

# Metallographic examination of early medieval knives from the UK

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*ABSTRACT: A review in 2007 of archaeometallurgical studies carried out in the early 1980s and 1990s of early medieval (cAD 410-1100) iron knives revealed several patterns, with clear differences in knife manufacturing techniques present in rural cemeteries and later urban settlements. The main aim of the research presented here 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 both settlements and cemeteries in this period, filling the gaps. The analysis revealed a clear change through time, with a standardisation in manufacturing techniques in the 7th century.*

## Introduction

The early medieval period in England was a time of change. The well-structured and urbanised Roman settlements collapsed, and were replaced by small Early Saxon or post-Roman rural settlements (cAD 410-650) sometimes with large cemeteries. During the 5th to 6th centuries AD rural settlements often only contained a few farmsteads with no evidence for defined boundaries or planned layouts (Hamerow 2002, 1-8). The cemeteries in the Early Saxon period returned to furnished burial (Lucy 2000, 63-64). There is negligible direct evidence for workshops and craft production at this time although most excavated settlements have smithing slag present. By the Middle Saxon period (cAD 650-850) there was a re-emergence of urban, political and religious centres. At the same time there were also changes occurring in burial practices, the most significant being the reduction in the quantities and types of grave goods in the 7th century, gradually leading to the absence of grave goods altogether by the 9th century (Geake 1992; Geake 2002). The Late Saxon period (cAD 850-1100) brought further changes to both rural and urban settlements. Even

though there were significant changes between the Early, Middle and Late Saxon periods, settlements tend to span the boundaries between these periods, and it can often be difficult to date contexts to one specific period. The Saxon period sub-divisions are capitalised in this paper, eg Early Saxon, whereas when comparisons are made between Saxon sites the terms 'early' and 'later' will be used, ie 'early' refers to earlier in the Saxon period.

Over the last 50 years numerous archaeometallurgical studies of iron artefacts have been carried out, by many different researchers in countries across Europe. Knives are commonly recovered during excavations and are particularly common on many early medieval sites so they are ideal for archaeometallurgical studies. In addition they are often composite artefacts utilising the different properties of each iron alloy available, and also different blacksmithing skills, eg heat-treatment, welding, etc. Therefore metallurgical analysis of knives can provide an insight into the development of ironworking technology.

In 2005 a review of the metallurgical analysis of knives

from early medieval England was carried out (Blakelock and McDonnell 2007). This revealed some distinct patterns in knife manufacture, with clear differences between those from settlements and cemeteries. Early Saxon cemeteries had a wider variation in knife manufacturing technology while knives from settlements were dominated by those manufactured by butt-welding a steel cutting edge to an iron back (Fig 2, type 2). The review also suggested possible geographical variations in the alloys used, eg the majority of knives made with phosphoric iron were recovered from excavations in York (Blakelock and McDonnell 2007, 55). The review clearly showed that there were differences between settlements and cemeteries, however it was not then possible to investigate these differences because there was a lack of data for knives from Middle to Late Saxon rural settlements. In addition there were very few knives analysed from settlements contemporary with the Early Saxon cemeteries.

Several hypotheses were put forward to explain the patterns seen in the review paper. The first was that the patterns related to the difference between urban and rural, or high status sites. The second was that the change in manufacturing methods occurred over time, and the final possible, but not mutually exclusive, hypothesis is that knives were being constructed specifically for burial, perhaps representing their owners.

The first suggestion, that the patterns are due to differences in manufacture in urban centres compared to that in rural settlements, was tested through the analysis of knives from the rural settlements at Wharram Percy, Burdale and Sedgeford, which revealed a similar standardisation of knives. However there were clear differences in the quality of the alloys used and the heat-treatment techniques of the blacksmiths (Blakelock and McDonnell 2011).

## Aim and objectives

To investigate the remaining hypotheses (Blakelock and McDonnell 2007, 51-52) new knife assemblages from Early Saxon settlements were examined (Blakelock 2012). This allowed a comparison to be made between the knives from these settlements, and knives from contemporary cemeteries to determine whether there were differences between settlements and cemeteries, and whether the knives were manufactured for burial. These results were then compared to knives from Middle to Late Saxon settlements to reveal whether there were changes in manufacturing methods over time. For this study two new assemblages were selected (Fig 1). The



Figure 1: Map showing the location of the sites mentioned. Triangles indicate Early settlements, stars cemeteries, and circles Middle to Late Saxon and Viking settlements. Blakelock and McDonnell (2007) studied the knives from sites with open symbols; Blakelock (2012) those with solid symbols.

first is that from the Early Saxon rural settlement at West Stow, Suffolk, dated to the 5th to 7th centuries (West 1985). The second assemblage was from a small rural post-Roman settlement with evidence for craft industries and trade networks at Gwithian, Cornwall, dated to the 5th to 7th centuries (Nowakowski *et al* 2008); for the rest of this article this settlement will be considered and grouped together with Early Saxon settlements. Finally a review of the knives from Poundbury, Dorset analysed by Tylecote (1987) was also carried out. This 5th to 7th century rural settlement was established over what had been a Roman cemetery site near to the Roman town of Dorchester (Green *et al* 1987).

In addition more knives from rural Early Saxon cemeteries were analysed, including Quarrington, Twyford and Collingbourne Ducis. The cemetery at Collingbourne Ducis cemetery spanned the late 5th to 7th centuries and had a good spatial separation between the 5-6th-century and the 7th-century burials, allowing changes through time to be plotted (Dinwiddy and Stoodley 2016).

## Methodology

Prior to sampling, the knives were recorded using descriptions, sketches, photographs and X-radiographs. The knives were sampled by removing a single section or two half sections of metal using a micro-slice diamond wafering blade. The sections were then mounted in cold-setting epoxy resin, ground and then polished to a one micron diamond finish.

The samples were examined using reflected light microscopy and the microstructures present in the knives were noted, both prior to and after etching in 2-4% nital. The grain sizes were recorded using an ASTM grain size standard at 100x magnification. Vickers micro-hardness tests were also carried out on many of these sections. Where carried out, the chemical composition of the metal was determined using scanning electron microscopy with energy dispersive X-ray analysis (SEM-EDS) or in some cases by wave-length dispersive (WD) X-ray analysis (by electron probe micro-analysis – EPMA).

Four main types of iron were available to early medieval smiths: ferritic iron which contained few alloying elements (<0.1%); low carbon iron iron, generally with a fine grain structure and containing approximately 0.1 to 0.3% carbon; phosphoric iron containing more than 0.1% phosphorus (but usually carbon-free); and steel which usually contains (approximately 0.3% to 1%) carbon as the main alloying element (McDonnell 1989a; Pleiner 2006, 21-2). Once steel is heat-treated it is difficult to determine the specific carbon content but the higher quality steels often achieve higher hardness values and often appear to contain a greater volume of slag inclusions. High-quality steel first identified in an 8th to 9th century Anglo-Saxon context at Hamwic (Mack *et al* 2000) 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. The term ‘piled

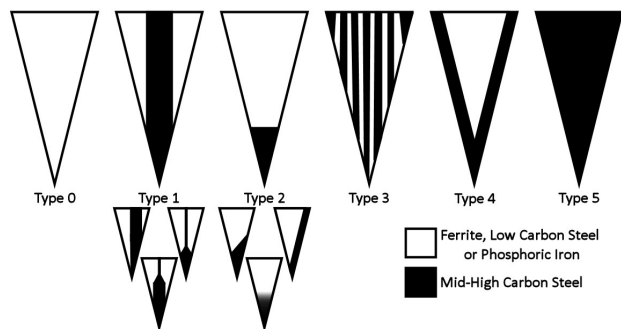


Figure 2: Manufacturing typology based on Tylecote and Gilmour (1986).

iron’ is used to describe banded structures of mixtures of various types of iron. 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 iron during the iron-making process and during the consolidation of the bloom (McDonnell 1989a).

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. 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 (Fig 2) which were further divided into subgroups (Tylecote and Gilmour 1986, 2-7).

## Results

### Early Saxon and post-Roman settlements

The excavations at West Stow uncovered a total of 77 knives. Many of these were well preserved so 15 knives were sectioned and considered alongside the five knives previously analysed by Tylecote and Gilmour (1986). A total of 15 knives were recovered during excavations at Gwithian but, as many of the knives were very badly corroded or fragmented, only four were suitable for analysis.

The metallographic analysis of 20 knives from West Stow revealed that twelve were either simple type 0 knives or type 2 knives (Table 1). There were also three type 1 knives, three type 3 knives as well as one type 4 and one type 5. Only five knives had high-carbon steel and heat-treated (tempered martensite) cutting edges. The others had either pearlitic, low carbon steel or phosphoric iron cutting edges; the steels were too low in carbon to successfully heat-treat. The majority of the knife backs were ferritic or phosphoric iron, but there was also a high proportion (35%) of piled iron backs. Radiographic analysis of the 21 remaining knives revealed another eleven possible type 2 butt-welded knives. This suggests that unlike Middle and Late Saxon settlements in England, the knives at West Stow were manufactured using a range of techniques.

The metallographic analysis of four knives from post-Roman Gwithian revealed that the majority were either type 0 knives or type 2 knives (Table 2). Only one

Table 1: Summary of the data for the fifteen knives analysed from West Stow.

Knife No	Wear	Type	Cutting edge			Back			Heat treated
			Microstructure	HV	HV range	Microstructure	Avg HV	HV range	
72	slight	3	phosphoric iron	183	148-192	phosphoric iron	170	148-192	no
86	slight	0	phosphoric iron	221	127-221	phosphoric iron	184	161-201	no
100	none	2	tempered martensite	549	412-593	piled ferritic/phosphoric iron	224	132-340	yes
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	no
659	slight	2	pearlite	165	107-244	ferrite	140	137-148	no
794	heavy	1	pearlite	303	271-340	ferrite	203	171-232	no
828	some	2	pearlite	271	210-271	phosphoric iron	167	148-201	no
928	some	0	piled ferritic/phosphoric iron	168	107-175	piled ferritic/phosphoric iron	148	107-175	no
973	slight	3	ferrite with pearlite	175	148-175	piled ferrite/mid carbon steel	186	132-232	no
1135	some	2	tempered martensite	473	473-509	piled ferritic/phosphoric iron	160	118-238	yes
1661	slight	4	pearlite	201	201-244	ferrite	117	103-132	no
2191	slight	3	pearlite	386	232-386	ferrite	159	123-205	no
2208	none	2	tempered martensite	549	374-549	piled ferritic/phosphoric iron	163	137-201	yes
716210*		2	pearlite with ferrite			piled ferritic/phosphoric iron			no
716216		0	ferrite	216	148-244	ferrite	189	148-244	no
716232		0	ferrite	137	135-168	phosphoric iron	182	137-221	no
716248		0	ferrite	188	164-188	ferrite with pearlite	216	148-321	no
716300		1	ferrite with pearlite	221	221-490	piled ferritic/phosphoric iron/ low carbon steel	282	183-441	no

Note: \*This sample was not found; data from Tylecote and Gilmour (1986).

Cutting edge HV in Tables 1-5 is value at tip of section.

knife had a high carbon steel cutting edge. This cutting edge was not treated to create the ideally hard but tough tempered martensite but had been cooled quickly to form an intermediate quenched structure (probably bainite), perhaps using a different quenching medium (Tylecote and Gilmour 1986, 17-18). The others 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 eleven knives from Gwithian revealed another two possible type 2 butt-welded knives.

The analyses of seven knives from Poundbury (Tylecote 1987; Tylecote and Gilmour 1986) can be added to this new data. These were summarised by Blakelock and McDonnell (2007, table 8) and date to the post-Roman to Early Saxon period. Four of the seven knives were made by butt-welding a steel cutting edge onto a back of ferritic or low carbon steel. The cutting edges were heat-treated to form tempered martensite. The remaining knives were a range of types. Over half of the knives from Poundbury had been heat-treated, and a further

two had a high enough carbon content to have been heat-treated but were not. 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 phosphoric iron was not identified, although the relative high hardness of some of the microstructures suggests that phosphorus may have been present.

### Early Saxon cemeteries

In total eleven knives were recovered during excavations at the small inhumation cemetery at Quarrington, Lincs. Six knives were selected from this 5th to 6th century assemblage. Only five knives were found during the partial excavation of the 6th to early 8th century cemetery at Twyford, Hampshire, and all were examined in this study. There is a Saxon cemetery at Collingbourne Ducis which spans from the Early Saxon period into the 'final phase', when the number of grave goods decreased, and therefore includes burials dated to the 7th century. In total 55 knives were recovered during excavations and 25 were analysed for this study; 15 were from 6th to

Table 2: Summary of the data for the four knives analysed from Gwithian.

Knife No	Wear	Type	Cutting Edge			Back			Heat treated
			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	no
37	some	2	pearlite/Bainite	457	362-457	ferrite	248	179-321	yes, fast cooled
53	very	0	ferrite with some pearlite	232	232-386	ferrite with some pearlite	271	215-340	no
61	some	0	ferrite/Phosphoric Iron	232	201-278	ferrite/phosphoric iron	251	210-303	no

Table 3: Summary of the data for the six knives analysed from Quarrington.

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	

early 7th century contexts while the remaining 10 were from securely dated 7th century contexts.

The metallographic analysis of the six knives from Quarrington revealed a range of different knife types (Table 3) although two type 0 knives were identified. One knife was so badly corroded identification was impossible. Only one knife had a heat-treated cutting edge, although another had a mid to high carbon steel cutting edge. 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. Analysis of the remaining knives that were radiographed revealed another two possible type 2 butt-welded knives and up to three more knives which have been heat-treated.

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 4). All three type 2 knives had high-carbon steel, heat-treated cutting edges. The others had low carbon iron cutting edges, which would have been too low in carbon to heat-treat (hence not being termed steel). The majority of the knife backs were low carbon iron or phosphoric iron.

The metallographic analysis of 25 knives from Collingbourne Ducis revealed distinct differences between the two chronological groups. The 6th to early 7th century knives were constructed using a range of different manufacturing techniques (Table 5, upper section) with 60% being either plain iron type 0 knives

or all steel type 5 knives. Eight 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 (70%) type 2 knives (Table 5, lower section). The rest of the group consisted of one each of type 0, type 1 and type 3. Six of the ten knives had been heat-treated. As in the earlier 6th-7th century knives, the majority of the knife backs were low carbon steels or phosphoric iron. The X-radiographs of the remaining 30 knives, most of which were 6th century though some were undateable, revealed up to another 14 butt welded knives, of which 11 may have had a steel cutting edge. Only two knives had neither weld lines nor evidence for steel and these may have been type 0 or type 3 knives.

## Discussion

### Middle to Late Saxon settlements

As previously mentioned, in the past the majority of English early medieval metallographic analysis programmes concentrated on either urban centres or cemeteries, but when the knives were compared (Blakelock and McDonnell 2007) some clear differences in knife manufacture were seen. One hypothesis was that this was due to differences between urban and rural settlements. Analysis of knives from rural and higher status settlements were carried out to explore this possibility and the results were published by Blakelock and McDonnell (2011) and are summarised here.

Table 4: Summary of the data for the five knives analysed from Twyford.

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: Summary of the data for the twenty five knives analysed 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	

Note: The upper part of the table is data from the 6th to early 7th century knives; the lower part the data from the 7th century knives.

The first point that emerges from their work is that the main manufacturing method for Middle to Late Saxon urban, high status and rural settlements is to butt-weld a steel cutting edge onto a back consisting of ferritic iron, phosphoric iron, piled iron or occasionally mild steel. This standardisation of knives appears to be widespread in the Middle to Late Saxon period, occurring across the country (Blakelock and McDonnell 2007; 2011). The type 2 (butt-welded) knife allowed the smith to create a steel-edged tool utilising the smallest quantity of steel, perhaps necessary if the steel used was a high-priced high-quality product. There is another change in manufacture preference during the 9th-10th centuries from a type 2 to a type 1 (Fig 3). 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.

Another pattern noted during this analysis was the relative absence of heat-treated knives in rural settlements compared to those from urban centres (Blakelock and McDonnell 2011). This, in addition to the absence of some types of stock iron and the many repairs utilising unusual softer alloys, suggests that many of the better quality knives from rural settlements were being manufactured elsewhere and were brought to the sites. There is also a difference in the alloys used, with more ferritic iron found in knives in urban centres, and more phosphoric iron in those from rural settlements. In addition, more piled iron was found in the rural settlements which may suggest that these settlements were more inclined to recycle iron. This may relate to differences in availability of iron, perhaps influenced by necessary local production of iron using local bog iron ores in the rural settlements in comparison to the ability to source specific iron alloys in urban settlements.

Table 6: Summary of the cutting edge data for the knives of each manufacturing type from Early to Middle Saxon settlements. For comparison the same data is given for knives from both Early to Middle Saxon cemeteries and Middle to Late Saxon settlements.

Sites		Manufacturing Type (see Figure 2)						Overall	Data source
		0	1	2	3	4	5		
West Stow	Number	6	3	6	3	1	1	20	Table 1
5th-7th	Avg HV	198	326	401	248	201	549	303	
	Range HV	137-257	221-453	165-549	175-386	201	549	137-549	
Gwithian, Cornwall	Number	2		2				4	Table 2
5th-7th	Avg HV	422		232				327	
	Range HV	386-457		232				232-457	
Poundbury, Dorset	Number	1	1	4	1			7	Tylecote 1987
5th-7th	Avg HV	210	245	505	214			384	
	Range HV	210	245	330-615	214			210-615	
All Early to Middle Saxon cemeteries	Number	16	17	22	9	7	13	84	
	Avg HV	172	316	560	215	513	267	350	
	Range HV	130-303	100-724	238-1000	143-593	388-775	116-593	100-1000	
All Early to Middle Saxon settlements	Number	9	4	12	4	1	1	31	
	Avg HV	249	306	408	240	201	549	325	
	Range HV	137-457	221-453	165-615	175-386	201	549	137-615	
All Middle to Late Saxon settlements	Number	9	4	67	6	3	2	91	
	Avg HV	184	581	445	211	446	558	412	
	Range HV	123-268	476-766	121-847	137-314	309-549	509-607	121-847	

**Early Saxon settlements and cemeteries**

When construction methods are compared, there is a clear difference between Early Saxon settlements and Middle to Late Saxon settlements. The knives from the Early Saxon settlements showed a variety of different construction techniques (Fig 4 and Table 6). This is similar to the knives from the contemporary cemeteries which equally revealed a range of different manufacturing techniques. A chi-square test was used

to confirm similarities between assemblages. In this, the closer the probability value is to 1, the more similar the assemblages are. When the Early Saxon settlements were compared to the contemporary cemeteries there was a clear relationship (chi-square value 6.47, degrees of freedom 5 and probability 0.26) but when cemetery knives were compared to the Middle to Late Saxon settlement knives there was a significant difference (chi-square value 37.42, degrees of freedom 5 and probability 0.00). The statistical test has shown that Early Saxon settlement and cemetery knives are similar, and that changes in manufacturing type occur through time, as shown by the higher chi-square value.

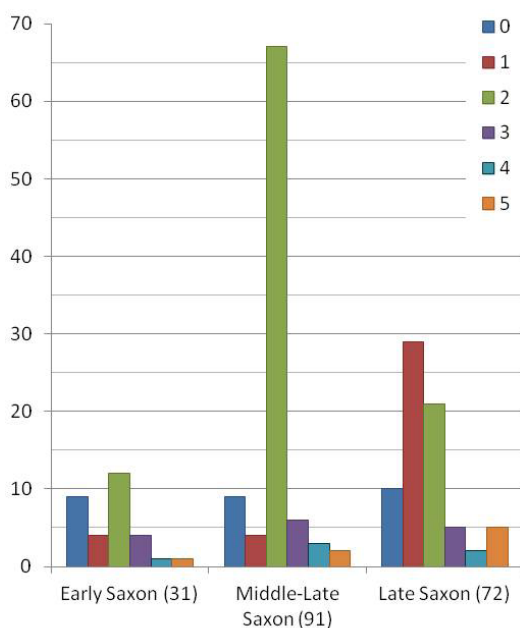


Figure 3: Bar chart showing the distribution of each knife type through time, the number in brackets indicates the total number of samples for that period.

The analysis of early knives revealed different patterns to those from later settlements in the quality of the knives, the heat-treatments carried out and the alloys used. The overall quality of the Early Saxon knives is poorer than the knives utilising the high-quality high-carbon steels seen in the later Saxon settlements. The alloys chosen for creating the early knives would have influenced the number that could have been heat-treated; even so only 10 knives out of the 31 analysed from Early Saxon settlement sites showed any evidence for heat-treatment compared with 52 of 91 from later settlements.

The data presented above 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

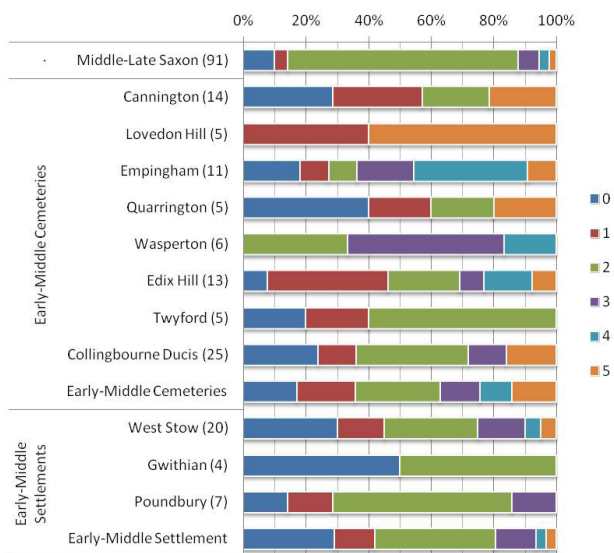


Figure 4: Stacked bar chart showing the distribution of knife manufacturing types in early settlements and cemeteries, compared to Middle to Late Saxon settlements. The numbers in brackets indicate the number of samples.

in the latter period suggests significant changes in technology and in the 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 or insecure contexts. Exceptions to this pattern are Early Saxon graves, as some can be dated to specific centuries based on the types of grave goods present, or via associated evidence, *eg* radiocarbon dating (Lucy 2000, 16-64; Lucy and Reynolds 2002). To determine a specific time frame for these manufacturing changes, knives in securely-dated 7th century burials were compared to the other Early Saxon cemetery knives (Fig 5 and Table 7). Both sets of data were then re-analysed to see if a distinct change could be observed. Note however, that because it is very difficult to precisely date artefacts in early medieval settlements and cemeteries, it is not always possible to identify all 7th century knives so there may be some later knives within the Early Saxon groups.

Table 7: Summary of the data for the knives of each manufacturing type from Early Saxon cemeteries. For comparison the same data is given for knives from Early to Middle and Middle to Late Saxon settlements.

Sites		Manufacturing Type (see Figure 2)					Overall	Data source	
		0	1	2	3	4			5
Cannington 4th-6th	Number	4	4	3			3	14	McDonnell 1989b
	Avg HV	145	260	866			218	348	
	Range HV	130-171	182-400	672-1000			194-257	148-1000	
Lovedon Hill 5th-7th	Number		2				3	5	McDonnell 1989c
	Avg HV		442				218	308	
	Range HV		160-724				116-299	116-724	
Empingham 5th-7th	Number	2	1	1	2	4	1	11	Timby and Bartlett 1996
	Avg HV	195	213	258	189	592	475	371	
	Range HV	182-208	213	258	181-196	433-775	475	181-775	
Quarrington 5th-7th	Number	2	1	1			1	5	Table 3
	Avg HV	165	549	271			183	266.6	
	Range HV	154-175	549	271			183	154-549	
Wasperton 5th-7th	Number			2	3	1		6	Starley 2009
	Avg HV			420	210	445		319.1667	
	Range HV			238-602	144-285	445		144-602	
Edix Hill 6th-7th	Number	1	5	3	1	2	1	13	Gilmour and Salter 1998
	Avg HV	144	302	649		388		337	
	Range HV	144	100-586	312-824		388		100-824	
Twyford 6th-7th	Number	1	1	3				5	Table 4
	Avg HV	143	168	531				381	
	Range HV	143	168	441-644				143-644	
Collingbourne Ducis 6th-7th	Number	6	3	9	3		4	25	Table 5
	Avg HV	193	337	535	309		376	377	
	Range HV	132-303	161-593	303-841	143-593		286-593	132-593	
All Early to Middle Saxon cemeteries	Number	16	17	22	9	7	13	84	
	Avg HV	172	316	560	215	513	267	350	
	Range HV	130-303	100-724	238-1000	143-593	388-775	116-593	100-1000	
All Early to Middle Saxon settlements	Number	9	4	12	4	1	1	31	
	Avg HV	249	306	408	240	201	549	325	
	Range HV	137-457	221-453	165-615	175-386	201	549	137-615	
All Middle to Late Saxon Settlements	Number	9	4	67	6	3	2	91	
	Avg HV	184	581	445	211	446	558	412	
	Range HV	123-268	476-766	121-847	137-314	309-549	509-607	121-847	

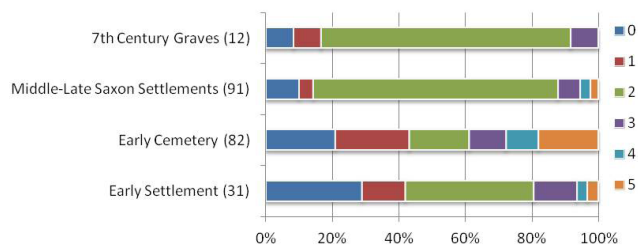


Figure 5: Stacked bar chart showing the distribution of knife manufacturing types in 7th century graves compared to Early Saxon cemeteries and settlements, and Middle to Late Saxon settlements. The numbers in brackets indicate the number of samples.

The most striking difference is that the vast majority of the 7th century knives from cemeteries were type 2s (Fig 5 and Table 7). The distribution of types in the 7th century knives from cemeteries was similar to that in the Middle Saxon settlements, and when a 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 also used to check that there was a statistical difference in the manufacturing types of knives in the early cemetery group compared to those from 7th century burials; 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 used to make knives placed in burials in the 7th century.

During the 6th-7th century trading and industrial urban settlements were starting to re-appear, eg Ipswich and Lundenwic (Hinton 2005, 75-77; Hodges 1982, 69-71), possibly around the same time as there were changes in knife manufacture. The sudden standardisation of knives could have been influenced by 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. However, standardisation was not limited to the urban settlements as it is also seen in rural and high status settlements suggesting that if these urban settlements started the process of change, the result was 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 of resources and control of the landscape. The landscape was split into administrative areas known as hundreds with enough resources, eg water, woodland etc, and land to support 100 families; these would eventually become 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, eg 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 which may have had better access to higher quality alloys, in contrast to the more frequent piled iron knives seen in the rural settlements.

## Conclusion

The standardisation of knife manufacture in the 7th century revealed through analysis of securely dated cemetery contexts strongly points to specialisation in the iron industry in this period. This coincided with the development of urban trading centres, which may have facilitated the movement of ideas and ironworking techniques. The change in manufacturing methods may also relate to new levels of control as kingdoms emerged and the new religion, Christianity, was adopted. It is however clear that there are significant changes in iron technology occurring in Saxon Britain, but also differences between urban, rural and high status sites in the technologies the smiths choose or were able to employ.

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