A review of metallographic analyses of early medieval knives

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ABSTRACT: Early medieval knives provide a wealth of technological data, including information about the quality of iron alloys and smithing techniques (such as manufacturing techniques and heat treatments), and information on cultural aspects such as the treatment of knives found in cemeteries and whether they differ from settlement knives. This paper synthesises the metallographic data obtained from the analysis of iron knives recovered from both settlement and cemetery sites of early medieval date, cAD 400–900, with the aim of reviewing the technology used in the manufacture of these knives. Data from 79 knives has shown some clear differences in the manufacture of knives found in cemeteries compared with those found at settlement sites. Most of all, the data demonstrates the paucity of archaeometallurgical investigations of this vital commodity, and the importance of reviewing and re-assessing past studies.

Introduction

A number of archaeometallurgical investigations of early medieval iron artefacts have been carried out, more than from any other period. These results now require further analysis and interpretation especially in the light of our new understanding of the high levels of craft skills attained by early medieval smiths (Mack *et al* 2000). The knife is one of the commonest iron artefacts found during excavations of both early medieval settlements and cemeteries. Archaeometallurgical examination of knives provides a deep insight into ironworking technology and skills. Many knife blades are composite artefacts having ferritic or phosphoric iron backs, with inserted steel cutting edges. The quality of the iron alloys, the skill in manufacture, and the effectiveness of heat treatments can all be revealed by metallurgical analysis of the blades. The archaeometallurgical analysis of iron knives therefore provides an exceptional opportunity to analyse the ironworking skills of a society. These studies can be integrated into archaeological typological studies of knives, hence providing an enhanced holistic study of these vital artefacts in this period.

The primary aim of this paper is to review the technology used in the manufacture of early medieval iron knives, spanning the period *c*AD 400–900. A synthesis of the metallurgical evidence derived from the metallographic analysis of 79 knives, together with X-radiographic study of a further 235 examples, is presented. The data is analysed chronologically, regionally and through comparison of data from settlement sites and cemeteries (Fig 1). The data is then placed in a wider context by summarising the evidence for knife manufacture from preceding and subsequent periods.

Background

Previous archaeometallurgical studies of iron artefacts from early medieval contexts have shown that during the 5th–11th centuries AD the highest level of smithing skill was achieved (McDonnell 1989c, 380; Mack *et al* 2000). This suggests that new, better iron-working techniques were being used in the post-Roman period. Study of artefacts from the early medieval urban site at Hamwic revealed that high-quality high-carbon steels were produced by refining cast irons. This showed that the Anglo-Saxons had a high degree of sophistication in the use of alloys and manufacturing techniques, and used them to produce steel-edged tools such as knives (Mack *et al* 2000).

Figure 1: Map showing the locations of early medieval settlements (open squares) and cemeteries (solid triangles) used in this study. The solid spots indicate Roman and later medieval sites with knives that have been examined using archaeometallurgical techniques.

Iron knives range in size, shape and function, and are suitable for archaeometallurgical analysis. They can be classified according to a typology based on the shape of the knife (Fig 2), and six different methods of manufacturing the knife blade have been identified (Fig 3). These factors allow for the correlation between quality, typology and the method of construction to be investigated (McDonnell 1989c). Knives in early medieval societies were an essential everyday tool and would have been used for many purposes. In cemeteries they are the most common grave good deposited, and are present in most adult (both male and female) graves and in many children's graves (Lucy 2000, 59–60). One question that can be asked of knives from Anglo-Saxon cemeteries is whether they were made especially for burial or whether they had been used by the individual in life.

Knife typologies

The classification of knife forms encounters the usual problem of objects that are individually hand made, which is that no two will be identical. Classification becomes a question of grouping together objects that are similar. In 1987 Evison published a typology for knives from the early medieval cemetery at Buckland, Dover. The knives were split into six groups based on whether the back was straight, curved or angled and whether the cutting edge was straight or curved (Evison 1987, 113–7). Classification using the cutting-edge shape is unreliable because the shape will have been changed by wear and sharpening. For this reason Ottaway developed an alternative typology for his study of Anglo-Scandinavian ironwork from Coppergate, using the shape of the knife

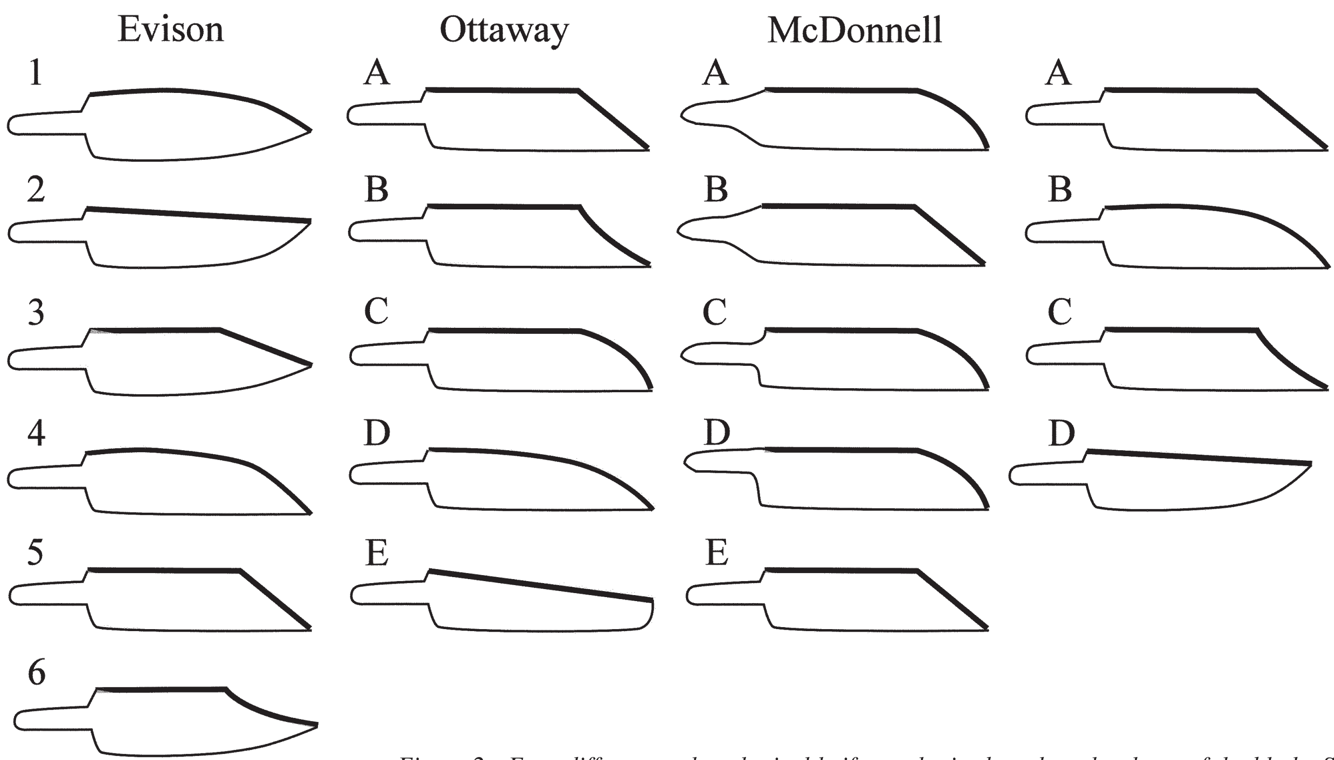

Figure 2: Four different archaeological knife typologies based on the shape of the blade. See text for details. The simplified typology of knife forms at the far right is that used in this paper.

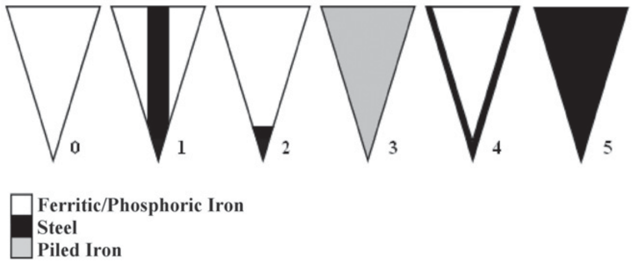

Figure 3: Knife manufacturing typology based on blade cross-sections (adapted from Tylecote and Gilmour 1986). 0 = all ferrite (or phosphoric iron) with no steel cutting edge, 1 = steel core flanked by ferritic or phosphoric iron, 2 = steel cuttlng edge butt-welded to the iron back, 3 = piled or banded structure throughout the section, 4 = steel forms a jacket around an iron core, 5 = all steel blade.

back as this is unlikely to alter through use (Ottaway 1992). McDonnell (McDonnell *et al* 1991) also created a typology, based upon an earlier version of Ottaway's criteria (Ottaway 1984, 86), that took into account the blade to tang interface, identifying distinct interfaces on both sides, one side only or blades with no interface. All three typologies are illustrated in Figure 2.

Comparison between the typologies illustrated in Figure 2 is difficult, as none of them can be easily matched or linked to each other. Evison's typology has most often been used to classify knives from cemeteries while Ottaway's has been used on settlement sites. McDonnell's typology has only been applied to the knives from Hamwic and relies on the presence of a tang to blade interface, without which this classification is difficult if not impossible. For this paper a simplified typology has been devised (Fig 2, right), to which the older typologies can be linked. This has four forms (A–D) based upon the shape of the back alone because the cutting edge shape is often variable, as mentioned above. The first (Form A) is the angle-back knife which is roughly equivalent to Evison types 3 and 5, Ottaway type A and McDonnell types B and E. The next (Form B) includes all knives with curved backs, although in Ottaway's typology a distinction was made between those with a straight back which later curved to the tip and a wholly curved back. Form B hence consists of Evison types 1 and 4, Ottaway types C and D as well as McDonnell types A, C and D. Form C comprises knives with a straight back which is incurved near the tip, Evison type 6 and Ottaway type B. The final knife form (Form D) has a straight back, which was included by both Evison (type 2) and Ottaway (type E).

Metallographic analyses of iron edged-tools can provide an insight into the methods of fabrication, levels of technology and in some cases the function of the tool. Knives can be made of one or more iron alloys, combined in different ways, which can be considered as a manufacturing typology. During construction a small amount of steel was often added to the knife to create a cutting edge; this harder edge could then be re-sharpened when it became blunt. Tylecote and Gilmour's pioneering study of edged tools produced a typology of six different methods of manufacturing knives which were further divided into subgroups (Tylecote and Gilmour 1986, 2–7). This typology was simplified and refined by McDonnell (1992) in his study of iron knives from Coppergate (Fig 3); this is the manufacturing typology used in this paper.

Three main types of iron were available to early medieval smiths: ferritic iron which contained few alloying elements (<0.1%), phosphoric iron containing more than 0.1% phosphorus, and steel which contains carbon as the main alloying element (McDonnell 1989c). High-quality steel is characterised by homogenous high carbon contents (>1% carbon), has often been well heat treated, has high hardness values (*c*600HV) and few small spheroidal slag inclusions (Mack *et al* 2000). Steel containing less than 0.3% carbon cannot be successfully heat treated, and though steels with carbon contents of *c* 0.3–1% can be heat treated, they tend not to achieve the hardness values of the higher-carbon steels, and often appear to contain a greater volume of slag inclusions. The term 'piled iron' is used to describe banded structures of mixtures of various types of irons. In most cases it cannot be determined whether the piling is deliberate, *ie* welding together of iron strips of different compositions, or 'natural' resulting from segregation of irons during the iron-making process (McDonnell 1989c).

Methods

Published and unpublished metallographic and X-radiographic data for knives from 11 excavations of early medieval sites (Fig 1) have been collated, and are presented below to permit easy comparison. For each site a brief excavation summary is provided, together with a table of results summarising the archaeometallurgical data for each knife investigated (Tables 1–12).

All the knives have been allocated a knife form based on the typology illustrated in the right-hand column of Figure 2. The original knife drawings have been consulted but where this was not possible, the assumption has been made that the knife was originally correctly classified, and the equivalents given above have been used.

In most cases a metallographic section was cut from

Figure 4: X-radiograph of knife 434 from St Mary's Stadium, Southampton. Note the 'spotted' texture indicative of steel in the cutting edge (bottom strip) and a distinct weld line (arrowed) running along the blade. Length 166mm.

both the cutting edge of the blade and the knife back, but in some cases (*eg* Edix Hill) only sections from the blade edge were removed (for a description of the procedure see McDonnell 1992, fiche 3: B12–B14). Examination of these sections allowed a manufacturing type, as defined in Figure 3, to be allocated to each knife. Micro-hardnesses were measured with a Vickers hardness tester using a 100gf load; these values are quoted as hardness (HV). The knife form and manufacturing type, as well as the dominant microstructure and average hardness of both the cutting edge and back, are included in Tables 1–4 and 7–10; the range of hardness values for the back is also given when available (NA = not available). The microstructural descriptor in the tables is a broad interpretation of the microstructure present in either the back or the cutting edge, with the dominant phase placed first. For example, ferrite with pearlite has a structure dominated by ferrite (*ie* it is low-carbon steel containing <0.4% C), while pearlite with ferrite shows predominance of pearlite. The microstructure can vary significantly across weld lines due to variations in carbon content or heat treatments. For example in the tables a microstructure described as 'tempered martensite and pearlite' refers to the cutting edge being tempered martensite at the tip and the microstructure changing to pearlite at or towards the weld.

The knives from St Mary's Stadium, Mucking and Ipswich were too badly corroded to be metallurgically analysed. Instead X-radiographs of the knives were examined to assess whether steel edges and/or weld lines could be identified. The original X-radiographs of the St Mary's Stadium knives were scanned using an Agfa FS50B scanner with Radview Workstation software with a pixel pitch of 50μm allowing enhancement and magnification of the images.Weld lines occur as distinct lines on X-radiographs. During the analysis of the Hamwic (McDonnell 1987a and 1987b) and Coppergate knives (McDonnell 1992) it became apparent that the high-quality steel edges had a characteristic X-radiographic image. This 'spotted' appearance, which was enhanced by corrosion penetration, was due to the presence of spheroidal inclusions, confirmed by metallography; Figure 4 is a good example. This characteristic appearance has also been noted on X-radiographs by Fell and Starley (Starley 1996; Fell and Starley 1999). A Type 2 knife can therefore be identified by the presence of a weld line, with (or without) the 'spotted' appearance. Knives of Types 1 and 5 are identified by the presence of steel with the absence of a weld line, although it is difficult to distinguish between the two types.

Results for cemeteries

Cannington

The 4th–7th century cemetery at Cannington, Somerset was excavated in 1962–3 and revealed over 540 inhumations. All ages and both sexes were represented but there was a higher proportion of females buried at the site. The grave goods included knives and other objects of Roman, western British and Anglo-Saxon types (Rahtz *et al* 2000). In total 31 knives were found and 14 were analysed to reveal their microstructure (McDonnell 1989a).

A range of manufacturing techniques was used to make the Cannington knives (Table 1). The metallurgical and hardness results demonstrate that the Type 2 knives (average 866HV) were manufactured to a much higher quality than the other types. There was evidence for spheroidisation of the pearlite in one knife (No 5) which would have resulted if it had remained at about 700°C for some time, perhaps cooled very slowly or deliberately annealed (Samuels 1999, 117). An analysis of the distribution of knives within the cemetery suggests that blades with high-quality steel edges were present at the centre/focus of the cemetery whereas the lower-carbon knives were found in the periphery. However, there is insufficient data to substantiate this as fact, but it may be worth future research.

Loveden Hill

Rescue excavations of the 5th–7th century cemetery at

Loveden Hill, Lincolnshire began in 1955. Almost 2000 burials were found at the cemetery and of these over 1200 were cremations. This very large cemetery may have served a whole region rather than just one community. Finds included a large quantity of elaborately stamped pottery, copper-alloy toilet sets, brooches, combs, knives and buckets (Fennell 1974, 285–6). Some of the buckets appear to have been purposely killed by stabbing through their bases (Wilson and Hurst 1957, 148).

The metallographic analyses (Table 2) of five knives found that Types 1 and 5 were present. The iron and steel used in the knives was good quality with few slag inclusions, except for knife LH651 which had a heterogeneous structure of mid-carbon steel. Knife 608(1) had a cutting edge of tempered martensite but also a very low hardness, suggesting that it had been overtempered. Three knives (LH606, LH651 and LH654) came from cremation burials and all had low hardness values; one (LH651) had a slow-cooled/annealed structure while the others had 'carbonitride needles'. It is unknown how and why these needles formed in the knives but it is possible that heating at high temperatures for many hours with subsequent burial for over a thousand years was responsible (Samuels 1999, 421–425). Their microstructures suggest that the three knives from cremation burials had been placed on the cremation pyre.

Empingham II

Excavations carried out in 1974–75 at the cemetery at Empingham II in Rutland recorded 135 inhumations and one cremation. Over half of those buried in the cemetery were adults and there were equal numbers of males and females.The use of the cemetery extended from the late 5th through to the early 7th century based on the occurrence of specific grave goods. The burials were not laid out in any formal organisation such as rows or groups that would suggest family plots (Timby 1996). In total 69 knives were found in 64 burials; of these 12 were analysed (Wiemer 1996).

Table 1: Metallographic data for knives from the cemetery at Cannington (adapted from McDonnell 1989a).

Knife no	Knife form	Manufacturing type	Cutting edge		Back		
			Hardness	Microstructure	Hardness		Microstructure
					Average	Range	
5	B	1	233	pearlite with ferrite and spheroidal structure	238	NA	ferrite and phosphoric iron
6	D	1	182	ferrite with pearlite	174	NA	ferrite and phosphoric iron
9	B	2	927	tempered martensite	178	NA	ferrite with pearlite
12	D	1	224	ferrite with pearlite	220	170–207	ferrite with pearlite
16	D	5	204	ferrite with some pearlite	270	187–406	ferrite with pearlite
18	D	5	257	pearlite	274	NA	pearlite
107	B	0	130	ferrite	130	125–153	ferrite
117	B	2	672	tempered martensite	187	163–349	ferrite with pearlite
123	B	0	130	ferrite	150	136–160	ferrite
129	B	5	194	ferrite with pearlite	199	NA	ferrite with pearlite
136	D	1	400	tempered martensite	200	NA	ferrite with pearlite
159	B	2	1000	tempered martensite and pearlite	260	183–351	ferrite with pearlite
165	B	0	171	phosphoric iron	180	172–205	ferrite
169	B	0	148	ferrite	139	NA	ferrite

Table 2: Metallographic data for knives from the cemetery at Loveden Hill (adapted from McDonnell 1989b).

Knife no	Knife form	Manufacturing type	Hardness	Cutting edge	Back		
				Microstructure	Hardness		Microstructure
					Average	Range	
LH 606	B	5	116	ferrite with carbonitride needles	104	NA	ferrite with carbonitride needles
LH 608 (1)	D	5	299	tempered martensite	302	249–354	ferrite with pearlite
LH 608 (2)	D	1	724	tempered martensite	215	210–222	ferrite with pearlite
LH 651	D	5	240	pearlite	214	212–162	ferrite with pearlite
LH 654	B	1	160	ferrite with carbonitride needles	156	146–165	ferrite

Table 3 shows that one third of the knives were of Type 4 with a steel jacket over a phosphoric iron core. The metallographic analysis revealed that the Type 4 (average 592HV) knives and the one Type 5 (475HV) had good quality, tempered medium- to high-carbon steel edges. In contrast, the other types were all of a much lower standard. Three knives of different types had been subjected to sub-critical annealing and contained spheroidised carbides, yet they did not come from cremation burials. This may be evidence of 'killing' blades, *ie* making them ineffective, prior to burial.

Edix Hill

The cemetery of Edix Hill is situated on the western edge of Barrington parish, Cambridgeshire. Excavations between 1989 and 1991 established a date range from the early 6th to the early 7th century AD. It was estimated that at least 300 people were buried at the site over a period of about 150 years (Malim and Hines 1998). A total of 55 knives were found during these excavations and 14 of these were analysed (Gilmour and Salter 1998).

A range of knife manufacturing types was found at Edix

Table 3: Metallographic data for knives from the cemetery at Empingham II (adapted from Wiemer 1996).

Knife no	Knife form	Manufacturing type	Hardness	Cutting edge	Back		
				Microstructure	Hardness		Microstructure
					Average	Range	
14/1	B	unclear	–	unclear	–	NA	ferrite and phosphoric iron
33/3	B	5	475	tempered martensite	267	198–334	ferrite with some pearlite
42/10	C	0	182	phosphoric iron	176	152–199	phosphoric iron
48/11	B	0	208	phosphoric iron	208	180–236	phosphoric iron
50/11	B	3	196	phosphoric iron with tempered carbides	166	NA	tempered carbides and phosphoric iron
61/5	B	4	627	tempered martensite	189	NA	phosphoric iron
84/2	B	4	433	tempered martensite	214	NA	phosphoric iron
90/5	A	2	258	phosphoric iron with tempered and spheroidised carbides	197	167–228	phosphoric iron
100/10	B	4	534	tempered martensite	208	NA	phosphoric iron
107/7	B	4	775	tempered martensite	154	NA	phosphoric iron
199A/2	B	1	213	phosphoric iron with ferrite and spheroidised carbides	–	NA	phosphoric iron

Table 4: Metallographic data for knives from the cemetery at Edix Hill (adapted from Gilmour and Salter 1998).

Knife no	Knife form	Manufacturing type	Hardness	Cutting edge	Back		
				Microstructure	Hardness		Microstructure
					Average	Range	
46.1	B	1	586	martensite and pearlite	–	NA	–
3.4	B	2	794	tempered martensite and pearlite	–	NA	ferrite
547.1	A	1*	125	phosphoric iron	–	NA	tempered martensite
156.1	D	0	144	ferrite	144	134–154	ferrite
551.1	B	2	824	untempered martensite	316	NA	ferrite and pearlite
428.144	B	4	388	tempered martensite and pearlite	150	140–160	ferrite
526.20	B	1	223	phosphoric iron	155	NA	ferrite
29.3	B	2	330	untempered martensite	168	NA	ferrite with pearlite
553.1	B	1	273	tempered martensite	–	NA	ferrite with pearlite
436.24	A	1	–	tempered martensite	–	NA	ferrite
9.52	A	3	–	–	–	NA	
117.2	D	5	–	tempered martensite	–	NA	tempered martensite
359.15	D	4	–	tempered martensite	–	NA	–
626.193	D	–	–	tempered martensite and ferrite	–	NA	ferrite

Note: * Type 1 due to its manufacture but see text for discussion.

Table 5: X-radiographic interpretation for knives from the cemetery at Mucking (adapted from Starley 1996).

	Knife form					
Manufacturing type	A	B	C	D	O/U	Total
Butt-welded (Type 2)	1	18	2	2	1	24
Homogeneous (Types 0 and/or 5)	8	35	4	16	9	72
Piled (Type 3)				1		1
Pattern welded		2		1		3
Some structure	1	4	1	1		7
Other weld lines	2	1	1	3	1	8
Other/indeterminate	5	24	2	5	17	53
Total	17	84	10	29	28	168

Note: O/U = other or unidentifiable

Table 6: X-radiographic interpretation for knives from the cemeteries at Ipswich (adapted from Fell and Starley 1999).

Manufacturing type	Boss Hall	Buttermarket	Total
Butt-welded (Type 2)	8	9	17
Piled (Type 3)	6	1	7
Pattern welded	0	1	1
Complex	1	4	5
No features (?Types 0 and/or 5)	5	8	13
No X-radiograph	2	0	2
Total	22	23	45

Table 7: X-radiographic interpretation for knives from the cemetery at St Mary's Stadium.

Knife no	Knife form	Manufacturing type		
		1	2	5
332	A	Y		
338	B			
346	A			
366	A	?	?	?
448	B	?	?	?
481	B	?		?
519	A	?		?
532	–	?		?

Notes: Y = certainty of identification (weld line clearly identified or steel cutting edge); ? = possible identification (no clear weld visible but signs of steel present).

Hill (Table 4). Knife 547.1 was enigmatic as the back was constructed of two tempered-martensite halves separated by a central weld, and the cutting edge was constructed from lower-quality phosphoric iron.

Mucking

Two Anglo-Saxon cemeteries at Mucking, Essex were excavated between 1965 and 1977. Cemetery II, dated to the 5th–7th centuries, was the larger with 274 inhumations and 450 cremations. The smaller cemetery was partially destroyed before excavation and contained 64 graves (Clark and Hamerow 1993). A total of 168 knives from both cemeteries were examined by X-radiography as the blades were too poorly preserved to justify metallographic examination (Starley 1996). Detailed examination of X-radiographs enabled butt welds and steel edges to be identified.

The majority of the knives from Mucking (Table 5) had curved backs. The X-radiographs were interpreted by Starley (1996) to suggest the presence of 24 Type 2 butt-welded blades (14%) and 72 homogeneous knives (Types 0 and 5) (43%), suggesting that, like the other cemeteries, a range of manufacturing types was deposited.

Ipswich

Excavations at the cemetery at Boss Hall recovered 22 knives. All were found in graves dating to the 6th century, with the exception of one fragment found in grave 93 which dated to the late 7th century. In addition, 23 knives were recovered from the nearby 7th-century cemetery at Buttermarket.

The knives were too badly corroded for metallurgical analysis, so X-radiographs were examined for features which could suggest their method of construction (Fell and Starley 1999). No information on knife forms was available. Interpretation of the X-radiographs by Fell and Starley (1999) again suggested a range of knife types was present (Table 6). Of the 45 knives X-radiographed, 17 (38%) were Type 2 and 13 (29%) had no visible features so were possibly Types 0 or 5.

St Mary's Stadium

Excavations in 1998 at St Mary's Stadium, Southampton, revealed part of the 7th–9th century settlement of Hamwic and a 7th-century cemetery containing 23 inhumations and 18 cremations which may have formed part of a larger cemetery (Smith *et al* 2000, 10–16). A total of eight knives was recovered from burial contexts (*ibid*, 19–24). The knife form and manufacturing type were determined by detailed examination of X-radiographs.

Both angled- and curved-back knives were found in the cemetery at St Mary's Stadium (Table 7). One knife was identified as Type 1 because steel was visible throughout the knife, but no weld was visible. In addition, a distinctive curved cutting edge due to repeated resharpening was noted; this curved cutting edge was typically seen in Type 1 knives from Coppergate, York (Ottaway 1992, 572–4). There were also a number of knives possibly of Types 1 and 5 and two possible Type 2 knives. This

Table 8: Metallographic data for knives from the settlement at Poundbury (adapted from Tylecote 1987b).

Knife no	Knife form	Manufacturing type	Hardness	Cutting edge	Back		
				Microstructure	Hardness		Microstructure
					Average	Range	
125	D	2	520	tempered martensite	160	NA	ferrite
126	B	1	245	ferrite and pearlite	185	NA	ferrite with pearlite
508	A	2	330	tempered martensite	172	NA	ferrite with pearlite
603	A	2	615	tempered martensite	166	NA	ferrite
605	A	2	553	tempered martensite	186	NA	ferrite
786	B	0	210	ferrite with cementite	105	NA	ferrite
809	A	3	214	ferrite with cementite	–	NA	–

indicates that a range of manufacturing types was present at the cemetery.

Results for settlements

Poundbury

The 5th–7th century settlement at Poundbury, Dorset was established over what was the Roman cemetery site near to the Roman town of Dorchester. The main features include small ditched enclosures, several groups of pits and a series of buildings. At the site there were examples of post-built, beam-slot and sunken featured buildings. In total nine knives were found from the post-Roman period all of which showed signs of considerable use and re-sharpening on their cutting edges (Green 1987).

Seven knives were analysed further (Tylecote 1987b) and four were shown to be Type 2 butt-welded knives (Table 8). These were of consistently better quality (average 505HV) than the other knife types found at Poundbury.

Hamwic

Excavations began in 1977 in the Six Dials area of Southampton to assess the possible damage that a proposed major road improvement scheme would have on Hamwic, a substantial Saxon town of over 100 acres (40ha). The origins of the town can be dated to the first decades of the 8th century AD although there is some evidence for occupation prior to AD 700. The town developed a clear grid plan pattern to the streets, which were gravelled and well-maintained

Table 9: Metallographic data for knives from the settlement at Hamwic (adapted from McDonnell 1987a and 1987b).

Knife no	Knife form	Manufacturing type	Hardness	Cutting edge	Back		
				Microstructure	Hardness		Microstructure
					Average	Range	
30/173	A	2	427	tempered martensite and pearlite with ferrite	157	154–222	ferrite
99/38	B	2	445	ferrite with some pearlite	140	NA	ferrite
99/92	B	2	160	ferrite with some pearlite	160	NA	ferrite
169/421	A	2	160	pearlite with ferrite	130	NA	ferrite with pearlite
169/610	A	2	315	tempered martensite and pearlite	101	NA	ferrite with pearlite
169/2407	A	2	153	ferrite with nodular carbide	166	NA	ferrite with carbide
31/340	B	5	607	tempered martensite with retained austenite?	607	572–642	tempered martensite with retained austenite
31/663	A	2	174	tempered martensite and pearlite	192	162–198	ferrite
169/417	A	2	603	tempered martensite and pearlite	169	124–238	ferrite
169/540	A	2	644	tempered martensite	218	NA	ferrite
169/558	A	2	813	tempered martensite	153	NA	ferrite
169/1617	B	2	677	tempered martensite	168	133-181	ferrite
169/2502	B	2	593	tempered martensite	262	243–73	bainite
169/2516	B	–	345	tempered martensite and pearlite	152	NA	ferrite

(Andrews 1997, 20–32). Hamwic seems to have been a settled population of artisans, rather than farmers, engaged in industry and long distance trade across the Channel and the North Sea (*ibid*, 205–6). Large amounts of ironworking residues were found including slag and smithing debris such as hammerscale, as well as a large assemblage of finished artefacts including knives (*ibid*, 222–6). The settlement was abandoned in the late 9th century (*ibid*, 20–32).

Analysis of 14 knives (Table 9) showed that the most common method of manufacture was Type 2, with cutting edges butt-welded to the knife back. There were two exceptions, knife 31/340 was all steel and knife 169/2516 was of indeterminate manufacture. Most of the Type 2 blades were of the highest quality, with the exception of four knives which had lower hardness values (153–174 HV). Five of the knives had exceptionally hard cutting edges, in excess of 600 HV.

Fishergate

The 1985–86 excavations at 46–54 Fishergate, York uncovered the remains of a substantial area of Anglian occupation. This lasted approximately 150 years from *c*AD 700–850 and may have represented part of a trading settlement or emporium, similar to the settlements identified at Hamwic and Ipswich. The deposits excavated contained a rich selection of personal artefacts such as dress pins and some brooches, but there was also evidence for craft activities, including metalworking. Of all the tools found on the site, those recovered in greatest abundance were knives (Rogers 1993, 1273). Five of the 29 knives and knife fragments were analysed further (Wiemer 1993).

All the analysed knives from Fishergate (Table 10) were of Type 2; the majority had quenched and tempered blades. The metals used in the construction of the knives include ferritic iron, phosphoric iron and steel. X-radiographs of a further 24 knives were examined and these showed that at least eight had butt-welds and a further twelve had possible welds. Thus butt welding a steel edge to a ferritic or phosphoric iron back seems to have been the main method of making the knives recovered at Fishergate.

Coppergate

The site of 16–22 Coppergate, York lies in what was the heart of the Anglo-Scandinavian city. The anaerobic nature of the soil meant that the timber, other organic remains and iron objects were well preserved. Timber buildings survived at the front of the properties while behind them in the yards lay pits full of rubbish deposits. Extensive evidence for craft working was recovered

Table 10: Metallographic data for knives from the settlement at Fishergate (adapted from Wiemer 1993).

Knife no	Knife form	Manufacturing type	Hardness (VPN)	Cutting edge	Back		
				Microstructure	Hardness (VPN)		Microstructure
					Average	Range	
4984	B	2	383	tempered martensite and pearlite	223	142–304	phosphoric iron
4988	B	2	314	pearlite	179	NA	phosphoric iron
4989	B	2	469	tempered martensite and pearlite	205	164–246	phosphoric iron
5000	B	2	428	tempered martensite and pearlite	154	130–77	ferrite
5002	B	2	630	tempered martensite	141	120–162	ferrite and phosphoric iron

Table 11: Metallographic data for knives from the early settlement at Coppergate (adapted from McDonnell 1992).

Knife no	Knife form	Manufacturing type	Hardness (VPN)	Cutting edge	Back		
				Microstructure	Hardness (VPN)		Microstructure
					Average	Range	
2756	A	–	–	–	–	NA	–
2757	A	2	874	tempered martensite	213	NA	ferrite
2765	A	2	927	tempered martensite	141	118–162	ferrite
2767	B	2	244	pearlite	157	NA	ferrite
2771	B	2	841	tempered martensite	191	176–205	ferrite
2777	B	2	655	tempered martensite	336	NA	bainite and pearlite
2778	B	1	407	tempered martensite	174	NA	phosphoric iron
2795	–	4	309	pearlite with ferrite	104	89–118	ferrite

Table 12: X-radiographic interpretation for knives from the settlement at St Mary's Stadium.

Knife no	Knife form	Manufacturing type		
		1	2	5
18	B		Y	
19	B		Y	
102	A		Y	
241	A	?	?	?
385	A			
418	B	?		?
419	B			
434	A		Y	
436	B		Y	
461	A	?	?	?
545	–	?		?
551	–		Y	
569	–		Y	
912	B			

Notes: Y = certainty of identification (weld line clearly identified or steel cutting edge); ? = possible identification (no clear weld visible but signs of steel present).

from the excavations, including large-scale manufacturing in jet, amber, wood and metal (Ottaway 1992, 460–62). There were 41 knives of various forms found in period 3 contexts (AD 850–900) and eight of these were analysed further (McDonnell 1992).

The majority of the analysed knives from Coppergate (Table 11) were of Type 2 manufacture. The two exceptions were knife 2778 which had a steel core flanked by iron (Type 1), and knife 2795 which had a jacket of steel round an iron core (Type 4). The average hardness of all the Type 2 blades (708 HV) showed that they were often of better quality than the two knives manufactured by other methods.

St Mary's Stadium

Excavations in 1998 at St Mary's Stadium revealed part of the 7th–9th century settlement of Hamwic, including a street surface, pits, wells, structures and an associated 7th-century cemetery (see above). A total of 15 knives were recovered from the settlement (Smith *et al* 2000, 19–24). Evidence for weld lines and the spotted appearance of high-quality steel was sought on X-radiographs of the knives.

A similar distribution of knife forms to those in the cemetery (Table 7) was seen in the settlement (Table 12) with roughly equal numbers of curved- and angled-back knives. Of the 15 knives examined using X-radiographs seven were clearly Type 2 with very obvious weld lines and another two were possibly Type 2 as there were hints of a weld line, though they could be Type 1 or 5 as steel was present. Of the remaining knives, two were either Type 1 or 5 and the manufacturing type of the rest could not be determined.

Discussion

The discussion deals with five topics: archaeological

Table 13: Knife forms for all knives from each site.

Site	Date range (centuries)	Knife form					Total
		A	B	C	D	O/U	
Cannington[1]	4th–7th		18 (9)	1 (0)	9 (5)	3 (0)	31 (14)
Empingham II[2]	5th–7th	7 (1)	15 (10)	1 (1)	12 (0)	34 (0)	69 (12)
Mucking[3]	5th–7th	17	84	10	29	28	168
Edix Hill[4]	6th–7th	3 (3)	44 (7)		6 (4)	2 (0)	55 (14)
St Mary's Stadium	7th	4	3			1	8
Cemetery total:		31 (4)	164 (26)	12 (1)	56 (9)	68 (0)	331 (40)
Poundbury[5]	5th–7th	4 (4)	3 (2)		1 (1)	1 (0)	9 (7)
Hamwic[6]	8th–9th	42 (8)	77 (6)			13 (0)	132 (14)
Fishergate[7]	8th–9th	1 (0)	15 (5)		1 (0)	12 (0)	29 (5)
Coppergate[8]	9th	11 (3)	20 (4)			10 (1)	41 (8)
St Mary's Stadium	7th–9th	5	6			4	15
Settlement total:		63 (15)	121 (17)		2 (1)	40 (1)	226 (34)
Grand total:		94 (19)	285 (43)	12 (1)	58 (10)	108 (1)	557 (74)

Notes: O/U = other or unidentifiable. The number in brackets indicates the number of that type analysed.
No information on knife forms was available for the Ipswich and Loveden Hill cemeteries (with the exception of the five knives in Table 2).
Sources: 1 - Rahtz *et al* 2000, 2 - Timby 1996, 3 - Starley 1996, 4 - Malim and Hines 1998, 5 - Green 1987, 6 - McDonnell *et al* 1991, 7 - Rogers 1993, 8 - Ottaway 1992.

knife typologies in relation to the sites in this paper, a comparison of manufacturing types found in settlements and cemeteries, microstructures and hardness in relation to manufacturing types, spheroidisation and 'carbonitride needles' in early medieval knives from cemeteries, and a chronological overview of knife technology.

Archaeological knife typology

Table 13 shows 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 the two site types. As the sites considered here are just a small sample of the many different early-medieval sites already excavated, only with a full study of knife forms will real trends be revealed.

Table 14: Cutting edge hardness (HV) for each knife manufacturing type by site.

Sites		Manufacturing type						Overall values
		0	1	2	3	4	5	
Cannington 4th–7th	Number	4	4	3			3	14
	Average	145	260	866			218	348
	Range	148–171	182–400	672–1000			157–194	148–1000
Loveden Hill 5th–7th	Number		2				3	5
	Average		442				218	308
	Range		160–724				116–299	116–724
Empingham 5th–7th	Number	2	1	1	2	4	1	11
	Average	195	213	258	189	592	475	371
	Range	182–208	213	258	181–196	433–775	300–650	181–775
Edix Hill 6th–7th	Number	1	5	3	1	2	1	13
	Average	144	303	649	–	388	–	398
	Range	144	125–586	312–824	–	388	–	125–824
Cemetery total:	Number	7	12	7	3	6	8	43
	Average	159	304	686	189	551	255	363
	Range	144–208	125–724	258–1000	181–196	433–775	116–650	125–1000
Poundbury 5th–7th	Number	1	1	4	1			7
	Average	210	245	505	214			384
	Range	210	245	330–615	214			210–615
Hamwic 8th–9th	Number			12			1	13
	Average			430			607	444
	Range			153–813			572–642	153–813
Fishergate 8th–9th	Number			5				5
	Average			445				445
	Range			314–630				314–630
Coppergate 9th	Number		1	5		1		7
	Average		407	708		309		608
	Range		407	244–927		309		244–927
Settlement total:	Number	1	2	26	1	1	1	32
	Average	210	326	498	214	309	607	467
	Range	210	245–407	153–927	214	309	572–642	153–927
Grand total:	Number	8	14	33	4	7	9	75
	Average	165	307	545	197	511	299	407
	Range	144–210	125–724	153–1000	181–214	309–775	116–650	125–1000

Knife manufacturing types in cemeteries and settlements

The synthesis of the data collected from the early medieval knives (Table 14) demonstrates some clear patterns in the manufacturing types found in cemetery and settlement sites. The first and most striking observation is that 81% (26 of 32) of the knives analysed from settlement sites were of Type 2 (butt-welded blades) compared with only 16% (7 of 43) from cemetery sites. This observation is supported by the number of possible Type 2 knives found in pits at the St Mary's Stadium settlement. At the cemetery sites the whole range of knife manufacturing types was found in significant numbers. Type 1 is the most common but only comprises 28% of the total. The St Mary's Stadium cemetery knives also suggest that a range of knife types was deposited.

One possible reason for the difference between settlement and cemetery knives is that it reflects change over time, or the differences between urban settlements, such as Hamwic and York, and rural cemeteries. This is a possibility, but the evidence from St Mary's Stadium, which included

Table 15: Knife back hardness (HV) for each knife manufacturing type by site.

Sites		Manufacturing type						Overall values
		0	1	2	3	4	5	
Cannington 4th–7th	Number	4	4	3			3	14
	Average	150	208	208			248	200
	Range	130–180	174–238	178–260			199–270	130–270
Loveden Hill 5th–7th	Number		2				3	5
	Average		186				207	198
	Range		156–215				104–302	104–302
Empingham 5th–7th	Number	2	1	1	2	4	1	11
	Average	192	–	197	198	191	267	201
	Range	176–208	–	197	166–230	154–214	267	154–267
Edix Hill 6th–7th	Number	1	5	3	1	2	1	13
	Average	144	155	242	–	150	–	177
	Range	144	155	168–316	–	150	–	144–330
Cemetery total:	Number	7	12	7	3	6	8	43
	Average	161	179	221	198	178	204	204
	Range	130–208	155–238	167–330	166–230	150–214	104–302	104–330
Poundbury 5th–7th	Number	1	1	4	1			7
	Average	105	185	171	–			162
	Range	105	185	160–186	–			105–186
Hamwic 8th–9th	Number			12			1	13
	Average			168			607	198
	Range			153–262			607	153–607
Fishergate 8th–9th	Number			5				5
	Average			180				180
	Range			141–223				141–223
Coppergate 9th	Number		1	5		1		7
	Average		174	207		118		188
	Range		174	133–336		118		118–336
Settlement total:	Number	1	2	26	1	1	1	32
	Average	105	180	179	–	118	607	182
	Range	105	174–185	133–336	–	118	607	105–607
Grand total:	Number	8	14	33	4	7	9	75
	Average	154	179	187	198	172	280	186
	Range	130–208	155–238	133–336	166–230	150–214	104–607	104–607

Table 16: Knife manufacturing type frequency and hardness for each cutting edge and back microstructure.

	Microstructure	Manufacturing type						Total no	Hardness (HV)	
		0	1	2	3	4	5		average	range
Cutting edge	tempered martensite		6	26		6	4	42	586	273–1000
	ferrite	4	1	1			2	8	148	130–204
	ferrite with pearlite	1	3	2	1		1	8	242	160–445
	pearlite with ferrite		1	1		1		3	234	160–309
	pearlite			2			2	4	374	240–336
	phosphoric	3	3	1	2			9	195	125–223
	Total:	8	14	33	3	7	9	74		
Back	tempered martensite		1				2	3	623	166–607
	ferrite	6	3	17		2	2	30	160	104–267
	ferrite with pearlite		4	9			4	17	208	101–330
	pearlite			2			1	3	291	262–336
	phosphoric	2	4	4	2	4		16	192	141–238
	Total:	8	12	32	2	6	9	69		

contemporary urban pits and a cemetery, showed a clear difference between knife types from the two contexts. Another possibility is that there was a range of domestic knives in use, and these were placed with their owners as grave goods, whereas the higher-quality Type 2 blades may be ‘craft’ knives and were not deposited widely in burials. Although the assessment of drawings and X-radiographs of the cemetery knives indicate that only about half showed evidence of wear of the cutting edge—indicated by an S-shaped profile—the other half were either little-worn or appear to have been unused, which could suggest manufacture for the burial rite. The manufacturing types may have been associated with the status of the individual being buried. Those of higher status were given a never-ending knife, such as Types 1 or 3, while those who could not afford such a status symbol were buried with a Type 0 knife. This theory is supported by the occasional unusual knife, such as no 547.1 from Edix Hill, which may have been designed for visual effect rather than functional use, and was possibly created for burial. However, it is difficult on the basis of a small sample to demonstrate any significant trends, so more metallographic studies of knives from the full spectrum of early medieval sites are required before any of these patterns can be confirmed.

Manufacturing types, microstructures and hardness

The Type 2 blades, from both cemetery and settlement sites, had cutting edges of high-quality steel with high carbon contents, which were low in slag inclusions and quenched then tempered. Table 16 shows that the predominant microstructure in Type 2 cutting edges is tempered martensite (26 of 33). Remaining edges had a range of different microstructures. At least some of this steel most likely derives from the decarburization of cast iron (Mack *et al* 2000), producing high-carbon steels (>1% carbon, demonstrated by hardness values). It is possible that at settlement sites early medieval smiths made economical use of high-quality steel that was time-consuming to make and therefore valuable. Tylecote (1987a, 278–81) argued that Type 2 blades had a steel edge that was potentially easily worn away by repeated sharpening and had a possible weakness where the steel was welded to the iron. However, many of the welds are excellent, with evidence of low slag content, significant carbon diffusion and the presence of ‘white’ weld lines, and would not therefore be a point of weakness. The high quality of the steel would reduce wear, but ultimately the edge would be worn through which would result in the blade appearing to be Type 0, if the loss was uniform along the length of the blade. Even though there were only a few Type 2 knives found in the cemeteries, their average hardness is higher (686HV) than the average of the Type 2 knives found at settlement sites (498HV); this might be because those from cemeteries were created for, or re-treated before, burial.

Table 16 also shows that the backs of Type 2 knives are dominated by ferrite or ferrite with pearlite microstructures. In the cemeteries, five of the seven have ferrite with pearlite backs, the remaining two being one ferrite and one pearlite. In the settlement knives ferritic backs predominate (16 of 25). Three of the rest were ferrite with pearlite, two were pearlite and four (all from Fishergate) had phosphoric backs. Table 15 shows that the backs of Type 2 blades in cemeteries (average 221HV) were of better quality than those from settlements (average 179HV). The low occurrence of phosphoric iron (only 17%) is notable. The average hardness of phosphoric iron is higher than that of ferrite; in this study the average values are 193HV and 157HV respectively (Table 16).

Nearly half (43%) of the Type 1 cutting edges had heat-treated structures (tempered martensite), while slightly more (57%) were ferritic/phosphoric irons. The lower cutting-edge hardness of the Type 1 knives (307HV) indicates that the raw material was not as good as that used to make the Type 2 knives (545HV). The alloy used to form the jackets of the Type 1 knives is either a low-carbon iron (ferrite with pearlite), ferrite or phosphoric iron. There was one example of a heat-treated jacket from Edix Hill, but the blade seems to have been incorrectly manufactured, constructed in the opposite way to most Type 1 blades, with a soft phosphoric iron cutting edge and a hard steel jacket. Phosphoric iron occurs more often in Type 1 blades (27%) than in Type 2 blades (17%).

Four of the 'all steel' Type 5 blades had heat-treated (tempered martensite) cutting edges and four had ferrite with pearlite or pearlitic structures. The remaining knife, from Loveden Hill, was ferrite with some pearlite and had carbonitride needles present throughout, possibly indicative of overheating. Two of the blades had been fully quenched and tempered, generating heat-treated microstructures in the back of the knife, while the remainder had ferrite with pearlite or pearlitic microstructures.

The examination of the seven Type 4 knives with a steel jacket surrounding an iron core, revealed that six of them had heat-treated cutting edges, with one example of a slow-cooled/normalised microstructure. The iron cores were either ferritic or phosphoric iron. There are only three possible examples of Type 3, piled, blades. Two examples (from Empingham) were piled ferritic and phosphoric iron, whilst the third (from Poundbury) was piled ferrite with pearlite microstructures.

There were eight examples of blades with no steel cutting edge (Type 0). Four were wholly ferritic, three phosphoric and one ferrite with carbide. The Type 0 blades with no steel cutting edge had the expected low hardness with a value of 165HV, although this is significantly higher than the expected value of plain slow-cooled ferritic iron which has a hardness of *c*100HV. The increased hardness of the mainly ferritic knives may be due to the presence of phosphorus or the effect of cold working, or both. Although phosphoric iron seems not to have been widely used in the early medieval period, the data in this study show iron, described as phosphoric, ranging in hardness from 125HV to 258HV with an average of 192HV. There seems to be bias in the identification of phosphoric iron by the different researchers as only McDonnell and Wiemer consistently note the presence of phosphoric iron while other researchers do not, with the exception of two knives from Edix Hill (526.20 and 547.1). Samuels (1999, 141–2) observed that cold working in iron does not become apparent until it is reduced by *c*30–40%. Research at Bradford by Swiss and McDonnell (2003) has confirmed this and demonstrated that the greatest increase in hardness (73%) is achieved after only 20% reduction (110HV of stock iron to 190HV at 20% reduction), comparable to the ferrite hardness (157HV) presented here.

The hardness values obtained from the cutting edges and knife backs reflect the metallographic microstructural variations described above. The butt-welded (Type 2) high-quality steel cutting edges with quenched and tempered microstructures displayed consistent high hardness values (overall average 545HV). In some examples of Type 2 blades the edges were very poor in comparison with the average, with hardness values of *c*200HV or less. In many of these examples the blades had been overheated producing spheroidised carbides in a ferrite matrix. A few examples were manufactured from poorer-quality steel and had not been heat treated, *eg* knife 99/92 from Hamwic (160HV). The Type 1 cutting edges showed a broad range of hardness values (average 307HV), exceptional examples used high-quality heat-treated steels, producing values in excess of 400HV. This pattern was reflected in the Type 4s (steel jacket, iron core), the reverse of Type 1 (steel core, iron jacket), which had an average hardness value of 511HV. The all-steel (Type 5) and piled blades (Type 3) were of poorer quality with average hardness values 299HV and 197HV respectively.

Spheroidisation and 'carbonitride' needles

Spheroidisation occurs if the metal is heated to *c*700°C and kept at this temperature for between 8–32 hours and is unlikely to be accidental (Samuels 1999, 117). Once it has been spheroidised the hardness of the blade will be dramatically reduced. This is one of the few methods of making high-quality knives more easily blunted and therefore unusable. Spheroidisation occurred in four knives from cemetery contexts (from Empingham II and Cannington) and may be an indication that the knives are being deliberately heat treated before burial. For example, a Type 2 knife would normally have a hardness of 528HV but knife 90/5 from Empingham II has a hardness of just 258HV. Some grave-goods, especially weapons, appear to have been deliberately damaged before burial. 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, 94–5). 'Ritual killing' may explain the spheroidisation of knives at inhumation cemeteries, or it may have been a practical attempt to make valuable objects obsolete to deter grave robbers. There were no examples of spheroidisation in the early medieval settlements, although two spheroidised knives have been found in later (10th–12th century) contexts at Fishergate (Rogers 1993, 1303).

All three knives from cremation burials at Loveden Hill showed signs of being exposed to heat. One knife suffered from annealing while two knives had 'carbonitride needles' present. It is unknown how and why these needles form in knives, but it is possible that they developed when heated to high temperatures for many hours and subsequently buried over an archaeological timeframe (Samuels 1999, 421–5). Experiments carried out on pyre cremations and the excavations at Spong Hill indicate that temperatures over 1000°C were attained, and kept, although the temperature would vary depending on the location within the pyre (McKinley 1994, 84; McKinley 1997). The placing of iron artefacts on a cremation pyre has been argued against on metallurgical grounds as there is no evidence for iron from cremations having been 'burnt', *ie* partially oxidised. However, if a pyre generated reducing or neutral conditions then the microstructures in the blades would be annealed, possibly spheroidised. It is difficult on the basis of a small sample to demonstrate significant trends but it should be noted that the 'carbonitride needles' and annealed structure in the three knives from cremation burials might be evidence that knives were placed on the cremation pyre.

Wider chronological overview

Over time the types of iron used differed, as did the quality of the metals used and the manufacturing techniques (McDonnell 1989c). Tylecote and Gilmour's (1986) study of ferrous edged tools showed that most Romano-British knives were made using low-carbon iron and Tylecote's (1987b) examination of Roman knives from Poundbury revealed that they were poor quality with no heat treatments. These findings are supported by the analysis of four Roman knives from Carlisle, only one of which had a steel cutting edge. The hardness values for these Roman knives (average 270HV) shows that there was an improvement in the quality of the knives from the Romano-British to the early medieval period (Swiss 2000), although few Romano-British knives, or other iron artefacts, have been metallographically examined, which makes comparison difficult. The apparent change in quality, *ie* quality of raw metal and subsequent heat treatments, between the Romano-British and the early medieval periods may be due to the introduction of high-quality steel-making technology, in particular the decarburisation of cast irons to make high-carbon (>1.5% C) steels (Mack *et al* 2000).

Table 17 shows that there is an apparent increase in hardness from the 5th to 10th centuries, and then a general decline during the medieval period. Note that the data is an average of all knives. It includes those that have been on a cremation pyre or appear to have been 'ritually killed', which dramatically reduces their hardness and therefore lowers the average values.

Analysis of later 9th to 12th century knives from both Winchester (Rulton 2003; Tylecote and Gilmour 1986) and York (Ottaway 1992) revealed that there was a change in the preferred knife type from a Type 2 to a Type 1. This change in preference was originally thought to have been due to regional differences between the sites, but this is unlikely as this pattern is repeated in the knives examined from Coppergate (Ottaway and Rogers 2002; Ottaway 1992), Winchester (Tylecote and Gilmour 1986) and medieval London (Wilthew 1987). Later in the 13th and 14th centuries there is an apparent shift from the Type 1 blades back to the Type 2 knives. This same pattern is also seen in the knives found at the medieval city of Novgorod, Russia. Here the shift from Type 1 knives to Type 2 knives occurs in the 12th century (Thompson 1967, 71–4; Brisbane 1992, 74–5). In addition to changes in patterns of knife manufacturing technology, there is an apparent increase in use of phosphoric iron at Coppergate after AD 925. This could be associated with Scandinavian influences. Most of all, the data above demonstrates the paucity of archaeometallurgical investigations of this vital commodity and all other classes of iron artefacts.

Conclusions

The metallurgical analysis of a sample of 79 early medieval knives has demonstrated the importance of such studies. This paper has shown some interesting trends but further studies are needed before any of them can be confirmed. The archaeological typological evidence gathered from settlement and cemetery sites shows that the curved-back knives are the most popular type in the early medieval period. Due to the small sample size in this study, it is impossible to note any other significant trends.

The results also clearly demonstrate that iron manufacturing technology reached a peak in the early medieval period not surpassed until the 18/19th centuries. There appears to be a gear change in technology from Romano-British to early medieval iron working. The pinnacle

Table 17: Frequency of knife manufacturing types through time.

Site/Site type	Date (centuries)	Manufacturing type						Total no	Hardness (HV)	
		0	1	2	3	4	5		average	range
Early medieval cemeteries	4th–7th	7	12	7	3	5	8	42	363	100–1000
Early medieval settlements	5th–9th	1	2	26	1	1	1	32	467	153–927
Coppergate[1]	9th–10th	2	9	14	2	3	1	31	510	161–985
Coppergate[1]	10th–11th	2	7	3			1	12	382	110–1283
York[2]	11th–12th	2	5	3			1	11	358	93–755
York[2]	13th–14th		5	3				8	498	140–620
Winchester[3]	11th–13th	1	6	4			2	13	373	100–633
Winchester[3]	13th–14th		1	11			2	14	363	169–557
Winchester[3]	14th onwards		3	5		1	2	11	343	175–701

Notes: 1 – adapted from data collected by McDonnell (1992); 2 – adapted from data collected by Ottaway and Rogers (2002); 3 – adapted from data collected by Tylecote and Gilmour (1986).

of the craft is the Type 2 knife (butt-welded) utilising high-quality, high-carbon, clean steels and heat treated to give high hardness values often in excess of 600HV. The second most common method of knife manufacture is the Type 1 (steel core with iron jacket) followed by Type 5 (all steel), Type 0 (no cutting edge, but possibly worn Type 2s), Type 4s (steel jacket, iron core) and finally Type 3s (piled structures). The Type 1, 5 and 4 knives all display examples of the use of the high-quality steel, followed by excellent heat treatments. Over 58% (44 out of 75) of the knives have cutting edges with hardness values greater than *c*300HV and 29% (22 out of 75) of the backs had hardness greater than *c*200HV. This data complements Mack *et al*'s (2000) argument for the production of high-quality steel in the early medieval period. The majority of the knife backs were manufactured from low-carbon irons or ferritic iron. There was some evidence for the use of phosphoric iron, which appears to become more common in the succeeding, Viking-influenced, period.

The data shows a different pattern of manufacturing typology between settlement sites and cemeteries. The cemeteries have a wider variation in knife manufacturing technology, while the settlements are dominated by Type 2 knives. A number of different models has been proposed to explain this observation. There is some evidence to suggest that the knives used in the cemeteries are related to the status of the individual being buried. Spheroidisation of some of the knives found at Cannington and Empingham II could also indicate that 'ritual killing' is not just limited to weapon burials and suggests that more complex rituals are taking place at the time of burial.

This data has demonstrated some clear patterns in early medieval knife manufacture. There are suggestions of some geographical variation, *eg* the majority of knives with phosphoric iron were recovered from excavations in York. These observations must be tested by further analysis of more early medieval material as well as establishing substantial programmes of analyses for the preceding Romano-British and subsequent Medieval periods.

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