart is available in table 2.1 in Volume 2. The knife shape typology is in the appendix volume on page 38.

Knife Manufacture Methods

The increase in type 1 knives in the English assemblages most likely occured during the 10th century, but Viking settlement of the Danelaw started in the 9th century. During the 10th century the kingdoms of England unified against the Danes but this factor is unlikely to have influenced the change in manufacturing technique, as it changed both in the Danelaw and also in Winchester. It is therefore unlikely that Viking settlement alone was the reason for these changes. At pre-Viking Helgö (5th-9th century) in Sweden the knives revealed a distribution of manufacturing types similar to middle Saxon York, suggesting that if the change in manufacturing types did originate from Scandinavia it was not developed much before the 10th century. When the knives from other later 10th century Viking settlements in Europe are examined (Figure 6.36) it is clear that the type 1 knife is the predominant manufacturing technique. It therefore appears that blacksmiths in England continued to produce knives using the manufacturing techniques that had been used in previous centuries.

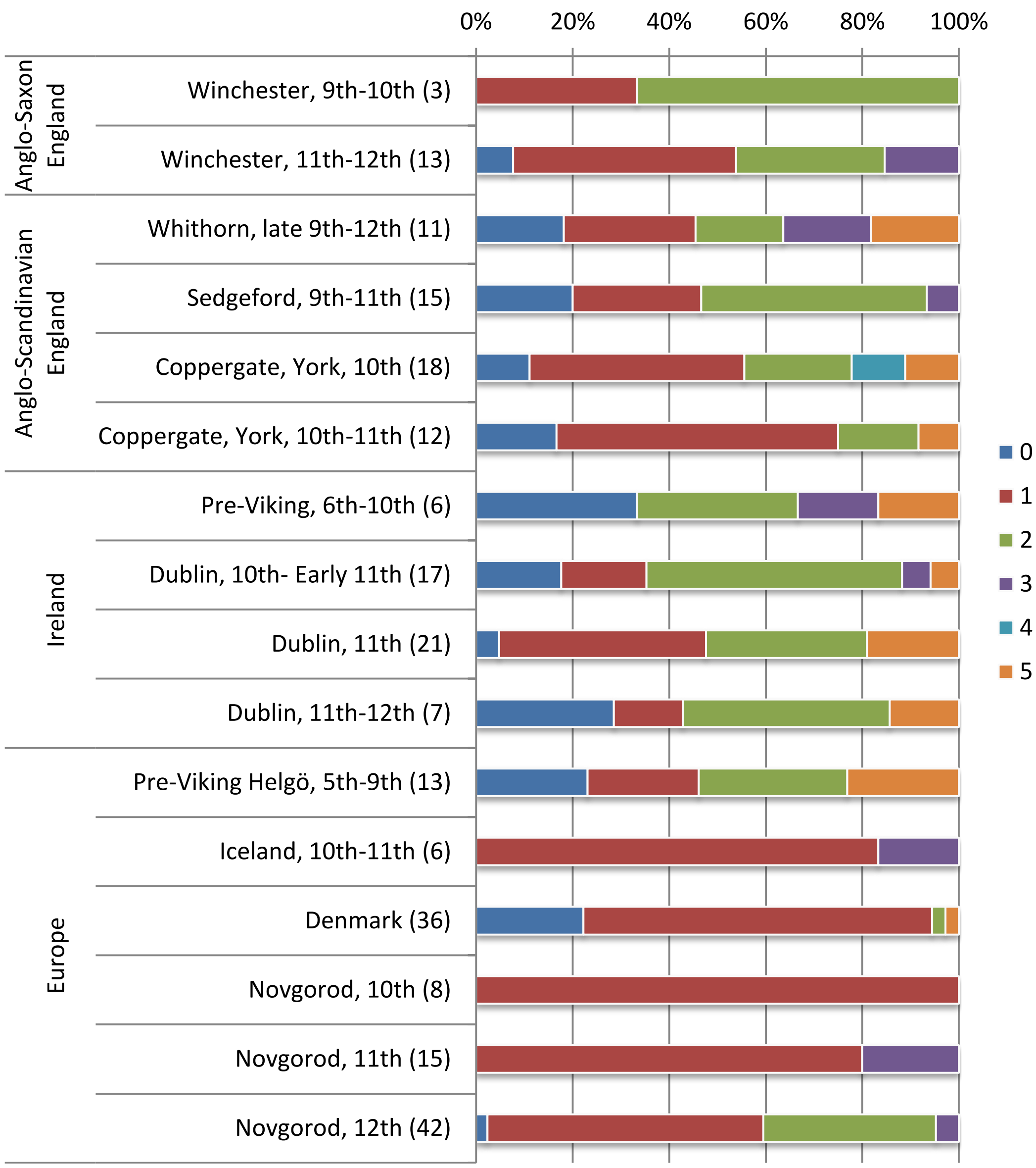


Figure 6.36: Stacked bar chart showing the distribution of knife manufacturing techniques through time, and comparing knives from Britain, Ireland (Scott 1991a) and Viking Europe (Thompson et al. 1967; Tomtlund 1973; Brisbane 1992; Sigurðardóttir 1999; Lyngstrøm 2008). The data for this graph is in table 6.6, and table 2.12 in Volume 2. The manufacturing typology is in the appendix volume on page 38.

When the knives from Viking Dublin were examined there was clearly a different pattern. Prior to the Viking settlement of Ireland the knives revealed a range of knife manufacturing types, though no type 1 knives were identified. In Viking Dublin type 1 knives started to appear, although they never dominated the assemblage, unlike elsewhere in the Viking world. There was also a higher proportion of type 5 (all steel) knives in Ireland than elsewhere. This suggests that in Viking Dublin, as in England, the smiths were continuing with their own blacksmithing traditions.

Cutting Edge Heat-treatment and Alloys

The most distinct difference between the English knives and the Irish knives is the method of heat-treatment (Figure 6.37). Tempered martensite is the most common heat-treatment technique used in the Saxon period in Britain but in Viking Dublin un-tempered martensite dominates the assemblage. This is a much harder microstructure, resulting in extremely high average hardness values. This is not a Viking technique as most of the Viking knives from Iceland were tempered martensite (Sigurðardóttir 1999). Instead the use of un-tempered martensite seems to be a 'native' Irish ironworking method, as it is also present in the pre-Viking knives. This conservatism can also be seen in other crafts such as copper alloy working where Irish smiths were using Viking styles and materials while maintaining their own methods and techniques (Wallace 1981; Ó Floinn 2001).

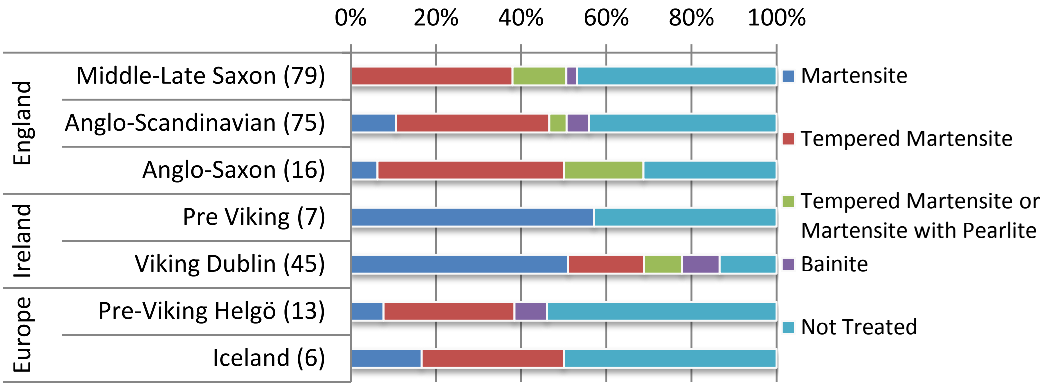


Figure 6.37: Stacked bar chart showing the distribution of different heat-treatments through time, and comparing knives from Britain, Ireland (Scott 1991a) and Viking Europe (Tomtlund 1973; Sigurðardóttir 1999). The data for this chart is available in table 2.2 in Volume 2.

The alloys used for cutting edges that were not heat-treated were similar (Figure 6.38). Unfortunately, due to the small sample size of the pre-Viking knives from Ireland and Viking knives from Iceland, the results are difficult to compare. However it is clear that in both groups the remaining knives were high carbon steels. In Helgö the knives were similar although more piled iron was used to construct some of the cutting edges. Many more knives from Viking Dublin were heat-treated; the remainder were piled iron or low to mid carbon steels.

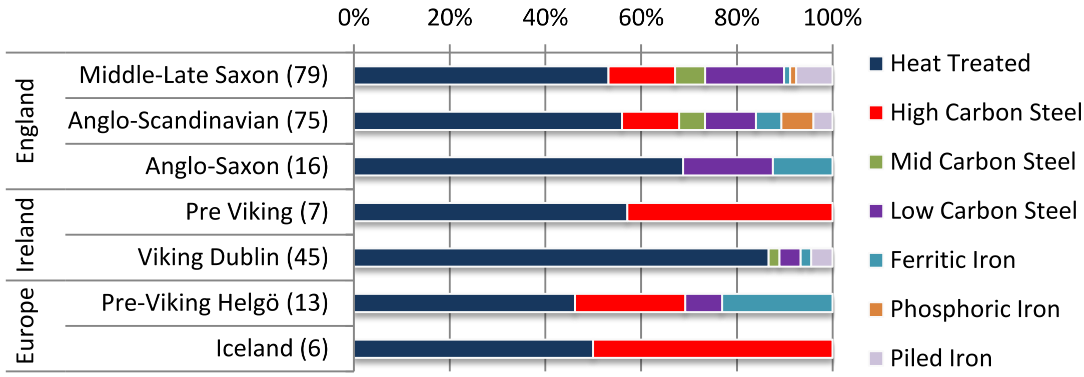


Figure 6.38: Stacked bar chart showing the distribution of heat-treatments and iron alloys in the cutting edges through time, and comparing knives from Britain, Ireland (Scott 1991a) and Viking Europe (Tomtlund 1973; Sigurðardóttir 1999). The data for this chart is available in table 2.2 in Volume 2.

Knife Backs

When he examined the Winchester knives, Tylecote unfortunately did not have access to SEM-EDS to analyse for phosphoric iron, therefore some of the ferritic iron in the Anglo-Saxon knives noted in figure 6.39 may actually be phosphoric iron. The main difference between Viking Dublin and Anglo-Scandinavian England was the amount of phosphoric iron used to construct the knife backs, with increased amounts of phosphoric iron and smaller quantities of ferritic and piled iron used in the Dublin knives. In Viking Iceland there was a high proportion of ferritic iron rather than phosphoric iron. The use of phosphoric iron most likely relates to the iron alloys available, and therefore to the iron ores accessible to the smelters (Piaskowski 1989; Godfrey *et al.* 2003; Rubinson 2009). At Helgö ferritic iron was also more commonly used in knives than phosphoric iron, even though phosphoric iron was clearly present and available as suggested by the iron bars found on the site (Modin & Lagerquist 1978).

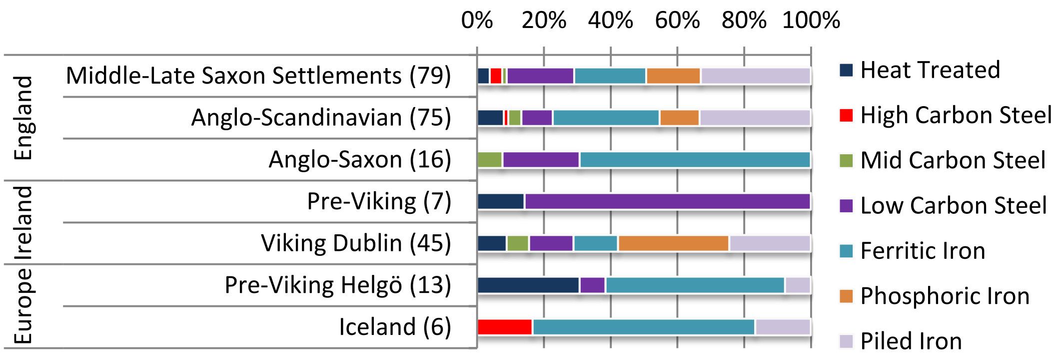


Figure 6.39: Stacked bar chart showing the distribution of heat-treatments and iron alloys in the knife backs through time, and comparing knives from Britain, Ireland (Scott 1991a) and Viking Europe (Tomtlund 1973; Sigurðardóttir 1999). The data for this chart is available in table 2.2 in Volume 2.

	Sites		Manufacturing Typology and Cutting Edge Data							Manufacturing Typology and Knife Back Data						
			0	**1**	**2**	**3**	**4**	**5**	**Overall**	**0**	**1**	**2**	**3**	**4**	**5**	**Overall**
England	Middle-Late Saxon Settlements	Number	9	4	67	6	3	2	**91**	9	4	67	6	3	2	**91**
		Avg HV	184	581	445	211	446	558	**412**	183	179	179	187	172	473	**186**
		Range HV	137-268	476-766	121-847	137-314	309-549	509-607	**121-847**	138-242	153-199	101-707	148-294	89-233	339-607	**89-707**
	Anglo-Scandinavian Settlements	Number	10	25	15	3	3	5	**61**	10	25	15	3	3	5	**61**
		Avg HV	163	491	461	132	365	316	**391**	166	191	201	154	176	263	**193**
		Range HV	123-230	155-907	156-689	110-148	206-592	183-420	**110-907**	130-215	95-348	133-340	121-183	145-200	186-416	**95-416**
	Anglo-Saxon Settlements	Number	1	7	6	2			**16**	1	7	6	2			**16**
		Avg HV	113	444	448	121			**384**	113	220	114	121			**161**
		Range HV	113	290-633	102-636	99-143			**99-636**	113	165-262	95-127	99-143			**95-262**
Ireland	Early Christian 6th-10th Settlements	Number	2		2	1		1	**6**	2		2	1		1	**6**
		Avg HV	161		947	199		866	**547**	144		177	186		727	**259**
		Range HV	155-167		910-983	199		866	**155-983**	120-167		166-188	186		727	**120-727**
	Dublin 10th–Early 11th	Number	3	2	10	1		1	**17**	3	2	10	1		1	**17**
		Avg HV	157	545	821	386		1283	**673**	121	235	252	242		775	**257**
		Range HV	110-232	473-593	441-1283	386		1283	**110-1283**	110-128	107-362	114-360	242		775	**107-775**
	Dublin 11th	Number		9	7			5	**21**		9	7			5	**21**
		Avg HV		895	757			559	**769**		298	319			454	**342**
		Range HV		509-1288	457-1288			362-927	**362-1288**		186-519	152-334			283-713	**152-713**
	Dublin 11th-12th	Number	2	1	3			1	**7**	2	1	3			1	**7**
		Avg HV	241	473	1050			1133	**748**	438	171	343			633	**387**
		Range HV	161-321	473	841-1283			1133	**161-1283**	372-504	171	321-377			633	**171-633**
	Viking Dublin Settlement Total	**Number**	**5**	**12**	**20**	**1**		**7**	**45**	**5**	**12**	**20**	**1**		**7**	**45**
		Avg HV	**190**	**801**	**833**	**386**		**745**	**730**	**248**	**277**	**289**	**242**		**525**	**317**
		Range HV	**110-321**	**473-1288**	**441-1283**	**386**		**362-1283**	**110-1288**	**110-504**	**107-519**	**114-377**	**242**		**470-775**	**107-775**
Europe	Pre-Viking Helgö 5th-9th	Number	3	3	4			3	**13**	3	3	4			3	**13**
		Avg HV	224	553	514			430	**437**	216	405	289			350	**313**
		Range HV	206-233	240-720	191-820			205-685	**191-820**	194-233	245-669	109-485			199-487	**109-669**
	Iceland 9th-11t Settlements	Number		5		1			**6**		5		1			**6**
		Avg HV		635		179			**559**		176		238			**186**
		Range HV		546-681		179			**179-681**		140-239		238			**140-239**

Table 6.6: Table showing the number, average hardness and hardness range for the cutting edge and knife backs of knives from late Saxon settlements, compared to the knives Early Christian Ireland (Scott 1991a) and Viking Dublin, and Helgö (Tomtlund 1973) and Iceland (Sigurðardóttir 1999).

6.7 Summary

The main aim of this chapter was to discuss the first four objectives of this research project. The first objective was to determine why there is a dramatic difference between knife manufacturing methods in the early Saxon cemeteries compared to the middle to late Saxon urban settlements. This analysis has shown that the differences in manufacture styles are not connected to the differences between urban and rural sites. Other differences in quality of iron alloys and the blacksmiths' skills are apparent particularly in heat-treatments. The change in knife manufacture occurs sometime in the 7th century, but also during this period there is a development of kingdoms, the introduction of Christianity and the re-emergence of urban settlements.

There were still some differences in knife manufacture and quality between the early settlements and cemeteries, but this may be explained by the creation of some knives specifically for burial. This needs to be investigated further as the rather small sample size may have influenced the results presented.

The third objective of the research, and this chapter, was to investigate knife manufacture through time and also what impact Vikings had on iron technology in England. The forth objective was to compare knives in England, Ireland and the rest of Europe to investigate changes in manufacture and blacksmithing techniques. This research has demonstrated that there is a clear change in knife manufacturing methods in the 10th century in England. This may be connected to the preferred manufactured techniques in Viking Europe although the change is more gradual in England. Craft workers are by their nature conservative and new techniques are rarely adopted unless they bring benefits or are necessary (Cameron & Mould 2004: 465). The rise in population in the 9th century (Hinton 2005: 157) may have led to the necessity to mass produce knives. By analysing knives from Viking Dublin it is clear that while the Irish may have adopted some techniques from the Vikings, they mostly continued with their own manufacturing methods and heat-treatment techniques.

Chapter 7: Early Medieval Ironworking Technology

7.1 Introduction

This chapter will synthesise the research undertaken and re-evaluate current understanding of the early medieval iron industry. The final objective of this research is explored in this chapter which summarises current knowledge of early medieval iron technology, gained from the previous results and discussion.

The results have shown that there was a specific order when constructing a knife and it is possible to reconstruct some of the decisions made by the blacksmiths at each stage of the process. This chapter, while discussing the nature of knife manufacture, will provide information about the entire early medieval ironworking technology which may be applicable to other iron artefacts and tools.

The first stage in knife manufacture was the selection of bars of the correct iron alloy by the smith. This selection would be influenced by a number of factors, e.g. alloy availability, cost and knife function. Therefore the first section (7.2) will describe each different iron alloy including its specific properties. Once the iron alloys to be used had been chosen, they were often welded together to create a steel cutting edge. Section 7.3 discusses the different manufacturing techniques and the decisions made by the blacksmiths. The method of construction influenced how much of each alloy was used, for example the type 2 knife reduced the amount of steel needed. On the other hand some construction methods would have been significantly simpler and/or less time consuming, which may have been of advantage to a smith.

After the alloys have been welded together, the knife is then shaped. This can be clearly seen by the distortion in many of the weld lines. The shape of the knife has often been associated with the use of the knife, and this will be discussed in section 7.4. Only once the knife has been shaped can the knife be heat-treated. Heat-treatments bring out the best in carbon steel and allow the knife to last much longer, but this final stage of blacksmithing would have most likely been the most 'secretive' aspect of the process. It may even have seemed 'magical' with its bright colours, sparks, heat and the steam produced when quenching the object. This technique may have been restricted to certain smiths. Therefore in section 7.5 the use and types of heat-treatments will be discussed, along with the status of the blacksmiths.

After the knife has been made, hone stones would have been used to sharpen the knife, and a handle would be attached. How the iron knife would have appeared in the early medieval period is unknown, while it is very likely that some knives were entirely polished, i.e. pattern-welded knives, it is unclear whether they all were. Section 7.6 will therefore discuss the various possibilities.

Section 7.7 will discuss the evidence for how the knives were used. It will discuss whether it is possible to identify craft knives from those used in domestic tasks by using the metallographic information from the knives, including; alloys used, manufacturing methods, shape, heat-treatments, wear and repair. After this section 7.8 will use the knife data from Viking Dublin from the different excavations, which represented different craft zones to determine whether knife data collected in this research, can be used to provide evidence for knives used in different types of crafts. The final section (7.9) will discuss the evidence for iron working specialisation in the early medieval period using all the information gathered during this research.

7.2 Alloy Selection

One of the most important decisions that the blacksmith would have to make is which iron alloys to use. This selection will affect the overall quality of the knife, how tough it was and also how hard the cutting edge will be. This decision would be influenced firstly by what iron alloy the smith had available locally, or could import. Secondly it would be influenced by the cost as some iron alloys, particularly those that were good quality or with certain properties would have been more costly to produce due to the extra time needed to make them. The final influence would be the blacksmith themselves. Only with the right knowledge of each iron alloy would they know which ones to use to create the best quality knife. This would most likely be the result of practice over time, but also how skilled they were.

Ferritic iron

The first alloy, ferritic iron, contains no carbon or phosphorus. Ideally this metal should not contain any other impurities but the SEM-EDS analysis revealed the presence of arsenic, nickel and copper in some ferritic iron in some of the knives from early medieval Britain, and Ireland (Table 7.1). These impurities are presumably incorporated into the metal from the ore, during smelting (Navasaitic *et al.* 2010).

The analysis of the iron alloys has suggested that ferritic iron was predominately used for the knife backs in urban settlements (38 out of 84), while this was less common (10 out of 55) in the rural settlements (Figure 7.1). The exception was the urban settlement at Viking Dublin, where fewer examples of ferritic iron used in the knife backs (6 out of 45) and instead phosphoric iron was being used more frequently (15 out of 45).

	Cutting Edge			Knife Back		
	No Impurities	Traces	Over 0.3%	No Impurities	Traces	Over 0.3%
Early Saxon Settlement	7	7	9	5	9	9
Early Saxon Cemeteries	4	19	13	0	22	14
Middle-Late Settlements	12	40	20	9	41	22
Dublin	9	15	17	1	19	21

Table 7.1: Table showing the numbers of cutting edges and knife backs with over 0.3% of arsenic, nickel and copper or traces present.

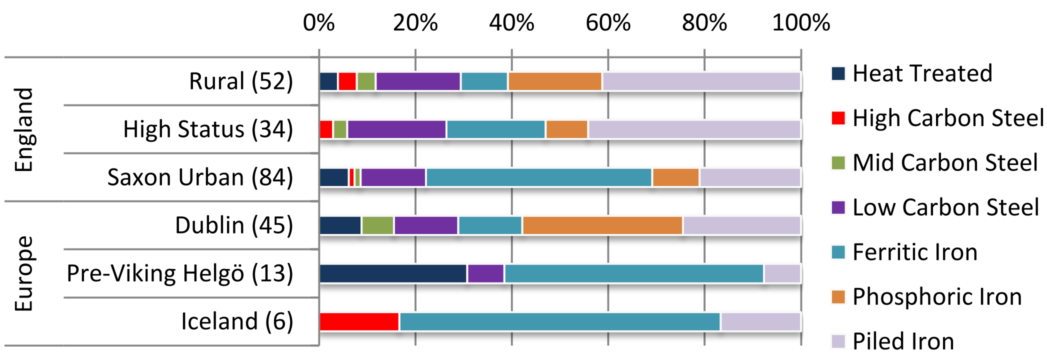


Figure 7.1: Stacked bar chart showing the distribution of various iron alloys used in knife backs in rural, high status and urban settlements. The knives from Dublin, Helgö (Tomtlund 1973) and Iceland (Sigurðardóttir 1999) have been included to compare the alloys used by Vikings. The raw data for this graph is in table 2.2 in Volume 2.

This would therefore suggest that ferritic iron may have been seen as a more specialised iron alloy which was more accessible in the urban settlements. Analysis and experiments have clearly shown that any phosphorus in the ore would have transferred into the iron (Piaskowski 1989; Høst-Madsen & Buchwald 1999; Godfrey *et al.* 2003), therefore ferritic iron would have been produced by smelting iron from phosphorus depleted ore sources, which are much rarer, e.g. Forest of Dean (Paynter 2006). It is therefore likely that ferritic iron would have been scarcer and possibly more expensive. One benefit of ferritic iron over any other iron alloy is its ability to allow carbon to diffuse into it which may have added extra strength to welds. Ferritic iron is also ideal for constructing some anvils as it is more malleable.

Phosphoric iron

There is much debate as to how much phosphorus content constitutes phosphoric iron. The general consensus appears to be that anything over 0.15% is phosphoric iron (Rubinson 2009). The analysis of the knives has revealed a high proportion of phosphoric iron was used compared to previous studies, and it was particularly common in the rural settlements but also in Viking Dublin (Figure 7.1). Again this pattern was confirmed by the stock iron available in the rural settlement sites (Figure 7.2). There is a prevalence of high phosphorus ores in Britain in the form of bog ores, therefore this iron alloy would have been accessible to most smiths.

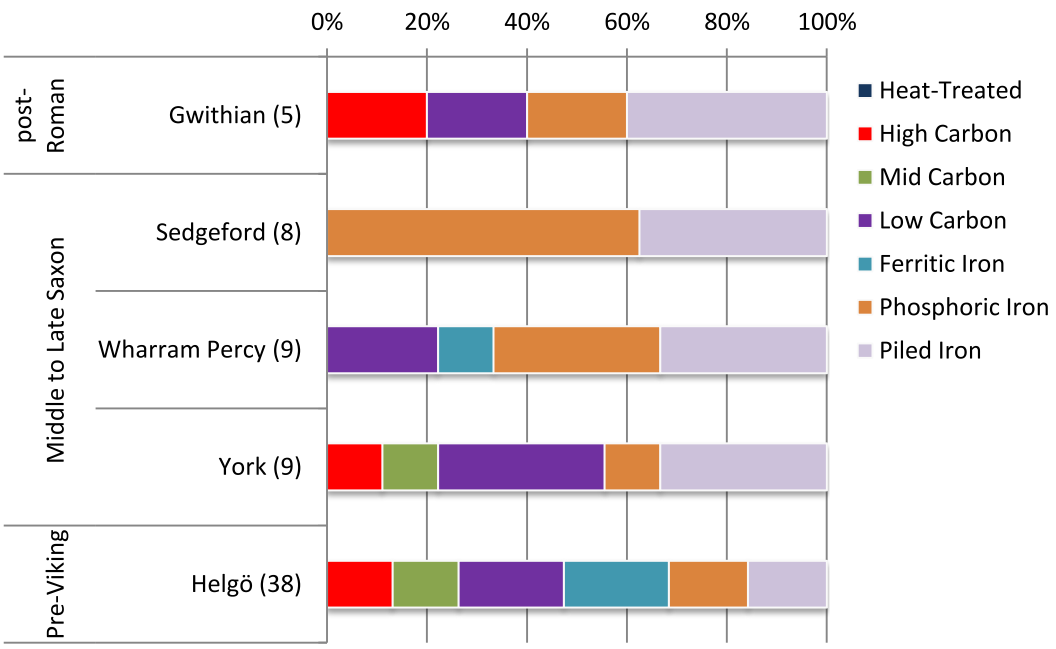


Figure 7.2: Stacked bar chart showing the iron alloys of stock iron, bars and strips, examined at various sites. The data for this graph is in table 2.13 in Volume 2.

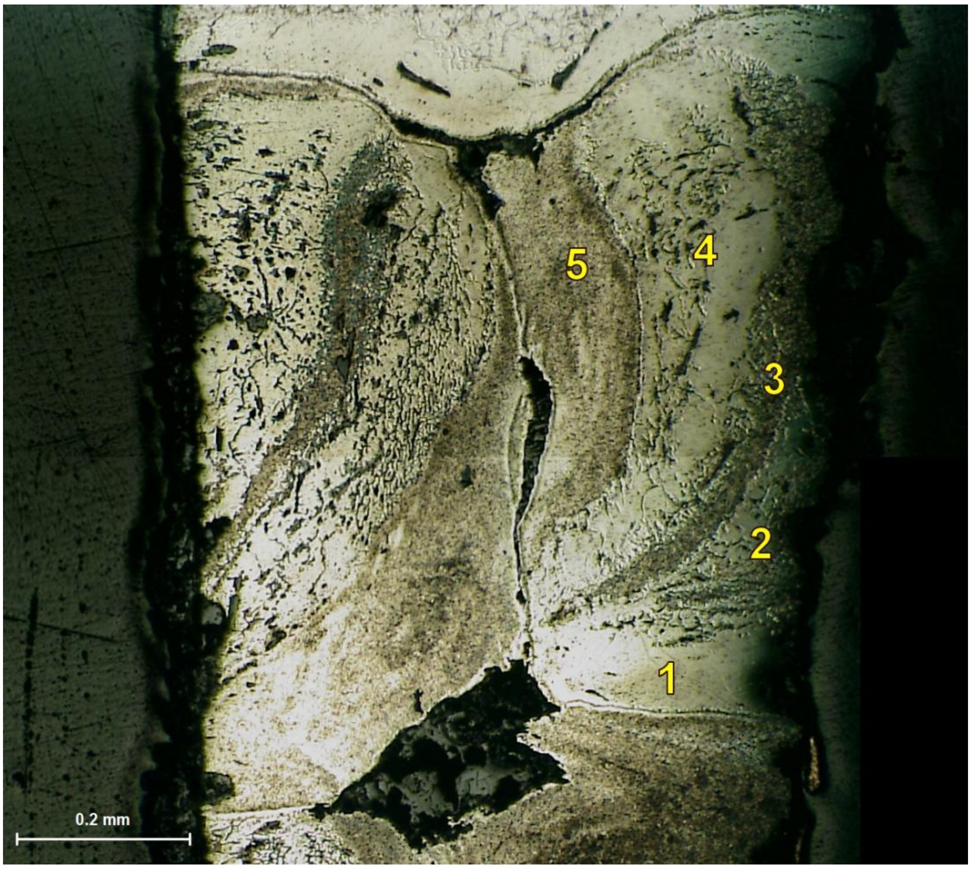


Figure 7.3: Two pieces, of the four, that made up the central pattern-welded strip. 1) Ferrite, 2) Phosphoric iron, 3) Mid-high carbon steel, 4) Phosphoric iron and 5) Heat-treated steel. In each case phosphoric iron is used to separate the steel from any ferrite used.

As mentioned previously in chapter 3 phosphoric iron is harder than ferritic iron, and results in a metal that is tougher (McDonnell 1989a). Modern metallurgy treats it as detrimental, because in cast metals it encourages segregation, but in wrought irons it can easily be hot, and cold, forged (Goodway 1987; Piaskowski 1989; Stewart *et al.* 2000a; Stewart *et al.* 2000b; Trivedi *et al.* 2010). The main property of phosphoric iron is that it can inhibit the diffusion of small quantities of carbon. This was particularly useful in pattern-welding where phosphoric iron was used to separate layers of mid-high carbon from areas of ferrite, as seen in the Coppergate and Dublin pattern welded knives (Figure 7.3). In addition phosphorus when etched will occasionally appear a slightly different colour due to the ghosting effect.

Steel

Most steels, even low carbon examples, have a higher hardness than ferritic or phosphoric iron. But what makes it superior is the ability to heat-treat this iron alloy and in many cases this has been carried out, particularly in the urban settlements. There were generally more mid- to high-carbon steels in the urban (65 out of 84) and high status settlements (30 out of 22) than the rural ones (37 out of 55; Figure 7.4). Within this steel other impurities were often present including arsenic, copper and nickel (Table 7.1), as well as small quantities of phosphorus. These impurities derived from the smelting process may have increased the hardness (Božić & Lučić 1976).

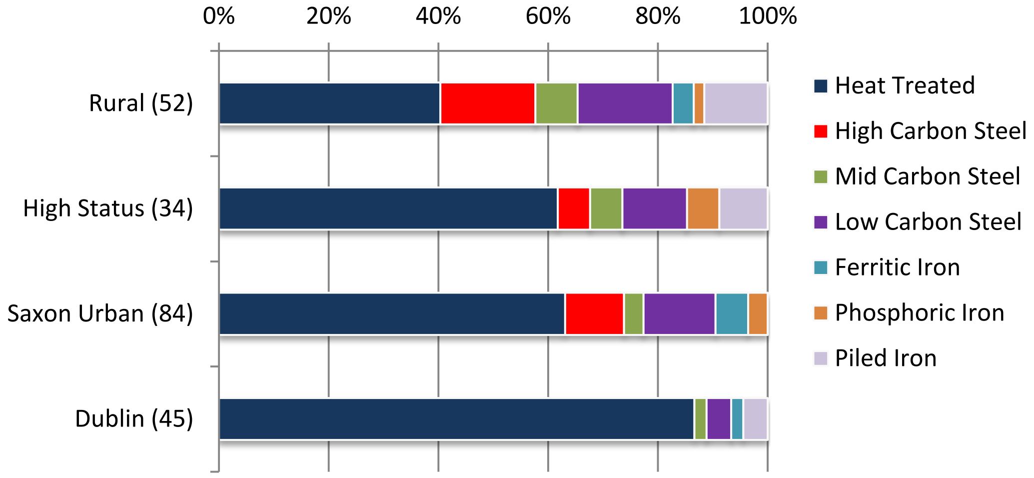


Figure 7.4: Stacked bar chart showing the distribution of different alloys used in the cutting edges of the knives in different types of settlements. The raw data for this graph is available in table 2.2 in Volume 2.

Analysis has shown that the high-quality high-carbon steels seen in the knives from Hamwic and Coppergate (Mack *et al.* 2000) were much rarer in the rural knives, or in those from the early Saxon period. This suggests that this extremely good quality material may have been reserved for the craft workers in these settlements, and was not traded further into the countryside. This in turn suggests that it may have been valuable.

There is still unfortunately no evidence for its production in early medieval Britain. If the conditions in a smelting furnace are just right it would be theoretically possible to create cast iron, which could then be de-carburised to create a high carbon steel. Recent experiments at West Dean College have also shown that it was possible using a very small furnace, large quantities of charcoal and a high air flow to raise the carbon content and therefore melt small pieces of low to mid carbon iron into a small quantity of liquid steel (Figure 7.5). Therefore it is possible that a higher status blacksmith in the early medieval period may have known how to produce the steel needed to manufacture their knives.

Figure 7.5: Experiment using a small furnace to create liquid steel, demonstrated by Lee Sauder, Shelton Browder and Steve Mankowski based on Ole Evenstad's description in 1790 of a traditional Norwegian steelmaking method (Wagner 1990). This resulted in a small amount of steel which could have been used to edge two or three knives, using the type 2 manufacturing method. Note that the furnace has been placed on a tree trunk resulting in very little evidence for the archaeologist, apart from a bit of vitrified clay.

Another suggestion was that this alloy was being traded from the continent or further afield, as this steel only seems to be found in settlements associated with trade. The Vikings had vast trade connections, with the East and therefore they may have discovered a source of liquid crucible steel in the Middle East (Rehren & Papakhristu 2000; Craddock 2003), and have brought some examples back to trade. In Sri-Lanka large, wind-blown, furnaces were producing large quantities of liquid high-quality, high-carbon steel, and the zenith of this technology was in the 9th century (Juleff & Rehren 2000; Tabor *et al.* 2005). It is therefore possible that this steel, which was well known in the Middle East, could have been traded and travelled to Europe to be used to construct high quality tools.

Piled/Banded Iron

Piled iron was the most common iron alloy found at all sites, with a quarter of all knife backs constructed from piled iron. Often it consists of a combination of either ferritic and phosphoric iron or phosphoric iron and steel. It is possible that in some cases this was a deliberate decision by the smith to use two or three different iron alloys in the knife back. Occasionally these were arranged in such a way to make it decorative if the knife was etched, but the extremely piled or banded iron was very unlikely to have been decorative or indeed functional, as the presence of many inclusions would have made it difficult to work intensively. There are two possible explanations as to how this type of iron was formed, neither of which are entirely exclusive of the other.

The first possibility is that piled iron is formed when the heterogeneous bloom produced from smelting is turned into a bar. Often the bloom would need to be repeated forged and folded to create a single bar (Tylecote 1986; Crew 1991). The fact that some iron does not have slag stringers or is not banded argues against this theory, although it is likely that different qualities of bloom were available and that piled iron is formed when working with poorer blooms. Another similar possibility is that piled iron is formed using the various iron fragments which were removed during bloom smithing, possibly even from several different blooms. This would therefore explain the differences in composition seen in some piled iron, and explain the high slag content often seen.

Figure 7.6: Section through bar 60 from Gwithian. Note the folded nature of the knife but also the presence of a white weld line separating two microstructures, this suggests that this bar was originally something else.

The second theory is that piled iron is the result of recycling iron. It is uneconomic to recycle small artefacts or fragments of bars as too much iron is lost due to oxidation in the smithing process. In addition the amount of iron recovered would not outweigh the amount of slag included in the metal, and therefore the resulting metal would likely fail. Larger iron artefacts, i.e. knives, axes, horse-shoes etc, could be recycled and then used to create a bar to be used to make something else. To date there is little direct evidence for recycling of iron, with the possible exception of an iron bar found at Gwithian (Figure 7.6). The presence of more piled iron in rural settlements supports the theory that some iron was being recycled as this practice tends to occur in areas with less access to new iron (Woodward 1985).

7.3 Knife Manufacture

Once the alloys to be used were selected the next decision the smith had to make was how to use the iron alloys chosen. This depended firstly on which alloys were chosen. For example, if no steel was available there would only be two options. The first would be to make a type 0 knife (e.g. West Stow knife 86 and 928). This was simple, requiring no further welding of iron. The alternative option was a piled (type 3) iron knife, using piled iron which was either the heterogeneous from forging the bloom or a bar of recycled iron (e.g. Burdale 113). A deliberate piled iron knife could also be made by deliberately welding lots of bars together (e.g. Wharram Percy 442).

If steel was available the next variable was the amount of steel available to the smithy, this depended on availability and cost. If large amounts of steel was available the simplest method for the blacksmith would be to make a blade entirely made from steel (type 5, e.g. Dublin 6255, 12499 and 1114), this, like the all iron type 0 knife, would need no further welding.

As steel would have required more time or skill to create it was most likely an expensive commodity, and was being used sparingly. The remaining three methods, type 1, 2 and 4, would have required varying amounts of steel. The type 4 knife was not a common way of manufacturing a knife in the early medieval period (e.g. Burdale 218, Figure 7.7), presumably since it used more steel than the type 1 and 2 knives, but would have worn through to the softer core quicker. It therefore was not the most efficient or cost-effective knife type.

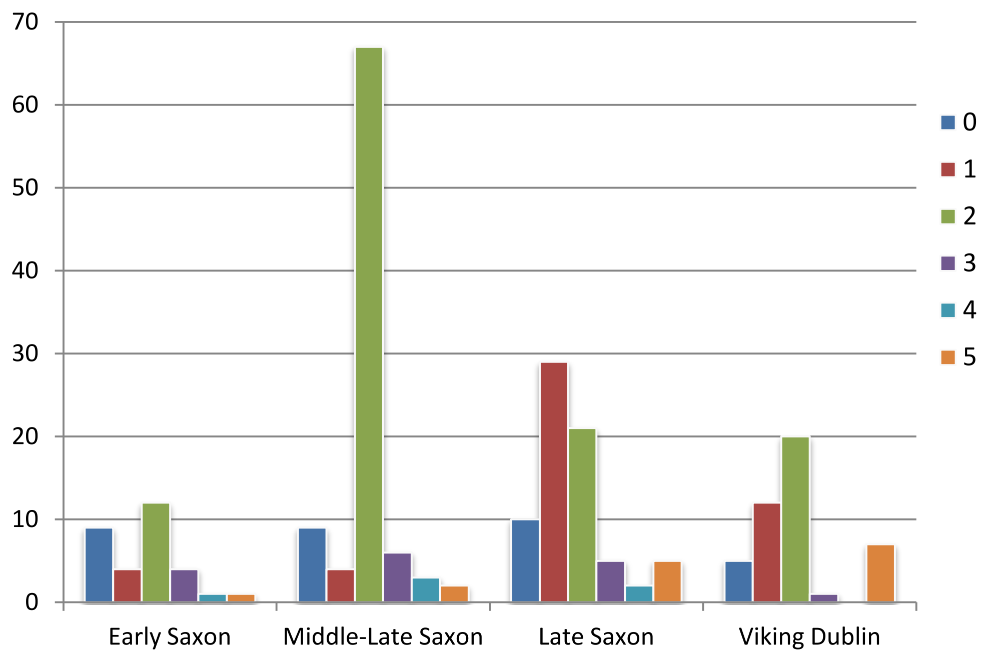


Figure 7.7: Bar chart showing the distribution of each knife type in the different periods in England and the Viking Dublin knives. The raw data for this graph was in table 6.1, 6.2 and 6.5. The manufacturing typology is in the appendix volume on page 38.

The type 2 knife was the preferred method of manufacturing a knife in the middle to late Saxon period (74%), and while there were changes across Viking Europe it was still the preferred method in Dublin (44% type 2 over 27% type 1). This method would have required the least amount of steel of all the knife types, save the type 0 and type 3. Discussions with blacksmiths have suggested that this technique would have been more time-consuming to manufacture, than the type 1 knife (Cole *pers.comm*. 16/11/2010). This suggests that the cost of the steel may have been a bigger influence than the smith hours used during forging. This is also supported by the high quality of many of these blades and the high hardness of their cutting edges.

On the other hand the type 1 knife would have require much more steel, but would have been quite simple and quick to produce (e.g. Dublin 2041, 12055 and 12477). Modern blacksmiths, like Hector Cole, prefer this technique as the steel strip stiffens the blade during heat-treatment and there is less chance of over-heating and decarburising the steel core (Cole *pers.comm*. 16/11/2010). The steel core would have meant that there would always be steel present at the cutting edge after sharpening, therefore it would last much longer than a type 2 knife. Even so some of the heat-treatments did not penetrate deep into the back of the knife in these cases it would have to been necessary to repeatedly heat-treated after it was sharpened, to get the better hardness values (e.g. Dublin 13135). This manufacturing technique becomes more prominent in the 10th century.

Very occasionally knives were constructed using the same manufacturing techniques, butt-welding or sandwich welding, but with the opposite to expected iron alloys, e.g. phosphoric iron cutting edge and a steel back. The reversal of iron and steel in these knives would have resulted in an expensive yet easily worn knife. Their small numbers, mostly in cemeteries, suggest that they may have been more decorative than functional, perhaps being a status symbol rather than functional (Gilmour & Salter 1998). In each case the knives had a phosphoric iron cutting edge, this was harder than soft ferrite, and would have also resisted carbon diffusion from the sides. Both the cemetery knives had been heat-treated, this would have made the backs stand out if it was etched. The settlement knife was not heat-treated but would still have looked different if etched.

Site	Knife		Manufacture Type	Cutting Edge Microstructure	Back Microstructure
Cemetery Edix Hill	547.1	RAIC 5, Female 25-35	1	Phosphoric Iron	Tempered Martensite
Cemetery Collingbourne Ducis	123	RAIC 1, Female 25-40	1	Phosphoric Iron	Bainite/ Tempered Martensite
Settlement Sedgeford	337		2	Phosphoric Iron	Pearlite with ferrite

Table 7.2: Table showing the three reverse type knives, their locations and alloys used. As well as the age, sex and status of the individuals buried they were deposited with (Gilmour & Salter 1998).

Two of these knives were found in cemetery contexts, although as previously discussed not associated with high status graves (Table 7.2). One knife was found in a rural settlement context. No reverse type knives have been found with high status individuals or in urban or high status settlements. This suggests that these knives may not have been related to status, or acted as a status symbol. So another possibility to bear in mind is that these may have been mistakes, where the wrong iron alloy was selected. In each case it is clear that they were from rural settlements and therefore may indicate that these smiths did not have the same skill base, as already seen with the heat-treatments and repairs carried out in rural settlements.

Standardisation of knife manufacture

The presence of type 2 knives in all settlement types suggests that there was a standardisation in knife manufacture. This change in manufacturing method has been shown to occur during the 7th century, when we see a shift from a variety of knife manufacturing types being produced to the domination of the type 2 butt-welded knife in the assemblages. Standardisation often is related to changes in specialisation, as it is linked to a reduction in the number of workshops, industrialisation of the production process or overall control of the craft (Costin 1991; Sillar & Tite 2000). The standardisation in knife manufacture suggests some dramatic changes were occurring in early medieval iron specialisation, which will be discussed further in section 7.8.

In the 10th century there is another change in knife manufacturing types in England from the type 2 to the type 1, although this pattern is not seen in Viking Dublin. In Viking Europe the vast majority of knives were type 1 sandwich welds. This knife was easier to mass produce and continues in production well into the medieval period. At the same time as this change there is also a slight decrease in the quality of the knives, as seen in the average hardness values; this is to be expected of mass-produced objects (Blackman *et al.* 1993).

Weld lines

White weld lines have been noted in many iron artefacts, and there have been a few theories about why these occur (Tylecote & Thomsen 1973), but few extensive studies have been carried out, with the exception of the MSc research by Castagnino (2007). There is still as yet no agreed explanation for these lines. This study has revealed many new examples in early medieval knives. The weld lines are seen throughout the period in both cemeteries and settlements. The analysis suggested that they were slightly more prominent in the rural settlement knives compared to urban knives.

Two different types of weld line were noticed in this research, a solid white weld line which could often be seen before etching and a faded yellow weld line. Both lines had similar ranges of compositions with arsenic, nickel and copper in varying amounts. Occasionally other weld lines with more unusual compositions were identified, like the copper rich weld lines in knife 118 from Collingbourne

Ducis. Where these elements come from, and how these lines form is still unknown but there are three main theories.

The first suggestion is that a flux was being added during the welding process (Tylecote & Thomsen 1973). Modern smiths often use fluxes to assist during the welding process (Cole *pers.comm*. 16/11/2010), therefore it would not be totally unrealistic to suggest that ancient smiths also used a flux (Castagnino 2007). If this was the case very little arsenic, nickel or copper should be found in the metal itself (Figure 7.8) whereas it is clear that arsenic, nickel and copper are found in many samples, even those without white weld lines (Table 7.1).

Another possibility is that arsenic may have been used as a brazing agent, using a crushed ore with an arsenic content >0.005%-0.01% (Tylecote & Thomsen 1973; Tylecote 1990a; Castagnino 2007). But the presence of nickel and/or copper suggest that this is unlikely to be the reason for the weld lines.

The final suggestion was that these white weld lines were caused by an accumulation of arsenic at the surface of a piece of iron during oxidation which was then sealed within two pieces of metal forming the white weld line. This process may also explain the presence of the other elements detected, i.e. nickel and copper. If enrichment was the reason for the white weld lines the metal to either side might be expected to contain significant quantities of these elements. This was indeed the case in many knives, with either the cutting edge or knife back, or in some cases both containing high quantities of impurities (Figure 7.9). These presumably were impurities present in the ore which transferred into the metal during smelting.

None of these theories explain the white lines that were not associated with slag inclusions. Although many of these white lines occurred in metals rich in arsenic and/or nickel. It is therefore possible that, as well as the two theories above, another yet unknown phenomenon was occurring. In addition, there is an increasing number of copper-rich weld lines seen. One possible reason for these lines could be the transfer of copper alloy residues from metalworking tools, when a smith was working both iron and copper, although this seems unlikely. Further research is required of white weld lines, including both the analysis of examples in iron artefacts, but also smithing experiments using iron alloys with traces of nickel and arsenic present.

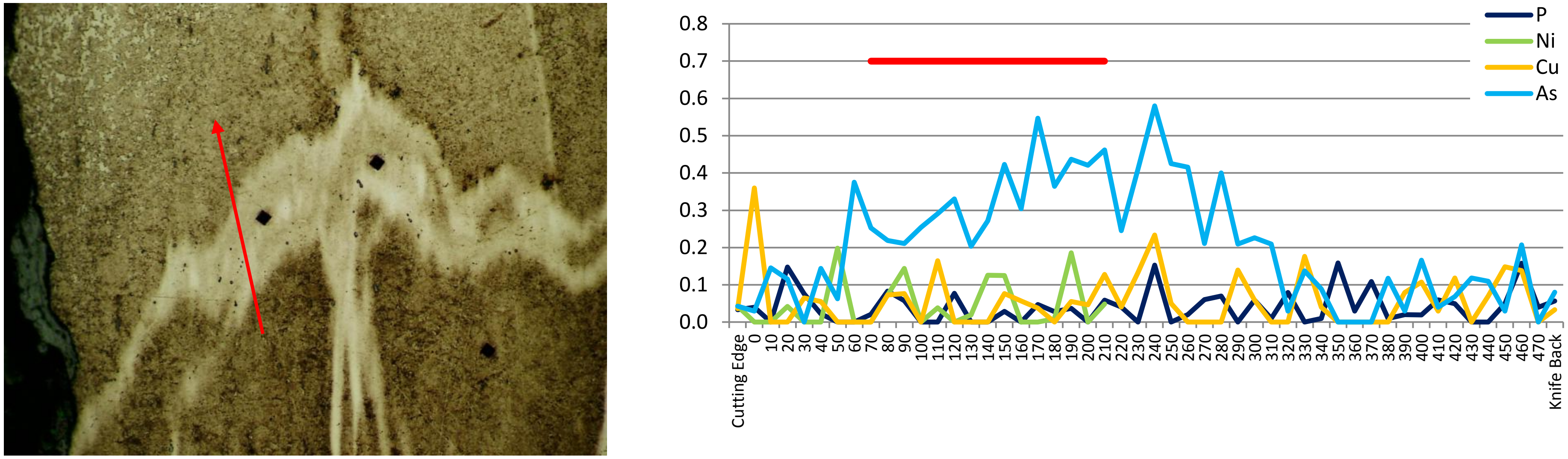


Figure 7.8: Faded yellow white line in knife 323 from Dublin, with some diffusion beyond the weld. Values below the 0.1% detection limit of the SEM-EDS may not be reliable.

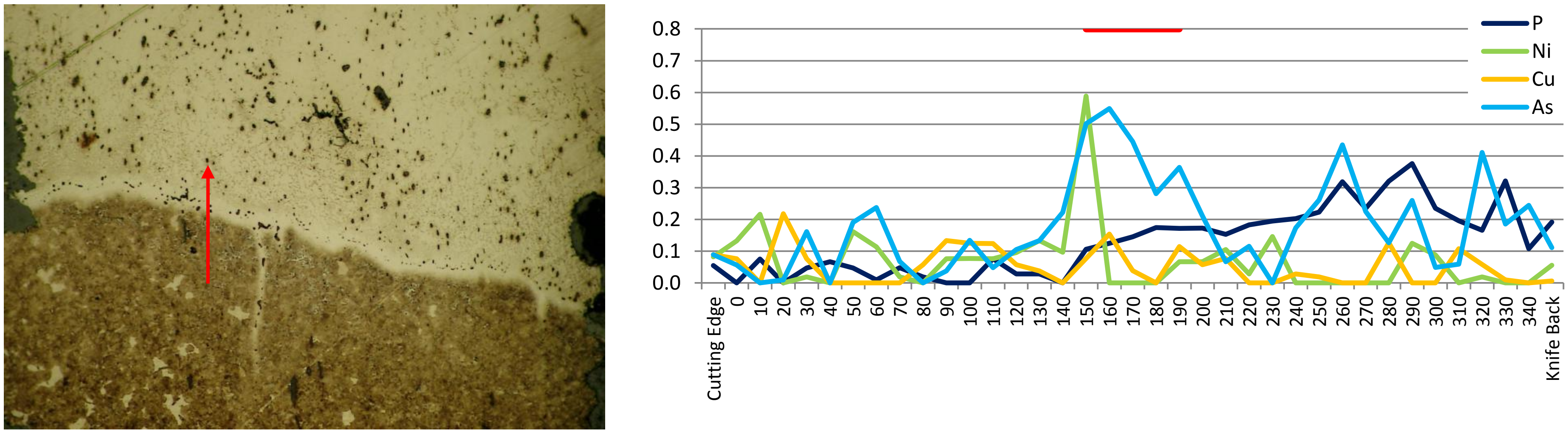


Figure 7.9: Solid white weld line in knife 3138 from Sedgeford, with some diffusion beyond the weld. Values below the 0.1% detection limit of the SEM-EDS may not be reliable.

7.4 Shaping the Knife

It has been suggested that the shape or size of the knife relates to the type of activities it was used for (Ottaway 1987). Later medieval illustrations show the angle-backed knife mostly being used for various craft activities (Figure 7.10). When the manufacturing types were compared to the knife shape it was clear that there was a correlation between the type 2 and the angle-backed knife (Figure 7.11). This supports the theory that the angle-backed, type 2 knife may have been predominately used by craft workers.

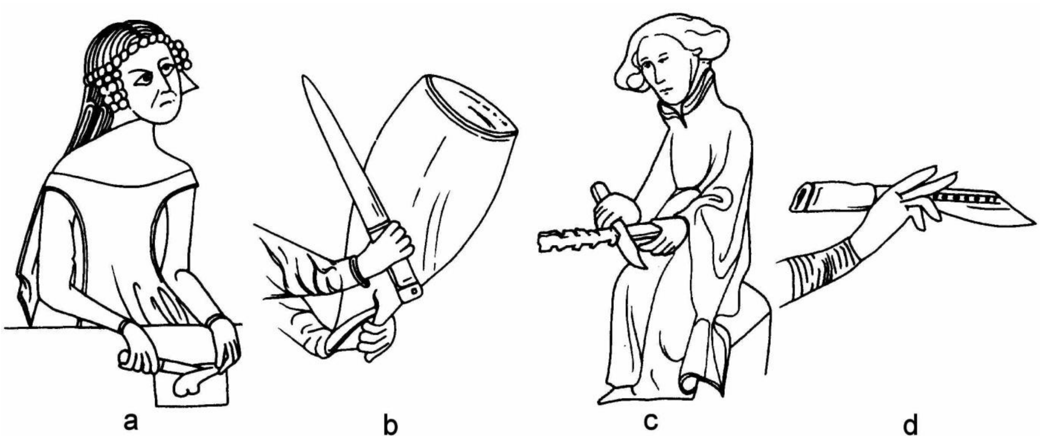


Figure 7.10: Medieval manuscript illustrations of knives being used for various tasks; a) feasting, b) gutting fish, c) cutting notches in a tally stick and d) surgery (Cowgill et al. 1987: 57).

In some cases, the shape may not have had any relation to the function, but it may have been a preference depending on the user. Other researchers have suggested that smaller, slender blades would be required to work on resistant materials (Ottaway 1987) or more delicate activities, e.g. surgery (Figure 7.11). The seax, although technically a knife, is not discussed in detail in this research, but is a clear example of a knife with a specific function which needs a specific shape and more importantly size. To investigate this further a full survey of knife shapes and sizes is required, investigating the differences between domestic and craft knives from a range of different settlements, which was unfortunately beyond the scope of this study.

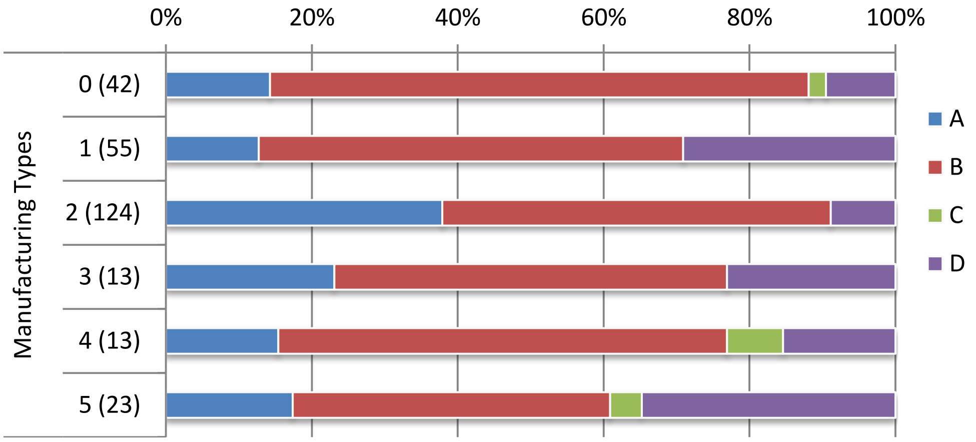


Figure 7.11: Stacked bar chart showing the relationship between knife manufacturing methods and the knife back shape. The raw data is available in table 2.8 in Volume 2. The knife shape typology is in the appendix volume on page 38.

The tang interface has not been heavily discussed during this research as few researchers have classified the tang interfaces of their knives so there were no examples for comparison. Presumably these different interface types reflect different ways of attaching handles. The preferred tang interface was distinct on both sides, and the majority of the remaining knives have a distinct interface on one side. This, in addition, to the square section, and the fact that the tang tends to taper toward a point, would allow the handle to be attached to the knife more easily. Most whittle-tang handles are cylindrical with a wide diameter to prevent the handle splitting when the knife is flexed. The holes prepared for the whittle tangs are roughly shaped and may not have been made for each tang individually, suggesting that there was some form of standardisation. Some researchers suggest that the tangs may have been burnt into position or held in place with glue or wedges (Cowgill *et al.* 1987: 25-26). Comparison between the manufacturing types and the four different tang interfaces (Figure 4.1) was carried out, which revealed no clear patterns (Figure 7.12). New typology studies of knives across a full spectrum of sites may reveal patterns in tang interface preference in different contexts. The measurement width, length and the degree of taper of tangs may also reveal whether the shape of the tang was standardised so that any handle could be used.

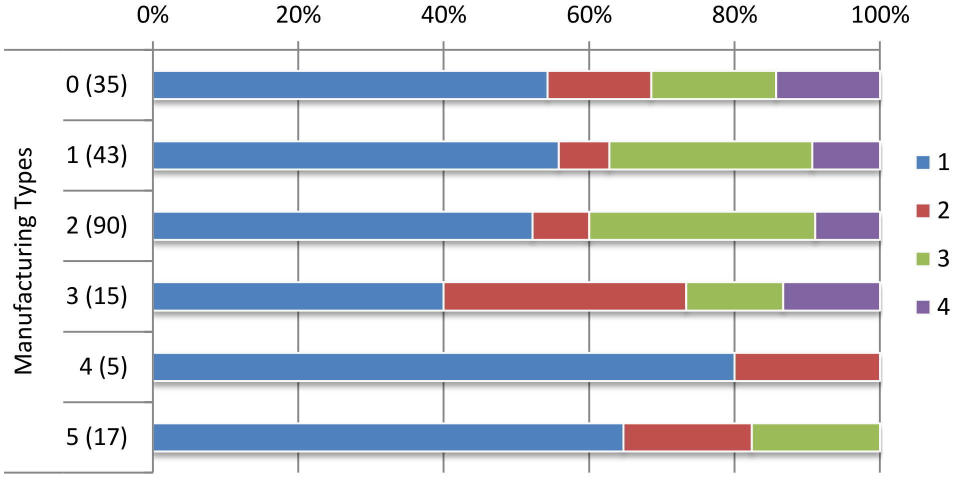


Figure 7.12: Stacked bar chart showing the relationship between knife manufacturing methods and the tang interface shape. The raw data is available in table 2.8 in Volume 2. The tang interface typology is in the appendix volume on page 38.

7.5 Heat-treatment

Heat-treatment of the blades occurred after the knife was shaped, for two reasons; hot working after treatment would soften the metal again, cold working could result in stresses forming in the metal and might result in failure. The type of treatment carried out would have been influenced firstly by the intended use of the knife. Harder blades would have been required if the knife was to be used on harder materials, e.g. wood, whereas a table knife would not necessarily need to be extremely hard. The skill and knowledge of the blacksmith would also have affected the type of treatment carried out as would any regional or cultural factors.

The vast majority of knives were heat-treated in the early medieval period, with the lowest number of treated knives occurring in rural settlements. Analysis of heat-treatments has shown that a range of different treatments were being carried out (Figure 3.9). In England the majority of cutting edges were tempered martensite. Both quenching and then tempering or a single self-tempering treatment would result in a similar microstructure therefore it is difficult, if not impossible, to identify self-tempered blades.

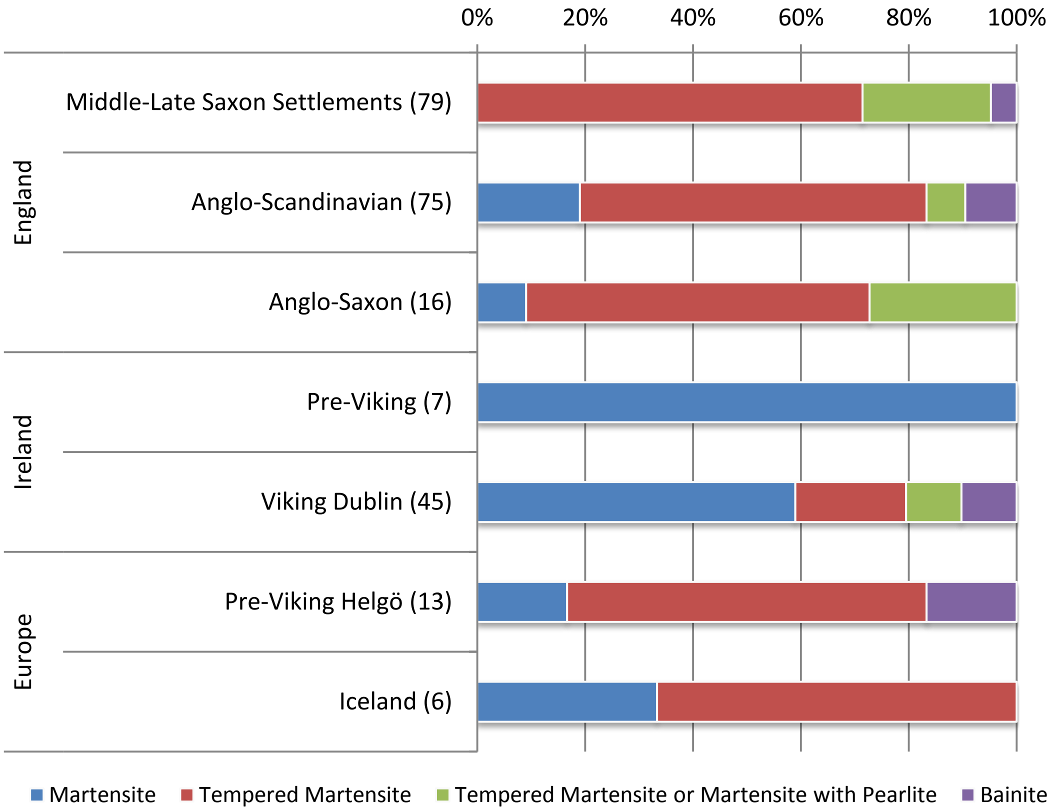


Figure 7.13: Stacked bar chart showing the distribution of different heat-treatments in various site types, across time and also the heat-treatments in Ireland (Scott 1991a) and Viking Europe (Tomtlund 1973; Sigurðardóttir 1999). The raw data for this graph is available in table 2.2 in Volume 2.

The most distinct pattern seen in heat-treatments was the number of martensitic cutting edges in the Viking Dublin knives. This is a dramatic contrast to the tempered martensite preferred by the Anglo-Saxon blacksmith in England (Figure 7.13) and was even distinct from the Viking tradition. As discussed in the previous chapter this appears to have been a distinct choice by the Dublin blacksmiths to continue using the 'native' Irish heat-treatment technique (all 4 heat-treated pre-Viking Irish knives were martensitic).

Before this study no examples of gradient quenching had been noted. This heat-treatment technique would have resulted in a heat-treated cutting edge, but a back that was still un-treated, whereas other techniques for heat-treating would have resulted in an entirely tempered martensite (or martensite) blade. In Viking Dublin a high proportion of the all steel knives showed signs for this technique (Figure 7.14), possibly due to the absence of tempered blades.

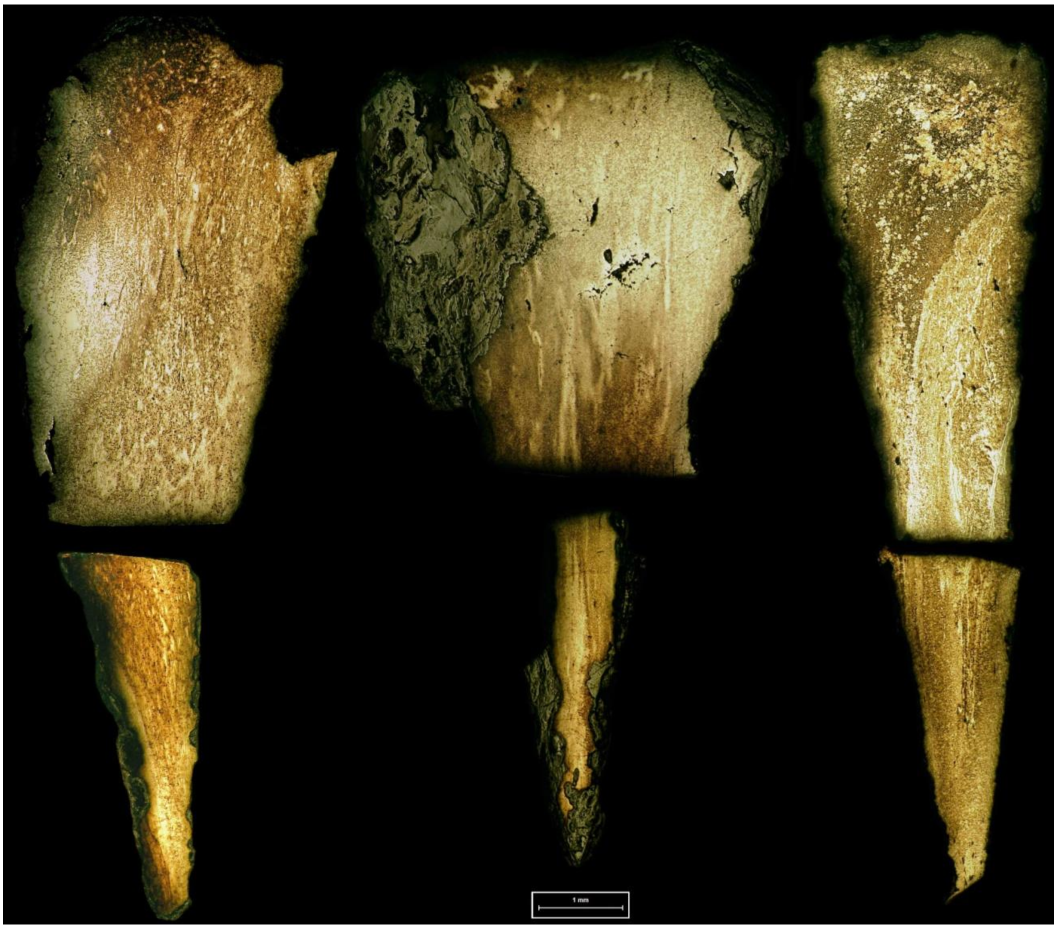


Figure 7.14: Three type 5 all steel knives with martensite cutting edges and pearlite backs suggesting gradient quenching. Left) 190:4485 from Fishamble street, Centre) 122:12499 from Christchurch Place and Right) 122:16826a from Christchurch Place.

Bainite was identified in the cutting edges of many knives, across all periods and cultural areas. This microstructure forms if the steel is cooled rapidly, but not fast enough to form martensite. In modern metallurgy, and experiments, this microstructure is formed by slack quenching the steel in oil. The quenching velocity of oil is much less than water, this means that it does not conduct the heat as much as water so the heat builds up around the steel being quenched (Reed-Hill 1973; Samuels 1999: 33-34). Fish or vegetable oil may have been used to quench these knives, but other liquids e.g. urine, blood, milk etc would more likely have been used and may have made up the more ritual and magical appearance of the blacksmith. In Beowulf there is mention of a blade that has been quenched in blood (Heaney & Donoghue 2002: 39), which could refer to its use in battle but it could also relate to how it was created.

Another possibility is that as the water was used to quench blades, the water temperature increases, which would in turn affect the quenching velocity and may result in softer bainite being produced (Reed-Hill 1973). To avoid this problem, modern quenching baths are usually large to allow the heat to dissipate rapidly, but since archaeologically we have not identified any quenching baths it would be difficult to determine whether this could be a factor. Residues found in Novgorod consisting of hammerscale formed during smithing and a matrix of sand and dust that formed around the base of a wooden barrel (diameter of 0.4-0.5m) are possible evidence for quenching tubs (Rehren 2008).

The almost 'magical' nature of quenching, taking relatively soft steel and turning it into a extremely hard material would have most likely been one of the guarded secrets of blacksmithing (Scott 1991a: 184-188; Reid & MacLean 1995). It is therefore possible that only high status smiths understood the heat-treatment of steels, and may even have restricted its use to the 'master' smith. If this was the case then apprentice or poorer rural smiths may not have had the skills necessary to heat-treat knives. This suggestion seems to have been supported by the lower number of heat-treatments seen in rural settlements when compared to urban or high status settlements, even though the steels used in the cutting edges could have been treated (Figure 7.15).

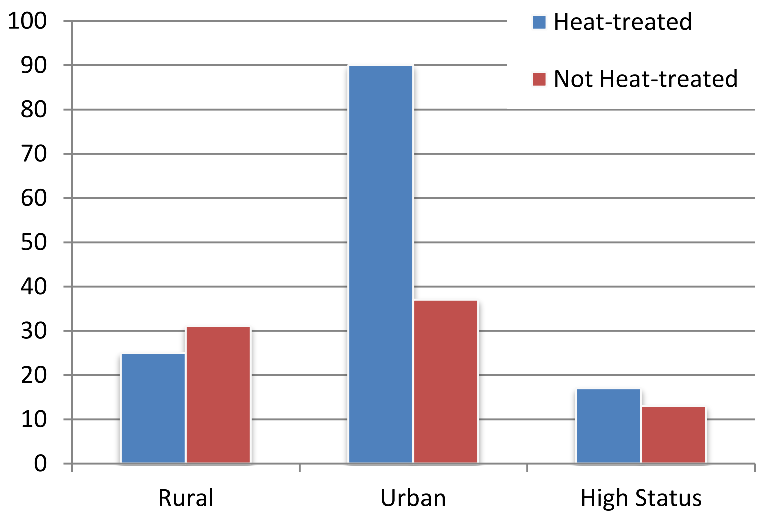


Figure 7.15: Bar chart showing the number of heat-treated cutting edges compared to the number of cutting edges that were not treated, in rural, urban and high-status/ecclesiastical settlements.

7.6 Finishing Touches

Once the knife has been forged, shaped and heat-treated the final task would be to sharpen the cutting edge. Forging the blade could not achieve the overall sharp cutting edge needed. Hone stones of varying grain size would be used to sharpen the cutting edge (McDonnell *et al.* Forthcoming). It is unknown exactly how the early medieval knife blade would have appeared. There are two possibilities, either the knife surfaces would be entirely polished or they could have been left mostly oxidised, except for the cutting edge which would have been polished during sharpening. Both suggestions have advantages and disadvantages, and there are also arguments both for and against each.

In modern metallurgy iron and steel is often polished and shiny, and we often project this image on to ancient metallurgy, i.e. knights in shiny armour (Gilmour 2008). There is evidence that some knives, and other tools or weapons, were polished particularly when you consider pattern-welded knives and swords (Figure 7.16). In these cases the etching process to bring out these patterns would only work if the metal was polished. Even the knives that had not been pattern-welded would have revealed interesting patterns if etched, and this would certainly explain the knives that used iron and steel in unusual combinations. The main disadvantage of polishing the iron knife would be that it is exposed to the air and would therefore suffer from corrosion. In Beowulf there are many mentions of shiny, glittering or gleaming blades (Heaney & Donoghue 2002: 8, 35, 65), this suggests that at least some weapons were polished

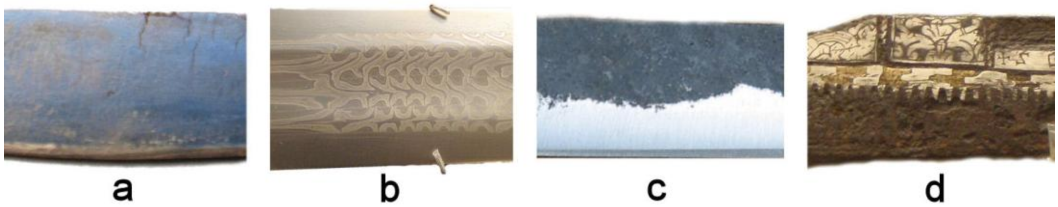


Figure 7.16: Four possible appearances for Anglo-Saxon iron; a) sharpened and polished knife, b) polished and etched metal to reveal the pattern, c) oxidised knife except for the cutting edge which has been sharpened and d) knife with non-ferrous inlays in a oxidised and corroded surface (source author).

The other option is that the knife is left oxidised with a black appearance, or underwent patination induced by other chemical processes as this may have acted as a protective film against corrosion (Figure 7.16; Gilmour 2008; Scott & Eggert 2009). Our current understanding of the appearance of iron has been pre-set by past over-vigorous conservators who may have removed patination layers on ancient artefacts. Recent studies by Gilmour have suggested that not all iron was indeed ‘shiny’ (Gilmour 2008). This is supported by the presence of non-ferrous inlays, as these would have been more visible on contrasting oxidised black surfaces than the shiny grey metal (Figure 7.16).

This research suggests that a combination of the two options was most likely in use, as there is evidence for both pattern-welded or composite iron alloy knives and knives with non-ferrous inlays. Once the knife had been prepared a handle would have been added. As mentioned above the vast majority of the knives had a distinct tang interface on both sides, or alternatively on one side. This would have made attaching the handle much easier.

7.7 Use, Wear and Repair

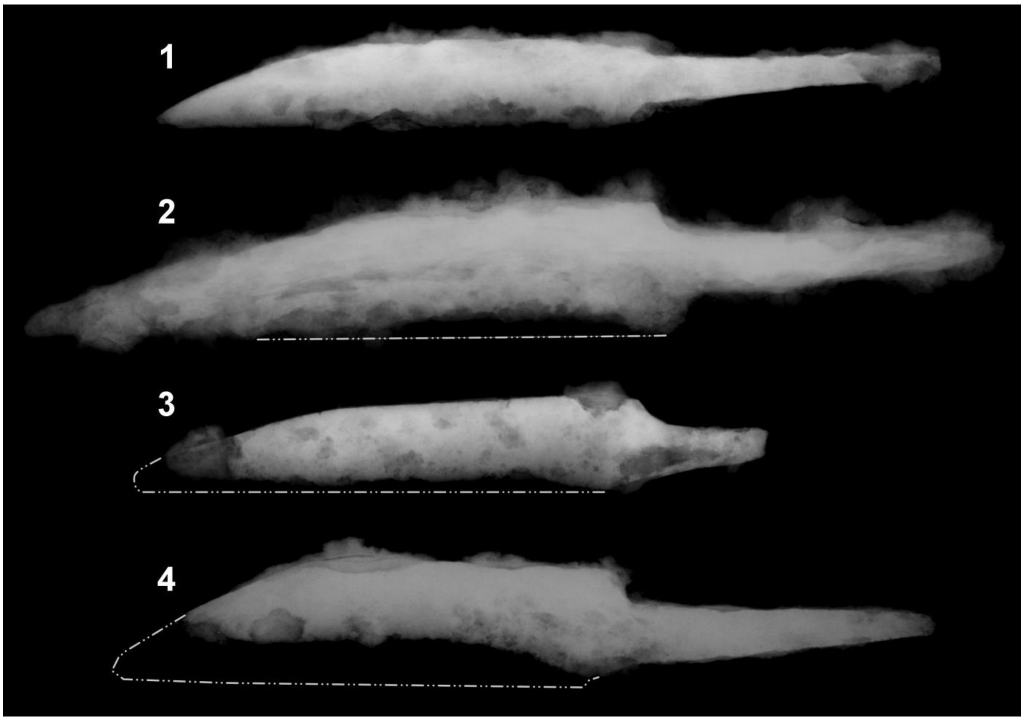


Figure 7.17: X-radiographs of knives from Burdale and Wharram Percy showing the various degrees of wear. 1) Un-worn Burdale knife 244, 2) slight wear present Wharram Percy knife 237, 3) some wear in knife 307 from Wharram Percy and 4) a heavily worn knife 44 from Wharram Percy.

As the knife is used it suffers wear, both from the activity taking place but also from the subsequent re-sharpening (Figure 7.17 and 7.18). Previous studies have suggested that the typical S-shape curve seen on many worn knives were likely to relate to the manufacturing technique used, i.e. the type 1 knife (Figure 7.17; Ottaway 1992). This has been confirmed by the analysis of wear seen on knives sectioned during this research as the type 1 knife appears to have a relatively larger proportion of wear. This was likely due to the steel strip running through the blade which, when sharpened, would continue to produce a steel cutting edge, no matter how much the knife is used (Blakelock 2006; Kendall

2009). Unsurprisingly the type 0 and type 3 knives had the higher proportion of heavily worn knives. The type 4 and 5 knives in this study were not heavily worn, and most had only slight, or no evidence of wear.

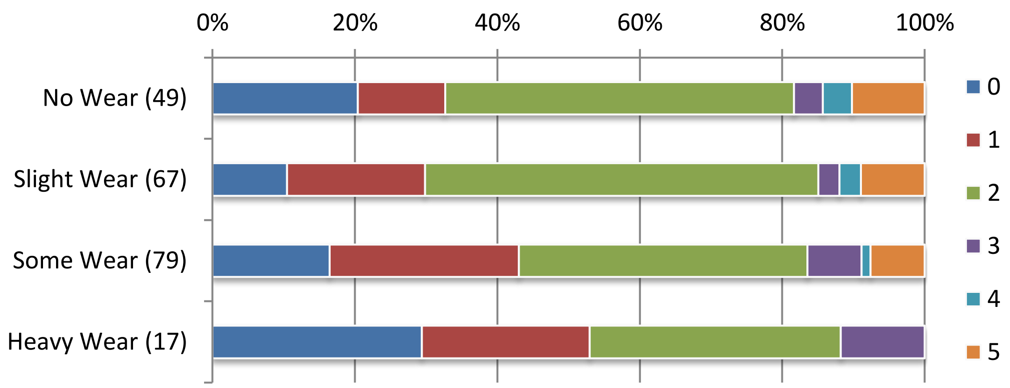


Figure 7.18: Stacked bar chart showing the relationship between knife manufacturing methods and the amount of wear present (based on figure 7.17). The raw data is available in table 2.8 in Volume 2. The manufacturing typology is in the appendix volume on page 38.

When the alloys used in the cutting edges are considered, rather than the manufacturing method, it becomes clearer that those knives suffering from highest wear are often the ones that have not been heat-treated (Figure 7.19). This is either due to the absence of a steel cutting edge, which has perhaps worn through the steel into the knife back. Or when steel is present, the knife has been sharpened continuously but no heat-treatment was re-applied.

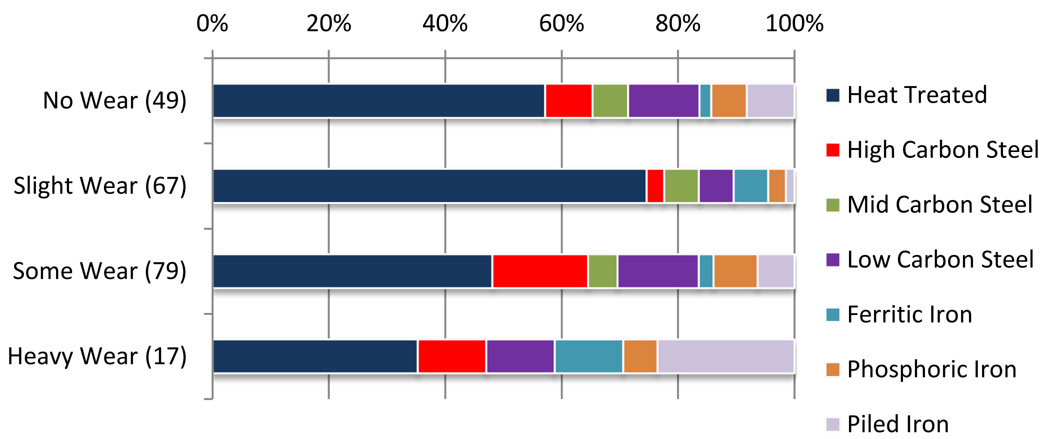


Figure 7.19: Stacked bar chart showing the relationship between iron alloys present at the cutting edge and the amount of wear seen. The raw data is available in table 2.9 in Volume 2.

Even so the biggest factor affecting the wear is how the knife was used, and what it was used for. Knives, although small, could be repaired. Even so, very few show evidence of repairs. Knives that were repaired occur both in rural and urban contexts. The repairs to knives in rural contexts were often not very good, and the smith used iron alloys that were soft and that could not be heat-treated, particularly in Wharram Percy. In the urban settlements the repairs were usually excellent, with high quality steels used and heat-treatments applied making it difficult to distinguish the metal between the cutting edge, and the repair.

Some knives appear to have been deliberately damaged before they were deposited. The large number of bent knives at rural settlements, along with the higher proportion of piled iron, suggests that they may have been bent prior to recycling. Most of these knives could not be damaged through normal use, instead the high temperatures reached in the blacksmith forge would be necessary. Bending the knives would allow the blacksmith to determine what iron alloys were present.

The few pattern-welded knives found in the urban settlements, e.g. York and Dublin were broken, the fracture patterns seen on these knives could not be created through normal use. The metallographic examination of both knives revealed that they had been heated, reducing their hardness, which suggests that these knives were deliberately broken before burial. This could therefore suggest some form of 'ritual' deposition of these high status objects. Unfortunately, the nature of the excavations at York and Dublin mean that it is impossible to determine exactly which context these knives derived from.

7.8 Viking Dublin Craft Activities

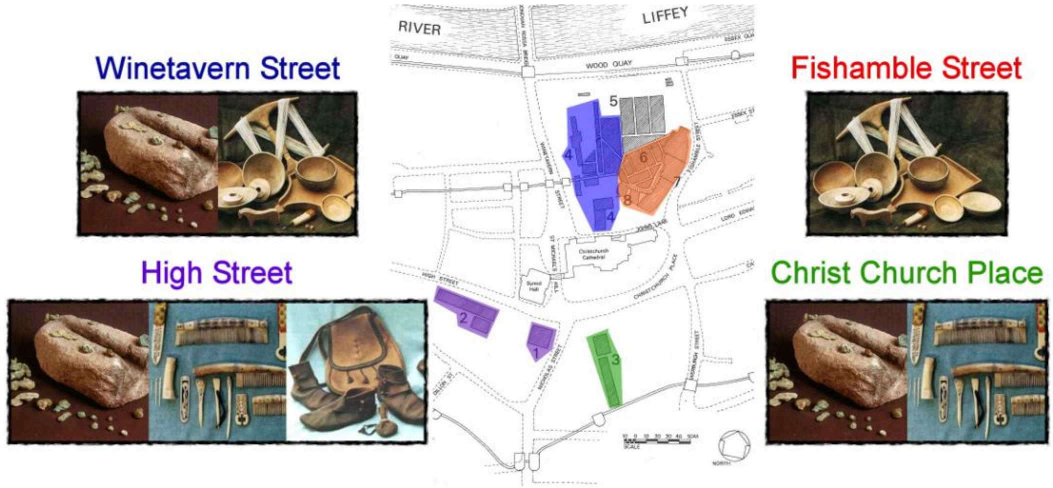


Figure 7.20: Map of Viking Dublin showing the main excavations and the different craft activities taking place. Area 4, Winetavern Street had evidence for metal and wood working; Areas 6, 7 and 8 Fishamble Street had woodworkers; Areas 1 and 2, High Street had metal, bone, antler and leather workers while area 3, Christchurch Place had evidence for metal, bone and antler working.

Excavations were carried out in various locations across Viking Dublin. The majority of these had similar date ranges (10^{th}-12^{th} Century AD) except for Fishamble Street which had the earliest dated knives (9^{th}-11^{th} Century AD). The excavations revealed clear evidence for specific craft areas (Chapter 5 section 5; Figure 7.20). These different crafts would all require knives during the process, and different properties were most likely required in the knives. Crafts such as wood and antler working would have required hard and tough cutting edges, while leather working would have required a sharp edge but not necessarily a hard cutting edge. Metal workers may have used knives to carve out patterns or possibly for cutting small bits of non-ferrous metal. The crafts would have also resulted in different wear patterns in the knife. To investigate whether this is the case a selection of knives from each different area were sampled.

Iron Alloy Choice

The vast majority of the cutting edges in all four excavation areas had been heat-treated and therefore must have been mid to high carbon steels, above 0.3% carbon (Figure 7.21). When the alloys in the knife backs were examined it was clear that similar alloys were present in the Christchurch Place and Fishamble Street knives. These two areas had the highest proportion of high to mid carbon steel in the knife backs. In stark contrast in the knives from Winetavern Street and High Street piled and phosphoric iron dominated the assemblage. The Dublin knives unlike the Coppergate knives used very little ferritic iron.

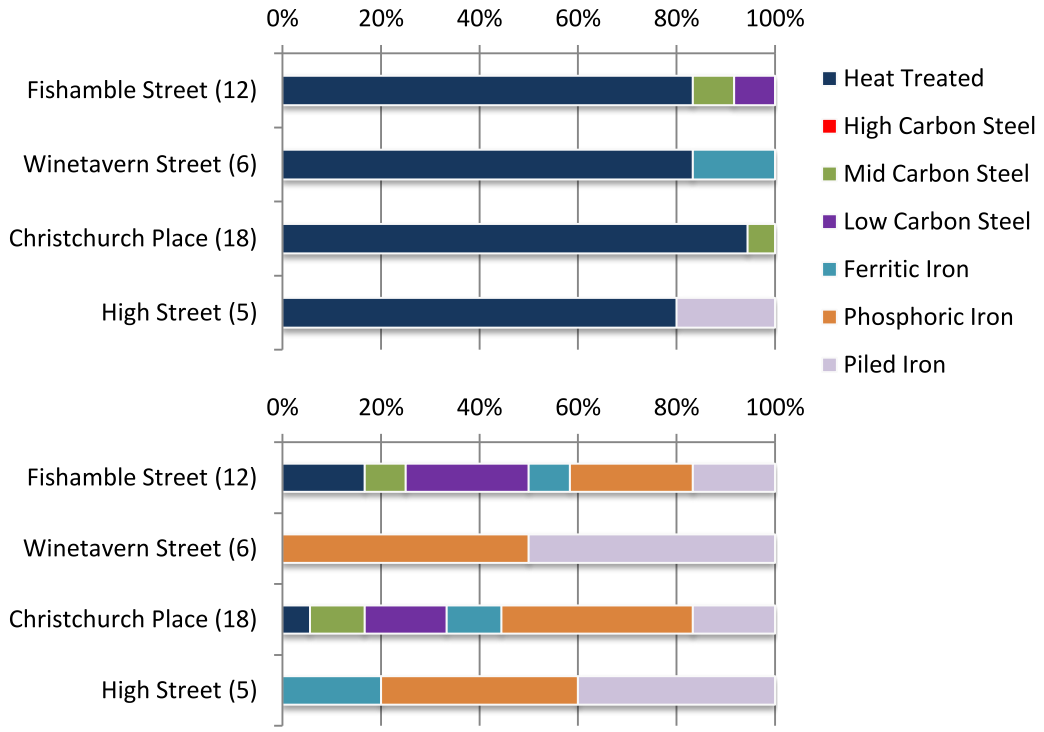


Figure 7.21: Two stacked bar charts showing the alloys used in the cutting edges (top) and knife backs (bottom) in the different areas of Viking Dublin. The raw data is available in table 2.5 in Volume 2.

Knife Manufacturing Method

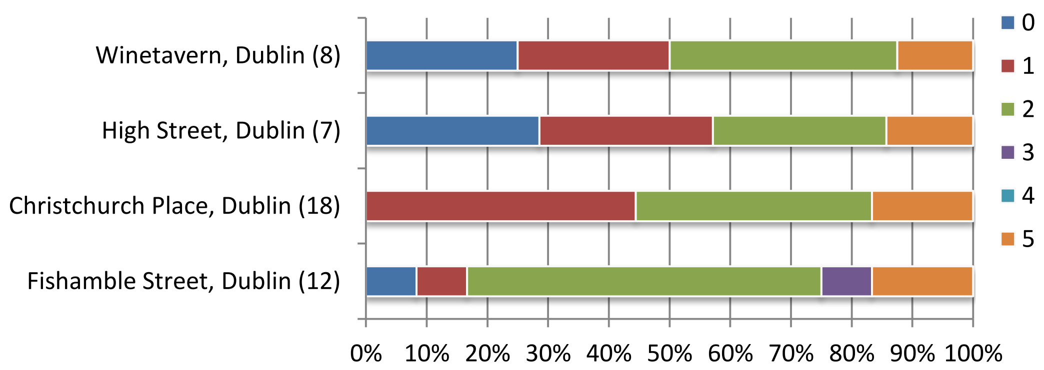


Figure 7.22: Stacked bar chart showing the different methods of knife manufacture in the different areas of Viking Dublin. The raw data is available in table 7.3. The manufacturing typology is in the appendix volume on page 38.

There were some clear differences in the way knives were manufactured (Figure 7.22 and Table 7.3). The biggest difference was seen at Fishamble Street where the vast majority of the knives were butt-welded. This may have been due to differences in date, as Fishamble Street was dated slightly earlier than the others, but even so this does not entirely explain the differences. In Christchurch Place there was a higher proportion of type 1 and 5 knives, along with the type 2 knives. While at Winetavern Street and High Street there was a range of different knife types, including a few basic type 0 knives.

Shape

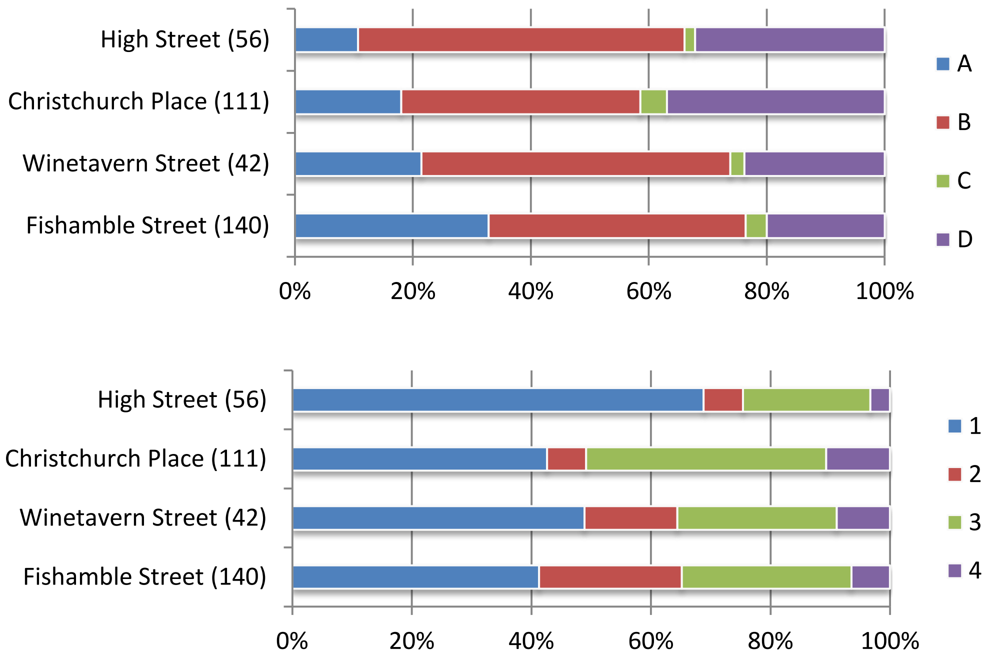


Figure 7.23: Two stacked bar charts showing the knife back shapes (top) and tang interface (bottom) in the different areas of Viking Dublin. The raw data is available in table 5.36. The knife shape and tang interface typologies are in the appendix volume on page 38.

As previously discussed in section 4, it is unknown whether certain crafts needed knives of a specific shape although some must have, e.g. knives for surgery, seaxes etc. The analysis of knives from Viking Dublin revealed similar proportions of each knife type. At Christchurch Place there were more straight backed knives, whereas at Fishamble Street there were fewer straight-backed knives but more angle-backed knives (Figure 7.23). Analysis of the tang interfaces revealed similar proportions between Christchurch Place, Winetavern Street and Fishamble Street, but far more examples with distinct tang interfaces on both sides at High Street (Figure 7.23).

Sites		Manufacturing Typology and Cutting Edge Data							Manufacturing Typology and Knife Back Data						
		0	**1**	**2**	**3**	**4**	**5**	**Overall**	**0**	**1**	**2**	**3**	**4**	**5**	**Overall**
Fishamble Street	Number	1	1	7	1		2	**12**	1	1	7	1		2	**12**
	Avg HV	232	644	969	386		896	**820**	124	385	256	242		674	**324**
	Range HV	232	644	612-1283	386		509-1283	**232-1283**	124	385	178-345	242		573-775	**124-775**
Christchurch Place	Number		7	8			3	**18**		7	8			3	**18**
	Avg HV		999	721			599	**809**		292.7143	255			436	**300**
	Range HV		473-1288	441-1288			362-927	**362-1288**		186-519	152-360			283--713	**152-713**
High Street	Number	2	2	2			1	**7**	2	2	2			1	**7**
	Avg HV	225	485	1062			1144	**670**	250	139	349			633	**301**
	Range HV	128-321	473-497	841-1283			1144	**128-1283**	128-372	107-171	321-377			633	**107-633**
Winetavern Street & John's Lane	Number	2	2	3			1	**8**	2	2	3			1	**8**
	Avg HV	135.5	551	724			490	**504**	307	332	230.6667			388	**295**
	Range HV	110-161	509-593	519-1144			490	**110-1144**	110-504	302-362	114-334			388	**110-504**
Dublin 10th–Early 11th	Number	3	2	10	1		1	**17**	3	2	10	1		1	**17**
	Avg HV	157	545	821	386		1283	**673**	121	235	252	242		775	**257**
	Range HV	110-232	473-593	441-1283	386		1283	**110-1283**	110-128	107-362	114-360	242		775	**107-775**
Dublin 11th	Number		9	7			5	**21**		9	7			5	**21**
	Avg HV		895	757			559	**769**		298	319			454	**342**
	Range HV		509-1288	457-1288			362-927	**362-1288**		186-519	152-334			283-713	**152-713**
Dublin 11th-12th	Number	2	1	3			1	**7**	2	1	3			1	**7**
	Avg HV	241	473	1050			1133	**748**	438	171	343			633	**387**
	Range HV	161-321	473	841-1283			1133	**161-1283**	372-504	171	321-377			633	**171-633**
Viking Dublin Settlement Total	**Number**	**5**	**12**	**20**	**1**		**7**	**45**	**5**	**12**	**20**	**1**		**7**	**45**
	Avg HV	**190**	**801**	**833**	**386**		**745**	**730**	**248**	**277**	**289**	**242**		**525**	**317**
	Range HV	**110-321**	**473-1288**	**441-1283**	**386**		**362-1283**	**110-1288**	**110-504**	**107-519**	**114-377**	**242**		**470-775**	**107-775**

Table 7.3: Table showing the number, average hardness and hardness range for the cutting edge and knife backs of knives from the different excavated areas of Viking Dublin, and also distributed by phase.

Heat-Treatment

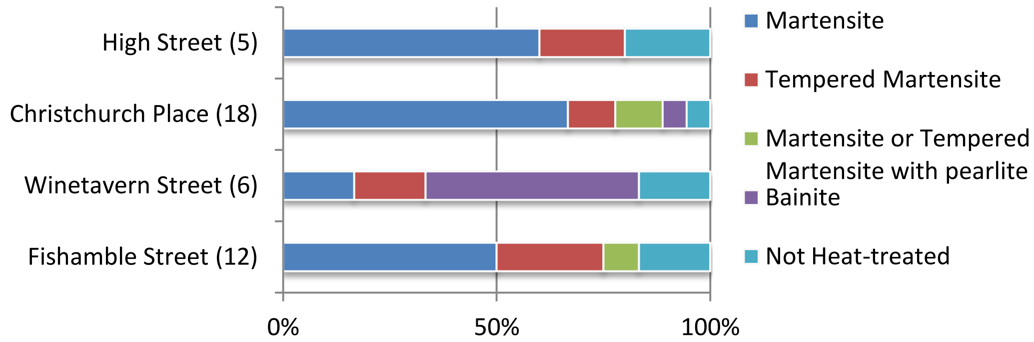


Figure 7.24: Stacked bar chart showing the distribution of knife heat-treatments in the different areas of Viking Dublin. The raw data is available in table 2.5 in Volume 2.

The vast majority of the knives from Dublin were heat-treated, but a range of different techniques were used, resulting in different cutting edge hardness (Figure 7.24 and Table 7.3). There were a high proportion of martensite cutting edges with extremely hard cutting edges, particularly at Christchurch Place, High Street and Fishamble Street where the high hardness was sought for crafts. The biggest difference seen in the heat-treatments was at Winetavern Street where there were a large number of softer bainite cutting edges, these would have been harder than steels that had not been treated at all.

Wear & Repair

The heaviest wear was seen in the knives from Fishamble Street where woodworking was being carried out. On the other hand, few of the knives from High Street suffered from heavy wear. This is to be expected, since to work leather sharp knives were required (Figure 7.25). At Christchurch Place 50% of the knives were not worn.

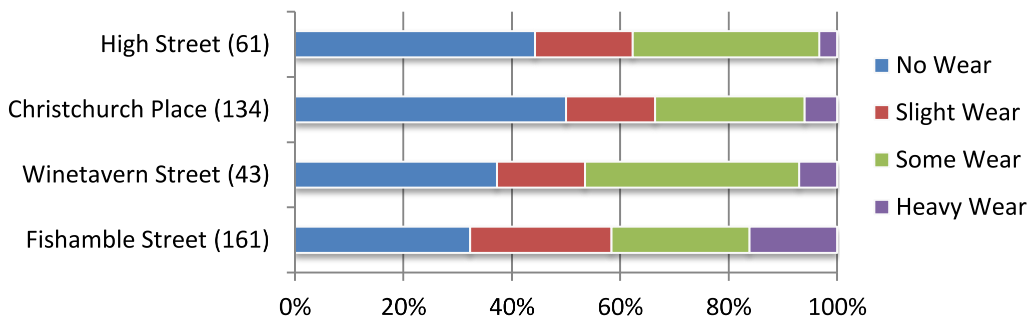


Figure 7.25: Bar chart showing the distribution of knife wear in the different areas of Viking Dublin. The raw data is available in tables 5.38.

Dublin Craft Summary

At Fishamble Street both wood and amber working was carried out. The knives in this area had hard martensitic cutting edges; even so, they suffered from heavy wear. The angle-backed shape of the knife would allow the user to grip and apply pressure when cutting wood or working amber. The backs of the knives were often made of hard and durable steel rather than piled iron seen in the other areas.

The excavations at Christchurch Place revealed evidence for bone and antler working as well as metalworking. Antler is much harder than wood and would therefore require harder cutting edges, therefore it is no surprise that the vast majority of the knives from this area were heat-treated. Many were martensitic, with very high hardness values (Table 7.3). The Christchurch Place knives were similar to the Fishamble Street knives as the backs were mostly steels rather than softer piled or phosphoric iron. Most of the knives had straight backs.

Winetavern Street had evidence for non-ferrous metalworking, but also some residual wood working from nearby Fishamble Street. These knives while angle-backed were poorer quality, using piled and phosphoric iron in the knife backs and with poorer quality heat-treatments. This supports the theory that knives with high quality and high hardness cutting edges were not required by the metalworkers.

At High Street there was a range of craft activities taking place including leather, metal and antler working. The alloys used in the High Street knife backs were poor quality with a high proportion of piled iron. The cutting edges of the knife were predominately martensitic. This would have allowed the blades to retain a high hardness, but also a sharp cutting edge. This in addition to the small amount of heavy wear at the site suggests that these knives were predominately used for leatherworking.

7.9 Specialisation and Early Medieval Ironworking

Craft specialisation in the ceramic industry has been intensively studied (Brumfiel & Earle 1987; Costin & Hagstrum 1995; Costin 2000; Sillar & Tite 2000) but to date few studies have investigated craft specialism in the metalworking industry (Kristiansen 1987; Ottaway 2001), and no studies have focused on ironworking industry. This section therefore places the early medieval ironworking industry in England into its archaeological context; including the environmental, political, social and economic systems. Specialisation is defined as the 'repeated provision of some commodity or service in exchange for some other' (Costin 1991: 3). Even so there are degrees of specialisation, i.e. different ratios of producers to consumers and also different types of specialisation with a clear distinction between production of high value goods for elite consumption or utilitarian items for general distribution (Brumfiel & Earle 1987). There are four main parameters used to help identify specialisation; context or the nature of production control, the regional concentration of the production facilities, the scale of the production and finally the intensity of the production (Costin 1991). Each of these factors, much like the choices made by the smiths, will be influenced by any social, economic, political or environmental variables as well as the skills and knowledge of the craft workers themselves (Costin 1991; Sillar & Tite 2000). Identifying these parameters in the archaeological record is difficult. There are two types of evidence that we can rely on: direct evidence in the form of production sites themselves, but also indirect evidence from the objects being produced, i.e. standardisation, efficiency, skill and regional variation (Costin 1991).

The first parameter to consider is the context of the production which is determined by who is in control: for example is it controlled by the elite, or did it cater for the community? In pre-industrial societies attached, i.e. elite specialists, would produce luxury items including weaponry and would have been heavily controlled with limited distribution, while the independent specialists would be producing different types of goods, mostly utilitarian, and would be motivated by decisions based on the cost, quality and social demands (Brumfiel & Earle 1987; Costin 1991). It is clear that in the early medieval period some iron objects would have been produced, or at least commissioned, by high status individuals, for example, pattern welded swords (Hinton 2000: 112-113; Hinton 2005: 98-99, 165). There are documentary sources that confirm that some blacksmiths were under the control of high status individuals (Scott 1991a: 184-188; Hinton 2005:

98-99, 165). There is plenty of evidence for smithing taking place in most settlements, but since very few, if any, definite smithy buildings have been located (Birch 2011) it is impossible to know whether they were associated with elite structures, suggesting attached specialism. Instead, the vast majority of the early medieval evidence points to the general smith being independent either located in common domestic locations in rural settlements or urban workshops with open access (Hinton 2000: 112; Hinton 2005: 36). Most middle to late Saxon smelting sites appear to be associated with religious or high status settlements (Haslam *et al.* 1980; Starley 1999), although the limited number of examples excavated may introduce bias.

Concentration of production focuses on how specialists are distributed across the landscape and their relationship between each other, and with the consumer. In these cases there is a strong relationship between the environment, i.e. location of the raw materials, but also depends on the social hierarchy and settlement organisation (Costin 1991). In economies like the early medieval period the presence of markets and marketplaces allow producers to nucleate (Costin 1991; Blinkhorn 1999). The limited evidence for smelting of iron suggests that these production sites were nucleated near to the raw materials (Nørbach 1999: 245; Birch 2011). On the other hand smithing was carried out in practically every settlement, although there is clearly increased production in the urban settlements (Birch 2011; McDonnell *et al.* Forthcoming).

Scale of production reflects the number of craft workers and whether the workshops are small with individual or family based production systems or large factories with wage-based labour. This can be determined by the size of the production sites. Larger workshops may indicate large scale production, while the presence of evidence for domestic activities will suggest family-based production (Costin 1991). Smelting is a complex process and would have required many people to run a single smelt, although only one master smelter would be necessary as the bellows could be run by unskilled labour (Ottaway 2001). It is therefore possible that one family could have successfully run multiple smelts over a period of time. Larger scale operations with multiple smelts carried out at the same time or continuously would require a larger workforce to sustain it; to gather ore, create charcoal and build furnaces. In the Roman period the scale of smelting varies but many sites yield up to 1000s of tons of slag (Bayley *et al.* 2008). The relatively small quantities of slag found at early medieval sites suggests that smelting was on a fairly small scale (Birch 2011). Smithing took place across the country in many settlements, but never on a large scale, with small amounts of smithing slag found at each site. Instead it appears that in urban settlements where more debris was found, ironworking was being carried out in many different small workshops (Hinton 2005: 166).

	Smelting	Rural Smithing	High Status Smithing	Urban Smithing
Context	Attached?	Independent	Unknown	Independent
Concentration	Nucleated	Widespread	Widespread	Widespread
Scale	Small	Small	Small	Small
Intensity	Full-time or Seasonal?	Part-time or Seasonal	Unknown	Full-time
Standardisation	No	Yes	Yes	Yes
Efficiency	Yes	Yes	Yes	Yes
Skill	High	Poor	High	High

Table 7.4: Table showing the nature of specialisation in early medieval smelting sites, and smithing sites in various settlements.

The final parameter is the intensity of specialisation which reflects the amount of time producers spend at their craft. This is very difficult to identify archaeologically. There are two extremes. The first is the casual part-time specialist who augments craft activities with subsistence work, while the other is the full time specialist who exchanges goods produced for other provisions (Costin 1991). Another aspect to bear in mind is the ability to leave activities if and when required (Sillar & Tite 2000). For example, iron smelting is a continuous process which, if interrupted, could result in a failure, whereas smithing could be taken up or left as demands allowed. The density of production debris has been used in the past to distinguish between full- and part-time production, but previous studies have suggested there is insufficient data to confirm this (Costin 1991). This was for ceramic production, but many iron smelting experiments have allowed archaeometallurgists to estimate the amount of iron produced in a single smelt, compared to the amount of slag produced (Crew 1991; Hjärthner-Holdar *et al.* 1997; Nørbach 1997). This data therefore suggests that early medieval smelting was not very intensive, although this is influenced by the lack of known smelting sites. Instead the evidence points to part-time or seasonal production. There is much less experimental data for smithing, but the nature of the different settlements themselves points to different intensities in smithing activity. A rural smith would most likely need to also take part in the rural economy as suggested by the other tools and household items at these sites (McDonnell *et al.* Forthcoming), perhaps blacksmithing, on a part-time or seasonal basis. On the other hand, urban smiths would not have been required to create their own subsistence, although they may have been involved in other crafts as well as smithing, so would have been full time craft specialists (Hall 2004: 293).

Standardisation is usually assumed to be linked to specialisation mostly because it is more efficient, is demanded by local regulations, is more economic or because the consumer demands it (Costin 1991). The variety of different smelting slag from tap or raked slag to slag blocks (McDonnell *et al.* Forthcoming) suggests that the smelting industry was very diverse with many different technologies. The standardisation of knives in the 7th century, and the change in the 10th century, strongly points to craft specialisation. This did not occur entirely in the urban settlements but was widespread. Even so, knife manufacture in this period was not entirely standardised, with different iron alloys being used for different knives. This could suggest that even in the urban settlements there were many different small workshops present producing a range of different knives.

Efficiency is also a key feature of specialised production and is a measure of time, energy and raw materials (Costin 1991). In smelting, efficiency is often achieved by locating the smelting near to the raw materials rather than places of population, whereas smithing was carried out near to the consumers (Veldhuijzen & Rehren 2007; Birch 2011). This is clearly seen in the early medieval period, as the smelting sites were located near ore sources while smithing slag was found in every settlement. In addition, the manufacturing method of the type 2 knives, while technically not the most efficient use of time, was the most efficient use of the costly steel. The type 1 knife used more steel, but was much more efficient to construct.

The third type of indirect evidence that can be determined by examining the final product is the skill of the craft worker (Costin 1991). Experiments and evidence from archaeological failures has shown that smelting is an extremely skilful process: any small mistake or omission during the production process may lead to an unsuccessful smelt (Crew 1991; Ottaway 2001). That, in addition to the ritual aspects of the process, has shown that smelting is a skilful and specialised craft, requiring at least one skilled worker. Smithing, like smelting, was a skilled activity. Research has shown that the early medieval blacksmiths were able to choose the correct iron alloys to use and also applied effective heat-treatments. Even so, this research has shown differences between settlements. For example, the urban smiths were clearly more skilled, applying more heat-treatments than their rural counterparts, suggesting that they were more specialised.

The final type of indirect evidence is the distribution patterns and regional variations in production. It is assumed regions with few variants infer high specialisation while those with more variation suggest more production centres (Costin 1991). This is a difficult parameter to understand in archaeological iron. The analysis of the iron knives has suggested that there are many centres of production, both urban and rural, and there is clear variation between the different groups, but there is also a certain amount of bias as this research was unable to analyse knives from across the country so more work is needed.

7.10 Summary

This chapter has clearly shown that it is possible through metallographic examination to reconstruct the manufacture of a knife. It has also revealed that the early medieval blacksmith made a number of technical choices throughout the process. Some of these choices were influenced by the function of the knife and/or the cost of the raw materials while other decisions were based on the skill and knowledge of the blacksmith.

The most important decisions the blacksmith would make is the type of iron alloys to be used. This would have an impact on later stages in the production process i.e. manufacturing methods and heat-treatments, and is influenced by the cost and availability of the relevant alloys. Once the iron had been selected the smith would have to decide how to construct the knife. This was heavily influenced in the middle to late Saxon period by what appears to be the preferred, standardised, manufacturing method at the time (type 2 between the 7th-10th century, type 1 after the 10th century). In the post-Roman and early Saxon period a range of different methods were used. The next task was to shape the knife, and this research has suggested that shape was likely related to the function, especially with the small, angle-backed type 2 knives which would have been ideal for craft working. Heat-treatments were carried out to bring the best out of the steels used and were found in most settlements. Urban and high-status settlements had a higher proportion of treated knives, compared to rural settlements, pointing to high skilled blacksmiths in these locations. The heat-treatment techniques carried out were also influenced by cultural choice, as revealed by the Viking Dublin knives that showed Viking manufacturing techniques, but the Irish heat-treatment tradition. Once the knife had been formed and treated the final task is to sharpen the blade, some knives were also polished and etched to reveal any patterns.

Chapter 8: Conclusion

8.1 Introduction

There were a number of metallographic studies of Early Medieval iron in the 1980s-1990s. These studies provided information about iron production and manufacturing, but the number of assemblages was limited by what was being excavated at that time. These were middle to late Saxon urban settlements and early Saxon rural cemeteries.

The early medieval period was a time of change, with the adoption of pagan furnished burial rites, and then their abandonment, after the introduction of Christianity. There were also changes in settlement patterns with the re-development of urban settlements in the middle Saxon period after the earlier urban settlements were abandoned at the end of the Roman period.

A recent review of iron knives revealed some clear differences between the assemblages examined and several hypothesises were put forward (Blakelock & McDonnell 2007).

The main aim of this research was to explore the patterns seen in this previous research and to add more data from new assemblages, targeting specific periods and site types, to gain an understanding of the early medieval iron industry. This study was carried out using a combination of x-radiography and metallographic examination and also incorporating SEM-EDS analysis.

Five objectives were considered to achieve this aim. The initial objective of this research was to investigate the differences observed during a review of metallographic studies, in particular the difference in knife manufacture in the early Saxon rural cemeteries and the middle to late Saxon urban settlements. Several possible theories were put forward and these possibilities were all explored and discussed (sections 8.2 and 8.3). The second objective was to determine whether early Saxon iron knives reflect the status of their owners by comparing them with grave goods present, as well as the age and sex of the individual (section 8.4). The third and fourth objective of this research project was to investigate whether different cultural groups influenced the way knives were manufactured or the types of iron alloys used in England, and Viking Europe. This has revealed some interesting differences between Anglo-Scandinavian knives from Britain and the Irish knives from Dublin, as well as differences from the Viking iron tradition (section 8.5). The final objective of this study was to investigate early medieval ironworking technology, specifically the manufacture of a complex artefact like the knife. This research has attempted to reconstruct the stages in the production of a knife, and discussed some of the decisions made by the early medieval blacksmiths. A chaîne opértoire was constructed for early medieval knife manufacture, this includes stages and decisions made but also the nature of iron specialism and craft skills (section 8.6). Many of these processes and decisions can then be applied to other iron artefacts.

The final section of this conclusion will suggest some areas for further research (section 8.8). These studies include both archaeological and typological research, and experiments and subsequent analysis to gain a better understanding of early medieval knives and the iron industry as a whole.

8.2 Differences between Urban and Rural Settlements

One of the hypotheses put forward to explain the difference in knife manufacturing techniques in the previous studies was that knives recovered from rural sites would be different from those in the contemporary urban settlements. The examination of knives from rural settlements has shown that there is no difference in the way knives were manufactured in rural settlements when compared to urban sites, or even high status ecclesiastical settlements. This suggests that there was a standardised way of manufacturing knives in the middle to late Saxon period and this was not limited to the more ‘skilled’ urban blacksmiths. The type 2 knife makes the most economical use of steel which would have been more time consuming to manufacture, may have been scarcer and/or have travelled large distances. This in turn points to the technique being preferred for economic reasons rather than from a cultural view point.

Instead, the biggest difference was the quality of the knives. Even though most iron alloys were available, many of the rural knives were not heat-treated to bring the best out of the steels used. Practically every settlement in the early medieval period had access to blacksmiths, as evidenced by the presence of smithing slag at most sites. But even within a smithy different skill levels are apparent, e.g.

master vs apprentice. This study therefore points to a lack of what could be classed ‘master’ smiths in the rural settlements, with the knowledge of how to apply this final heat-treatment technique. There were also some dramatic differences in how the knives were repaired. In the urban settlements the repairs were done using high quality steels and heat-treatment techniques while the rural smiths had used poor quality iron to repair their knives, resulting in softer cutting edges. In addition a higher proportion of piled iron in the rural settlements suggested that recycling of iron was most likely taking place, whereas the urban settlements had access to better quality iron alloys.

8.3 Differences through Time

The next hypothesis was that there were changes in ironworking technology and knife manufacture between the early period (c. AD410-650) and the middle to late period (c. AD650-1100). This was investigated by analysing knives from early Saxon settlements, but also by examining knives from later dated Saxon cemeteries to compliment earlier studies.

This analysis revealed similarities between iron knives in the early settlements and cemeteries, with a range of different manufacturing types present rather than the type 2 dominated assemblages seen in the later Saxon period. The analysis of securely dated cemetery knives revealed a dramatic change in technology in the 7th century. This coincided with the development of some urban trading centres, which may have facilitated the movement of ideas and ironworking techniques. The changes in the 7th century may also relate to new levels of control as kingdoms emerged and the new religion, Christianity, was adopted.

The analysis also revealed differences in alloy use between the early period settlements and cemeteries, and the later Saxon settlements. There were fewer heat-treatments carried out; some of this is influenced by the range of manufacturing methods. More ferritic iron was identified in the cutting edges in the earlier sites in place of the mid to high carbon steels present in the later Saxon sites, but surprisingly piled iron was less frequent in these early settlements.

The final hypothesis was that knives were being made for burial. The evidence from the knife wear suggests that this is not the case. Instead the majority of the knives appeared to be those used during the individual's life, confirmed by the wear. Even so, there are some differences between the early settlement and cemeteries which does suggest that at that period some knives were made for burial. The range of iron alloys present in the early settlements and cemeteries are very similar, but the biggest difference was the number of heat-treated blades. The cemeteries had a much higher proportion of heat-treated cutting edges (41 out of 83) whereas the settlements had a smaller number (10 out of 31), even though some of the settlement knives had the potential to be treated. A possible explanation for these differences could be that knives for burial had heat-treatments re-applied before being placed in the grave. An alternative is that some of these knives were being made for burial, suggested by the higher quality iron alloys used, that is low carbon steel was used rather than piled iron.

8.4 Cemetery Analysis

The second objective of this research project was to compare grave knives with their respective owners to determine whether age, sex and/or the status of the deceased influenced the manufacturing methods or alloys used. It has already been shown that there were some differences between the knives in settlements compared to the contemporary settlements. Several theories have been put forward to explain these differences. The first is that poor individuals may have kept the deceased's knife, particularly if it was good quality, substituting a cheaper token knife for burial. There is little evidence for this. Many of the knives that may have been made for burial, with no evidence for wear, were associated with higher status individuals, constructed using a variety of techniques and often good quality. An alternative theory is that the majority of burial knives were those used by the deceased individual in life. If this was the case it might be expected to see the quality of that knife (manufacturing methods, heat-treatments and alloys used) reflected by the individual's standing in society (sex, age and status).

The analysis of the cemetery knives suggested that younger male individuals between the ages of 15 to 30, or those of lower status, often had type 2 knives, and/or knives that were heat-treated. This pattern was not seen in female graves, where type 2 knives were deposited with older women over the age of 30. The evidence from chapter 7 suggests that the type 2 knife in settlements were associated with craft activities, therefore this analysis of early Saxon knives could be revealing which sectors of early Saxon society were craft workers. This was also supported by the heat-treatments of knives, as younger men (15 to 30 years old) and older women (over 30 years old) had the highest proportion of heat-treated cutting edges.

There were few obvious patterns when other manufacturing types were compared. Some knife manufacturing methods only occurred with individuals over 20 years of age, such as the type 1 and type 5 knives, whereas the cheaper plain iron type 0 knives more often occurred with younger individuals, i.e. under 15 years old. In addition when the status of an individual was considered it was clear that the better quality knives, type 4 and 5, increased as the status increased. The proportion of heat-treatments in male graves was stable as the status increased but in female graves this was more varied, suggesting no connection between heat-treatment and status. Even so the absence of type 0 knives in the lower status male burials in addition to the presence of piled iron knives in the higher status female graves suggests that knives may not always represent the status of the individual. This analysis was hampered by the relatively small sample size and therefore more metallographic research of early Saxon cemetery knives is required to investigate further the patterns observed.

8.5 Anglo-Saxons, Irish and Scandinavians

The third objective of this research was to investigate the changes in knife production and therefore iron technology, through the early medieval period. Knives from the early period and the middle to late Saxon periods were compared. This revealed two changes in manufacturing method, the first in the 7th century, from a range of types to predominately type 2 knives but also in the 10th century there was another change in knife manufacture in Britain, when the type 1 sandwich weld became more common. There was a reduction in quality and cutting edge hardness, even though the number of heat-treatments taking place slightly increased. This change in preference, as well as the reduction in quality, points to mass production of knives occurring in the 10th century, particularly in the urban settlements. Possibly related to the increase in population in the 9th century.

Comparison between the knives from England and those from Viking Europe revealed that the type 1 knife is the predominate manufacturing technique in Europe until after the 11th century. The fourth objective of this research was to investigate early medieval knives from across Europe to determine whether the Vikings impacted on local ironworking traditions. Analysis of the knives from Viking Dublin, and subsequently those from Britain revealed significant differences between the two countries. In Viking Dublin there was a higher proportion of type 2 knives and type 5 knives suggesting that 'native' Irish techniques were still continuing, also supported by the heat-treatment technique carried out resulting in martensitic cutting edges. The analysis of the knife back alloys also revealed some differences; in England ferritic iron was found in urban sites but in Viking Dublin there was a higher proportion of phosphoric iron.

Very few studies of knives from pre-Viking (5th-9th century AD) Europe have been carried out; the exception is Helgö which revealed a similar pattern in manufacturing techniques and alloys to early and middle Saxon England. When knives from both Britain and Ireland were compared with those from Viking Europe it was clear that between the 10th-12th century AD the predominant manufacturing technique was to sandwich weld steel between iron, either ferritic or phosphoric. This suggests that the change in manufacturing methods in the 10th century was across Europe and it could therefore be argued that there was diffusion in ironworking techniques and methods across Europe. Viking Dublin was the exception to this as they continued manufacturing the type 2, preferring to instead continue with their own 'native' iron technology.

8.6 Early Medieval Ironworking Techniques

The final objective of this research was to reconstruct the manufacture of the knife, the steps taken by the blacksmith and the decisions made. This therefore contributes to our overall understanding of the early medieval iron economy. In this research the chaîne opértoire, sequence of processes, for an iron knife was constructed which can be applied to other early medieval iron artefacts. The metallographic analysis has revealed a clear sequence to the manufacture of an iron knife. At each stage the blacksmith would have to make a number of decisions based on the intended use of the knife, but also the cost of production, in terms of cost of materials but also in blacksmith hours. The ability of the smith should also be taken into account, as well as the location and cultural influences.

Using the evidence gathered during this analysis it is possible to start placing ironworking technology into its archaeological context (Table 8.1). The initial steps when creating a knife would be to create the raw materials needed, i.e. iron and steel. Very few smelting sites have been identified but those that have reveal a specialised industry, which may have been under the control of the early medieval elite. These industrial sites, although small-scale would most likely have involved full-time processes, although they might have been full-time, but seasonal activities carried out during winter months. To increase the efficiency of the process they were located close to the raw materials, which meant that the iron created would have to be transported, perhaps long distances, to the smithy workshops.

The first step the blacksmith constructing the knife would make is to select an iron alloy. This was shown to be heavily influenced by the properties of the metal; for example steels could be heat-treated and were harder than ferritic and phosphoric iron. Availability of the iron was another consideration, phosphoric iron appears to be much more common than ferritic iron which suggests that the majority of smelting sites were using the commonly available bog ores. Ferritic iron and high-quality, high carbon steels tended to be used by the more specialised urban smiths, suggesting that these may have been more easily accessible to these urban smiths, or perhaps more costly. Piled iron tended to be more associated with rural settlement which could be explained if this was formed during recycling of iron.

Once chosen, the next step in the process is to weld these alloys together to create high quality tools. This was influenced again by the knife's intended use, cost and/or availability of steel and the ability of the smith. After the 7th century there appears to be a certain amount of standardisation with the majority of knives being type 2s, and after the 10th century there was a high proportion of mass-produced type 1 knives. The analysis of the knives has shown that while both rural and urban smiths created standardised knives, the rural smith was less skilled than the urban one. This may be explained by the fact that the urban smith most likely spent the vast majority of his time ironworking, while the rural smith would have also taken part in the rural economy.

After the iron alloys had been welded together, the next step in the process was to shape the knife. This analysis has shown that in some cases the function of the knife would be directly related to the shape and size. Small blades were needed for precise activities, e.g. craft or surgery, while larger knives could be used as weapons, e.g. seax. The angle-backed knife would have allowed the user to grip and apply pressure to the knife making it ideal for craft working, supported by the better quality of these knives (alloys, manufacturing and heat-treatments).

Only once the knife has been shaped can it be heat-treated. This would bring the best out of the steels used to manufacture the knife, resulting in a very hard cutting edge. This stage in the process was mostly influenced by the skill of the blacksmith. Urban smiths, who have been previously shown to be specialised, carried out more and better quality heat-treatments than their rural counterparts. In addition heat-treatment techniques could also be influenced by cultural factors, for example most of Europe tempered the blade once it had been quenched to release some tension in the knife, but in Viking Dublin and pre-Viking Ireland they did not temper their blades. This suggests a continuation of traditional blacksmithing skills.

The final step in the manufacture of a knife would be to sharpen the cutting edge using honestones. The knife could then be polished and etched to reveal any patterns, or alternatively it could be left oxidised or patinated, especially if non-ferrous inlays were present. A handle would then be attached to the tang and a leather scabbard made

During the life of the knife it would suffer wear and would need to be sharpened, and in many cases the heat-treatments would need to be re-applied at regular occasions. Examination of the wear patterns and the metallographic analysis has clearly shown that knives were constantly being re-sharpened. Eventually the knife would reach a point where it either needed to be repaired or discarded. The specialised nature of the urban smith meant that they could affectively repair the knife to an almost new state, whereas the rural repairs were much poorer using softer alloys. Repairs were rare and most knives where either discarded or were possibly recycled, particularly in the rural settlements.

8.7 Conclusion

This research has shown that through a combination of physical examination, x-radiography and metallography it is possible to gain an understanding about the early medieval iron industry. This research has also shown that the scientific examination of iron objects, in this research iron knives, can contribute to early medieval research. It is clear that there are significant changes in iron technology occurring in Saxon Britain, but also differences between urban, rural and high status sites. The standardisation of knife manufacture in the 7th century strongly points to specialisation in the iron industry in this period. The analysis has also shown that while the Vikings did have a huge impact on other aspects of Anglo-Saxon life they had little overall impact on the iron industry in Britain, and even less impact on the Irish who continued using their own blacksmithing techniques.

8.8 Further Work

A full survey of knife shapes and sizes, as well as knife wear across the full spectrum of early medieval sites is required. This analysis would require access to the entire assemblage, rather than just the excavation reports. It would determine how knives were used through time, but also in a full spectrum of settlement types.

Experiments reconstructing knives based on these findings would be essential to gain an understanding about the manufacture of knives, particularly the time and energy required to make each of the main types. This would provide the data necessary to support the theory that the type 1 knife was mass produced. More work on heat-treatments is also required to investigate the theoretical models put forward in this research, as well as the archaeological evidence seen. This research will determine whether there are any identifiable microstructure evidence that could be used in future metallographic analysis of other iron artefacts.

The current research suggests that, in the future, slag inclusions may be used to provenance iron, if not to the ore source, at least to the smelting site. Therefore once this has been proven, the analysis of the slag inclusions in each piece of iron used to construct the knife should be carried out. This may show whether the rural knives are using iron from a single smelting source, and if the urban settlements have access to a wide variety of smelting sites. This analysis might also help determine whether piled iron was recycled or whether it was heterogeneous iron that has been folded.

Detailed analysis of many more Saxon knives in cemeteries is necessary to determine whether the patterns seen in this small sample of cemetery knives is correct. Knives from a range of cemeteries, from across England, should be examined and compared to the age, sex and status of the individuals buried. This analysis may also assist in our understanding of ‘ritual killing’ of knives. In addition more research is needed on cremation knives to determine whether they were placed on the cremation pyre, along with the body or whether they were placed in the urn afterwards. But first experimental cremations may be necessary to determine whether the microstructures seen in the Lovedon Hill knives were due to the heat of the pyre.

Finally a full study of iron knives in the Iron Age and Roman Britain is required along with the analysis of knives from the later medieval periods. This will allow a full reconstruction of iron technology and techniques through time and will provide archaeometallurgists, and archaeologists with an understanding of how ironworking industry, developed over time.

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