

**AN ARCHAEOLOGICAL STUDY OF EARLY MEDIEVAL
IRON TECHNOLOGY**

**An examination of the quality and use of iron alloys in iron
artefacts from Early Medieval Britain**

Volume 2

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Figures



Figure 1 - Map of sites across Britain

Map of Britain with the sites indicated by the red stars



The Civitates of Roman Britain in the second century

Figure 2 – Map of Roman Britain (c. AD400)

(James 2001: 35)

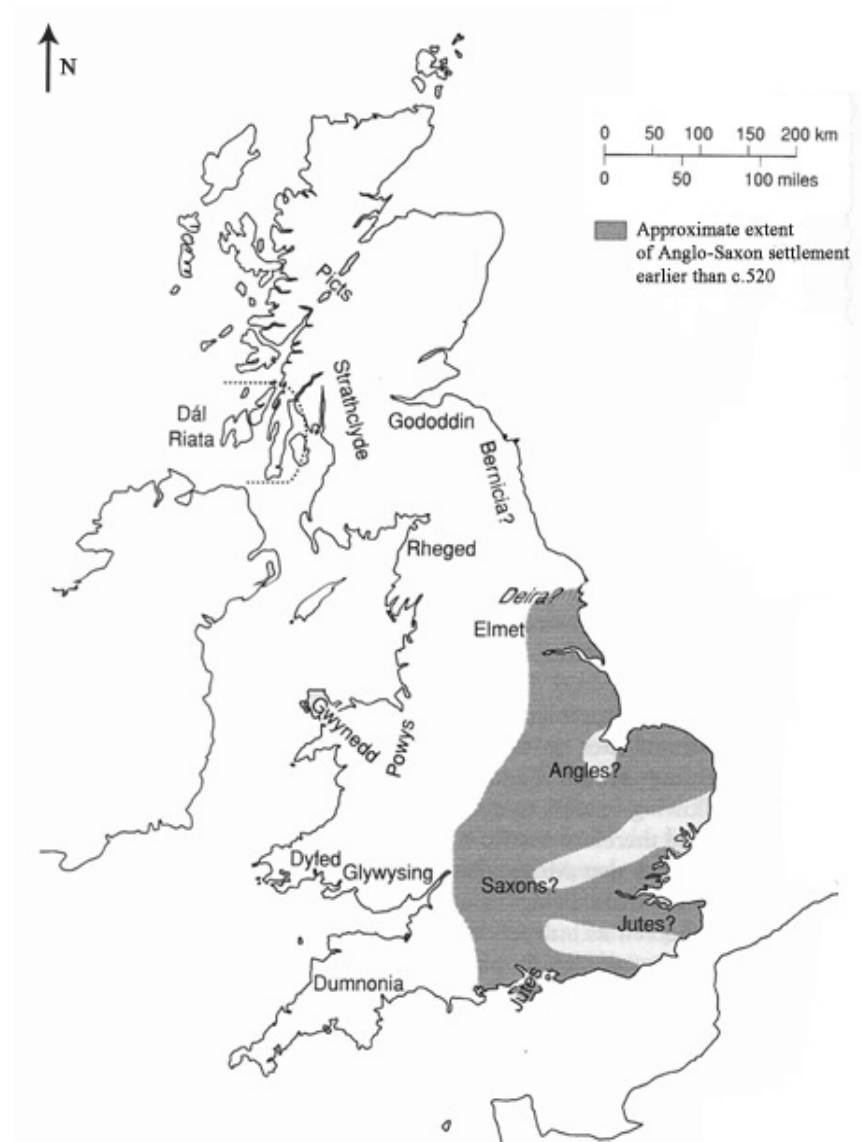


Figure 3 - Map of Early Anglo-Saxon Britain (AD500)

(James 2001: 102)



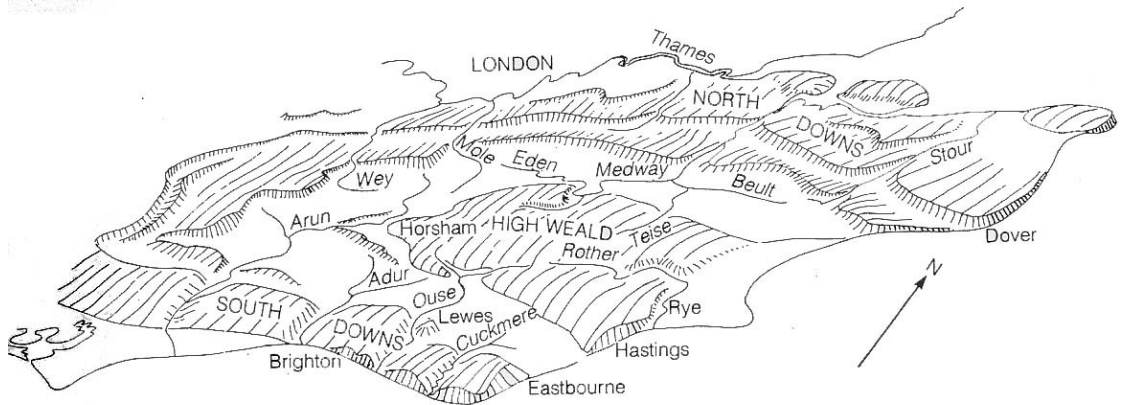
Figure 4 - Map of Middle Saxon Britain (AD700)

(James 2001: 130)



Figure 5 – Late Saxon Britain (AD900)

(James 2001: 235)



Relief of the Weald.

Figure 6 - Map of the Weald

Geographical Map of the Weald (Cleere and Crossley 1995)

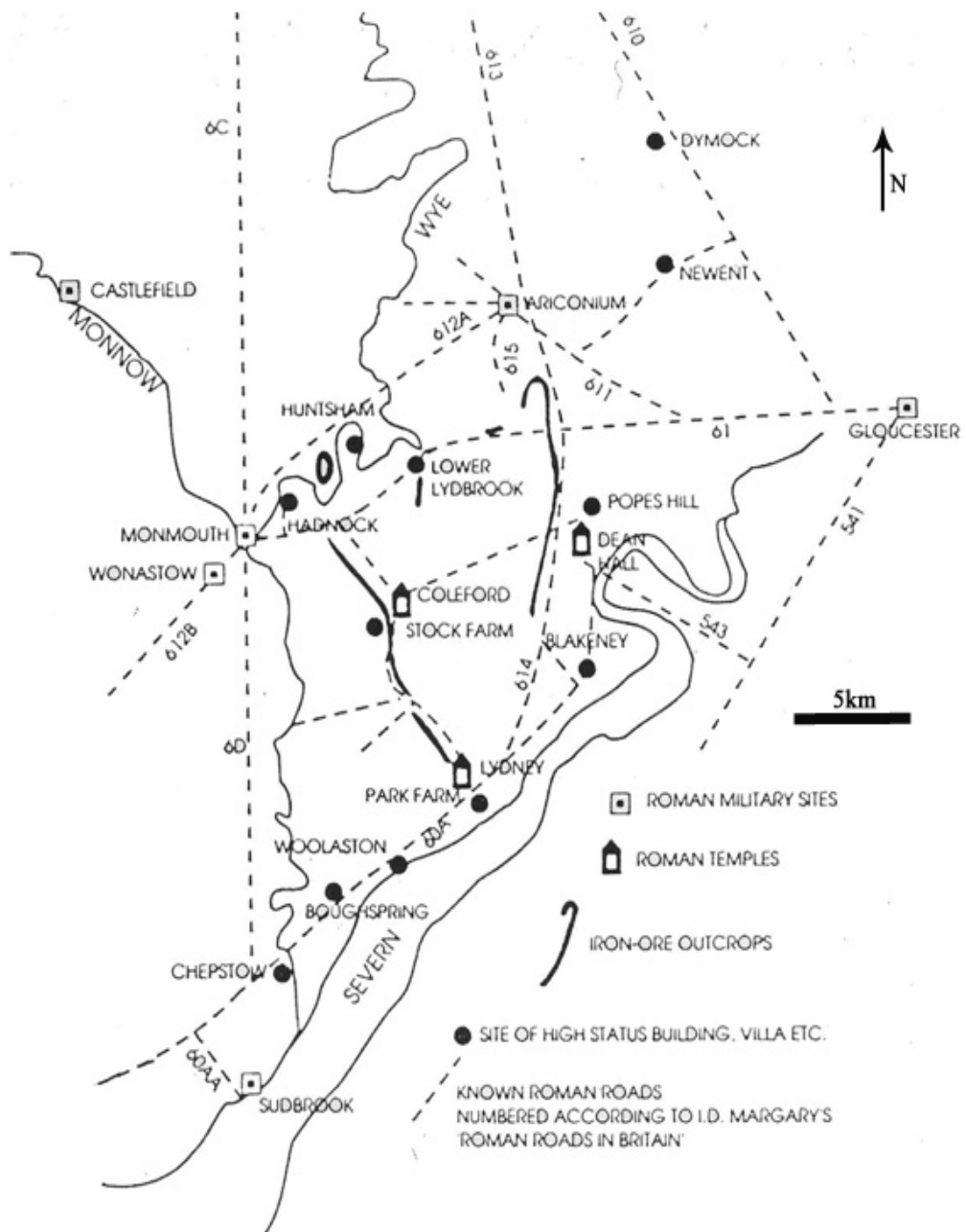


Figure 7 - Map of the Forest of Dean

Geographical Map of the Forest of Dean

(Walters 1999: 127)

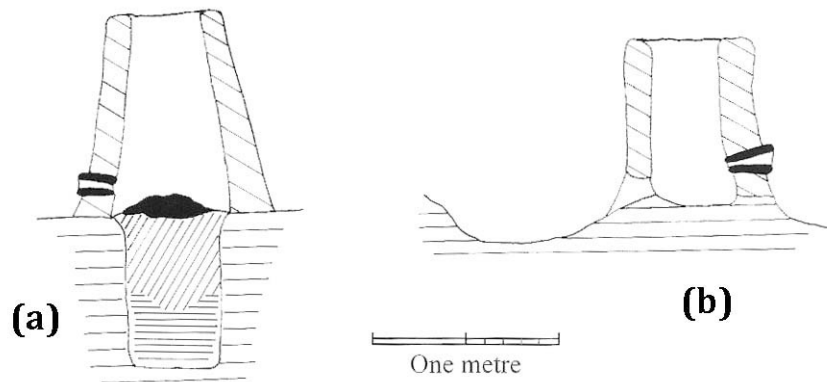


Figure 8 - Iron bloomery furnaces

Iron Bloomery Furnaces (a) Slag block furnace (b) Slag tapping furnace

(Leahy 2003: 113)

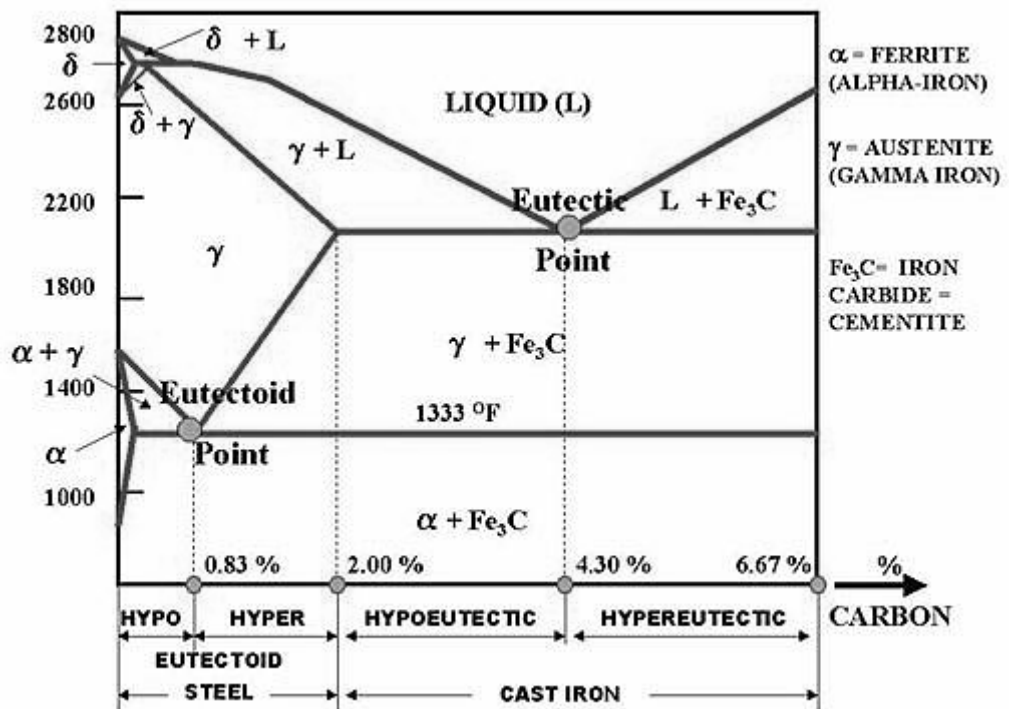


Figure 9 - Fe-C phase diagram

Fe-C phase diagram (from www.geo-res.net/node/90)

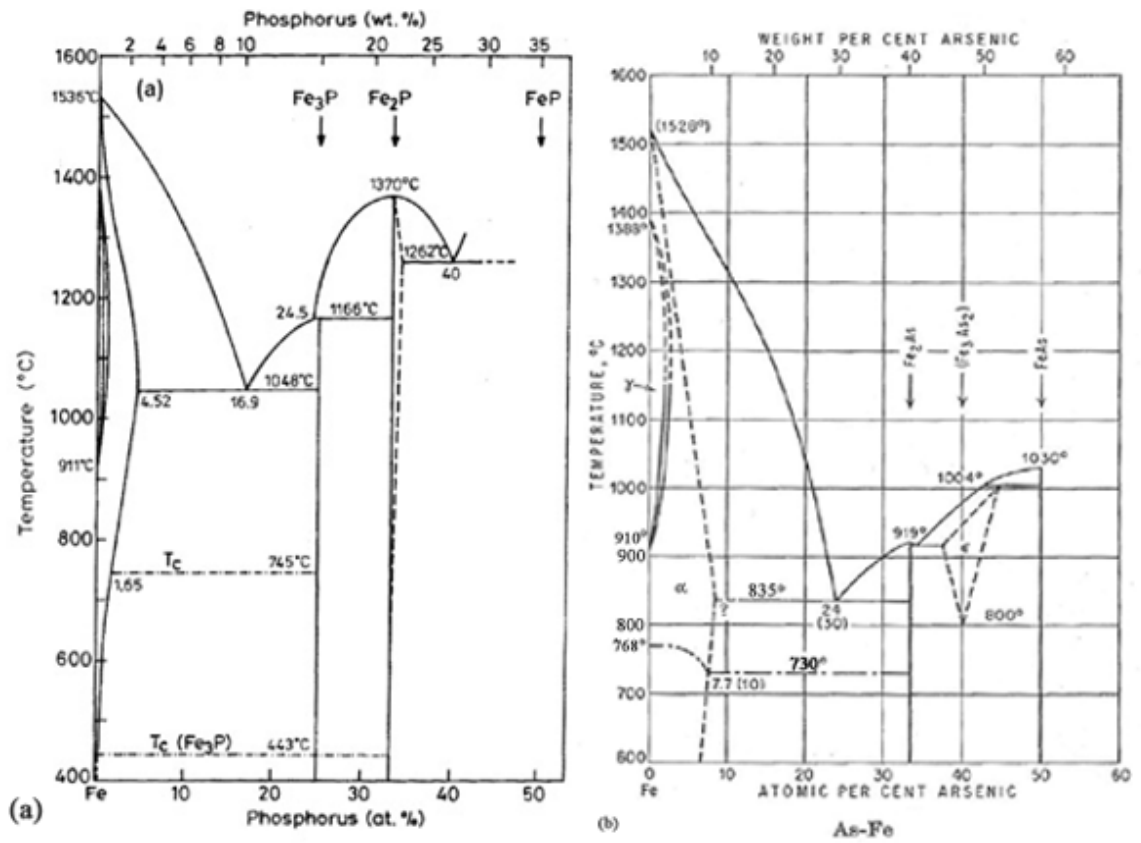


Figure 10 - Fe-P and Fe-As phase diagrams

(a) Fe-P phase diagram (from Gouthama and Balasubramaniam, 2003) (b) Fe-As phase diagram from (Hansen 1958: 163)

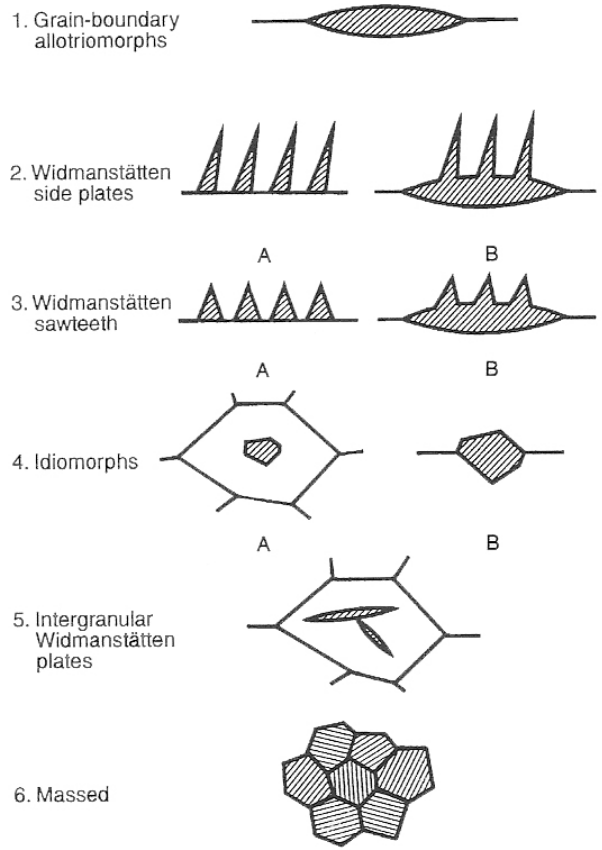


Figure 11 - Dubé classification system

(Samuels 1999: 202)

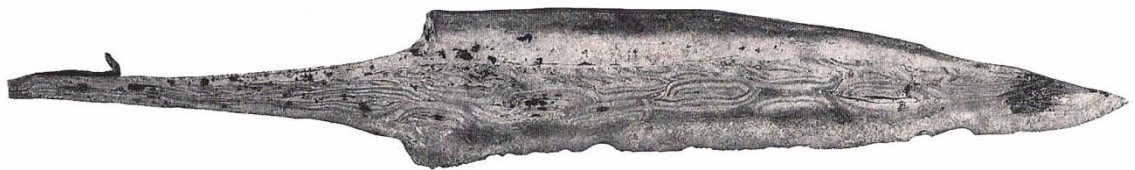


Figure 12 - Pattern welded blade

Pattern welded blade from Coppergate, York (Ottaway 1992)

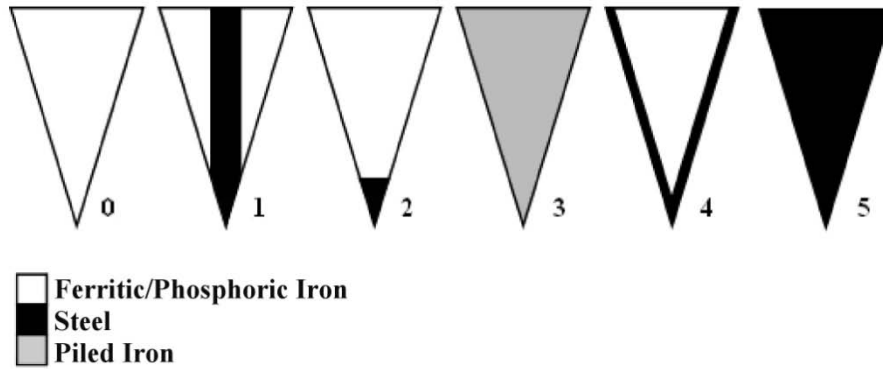


Figure 13 – Knife manufacturing typology

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 cutting 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. *(The term steel in this figure can be either high carbon or low carbon steel)*

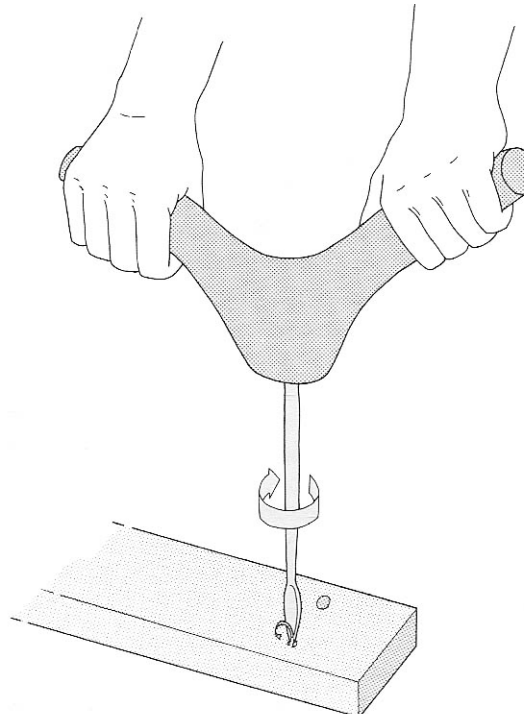


Figure 14 – Viking spoon auger from Coppergate

The Viking spoon auger from Coppergate (Ottaway 1992: 532)

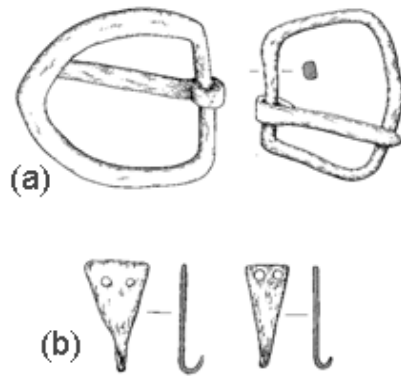


Figure 15 – Dress fittings

Dress fittings: (a) belt buckles and (b) hook tabs from Saxon Worchester (Dalwood and Edwards 2004: 229)

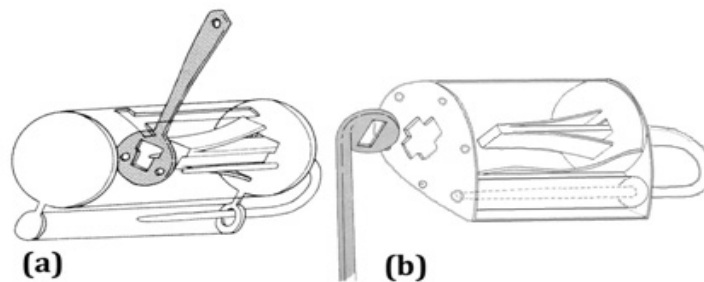


Figure 16 – Early Medieval locks

Early medieval locks (a) Bolt lock with side key hole (Ottaway, 1992 666) (b) Bolt lock with bottom key hole (Ottaway 1992: 664)

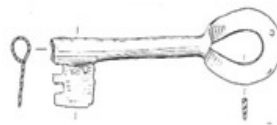


Figure 17 – Viking key from Coppergate

(Ottaway 1992)

Illustration of Key Yo6295

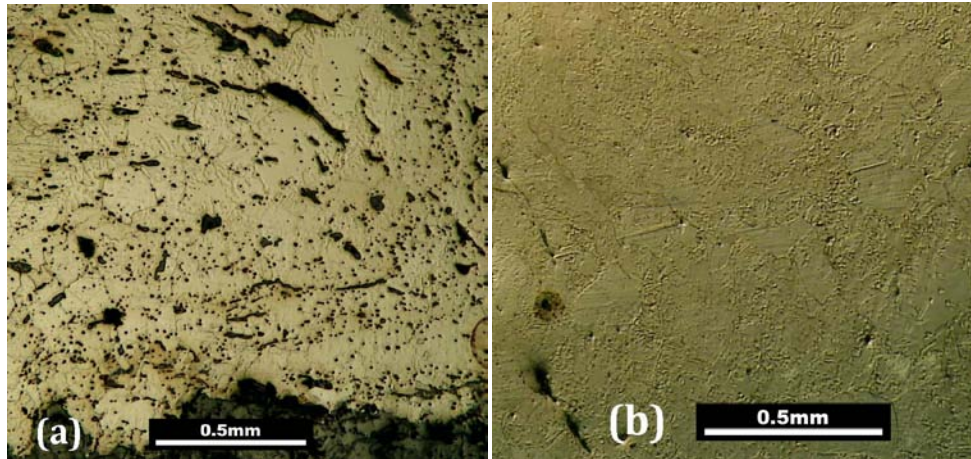


Figure 18 - Examples of material quality

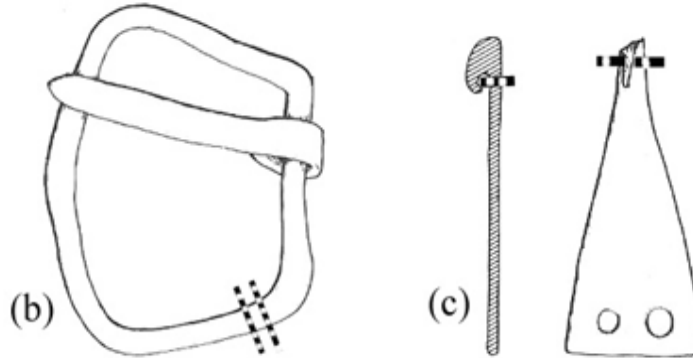
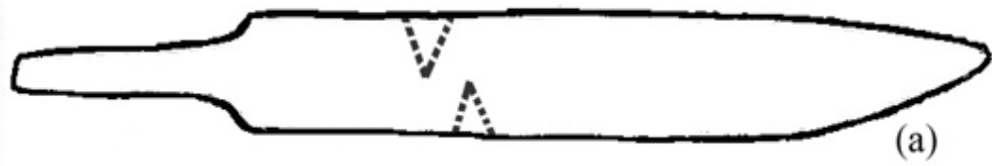
Examples of material quality (a) a dirty microstructure (b) a clean microstructure
(CC977 and CC161 respectively)



Figure 19 - Examples of artefact classes

(a) Knife BN300 (b) Buckle SOU1073 (c) Nail Thet277A (d) Hook CC161 (e) Bar
CC292

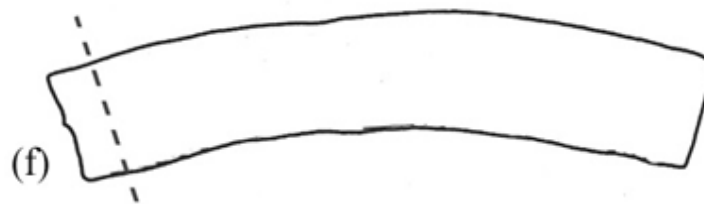
Class 1



Class 2



Class 3



..... indicates where section was removed

Figure 20 - Examples of section placements

(a)knife (b)belt (c)dress tab (d)nail (e)staple (f)bar

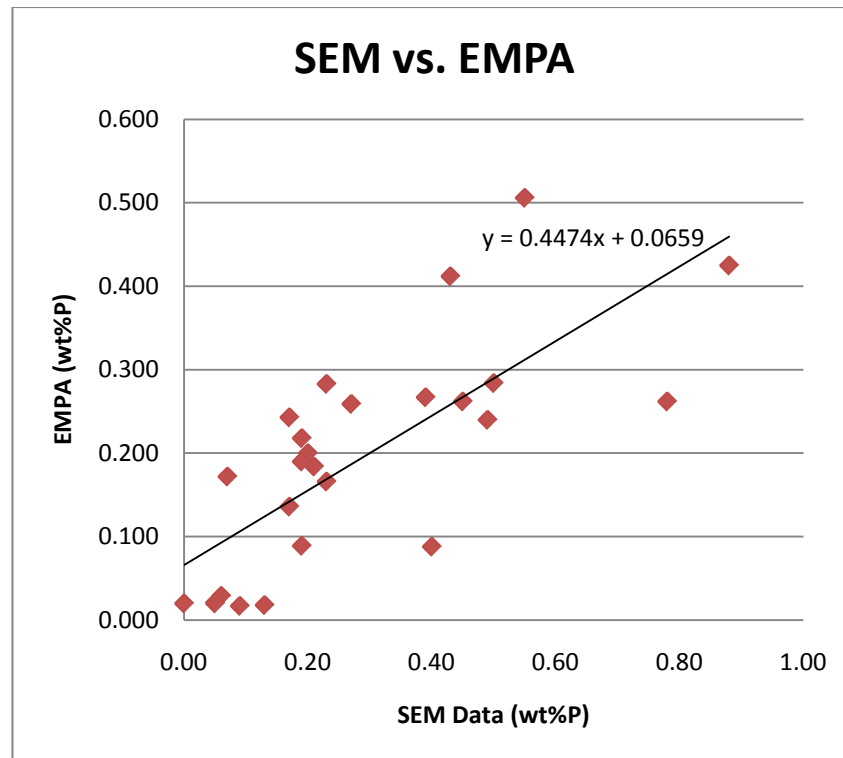


Figure 21 – SEM vs. EMPA analyses

A graph of Scanning Electron Microscope values vs. Electron Microprobe Analyses values

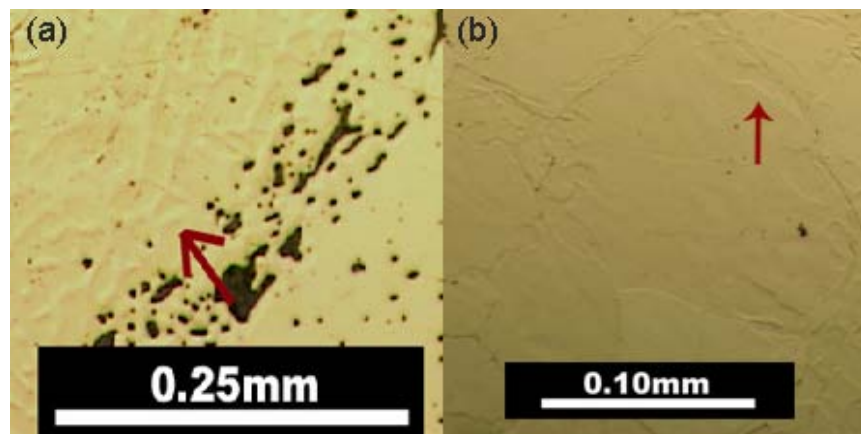


Figure 22 – Grain boundary ghosting

(a) Ghosting with overlying current structure (red arrow) Thet203-5 (b) Ghosting along the grain boundaries (red arrow) Thet248

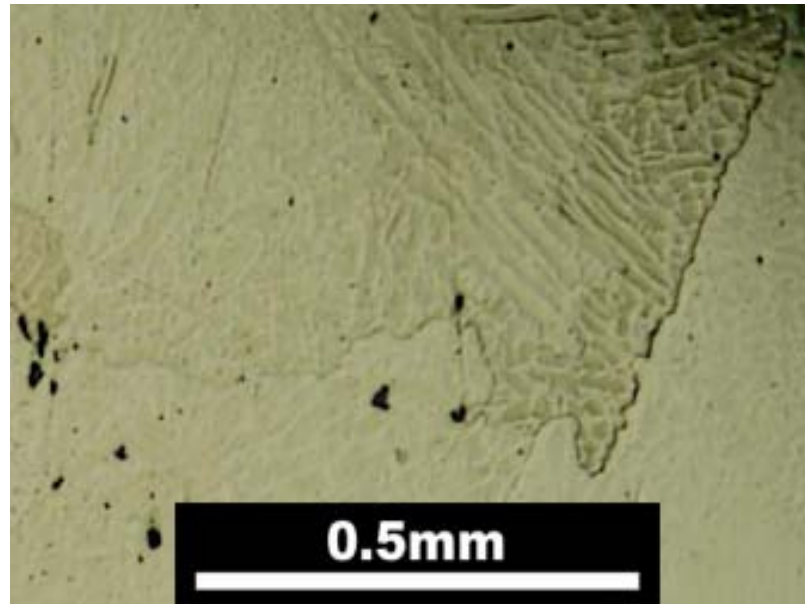


Figure 23 - Inter-granular ghosting

Inter-granular Ghosting (Image from WP95)

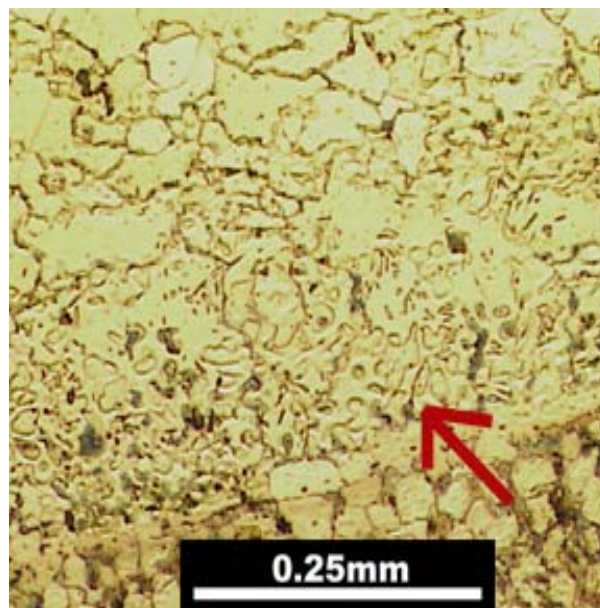


Figure 24 - Edge effect ghosting

Edge Effect Ghosting Where P-iron Meets Pearlite (red arrow)

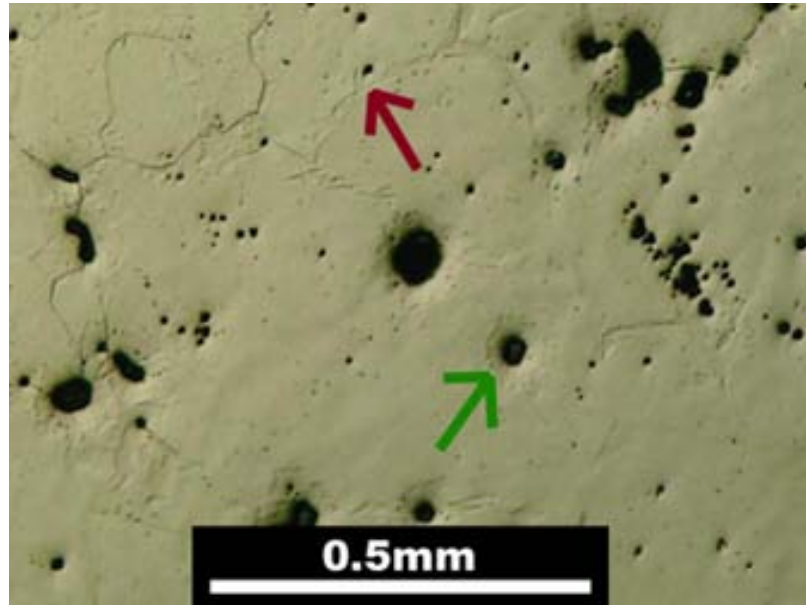


Figure 25 - Slag inclusion ghosting in WP115

Grain Boundary Ghosting (red arrow) and Slag Inclusion Ghosting (green arrow)

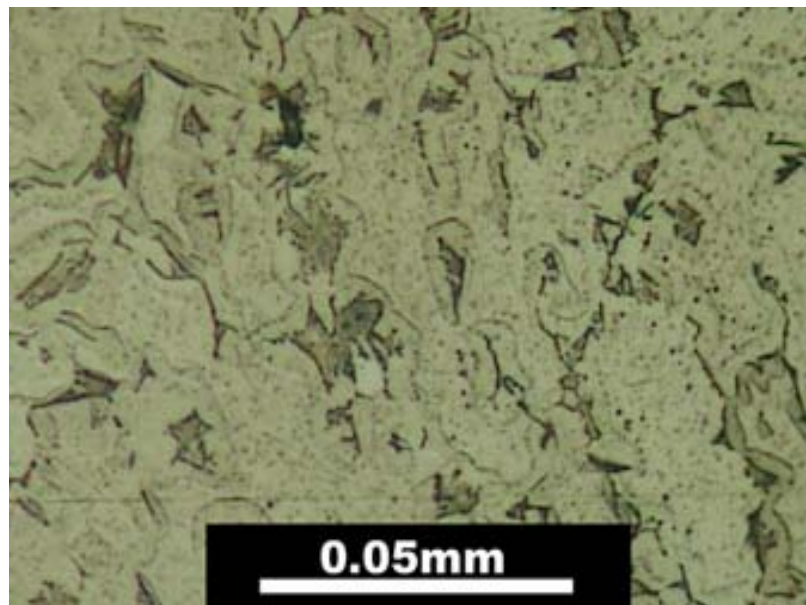


Figure 26 - Pearlitic Ghosting in SOU99-92

Pearlitic Ghosting

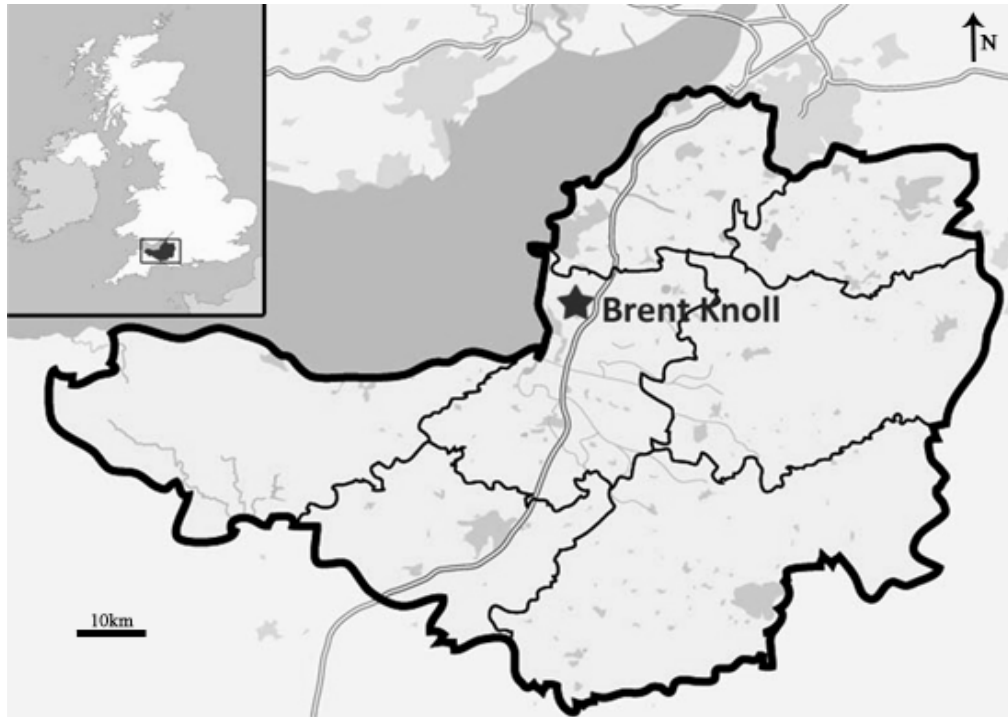


Figure 27 - Map of the location Brent Knoll

(from

http://en.wikipedia.org/wiki/Template:Location_map_United_Kingdom_Somerset)

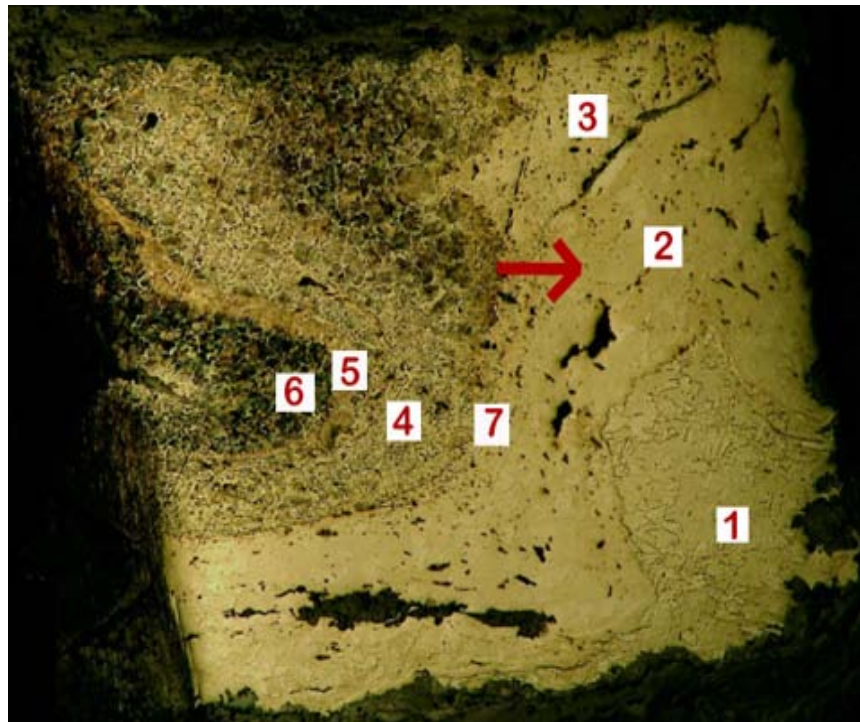


Figure 28 - Cross-section of nail BN310

A cross-section of nail BN310
 (areas of hardness testing and other analyses are indicated; also indicated is the area
 of high arsenic)

Table 15 Analysis results for nail BN310

(Hv# - The hardness test number corresponding the image above)

HV #	Alloy type	Vickers Hardness (Hv)	SEM %P	SEM %As	ASTM Grain Size	Notes
Hv1	Ferrite	176	0.1 ± 0.1	0.1 ± 0.2	5	
Hv2	Arsenical Iron	180	0.1 ± 0.1	0.40 ± 0.2	6	Etch Resistant
Hv3	Phosphoric Iron	257	0.7 ± 0.1	0.1 ± 0.2	6	Ghosted
Hv4	Ferrite + Pearlite 0.4%C	184	nd	0.40 ± 0.2	n/a	
Hv5	Weld-line	220	nd	nd	n/a	Weld-line
Hv6	Pearlite	274	0.1 ± 0.1	nd	n/a	
Hv7	Weld-line	187	nd	1.1 ± 0.2	8	

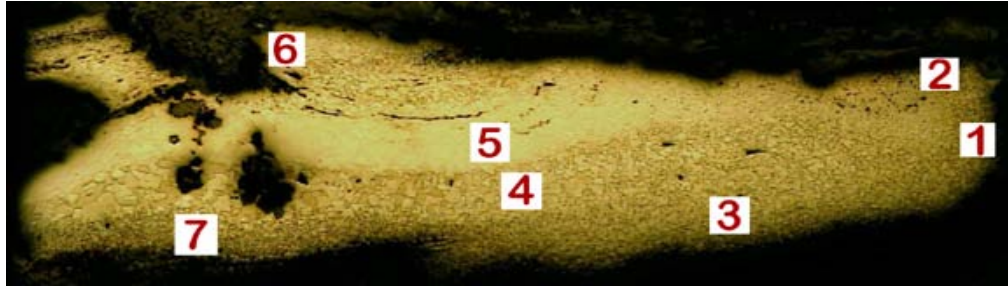


Figure 29 - Cross-section of nail BN334

A cross-section of nail BN334 (areas of hardness testing and other analyses are indicated)

Table 16 Analysis results for nail BN334

(Hv # - The hardness test number corresponding the image above; nd = not detected)

HV #	Alloy type	Vickers Hardness (Hv _{0.2})	SEM %P	SEM %As	ASTM Grain Size	Notes
Hv1	Ferrite + Pearlite <0.1%C	148	0.1 ± 0.1	0.3 ± 0.2	8	
Hv2	Pearlite + Ferrite 0.7%C	314	0.1 ± 0.1	0.5 ± 0.2	n/a	
Hv3	Ferrite	164	nd	0.2 ± 0.2	7	Ghosted
Hv4	Ferrite	219	nd	0.3 ± 0.2	6	
Hv5	Phosphoric Iron	241	0.2 ± 0.1	0.6 ± 0.2	6	Etch Resistant
Hv6	Ferrite + Pearlite 0.1%C	278	0.1 ± 0.1	0.4 ± 0.2	8	
Hv7	Pearlite + Ferrite 0.7%C	293	nd	0.5 ± 0.2	n/a	

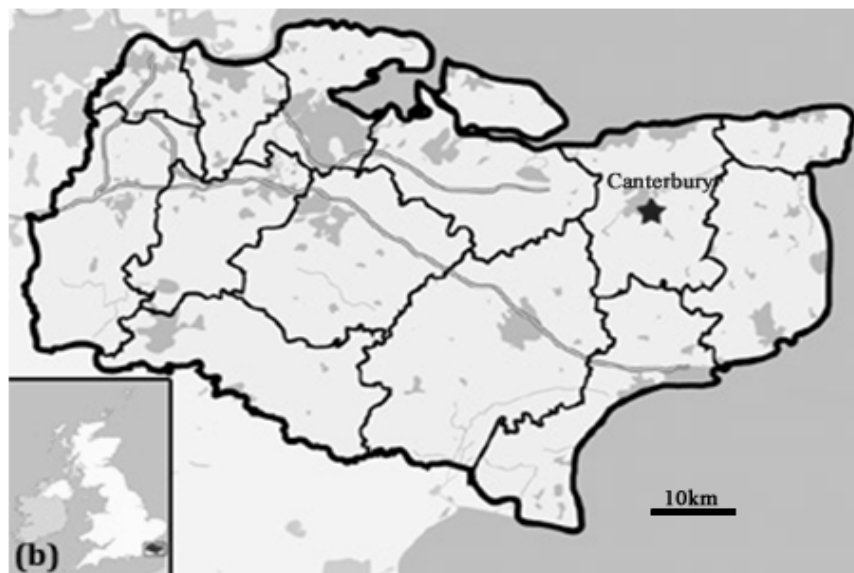
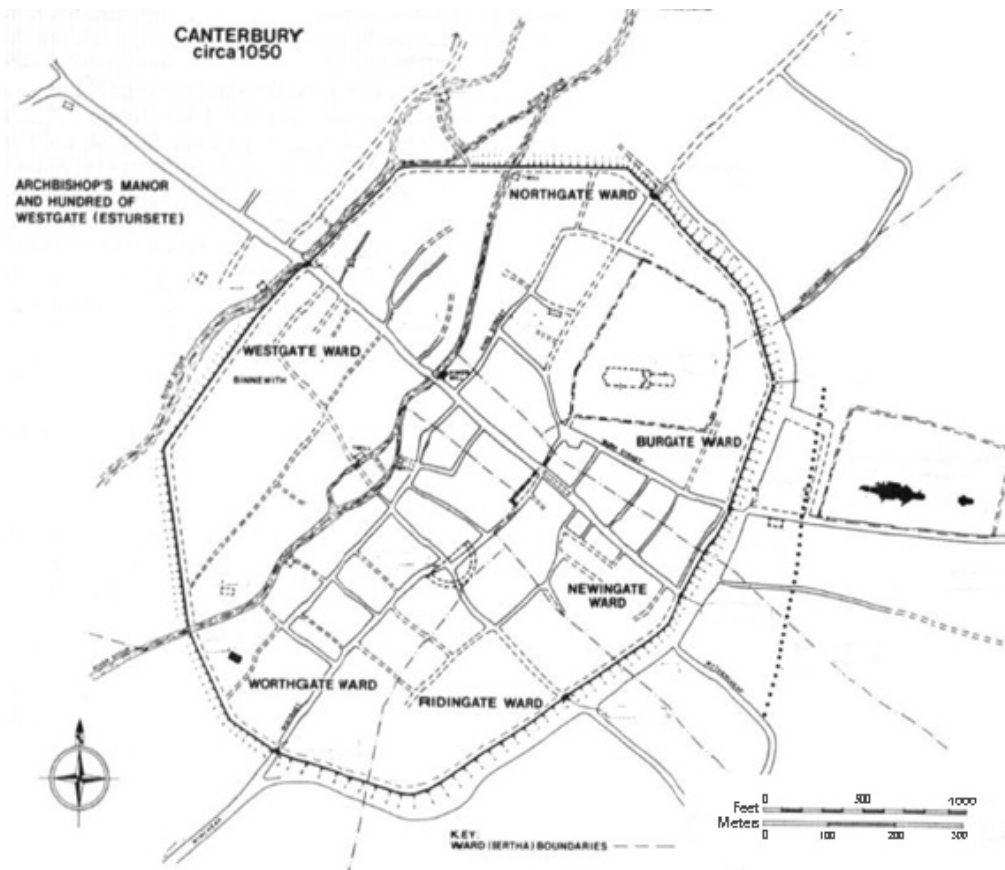


Figure 30 – Map of the location of Canterbury

(a) Map of Kent with Canterbury indicated (adapted from http://en.wikipedia.org/wiki/File:Kent_outline_map_with_UK.png) (b) Map of Canterbury AD1050 (Tatton-Brown 1992: 82)

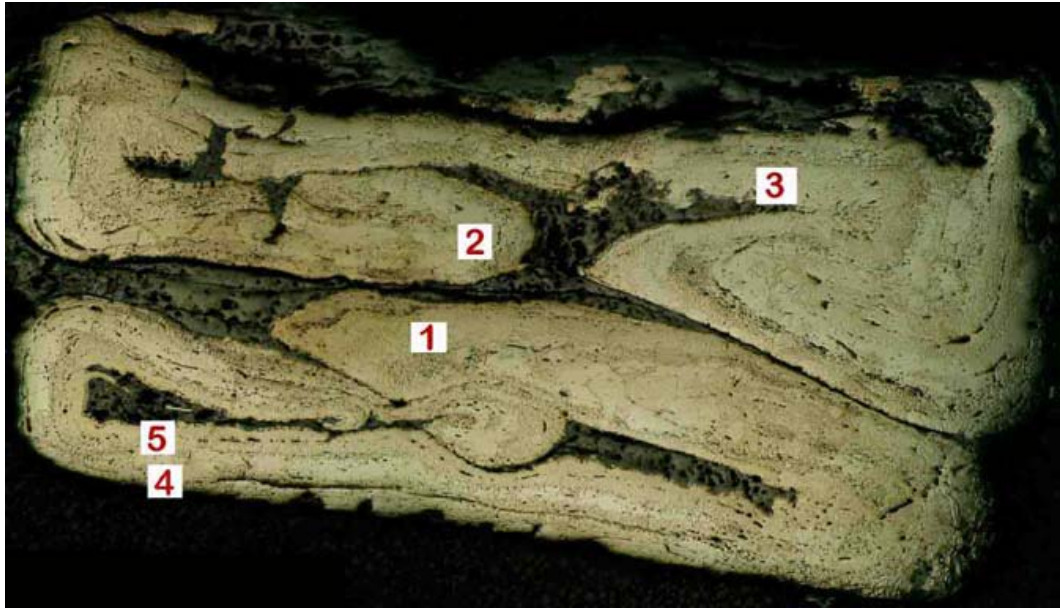


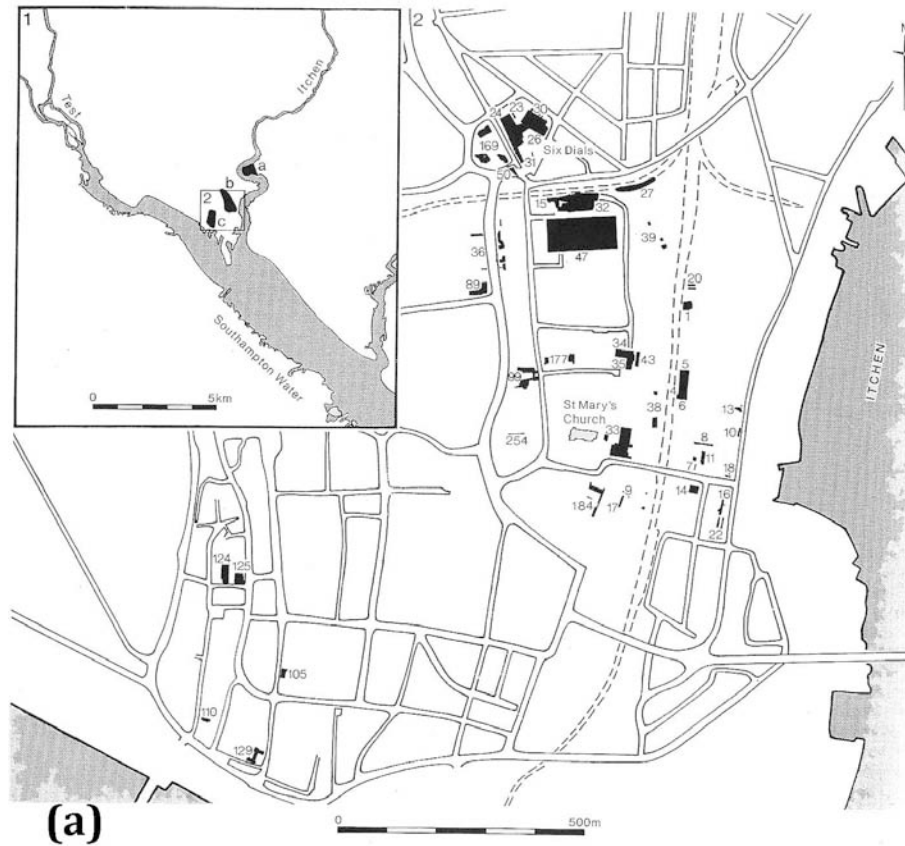
Figure 31 - The cross-section of bar CC299

The cross-section of bar CC299 with areas of hardness testing and other analyses are indicated.

Table 30 Analysis results for bar CC299

(Hv# - The hardness test number corresponding the image above)

Hv #	Alloy Type	Vickers Hardness (Hv _{0.2})	SEM Wt%P	SEM Wt%As	ASTM Grain Size	Notes
Hv 1	Phosphoric Iron	189	0.4 ± 0.1	0.7 ± 0.2	1	Slag Inclusion Ghosting + Etch Resistant
Hv 2	Phosphoric Iron	212	1.1 ± 0.1	nd	2	Etch Resistant
Hv 3	Phosphoric Iron	174	0.6 ± 0.1	0.2 ± 0.2	4	
Hv 4	Phosphoric Iron	173	0.8 ± 0.1	0.3 ± 0.2	1	
Hv 5	Phosphoric Iron	159	0.4 ± 0.1	0.1 ± 0.2	1	Slag Inclusion and Alloy Edge Effects



(a)



(b)

Figure 32 - Map of the location of Southampton

(a) Map of Southampton/Hamwic (Brisbane 1988: 102) (b) Location of Winchester in Hampshire (from

http://en.wikipedia.org/wiki/File:Hampshire_outline_map_with_UK.png)

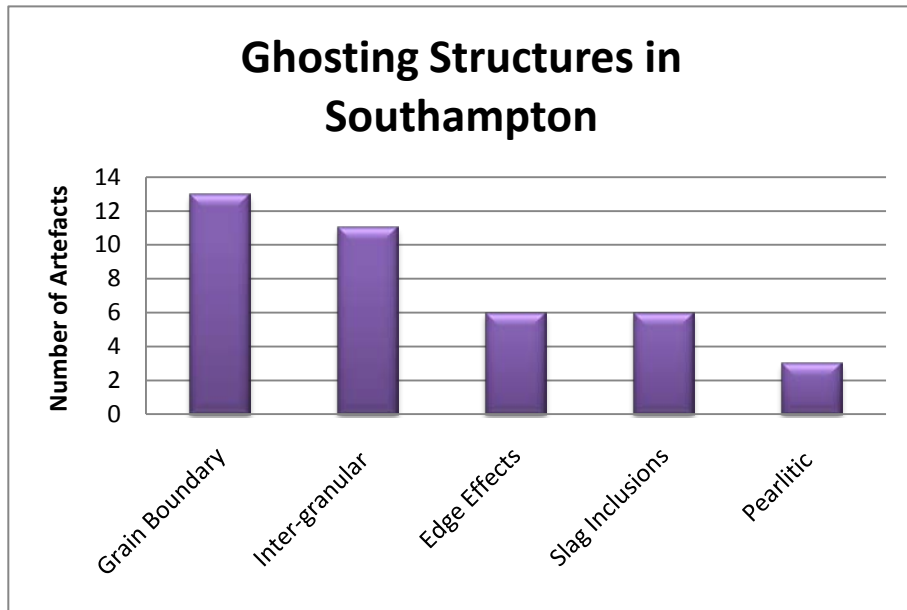


Figure 33 – Ghosting Structures in Southampton

Summary of ghosting structures in artefacts from Southampton



Figure 34 – The cross-section of knife SOU98-38

The cross-section of knife SOU98-38 with areas of hardness testing and other analyses are indicated

Table 43 Analysis results for knife SOU98-38

(Hv# - The hardness test number corresponding the image above)

Hv #	Alloy Type	Vickers Hardness (Hv)	SEM Wt%P	SEM Wt%As	ASTM Grain Size	Notes
HV1	Tempered Martensite	546	0.3 ± 0.1	0.0	-	
HV2	Fine Pearlite	348	0.1 ± 0.1	0.1 ± 0.2	-	
HV3	Weld-line	226	0.1 ± 0.1	3.1 ± 0.2	-	
HV4	Phosphoric Iron + Pearlite 0.3%C	196	0.2 ± 0.1	0.4 ± 0.2	7	
HV5	Ferrite	140	0.1 ± 0.1	0.7 ± 0.2	4	Etch Resistant
HV6	Phosphoric Iron + Pearlite 0.2%C	149	0.2 ± 0.1	0.4 ± 0.2	7	
HV7	Phosphoric Iron	149	0.4 ± 0.1	0.2 ± 0.2	1	Ghosting

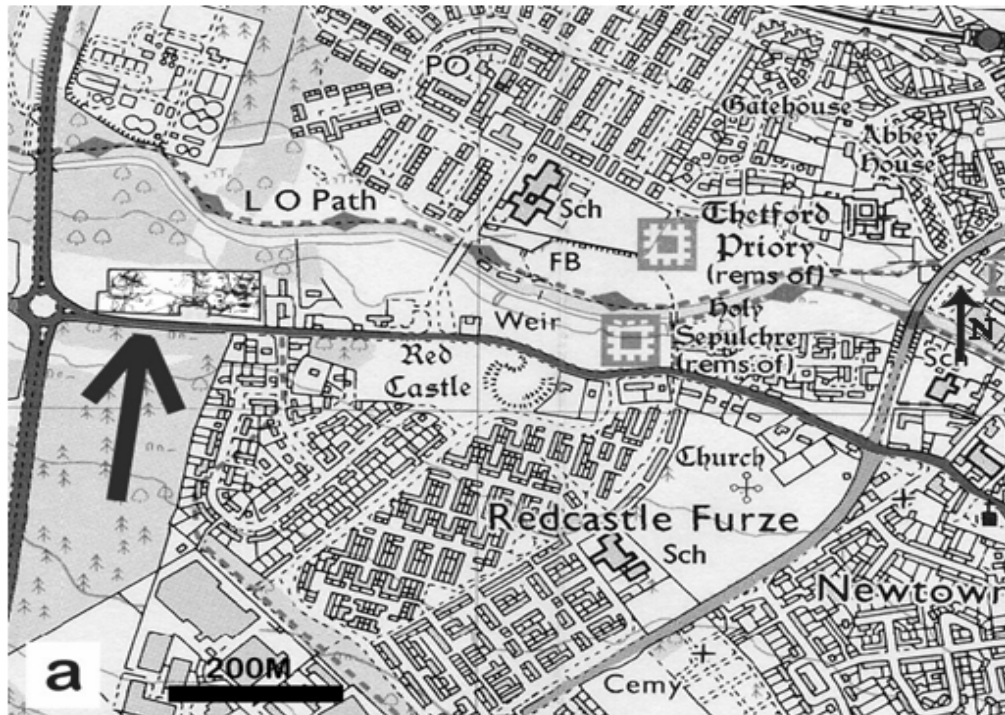


Figure 35 – Map of the location of Thetford and the Brandon Road excavation

(a)The placement of the Brandon Road excavation in Thetford (adapted from (Atkins and Aileen 2002)) (b)Location of Thetford in Norfolk (from http://en.wikipedia.org/wiki/File:Norfolk_outline_map_with_UK.png)

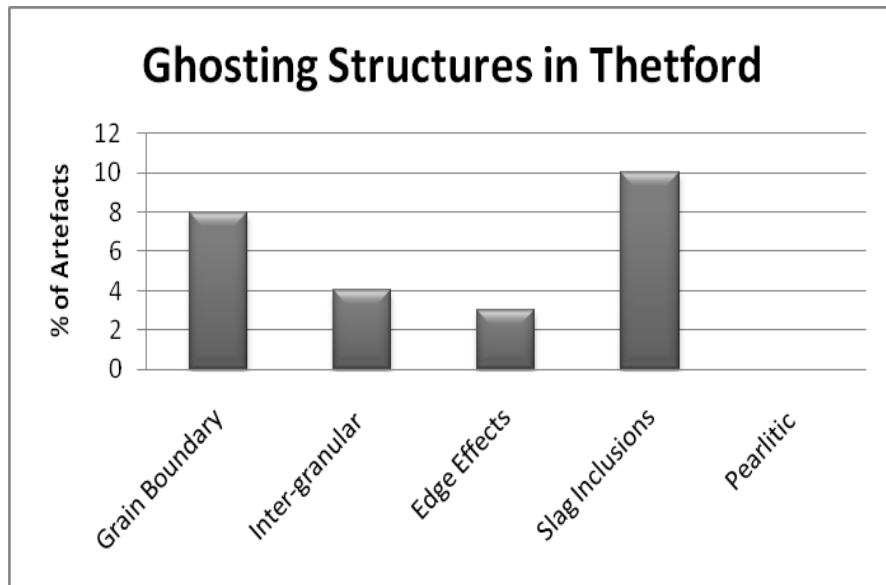


Figure 36 - Ghosting structures of Thetford

Summary of ghosting structures in artefacts from Thetford

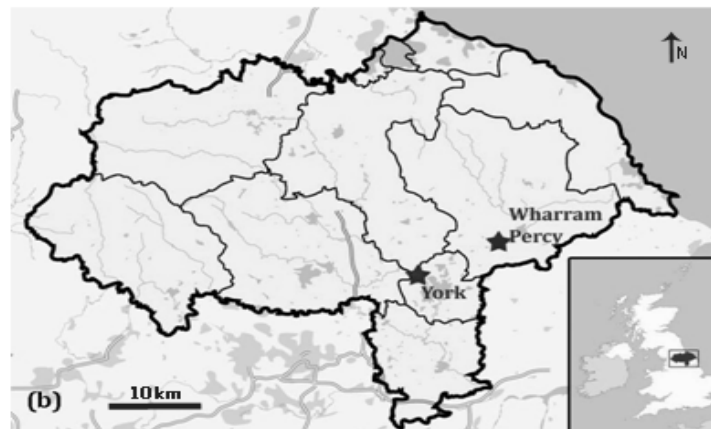


Figure 37 - Map of the location of Wharram Percy

(a)Map of the Wharram Percy Excavation (Milne and Richards 1992: 4) (b) Location of Wharram Percy in North Yorkshire (from http://en.wikipedia.org/wiki/File:North_Yorkshire_outline_map_with_UK.png)

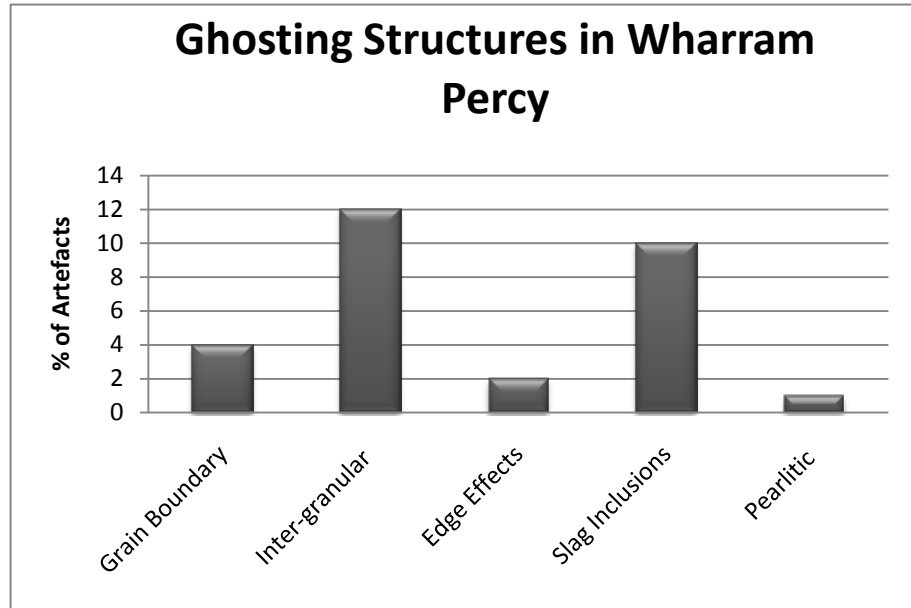


Figure 38 - Ghosting structures at Wharram Percy

Summary of ghosting structures in artefacts from Wharram Percy

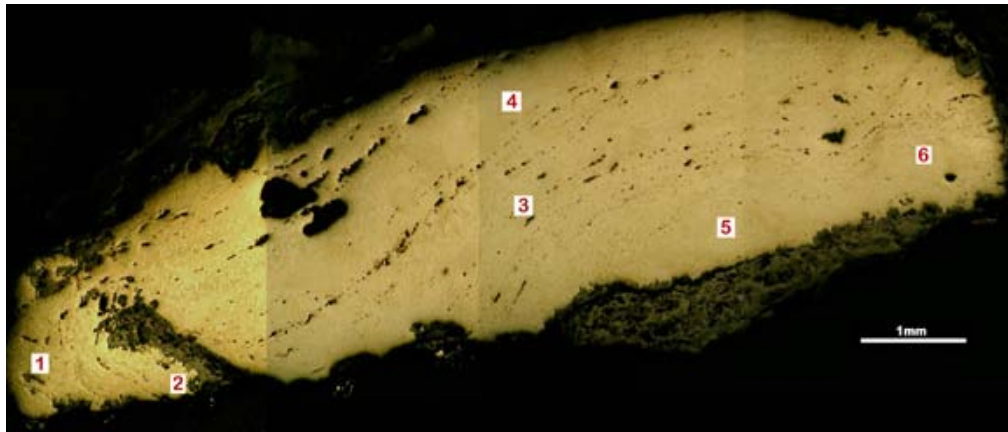


Figure 39 - The cross-section of nail head WP218

A cross-section of the nail head WP218 with areas of analysis indicated.

Table 77 Analysis results for bar nail WP218

(Hv# - The hardness test number corresponding to the image above)

Hv #	Alloy Type	Vickers Hardness (Hv _{0.2})	SEM Wt%P	SEM Wt%As	ASTM Grain Size	Notes
Hv1	Phosphoric Iron	151	0.3 ± 0.1	0.4 ± 0.2	7	Ghosting
Hv2	Phosphoric Iron	155	0.2 ± 0.1	0.6 ± 0.2	4	Etch Resistant
Hv3	Phosphoric Iron	230	0.3 ± 0.1	0.4 ± 0.2	5	Ghosting + Etch Resistant
Hv4	Phosphoric Iron	219	0.2 ± 0.1	0.3 ± 0.2	3	Ghosting + Etch Resistant
Hv5	Phosphoric Iron	258	0.3 ± 0.1	0.8 ± 0.2	5 elongated	Ghosting + Etch Resistant
Hv6	Phosphoric Iron	292	0.2 ± 0.1	0.6 ± 0.2	6 elongated	Ghosting + Etch Resistant
Hv7	Phosphoric Iron	262	0.2 ± 0.1	0.6 ± 0.2	6	

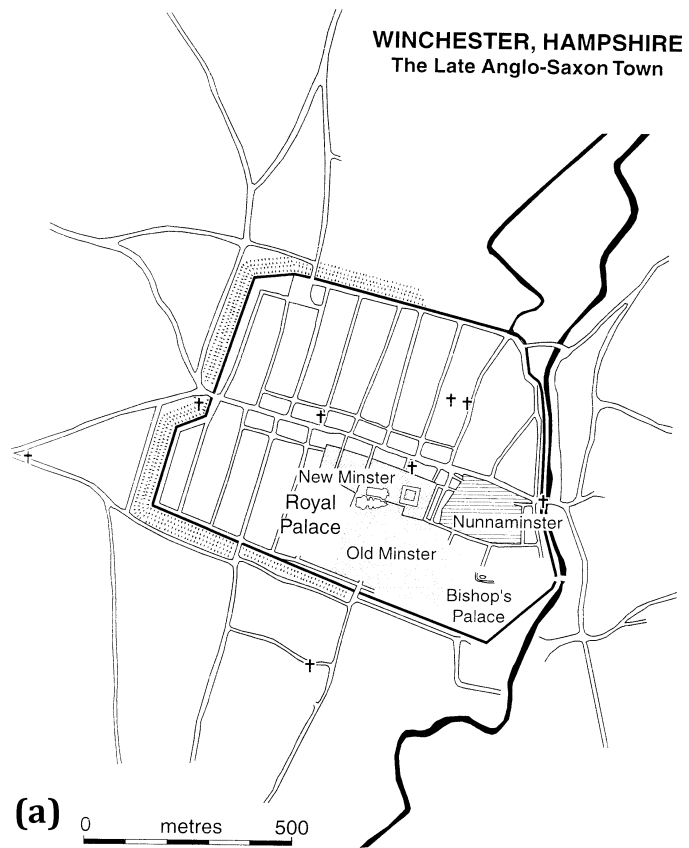


Figure 40 - Map of the location of Winchester

(a)Map of Anglo-Saxon Winchester (Reynolds 1999: 89) (b)Location of Winchester in Hampshire (from http://en.wikipedia.org/wiki/File:Hampshire_outline_map_with_UK.png)

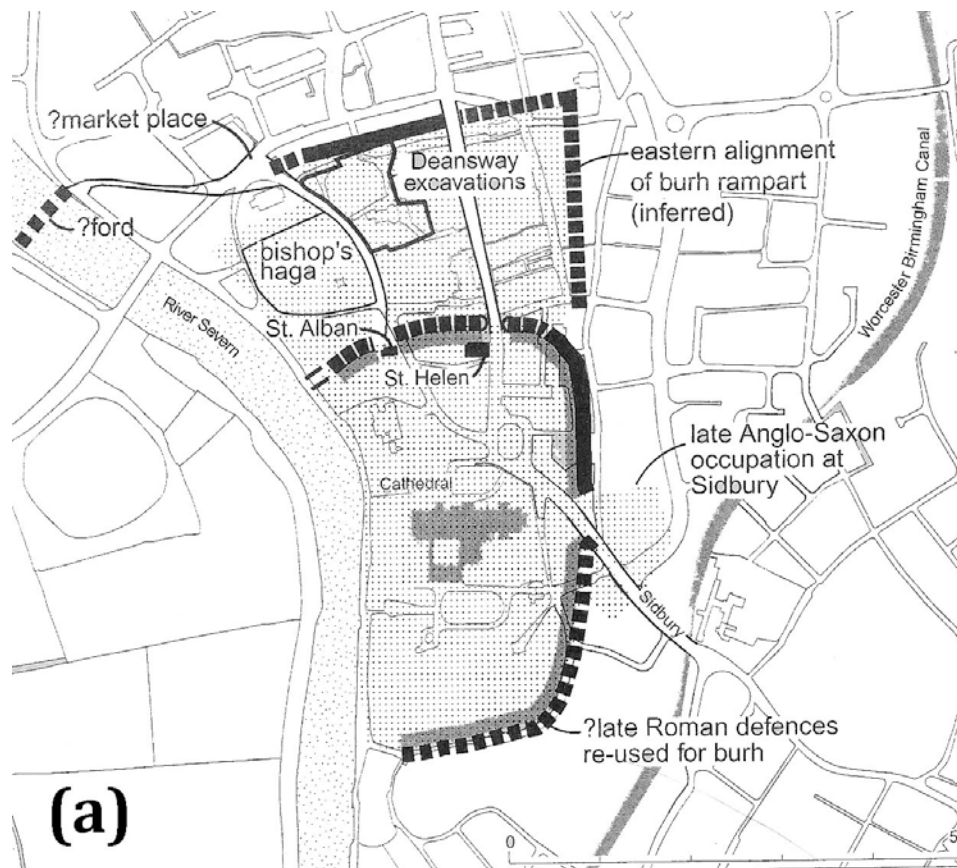


Figure 41 - Map of the location of Worcester

Worcester ((Dalwood and Edwards 2004: 19) (b)Map of Worcestershire (from http://en.wikipedia.org/wiki/File:Worcestershire_outline_map_with_UK.png)

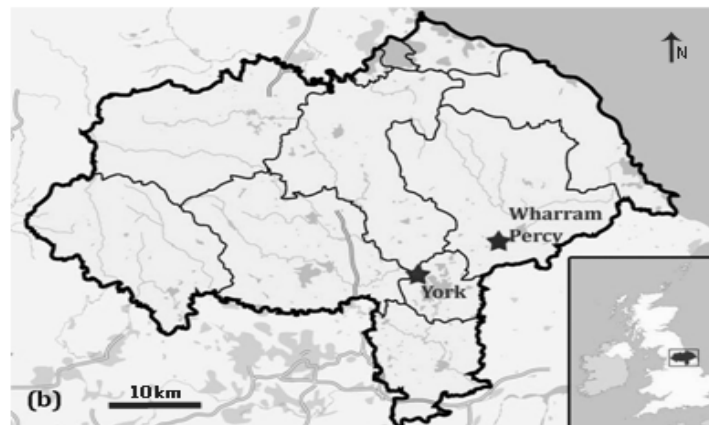
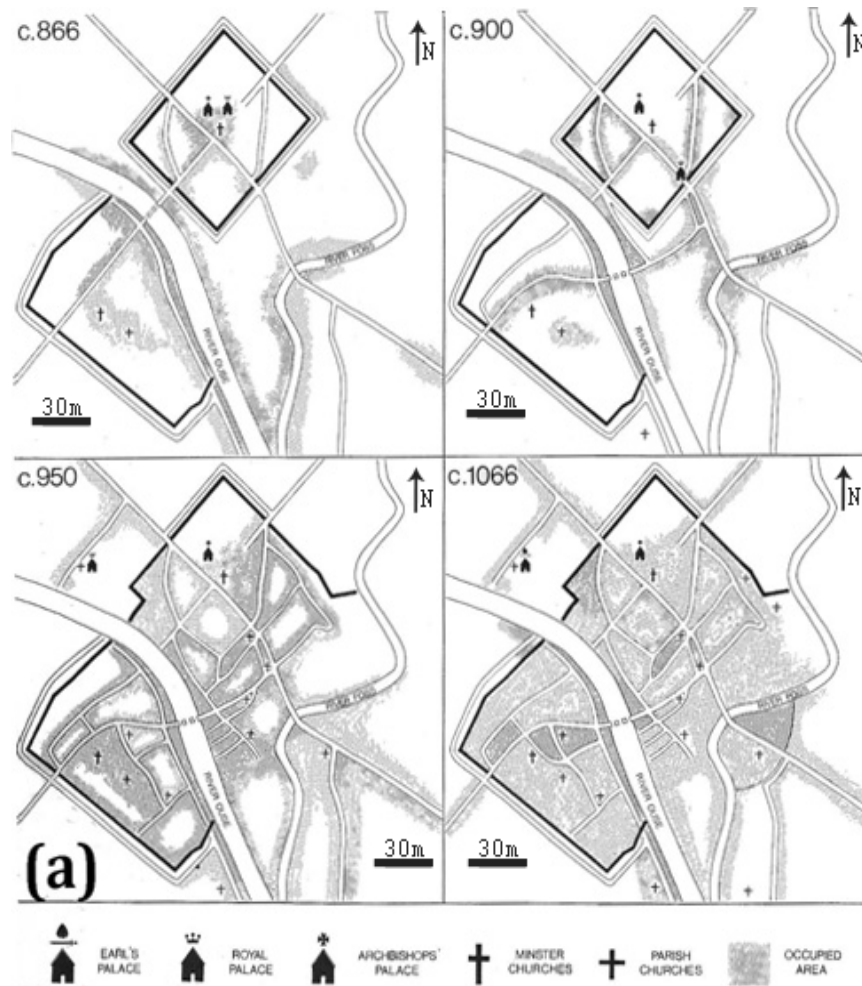


Figure 42 – Map of the location of York and of the layout of Jorvik

(a) Early Medieval maps of York (Hall 1994: 32) (b) Location of York in North Yorkshire (from http://en.wikipedia.org/wiki/File:North_Yorkshire_outline_map_with_UK.png)

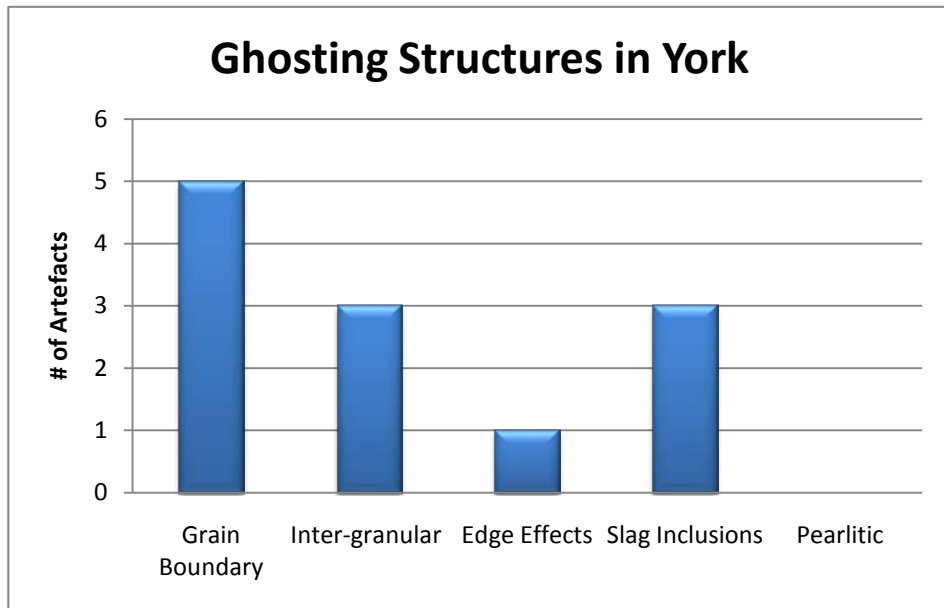


Figure 43 - Ghosting structures in York

Summary of ghosting structures in artefacts from Anglo-Scandinavian York

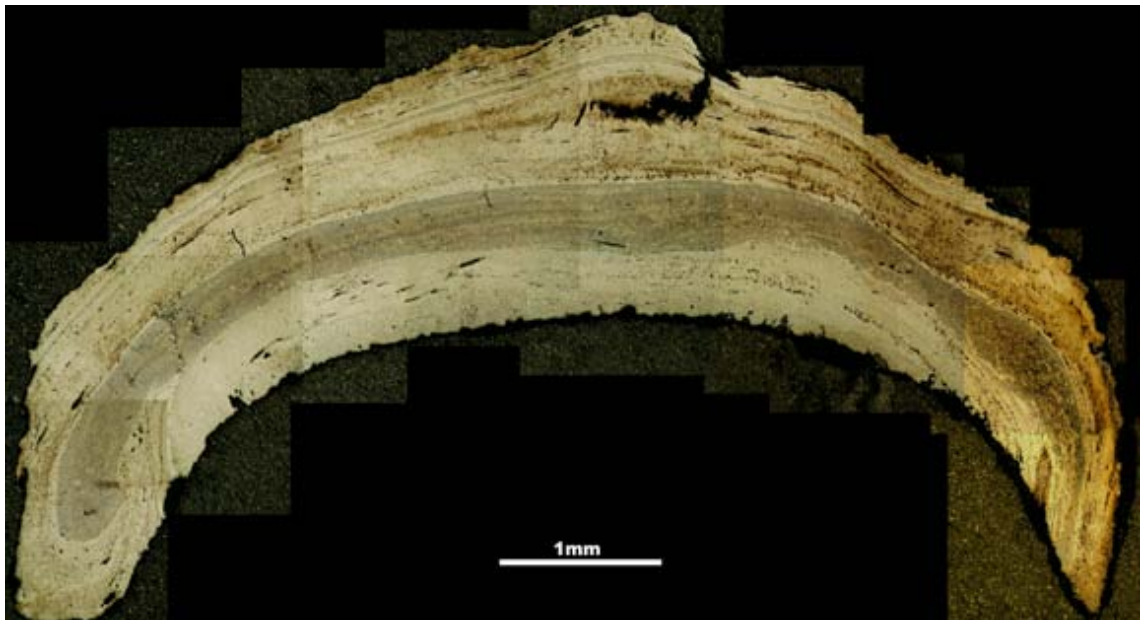


Figure 44 - The cross-section of spoon auger Yo9439

The cross-section of spoon auger Yo9439 with areas of test areas are indicated

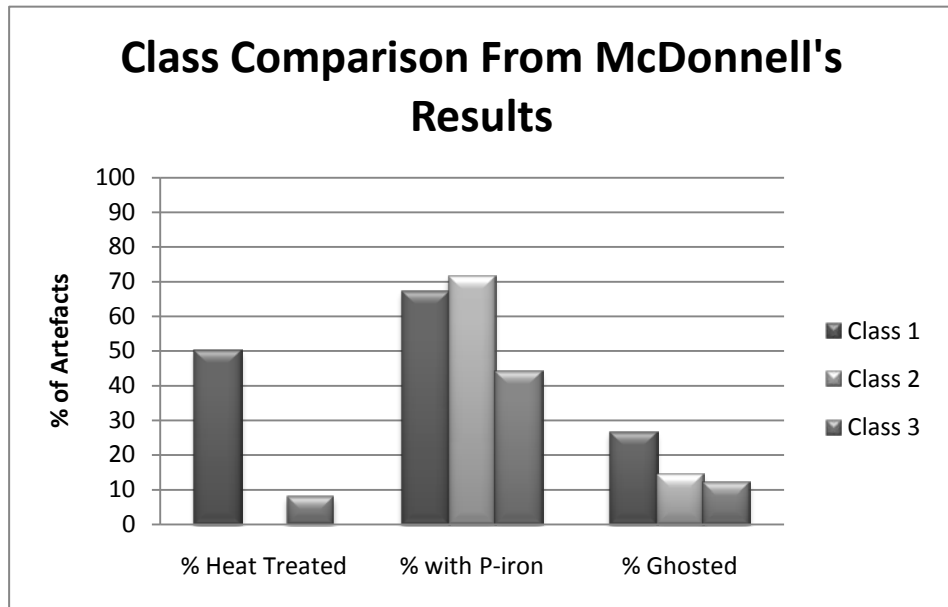


Figure 45 - McDonnell's (1992) results in terms of the classes

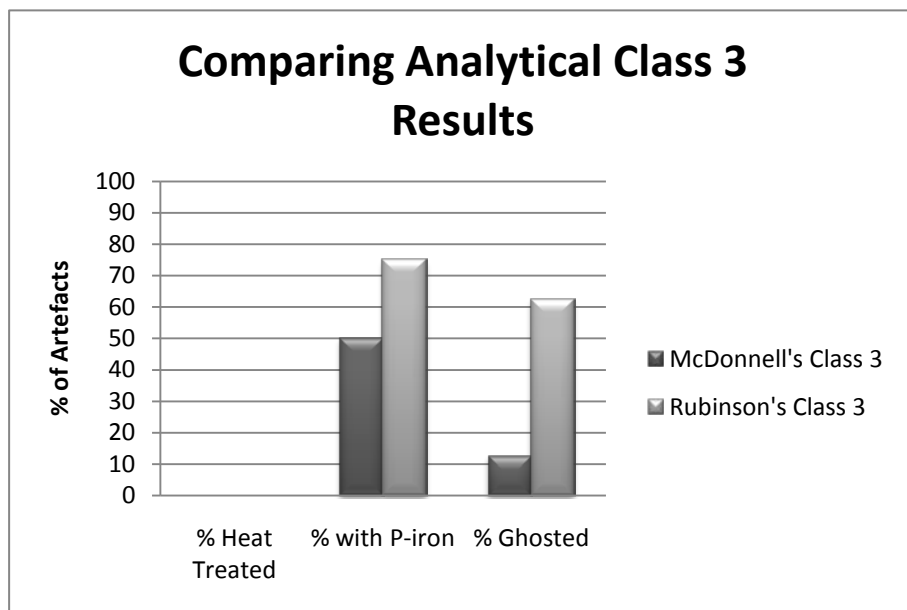
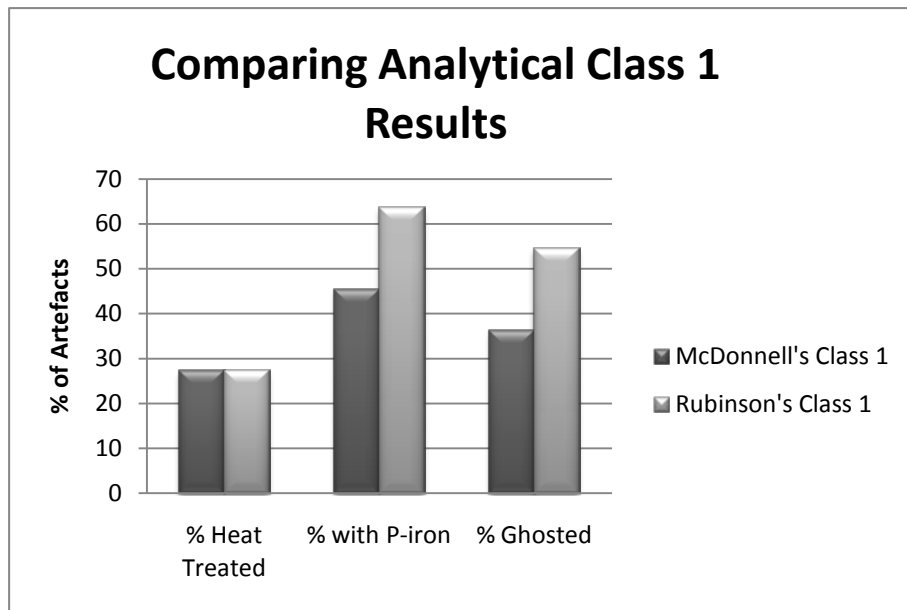


Figure 46 – Comparing McDonnell’s results to the current study for the Class 1 and Class 3 artefacts

Class 1 (11 artefacts) and Class 3 (8 artefacts) artefacts re-examined here

Site	5 th Century AD	6 th Century AD	7 th Century AD	8 th Century AD	9 th Century AD	10 th Century AD	11 th Century AD	Culture
Brent Knoll								Saxon
Canterbury								Saxon
York								Viking
Southampton								Saxon
Worcester								Saxon
Thetford								Saxon
Wharram Percy								Saxon
Winchester								Saxon

Figure 47 - Timeline of sites

(Blocks represent the period of habitation from which the artefacts are dated)

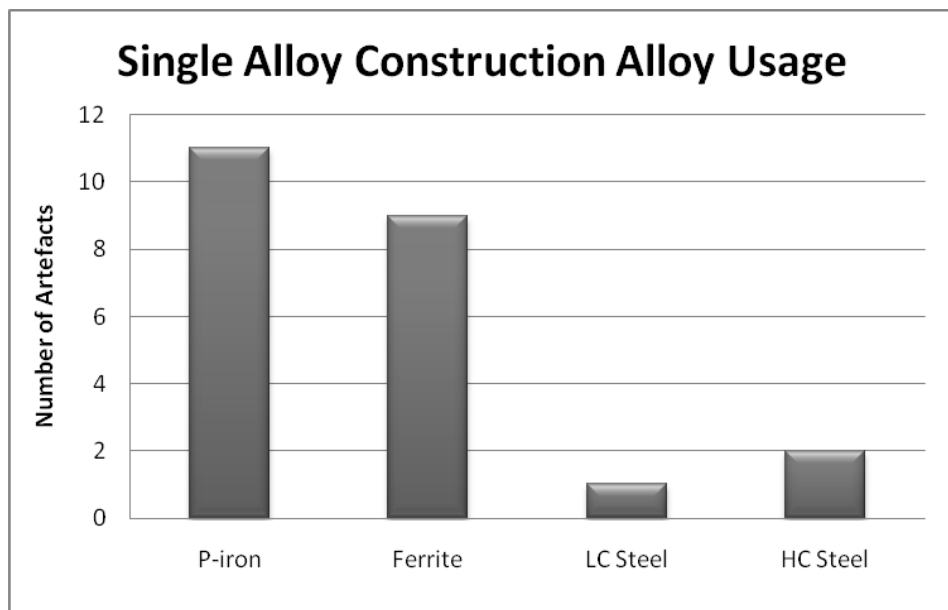


Figure 48 - Alloy usage in single alloy artefacts

(LC Steel = iron with less than 0.4%C; HC Steel = iron with 0.4%C or more)

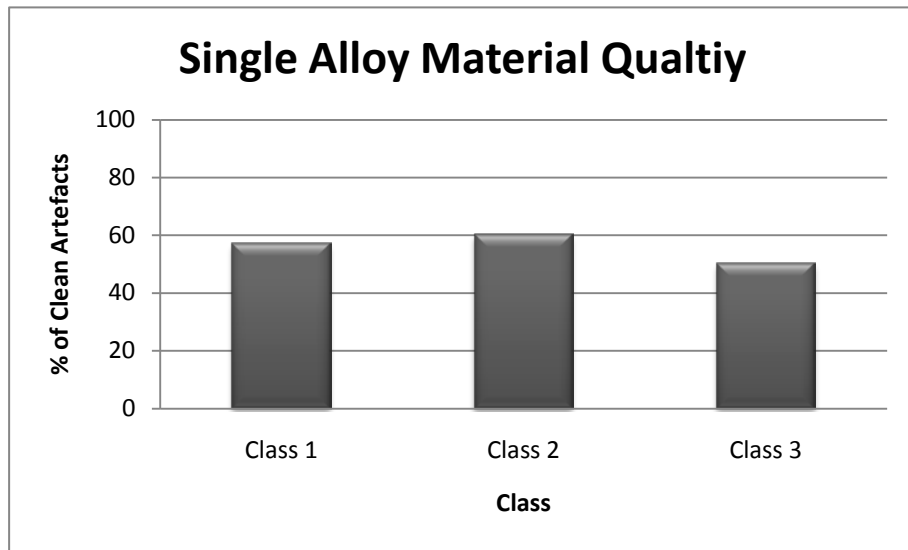


Figure 49 – Single Alloy Construction Material Quality

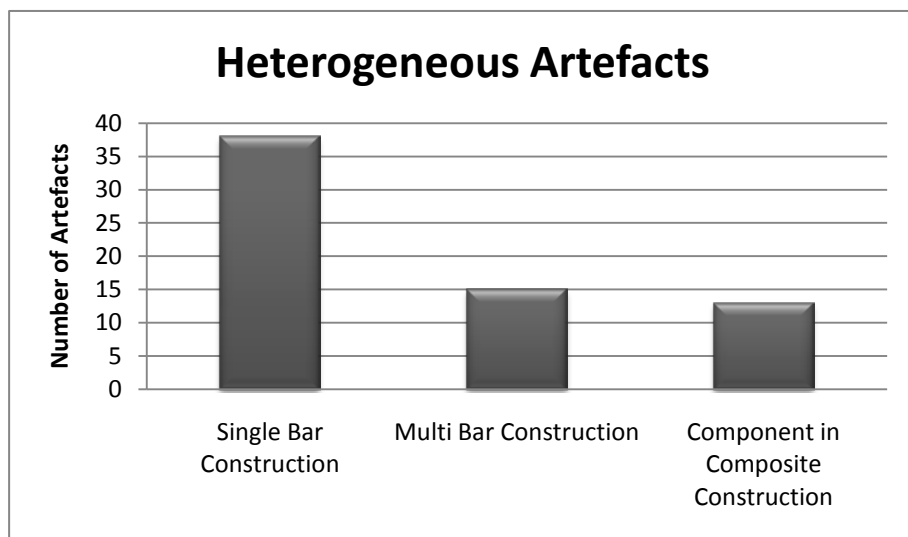


Figure 50 – Use of heterogeneous iron in artefact construction

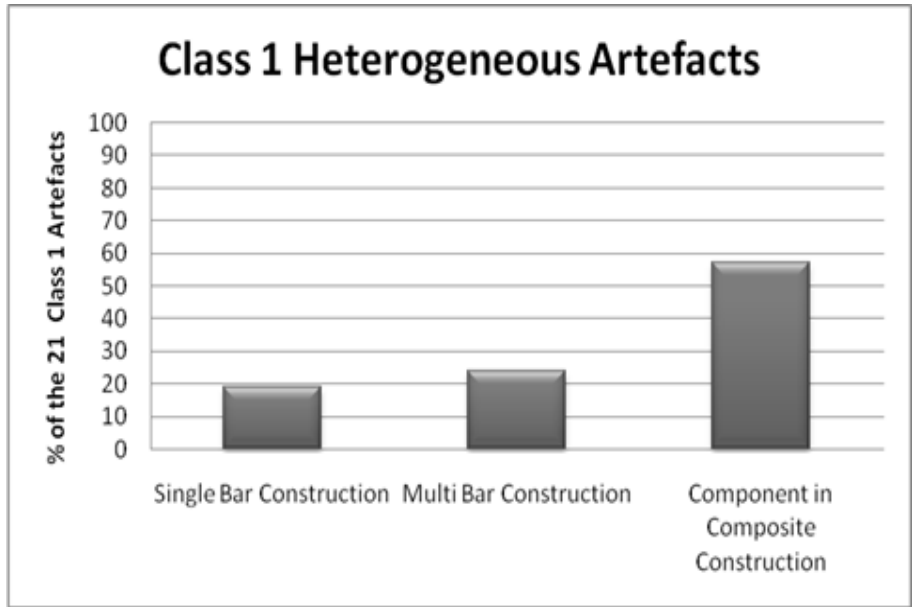


Figure 51 - The use of heterogeneous iron in Class 1 artefact construction

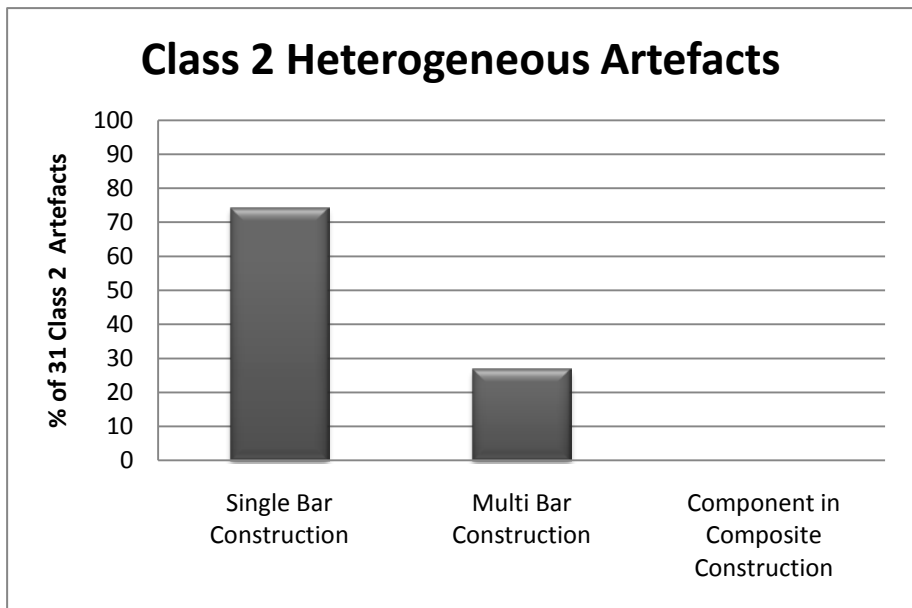


Figure 52 - The use of heterogeneous iron in Class 2 artefact construction

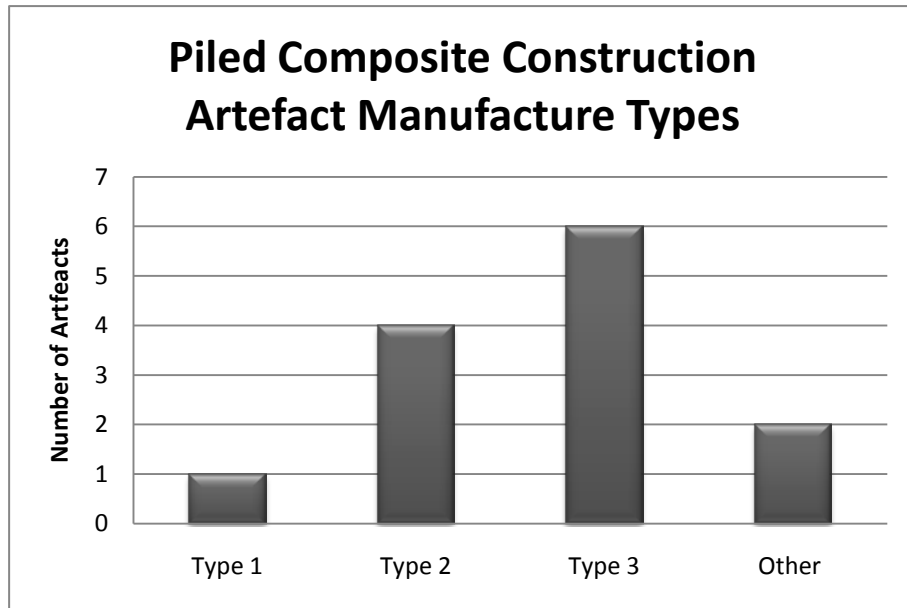


Figure 53 - Piled composite artefact manufacture types

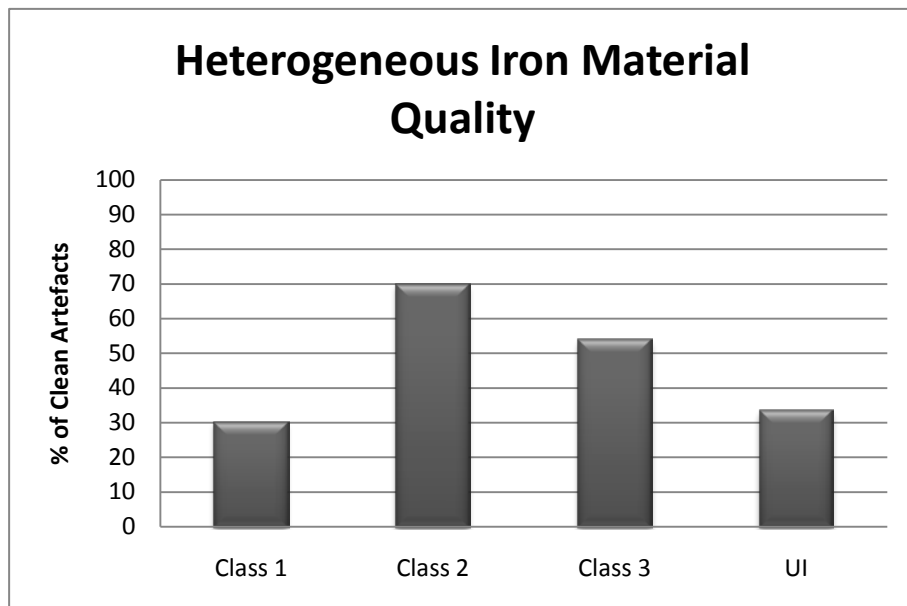


Figure 54 - Class distribution of clean artefacts

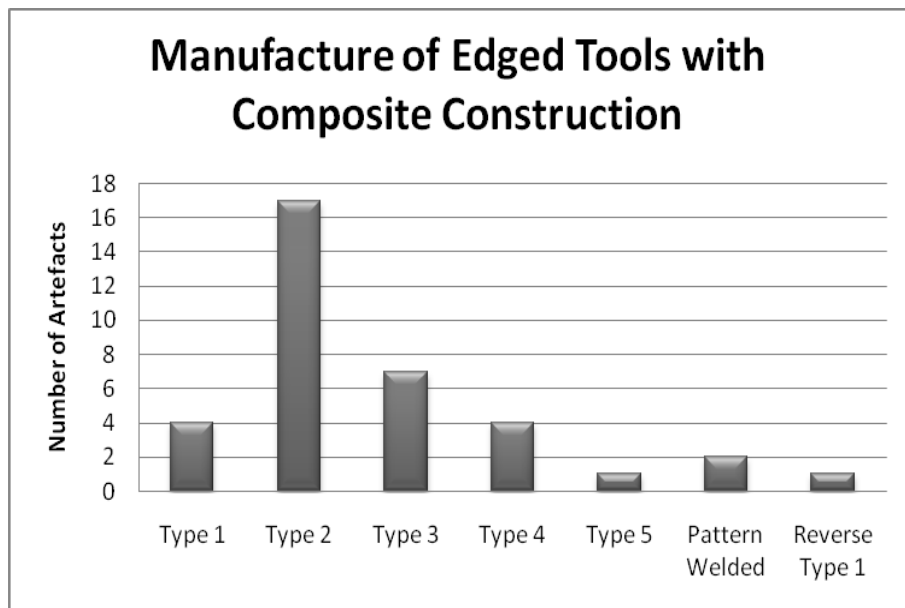


Figure 55 - Edged tool composite construction artefacts

(35 artefacts total)

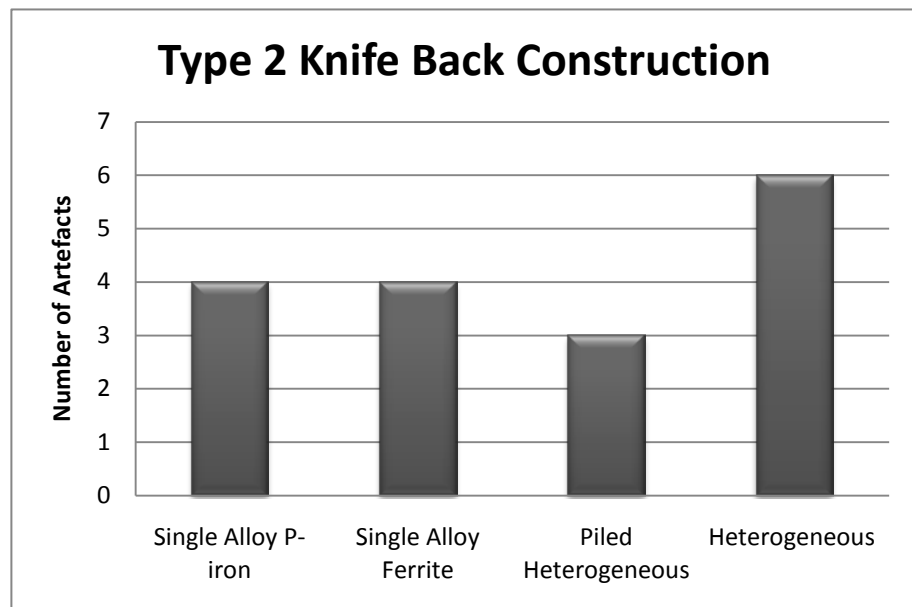


Figure 56 -Type 2 edged tool knife back construction

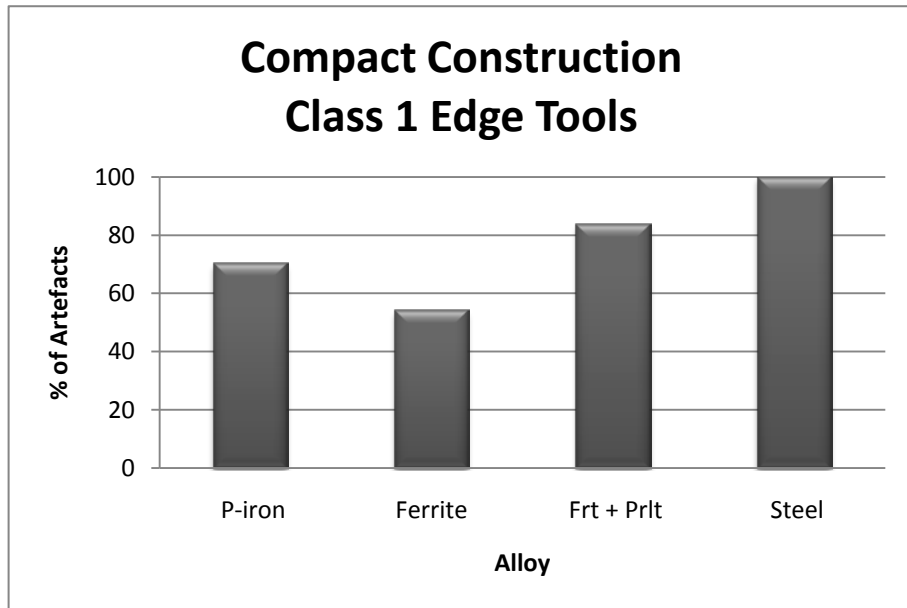


Figure 57 - Alloy usage in Class 1 edged tools with composite construction

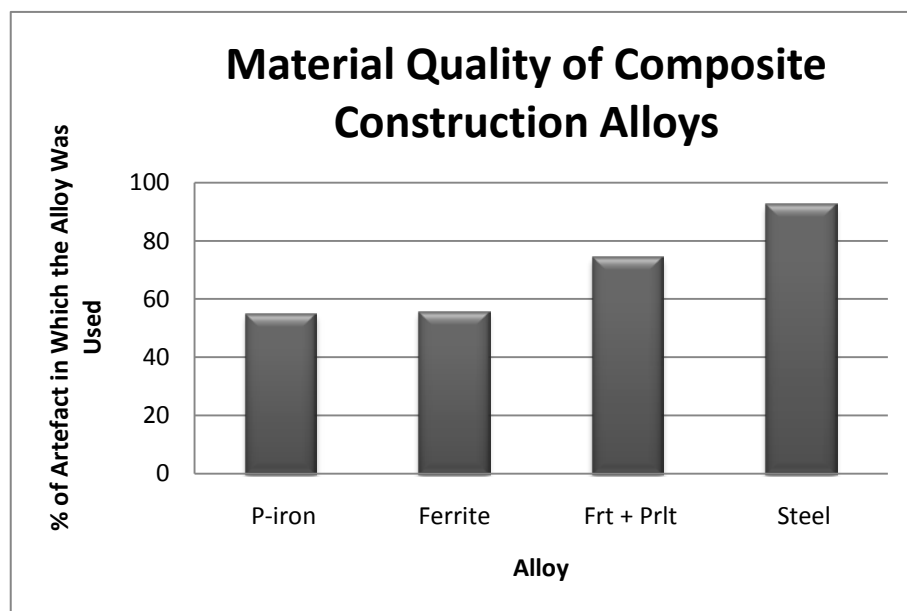


Figure 58 - Material quality of alloys used in composite construction artefacts

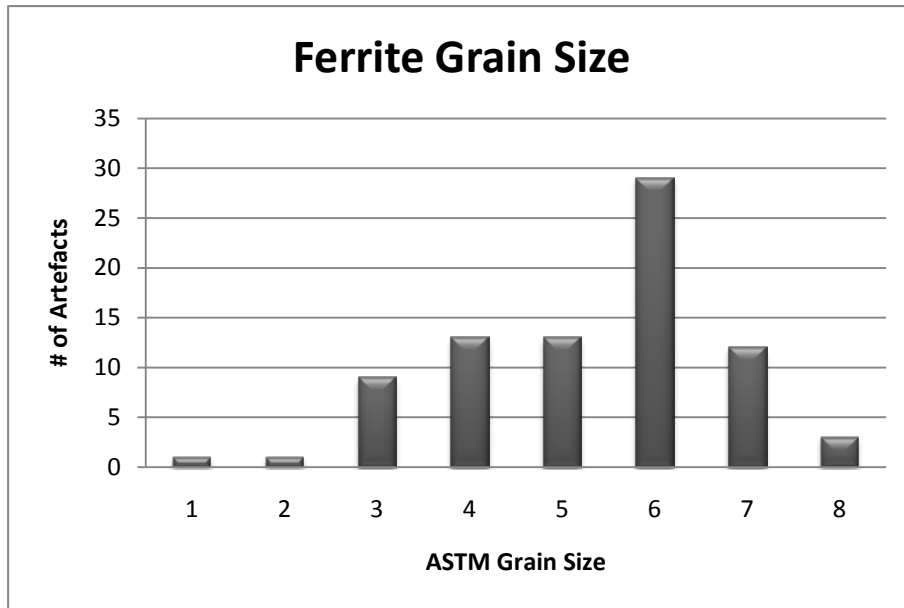


Figure 59 - Average ferrite grain size per artefact

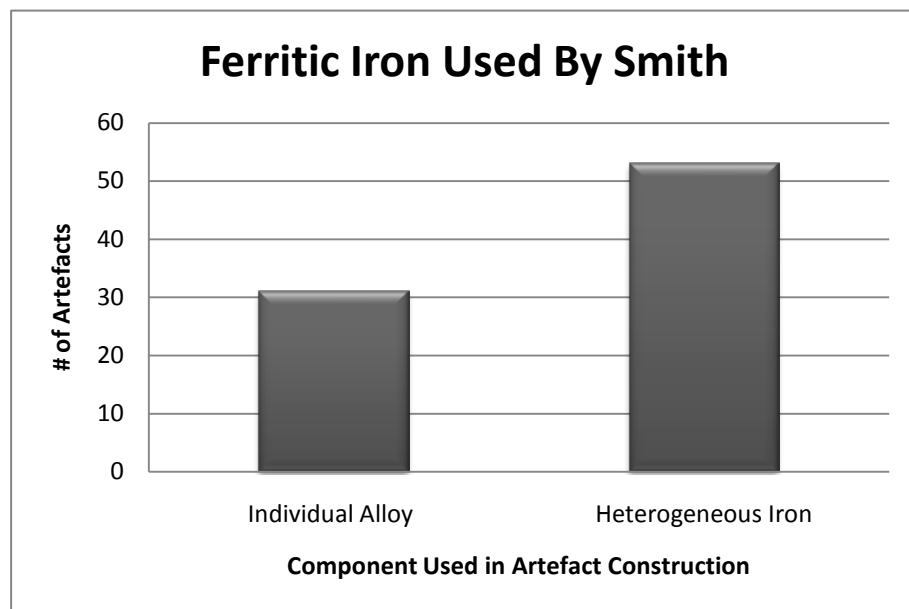


Figure 60 - Forms of ferritic iron used by early smiths

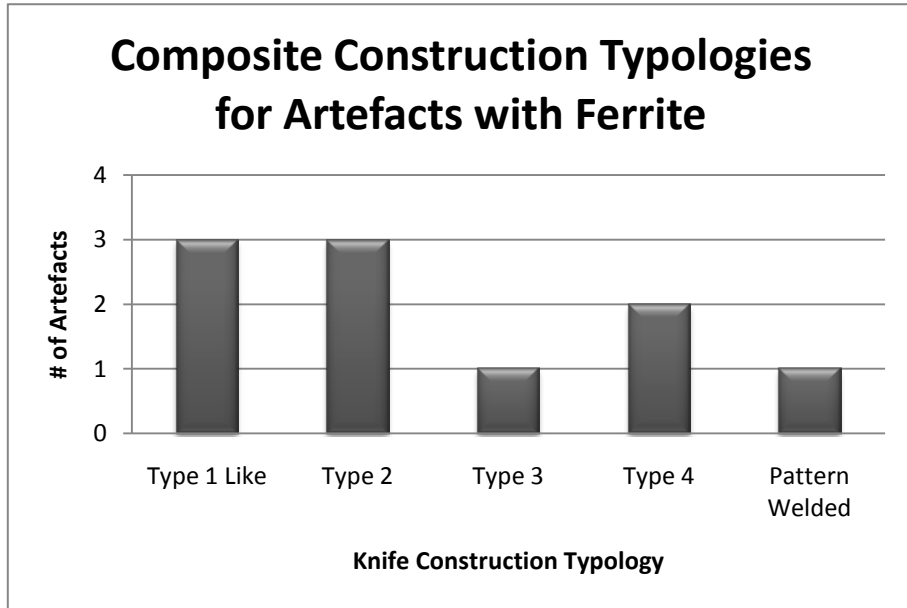


Figure 61 - Composite artefacts where ferrite was used as an individual alloy component

(the 'Type 1 like' artefacts were not edged tools)

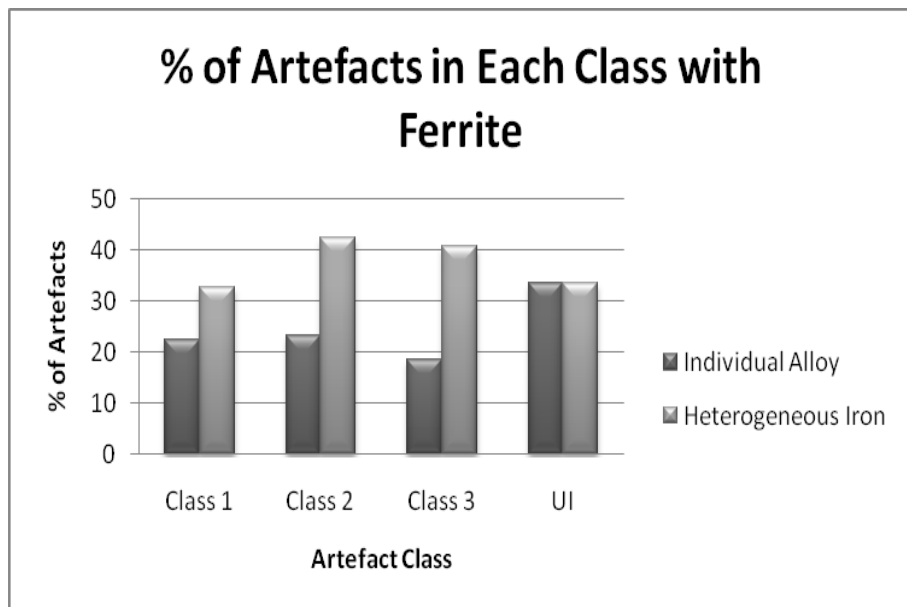


Figure 62 - Percent of artefacts based on class with ferrite both as individual alloy use and in heterogeneous iron

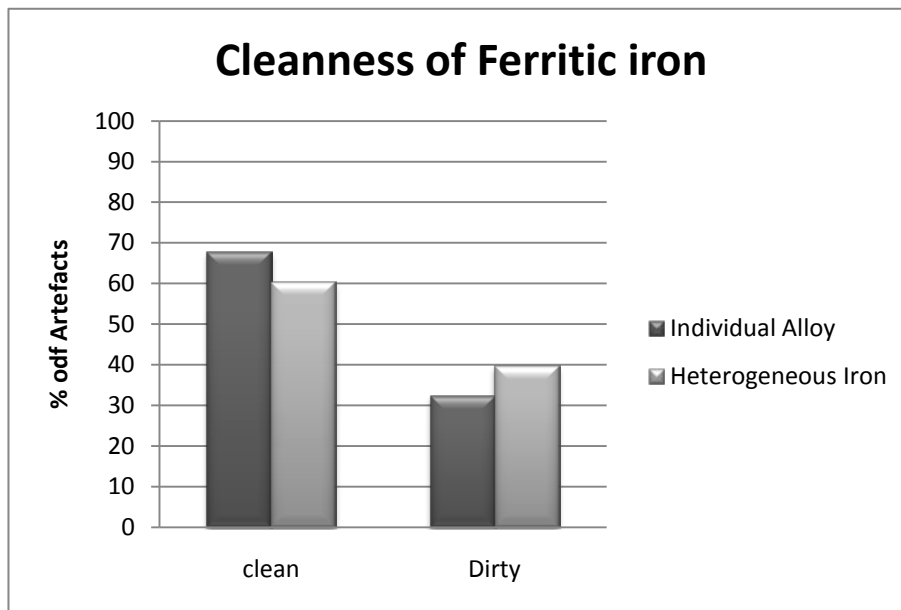


Figure 63 -Cleanness of ferritic iron used as individual components and in heterogeneous iron

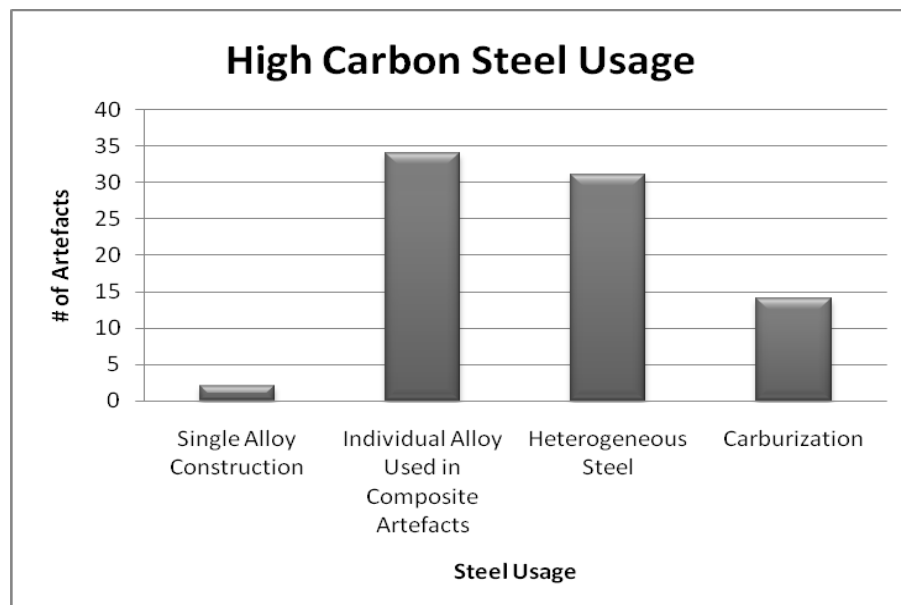


Figure 64 -Number of artefacts containing each form of high carbon steel

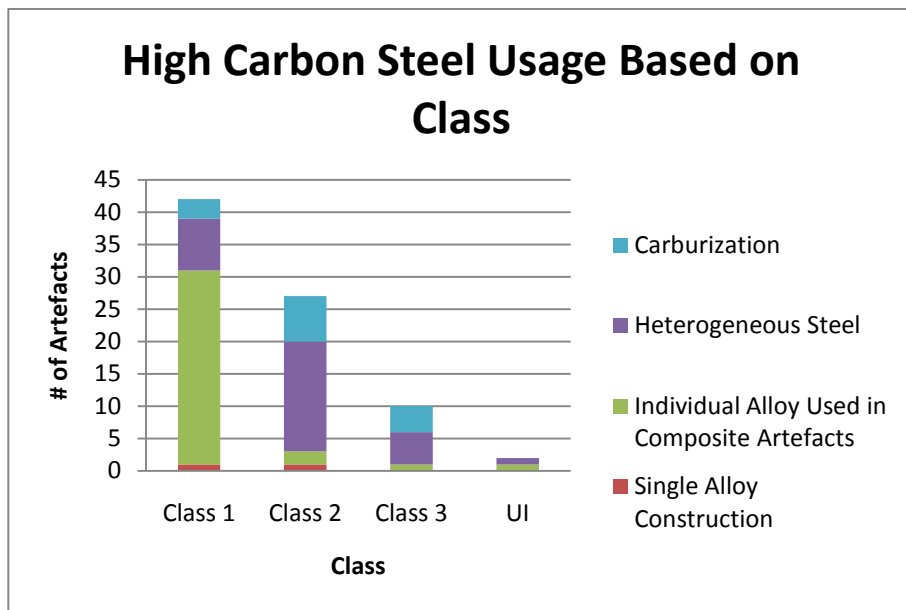


Figure 65 – High carbon steel usage based on class and form

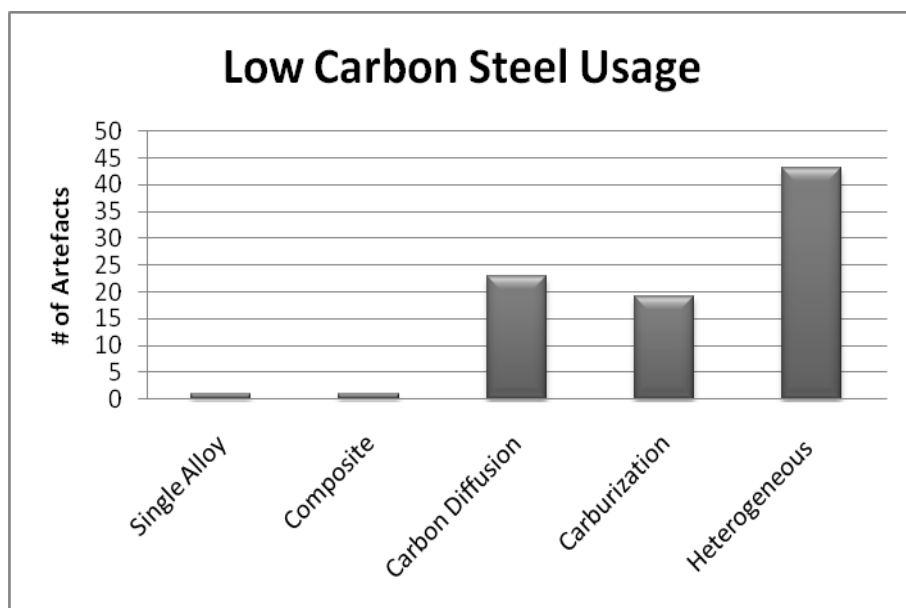


Figure 66 – The low carbon steel usage in the early medieval artefacts

(Single Alloy = single alloy construction artefacts; Composite = composite construction artefacts; Heterogeneous = low carbon steel in heterogeneous iron)

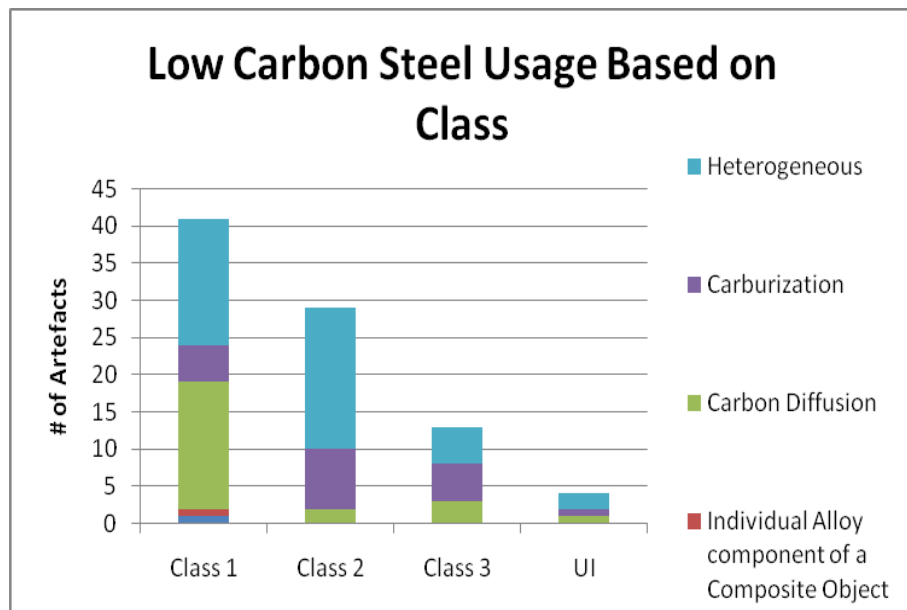


Figure 67 -Low carbon steel usage based on class and type of manufacture

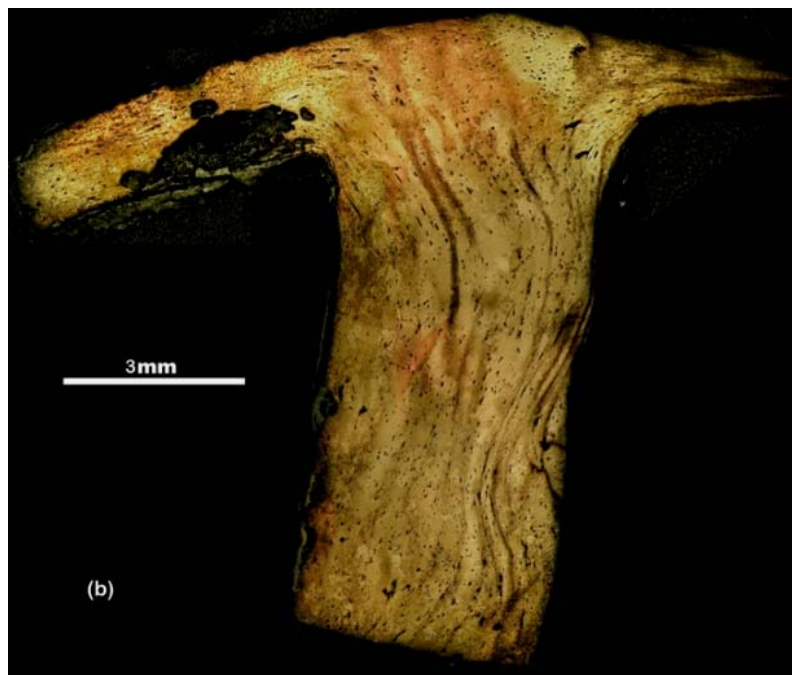
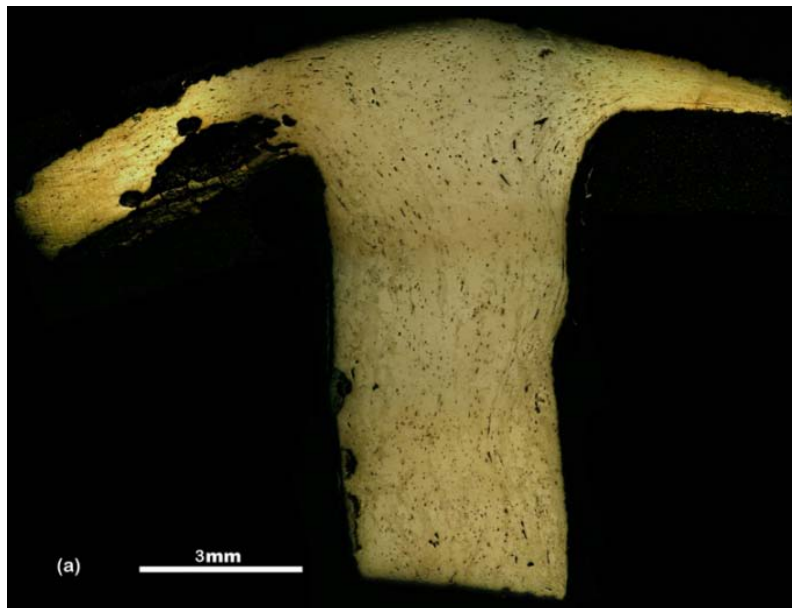


Figure 68 - Cross-sections of nail WP556

(a) etched with Nital (b) etched with Stead's Reagent

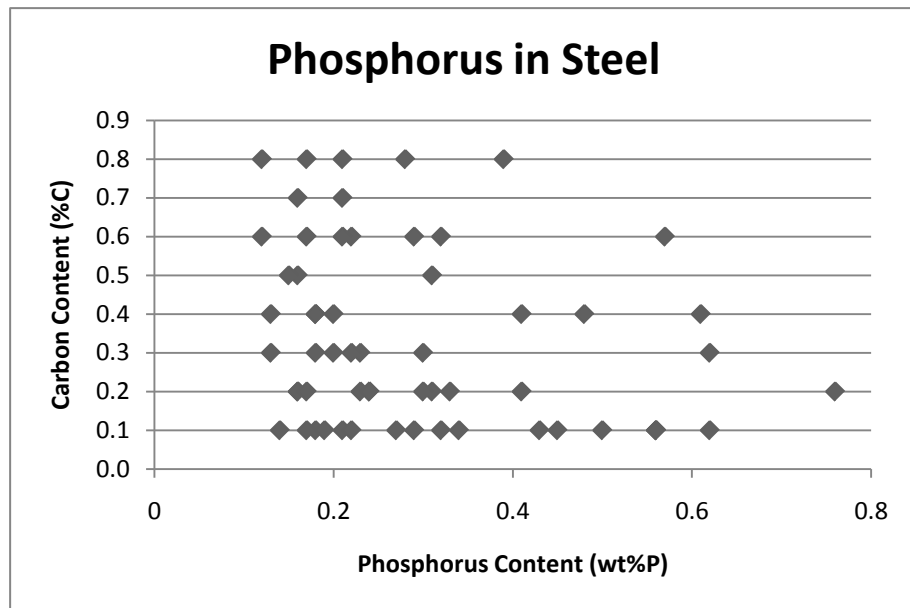


Figure 69 – Carbon versus phosphorus in steels

(Minimum phosphorus content limited to 0.1wt%P)

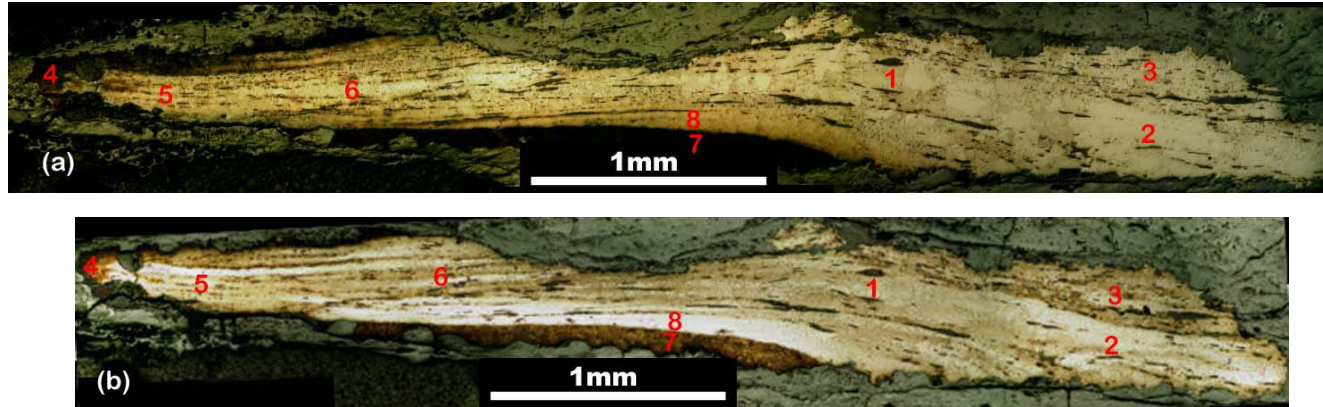


Figure 70 – Cross section from knife CC397

(a) etched with Nital (b) etched with Oberhoffer's reagent (Hardness test areas indicated)

Table 137 Analysis results for knife CC397

(Hv# - The hardness test number corresponding the red numbers in figure 70)

Hv #	Alloy Type	Vickers Hardness (Hv)	SEM Wt%P	SEM Wt%As	ASTM Grain Size	Notes
Hv 1	Tempered Martensite	382	0.1 ± 0.1	0.3 ± 0.2	-	
Hv 2	Ferrite + Pearlite 0.1%C	103	nd	0.3 ± 0.2	6	
Hv 3	Phosphoric Iron	170	0.6 ± 0.1	0.1 ± 0.2	3	Ghosting
Hv 4	Ferrite	136	0.1 ± 0.1	0.1 ± 0.2	6	
Hv 5	Ferrite	146	0.1 ± 0.1	0.1 ± 0.2	7	
Hv 6	Phosphoric Iron	195	0.7 ± 0.1	nd	4	Etch Resistant
Hv 7	Ferrite + Pearlite 0.1%C	191	0.1 ± 0.1	nd	6	
Hv 8	Phosphoric + Pearlite 0.1%C	222	0.2 ± 0.1	nd	6	Pearlitic Edge Effects
Hv 9	Phosphoric Iron	217	0.5 ± 0.1	0.1 ± 0.2	2	Etch Resistant

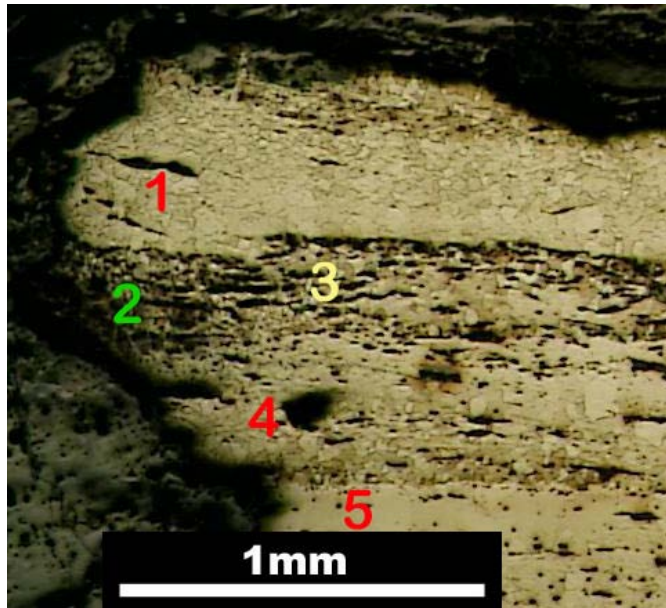


Figure 71 - Carburization of low phosphorus area
(Phosphoric iron in areas 1, 4, and 5; Ferrite in area 3; Pearlite in area 2)

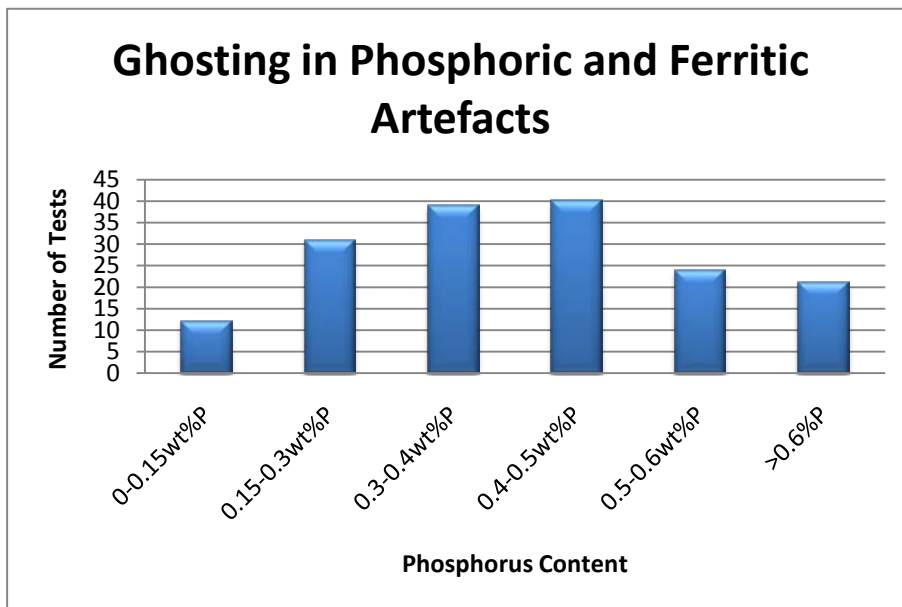


Figure 72 - The average phosphorus content from all 167 ghosted ferritic/phosphoric iron test sites

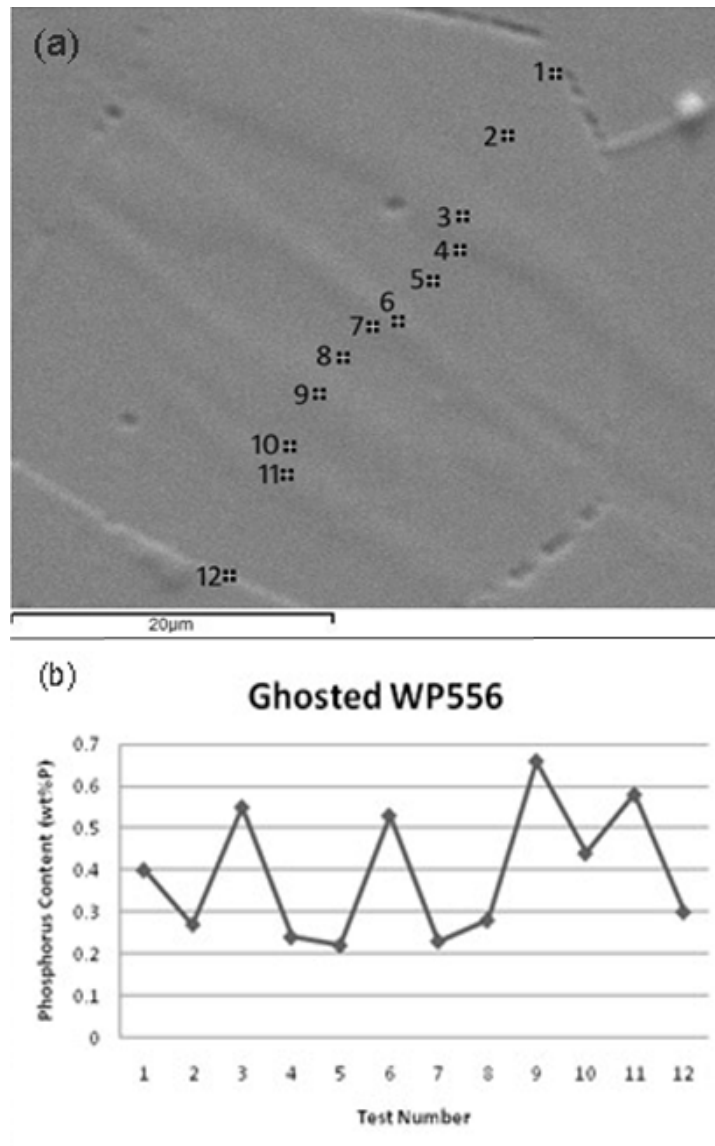


Figure 73 – Ghosting and phosphorus content in nail WP556

(a) SEM secondary electron image of a ghosted phosphoric iron grain from nail WP556 with test sites indicated; (b) Phosphorus content at test sites

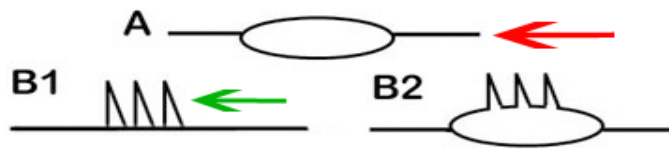


Figure 74 - Common Dubé forms including allotriomorphs

Figure 8.4.16

(A) and Widmanstätten-like structures (B1 & B2) (red arrow indicates grain boundary; green arrow indicates Widmanstätten)

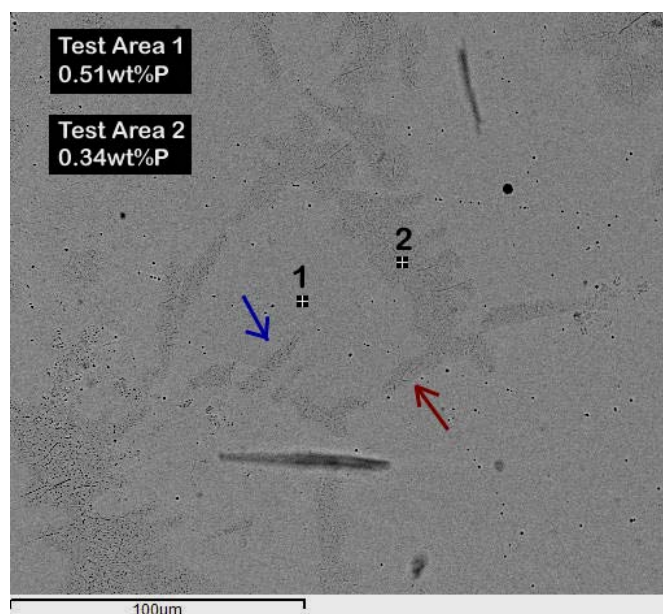


Figure 75 - SEM secondary electron image of grain boundary ghosting structures with SEM/EDS phosphorus measurements

SEM secondary electron image of grain boundary ghosting with allotriomorphs (red arrow) and Widmanstätten-like (blue arrow) structures as well as the SEM/EDS phosphorus measurements (Test areas indicated)

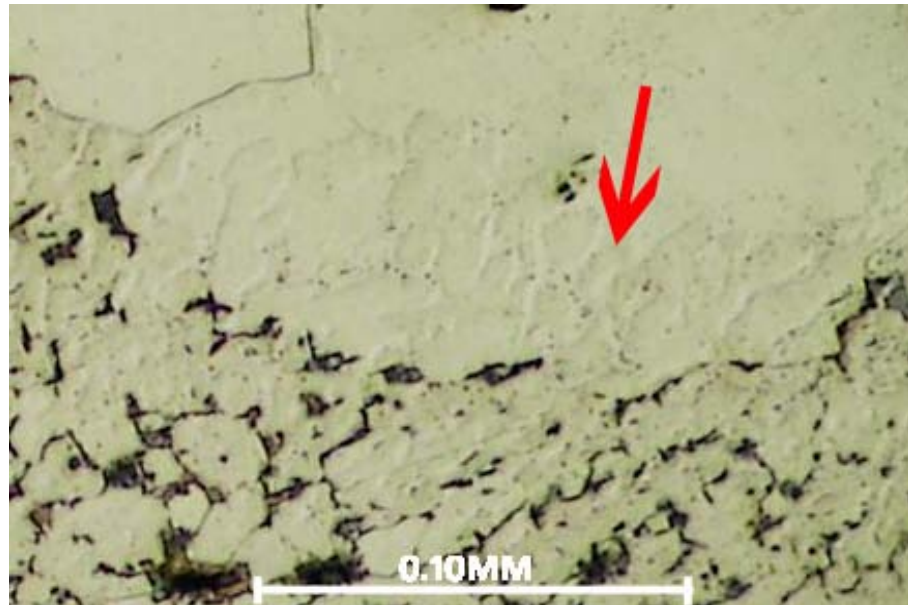


Figure 76 - Inter-granular ghosting as an edge effect in SOU31-669

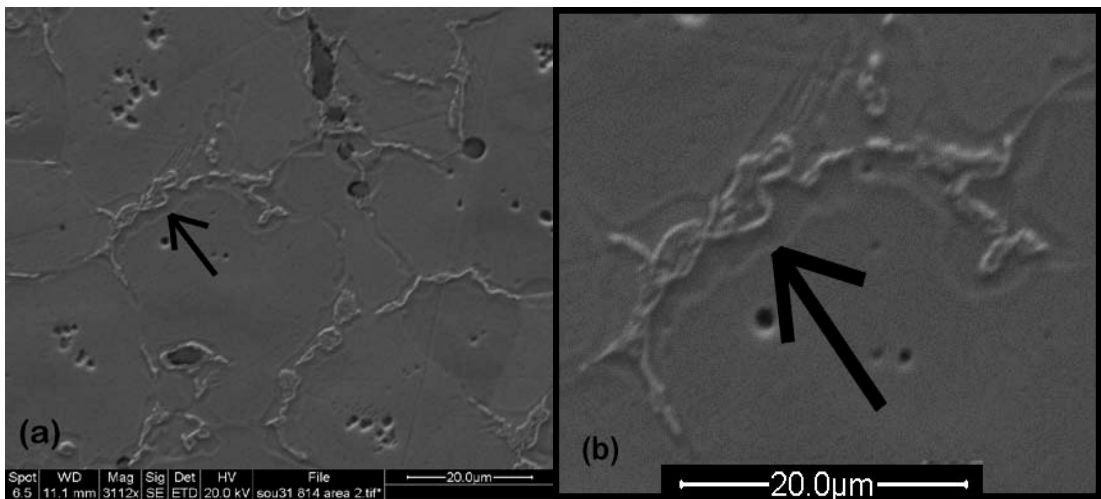


Figure 77 - SEM images of pearlitic ghosting in bar SOU31-814

(a) SEM secondary electron image of pearlitic ghosting in bar SOU31-814; (b) magnified image of pearlitic ghosting (pearlite indicated)

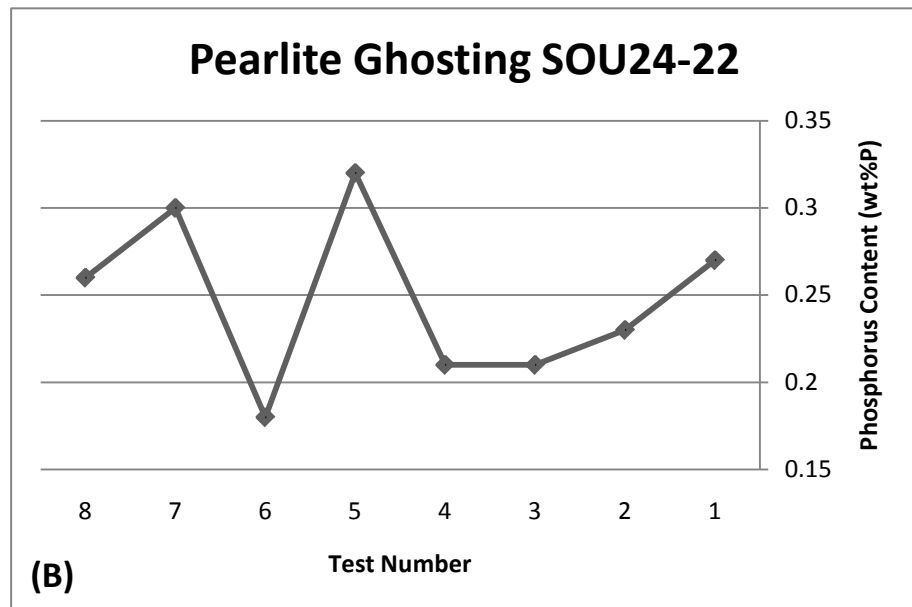
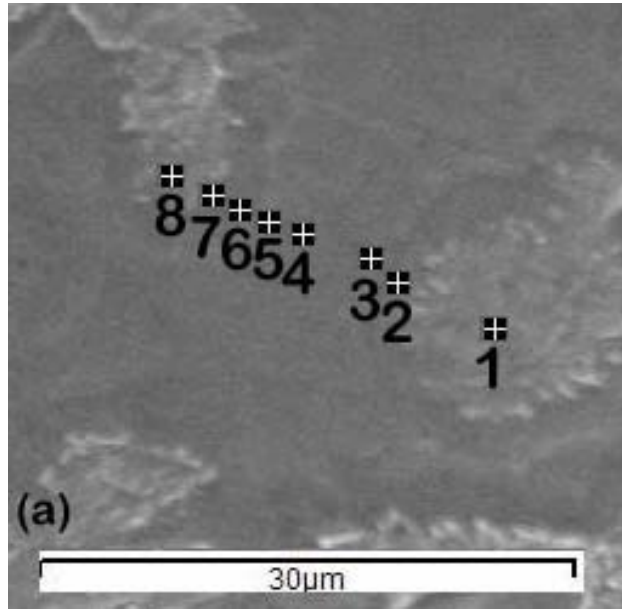


Figure 78 - SEM images of pearlitic ghosting in knife SOU24-22

(a) SEM secondary electron image of pearlitic ghosting in knife SOU24-22 with test sites indicated; (b) Phosphorus content at test sites

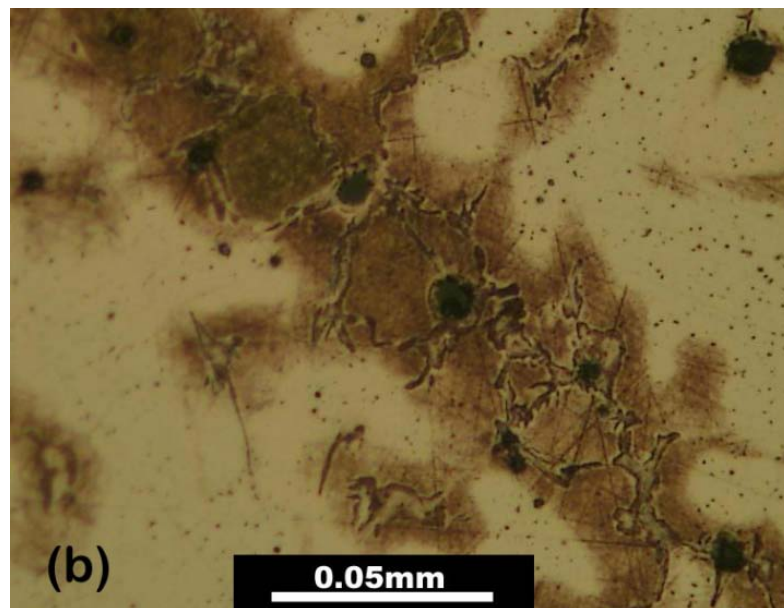
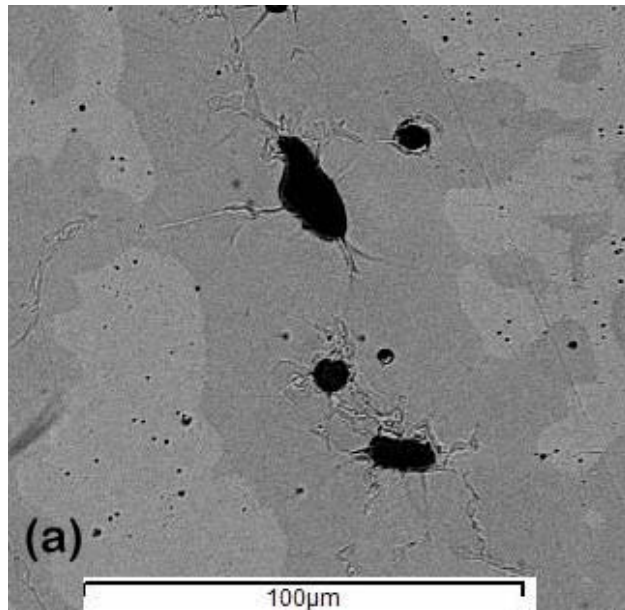


Figure 79 - Slag inclusion ghosting in bar SOU31-814

Slag inclusion ghosting in bar SOU31-814 in a (a) secondary electron image from the SEM and; (b) etched in Stead's reagent where copper deposits in low phosphorus areas

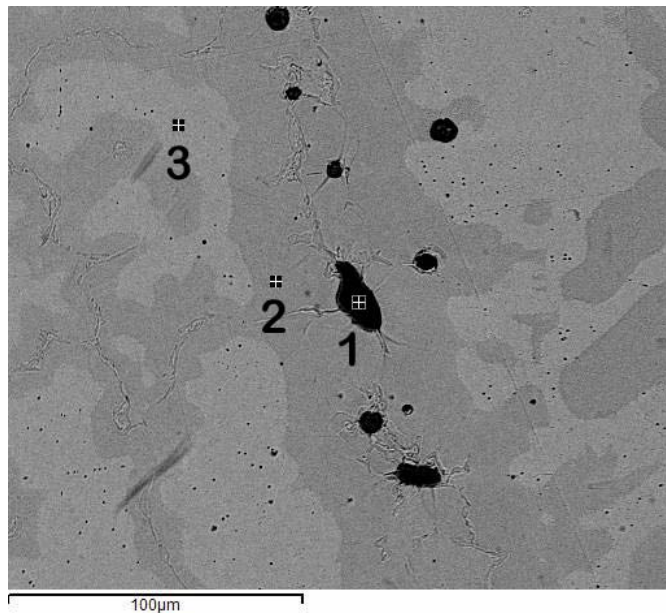


Figure 80 – SEM secondary electron image of a ghosted slag inclusion in bar SOU31-814

*SEM secondary electron image of a ghosted slag inclusion in bar SOU31-814
(Tests areas indicated)*

Table 141 Phosphorus analysis results for test areas indicated in Figure 8.2.12 from
SOU31-814

Area Description	Test #	Phosphorus (wt%P)
Slag Inclusion (P ₂ O ₅)	1	6.9
Inclusion Halo	2	0.3
Surrounding Grains	3	0.7

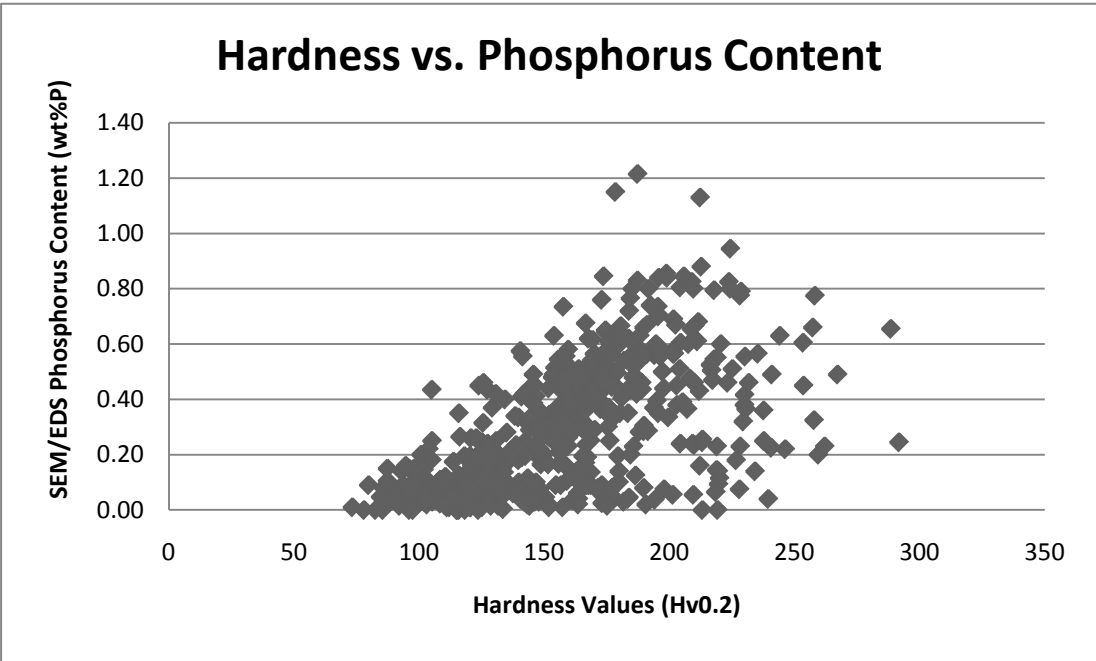


Figure 81 - Hardness values versus phosphorus content

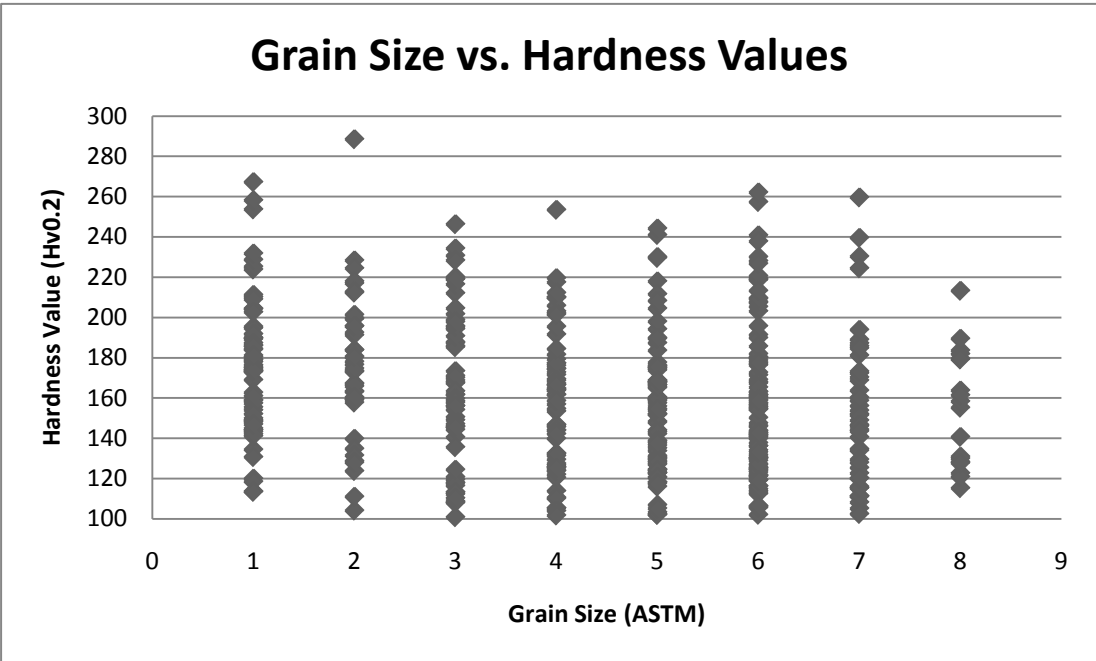


Figure 82 - Harness values versus grain size

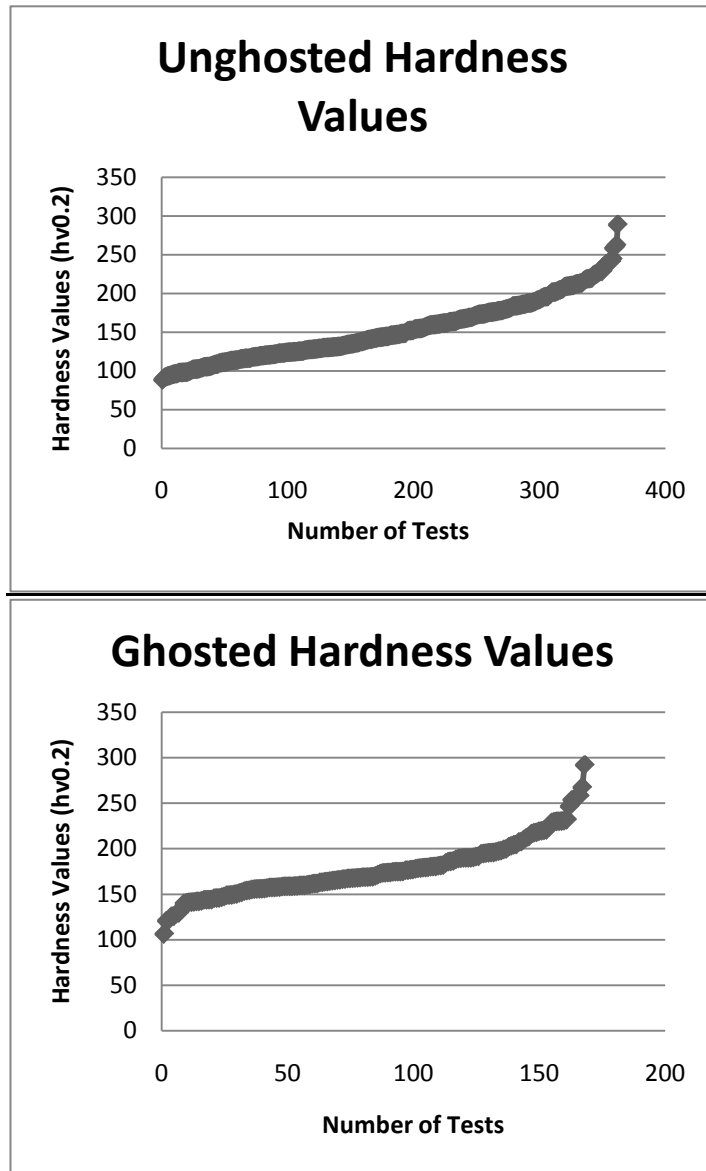


Figure 83 - Hardness values of ghosted phosphoric iron versus hardness values of un-ghosted phosphoric iron

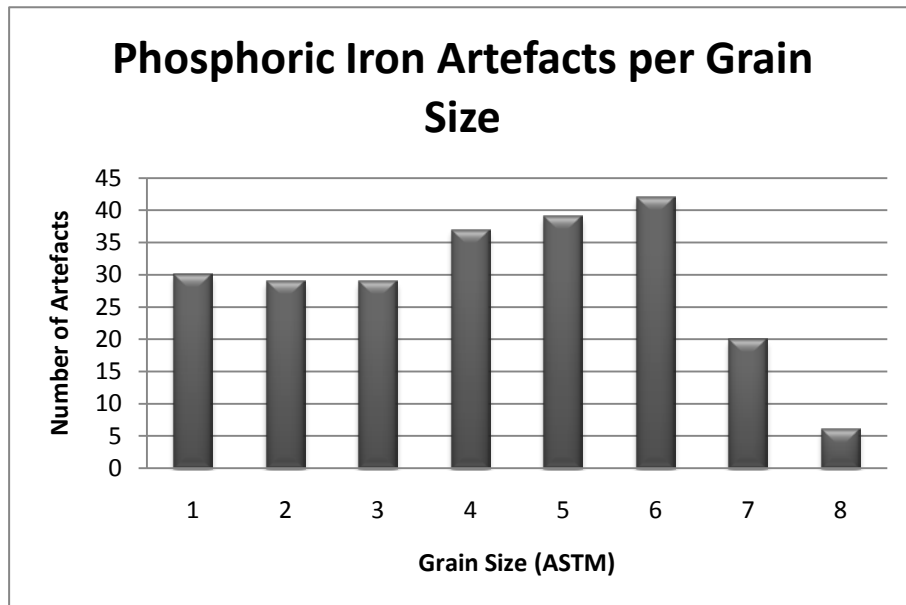


Figure 84 - Grain size distribution in phosphoric iron artefacts

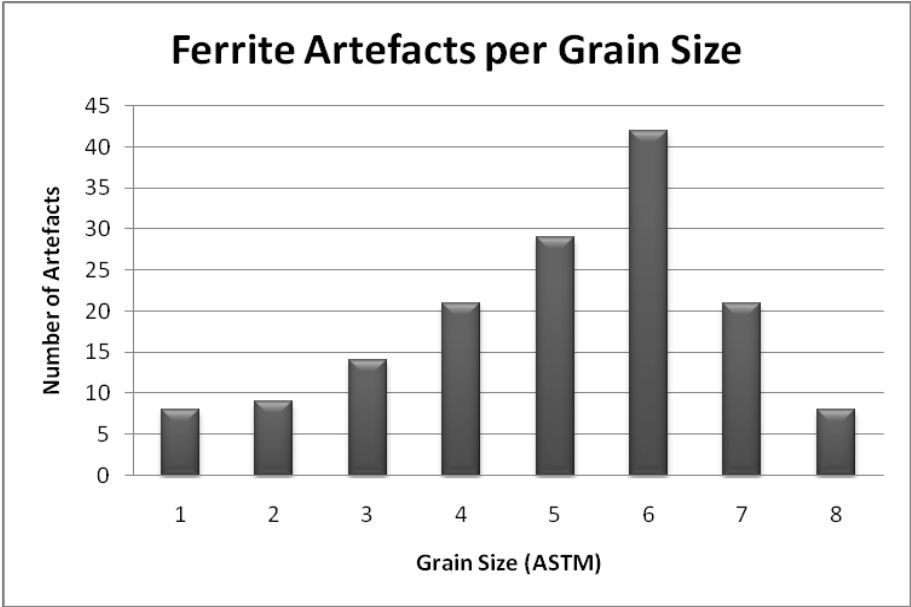


Figure 85 - Grain size distribution of ferritic iron artefacts

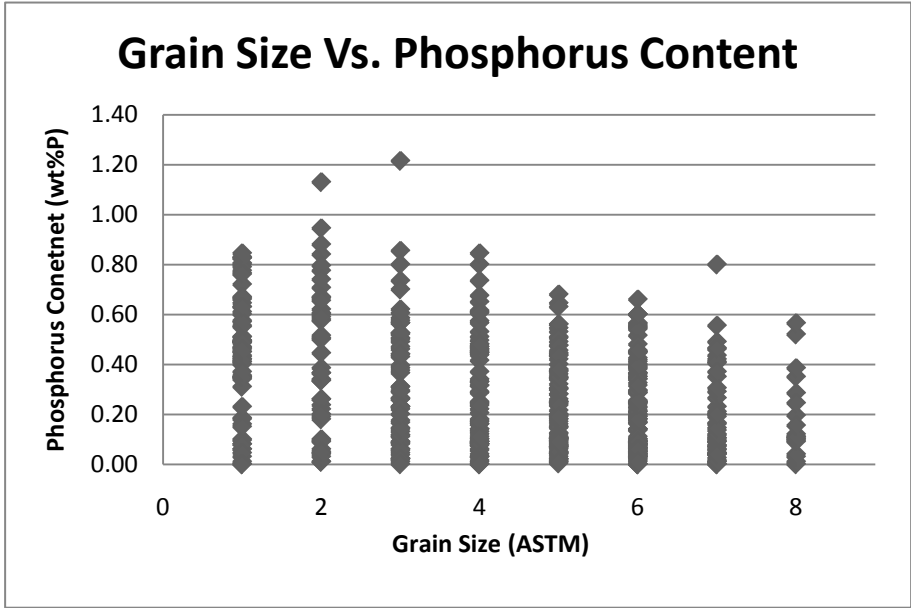


Figure 86 - Grain size versus elemental composition

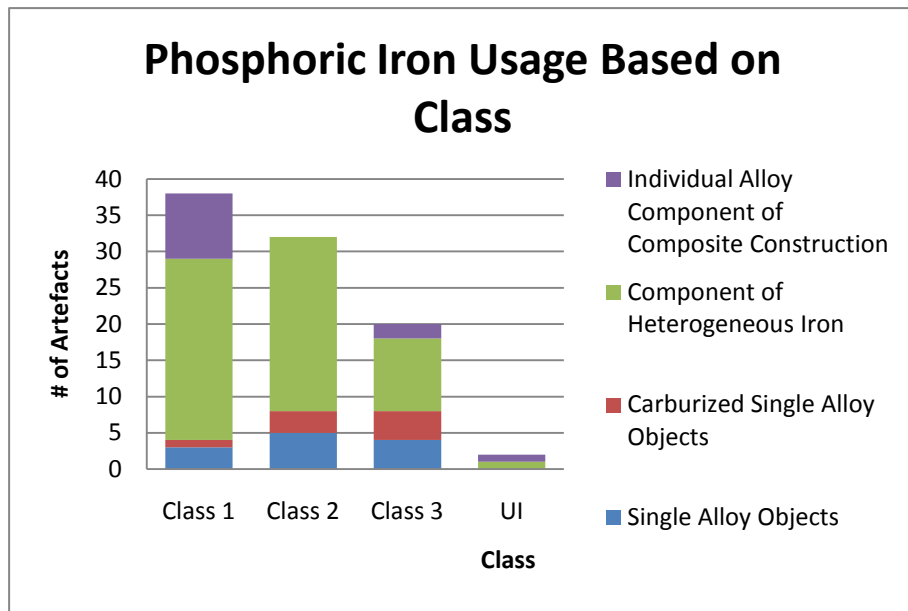


Figure 87 - Phosphoric iron usage based on class and construction

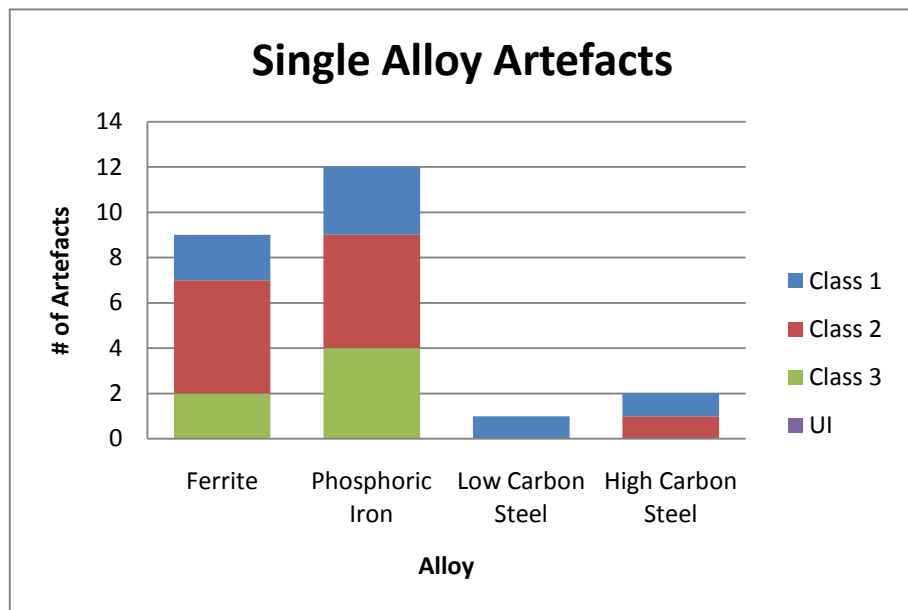


Figure 88 - Single alloy artefacts divided based on class

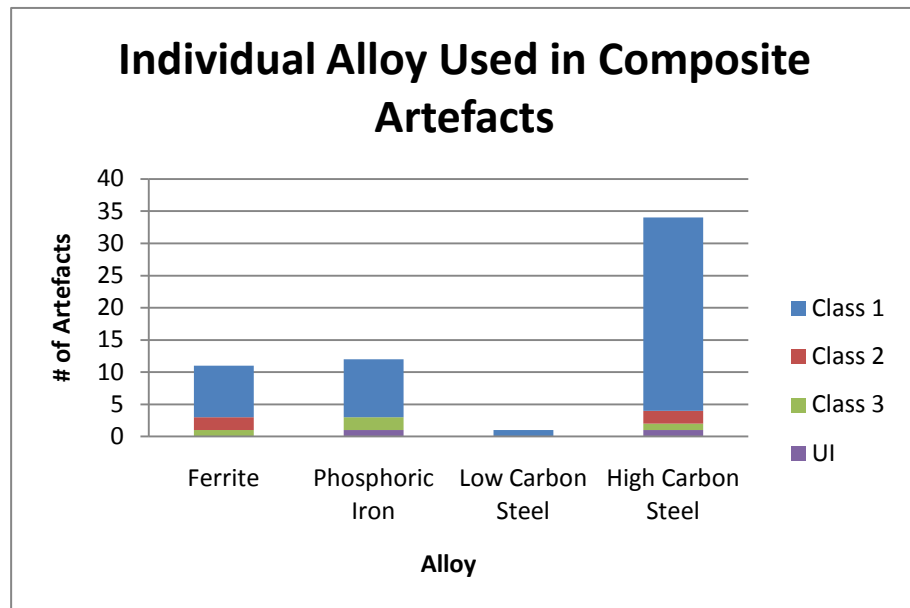


Figure 89 – Individual alloy components of composite artefacts divided based on class

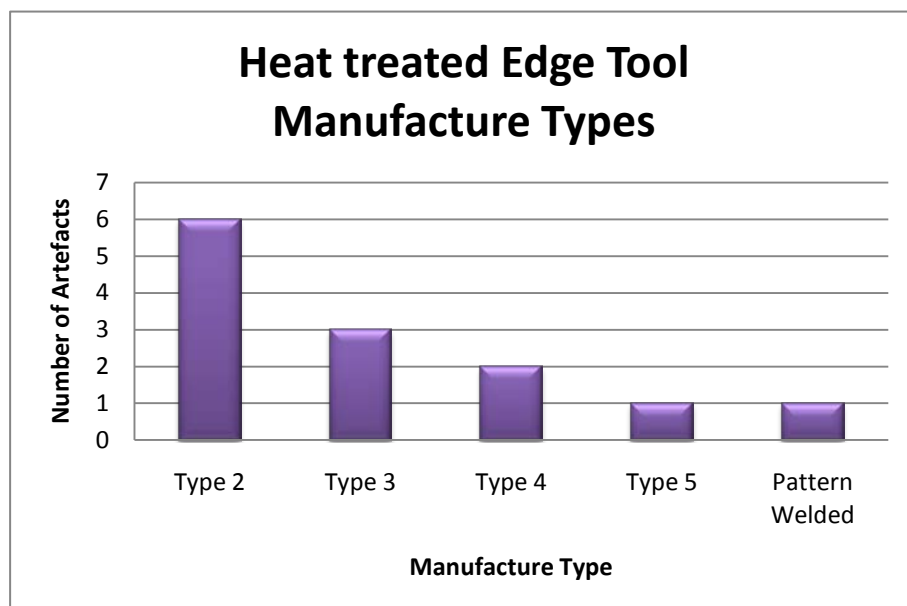


Figure 90 - Manufacture types of heat-treated artefacts

(Typology can be found in Section 5.1)

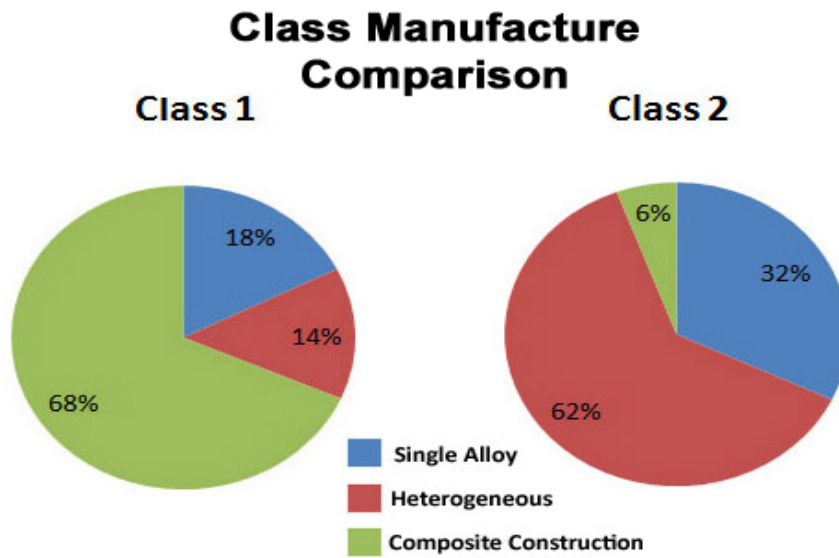


Figure 91 - Construction techniques in Class 1 and Class 2 artefacts

Figure 92 - Alloy usage based on class

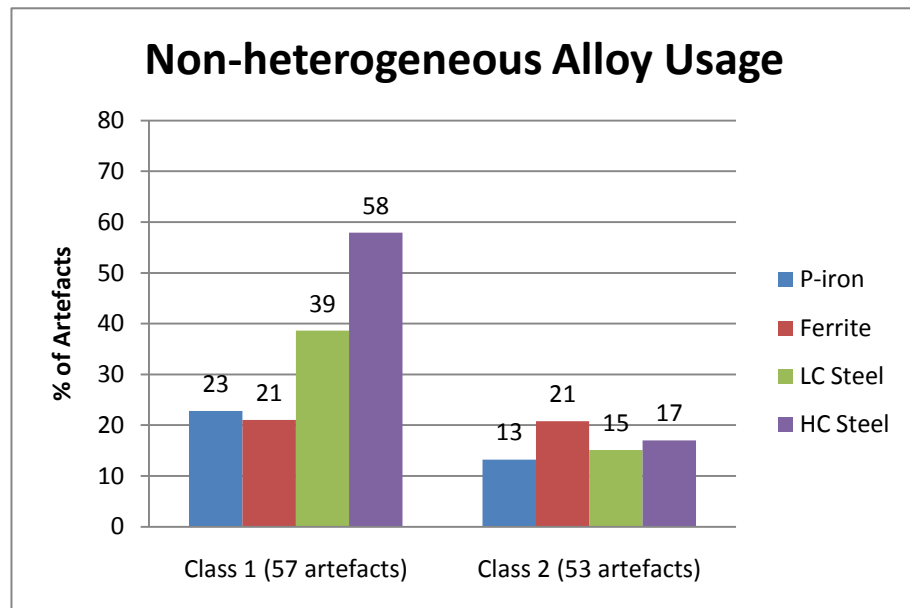
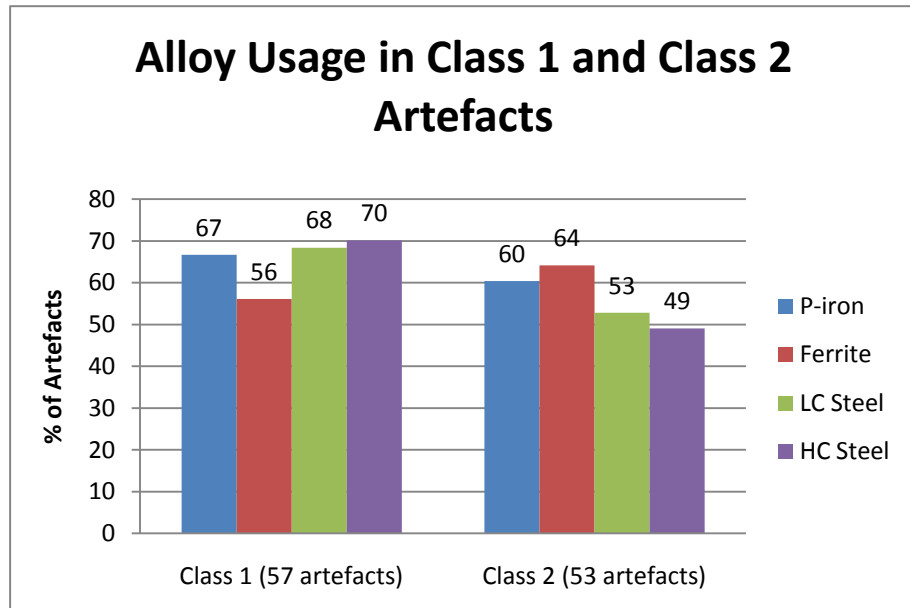


Figure 93 - Non-heterogeneous alloy usage

Class 3 Manufacture

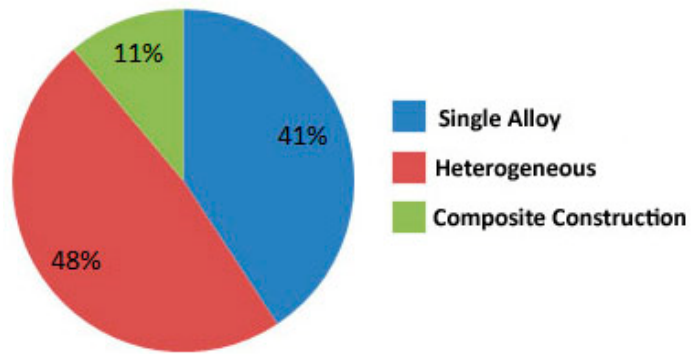


Figure 94 - Manufacture of the Class 3 artefacts

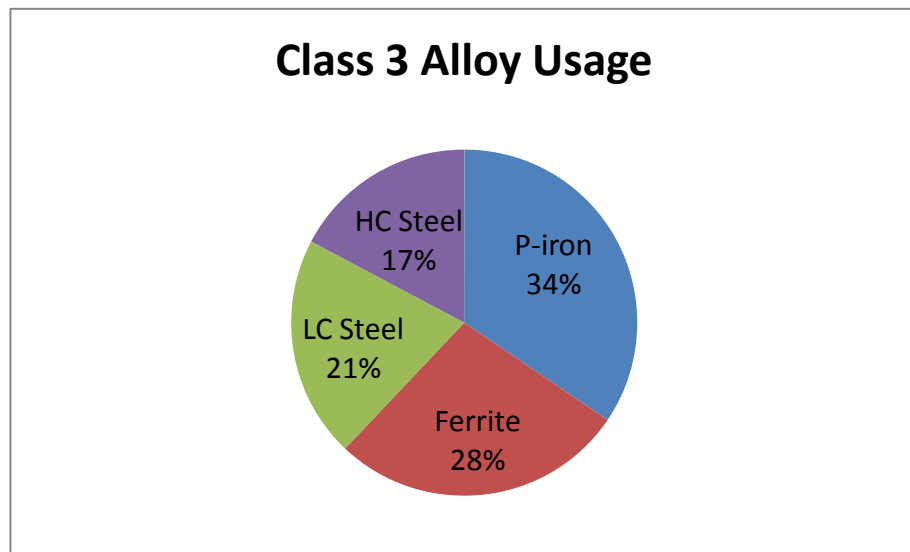


Figure 95 - Overall alloy usage for Class 3 artefacts

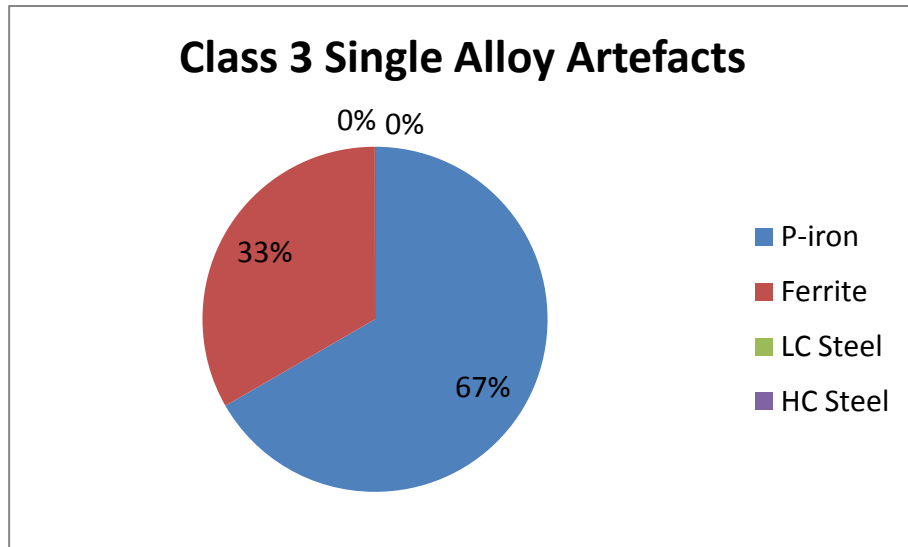


Figure 96 – Single alloy Class 3 artefacts

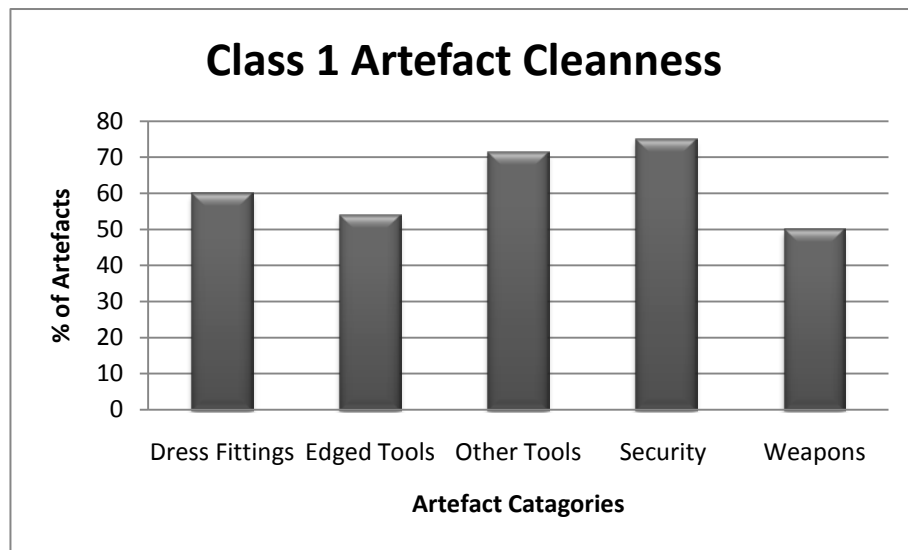
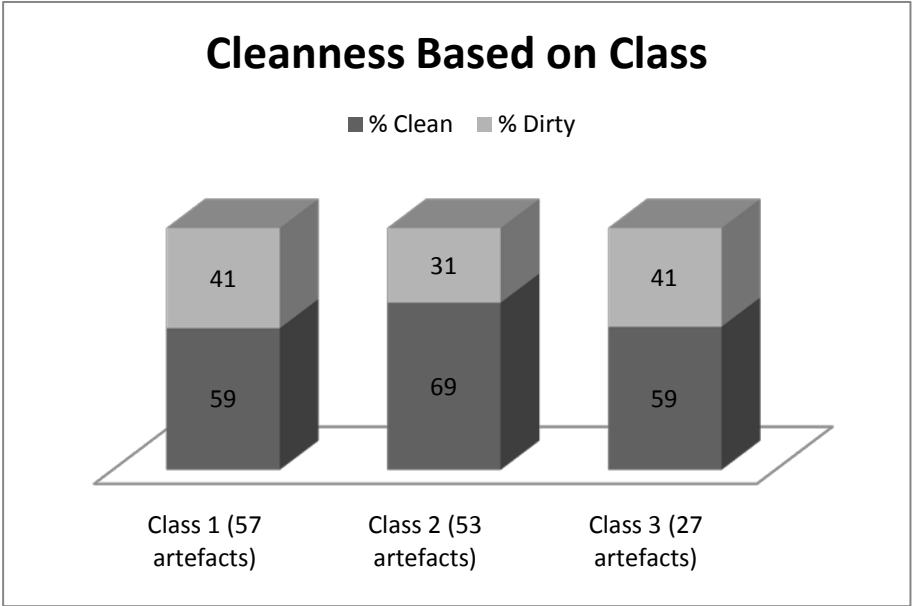


Figure 97 – Cleanness of the Class 1 artefacts

Figure 98 – Comparing the cleanness of the three classes



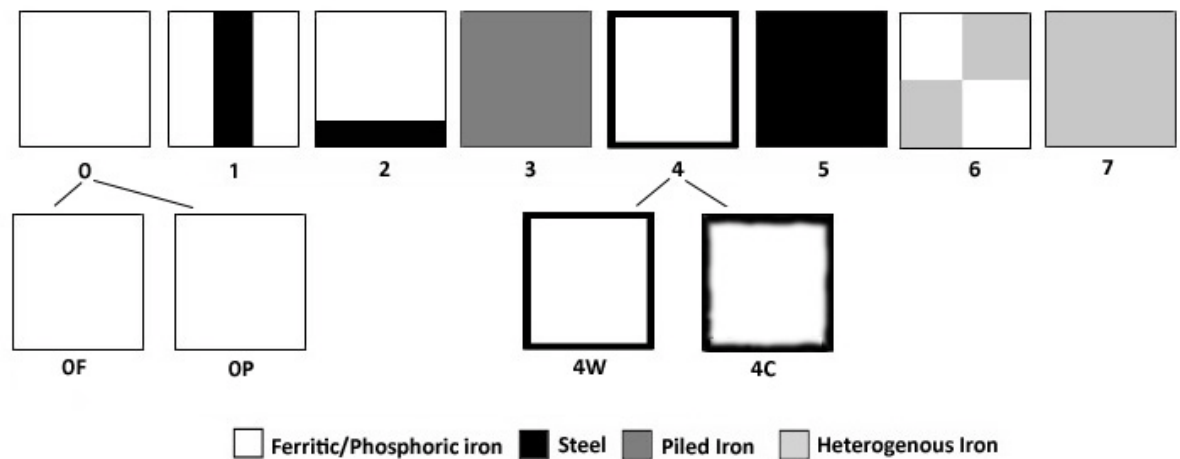


Figure 99 - Artefact manufacturing typology based on cross-sections

(adapted from Tylecote and Gilmour, 1986). OF = all ferrite , OP = all phosphoric iron, 1 = steel core flanked by ferritic or phosphoric iron, 2 = steel edge welded to the iron back, 3 = piled or banded structure throughout the section, 4W = a welded steel jacket around an iron core, 4C=a carburized layer outside a iron core, 5 = all steel, 6 = pattern welded, 7 = heterogeneous (The term steel in this figure can be either high carbon or low carbon steel)



Figure 100 - Map of sites

(green = rural; red = urban)

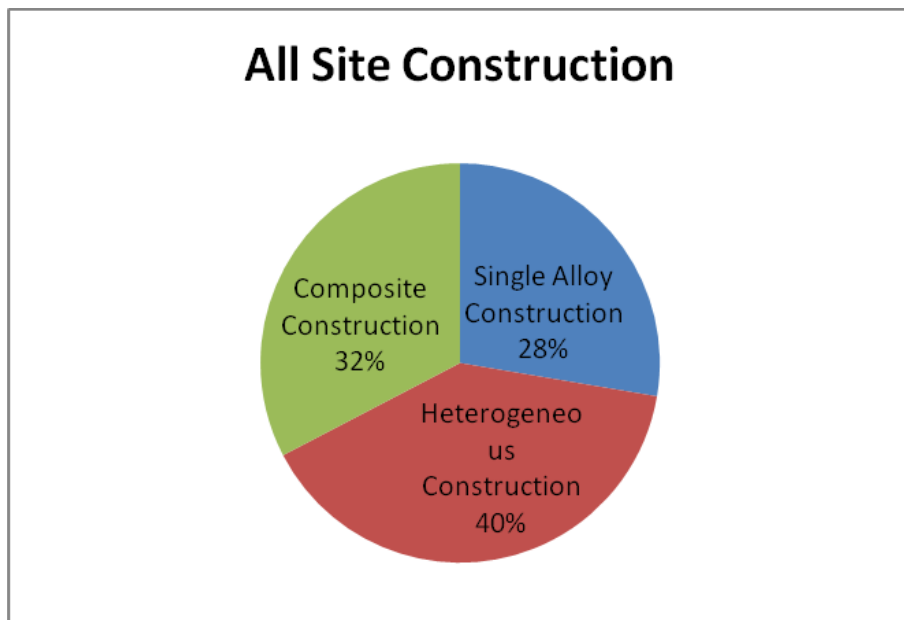


Figure 101 - Artefact construction from all sites

Artefact Manufacture by Site

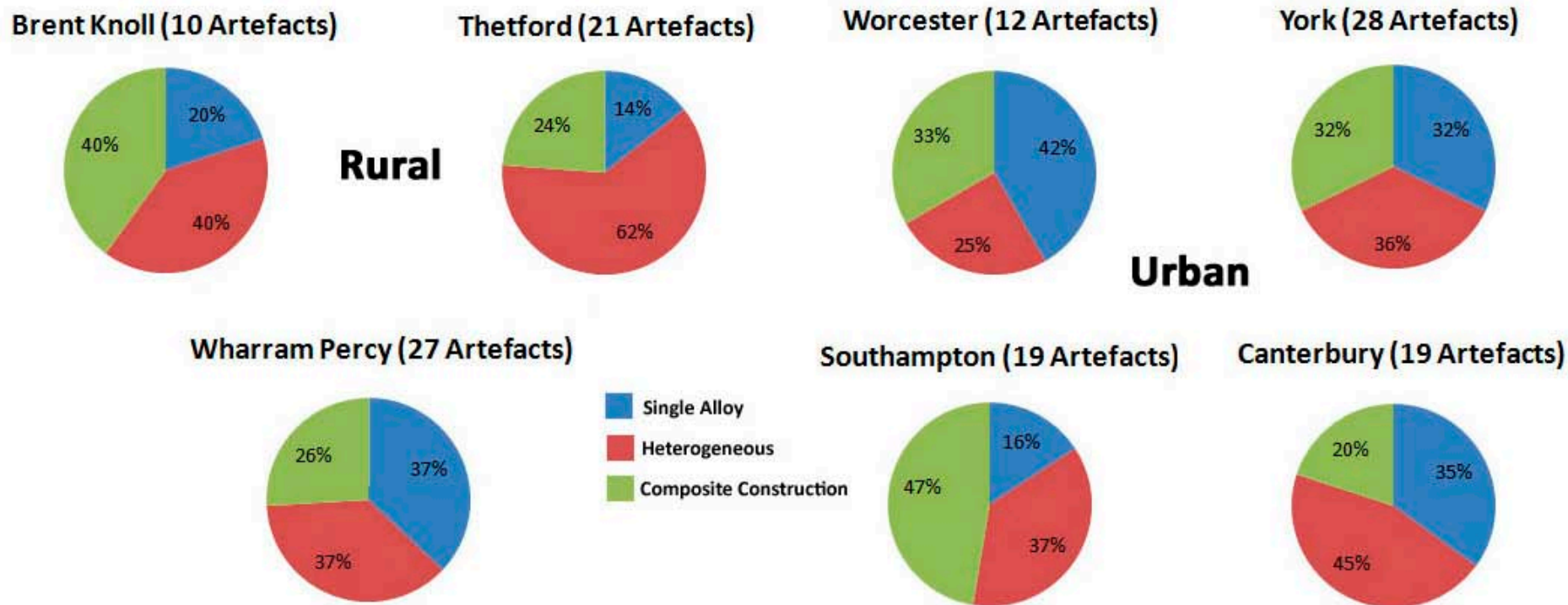


Figure 102 – Manufacture by site

(The Winchester assemblage was not included due to it only containing 4 composite knives)

Comparing Class 1 and Class 2 Manufacture

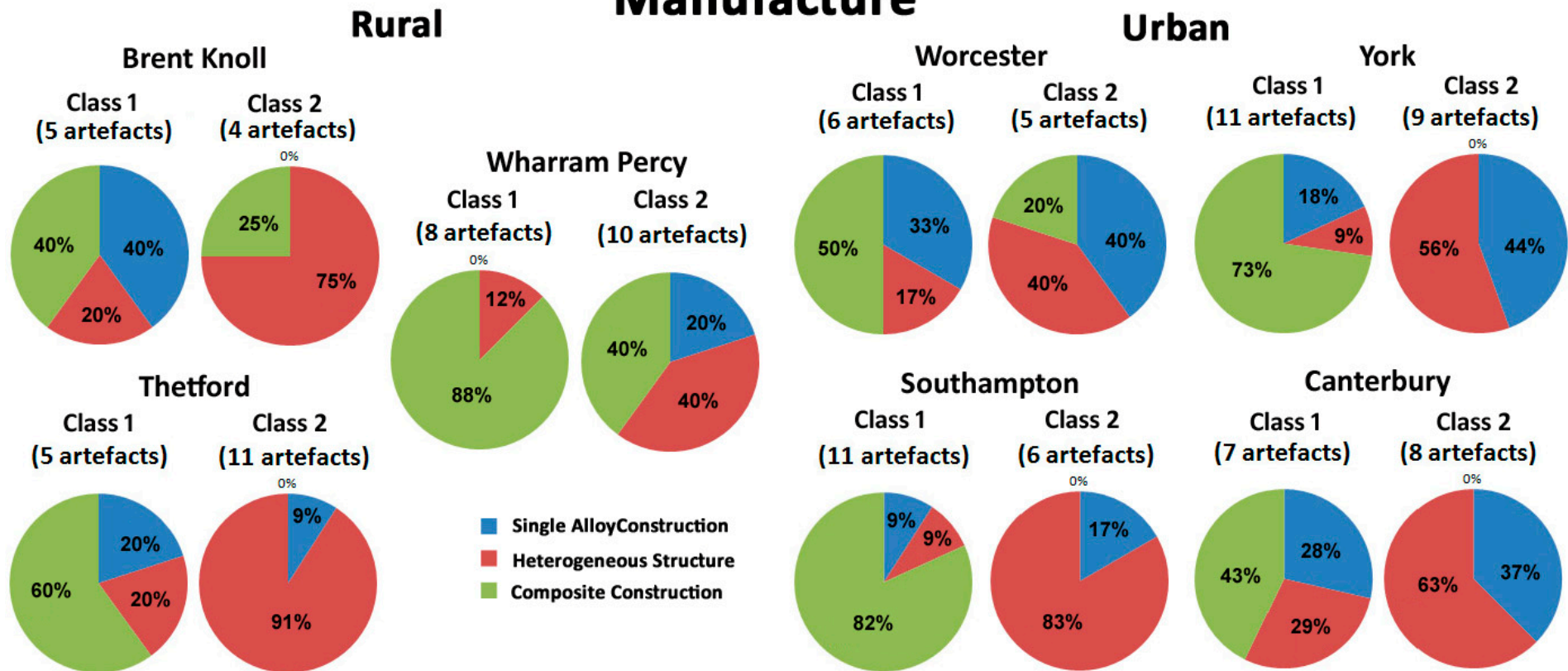


Figure 103 – Comparing Class 1 and Class 2 manufacture

Site Alloy Comparison

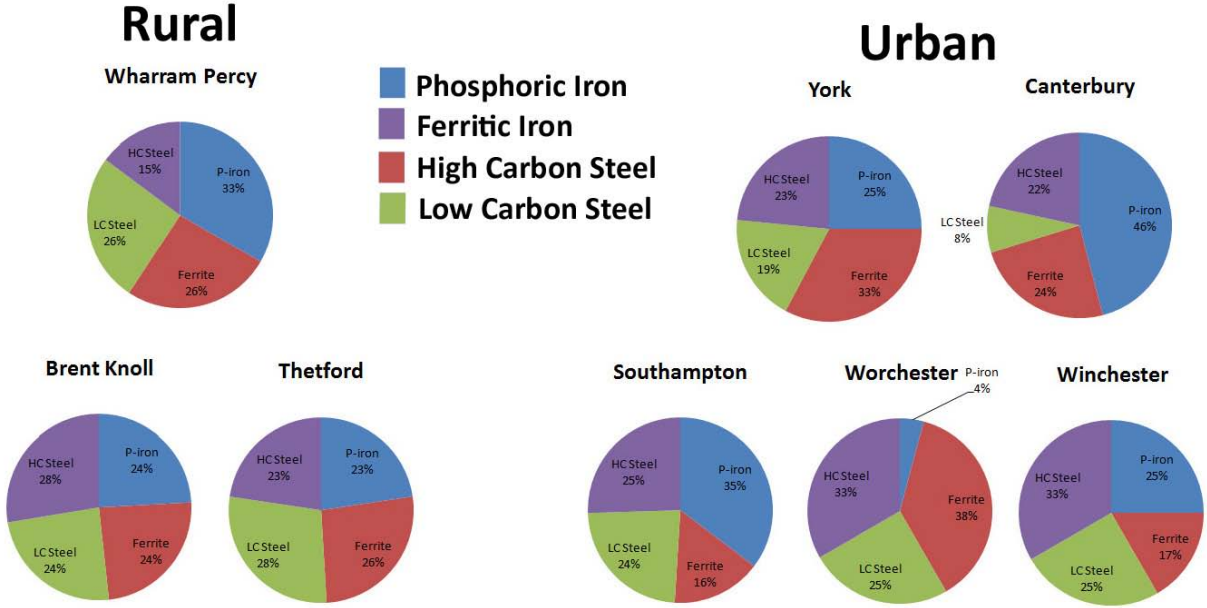


Figure 104 - A comparison of overall alloy usage in the archaeological sites

Site Non-Heterogenous Alloy Comparison

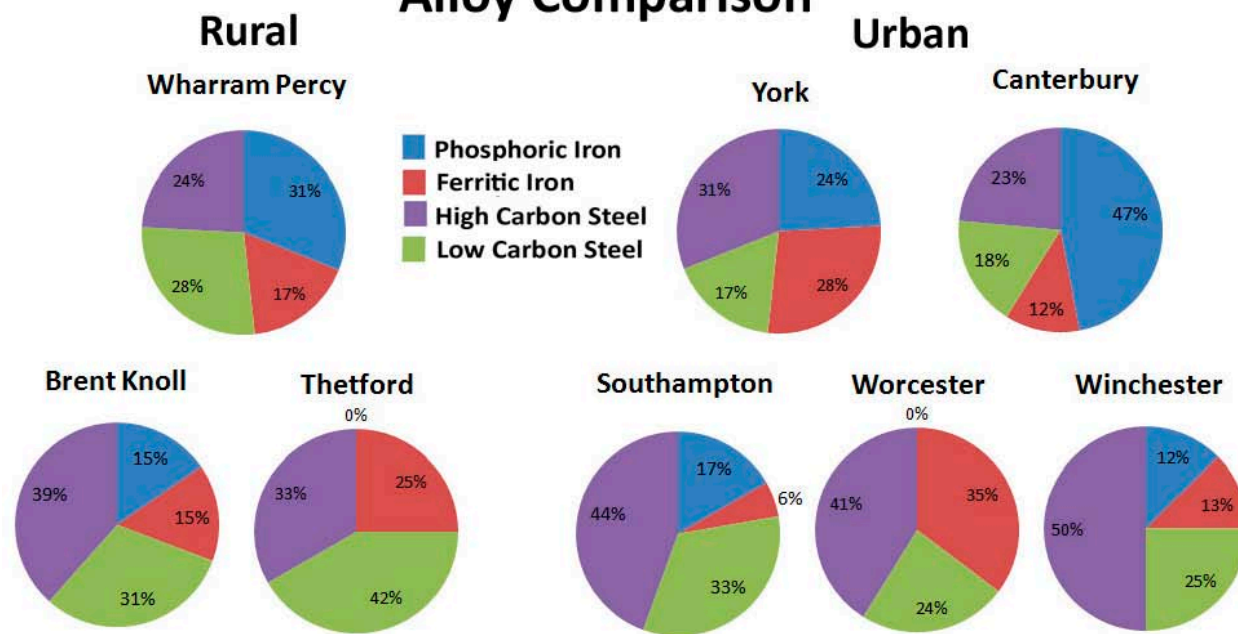


Figure 105 - A comparison of non-heterogeneous alloy usage in the archaeological site

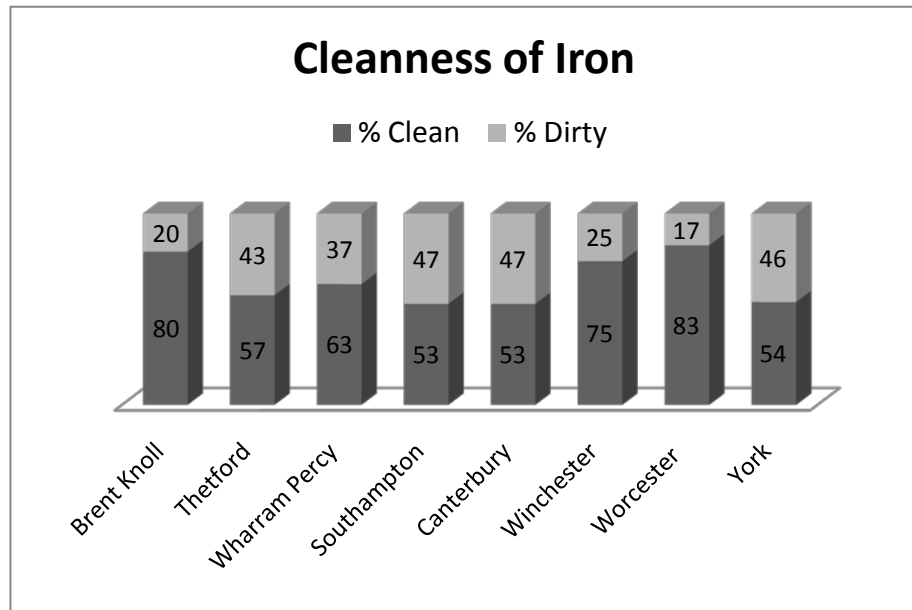


Figure 106 - Cleanness of iron by site

Tables

Table 1 – Hardness values for phases of carbon-iron alloys

Mean hardness values of different phases observed in microstructures of cutting edge from Early British Iron Edge tools
(Wiemer, 1993: Appendix IV)

Microstructure (cutting edge)	Hardness Hv0.1
Tempered Martensite	627
Pearlite	319
Spherodised Carbides	296
Phosphoric Iron	192
Ferrite	100

Table 2 – Heat-treatment at Early Medieval settlement sites

Occurrence of high carbon steel, heat-treatment and use as complete objects in Early Medieval settlement sites

(Data taken from McDonnell, 1992, 1987a, and 1987b)

Site	# Knives	% Containing Steel	% Heat Treated	% Completely Steel
Coppergate, York	47	91	60	4
Southampton	14	93	64	7
Fishergate, York	10	100	60	0

Table 3 – Major artefact types

Edged Tool	Nail	Bar	Other Craft Tools
Knife	Nail	Bar	Needle
Punch	Tack	Billet	Spoon Auger
Pick Head			Fishhook
Axe			Awl
Chisel			
Billhook			

Table 4 – Other artefact types

Dress Fitting	Construction Materials	Riding Equipment	Miscellaneous
Dress Pin	Rivet	Spur	Key
Buckle	Joiners Dog		Padlock
Hook Tab	Staple		Arrowhead
	Ferrule		Hook

Table 5 – Site Codes

Site Name	Site Code
Brent Knoll	BN
Canterbury	CC
Southampton	SOU
Thetford	Thet
Wharram Percy	WP
Winchester	Win
Worcester	DW
York	Yo

Table 6 – Results of SEM and EMPA analyses

Yo26736			W115			Thet 427		
Test #	SEM (wt%P)	EMPA (wt%P)	Test #	SEM P (wt%P)	EMPA (wt%P)	Test #	SEM (wt%P)	EMPA (wt%P)
Test 1	0.00	0.020	Test1	0.17	0.243	Hv1 Test 2	0.55	0.506
Test 2	0.05	0.020	Test2	0.45	0.262	Hv1 Test 3	0.23	0.166
Test 3	0.06	0.029	Test3	0.39	0.267	HV2 Test 1	0.21	0.184
Test 4	0.13	0.018	Test4	0.27	0.259	Hv3 Test1	0.07	0.172
Test 5	0.09	0.017	Test5	0.78	0.262	Hv3 Test 2	0.19	0.218
Test 6	0.05	0.021	Test6	0.88	0.425	Hv3 Test 3	0.17	0.136
			Test7	0.49	0.240	Hv4 Test 1	0.19	0.089
			Test8	0.50	0.284	Hv4 Test 2	0.19	0.190
			Test9	0.43	0.412	Hv4 Test 3	0.40	0.088
			Test10	0.20	0.200	Hv4 Test 4	0.23	0.283

Table 7 – Summary of Brent Knoll artefacts

Artefact #	Artefact Type	Class	Period (centuries AD)	Context	Dimensions (mm)	Weight (g)	# Sections Taken	Section Placement
Class 1								
300	Knife	1	11 th	Fill/Pit	115x19x12	34	2	Knife back and cutting edge
301	Knife	1	10 th -11 th	Layer	138x18x17	44	2	Knife back and cutting edge
324	Dress Pin	1	10 th -11 th	Fill/Structure	49x5x5	3	1	Cross section of thicker end
329	Punch	1	12 th	Layer	71x8x8	17	1	Cross section of tip
333	Arrowhead	1	11 th	Layer/Structure Interior	84x15x12	18	1	Cross section of thicker end
Class 2								
305	Hook	1	10 th -11 th	Fill/Ditch/Structure Interior	85x45x15	49	2	Longitudinal section of point and cross section of ball end
310	Nail	2	10 th -11 th	Layer/Structure Interior	40x19x8	7	1	Cross section of shank
317	Nail	2	11 th	Layer	35x7x6	10	1	Cross section of shank
334	Nail Tip	2	11 th	Soil above Interior Hearth	25x4x4	10	1	Longitudinal section of point
Class 3								
311	Tapering Iron Bar	3	11 th	Ash in Interior Hearth	45x18x10	20	2	Cross section of thick end and longitudinal section of tapered end

Table 8 – Class 1 alloy summary for Brent Knoll

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ alloy	3	2	2	3	1
Whole object	1	0	0	1	0
More than 1/2 of the object	1	0	1	0	0
Up to 1/2 of the object	1	2	1	2	1

Table 9 – Brent Knoll Class 1 artefact analyses

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Artefact Type	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 1											
300	Knife	A type 1 knife with a spherodised carbide pearlitic steel band encased in a phosphoric iron back	165	n/a	192	0.3	193	n/a	5	Dirty	No
301	Knife	A type 4 knife with a martensitic outer shell welded on ferritic core with extensive carbon diffusion	n/a	160	186	0.4	317	6	n/a	Clean	No
324	Dress Pin	Completely composed of phosphoric iron with mild ghosting	200	n/a	n/a	n/a	n/a	n/a	5	Clean	No
329	Punch	Composed of HC steel in the form of partially spherodised carbide	n/a	n/a	n/a	n/a	210	n/a	n/a	Clean	No
333	Arrowhead	Composed of heterogeneous phosphoric iron with small area that is ferritic iron	162	111	n/a	n/a	n/a	7	6	Dirty	No

Table 10 – Brent Knoll Class 2 and Class 3 artefact analyses

(Hv_{0.2} and grain size measurements are averaged; %C is estimate; n/a = not applicable)

Artefact #	Artefact Type	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 2											
305	Hook	A mostly ferritic body with a small eutectoid steel insert in the pointed tip with arsenical welds	n/a	122	152	0.2	263	3	n/a	Clean	No
310	Nail	A heterogeneous combination of eutectoid steel, phosphoric iron, and arsenical ferritic iron	257	176	184	0.4	274	5	6	Clean	No
317	Nail	A heterogeneous iron composed of a large areas of low carbon steel with small areas of ferrite, phosphoric iron, and high carbon steel	260	148	138	0.1	246	n/a	7	Clean	No
334	Nail Tip	Composed of heterogeneous phosphoric/ferritic iron with a carburized outer edge of HC steel and an unusually high arsenic content	202	219	213	0.1	303	7	6	Clean	No
Class 3											
311	Tapering Iron Bar	The back is a heterogeneous banded structure with ferrite, phosphoric iron and low carbon steel; the tip is a partial Type 1 construction with a band of very high carbon steel (>1.0%C) welded to a low carbon steel band	194	151	155	0.3	277	7	5	Clean	No

Table 11 – Class 2 alloy usage for Brent Knoll

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ alloy	1	1	1	1	0
Whole object	0	0	0	0	0
More than 1/2 of the object	0	0	0	0	0
Up to 1/2 of the object	1	1	1	1	0

Table 12 – Class 3 alloy usage for Brent Knoll

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ alloy	1	1	1	1	0
Whole object	0	0	0	0	0
More than 1/2 of the object	0	0	0	0	0
Up to 1/2 of the object	1	1	1	1	0

Table 13 – Phosphorus in Steel in the Brent Knoll assemblage

(Measurements are from individual test sites with estimated carbon content)

Artefact #	Artefact Type	High Carbon Steel wt%P	High Carbon Steel Hv _{0.2}	High Carbon Steel %C	Placement	P-iron in Artefact?	Heat Treated?
BN301	Knife	0.18	193	0.4	Back of knife back	No	No
BN311	Tapering Iron Bar	0.12	263	>0.8	Knife tip	Yes	No
BN329	Punch	0.12	210	0.6	In cross-section	No	No

Table 14 - Data on the phosphoric iron in the Brent Knoll assemblage

(n/a = not applicable; nd = not detected)

Artefact #	Artefact Type	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ave. ASTM)	P-iron ave. Hv _{0.2}
Class 1										
300	Knife	Knife back and sides	Inter-granular; Widmanstätten like	4	Mean	0.33	Yes	Yes	5	165
					Low	0.25	No	No	6	142
					High	0.39	Yes	Yes	2	173
301	Knife	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
324	Dress Pin	Through out	Inter-granular & GB	3	Mean	0.54	Yes	Yes	5	200
					Low	0.40	Yes	No	6	169
					High	0.68	No	Yes	5	212
329	Punch	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
333	Arrowhead	Most of the structure	Slag inclusion & inter-granular; Some Widmanstätten like	3	Mean	0.57	Yes	No	6	162
					Low	0.52	Yes	No	6	154
					High	0.65	No	No	5	175
Class 2										
305	Hook	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
310	Nail	Small corner of the section	Slag inclusion & EE; Ripple like	1	Mean	0.66	Yes	Yes	6	257
317	Nail	A small area in heterogeneous structure	n/a	1	Mean	0.2	No	No	7	260
334	Nail Tip	In heterogeneous structure	Inter-granular; Ripple like	1	Mean	0.23	Yes	Yes	6	202
Class 3										
311	Tapering Iron Bar	In heterogeneous section from thick end	GB, EE, & Slag inclusion; Ripple like	5	Mean	0.40	No	No	5	194
					Low	0.16	No	No	7	159
					High	0.80	No	No	4	210

Table 15 – Analysis of nail BN310*(Hv# - The hardness test number corresponding the Figure 28)*

HV #	Alloy type	Vickers Hardness (Hv _{0.2})	SEM %P	SEM %As	ASTM Grain Size	Notes
Hv1	Ferrite	176	0.1 ± 0.1	0.1 ± 0.2	5	
Hv2	Arsenical Iron	180	0.1 ± 0.1	0.40 ± 0.2	6	Etch Resistant
Hv3	Phosphoric Iron	257	0.7 ± 0.1	0.1 ± 0.2	6	Ghosted
Hv4	Ferrite + Pearlite 0.4%C	184	nd	0.40 ± 0.2	n/a	
Hv5	Weld-line	220	nd	nd	n/a	Weld-line
Hv6	Pearlite	274	0.1 ± 0.1	nd	n/a	
Hv7	Weld-line	187	nd	1.1 ± 0.2	8	

Table 16 – Analysis of nail BN334*(Hv # - The hardness test number corresponding the Figure 29; nd = not detected)*

HV #	Alloy type	Vickers Hardness (Hv _{0.2})	SEM %P	SEM %As	ASTM Grain Size	Notes
Hv1	Ferrite + Pearlite <0.1%C	148	0.1 ± 0.1	0.3 ± 0.2	8	
Hv2	Pearlite + Ferrite 0.7%C	314	0.1 ± 0.1	0.5 ± 0.2	n/a	
Hv3	Ferrite	164	nd	0.2 ± 0.2	7	Ghosted
Hv4	Ferrite	219	nd	0.3 ± 0.2	6	
Hv5	Phosphoric Iron	241	0.2 ± 0.1	0.6 ± 0.2	6	Etch Resistant
Hv6	Ferrite + Pearlite 0.1%C	278	0.1 ± 0.1	0.4 ± 0.2	8	
Hv7	Pearlite + Ferrite 0.7%C	293	nd	0.5 ± 0.2	n/a	

Table 17 – Manufacture summary for the Brent Knoll artefacts

	# Total Artefacts	# Class 1 Artefacts	# Class 2 Artefacts	# Class 3 Artefacts
# Total Artefacts	10	5	4	1
Evidence of Cold Working	0	0	0	0
Heat Treated	1	1	0	0
Carburized	2	0	2	0
Piled	1	0	0	1
Composite Construction	4	2	1	1
Single Alloy Construction	2	2	0	0
Heterogeneous	5	1	3	1
Clean	8	3	4	1

Table 18 – Alloy usage summary for class comparison in the Brent Knoll assemblage

(Numbers are based on the number of artefacts in the category)

Alloy Usage	# Total Artefacts	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
Class 1	5	3	2	2	3	1
Class 2	4	3	4	4	4	0
Class 3	1	1	1	1	1	0
Total	10	7	7	7	8	1

Table 19 – Alloy usage summary for the Brent Knoll assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ alloy	7	7	7	8	1
Whole object	1	0	0	1	0
More than 1/2 of the object	1	1	2	0	0
Up to 1/2 of the object	5	6	5	7	1

Table 20 – Cleanness of the Brent Knoll assemblage

	% Total Artefacts	% Class 1 Artefacts	% Class 2 Artefacts	% Class 3 Artefacts
Clean	53	45	50	100

Table 21 – Summary description of the iron artefacts from Canterbury

(n/a = not applicable)

Artefact #	Artefact Type	Period (centuries AD)	Context	Dimensions (mm)	Weight (g)	# Sections Taken	Section Placement
Class 1							
161	Fishhook	8 th -9 th	n/a	82x2	5	1	Cross section of the back of the hook
213	Tab	8 th -9 th	n/a	25x7x2	<1	1	Cross section of hook end
258	Needle	8 th -9 th	n/a	45x1x1	<1	1	Longitudinal section of needle
357	Buckle	8 th -9 th	n/a	28x11x4	6	1	Cross section of ring
397	Knife	8 th -9 th	n/a	22x38x6	12	1	Cross section of blade
829	Knife	8 th -9 th	n/a	84x24x8	26	1	Cross section of blade
211 Key	Key	8 th -9 th	n/a	44x15x6	12	1	Cross section of the pronged end
48-447	Knife	8 th -9 th	n/a	37x14x2	8	1	Cross section of blade
Class 2							
43	Staple	8 th -9 th	n/a	20x22x5	6	1	Cross section of one prong
211	Nail	8 th -9 th	n/a	37x9x5	5	2	Cross sections of head and tip
214	Fitting	8 th -9 th	n/a	50x14x5	10	1	Cross section of back
230	Staple	8 th -9 th	n/a	25x6x4	5	1	Cross section of prong
324	Tack	8 th -9 th	n/a	13x6x3	1	1	Complete longitudinal section
359	Staple	8 th -9 th	n/a	55x30x10	20	2	Cross section and longitudinal section of prong
418	Nail	8 th -9 th	n/a	22x11x7	3	1	Cross section of head
Class 3							
292	Bar/strip	8 th -9 th	n/a	7x59x3	5	1	Cross section of bar
299	Bar	8 th -9 th	n/a	3x31x10	6	1	Cross section of bar
363	Bar	8 th -9 th	n/a	10x49x7	6	1	Cross section of bar
977	Billet	8 th -9 th	n/a	3x35x10	10	1	Cross section of billet

Table 22 – Canterbury Class 1 artefact analyses

(Hv_{0.2} and grain size measurements are averaged; %C is estimated)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 1											
213	Hook Tag	Completely ferritic iron	n/a	169	n/a	n/a	n/a	1	n/a	Dirty	No
258	Needle	Phosphoric iron with a little grain boundary pearlite. Grains were elongated with minor ghosting	156	n/a	n/a	n/a	n/a	n/a	6	Clean	No
357	Buckle	Heterogeneous phosphoric iron with a small area of high carbon steel on one of the edges	201	n/a	n/a	n/a	n/a	n/a	1	Clean	No
397	Knife	A type 4 construction with a phosphoric banded core surrounded a tempered martensite/bainite outer casing; there was significant carbon diffusion into the central bands	157	n/a	n/a	n/a	463	n/a	3	Clean	Yes
829	Knife	A type 2 construction with a pearlitic tip with no clear weld to a banded phosphoric/ferritic back	194	141	147	0.1	382	7	4	Dirty	No
211 Key	Key	A piled structure of mostly phosphoric iron with slight carburization along one edge	166	113	133	0.1	n/a	6	2	Dirty	No
48-447	Knife	A type 4 construction with a phosphoric iron core with a pearlite edged tip and a line of pearlite width wise across the section not far from the tip	115	n/a	n/a	n/a	212	n/a	4	Clean	No

Table 23 – Canterbury Class 2 artefact analysis

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 2											
43	Staple	A heterogeneous microstructure mostly phosphoric iron, ferrite with carburized edges	224	164	130	0.3	324	4	4	Clean	No
161	Fishhook	Almost completely composed of phosphoric iron	183	157	n/a	n/a	n/a	4	2	Dirty	No
211	Nail	A phosphoric iron with an large area of high carbon steel welded to one side	187	n/a	n/a	n/a	268	n/a	4	Dirty	No
214	Fitting	A band of phosphoric iron that has been folded with slight carburization along the inside of the fold	215	n/a	n/a	n/a	257	n/a	4	Dirty	No
230	Staple	A folded banded structure of phosphoric and ferritic iron	169	133	n/a	n/a	n/a	6	5	Clean	No
324	Tack	Phosphoric iron, the shank has large ghosted equiaxed grains while in the head the grains and ghosting elongated across the top	169	n/a	n/a	n/a	n/a	n/a	5	Clean	No
359	Staple	The structure is mostly phosphoric iron carburized along the outside	181	138	n/a	n/a	177	n/a	5	Clean	No
418	Nail	A completely ferritic structure	n/a	86	n/a	n/a	n/a	4	n/a	Clean	No

Table 24 – Class 1 alloy usage summary for the Canterbury assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ alloy	7	4	2	3	2
Whole object	1	1	0	0	0
More than 1/2 of the object	2	0	0	0	0
Up to 1/2 of the object	4	3	2	3	2

Table 25 – Class 2 alloy usage summary for the Canterbury assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ alloy	6	4	1	4	0
Whole object	1	1	0	0	0
More than 1/2 of the object	3	0	0	0	0
Up to 1/2 of the object	2	3	1	4	0

Table 26 – Class 3 alloy usage summary for the Canterbury assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ alloy	4	1	0	1	0
Whole object	0	0	0	0	0
More than 1/2 of the object	2	0	0	1	0
Up to 1/2 of the object	0	1	0	0	0

Table 27 – Canterbury Class 2 artefact analysis

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Artefact Type	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
292	Bar/strip	A mostly ghosted phosphoric iron structure	229	220	n/a	n/a	n/a	4	1	Clean	No
299	Bar	Two phosphoric bands each folded into themselves with heavy ghosting on the edges of the folds with a small amount of grain boundary pearlite along the outer edge	182	n/a	n/a	n/a	n/a	n/a	2	Clean	No
363	Bar	Two bands welded together, one phosphoric iron and the other 0.4%C steel	116	n/a	n/a	n/a	133	n/a	3	Clean	No
977	Billet	Completely phosphoric iron	176	n/a	n/a	n/a	n/a	n/a	3	Clean	No

Table 28 – Phosphoric iron analyses for the Class 1 artefacts from the Canterbury assemblage

(Phosphorus content and hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Artefact Type	Location within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ave. ASTM)	P-iron (ave. Hv _{0.2})
Class 1										
213	Tab	nd	Slag inclusion	nd	Mean	nd	Yes	No	n/a	n/a
258	Needle	Throughout	Elongated; No structures visible	2	Mean	0.34	Yes	No	6	156
					Low	0.25	No	No	6	238
					High	0.42	Yes	No	6	230
357	Buckle	Throughout	GB & Slag inclusion	4	Mean	0.55	Yes	No	1	201
					Low	0.35	Yes	No	1	178
					High	0.78	No	No	1	258
397	Knife	The central band/back of the knife	GB & Slag inclusion	4	Mean	0.44	Yes	No	3	157
					Low	0.34	No	No	2	140
					High	0.58	Yes	No	2	160
829	Knife	Thin bands in the piled microstructure	n/a	3	Mean	0.6	No	Yes	4	194
					Low	0.51	No	Yes	2	217
					High	0.74	No	Yes	4	195
211Key	Key	Thin bands in the piled microstructure	GB & Slag inclusion	4	Mean	0.44	Yes	Yes	2	166
					Low	0.26	Yes	No	2	158
					High	0.53	No	Yes	3	173
48-447	Knife	The core and back of the knife	Slag inclusion, Pearlite, GB, & EE	3	Mean	0.36	Yes	Yes	4	156
					Low	0.26	No	No	5	123
					High	0.52	No	Yes	3	186

Table 28 (cont.) – Phosphoric iron analyses for the Class 2 artefacts from the Canterbury assemblage

(Phosphorus content and hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Artefact Type	Location within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ave. ASTM)	P-iron ave. Hv _{0.2}
Class 2										
43	Staple	Heterogeneously within the section	Inter-granular; Ripple-like	2	Mean	0.42	Yes	Yes	4	194
					Low	0.37	Yes	Yes	3	231
					High	0.47	Yes	No	4	217
161	Fishhook	Almost all the composition	Slag inclusions & GB	4	Mean	0.46	Yes	No	2	183
					Low	0.25	No	No	5	148
					High	0.66	Yes	No	1	190
211	Nail	Most of the heterogeneous microstructure	Inter-granular, Pearlite & EE; Ripple-like	4	Mean	0.47	Yes	Yes	4	187
					Low	0.4	Yes	No	6	171
					High	0.62	Yes	No	3	168
214	Fitting	Almost all the composition	Slag Inclusion & Inter-granular; Ripple-like	3	Mean	0.32	Yes	Yes	4	215
					Low	0.22	Yes	No	3	246
					High	0.46	Yes	No	4	210
230	Staple	Heterogeneous bands	Inter-granular; Ripple-like	2	Mean	0.4	Yes	Yes	5	169
					Low	0.38	Yes	No	5	156
					High	0.42	Yes	No	4	181
324	Tack	Throughout	Elongated; No structure visible	5	Mean	0.4	Yes	Yes	5	169
					Low	0.25	No	No	5	142
					High	0.57	Yes	No	6	191
359	Staple	Most of the staple	GB & Slag inclusion	3	Mean	0.5	Yes	Yes	5	181
					Low	0.5	Yes	No	4	179
					High	0.53	No	No	5	187
418	Nail	nd	n/a	nd	Mean	nd	no	Yes	n/a	n/a

Table 28 (cont.) – Phosphoric iron analyses for the Class 3 artefacts from the Canterbury assemblage

(Phosphorus content and hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Artefact Type	Location within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ave. ASTM)	P-iron ave. Hv _{0.2}
Class 3										
292	Bar/strip	Almost all the composition	Inter-granular & Slag inclusion	3	Mean	0.38	Yes	Yes	1	229
					Low	0.19	No	No	2	167
					High	0.49	Yes	No	1	267
299	Bar	Throughout	Slag inclusion, inter-granular, & GB; needle-like	5	Mean	0.65	Yes	Yes	2	182
					Low	0.37	Yes	Yes	1	189
					High	1.13	No	Yes	2	212
363	Bar	Half the microstructure; one band	Pearlite & Inter-granular; Ripple-like	2	Mean	0.26	Yes	No	3	119
					Low	0.26	Yes	No	3	121
					High	0.27	No	No	3	116
977	Billet	Throughout	Inter Granular & GB; Elongation	5	Mean	0.42	Yes	Yes	3	176
					Low	0.17	No	No	5	166
					High	0.81	No	No	1	204

Table 29 – Phosphorus in steel in the Canterbury assemblage

(Phosphorus content and hardness values averaged; nd = not detected; n/a = not applicable; ns = not significant (<0.15%P))

Artefact #	Artefact Type	Low Carbon Steel wt%P	Low Carbon Steel Hv _{0.2}	Low Carbon Steel %C	Placement of Low Carbon Steel	High Carbon Steel wt%P	High Carbon Steel Hv _{0.2}	High Carbon Steel %C	Placement of High Carbon Steel	P-iron also in Artefact?	Heat Treated?
Class 1											
258	Needle	0.34	214	<0.1	Along one side of needle	nd	n/a	n/a	n/a	Yes	No
397	Knife	nd	n/a	n/a	n/a	0.39	398	Martensite & Bainite	The knife tip	Yes	Yes
829	Knife	0.18	222	0.1	The back end of a steel band	nd	n/a	n/a	n/a	Yes	No
48-447	Knife	0.31	159	0.2	Back edge of the knife	ns	n/a	n/a	n/a	Yes	No
Class 2											
43	Staple	0.13	130	0.3	One edge of staple	ns	n/a	n/a	n/a	Yes	No
211	Nail	nd	n/a	n/a	n/a	0.61	261	0.4	Area of steel along one side of the nail	Yes	No
214	Fitting	nd	n/a	n/a	n/a	0.17	257	0.6	The outer edge of the bands	Yes	No
359	Staple	0.5	175	<0.1	The prong tip	ns	n/a	n/a	n/a	Yes	No
Class 3											
363	Bar	0.13	111	0.4	The steel band	nd	n/a	n/a	n/a	Yes	No

Table 30 – Analysis of bar CC299

(Hv# - The hardness test number corresponding the Figure 31)

Hv #	Alloy Type	Vickers Hardness (Hv _{0.2})	SEM Wt%P	SEM Wt%As	ASTM Grain Size	Notes
Hv 1	Phosphoric Iron	189	0.4 ± 0.1	0.7 ± 0.2	1	Slag Inclusion Ghosting + Etch Resistant
Hv 2	Phosphoric Iron	212	1.1 ± 0.1	nd	2	Etch Resistant
Hv 3	Phosphoric Iron	174	0.6 ± 0.1	0.2 ± 0.2	4	
Hv 4	Phosphoric Iron	173	0.8 ± 0.1	0.3 ± 0.2	1	
Hv 5	Phosphoric Iron	159	0.4 ± 0.1	0.1 ± 0.2	1	Slag Inclusion and Alloy Edge Effects

Table 31 – Manufacture summary for the Canterbury artefacts

	# Total Artefacts	# Class 1 Artefacts	# Class 2 Artefacts	# Class 3 Artefacts
# Total Artefacts	19	8	7	4
Evidence of Cold Worked	2	1	1	0
Heat Treated	1	1	0	0
Carburized	5	1	3	1
Piled	2	2	0	0
Composite Construction	4	3	0	1
Single Alloy Construction	4	1	2	1
Heterogeneous	8	3	4	1
Clean	9	3	4	2

Table 32 – Alloy usage summary for class comparison for the Canterbury assemblage

(Numbers are based on the number of artefacts in the category)

Alloy Usage	# Total Artefacts	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
Class 1	8	7	3	2	3	2
Class 2	7	6	5	1	4	0
Class 3	4	4	1	0	1	0
Total	19	17	9	3	8	2

Table 33 - Alloy usage summary of the Canterbury artefacts

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ alloy	17	9	3	8	2
Whole object	2	2	0	0	0
More than 1/2 of the object	7	0	0	1	0
Up to 1/2 of the object	6	7	3	7	2

Table 34 - Cleanness of the artefacts from Canterbury by class

	% Total Artefacts	% Class 1 Artefacts	% Class 2 Artefacts	% Class 3 Artefacts
Clean	47	38	57	50

Table 35 – Summary of the iron artefacts from Saxon Southampton

(n/a = not applicable)

Artefact #	Description	Period	Site/Context	Dimensions (mm)	Weight (g)	# Sections Taken	Section Placement
Class 1							
168-421	Knife	Middle Saxon	Six Dials	13x131	n/a	1	Cross section of the blade
169-1858	Chisel	Middle Saxon	Six Dials	16x165	n/a	1	Cross section of the blade
169-2407	Knife	Middle Saxon	Six Dials	12x107	n/a	1	Cross section of the blade
169-540	Knife	Middle Saxon	Six Dials	14x113	n/a	1	Cross section of the blade
169-610	Knife	Middle Saxon	Six Dials	10x117	n/a	1	Cross section of the blade
24-22	Axe	Middle Saxon	Six Dials	137x45x170	n/a	1	Only one section used, a cross section of the blade
31-1137	Needle	Middle Saxon	Six Dials	2.5x0.1x0.1	<1	1	Longitudinal section of the needle
31-663	Knife	Middle Saxon	Six Dials	92x11	n/a	1	Cross section of the blade
31-92	Bill hook	Middle Saxon	Six Dials	65x315	n/a	2	Longitudinal section of the point and a cross section of the ball end
99-38	Knife	Middle Saxon	Stoner Motors St.Marys St	12x2667	n/a	1	Cross section of the blade
99-92	Knife	Middle Saxon	Stoner Motors St.Marys St	15x135	n/a	1	Cross section of the blade
Class 2							
31-1015	Hook	Middle Saxon	Six Dials	5.4x0.9x0.4	7	1	Longitudinal section of the hook
31-1742	Nail	Middle Saxon	Six Dials	5x2x0.4	16	1	Cross section of the shank
31-1899	Nail	Middle Saxon	Six Dials	7.5x1.3x0.8	23	2	Cross section of the head and a cross section of the shank
31-1960	Nail	Middle Saxon	Six Dials	6.2x3.3x0.4	25	1	Cross section of the shank
31-402	Nail	Middle Saxon	Six Dials	2.5x0.7x0.7	5	1	Cross section of the shank
31-551	Nail	Middle Saxon	Six Dials	5.5x0.9x0.8	39	1	Cross section of the shank
Class 3							
31-2110	Bar	Middle Saxon	Six Dials	6x1.2x0.6	16	1	Cross section
31-814	Bar	Middle Saxon	Six Dials	4.8x1.8x0.6	24	1	Cross section

Table 36 – Southampton Class 1 artefact analysis

(Hv_{0.2} and grain size measurements are averaged; %C is estimated)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 1											
169-421	Knife	A Type 2 with a pearlite cutting edge welded to a back that had a slightly piled looking structure that is mostly phosphoric iron with carbon at the welds between bands	146	125	146	0.1	173	3	4	Dirty	No
169-1858	Chisel	A Type 3 piled structure with bands of low carbon steel, phosphoric iron and HC steel with grain boundary carbides at the tip	261	n/a	166	0.2	216	n/a	6	Clean	No
169-2407	Knife	A Type 2 with a nodular carbide and ferrite tip welded to a heterogeneous phosphoric/low carbon steel back	160	n/a	152	0.1	130	n/a	2	Dirty	No
169-540	Knife	A Type 2 a tempered martensite cutting edge welded to a phosphoric iron back with some carbon diffusion across the weld	155	n/a	n/a	n/a	601	n/a	3	Dirty	Yes
169-610	Knife	A Type 2 with a tempered martensite degraded to pearlite tip welded to a heterogeneous phosphoric iron/low carbon steel back	133	n/a	149	2	381	n/a	4	Dirty	Yes

Table 36 (cont.) – Southampton Class 1 artefact analysis

(Hv_{0.2} and grain size measurements are averaged; %C is estimated)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 1											
24-22	Axe	A Type 3 piled structure with a central band of phosphoric iron welded to bands of phosphoric iron, low carbon steel, and HC steel with tempered martensite near the tip	185	n/a	193	2	237	n/a	3	Clean	Yes
31-1137	Needle	Ferritic iron with exterior carburization	n/a	155	202	0.3	n/a	6	n/a	Clean	No
31-663	Knife	A Type 2 with a high phosphorus partial steel (0.1-0.7%C) tip welded to heterogeneous phosphoric iron with areas of low carbon steel back with carbon diffusion across the weld	187	n/a	171	1	180	n/a	2	Dirty	No
31-92	Bill hook	A Type 3 piled structure with bands of phosphoric iron, ferrite, low carbon steel, pearlite, bainite and tempered martensite	161	131	142	0.3	472	n/a	6	Clean	Yes
99-38	Knife	A Type 2 construction with a tempered martensitic tip welded to a heterogeneous phosphoric/ ferritic back with some high carbon steel along one edge and edge carbon diffusion across the weld	165	140	n/a	n/a	447	4	1	Clean	Yes
99-92	Knife	Mostly phosphoric iron with areas ferrite plus pearlite and carburization along the outside of the tip	163	n/a	155	0.1	253	6	3	Dirty	No

Table 37 – Southampton Class 2 and Class 3 artefact analyses

(Hv_{0.2} and grain size measurements are averaged; %C is estimated)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 2											
31-1015	Hook	A slightly piled structure with heterogeneous bands of phosphoric/ferritic iron and carbon at the weld lines	136	131	126	0.2	n/a	6	3	Clean	No
31-1742	Nail	Heterogeneous phosphoric iron with areas of ferrite	146	106	n/a	n/a	n/a	6	6	Dirty	No
31-1899	Nail	Piled phosphoric iron with carburization of the shank	162	n/a	n/a	n/a	256	n/a	4	Dirty	No
31-1960	Nail	Heterogeneous phosphoric iron with areas of ferrite with grain boundary pearlite	188	141	126	0.1	n/a	7	7	Dirty	No
31-402	Nail	Phosphoric iron with slight carburization along the exterior	184	n/a	n/a	n/a	n/a	n/a	1	Clean	No
31-551	Nail	Folded heterogeneous phosphoric iron carbon with carbon in the fold along with areas of grain boundary pearlite	176	n/a	n/a	n/a	291	n/a	4	Clean	No
Class 3											
31-2110	Bar	Heterogeneous phosphoric iron with areas of ferrite and a small area of low carbon steel	141	102	154	0.1	n/a	6	5	Clean	No
31-814	Bar	Heavily ghosted phosphoric iron with some exterior carburization	186	n/a	n/a	n/a	206	n/a	3	Clean	No

**Table 38 – Class 1 alloy usage summary for the Southampton
assemblage**

*(Numbers are based on the number of artefacts in the category with the alloy present
and how much of the alloy was present)*

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ alloy	10	4	9	10	5
Whole object	0	0	0	0	0
More than 1/2 of the object	6	1	0	0	0
Up to 1/2 of the object	4	3	9	10	5

**Table 39 – Class 2 alloy usage summary for the Southampton
assemblage**

*(Numbers are based on the number of artefacts in the category with the alloy present
and how much of the alloy was present)*

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ alloy	6	3	3	2	0
Whole object	0	0	0	0	0
More than 1/2 of the object	5	0	0	0	0
Up to 1/2 of the object	1	3	3	2	0

**Table 40 – Class 3 alloy usage summary for the Southampton
assemblage**

*(Numbers are based on the number of artefacts in the category with the alloy present
and how much of the alloy was present)*

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ alloy	2	0	1	1	0
Whole object	0	0	0	0	0
More than 1/2 of the object	2	0	0	0	0
Up to 1/2 of the object	0	1	1	1	0

Table 41 – Phosphoric iron in Southampton

(Phosphorus content and Hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Description	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ave. ASTM)	P-iron ave. Hv _{0.2}
Class 1										
168-421	Knife	In the piled structure of the knife back	Inter-granular & Slag inclusion	3	Mean	0.4	Yes	Yes	4	146
					Low	0.31	No	Yes	4	131
					High	0.48	Yes	No	4	153
169-1858	Chisel	Half of the piled structure	Inter-granular & Slag inclusion; Compacted structure	3	Mean	0.34	Yes	No	6	261
					Low	0.25	Yes	No	6	176
169-2407	Knife	The knife back was mostly Heterogeneous	Slag inclusion	3	Mean	0.47	Yes	No	2	160
					Low	0.41	No	No	1	143
					High	0.51	Yes	No	5	159
169-540	Knife	The knife back	EE, Slag inclusion, Inter-granular & GB	3	Mean	0.38	Yes	No	3	155
					Low	0.34	Yes	No	4	146
					High	0.46	No	No	4	162
169-610	Knife	The knife back	Inter-granular & EE	2	Mean	0.45	Yes	No	4	133
					Low	0.32	Yes	No	4	126
					High	0.58	Yes	No	3	140
24-22	Axe	A large part of the piled structure	EE, Pearlite, & Inter-granular; Ripple-like	4	Mean	0.42	Yes	No	3	185
					Low	0.22	Yes	No	6	147
					High	0.67	No	No	1	210
31-1137	Needle	n/a	n/a	nd	Mean	nd	No	No	n/a	n/a

Table 41 (cont.) – Phosphoric iron in Southampton

(Phosphorus content and Hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Description	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ave. ASTM)	P-iron ave. Hv _{0.2}
Class 1 (cont.)										
31-669	Knife	Heterogeneously majority of the knife back	GB, Slag Inclusion, & EE; Widmanstätten	5	Mean	0.55	Yes	Yes	2	187
					Low	0.27	No	No	7	152
					High	0.83	Yes	No	1	224
31-92	Bill hook	Bands of the piled structure	Slag Inclusion	1	Mean	0.41	Yes	No	6	161
98-38	Knife	Heterogeneously majority of the knife back	Inter-granular	1	Mean	0.35	Yes	Yes	1	165
99-92	Knife	Most of the knife	GB, Slag Inclusion, & EE	5	Mean	0.37	Yes	Yes	3	163
					Low	0.17	Yes	No	3	156
					High	0.62	No	Yes	2	184
Class 2										
31-1015	Hook	Heterogeneously part of the structure	EE	3	Mean	0.17	Yes	Yes	3	136
					Low	0.16	No	No	5	123
					High	0.19	No	No	1	148
31-1742	Nail	Heterogeneously part of the structure	Inter-granular	3	Mean	0.32	Yes	No	6	146
					Low	0.18	No	No	6	126
					High	0.46	Yes	No	5	168
31-1899	Nail	The nail head and some of the shank	Slag inclusion, GB & Inter-granular	4	Mean	0.49	Yes	No	4	162
					Low	0.25	No	No	6	125
					High	0.86	No	No	3	199

Table 41 (cont.) – Phosphoric iron in Southampton

(Phosphorus content and Hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Description	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ave. ASTM)	P-iron ave. Hv _{0.2}
31-1960	Nail	Heterogeneously the majority of the structure	Inter-granular & Slag inclusion	2	Mean	0.26	Yes	No	7	188
					Low	0.23	Yes	No	7	186
					High	0.29	Yes	No	6	190
31-402	Nail	The majority of the structure	Pearlitic & Inter-granular	3	Mean	0.58	Yes	No	1	184
					Low	0.31	No	No	1	144
					High	0.78	No	No	2	228
31-551	Nail	Heterogeneously the majority of the structure	GB, Inter-granular & Slag inclusion; Allotriomorphs	4	Mean	0.62	Yes	Yes	4	176
					Low	0.35	Yes	No	6	155
					High	0.85	No	Yes	4	206
Class 3										
31-2110	Bar	Heterogeneously the majority of the structure	Inter-granular	3	Mean	0.36	Yes	No	5	141
					Low	0.21	Yes	No	6	157
					High	0.65	Yes	No	4	174
31-814	Bar	Heterogeneously the majority of the structure	GB, Pearlitic, Inter-granular & Slag inclusion; Allotriomorphs	4	Mean	0.64	Yes	No	3	186
					Low	0.32	Yes	No	4	165
					High	0.95	No	No	2	224

Table 42 – Summary of Indicators in the Southampton assemblage

Indicator	# of Artefacts
P-iron Ghosting	17
P-iron Large Grains	13
P-iron Etch Resistance	6
Average Hardness (Hv _{0.2})	169

Table 43 – Analysis of knife SOU98-38

(Hv# - The hardness test number corresponding the image above)

Hv #	Alloy Type	Vickers Hardness (Hv)	SEM Wt%P	SEM Wt%As	ASTM Grain Size	Notes
HV1	Tempered Martensite	546	0.3 ± 0.1	0.0	-	
HV2	Fine Pearlite	348	0.1 ± 0.1	0.1 ± 0.2	-	
HV3	Weld-line	226	0.1 ± 0.1	3.1 ± 0.2	-	
HV4	Phosphoric Iron + Pearlite 0.3%C	196	0.2 ± 0.1	0.4 ± 0.2	7	
HV5	Ferrite	140	0.1 ± 0.1	0.7 ± 0.2	4	Etch Resistant
HV6	Phosphoric Iron + Pearlite 0.2%C	149	0.2 ± 0.1	0.4 ± 0.2	7	
HV7	Phosphoric Iron	149	0.4 ± 0.1	0.2 ± 0.2	1	Ghosting

Table 44 – Results from McDonnell’s (1987b , 1987a) analysis of

Southampton artefacts

	Total # of Artefacts	% Heat Treated	% with P-iron	% Ghosted
Knives	14	64	36	7
Other Edged tools	4	50	50	0
Total	18	67	39	6

Table 45 – Phosphorus in steel in the Southampton assemblage

(Phosphorus content and hardness values averaged; nd = not detected; n/a = not applicable; ns = not significant (<0.15%P))

Artefact #	Description	Low Carbon Steel wt%P	Low Carbon Steel Hv _{0.2}	Low Carbon Steel %C	Placement of Low Carbon Steel	High Carbon Steel wt%P	High Carbon Steel Hv _{0.2}	High Carbon Steel %C	Placement of High Carbon Steel
Class 1									
168-421	Knife	0.21	150	0.1	The knife back	nd	n/a	n/a	n/a
169-2407	Knife	0.27	152	0.1	Carbon diffusion just below the butt weld	nd	n/a	n/a	n/a
169-540	Knife	0.3	195	0.3	Carbon diffusion just below the butt weld	nd	n/a	n/a	n/a
169-610	Knife	0.24	149	0.2	Present in the heterogeneous knife back	ns	n/a	n/a	n/a
24-22	Axe	0.33	169	0.2	Carbon diffusion from central band	ns	n/a	n/a	n/a
31-1137	Needle	0.14	208	0.1	Carburization of the exterior	nd	n/a	n/a	n/a
31-663	Knife	0.32	171	0.1	Part of the knife tip	ns	n/a	n/a	n/a
98-38	Knife	0.18	196	0.3	Carbon diffusion just below the butt weld	0.28	546	Tempered martensite	Knife tip
99-92	Knife	0.3	180	0.2	Carburization of one side of the exterior	nd	n/a	n/a	n/a

Table 45 (cont.) – Phosphorus in steel in the Southampton assemblage

(Phosphorus content and hardness values averaged; nd = not detected; n/a = not applicable; ns = not significant (<0.15%P))

Artefact #	Description	Low Carbon Steel wt%P	Low Carbon Steel Hv _{0.2}	Low Carbon Steel %C	Placement of Low Carbon Steel	High Carbon Steel wt%P	High Carbon Steel Hv _{0.2}	High Carbon Steel %C	Placement of High Carbon Steel
Class 2									
31-1899	Nail	0.45	270	0.1	Carburization of the exterior	ns	n/a	n/a	n/a
31-402	Nail	0.43	185	0.1	Carburization of one side of the exterior	nd	n/a	n/a	n/a
31-551	Nail	0.56	173	0.1	Heterogeneously in the structure	0.21	291	0.6	Heterogeneously in the structure
Class 3									
31-814	Bar	0.76	175	0.2	Heterogeneously in the structure	0.57	206	0.6	Heterogeneously in the structure

Table 46 – Manufacture summary for the Southampton artefacts

	# Total Artefacts	# Class 1 Artefacts	# Class 2 Artefacts	# Class 3 Artefacts
# Total Artefacts	19	11	6	2
Evidence of Cold Worked	1	1	0	0
Heat Treated	5	5	0	0
Carburized	6	3	1	2
Piled	4	2	2	0
Composite Construction	9	9	0	0
Single Alloy Construction	0	0	0	0
Heterogeneous	16	10	5	1
Clean	10	5	3	2

Table 47 – Average hardness for ferrite in Southampton classes

	Class 1	Class 2	Class 3
Ave. Hv _{0.2} Ferrite	172	165	163

**Table 48 – Alloy usage summary for class comparison for
Southampton**

(Numbers are based on the number of artefacts in the category)

	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
Class 1	10	4	9	10	5
Class 2	6	3	2	2	0
Class3	2	1	1	1	0
Total	18	8	12	13	5

Table 49 - Alloy usage summary of the Southampton artefacts

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ alloy	18	8	12	13	5
Whole object	1	0	0	0	0
More than 1/2 of the object	12	1	0	0	0
Up to 1/2 of the object	5	7	12	13	5

Table 50 - Cleanness of the artefacts from Southampton by class

	% Total Artefacts	% Class 1 Artefacts	% Class 2 Artefacts	% Class 3 Artefacts
Clean	53	45	50	100

Table 51 – Summary description of the iron artefacts from**Thetford**

Artefact #	Description	Period (centuries AD)	Context	Dimensions (mm)	# Sections Taken	Section Placement
Class 1						
241	Punch	5 th -7 th	Fill/Structure	35x12x10	1	A cross section
249	Awl	8 th -9 th	Fill/Pit/Oven	60x5x3	1	A cross section of one point
271	Knife	2 nd -3 rd	Fill/Pit	66x14x3	1	A cross section of the blade
286	Buckle	4 th -early 5 th	Fill/Ditch	29x27x3	1	A Cross section of belt loop
414	Belt Buckle	3 rd -4 th	Layer	41x31x9	1	A Cross section of the loop end
427	Knife	4 th -early 5 th	Fill/Ditch	50x13x6	1	A cross section of the blade
203-4	Chisel	5 th -7 th	Fill/Structure	33x13x10	1	A cross section of the chisel head
Class 2						
170	Loop pin	5 th -7 th	Fill/Structure	80x30x6	1	A cross section of the shank
176	Ferrule	8 th -9 th	Fill/Ditch	19x12x3	1	Across section
198	Rivet	5 th -7 th	Fill/Structure	64x20x3	1	A cross section of the strip
199	Joiners Dog	5 th -7 th	Fill/Structure	55x33x4	1	A cross section of one arm
237	Joiners Dog	8 th -9 th	Layer/Hill Wash	40x8x2	1	A cross section of one arm
248	Unknown Tool	8 th -9 th	Fill/Ditch	104x65x4	2	A cross section of one tong and a cross section of the stock
277a	Nail	8 th -9 th	Layer/Pit	107x38x11	1	A cross section of the shank
277b	Nail	8 th -9 th	Layer/Pit	60x27x9	1	A cross section of the shank
287	Nail	4 th -early 5 th	Fill/Ditch	53x13x5	1	A cross section of the shank
302	Nail	8 th -9 th	Layer	52x9x4	2	Cross sections of the head and shank
334	Nail	8 th -9 th	Fill/Pit	60x11x9	1	A cross section of the shank

**Table 51 (cont.) – Summary description of the iron artefacts from
Thetford**

Artefact #	Description	Period (centuries AD)	Context	Dimensions (mm)	# Sections Taken	Section Placement
Class 3						
209	Bar	8 th -9 th	Fill/Pit	37x7x5	2	Two cross sections
228	Bar	5 th -7 th	Fill/Structure/Metal Working Evidence	44x13x9	1	A cross section
UI						
210	Sheet Fragment	8 th -9 th	Fill/Ditch/Enclosure	25x13x3	1	A cross section
305	Strip	3 rd -4 th	Fill/Pit	61x8x3	1	A cross section
322	Tapering Strip	8 th -9 th	Layer	57x12x2	1	A cross section
203-5	Chisel Set Fragment	5 th -7 th	Fill/Structure	37x13x10	1	A cross section

Table 52 – Class 1 alloy usage summary of the Thetford assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	4	6	5	5	1
Whole Object	0	0	0	0	0
More than 1/2 Object	2	1	1	1	1
Up to 1/2 Object	2	5	4	4	0

Table 53 – Class 1 artefact analysis from the Thetford assemblage

(Hv_{0.2} and grain size measurements are averaged; %C is estimate)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 1											
241	Punch	Heterogeneous mix containing an area of pearlite with carbon diffusing outward into a low carbon steel/ferrite	n/a	99	122	3	189	7	n/a	Clean	No
249	Awl	A small piece of high carbon steel welded to several pieces of low carbon steel that are the result of large amounts of carbon diffusion and some carburization of the exterior	n/a	n/a	159	2	241	n/a	n/a	Clean	No
271	Knife	A reverse Type 1 or Type 3 with a ghosted ferritic/phosphoric central band sandwiched between piled low carbon/bainitic steel bands	124	143	163	1	280	5	4	Clean	Yes
286	Buckle	A ferritic bar with significant carburization at one corner and side	n/a	109	157	2	211	4	n/a	Clean	No
414	Buckle	Mostly heterogeneous phosphoric iron with small areas to ferrite with moderate ghosting	141	160	n/a	n/a	n/a	5	6	Dirty	No
427	Knife	A Type 2 with a phosphoric tip welded to two other heterogeneous pieces of heavily ghosted phosphoric iron with small amounts of ferrite and carbon at the weld lines	154	174	n/a	n/a	n/a	5	4	Dirty	No
203-4	Chisel	A Type 1 or Type 3 with a central HC steel band sandwiched between piled ferritic/phosphoric bands with some carbon diffusion	121	125	160	2.0	178	6	6	Clean	No

Table 54 – Class 2 artefact analysis from the Thetford assemblage

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 2											
170	Loop Pin	A banded structure with a central band of large grained ferrite sandwiched between two bands of small grained ferrite with minor grain boundary pearlite	n/a	93	104	1	n/a	6	n/a	Clean	No
176	Ferrule	A phosphoric/ferritic ring with a low carbon steel band welded to the exterior and slight carbon diffusion	174	180	164	2	n/a	6	4	Dirty	No
198	Rivet	Heterogeneous mix of phosphoric iron and ferrite with a small area of low carbon steel at one end	192	138	153	1	n/a	7	4	Dirty	No
199	Joiner's Dog	Mostly low carbon steel with small areas of high carbon steel	n/a	n/a	193	3	176	n/a	n/a	Clean	No
237	Joiner's Dog	Mostly ferritic with a small corner area of phosphoric iron	162	134	n/a	n/a	n/a	6	4	Dirty	No
248	Unknown Tool	The arm was phosphoric iron with an area of ferrite with strings of inclusions; the stock is a naturally -banded structure of HC steel and phosphoric with a corner of ferrite welded on	156	163	n/a	n/a	204	6	6	Clean	No

Table 54 (cont.) – Class 2 artefact analysis from the Thetford assemblage

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 2 (cont.)											
277a	Nail	Phosphoric iron with a little carbon in the folds	159	n/a	165	2	126	n/a	5	Dirty	No
277b	Nail	Heterogeneous structure that is mostly phosphoric iron with areas of pearlite	161	n/a	n/a	n/a	n/a	n/a	6	Clean	No
287	Nail	A heterogeneous hyper eutectic steel with ferrite along one edge and large etch resistant area in the HC steel	n/a	n/a	189	1	221	n/a	n/a	Clean	No
302	Nail	A ferritic structure with some carburization along the exterior of the shank	n/a	108	n/a	n/a	213	6	n/a	Clean	No
334	Nail	A band of clean ferrite sandwiched between two bands of dirty ferrite/phosphoric iron	116	124	n/a	n/a	n/a	8	7	Dirty	No

Table 55 – Class 2 alloy usage summary of the Thetford assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	7	7	6	5	0
Whole Object	0	1	0	0	0
More than 1/2 of the Object	4	3	1	1	0
Up to 1/2 of the Object	3	3	5	4	0

Table 56 – Class 3 alloy usage summary of the Thetford assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	1	1	1	1	0
Whole Object	0	1	0	0	0
More than 1/2 of the Object	0	0	0	0	0
Up to 1/2 of the Object	1	0	1	1	0

Table 57 – UI alloy usage summary of the Thetford assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	2	3	3	3	0
Whole Object	0	0	0	0	0
More than ½ of the Object	0	2	1	0	0
Up to 1/2 of the Object	2	1	2	3	0

Table 58 – Class 3 and UI artefact analysis for the Thetford assemblage

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 3											
209	Bar	Completely ferritic iron	n/a	101	n/a	n/a	n/a	4	n/a	Clean	No
228	Bar	Piled structure with layers of phosphoric iron, low and high carbon steel	178	n/a	131	3	138	n/a	2	Dirty	No
UI											
210	Sheet Fragment	A piled ferritic structure with some low carbon bands	n/a	126	132	2	n/a	6	n/a	Clean	No
305	Strip	Heavily cold worked three ferritic bands welded together with one heavily corroded edge of HC steel; Neumann bands present	n/a	205	n/a	n/a	276	5	n/a	Clean	No
322	Tapering Strip	An interior band phosphoric iron completely encased by LC and HC steel	171	152	148	4	205	5	6	Clean	No
203-5	Chisel Set Fragment	A heterogeneous structure with areas of phosphoric iron, large areas of low carbon steel and high carbon steel in folds and carburized exterior	139	n/a	107	2	184	n/a	6	Dirty	No

Table 59 – Phosphoric analyses iron for the Thetford assemblage

(Phosphorus content and Hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Description	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ASTM)	P-iron ave. Hv _{0.2}
Class 1										
241	Punch	n/a	n/a	nd	none	n/a	No	Yes	n/a	n/a
249	Awl	n/a	n/a	nd	none	n/a	No	No	n/a	n/a
271	Knife	Central band of a reverse type 1 knife	n/a	1	Mean	0.16	No	No	4	124
286	Buckle	n/a	n/a	nd	none	n/a	No	No	n/a	n/a
414	Belt Buckle	Almost All	Slag inclusion, GB & Inter-granular; Ripple-like	5	Mean	0.3	Yes	Yes	6	141
					Low	0.18	No	Yes	4	127
					High	0.45	Yes	No	6	157
427	Knife	Almost All	GB & Inter-granular; Widmanstätten	4	Mean	0.35	Yes	No	4	154
					Low	0.2	Yes	No	6	150
					High	0.6	No	No	2	176
203-4	Chisel	Piled phosphoric/ferritic bands in a type 1	n/a	1	Mean	0.17	No	Yes	6	121
Class 2										
170	Loop pin	n/a	n/a	nd	none	n/a	No	No	n/a	n/a
176	Ferrule	The interior band	EE, GB & Slag inclusion	6	Mean	0.59	Yes	Yes	4	174
					Low	0.35	No	No	5	160
					High	1.22	No	No	3	187
198	Rivet	Heterogeneously mixed in	GB & Slag inclusion	4	Mean	0.61	Yes	Yes	4	192
					Low	0.36	Yes	No	5	166
					High	0.8	No	Yes	2	218

Table 59 (cont.) – Phosphoric analyses iron for the Thetford assemblage

(Phosphorus content and Hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Description	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ASTM)	P-iron ave. Hv _{0.2}
Class 2 (cont.)										
199	Joiner's Dog	n/a	n/a	nd	none	n/a	No	No	n/a	n/a
237	Joiner's Dog	Small corner area	Slag inclusion	1	Mean	0.29	Yes	Yes	4	162
248	Unknown Tool	Most of the structure	GB, EE & Slag inclusion	5	Mean	0.37	Yes	Yes	6	156
					Low	0.25	No	No	6	131
					High	0.56	Yes	No	6	141
277A	Nail	All	GB & Slag inclusion	5	Mean	0.41	Yes	Yes	6	161
					Low	0.3	Yes	No	8	165
					High	0.46	No	Yes	4	166
277B	Nail	Heterogeneously mixed in	Inter-granular, Slag inclusion & GB	6	Mean	0.41	Yes	Yes	5	160
					Low	0.18	Yes	No	6	140
					High	0.88	No	Yes	2	213
287	Nail	n/a	n/a	nd	none	n/a	No	No	n/a	n/a
302	Nail	n/a	n/a	nd	none	n/a	No	No	n/a	n/a
334	Nail	A corner area in the shank	n/a	1	Mean	0.35	No	No	7	116
Class 3										
209	Bar	n/a	n/a	nd	none	n/a	No	No	n/a	n/a
228	Bar	Layers mixed in the banded structure	GB & Slag inclusion; Widmanstätten	3	Mean	0.46	Yes	Yes	2	178
					Low	0.25	No	No	5	154
					High	0.63	Yes	No	1	154

Table 59 (cont.) – Phosphoric analyses iron for the Thetford assemblage

(Phosphorus content and Hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Description	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ASTM)	P-iron ave. Hv _{0.2}
UI										
210	Sheet Fragment	n/a	n/a	nd	none	n/a	No	No	n/a	n/a
305	Strip	n/a	n/a	nd	none	n/a	No	No	n/a	n/a
322	Tapering Strip	The interior band	EE & Slag inclusion	3	Mean	0.46	Yes	Yes	6	171
					Low	0.35	Yes	No	8	184
					High	0.62	No	Yes	4	169
203-5	Chisel Set	Small heterogeneous areas	Slag inclusion & Inter-granular	5	Mean	0.36	Yes	No	6	139
					Low	0.25	Yes	No	5	169
					High	0.44	No	No	5	127

Table 60 – Phosphorus in steel at Thetford

(Phosphorus content and hardness values averaged; nd = not detected; n/a = not applicable; ns = not significant (<0.15%P))

Artefact #	Description	Low Carbon Steel wt%P	Low Carbon Steel Hv _{0.2}	Low Carbon Steel %C	Placement of Low Carbon Steel	High Carbon Steel wt%P	High Carbon Steel Hv _{0.2}	High Carbon Steel %C	Placement of High Carbon Steel
Class 1									
271	Knife	ns	n/a	n/a	n/a	0.16, 0.21	328, 243	0.7, 0.7	The pearlite and bainite side bands
203-4	Chisel	ns	n/a	n/a	n/a	0.18	151	0.4	Carbon diffusion in ferritic side band
Class 2									
198	Rivet	0.17	153	0.1	Small area at one end of strip	nd	n/a	n/a	n/a
248	Unknown Tool	nd	n/a	n/a	n/a	0.41	223	0.4	Heterogeneously in the shank of the tool
277	Nail	0.62	182	0.1	Heterogeneous area in structure	nd	n/a	n/a	n/a
Class 3									
228	Bar	0.19	124	0.1	A corner of the bar section	ns	n/a	n/a	n/a
UI									
322	Tapering Strip	0.23	176	0.3	The exterior band	nd	n/a	n/a	n/a
203-5	Chisel Set Fragment	nd	n/a	n/a	n/a	0.15	120	0.5	In a carbon rich fold

Table 61 – Phosphoric iron indicators in the Thetford assemblage

	# of Artefacts
P-iron Ghosting	11
P-iron Large Grains	5
P-iron Etch Resistance	10
Average Hv _{0.2}	153

Table 62 – Manufacture summary for the Thetford artefacts

	# Total Artefacts	# Class 1 Artefacts	# Class 2 Artefacts	# Class 3 Artefacts	UI
# Total Artefacts	23	7	10	2	4
Evidence of Cold Working	2	0	1	0	1
Heat Treated	1	1	0	0	0
Carburized	5	3	1	0	1
Piled	4	2	0	1	1
Composite Construction	6	4	1	0	1
Single Alloy Construction	1	0	0	1	0
Heterogeneous	14	4	8	0	2
Clean	16	5	6	1	3

Table 63 – Average hardness for ferrite in the Thetford classes

	Class 1	Class 2	Class 3	UI
Ave. Hv _{0.2} Ferrite	135	134	101	161

Table 64 – Thetford alloy usage based on class

(Numbers are based on the number of artefacts in the category)

	Total # Artefacts	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
Class 1	8	4	6	5	5	1
Class 2	11	7	7	7	4	0
Class 3	2	1	1	1	1	0
UI	4	2	3	3	3	0
Total	24	14	17	16	14	1

Table 65 - Alloy usage summary for the Thetford assemblage

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	14	17	16	14	1
Whole Section	0	2	0	0	0
More than 1/2 of the Section	6	6	3	2	1
Up to 1/2 of the Section	8	9	13	12	0

Table 66 - Cleanness of the artefacts from Thetford by class

	# Total Artefacts	% Class 1 Artefacts	% Class 2 Artefacts	% Class 3 Artefacts	% UI Artefacts
Clean	70	71	60	50	75

Table 67 - Summary of the iron artefacts from Wharram Percy

(n/a = not applicable)

Artefact #	Description	Period (centuries AD)	Context	Dimensions (mm)	Weight (g)	# Sections Taken	Section Placement
Class 1							
134	Knife	7 th -8 th	44/139	65x14	n/a	1	Cross section of blade
159	Knife	7 th -8 th	85/29/4 Surface in a domestic zone	72x12	n/a	2	Cross-sections of cutting edge and back
176	Knife	7 th -8 th	85/29/6 Surface in a domestic zone	73x11	n/a	2	Cross-sections of cutting edge and back
237	Knife	7 th -8 th	85/104	144x15	n/a	1	Cross section of blade
307	Knife	7 th -8 th	85/148	73x12	n/a	2	Cross-sections of cutting edge and back
308	Knife	7 th -8 th	85/104/6	62x13	n/a	1	Cross section of blade
442	Knife	7 th -8 th	59/40/8 Surface in a domestic zone	67x14	n/a	2	Cross-sections of cutting edge and back
472	Knife	7 th -8 th	59/127/22 Smithy ditch fill	90x14	n/a	2	Cross-sections of cutting edge and back
Class 2							
160	Nail	7 th -8 th	85/29/11 Surface in a domestic zone	35x13x12	5	2	Cross sections of head and shank
218	Nail	7 th -8 th	85/72/17	27x15x10	4		Cross sections of head and tip
219	Nail	7 th -8 th	81/17/14	63x12x6	12	1	Cross section of upper shank
387	Nail	7 th -8 th	76/50/5	39x18x14	8	1	Cross section of head
394	Nail	7 th -8 th	76/68/24	36x11x16	6	2	Cross sections of head and shank
398	Nail	7 th -8 th	44/117	33x11x4	3	1	Cross section of head
430	Nail	7 th -8 th	59/74/16	82x6x4	5	1	Cross section of upper shank
532	Nail	7 th -8 th	81/119/3	22x8x6	4	1	Cross section of lower shank
550	Nail	7 th -8 th	76/28/3	29x11x4	3	1	Cross section of upper shank
556	Nail	7 th -8 th	76/68/24	20x19x13	3	1	Cross section of upper shank

Table 67 (cont.) – Summary of the iron artefacts from Wharram Percy

(n/a = not applicable)

Artefact #	Description	Period (centuries AD)	Context	Dimensions (mm)	Weight (g)	# Sections Taken	Section Placement
Class 3							
95	Bar	7 th -8 th	44/1	72x5x5	n/a	1	Cross section
115	Bar	7 th -8 th	44/9	51x1x0.9	n/a	1	Cross section
120	Bar	7 th -8 th	44/30	28x6x1	n/a	1	Cross section
260	Bar/Strip	7 th -8 th	81/109/19	49x5x3	n/a	1	Cross section
299	Bar/Strip	7 th -8 th	59/19/22	89x6x3	n/a	1	Cross section
320	Bar	7 th -8 th	59/10/21	158x2x1	n/a	1	Cross section
364	Bar	7 th -8 th	59/127/22	94x6x4	n/a	1	Cross section
369	Bar	7 th -8 th	81/111/19	80x4x4	n/a	1	Cross section
547	Bar	7 th -8 th	76/16/7	62x9x3	n/a	1	Cross section

Table 68 – Class 1 artefact analysis for Wharram Percy

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	P-iron Grain Size (ASTM)	Ferrite Grain Size (ASTM)	Clean?	Heat Treated
Class 1											
134	Knife	A Type 3 with bands of phosphoric iron and low carbon steel	183	n/a	n/a	n/a	n/a	5	n/a	Clean	No
159	Knife	A Type 2 with a tempered martensite tip containing several scarf welds and a phosphoric iron back also banded with scarf weld	161	n/a	n/a	n/a	473	4	n/a	Clean	Yes
176	Knife	A Type 2 low carbon steel worn cutting edge with a phosphoric iron heavily ghosted back	177	106	n/a	n/a	n/a	2	6	Clean	No
237	Knife	A Type 2 with a high carbon tip and a piled ferritic back	n/a	100	n/a	n/a	152	n/a	5	Clean	No
307	Knife	A Type 0/2 heterogeneous knife with mostly phosphoric and ferritic iron and small areas of low carbon steel	159	154	n/a	n/a	n/a	6	8	Clean	No
308	Knife	A Type 2 heavily worn high carbon steel tip and with slight carbon diffusion into a ferritic back	n/a	181	208	0.3	225	n/a	3	Clean	No
442	Knife	A Type 1/3 with a thin central 0.4%C steel band and bands of piled phosphoric iron on either side	142	n/a	182	0.3	n/a	3	n/a	Dirty	No
472	Knife	A Type 2 with a high carbon tip welded to a phosphoric iron back	185	n/a	137	0.3	323	4	n/a	Dirty	No

Table 69 – Class 2 artefact analysis for Wharram Percy

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	P-iron Grain Size (ASTM)	Ferrite Grain Size (ASTM)	Clean?	Heat Treated
Class 2											
160	Nail	Completely phosphoric iron and heavily ghosted	202	n/a	n/a	n/a	n/a	3	n/a	Clean	No
218	Nail	Completely phosphoric iron and heavily ghosted	224	n/a	n/a	n/a	n/a	5	n/a	Clean	No
219	Nail	Phosphoric iron with a small area of ferrite and a greater concentration of inclusions	168	86	n/a	n/a	n/a	1	6	Dirty	No
287	Nail	Completely ferritic iron	n/a	141	n/a	n/a	n/a	n/a	7	Dirty	No
394	Nail	A heterogeneous structure with areas of phosphoric iron and pearlite	155	n/a	125	0.3	141	3	n/a	Clean	No
398	Nail	A heterogeneous structure of low carbon steel with areas of ferrite	n/a	130	157	0.2	n/a	n/a	7	Clean	No
430	Nail	Ferrite with a small area with grain boundary pearlite	n/a	115	134	0.1	n/a	n/a	7	Clean	No
532	Nail	A completely ferritic iron	n/a	97	n/a	n/a	n/a	n/a	5	Clean	No
550	Nail	A heterogeneous structure mostly phosphoric iron with areas of pearlite	177	n/a	134	0.2	175	n/a	n/a	Dirty	No
556	Nail	Completely phosphoric iron and heavily ghosted with slight carburization along one edge of the shank	177	n/a	n/a	n/a	n/a	4	n/a	Dirty	No

Table 70 – Class 3 artefact analysis for Wharram Percy

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	P-iron Grain Size (ASTM)	Ferrite Grain Size (ASTM)	Clean?	Heat Treated
Class 3											
95	Bar	Completely phosphoric iron and heavily ghosted	166	n/a	n/a	n/a	n/a	3	n/a	Clean	No
115	Bar	Mostly phosphoric iron with a small carburized corner of low carbon steel	131	n/a	n/a	n/a	n/a	2	n/a	Dirty	No
120	Bar	A central band of ferrite/low carbon steel sandwiched between bands of phosphoric iron	177	158	209	0.2	n/a	5	8	Dirty	No
260	Bar	A heterogeneous structure of phosphoric iron, ferrite and low carbon steel	140	127	104	0.1	n/a	5	6	Dirty	No
299	Bar	Mostly ferritic with carburization along 2 edges	n/a	118	157	0.1	207	n/a	5	Dirty	No
320	Bar	Completely phosphoric iron and heavily ghosted	205	n/a	n/a	n/a	n/a	6	n/a	Dirty	No
364	Bar	A heterogeneous structure of ferrite/low carbon steel	n/a	90	130	0.2	n/a	n/a	6	Clean	No
369	Bar	A small area of high carbon steel diffusing into the almost homogenous low-carbon steel that comprises the rest of the section	n/a	n/a	n/a	n/a	273	n/a	n/a	Clean	No
547	Bar	A naturally banded mostly phosphoric/ferritic structure with carbon at the weld lines	145	127	125	0.1	n/a	6	7	Dirty	No

Table 71 – Class 1 alloy usage for the Wharram Percy assemblage

(Numbers are based on the number of artefacts with that particular amount of the alloy present)

Composition of Artefact	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	6	4	3	4	1
Whole Object	0	0	0	0	0
More than 1/2 of the Object	4	2	0	0	0
Up to 1/2 of the Object	2	2	3	4	1

Table 72 – Class 2 alloy usage for the Wharram Percy assemblage

(Numbers are based on the number of artefacts with that particular amount of the alloy present)

Composition of Artefact	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	6	5	4	2	0
Whole Object	2	2	0	0	0
More than ½ of the Object	3	1	1	0	0
Up to 1/2 of the Object	1	2	3	2	0

Table 73 – Class 3 alloy usage for the Wharram Percy assemblage

(Numbers are based on the number of artefacts with that particular amount of the alloy present)

Composition of Artefact	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	6	5	7	2	0
Whole Object	2	0	0	0	0
More than ½ of the Object	2	2	2	0	0
Up to 1/2 of the Object	2	3	5	2	0

Table 74 – Phosphoric iron analyses from the Wharram Percy assemblage

(Phosphorus content and hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Description	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ASTM)	P-iron ave. Hv _{0.2}
Class 1										
134	Knife	The main component, but with carburized areas	n/a	2	Mean	0.43	No	No	5	183
					Low	0.3	No	No	6	165
					High	0.57	No	No	3	202
159	Knife	Part of the knife back	GB & Ghosted grains; Needle like	5	Mean	0.34	Yes	No	4	161
					Low	0.2	Yes	No	6	143
					High	0.67	No	No	2	181
176	Knife	All but cutting edge	Inter-granular, Slag inclusion & Edge Effects	4	Mean	0.56	Yes	Yes	2	177
					Low	0.37	Yes	Yes	2	159
					High	0.72	No	No	1	184
237	Knife	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
307	Knife	Heterogeneously in the structure	Slag inclusions & Inter-granular; Ripple-like	4	Mean	0.3	Yes	No	6	159
					Low	0.17	No	No	7	124
					High	0.45	Yes	No	4	184
308	Knife	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
442	Knife	Piled on either side of a central HC steel band	n/a	3	Mean	0.26	No	No	3	142
					Low	0.18	No	No	2	135
					High	0.3	No	No	3	147
472	Knife	The knife back	Inter-granular, Slag inclusion & Edge effects	5	Mean	0.55	Yes	No	4	185
					Low	0.35	No	No	5	166
					High	0.74	Yes	No	2	192

Table 74 (cont.) – Phosphoric iron analyses from the Wharram Percy assemblage

(Phosphorus content and hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Description	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ASTM)	P-iron ave. Hv _{0.2}
Class 2										
160	Nail	All	GB, Slag inclusion, & Inter-granular, Needle-like	7	Mean	0.65	Yes	Yes	3	202
					Low	0.53	Yes	No	4	169
					High	0.82	No	No	1	209
218	Nail	All	Inter-granular & Slag inclusion; Widmanstätten like	7	Mean	0.27	Yes	Yes	5	224
					Low	0.23	Yes	Yes	3	219
					High	0.31	Yes	No	7	151
219	Nail	All	Slag inclusions & Inter-granular; Ripple-like	5	Mean	0.65	Yes	No	1	168
					Low	0.41	Yes	No	1	141
					High	0.83	No	No	1	187
287	Nail	nd	n/a	nd	Mean	nd	No	Yes	n/a	n/a
394	Nail	Heterogeneously in the structure	Inter-granular & Pearlite; Ripple-like	6	Mean	0.4	Yes	Yes	3	155
					Low	0.2	No	No	5	120
					High	0.57	No	No	1	186
398	Nail	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
430	Nail	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
532	Nail	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
550	Nail	Heterogeneously a large part of the structure	Slag inclusion & Inter-granular; Ripple-like	5	Mean	0.5	Yes	No	n/a	177
					Low	0.15	Yes	No	n/a	133
					High	0.84	Yes	No	n/a	196
556	Nail	All	Inter-granular & Slag inclusion; Needle & Widmanstätten-like	8	Mean	0.49	Yes	No	4	177
					Low	0.45	No	No	1	163
					High	0.55	Yes	No	nd	196

Table 74 (cont.) – Phosphoric iron analyses from the Wharram Percy assemblage

(Phosphorus content and hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Description	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ASTM)	P-iron ave. Hv _{0.2}
Class 3										
95	Bar	All	GB & Inter-granular; Ripple-like	6	Mean	0.4	Yes	Yes	3	166
					Low	0.26	Yes	No	2	160
					High	0.61	No	No	1	211
115	Bar	All	Slag-inclusion & inter-granular; Ripple-like	3	Mean	0.4	Yes	No	2	131
					Low	0.37	Yes	No	4	129
					High	0.42	No	No	1	131
120	Bar	3/4s of the structure; Possibly heterogeneously	Slag-inclusion & GB	6	Mean	0.52	Yes	Yes	5	177
					Low	0.3	Yes	No	6	177
					High	0.81	No	Yes	5	176
260	Bar	Heterogeneously in the structure	Inter-granular; Ripple-like	2	Mean	0.22	Yes	No	5	140
					Low	0.17	No	No	6	130
					High	0.26	Yes	No	3	149
299	Bar	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
320	Bar	All	Slag inclusion & Inter-granular	3	Mean	0.65	Yes	Yes	6	205
					Low	0.54	Yes	No	6	182
					High	0.8	No	Yes	7	224
354	Bar	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
369	Bar	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
547	Bar	In heterogeneous bands that comprise the structure	n/a	2	Mean	0.25	No	Yes	6	145
					Low	0.21	No	No	6	136
					High	0.29	No	No	6	154

Table 75 - Phosphorus in steel in the Wharram Percy assemblage

(Phosphorus content and hardness values averaged; nd = not detected; n/a = not applicable)

Artefact #	Description	Low Carbon Steel wt%P	Low Carbon Steel Hv _{0.2}	Low Carbon Steel %C	Placement of Low Carbon Steel	High Carbon Steel wt%P	High Carbon Steel Hv _{0.2}	High Carbon Steel %C	Placement of High Carbon Steel
Class 1									
134	Knife	0.62	208	0.3	Knife back	nd	n/a	n/a	n/a
159	Knife	nd	n/a	n/a	n/a	0.21	370	Tempered Martensite	Knife tip
308	Knife	0.23	180	0.2	Carbon diffusion on back next to weld line	nd	n/a	n/a	n/a
Class 2									
398	Nail	0.16	184	0.2	Top of nail head	nd	n/a	n/a	n/a
550	Nail	0.29	152	0.1	Centre of heterogeneous structure	0.2	175	0.4	Centre of heterogeneous structure
556	Nail	nd	n/a	n/a	n/a	0.48	208	0.4	Carburized side of shank
Class 3									
115	Bar	0.56, 0.42	151, 157	0.1	Corner of the bar	nd	n/a	n/a	n/a
260	Bar	0.16	113	0.2	Heterogeneously in the structure	nd	n/a	n/a	n/a
369	Bar	0.41, 0.20	195, 184	0.2, 0.3	Centre of bar section	0.22, 0.32	266, 283	0.6	On outer edge of cross section
547	Bar	0.24	143	0.2	Edge of bar section	nd	n/a	n/a	n/a

**Table 76 – Phosphoric iron indicators in the Wharram Percy
assemblage**

	# of Artefacts
P-iron Ghosting	15
P-iron Large Grains	13
P-iron Etch Resistance	9
Average Hv _{0.2}	171

Table 77 – Analysis of nail WP218

(Hv # - The hardness test number corresponding to the image above)

Hv #	Alloy Type	Vickers Hardness (Hv _{0.2})	SEM Wt%P	SEM Wt%As	ASTM Grain Size	Notes
Hv1	Phosphoric Iron	151	0.3 ± 0.1	0.4 ± 0.2	7	Ghosting
Hv2	Phosphoric Iron	155	0.2 ± 0.1	0.6 ± 0.2	4	Etch Resistant
Hv3	Phosphoric Iron	230	0.3 ± 0.1	0.4 ± 0.2	5	Ghosting + Etch Resistant
Hv4	Phosphoric Iron	219	0.2 ± 0.1	0.3 ± 0.2	3	Ghosting + Etch Resistant
Hv5	Phosphoric Iron	258	0.3 ± 0.1	0.8 ± 0.2	5 elongated	Ghosting + Etch Resistant
Hv6	Phosphoric Iron	292	0.2 ± 0.1	0.6 ± 0.2	6 elongated	Ghosting + Etch Resistant
Hv7	Phosphoric Iron	262	0.2 ± 0.1	0.6 ± 0.2	6	

**Table 78 – Manufacture summary for the Wharram Percy
artefacts**

	# Total Artefacts	# Class 1 Artefacts	# Class 2 Artefacts	# Class 3 Artefacts
# Total Artefacts	27	8	10	9
Evidence of Cold Working	2	0	2	0
Heat Treated	1	1	0	0
Carburized	5	1	2	2
Piled	2	2	0	0
Composite Construction	7	7	0	0
Single Alloy Construction	6	0	4	2
Heterogeneous	11	2	4	5
Clean	17	6	7	4

Table 79 – Average hardness for ferrite in the Wharram Percy classes

	Class 1	Class 2	Class 3
Ave. Hv _{0.2} Ferrite	168	184	161

Table 80 – Wharram Percy alloy usage based on class

(Numbers are based on the number of artefacts in the category)

Class	Total # Artefacts	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
Class 1	8	6	4	3	4	1
Class 2	10	6	5	4	2	0
Class 3	9	6	5	7	2	0
Total	27	18	14	14	8	1

Table 81 – Alloy usage summary for the Wharram Percy assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

Composition of Artefact	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	18	14	14	8	1
Whole Object	4	2	0	0	0
More than ½ of the Object	9	5	3	0	0
Up to ½ of the Object	5	7	11	8	1

Table 82 – Cleanness of the artefacts from Wharram Percy by class

	# Total Artefacts	% Class 1 Artefacts	% Class 2 Artefacts	% Class 3 Artefacts
Clean	27	75	70	44

Table 83 – Summary of the iron artefacts from Winchester

(Measurements and dates from Rulton (2003))

Artefact #	Artefact Type	Period (centuries AD)	Class	Context	Dimensions (mm)	# Sections	Placement
NR 8	Knife	9 th -11 th	1	Pit	146 x 18	2	The back and cutting edge
SXS 93	Knife	9 th -11 th	1	Pit	108 x 16	2	The back and cutting edge
BRI 4154	Knife	9 th -11 th	1	n/a	144 x 16	1	A complete cross-section
VR 8580	Knife	11 th -12 th	1	Pit	202 x 20	1	A small piece of the back section

Table 84 – Manufacture summary for the Winchester artefacts

	# Total Artefacts
# Total Artefacts	4
Evidence of Cold Working	1
Heat Treated	1
Carburized	0
Piled	0
Composite Construction	3
Single Alloy Construction	0
Heterogeneous	2
Clean	3

Table 85 – Class 1 alloy usage for the Winchester assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	3	2	3	4	1
Whole Object	0	0	0	0	0
More than 1/2 Object	0	1	0	0	0
Up to 1/2 Object	3	1	3	4	1

Table 86 – Phosphoric iron in the Winchester assemblage

(n/a =not applicable; nd = not detected)

Artefact #	Artefact Type	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting ?	Etch Resistance ?	Grain Size (ave. ASTM)	P-iron ave. Hv _{0.2}
NR 8	Knife	nd	nd	nd	Mean	nd	No	No	3	n/a
SXS 93	Knife	Bands either side of Central steel band	Slag inclusion and intra granular	6	Mean	0.39	Yes	Yes	4	166
					Low	0.18	Yes	No	1	150
					High	0.50	No	Yes	3	171
					Mean	0.41	Yes	No	6	169
BRI 4154	Knife	Alternating bands	Slag inclusion, intra granular, and grain boundary	5	Low	0.31	Yes	No	5	190
					High	0.48	No	No	5	154
VR 8580	Knife	The edge of one band	n/a	1	Mean	0.19	No	No	7	123

Table 87 -Class 1 artefact analysis for the Winchester assemblage

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Artefact Type	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	P-iron Grain Size (ASTM)	Ferrite Grain Size (ASTM)	Clean?	Heat Treated
NR 8	Knife	Type 2 knife with a large grained ferritic back welded to martensite cutting edge with carbon diffusion across the weld-line. Also Neumann bands can be seen in the knife back.	n/a	130	187	0.1	520	3	3	Clean	Yes
SXS 93	Knife	Type 1 knife with pearlite sandwiched between bands of ferrite and phosphoric iron	166	204	112	0.1	395	4	3	Dirty	No
BRI 4154	Knife	Pattern welded with a series of transverse phosphoric iron and HC steel bands with a HC steel tip	169	n/a	n/a	n/a	329	6	n/a	Clean	No
VR 8580	Knife	Heavily corroded only back survived consisting of bands of ferrite and pearlite	123	n/a	165	0.3	372	7	n/a	Clean	No

**Table 88 – Phosphorus in the steel from the Winchester
assemblage**

(Measurements are from individual test sites with estimated carbon content)

Artefact #	Description	High Carbon Steel wt%P	High Carbon Steel Hv_{0.2}	High Carbon Steel %C	Placement
NR 8	Knife	0.16	244	0.5	In carbon diffusion near weld line
VR 8580	Knife	0.29	215	0.6	At edge of steel band

Table 89 – Summary of the iron artefacts from Worcester

Artefact #	Description	Period (centuries AD)	Context	Dimensions (mm)	Weight (g)	# Sections Taken	Section Placement
Class 1							
(16692) 5657	Hook Tag	9 th -11 th	Soil accumulation; Pasture	28x17x2	2	1	Cross section of hook
(17274) 6302	Key Bit	9 th -11 th	Ground surface	20x28x9	84	1	Cross section of the key
(17300) 6411	Padlock	9 th -11 th	Dump; Intrusive in earlier period	87x25x24	73	1	Sliver taken from outer casing
16758	Pick Head	9 th -11 th	Secondary fill of pit	129x20x15	101	2	Cross section of head and longitudinal of one point
17106	Knife	9 th -11 th	Secondary rubbish fill of pit	96x14x4	8	1	Cross section of blade
(17304) 6489	Knife Tang	9 th -11 th	Arbitrary layer; Intrusive fill in early period	87x11x2	4	1	Cross section of knife tang
Class 2							
(16692) 5609	Nail	9 th -11 th	Arbitrary layer; Intrusive fill in early period	19x3x2	1	1	Cross section of shank
(16692) 5620	Nail	9 th -11 th	Arbitrary layer; Intrusive fill in early period	unknown	20	1	Cross sections of head and shank
(16692) 5646	Nail	9 th -11 th	Arbitrary layer; Intrusive fill in early period	65x9x7	11	1	Cross section of the shank
(17289) 6319	Nail	9 th -11 th	Arbitrary layer; Intrusive fill in early period	45x3x2	4	1	Cross section of the shank
(17300) 6477	Nail	9 th -11 th	Dump; Intrusive in earlier period	25x4x3	1	1	Cross section of the shank
Class 3							
(17289) 6317	Strip Fragment	9 th -11 th	Trampled soil accumulation	47x8x4	6	1	Cross section

Table 90 – Class 1 artefact analysis for the Worcester assemblage

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 1											
(16692) 5657	Hook Tag	A natural slightly banded structure with phosphoric large grain bands and ferritic smaller grain bands	178	106	n/a	n/a	n/a	6	5	Clean	No
(17274) 6302	Padlock Key	Entirely composed of low carbon steel	n/a	n/a	205	0.2	n/a	8	n/a	Clean	No
(17300) 6411	Padlock	Completely ferritic iron	n/a	131	n/a	n/a	n/a	4	n/a	Clean	No
16758	Pick Head	A type 5 Several pieces of high/medium carbon steel welded together with a martensitic tip	n/a	n/a	n/a	n/a	414	n/a	n/a	Clean	Yes
17106	Knife	A type 2 with an medium/high carbon steel tip scarf welded a high carbon steel piece butt welded to a ferritic back	n/a	91	145	0.3	165	5	n/a	Clean	No
(17304) 6489	Knife Tang	A possible type 2 knife tang with a ferritic band welded to a high carbon steel diffusing into low carbon steel	n/a	183	175	0.1	244	6	n/a	Dirty	No

Table 91 - Class 2 and Class 3 artefacts analysis for the Worcester assemblage

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Description	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 2											
(16692) 5609	Nail	A heterogeneous structure with an area of high carbon steel diffusing in to ferrite	n/a	156	163	0.2	154	3	n/a	Clean	No
(16692) 5620	Nail	A high carbon steel piece welded to the head of a ferritic nail with carbon diffusion	n/a	124	n/a	n/a	157	5	n/a	Clean	No
(16692) 5646	Nail	A heterogeneous naturally banded structure of low/medium carbon steel with a small corner band of ferrite	n/a	184	149	0.15	156	6	n/a	Clean	No
-17289 6319	Nail	Completely ferritic iron	n/a	145	n/a	n/a	n/a	5	n/a	Clean	No
(17300) 6477	Nail	A medium/high carbon steel structure	n/a	n/a	n/a	n/a	253	8	n/a	Dirty	No
Class 3											
(17289) 6317	Strip Fragment	Mostly ferritic with carburization on one edge	n/a	150	128	0.2	153	3	n/a	Clean	No

Table 92 – Class 1 alloy usage in the Worcester assemblage

(Numbers are based on the number of artefacts with that particular amount of the alloy present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	1	4	3	3	1
Whole Section	0	1	1	1	0
More than 1/2 of the Section	0	0	0	1	0
Up to 1/2 of the Section	1	3	2	1	1

Table 93 – Class 2 alloy usage in the Worcester assemblage

(Numbers are based on the number of artefacts with that particular amount of the alloy present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	0	4	2	4	0
Whole Section	0	1	0	1	0
More than 1/2 of the Section	0	1	1	0	0
Up to 1/2 of the Section	0	2	1	3	0

Table 94 – Class 3 alloy usage in the Worcester assemblage

(Numbers are based on the number of artefacts with that particular amount of the alloy present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	0	1	1	1	0
Whole Section	0	0	0	0	0
More than 1/2 of the Section	0	1	0	0	0
Up to 1/2 of the Section	0	0	1	1	0

Table 95 - Phosphoric iron analyses from Worcester

(Phosphorus content and hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Description	Phosphoric iron placement	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ave. ASTM)	P-iron ave. Hv _{0.2}
5657	Hook Tag	Large grain bands in a slightly piled structure	Inter-granular	4	Mean	0.3	Yes	Yes	5	178
					Low	0.18	No	No	5	131
					High	0.49	No	Yes	5	241

Table 96 – Manufacture of the Worcester artefacts

	# Total Artefacts	# Class 1 Artefacts	# Class 2 Artefacts	# Class 3 Artefacts
# Total Artefacts	12	6	5	1
Evidence of Cold Working	0	0	0	0
Heat Treated	1	1	0	0
Carburized	1	0	0	1
Piled	0	0	0	0
Composite Construction	4	3	1	0
Single Alloy Construction	4	2	2	0
Heterogeneous	4	1	2	1
Clean	9	5	4	1

Table 97 – Average hardness for ferrite in the Wharram Percy classes

	Class 1	Class 2	Class 3
Ave. Hv _{0.2} Ferrite	128	152	150

Table 98 – Worcester alloy usage based on class

(Numbers are based on the number of artefacts in the category)

Class	Total # Artefacts	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
Class 1	6	1	4	3	3	1
Class 2	5	0	4	2	4	0
UI	1	0	1	1	1	0
Total	12	1	9	6	8	1

Table 99 – Alloy usage summary for the Worcester assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	1	9	6	8	1
Whole Section	0	2	1	1	0
More than 1/2 of the Section	0	2	1	1	0
Up to 1/2 of the Section	1	5	4	6	1

Table 100 – Cleanness of the artefacts from Worcester by class

	# Total Artefacts	% Class 1 Artefacts	% Class 2 Artefacts	% Class 3 Artefacts
Clean	83	83	80	100

Table 101 – Summary of the iron smelting and smithing evidence from Coppergate, York, excavation

(Data taken from McDonnell (1992 477))

Smelting Slag (kg)	Run Slag (kg)	Smithing Slag (kg)	Cinder (kg)	Fuel Ash Slag (kg)	Hearth Lining (kg)	Ore (kg)	Other (kg)
21746	2925	179109	13020	17102	14500	120	181

Table 102 – Summary of the iron artefacts from York

(n/a = not applicable)

Artefact #	Artefact Type	Period (centuries AD)	Dimensions (mm)	Weight (g)	# Sections Taken	Section Placements
Class 1						
1638	Punch	c.975 - mid 11 th	84x10x17	n/a	1	Cross-section of the point
3810	Knife	c.975 - mid 11 th	60x9x4	n/a	1	Cross-section of the cutting edge
3859	Knife	c.975 - mid 11 th	132x21x7	n/a	2	Cross-section of the knife back and a cross-section of the cutting edge
4070	Knife	c.975 - mid 11 th	93x12x51	n/a	1	Cross-section of the cutting edge
5802	Knife	c.975	100x15x5	n/a	1	Cross-section of the cutting edge
6295	Key (bit and the ring)	c.975	78x24x6	n/a	2	A section of the bit and a section of the bow
7454	Punch	c. 930/5 - c. 975	83x17	n/a	1	A cross-section of the point
9439	Spoon Auger	c. 930/5 - c. 975	74x27x13	n/a	2	Cross-section of the spoon and a section of the cutting tip
10395	Knife	c. 930/5 - c. 975	13x18x2	n/a	1	Cross-section of the cutting edge
12229	Knife	c. 930/5 - c. 975	55x10x5	n/a	1	Cross-section of the cutting edge

Table 102 (cont.) – Summary of the iron artefacts from York

(n/a = not applicable)

Artefact #	Artefact Type	Period (centuries AD)	Dimensions (mm)	Weight (g)	# Sections Taken	Section Placements
Class 2						
2920	Nail	9 th -11 th	20x4x13	3	1	Cross-section of the shank
8454	Nail	9 th -11 th	53x7x8	10	2	Cross-section of head and cross-section of shank
15404	Nail	9 th -11 th	60x12x7	12	1	Cross-section of head
25990	Nail	9 th -11 th	55x10x32	23	1	Cross-section of shank
26171	Nail	9 th -11 th	48x4x10	3	2	Cross-section of head and cross-section of shank
26247	Nail	9 th -11 th	40x3x24	7	2	Cross-section of head and cross-section of shank
26736	Nail	9 th -11 th	30x5x27	7	1	Cross-section of head
27819	Nail	9 th -11 th	52x5x20	8	1	Cross-section of head
28589	Nail	9 th -11 th	35x3x11	4	1	Cross-section of the upper shank
Class 3						
8364	Blank	c. 930/5 - c. 975	84x8x4	n/a	1	Cross-section of the bar
8376	Blank	c. 930/5 - c. 975	67x9x7	n/a	1	Cross-section of the bar
8439	Blank	c. 930/5 - c. 976	55x8x3	n/a	1	Cross-section of the bar
8794	Blank	5 th -mid 9 th	211x6x5	n/a	1	Cross-section of the bar
9938	Blank	late 9 th /early 10 th	66x7x55	n/a	1	Cross-section of the bar
11208	Blank	late 10 th -mid 11 th	96x3x1.5	n/a	1	Cross-section of the bar
11352	Blank	late 9 th /early 10 th	59x8x6	n/a	1	Cross-section of the bar
11550	Blank	late 9 th /early 10 th	93x12x5	n/a	1	Cross-section of the bar

Table 103 –Class 1 artefacts analysis for the York assemblage

(Hv_{0.2} and grain size measurements are averaged; %C is estimated)

Artefact #	Artefact Type	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 1											
1638	Punch	A banded structure of converging towards the tip with bands of bainite, tempered martensite, pearlite, and ferrite	n/a	130	175	0.2	165	6	n/a	Dirty	Yes
3810	Knife	A Type 0 completely composed of phosphoric iron	194	n/a	n/a	n/a	n/a	n/a	2	Dirty	No
3859	Knife	A pattern welded blade with a heat treated steel tip and areas of low carbon steel, and phosphoric iron	148	n/a	185	0.2	335	n/a	3	Dirty	Yes
4070	Knife	A Type 3 piled structure with thin bands of ferrite sandwiched by a broad band of 0.5%C steel and another band of 0.2%C steel sandwiching the ferrite	n/a	143	129	0.2	234	6	n/a	Clean	No
5802	Knife	A Type 1 with a banded ferritic/phosphoric iron and carbon diffusion from a missing tip	125	121	n/a	n/a	n/a	6	2	Dirty	No
6295	Key	Heterogeneous with mostly ferritic iron with areas of phosphoric iron; may have been work hardened	194	194	n/a	n/a	n/a	4	3	Clean	No
7454	Punch	Ferritic iron core with a low carbon steel sheath welded around it	n/a	111	126	0.3	n/a	3	n/a	Dirty	No

Table 103 (cont.) – Class 1 artefacts analysis for the York assemblage

(Hv_{0.2} and grain size measurements are averaged; %C is estimated)

Artefact #	Artefact Type	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
Class 1 (cont.)											
9439	Spoon Auger	A HC steel core sheathed in piled ferrite/phosphoric iron	199	160	192	0.1	178	6	4	Dirty	No
10395	Knife	A Type 2 pearlitic blade with a tempered martensite tip and a piled phosphoric iron/ferrite/bainite back	139	127	185	0.3	174	5	6	Clean	Yes
11067	Arrowhead	Similar to a Type 1 with a high carbon steel central band sandwiched between two ferritic bands	n/a	234	277	0.1	260	6	n/a	Clean	No
12229	Knife	A Type 0 completely composed of phosphoric iron and heavily ghosted	169	n/a	n/a	n/a	n/a	n/a	3	Dirty	No

Table 104 – Class 2 artefacts analysis for the York assemblage

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Artefact Type	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
2920	Nail	A heterogeneous structure low to medium carbon steel	n/a	n/a	132	0.2	n/a	n/a	n/a	Clean	No
8454	Nail	A ferritic iron nail that has been carburized along the top and down one side	n/a	99	109	0.2	193	4	n/a	Clean	No
15404	Nail	A heterogeneous low to medium carbon steel	n/a	n/a	107	0.1	149	n/a	n/a	Clean	No
25990	Nail	Structure is mostly ferritic with light carburization along the edges and one area of eutectoid steel	n/a	108	n/a	n/a	258	5	n/a	Clean	No
26171	Nail	Almost homogenous phosphoric iron	98	93	n/a	n/a	n/a	4	3	Clean	No
26247	Nail	A mostly phosphoric iron structure with some carburization of the outer edges and a core of Widmanstätten high carbon steel	181	133	157	0.1	189	6	4	Clean	No
26736	Nail	Completely ferritic iron	n/a	114	n/a	n/a	n/a	5	n/a	Clean	No
27819	Nail	A heterogeneously banded mix largely high carbon steel with smaller bands of ferrite	n/a	90	127	0.4	166	4	n/a	Clean	No
28587	Nail	Almost homogenous phosphoric iron	170	n/a	n/a	n/a	n/a	n/a	2	Dirty	No

Table 105 – Class 3 artefacts analysis for the York assemblage

(Hv_{0.2} and grain size measurements are averaged; %C is estimated; n/a = not applicable)

Artefact #	Artefact Type	Description of Microstructure	P-Iron Hv _{0.2}	Ferrite Hv _{0.2}	LC Steel Hv _{0.2}	LC Steel %C	HC Steel Hv _{0.2}	Ferrite Grain Size (ASTM)	P-iron Grain Size (ASTM)	Clean?	Heat Treated
8364	Blank	Heterogeneous banded structure with bands of phosphoric iron welded to ferrite	242	224	n/a	n/a	n/a	6	5	Clean	No
8376	Blank	A heterogeneous mixture of phosphoric iron, ferrite and HC steel	124	134	n/a	n/a	366	7	8	Dirty	No
8439	Blank	A phosphoric iron with a small area of pearlite, possibly due to carburization	179	n/a	n/a	n/a	155	n/a	7	Clean	No
8794	Blank	A composite piled structure of alternating phosphoric and ferritic bands	201	133	n/a	n/a	n/a	n/a	n/a	Dirty	No
9938	Blank	Heterogeneous high carbon steel welded to ferrite with carbon diffusion	n/a	127	n/a	n/a	212	5	n/a	Clean	No
11208	Blank	Completely phosphoric iron	212	n/a	n/a	n/a	n/a	n/a	6	Dirty	No
11352	Blank	Heterogeneous phosphoric/ferritic iron	213	142	n/a	n/a	n/a	4	5	Dirty	No
11550	Blank	Completely ferritic iron	n/a	118	n/a	n/a	n/a	3	n/a	Dirty	No

Table 106 – Class 1 alloy usage in the York assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	7	9	7	7	3
Whole Section	2	0	0	0	0
More than 1/2 of the Section	0	3	0	1	0
Up to 1/2 of the Section	5	6	7	6	3

Table 107 – Class 2 alloy usage in the York assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	3	6	5	5	0
Whole Section	2	1	1	0	0
More than 1/2 of the Section	1	2	1	0	0
Up to 1/2 of the Section	0	3	3	5	0

Table 108 – Class 3 alloy usage in the York assemblage

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	6	6	0	3	0
Whole Section	1	1	0	0	0
More than 1/2 of the Section	1	0	0	0	0
Up to 1/2 of the Section	4	5	0	3	0

Table 109 – Phosphoric iron in York

(Phosphorus content and Hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Artefact Type	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ave. ASTM)	P-iron ave. Hv _{0.2}
Class 1										
1638	Punch	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
3810	Knife	Throughout	n/a	4	Mean	0.58	No	No	2	194
					Low	0.37	No	No	1	176
					High	0.7	No	No	3	196
3859	Knife	Pattern welled bands in knife back	Inter-granular, GB, Slag inclusion & Pearlite	1	Mean	0.26	Yes	Yes	3	158
4070	Knife	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
5802	Knife	Large grain band	n/a	3	Mean	0.22	No	No	2	125
					Low	0.2	No	No	2	124
					High	0.23	No	No	1	147
6295	Key	Small areas in heterogeneous structure	Inter-granular; Ripple like	2	Mean	0.23	Yes	No	3	194
					Low	0.23	Yes	No	3	160
					High	0.23	No	No	3	228
7454	Punch	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
9439	Spoon Auger	In piled bands sheathing a steel core	EE & GB; Widmanstätten	3	Mean	0.34	Yes	Yes	4	199
					Low	0.17	No	Yes	5	171
					High	0.55	Yes	Yes	3	223
10395	Knife	One band in the piled back	n/a	1	Mean	0.24	No	No	5	139

Table 109 (cont.) - Phosphoric iron in York

(Phosphorus content and Hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Artefact Type	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ave. ASTM)	P-iron ave. Hv _{0.2}
Class 1										
11067	Arrowhead	nd	n/a	nd	Mean	nd	No	Yes	n/a	n/a
12229	Knife	Throughout	Inter-granular, GB & Slag inclusion	3	Mean	0.54	Yes	No	3	169
					Low	0.32	Yes	No	6	159
					High	0.85	Yes	No	1	174
Class 2										
2920	Nail	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
8454	Nail	nd	n/a	nd	Mean	nd	No	Yes	n/a	n/a
15404	Nail	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
25990	Nail	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
26171	Nail	Almost all except a small area of slightly less Phosphorus	n/a	5	Mean	0.17	No	No	3	98
					Low	0.15	No	No	1	87
					High	0.2	No	No	3	101
26247	Nail	Heterogeneously part of the structure	n/a	4	Mean	0.39	No	No	4	181
					Low	0.19	No	No	5	137
					High	0.48	No	No	4	159
26736	Nail	nd	n/a	nd	Mean	nd	No	Yes	n/a	n/a
27819	Nail	nd	n/a	nd	Mean	nd	No	Yes	n/a	n/a
28589	Nail	Throughout	Slag inclusion	5	Mean	0.52	Yes	Yes	2	170
					Low	0.44	Yes	No	3	158
					High	0.63	No	Yes	1	181

Table 109 (cont.) - Phosphoric iron in York

(Phosphorus content and Hardness values averaged per test site; nd = not detected; n/a = not applicable)

Artefact #	Artefact Type	Placement within Artefact	Ghosting Structures	# P-iron Areas Analyzed	Data Type	P-iron (ave. wt%P)	Ghosting?	Etch Resistance?	Grain Size (ave. ASTM)	P-iron ave. Hv _{0.2}
Class 3										
8364	Blank	Bands within on side of the structure	n/a	3	Mean	0.55	No	No	5	242
					Low	0.37	No	No	7	194
					High	0.66	No	No	2	289
8376	Blank	Areas heterogeneously mixed in	n/a	2	Mean	0.15	No	No	8	124
					Low	0.15	No	No	7	120
					High	0.16	No	No	8	128
8439	Blank	Almost through-out	GB	6	Mean	0.47	Yes	No	7	179
					Low	0.39	No	No	8	161
					High	0.60	Yes	No	8	189
8794	Blank	Alternating bands	Inter-granular	6	Mean	0.45	Yes	Yes	n/a	201
					Low	0.17	No	No	n/a	152
					High	0.66	No	Yes	n/a	209
9938	Blank	nd	n/a	nd	Mean	nd	No	No	n/a	n/a
11208	Blank	Throughout	GB & Slag inclusion	6	Mean	0.25	Yes	No	6	212
					Low	0.18	No	No	6	227
					High	0.38	Yes	No	5	230
11352	Blank	Most of the heterogeneous microstructure	GB	2	Mean	0.21	Yes	No	5	213
					Low	0.16	No	No	4	212
					High	0.26	Yes	No	6	213
11550	Blank	nd	n/a	nd	Mean	nd	No	No	n/a	n/a

Table 110 – Phosphorus in the steel of the York assemblage

(Measurements are from individual test sites with estimated carbon content)

Artefact #	Artefact Type	Low Carbon Steel wt%P	Low Carbon Steel Hv _{0.2}	Low Carbon Steel %C	Placement of Low Carbon Steel	High Carbon Steel wt%P	High Carbon Steel Hv _{0.2}	High Carbon Steel %C	Placement of High Carbon Steel
4070	Knife	0.17	140	0.2	The side of the knife	nd	n/a	n/a	n/a
8376	Blank	nd	n/a	n/a	n/a	0.17	357	0.8	Area along the exterior of the bar
10395	Knife	0.22	145	0.3	Part of the piled knife back	ns	n/a	n/a	n/a
26247	Nail	0.22	132	0.1	Centre of the nail shank	0.31	153	0.5	Carburization of the nail head

Table 111 – Phosphoric iron indicators in the York assemblage

	# of Artefacts
P-iron Ghosting	8
P-iron Large Grains	9
P-iron Etch Resistance	8
Average Hv _{0.2}	174

Table 112 – Analysis of spoon auger Yo9439

(Hv# - The hardness test number corresponding to numbers in Figure 44)

Hv #	Alloy Type	Vickers Hardness (Hv _{0.2})	SEM Wt%P	SEM Wt%As	ASTM Grain Size	Notes
Hv1	Phosphoric Iron	203	0.6 ± 0.1	0.2 ± 0.2	5	Ghosting and etch resistant
Hv2	Ferrite	139	0.1 ± 0.1	nd	7	Grain boundary pearlite
Hv3	Weld Line	152	nd	0.7 ± 0.2	n/a	Some carbon diffusion 0.3%C
Hv4	Pearlite 0.7%C	186	nd	nd	n/a	
Hv5	Pearlite + Ferrite 0.4%C	170	nd	nd	8	
Hv6	Ferrite + Pearlite 0.1%C	192	nd	nd	8	Carburized inner edge
Hv7	Ferrite	181	0.1 ± 0.1	nd	5	Etch resist
Hv8	Phosphoric Iron	171	0.3 ± 0.1	0.6 ± 0.2	3	Grain boundary ghosting
Hv9	Phosphoric Iron	223	0.2 ± 0.1	0.9 ± 0.2	3	Etch resist

Table 113 – Artefacts examined by McDonnell’s (1992) analysis of artefacts from York

(The number of artefacts is indicated next to the type)

Class 1 Artefacts	Class 2 Artefacts	Class 3 Artefacts
Anvil 1	Ferrule 1	Stock iron 25
Arrowhead 1	Hinges 3	
Auger 1	Hook 1	
Axe 1	Staples 2	
File 1		
Key 1		
Knives 47		
Needles 3		
Punches 4		
Shears 1		
Spearhead 1		
Sword 1		
Wedge 1		

**Table 114 – Results from McDonnell’s (1992) analysis of artefacts
from York**

	Total # of Artefacts	% Heat Treated	% with P-iron	% Ghosted
Class 1	64	50	67	27
Class 2	7	0	71	14
Class 3	25	8	44	12
Total	96	35	61	22

Table 115 – Manufacture summary for the York artefacts

	# Total Artefacts	# Class 1 Artefacts	# Class 2 Artefacts	# Class 3 Artefacts
# Total Artefacts	28	11	9	8
Evidence of Cold Working	2	2	0	0
Heat Treated	3	3	0	0
Carburized	4	1	2	1
Piled	6	4	0	2
Composite Construction	9	8	0	1
Single Alloy Construction	7	2	3	2
Heterogeneous	12	4	5	3
Clean	15	5	7	3

Table 116 – Average hardness for ferrite in the York classes

	Class 1	Class 2	Class 3
Ave. Hv _{0.2} Ferrite	135	106	146

Table 117 – York alloy usage based on class

(Numbers are based on the number of artefacts in the category)

Class	# Total Artefacts	% P-iron	% Ferrite	% LC Steel	%HC Steel
Class 1	11	64	82	64	64
Class 2	9	33	67	44	56
Class 3	8	75	75	0	38
Total	28	57	75	39	54

Table 118 – Alloy usage summary for the York assemblage

The Amount of the Section with the Alloy	P-iron	Ferrite	LC Steel	HC Steel	Heat Treated Steel
# Artefacts w/ Alloy	16	21	12	15	3
Whole Section	4	2	1	0	0
More than 1/2 of the Section	2	5	1	1	0
Up to 1/2 of the Section	9	14	10	14	3

Table 119 – Cleanness of the artefacts from York by class

	# Total Artefacts	% Class 1 Artefacts	% Class 2 Artefacts	% Class 3 Artefacts
Clean	54	45	78	38

Table 120 – Site background summary

Site	Excavation	Location (regional)	Settlement Status	Rural/Urban	Period (Centuries AD)	Total # of Artefacts	Settlement Type Notes
Brent Knoll, Somerset	St. Michael's House	Southwest	Low	Rural	10th -12th	10	Small Rural Village
Canterbury, Kent	Christ Church	Southeast	High	Urban	8th - 9th	19	Both Royal and Ecclesiastical
Southampton, Hampshire	Six Dials	South Coast	Low	Urban	9th - 9th	19	Market Town
Thetford, East Anglia	Brandon Road	East Midlands	Low	Rural	5th-9th	21	Outside of a Royal settlement
Wharram Percy, Yorkshire	South Manor	Northeast	High	Rural	7th-9th	27	Possibly Royal
Winchester, Hampshire	New Road, Sussex Street, Victoria Road, and The Brooks	South	High	Urban	9th-11th	4	Both Royal and Ecclesiastical
Worcester, Worcestershire	Deansway	West Midlands	High	Urban	9th-11th	12	Combined Royal, Ecclesiastical, and Market Town
York, Yorkshire	Coppergate	Northeast	High	Urban	9th-11th	28	Both Royal and Ecclesiastical

Table 121 – Summary of artefact types from all eight sites

Class 1 Artefact Type	# of Artefacts	Class 2 Artefact Type	# of Artefacts	Class 3 Artefact Type	# of Artefacts	UI Artefacts
Arrow Head	1	Ferrule	1	Bar	18	Chisel Set Fragment
Auger	1	Fitting	1	Billet	1	Strip
Awl	1	Hook	3	Blank	8	Sheet Fragment
Axe	1	Joiners Dog				Tapering Strip
Bill hook	1	Nail/Tack	40			
Buckle	3	Pin	1			
Chisel	2	Rivet	1			
Dress Pin	1	Staple	3			
Hook Tag	2	Unknown Tool	1			
Key	3					
Knife	34					
Lock	1					
Needle	2					
Pick Head	1					
Punch	4					

Table 122 – Summary of artefacts in each class per site

Site	# Total Artefacts	# Class 1 Artefacts	# Class 2 Artefacts	# Class 3 Artefacts	UI
Total	140	59	51	27	3
Brent Knoll	10	5	4	1	n/a
Canterbury	19	8	7	4	n/a
Southampton	19	11	6	2	n/a
Thetford	21	6	10	2	3
Wharram Percy	27	8	10	9	n/a
Winchester	4	4	n/a	n/a	n/a
Worcester	12	6	5	1	n/a
York	28	11	9	8	n/a

Table 123 – Single alloy construction summary of alloy usage and manufacture techniques

(23 artefacts in total)

Artefact Types	# of Artefacts	Alloy Type	# of Artefacts	Manufacture Evidence	# of Artefacts	Class	# of Artefacts
Dress Fittings	2	Ferrite	9	Clean	13	Class 1	7
Edged Tools	2	LC Steel	1	Evidence of Cold Worked	1	Class 2	10
Nails/Tacks/Staples	10	P-iron	11			Class 3	6
Security	2	HC Steel	2			UI	0
Stock Iron	6						
Other Tools	1						

**Table 124 – Heterogeneous structures summary of alloy use and
manufacture techniques**

(80 artefacts in total)

Artefact Types	# of Artefacts	Alloy Type	# of Artefacts	Manufacture Evidence	# of Artefacts	Class	# of Artefacts
Stock Iron	13	P-iron	63	Evidence of Cold Worked	3	Class 1	30
Nails +Tack	26	Ferrite	56	Heat Treated	6	Class 2	34
Edged Tools	24	LC Steel	58	Composite Construction	25	Class 3	13
Security	2	HC Steel	45	Carburized	10	UI	3
Dress Fittings	2			Clean	46		
Construction	7			Piled	19		
Weapons	1						
Unidentified	4						

Table 125 - The cleanness of piled artefacts

(19 artefact total)

# of Artefacts with Clean metal and Clean Welds	# of Artefacts with Clean Metal and Dirty Welds	# of Artefacts with Dirty Metal and Welds
6	8	5

**Table 126 – Composite Construction Summary of Alloy Use and
Manufacture Techniques**

(46 artefacts in total)

Artefact Types	# of Artefacts	Alloy Type	# of Artefacts	Manufacture Evidence	# of Artefacts	Class	# of Artefacts
Stock Iron	3	P-iron	32	Evidence of Cold Worked	3	Class 1	39
Nails +Tack	1	Ferrite	28	Heat Treated	13	Class 2	3
Edged Tools	37	LC Steel	35	Piled	15	Class 3	3
Other tools	1	HC Steel	40	Carburized	4	UI	1
Weapon	1			Clean	28		
Construction	2			Heterogeneous Components	25		
UI	1						

Table 127 – Alloy usage in Class 1 composite construction artefacts

	Total # of Artefacts	# of Artefacts with P-iron	# of Artefacts with Ferrite	# of Artefacts with LC Steel	# of Artefacts with HC Steel
Class 1 edged tools	37	27	22	31	35
Class 1 other tools	2	0	1	2	2
Totals	39	27	23	33	37

Table 128 – Alloy usage in Class 2 composite construction artefacts

	Total # of Artefacts	# of Artefacts with P-iron	# of Artefacts with Ferrite	# of Artefacts with LC Steel	# of Artefacts with Steel
Class 2	3	3	2	2	3

Table 129 – Alloy usage in Class 3 composite construction artefacts

	Total # of Artefacts	# of Artefacts with P-iron	# of Artefacts with Ferrite	# of Artefacts with LC Steel	# of Artefacts with Steel
Class 3	4	3	3	1	3

Table 130 – Microstructures with ferritic iron individual alloy components

Single Alloy Construction	Individual Alloy in Composite Construction	Carburized Ferritic Iron
9	13	9

Table 131 – Cleanness based on form of low carbon steel type of manufacture

	Single Alloy	Individual Alloy component of a Composite Object	Carbon Diffusion	Carburization	Heterogeneous
% Clean	100	0	61	68	63

Table 132 –Artefacts containing intentional carburization

(For both LC Steel and HC Steel Yes = it being present due to carburization)

Artefact	Type	Class	LC Steel	HC Steel
BN 334	Nail Tip	2	Yes	Yes
CC 258	Needle	1	Yes	No
CC 359	Staple	2	Yes	Yes
DW 16692-5609	Nail	2	Yes	Yes
SOU 99-92	Knife	1	Yes	Yes
Thet 203-5	Chisel Set Fragment	UI	Yes	No
Thet 249	Awl	1	Yes	Yes
Thet 302	Nail	2	No	Yes
WP 307	Knife	1	Yes	No
Yo 9439	Spoon Auger	1	Yes	Yes

Table 133 – Number of artefacts demonstrating of intentional steel use by type

	Single Alloy	Individual Alloy component of a Composite Object	Intentional Carburization	Total	% of Assemblage
Low Carbon Steel	1	1	9	11	8
High Carbon Steel	2	34	7	43	31

Table 134 – Artefact types with phosphorus

(Total per class indicated over total overall per class)

Class 1 Artefact Type	# of Artefacts	Class 2 Artefact Type	# of Artefacts	Class 3 Artefact Type	# of Artefacts	UI Artefacts
Arrowhead	1	Ferrule	1	Bar	13	Sheet Fragment
Auger	1	Fitting	1	Billet	1	Tapering Strip
Axe	1	Hook	2	Blank	6	
Bill Hook	1	Joiner's Dog	1			
Buckle	1	Nail/Tack	22			
Chisel	2	Rivet	1			
Dress Pin	1	Staple	3			
Hook Tag	1	Unknown Tool	1			
Key	2					
Knife	26					
Needle	1					
Total Class 1	38/58	Total Class 2	32/52	Total Class 3	20/27	Total UI
						2/3

Table 135 -Phosphoric iron artefacts with steel heat-treatment

Artefact #	Description	Construction Type	P-iron (ave. wt%P)	Ghosting?	P-iron ave. Hv _{0.2}	P-iron Range of Hv _{0.2}
CC397	Knife	4	0.44	Yes	157	140-160
SOU169-540	Knife	2	0.38	Yes	155	146-162
SOU24-22	Axe	3	0.42	Yes	185	147-210
SOU31-92	Bill hook	3	0.41	Yes	161	161
SOU98-38	Knife	2	0.35	Yes	165	165
Thet271	Knife	Reverse 1or 3	0.16	No	124	124
WP159	Knife	2	0.34	Yes	161	143-181
Yo10395	Knife	2	0.24	No	139	139
Yo3859	Knife	Pattern-welded	0.54	Yes	169	169

Table 136 - Artefacts with phosphorus in steel

(Some artefacts contained in both low and high carbon steels)

Phosphorus in Steel	# of Artefacts	Average of wt%P	Standard Deviation	Range wt%P
Total # Artefacts	49	0.30	0.16	0.12-0.76
Low carbon steel	39	0.32	0.16	0.14-0.76
High Carbon Steel	16	0.26	0.14	0.12-0.61
Heat-treatment	3	0.29	0.09	0.31-0.39

Table 137 - Analysis results for knife CC397

(Hv# - The hardness test number corresponding the red numbers in figure 70)

Hv #	Alloy Type	Vickers Hardness (Hv)	SEM Wt%P	SEM Wt%As	ASTM Grain Size	Notes
Hv 1	Tempered Martensite	382	0.1 ± 0.1	0.3 ± 0.2	-	
Hv 2	Ferrite + Pearlite 0.1%C	103	nd	0.3 ± 0.2	6	
Hv 3	Phosphoric Iron	170	0.6 ± 0.1	0.1 ± 0.2	3	Ghosting
Hv 4	Ferrite	136	0.1 ± 0.1	0.1 ± 0.2	6	
Hv 5	Ferrite	146	0.1 ± 0.1	0.1 ± 0.2	7	
Hv 6	Phosphoric Iron	195	0.7 ± 0.1	nd	4	Etch Resistant
Hv 7	Ferrite + Pearlite 0.1%C	191	0.1 ± 0.1	nd	6	
Hv 8	Phosphoric + Pearlite 0.1%C	222	0.2 ± 0.1	nd	6	Pearlitic Edge Effects
Hv 9	Phosphoric Iron	217	0.5 ± 0.1	0.1 ± 0.2	2	Etch Resistant

Table 138 – Summary of phosphoric iron indicators

Total P-iron Artefacts	Ghosted P-iron Artefacts	Large Grained P-iron (ASTM >4) Artefacts	Etch Resistant P-iron Artefacts	Range of P-iron Hardness (Hv _{0.2})	Mean P-iron Hardness (Hv _{0.2})
95	79	55	38	101 - 292	173

Table 139 – Class and manufacture summary for ghosted artefacts

Total # Artefacts with Ghosted Phosphoric Iron			
79			
Ghosted P-iron Artefacts In Each Class	% of Artefacts	Ghosted P-iron Artefacts of Each Construction	% of Artefacts
Class 1	53	Single Alloy	43
Class 2	54	Carburized Single Alloy	57
Class 3	67	Composite Construction	54
UI	67	Heterogeneous	68

Table 140 – Number of artefacts with ghosting structures

Ghosting Structures	# Total Artefacts
Grain Boundary	41
Inter-granular	45
Edge Effects	16
Slag Inclusions	43
Pearlitic	7

Table 141 – Phosphorus analysis results for test areas indicated in Figure 90 from bar SOU31-814

Area Description	Test #	Phosphorus (wt%P)
Slag Inclusion (P ₂ O ₅)	1	6.9
Inclusion Halo	2	0.3
Surrounding Grains	3	0.7

Table 142 - Class and manufacture summary for etch resistant artefacts

Total # Artefacts with Etch Resistance			
55			
Etch Resistant Artefacts In Each Class	% of Artefacts	Etch-Resistant Artefacts of Each Construction	% of Artefacts
Class 1	47	Single Alloy	32
Class 2	37	Composite Construction	50
Class 3	37	Heterogeneous	42
UI	0		

Table 143 - Non-phosphoric iron artefacts with etch resistance

Class	# of Artefacts	Alloy	# of Artefacts	Manufacture	# of Artefacts
Class 1	4	Ferrite	16	Composite Construction	2
Class 2	11	HC Steel	2	Heterogeneous	11
Class 3	3			Single Alloy	5

Table 144 – Summary of the areas of high arsenic in the eight artefacts containing the element

(All measurements from test areas containing high arsenic (>0.3wt%As) for each artefact; weld line data not included; a profile of each artefact can be found in the site summaries)

Site	Artefact #	Artefact Type	Ave. Hv _{0.2}	Range of wt%As	Ave. wt%As	Ave. wt%P	Range %C	Ave. Grain Size (ASTM)	Ghosting	Etch Resistance
Brent Knoll	310	Nail	180	0.4	0.40	0.1	nd	6	No	Yes
Brent Knoll	334	Nail	281	0.4-0.6	0.5	0.1	0-0.7	7	No	Yes
Canterbury	299	bar	189	0.7	0.7	0.4	nd	1	Yes	Yes
Southampton	98-38	Knife	161	0.4-0.7	0.5	0.2	0-0.3	6	No	Yes
Thetford	176	Ferrule	175	0.4-0.5	0.4	0.7	nd	4	No	Yes
Wharram Percy	218	Nail	225	0.4-0.8	0.6	0.3	nd	6	Yes	Yes
Wharram Percy	394	Nail	186	0.4	0.4	0.6	nd	1	No	Yes
York	9439	Spoon Auger	197	0.6-1.0	0.8	0.2	nd	3	Yes	Yes

Table 145 – Hardness and arsenic content for alloys containing >0.3wt% arsenic

	Low Arsenic wt%As	Low Arsenic Hv _{0.2}	High As %As	High Arsenic Hv _{0.2}	# of Artefacts	Ave. Hv _{0.2}	Ave. wt%As
Ferrite	0.40	180	0.68	140	2	160	0.5
P-iron	0.35	176	0.96	223	15	218	0.6
LC Steel	0.35	196	0.4	278	3	207	0.4
HC Steel	0.5	293	0.52	314	2	303	0.5

Table 146 – Microstructures in that contain arsenic in the iron

(Composite/heterogeneous indicates that the arsenic was present in a heterogeneous part of the composite microstructure)

Site	Artefact #	Artefact Type	Microstructure
Brent Knoll	310	Nail	Heterogeneous
Brent Knoll	334	Nail	Heterogeneous
Canterbury	299	bar	Heterogeneous
Southampton	98-38	Knife	Composite/Heterogeneous
Thetford	176	Ferrule	Composite/Heterogeneous
Wharram Percy	218	Nail	Single Alloy
Wharram Percy	394	Nail	Heterogeneous
York	9439	Spoon Auger	Composite/Heterogeneous

Table 147 – Alloy usage summary of the nine Class 1 artefacts

(Numbers are based on the number of artefacts in the category with the alloy present and how much of the alloy was present)

	P-iron	Ferrite	LC Steel	HC Steel
# Artefacts w/ Alloy	92	84	72	76
Whole Object	12	9	2	2
More than 1/2 of the Object	36	21	10	5
Up to 1/2 of the Object	41	54	60	69

Table 148 – Intentional usage of alloys

Alloys	# of Artefacts
Phosphoric iron	32
Ferrite	27
Low Carbon Steel	11
High Carbon Steel	43

Table 149 – Heat-treated microstructures present in heat-treated artefacts

Heat-treated Structure	Number of Artefacts	Range Hv _{0.2}	Ave. Hv _{0.2}
Martensite	3	605-733	691
Tempered Martensite	10	513-658	571
Bainite	6	377-483	420

Table 150 - Summary of the Class 1 artefacts based on artefact types

Total # of Artefacts									
57									
Dress Fittings	# of Artefacts	Edged Tool	# of Artefacts	Security	# of Artefacts	Other Tools	# of Artefacts	Weapons	# of Artefacts
Hook Tag	2	Knife	33	Key	3	Needle	2	Arrowhead	2
Dress Pin	1	Auger	1	Lock	1	Punch	4		
Buckle	2	Axe	1			Awl	1		
		Bill Hook	1						
		Pick Head	1						
		Chisel	2						

Table 151 - Summary of the Class 2 artefacts based on artefact types

Total # of Artefacts			
53			
Construction	# of Artefacts	Other	# of Artefacts
Rivet	1	Hooks	3
Fitting	1	Unknown tool	1
Joiners Dog	2	Ferrule	1
Nail/Tack	40	Pin	1
Staple	3		

Table 152 – Summary of the Class 3 artefacts based on artefact types

Total # of Artefacts	
27	
Stock Iron	# of Artefacts
Bar	26
Billet	1

Table 153 – The classification of all the early medieval artefacts

(OF = all ferrite , OP = all phosphoric iron, 1 = steel core flanked by ferritic or phosphoric iron, 2 = steel edge welded to the iron back, 3 = piled or banded structure throughout the section, 4W = a welded steel jacket around an iron core, 4C=a carburized layer outside a iron core, 5 = all steel, 6 = pattern welded, 7 = heterogeneous)

	OF	OP	1	2	3	4W	4C	5	6	7
Class 1	3	5	6	18	8	4	1	3	3	7
Class 2	8	9	1	3	3	0	1	4	0	23
Class 3	2	8	1	1	3	0	0	0	0	12
UI	0	0	0	0	1	1	0	0	0	1
Total	13	22	8	22	15	5	2	7	3	43

Table 154 – Summary of artefacts based on class

	Total # of Artefacts	Class 1 Artefacts	Class 2 Artefacts	Class 3 Artefacts	UI
Brent Knoll	10	5	4	1	0
Canterbury	19	7	8	4	0
Southampton	19	11	6	2	0
Thetford	21	5	11	2	3
Wharram Percy	27	8	10	9	0
Winchester	4	4	0	0	0
Worcester	12	6	5	1	0
York	28	11	9	8	0

Table 155 – Knife blade construction type per site

(See figure 14 for typology)

	Period (Century AD)	Urban / Rural	Type 0	Type 1	Type 2	Type 3	Type 4	Type 5	Pattern Welded	Other
Brent Knoll	10th -12th	Rural	0	1	0	0	1	0	0	0
Canterbury	8th - 9th	Urban	0	1	0	0	2	0	0	0
Southampton	9th - 9th	Urban	0	0	6	0	0	0	0	1
Thetford	5th-9th	Rural	0	0	1	1	0	0	0	0
Wharram Percy	7th-9th	Rural	1	0	5	2	0	0	0	0
Winchester	9th-11th	Urban	0	1	1	0	0	0	1	1
Worcester	9th-11th	Urban	0	0	2	0	0	0	0	0
York	9th-11th	Urban	2	1	1	1	0	0	1	0
Total			3	4	16	4	3	0	2	2

Table 156 – The use of heat treatment and piling in the sites

	# of Class 1 Artefacts	# Heat Treated	# Class 1 Piled
Brent Knoll	5	1	0
Canterbury	7	1	2
Southampton	11	4	4
Thetford	5	1	1
Wharram Percy	12	1	2
Winchester	4	1	1
Worcester	6	1	0
York	11	3	4

Table 157 – McDonnell’s (1992 , 1987b , 1987a) analysis of heat treatment in knives from Coppergate, York, and Southampton

	Total # of Artefacts	Heat Treated	% Heat Treated
Southampton	14	9	64
York	47	28	60

Table 158 – Class cleanness by site

	Total # of Artefacts	% Clean Class 1	% Clean Class 2	% Clean Class 3	% Clean UI
Brent Knoll	10	60	100	100	0
Canterbury	19	43	50	75	0
Southampton	19	45	50	100	0
Thetford	21	60	55	50	67
Wharram Percy	27	75	70	44	0
Winchester	4	75	0	0	0
Worcester	12	83	80	100	0
York	28	45	78	38	0

Table 159 – Smelting and smithing evidence for the sites

Site	Smelting Evidence?	Smithing Evidence?	Smithy?
Brent Knoll, Somerset	No	No	No
Canterbury, Kent	No	Yes	No
Southampton, Hampshire	No	Yes	Yes
Thetford, East Anglia	No	Yes	No
Wharram Percy, Yorkshire	No	Yes	Yes
Winchester, Hampshire	No	Yes	Yes
Worcester, Worcestershire	No	Yes	No
York, Yorkshire	Yes	Yes	No

Disc Information

Included with this research is a disc with additional information that would not fit into the printed volume. The following is a **table of contents** for the disc:

- Note to Examiners
- PhD Text
- PhD Data Sheets
- Assemblage data:
 - Images of artefact
 - X-radiographs
 - Drawings
 - Images of the sections
 - Description of the metallurgy
 - Analysis results for the sections

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