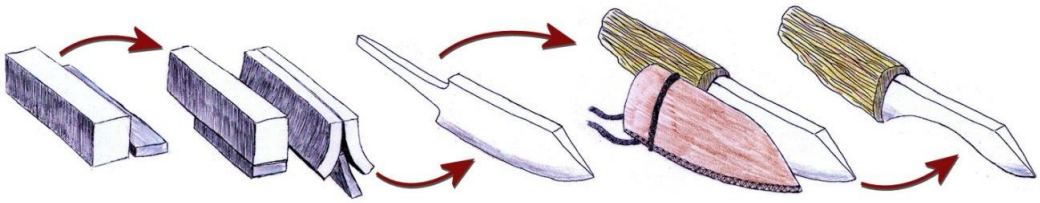

The Early Medieval Cutting Edge of Technology:

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

Volume 2

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Volume 2 Introduction

Results and Discussion Tables

Chapter 1 of this volume includes the metallographic data from past knife studies in table form referred to in the result chapter 5 of volume 1. The next chapter (2) presents the tables of data from which many of the graphs in discussion chapters 6 and 7 were derived.

Glossary

A glossary of important terms used in this PhD is included in Chapter 3. Also in this section the two main typologies for this research are included.

Appendix Layout

This appendix contains the detailed results for each new knife examined in this study, they are organised into groups based on the sites they were from. In addition to the descriptions of each knife, the slag distribution and microstructure were described. A photo and x-radiograph for each knife was included which showed where the sections were taken. For each site assemblage tables with the measurements for each knife found at the site are included, as were the SEM-EDS analysis results.

DVD Contents

The DVD included with this volume includes the excel spreadsheets for each site, as well as the spreadsheets with the raw data used to construct the many graphs used in the discussion chapters. Electronic copies of the thesis are also included on the DVD.

Chapter 1: Previous Metallographic Examinations

Early Saxon Settlement Knives

Knife No	Type	Cutting Edge		Back		Heat Treated	Other Details
		Microstructure	HV	Microstructure	Avg HV		
125	2	Tempered martensite	520	Ferrite	160	Yes	
126	1	Pearlite	245	Ferrite/Phosphoric iron?	185		
508	2	Tempered martensite	330	Ferrite with pearlite	172	Yes	
603	2	Tempered martensite	615	Ferrite	166	Yes	White weld line
605	2	Tempered martensite	553	Ferrite	186		
786	0	Pearlite with ferrite	210	Ferrite with pearlite	105		
809	3	Ferrite with pearlite	214	Ferrite with pearlite	-		

Table 1.1: Summary of the post-Roman to early Saxon settlement knives from Poundbury (Tylecote 1987). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Early Saxon Cemetery Knives

Knife No	Type	Cutting Edge		Back		Heat Treated	Other Details
		Microstructure	HV	Microstructure	Avg HV		
LH 606	5	Ferrite with carbo-nitride needles	116	Ferrite with carbo-nitride needles	104	Over heated	
LH 608 (1)	5	Tempered martensite	299	Ferrite with pearlite	302	Yes	
LH 608 (2)	1	Tempered martensite	724	Ferrite with pearlite	215	Yes	
LH 651	5	Pearlite	240	Ferrite with pearlite	214		
LH 654	1	Ferrite with carbo-nitride needles	160	Ferrite	156	Over heated	

Table 1.2: Summary of the cemetery knives from Lovedon Hill (McDonnell 1989b). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Knife No	Burial				Type	Cutting Edge		Back		Heat Treated	Other Details
	Grave/ Context	Sex	Age	RAIC		Microstructure	HV	Microstructure	Avg HV		
5	B3				1	Pearlite with ferrite and spheroidal structure	233	Ferrite/ phosphoric iron	238	Over heated	
6	Al				1	Ferrite with pearlite	182	Ferrite/ phosphoric iron	174		
9	51	Male	16	1	2	Tempered martensite	927	Ferrite with pearlite	178	Yes	
12	69	Female	44	1	1	Ferrite with pearlite	224	Ferrite with pearlite	220		
16	141	Female?	21	1	5	Ferrite with some pearlite	204	Ferrite with pearlite	270		
18	153	Unknown	30	1	5	Pearlite	257	Pearlite	274		
107	289	Male	20+	3	0	Ferrite	130	Ferrite	130		
117	312	Male	20	2	2	Tempered martensite	672	Ferrite with pearlite	187	Yes	
123	P1				0	Ferrite	130	Ferrite	150		
129	H1				5	Ferrite with pearlite	194	Ferrite with pearlite	199		
136	374	Female	22	1	1	Tempered martensite	400	Ferrite with pearlite	200	Yes	
159	402	Male	40+	3	2	Tempered martensite/pearlite	1000	Ferrite with pearlite	260	Yes	
165	FT 26B				0	Phosphoric iron	171	Ferrite	180		
169	413	Female	16	1	0	Ferrite	148	Ferrite	139		

Table 1.3: Summary of the cemetery knives from Cannington (McDonnell 1989a). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Knife No	Burial				Type	Cutting Edge		Back		Heat Treated	Other Details
	Grave/ Context	Sex	Age	RAIC		Microstructure	HV	Microstructure	Avg HV		
1218/6	6	Male	Adolescent	6	2	Martensite	602	Ferrite, phosphoric iron & ferrite with pearlite		Yes	
2404/5	75	Male	Unknown	2	2	Bainite	238	Phosphoric iron		Slow	
1217/8	4	Female	Unknown	7	3	Ferrite, phosphoric iron & ferrite with pearlite	201	Ferrite, phosphoric iron & ferrite with pearlite	195		
2402/11	73	Male	Unknown	3	3	Bainite	285	Ferrite, phosphoric iron & ferrite with pearlite	216	Slow	
3792/6	179	Unknown	Unknown	1	3	Ferrite	144	Ferrite, phosphoric iron & ferrite with pearlite	156		
1265/1	34	Unknown	Adult	1	4	Tempered Martensite	445	Bainite	282	Yes	

Table 1.4: Summary of the cemetery knives from Wasperton (Starley 2009). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Knife No	Burial				Type	Cutting Edge		Back		Heat Treated	Other Details
	Grave/ Context	Sex	Age	RAIC		Microstructure	HV	Microstructure	Avg HV		
42/10	42	Female	45+	6	0	Phosphoric iron	182	Phosphoric iron	176		
48/11	48	Female	18-23	8	0	Phosphoric iron	208	Phosphoric iron	208		
119A/2	199a	Male	30-50	5	1	Phosphoric iron/ferrite spheroidised carbides	213	Phosphoric iron	-		
90/5	90	Female	30-40	6	2	Phosphoric iron/ferrite spheroidised carbides	258	Phosphoric iron	197	Over heated	
50/11	50	Female	17-25	10	3	Phosphoric iron with tempered carbides	196	Tempered carbides and phosphoric iron	166		
131/4	131	Female	17-25	6	3	Phosphoric iron/ferrite spheroidised carbides	181	Phosphoric iron	230		
61/5	61	Female	25-35	5	4	Tempered martensite	627	Phosphoric iron	189	Yes	
84/2	84	Male	15-20	3	4	Tempered martensite	433	Phosphoric iron	214	Yes	
100/10	100	Unknown	30-40	10	4	Tempered martensite	534	Phosphoric iron	208	Yes	
107/7	107	Female	25-35	6	4	Tempered martensite	775	Phosphoric iron	154	Yes	
33/3	33	Unknown	16-20	3	5	Tempered martensite	475	Ferrite with some pearlite	267	Yes	
14/1	14	Unknown	3-4	2	-			Ferrite/phosphoric iron	-		

Table 1.5: Summary of the cemetery knives from Empingham II (Timby & Bartlett 1996). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Knife No	Burial				Type	Cutting Edge		Back		Heat Treated	Other Details
	Grave/ Context	Sex	Age	RAIC		Microstructure	HV	Microstructure	Avg HV		
3.4	2	Male	18	5	2	Tempered martensite/pearlite	794	Ferrite		Yes	
9.52	5	Female	25-29	3	3						
29.3	14	Female	35-45	4	2	Martensite	330	Ferrite with pearlite	168	Yes	
46.1	21	Unknown	Unknown	1	1	Martensite/pearlite	586			Yes	
117.2	34	Male	18-25	3	5	Tempered martensite		Tempered martensite		Yes	
156.1	53	Female	25-29	5	0	Ferrite	144	Ferrite	144		
359.15	69	Female	18	9	4	Tempered martensite				Yes	
428.144	79	Male	30-34	7	4	Tempered martensite/pearlite	388	Ferrite	150	Yes	
436.24	83	Male	25	6	1	Tempered martensite		Ferrite		Yes	
526.2	93	Female	35-45	6	1	Phosphoric iron	223	Ferrite	155		
547.1	96	Female	25-35	5	1	Phosphoric iron	125	Tempered martensite		Yes	Reverse Type 1
551.1	97	Male	20-30	3	2	Martensite	824	Ferrite with pearlite	316	Yes	
553.1	98	Male	45+	3	1	Tempered martensite	273	Ferrite with pearlite		Yes	
626.193	106	Male	18-20	2	-	Tempered martensite/ferrite		Ferrite		Yes	

Table 1.6: Summary of the cemetery knives from Edix Hill (Gilmour & Salter 1998). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Middle to Late Saxon Settlement Knives

Knife No	Type	Cutting Edge		Back		Heat Treated	Other Details
		Microstructure	HV	Microstructure	Avg HV		
169/2407	2	Ferrite with nodular carbide	153	Ferrite with carbides	166		
99/38	2	Ferrite with some pearlite	445	Ferrite	140		
99/92	2	Ferrite with some pearlite	160	Ferrite	160		
169/421	2	Pearlite with ferrite	160	Ferrite with pearlite	130		
169/540	2	Tempered martensite	644	Ferrite	218	Yes	
169/558	2	Tempered martensite	813	Ferrite	153	Yes	
169/1617	2	Tempered martensite	677	Ferrite	168	Yes	
169/2502	2	Tempered martensite	593	Bainite	262	Yes	Repair
169/610	2	Tempered martensite/pearlite	315	Ferrite with pearlite	101	Yes	
31/663	2	Tempered martensite/pearlite	174	Ferrite	192	Yes	
169/417	2	Tempered martensite/pearlite	603	Ferrite	169	Yes	
169/2516	-	Tempered martensite/pearlite	345	Ferrite	152	Yes	
30/173	2	Tempered martensite/pearlite with ferrite	427	Ferrite	157	Yes	
31/340	5	Tempered martensite with retained austenite	607	Tempered martensite with retained austenite	607	yes	

Table 1.7: Summary of the middle Saxon knives from urban Hamwic (McDonnell 1987a,c). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Knife No	Date	Type	Cutting Edge		Back		Heat Treated	Other Details
			Microstructure	HV	Microstructure	Avg HV		
464	1180-1188	1	Tempered martensite	824	Piled ferritic	164	Yes	
503	1180-1188	1	Martensite	907	Ferritic iron	186	Yes	
1565	1050-1060	1	Tempered martensite	627	Phosphoric iron/ ferrite with pearlite	251	Yes	
2796a	851-1100	0	Ferritic iron	187	Ferritic iron	165		
716	851-1100	4	Tempered martensite	592	Ferrite with pearlite	183	Yes	White weld line

Table 1.8: Summary of the middle to late Saxon knives from urban Lurk Lane, Beverley (McDonnell 1987b). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Knife No	Date	Type	Cutting Edge		Back		Heat Treated	Other Details
			Microstructure	HV	Microstructure	Avg HV		
CY276	9th-10th Century	1	Martensite and pearlite	533	Ferrite with pearlite	219	Yes	
BS271	10th Century	2	Tempered martensite	636	Ferrite	113	Yes	
BSSC6223	10th Century	2	Tempered martensite	439	Ferrite	127	Yes	
Bs128	11th Century	0	Ferrite	113				
BS6250	11th Century	2	Ferrite	102	Ferrite	95		
LBS41	11th-12th Century	3	Ferrite with pearlite	143	Ferrite with pearlite	143		
LBS25	11th-12th Century	3	Ferrite with pearlite	99	Ferrite with pearlite	99		
BS4200	11th-12th Century	1	Ferrite with carbides	229	Ferrite	165		
CY194	11th Century	1	Martensite	633	Pearlite and ferrite	232	Yes	
ACN127	11th Century	1	Martensite and ferrite	313			Yes	
BSSC329	12th Century	1	Martensite with ferrite	536	Ferrite	262	Yes	
CG1884	11th Century	1	Tempered martensite	290			Yes	
BS4085	11th-12th Century	1	Tempered martensite	571			Yes	
BS6458	11th-12th Century	2	Tempered martensite	426	Ferrite	117	Yes	
BS4263	11th-12th Century	2	Tempered martensite	551	Ferrite	116	Yes	
BSSC112	12th Century	2	Tempered martensite	536	Ferrite	116	Yes	

Table 1.9: Summary of the late Saxon knives from urban Winchester (Tylecote & Gilmour 1986). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Knife No	Date	Type	Cutting Edge		Back		Heat Treated	Other Details
			Microstructure	HV	Microstructure	Avg HV		
AML 980052	8th Century	0	Ferritic/phosphoric iron	139	Ferritic/phosphoric iron	139		
AML 980039	10th Century	0	Ferritic/phosphoric iron	268	Ferritic/phosphoric iron	242		
AML 980040	9th Century	2	Tempered martensite	535	Ferritic/phosphoric iron	203	Yes	
AML 980041	8th Century	2	Tempered martensite	577	Ferritic/phosphoric iron	182	Yes	
AML 980042	8th Century	2	Tempered martensite	578	Range of carbon contents	189	Yes	
AML 980048	7th-8th Century	2	Tempered martensite	532	Ferrite with pearlite	124	Yes	
AML 980049	9th-10th Century	2	Tempered martensite	588	Pearlite		Yes	
AML 980050	9th-10th Century	2	Tempered martensite	627	Ferritic/phosphoric iron	167	Yes	
AML 980051	9th Century	2	Tempered martensite	650	Ferritic/phosphoric iron	157	Yes	
AML 980043	10th Century	2	Tempered martensite	379	Ferrite with pearlite	168	Yes	
AML 980044	10th Century	2	Tempered martensite	547	Ferritic iron		Yes	
AML 980045	10th Century	2	Tempered martensite	567	Ferritic iron	144	Yes	
AML 980047	10th Century	2	Tempered martensite	538	Ferritic iron	117	Yes	
AML 980046	9th Century	4	Bainite	479	Ferrite with pearlite	195	Yes	

Table 1.10: Summary of the middle to late Saxon knives from high status Flixborough (Starley 1999). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Area	Knife No	Date	Type	Cutting Edge		Back		Heat Treated	Other Details
				Microstructure	HV	Microstructure	Avg HV		
Fishergate	4984	8th-9th	2	Tempered martensite/pearlite	383	Phosphoric iron	223	Yes	
Fishergate	4988	8th-9th	2	Pearlite	314	Phosphoric iron	179		
Fishergate	4989	8th-9th	2	Tempered martensite/pearlite	469	Phosphoric iron	205	Yes	
Fishergate	5000	8th-9th	2	Tempered martensite/pearlite	428	Ferrite	154	Yes	
Fishergate	5002	8th-9th	2	Tempered martensite	630	Ferrite and phosphoric iron	141	Yes	
Coppergate	1734	late 9th-early 10th	2	Pearlite	297	Ferrite	145		White weld line
Coppergate	8685	late 9th-early 10th	2	Martensite with ferrite	460	Ferrite	157	Yes	
Coppergate	8862	late 9th-early 10th	2	Tempered martensite	644	Ferrite with pearlite/ phosphoric iron	178	Yes	
Coppergate	9702	late 9th-early 10th	1	Tempered martensite	476	Phosphoric iron	199	Yes	
Coppergate	9892	late 9th-early 10th	2	Bainite	478	Ferrite	133	Yes (slow)	
Coppergate	10090	late 9th-early 10th	2	Martensite	847	Ferritic/phosphoric iron	213	Yes	White weld line
Coppergate	10168	late 9th-early 10th	1	Tempered martensite	530	Ferrite	153	Yes	Bent
Coppergate	10556	late 9th-early 10th	2	Martensite	660	Ferritic/phosphoric iron	158	Yes	White weld line
Coppergate	13198	late 9th-early 10th	2	Bainite	270	Tempered Martensite	707	Yes	
Coppergate	13446	late 9th-early 10th	4	Pearlite with ferrite	309	Ferrite	89		
Coppergate	13820	late 9th-early 10th	2	Martensite	550	Ferrite	147	Yes	White weld line
Coppergate		late 9th-early 10th	2	Tempered martensite	425	Ferrite	190	Yes	
Coppergate		late 9th-early 10th	2	Tempered martensite		Ferrite/ferrite with pearlite/phosphoric iron		Yes	P-welded & White weld line
Coppergate	5802	10th	1	Ferrite with pearlite	157	Ferrite	144		
Coppergate	7662	10th	1	Pearlite with ferrite	297	Phosphoric iron	255		
Coppergate	8421	10th	2	Pearlite with spheroidisation	156	Ferritic/phosphoric iron	168	Over heated	Spheriodisation
Coppergate	8574	10th	0	Phosphoric iron	178	Phosphoric iron	178		
Coppergate	8967	10th	2	Tempered martensite	665	Ferrite	160	Yes	
Coppergate	9045	10th	1	Tempered martensite	480	Ferritic/phosphoric iron	175	Yes	
Coppergate	9055	10th	2	Martensite	681	Ferritic/phosphoric iron	243	Yes	White weld line

Table 1.11: Summary of the middle to late Saxon knives from urban York (McDonnell 1992; Wiemer 1993). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Area	Knife No	Date	Type	Cutting Edge		Back		Heat Treated	Other Details
				Microstructure	HV	Microstructure	Avg HV		
Coppergate	9845	10th	1	Tempered martensite	813	Ferrite with some carbides/pearlite	227	Yes	
Coppergate	10272	10th	1	Bainite/Pearlite	548	Ferrite	220	Yes (slow)	
Coppergate	10277	10th	5	Pearlite	394	Ferrite with pearlite/ phosphoric iron	221		
Coppergate	10395	10th	5	Tempered martensite	420	Bainite/Pearlite	221	Yes	White weld line
Coppergate	10434	10th	2	Martensite	689	Ferrite with pearlite/ phosphoric iron	199	Yes	White weld line
Coppergate	12229	10th	0	Ferrite	230	Ferrite	215		
Coppergate	12889	10th	1	Tempered martensite	743	Bainite/pearlite with ferrite	348	Yes	White weld line
Coppergate	13374	10th	4	Ferrite with carbide	206	Ferrite with carbide	200	Over heated	
Coppergate	13404	10th	1	Pearlite with ferrite	366	Ferrite/ferrite with pearlite	159		White weld line
Coppergate	13608	10th	1	Pearlite	330	Ferrite/ferrite with pearlite	193		
Coppergate	14153	10th	4	Pearlite	297	Ferrite	145		
Coppergate	1532	Late 10th-mid 11th	1	Ferrite with pearlite	176	Ferrite	95		White weld line
Coppergate	3752	Late 10th-mid 11th	1	Ferrite with pearlite	155	Ferrite	137		
Coppergate	3800	Late 10th-mid 11th	1	Tempered martensite	488	Ferritic/phosphoric iron	180	Yes	
Coppergate	3810	Late 10th-mid 11th	0	Phosphoric iron	162	Phosphoric iron	183		
Coppergate	3859	Late 10th-mid 11th	2	Tempered Martensite	525	Ferrite/ferrite with pearlite/ phosphoric iron	223	Yes	P-welded & White weld line
Coppergate	4070	Late 10th-mid 11th	1	Pearlite	201	Ferrite/pearlite bands	152	Over heated	Needles
Coppergate	4287	Late 10th-mid 11th	1	Ferrite with pearlite	237	Ferritic/phosphoric iron	176		
Coppergate	4744	Late 10th-mid 11th	1	Tempered Martensite	554	Ferrite	145	Yes	White weld line
Coppergate	5719	Late 10th-mid 11th	2	Tempered Martensite with ferrite	420	Ferrite and pearlite/ phosphoric iron	190	Yes	
Coppergate	6229	Late 10th-mid 11th	1	Phosphoric iron	167	Phosphoric iron	172		
Coppergate	6487	Late 10th-mid 11th	0	Ferrite	136	Ferrite	136		
Coppergate	6770	Late 10th-mid 11th	5	Pearlite	195	Pearlite/pearlite with ferrite	273		

Table 11.11 cont: Summary of the middle to late Saxon knives from urban York (McDonnell 1992). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Viking Settlement Knives

Area	Knife No	Date	Type	Cutting Edge		Back		Heat Treated	Other Details
				Microstructure	HV	Microstructure	Avg HV		
Dublin, Winetavern Street	E81:6230	10th	2	Martensite	519	Ferrite	114	Yes	
Dublin, Winetavern Street	E81:6317	10th	0	Ferritic/phosphoric iron	110	Ferritic/phosphoric iron	110		Nitride needles?
Dublin, High Street	E71:16795	late 10th-early 11th	0	Ferrite and Pearlite	128	Ferrite and Pearlite	128		
Dublin, High Street	E71:16805	late 10th-early 11th	1	Martensite with some ferrite	497	Ferrite	107	Yes	
High Street	E71:16919	late 12th	3	Ferritic/phosphoric iron	134	Ferritic/phosphoric iron	123		P-Welded?
High Street	E71:16019	late 12th	0	Ferrite	106	Ferrite	106		
Christchurch Place	E22:1219	13th	2	Martensite	618	Ferritic/phosphoric iron	194	Yes	
Christchurch Place	E22:1311	13th	1	Pearlite with cementite needles	194	Ferrite	133		
Deerfin	76/203	6th -10th	0	Ferrite	155	Ferrite with pearlite	120		
Ballywee Rath A	76/180	6th -10th	0	Ferrite	167	Ferrite with pearlite	167		
Gransha	76/259a	6th -10th	2	Martensite	983	Ferrite with pearlite	166	Yes	
Ballywee Rath A	77/226	6th -10th	2	Martensite	910	Ferrite with pearlite	188	Yes	
Lough Faughan	DoENI	6th -10th	2	Martensite	1260	Ferrite with pearlite	341	Yes	
Deerfin	76/180	6th -10th	3	Ferrite	199	Ferrite with pearlite	186		
Deerfin	76/182	6th -10th	5	Martensite	866	Tempered martensite	727	Yes	

Table 1.12: Summary of the extra Viking knives from Dublin (Scott nd) and pre-Viking knives from Ireland (Scott 1991). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Area	Knife No	Date	Type	Cutting Edge		Back		Heat Treated	Other Details
				Microstructure	HV	Microstructure	Avg HV		
Vatnsdalur	1964:107	10th	1	Martensite	681	Ferrite	239	Yes	
Granastadir	Grst 61	11th	1	Pearlite		Ferrite			
Granastadir	grst 276	9th-11th	1	Pearlite		Ferrite			
Blondugeroi	pjms 14046	10th	1	Tempered Martensite	677	Ferrite	140	Yes	
Stori-Moshvoll	pjms	10th	1	Tempered Martensite	546	Ferrite/phosphoric iron	150	Yes	
Blondugeroi	pjms 14344	9th-10th	5	Pearlite	179	Pearlite	238		

Table 1.13: Summary of the Viking knives from Iceland (Sigurðardóttir 1999). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Knife No	Type	Cutting Edge		Back		Heat Treated	Other Details
		Microstructure	HV	Microstructure	Avg HV		
1377	2	Pearlite	191	Ferrite	210		
2439	2	Tempered Martensite	774	Ferrite with martensite	350	Yes	
3270	1	Tempered Martensite	700	Ferrite	245	Yes	
6551	0	Ferrite	206	Ferrite	194		
6636	1	Pearlite	240	Ferrite	300		
7177	2	Pearlite	270	Ferrite	109		
8734	5	Ferrite with some pearlite	205	Ferrite with some pearlite	199		
8882	0	Ferrite	233	Ferrite	233		
8918	2	Martensite	820	Ferrite/martensite	485	Yes	
9713	1	Tempered Martensite	720	Tempered Martensite	669	Yes	
10107	5	Bainite	400	Bainite	363	Yes (slow)	
10166	5	Tempered Martensite	685	Tempered Martensite	487	Yes	
10217	0	Ferrite	232	Ferrite	220		

Table 1.14: Summary of the Helgö knives (Tomtlund 1973). This shows the manufacturing typology, cutting edge and back microstructures along with their average hardness values.

Chapter 2: Discussion Data

				Back Shape					Tang Shape					Wear				
				A	B	C	D	X	1	2	3	4	X	No Wear	Slight Wear	Some Wear	Heavy Wear	Unknown
Part examination, Few illustrated	(Stamper & Croft 2000; Rahtz & Watts 2004)	Wharram Percy	7th-10th	7	6	0	0	6	7	0	3	1	8	1	0	6	6	0
Full Examination		Sedgeford	7th-10th	5	24	0	8	12	11	5	15	2	16	29	11	7	2	6
Full Examination		Burdale	8th-9th	7	9	0	2	11	9	4	10	4	4	1	8	13	1	6
Report, Few illustrated	(Wallis *et al.* 2004)	Mill Lane, Thetford	8th-9th	2	0	0	7	4										
Old AML report	(McDonnell *et al.* 1991)	Hamwic	8th-9th	42	66	0	0	24										
Report, Few illustrated	(Rogers 1993)	Fishergate	8th-9th	1	15	0	0	13										
Report, Few illustrated	(Ottaway 1992)	Coppergate	9th-10th	13	18	1	0	16										
Report, Few illustrated	(Ottaway 1992)	Coppergate	10th	6	42	1	0	35										
Report, Few illustrated	(Ottaway 1992)	Coppergate	10th-11th	12	33	0	1	31										
Full Examination		Whithorn	8th-10th	5	13	0	1	8	6	4	2	3	12	8	6	2	1	10
Report, Few illustrated	(Evans *et al.* 2009)	Flixborough	8th-10th	36	163	0	0	54										
Report, Some illustrated	(Frodsham & O'Brien 2005)	Yeavering	7th-8th	2	4	0	0	0	2	2	1	1	0	2	2	1	0	2
Report, All illustrated	(Rahtz & Hirst 1979)	Cheddar	7th-8th	2	3	0	1	1	7	0	0	0		3	2	1	0	1
Middle-Late Saxon Settlement				**140**	**396**	**2**	**20**	**133**	**42**	**15**	**31**	**11**	**40**	**44**	**29**	**30**	**10**	**25**
Full Examination		Quarrington	5th-6th	1	7	0	3	0	4	0	4	3	0	4	3	3	0	1
Report, All illustrated	(Drinkall *et al.* 1998)	Castledyke South	5th-7th	25	8	1	38	12	47	9	16	6	7	34	28	10	2	9
Report, Some illustrated	(Timby & Bartlett 1996)	Empingham II	5th-7th	8	18	0	13	30	22	11	7	5	24	21	13	6	1	28
Report, All illustrated	(Boyle 1998)	Lechdale	5th-8th	4	13	0	37	19	38	15	10	8	4	29	27	11	2	10
Report, All illustrated	(Evison 1987)	Buckland	5th-8th	34	5	5	47	42	33	15	24	16	6	38	53	17	2	13
Full Examination		Collingbourne	6th-7th	8	28	2	7	6	25	6	11	4	5	8	18	16	2	7
Full Examination		Twyford	6th-7th	1	4	0	0	0	3	0	2	0	0	2	2	1	0	0
Report, No images	(Evison 1994)	Great Chesterford	5th-6th	0	19	0	1	23										
Report, All illustrated	(Boyle 1995)	Berinfield	5th-6th	0	20	0	24	8	25	12	5	4	1	22	17	8	0	1
Old AML report	(Starley 1996)	Mucking	5th-7th	17	91	0	29	21										
Report, All illustrated	(Malim *et al.* 1998)	Edix Hill	6th-7th	3	44	0	6	6	38	6	4	9	2	17	21	17	1	3
Report, Some illustrated	(Sherlock & Welch 1992)	Norton	6th	11	8	11	15	13	33	6	3	5	11	9	20	16	1	12
Report, All illustrated	(Carver *et al.* 2009)	Wasperton	5th-7th	14	28	1	9	14	33	16	5	10	2	18	29	12	0	7
Early Saxon Cemeteries				**126**	**293**	**20**	**229**	**194**	**301**	**96**	**91**	**70**	**62**	**202**	**231**	**117**	**11**	**91**
Report, All illustrated	(West 1985a,b)	West Stow	5th-7th	16	27	3	14	17	31	15	17	6	8	22	22	13	6	14
Report, Some illustrated	(Green *et al.* 1987)	Poundbury	5th-7th	3	4	0	1	1	3	0	4	0	2	2	2	2	1	1
Full Examination		Gwithian	5th-7th	1	7	0	1	5	2	6	1	1	4	2	2	3	1	6
Report, Some illustrated	(Clark *et al.* 1993)	Mucking	5th-7th	3	11	2	1	2	10	3	2	3	1	6	6	4	1	2
Early Saxon Settlement				**23**	**49**	**5**	**17**	**25**	**46**	**24**	**24**	**4**	**15**	**32**	**32**	**22**	**9**	**23**

Table 2.1: Table showing the distribution of knife back shapes and tang interface, along with wear, across the various early medieval assemblages.

	Site	Date Range	Heat-Treatments							Knife Cutting Edges							Knife Backs						
			Martensite	Tempered Martensite	Tempered Martensite or Martensite with pearlite or ferrite	Bainite	Overheated	Repair	White Weld Line	Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron	Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron
Middle to Late Saxon Settlements	Wharram Percy	7th -9th		1				4	4	1	5	1	2	1		3				2	2	3	6
	Burdale	8th -9th		8		1			8	9	2		2		1			2		4		1	6
	Sedgeford	7th -9th		5	1				7	6	1	2	4			1	1			2	2	3	6
	Rural Settlement			***14***	***1***	***1***		***4***	***19***	***16***	***8***	***3***	***8***	***1***	***1***	***4***	***1***	***2***		***8***	***4***	***7***	***18***
	Whithorn	6th- late 9th					1		2		1	2	2							2	1		2
	Flixborough	7th -10th		11		1			10	12						2		1		3	3		7
	High Status Settlement			***11***		***1***	***1***		***12***	***12***	***1***	***2***	***2***			***2***		***1***		***5***	***4***		***9***
	Hamwic	8th -9th		4	5			1		9	1		3				2			3	8		
	Fishergate, York	8th -9th		1	3					4	1										1	3	1
	Urban Settlement			***5***	***9***			***1***		***14***	***2***		***3***				***2***			***3***	***10***	***3***	***1***
Middle to Late Saxon Settlements				**19**	**10**	**2**	**1**	**5**	**31**	**41**	**11**	**5**	**13**	**1**	**1**	**6**	**3**	**3**		**16**	**17**	**10**	**28**
Late Saxon Settlements	Whithorn	Late 9th -12th	1	3		1			5	5	1	1	1	1		2	1		2	1	1	3	3
	Sedgeford	9th -11th		8	1				5	9	1		2		2	1			1	2	3	3	6
	Lurk Lane, Beverley	9th -12th	1	3					1	4				1						1	2		2
	Coppergate, York	9th -10th	3	5	1	2			5	11	1	1					1				7	1	4
	Coppergate, York	10th	2	5		1	2		5	8	4	2	2	1	1		2			4	5	2	5
	Coppergate, York	10th -11th	1	3	1		1		4	5	2		3	1	2			1			5	2	5
	Winchester	9th -10th		2	1					3										1	2		
	Winchester	11th -12th	1	5	2					8			3	2					1	2	7		
Late Saxon Settlements			**9**	**34**	**6**	**4**	**3**		**25**	**53**	**9**	**4**	**11**	**6**	**5**	**3**	**4**	**1**	**4**	**11**	**32**	**11**	**25**
Ireland	Pre-Viking	6th-10th	4							4	3						1			6			
	Dublin	10th - Early 11th	7	4	1	1	7		9	13		1	2			1	1		1	4	3	4	4
	Dublin	11th	12	3	3	3	12		16	21							2		2	2	2	9	4
	Dublin	11th -12th	4	1			4	1	4	5				1		1	1				1	2	3
Viking Dublin			**23**	**8**	**4**	**4**	**6**	**1**	**29**	**39**		**1**	**2**	**1**		**2**	**4**		**3**	**6**	**6**	**15**	**11**
Viking Europe	Helgö	5th-9th	1	4						6	3		1	3			4			1	7		1
	Iceland	10th-11th	1	2						3	3							1			4		1

Table 2.2: Table summarising the heat-treatment methods and alloys used in the cutting edges and backs of the middle to late Saxon and late Saxon knives from England and Scotland. Also included in the table are the results from the analysis of knives from Ireland and the rest of Viking Europe.

	Site	Date Range	Heat-Treatments					Repair	White Weld Line	Knife Cutting Edges							Knife Backs						
			Martensite	Tempered Martensite	Tempered Martensite or Martensite with pearlite or ferrite	Bainite	Overheated			Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron	Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron
Early Saxon Cemeteries	Cannington	4^{th} -6^{th}		4						4	1	1	4	3	1			1		7	4		2
	Lovedon Hill	5^{th} -7^{th}		2			2			2	1			2						3	2		
	Empingham	5^{th} -7^{th}		5			1			5					2	4				1		9	2
	Quarrington	5^{th} -7^{th}		1					1	1		1	3		1					4		1	1
	Wasperton	5^{th} -7^{th}	1	1		2				4				1		1	1					1	4
	Edix Hill	6^{th} -7^{th}	2	4	4					10				1			2			3	6		
	Twyford	6^{th} -7^{th}		3					2	3			2						2	1		1	1
	Collingbourne Ducis	6^{th}		4		1			2	5		2	2	1	3	2	4			2	1	2	6
	Collingbourne Ducis	7^{th}	1	3	2	1			6	7		2			1				1	5		1	3
Early Saxon Cemeteries			**4**	**27**	**6**	**4**	**3**		**11**	**41**	**2**	**6**	**11**	**8**	**8**	**7**	**7**	**1**	**3**	**26**	**13**	**15**	**19**
Early Saxon Settlements	West Stow	5^{th} -7^{th}		5					7	5	5	1	2	3	1	3	1			2	6	5	6
	Gwithian	5^{th} -7^{th}				1			1	1			2			1				1			3
	Poundbury	5^{th} -7^{th}		4						4			3							3	4		
Early Saxon Settlements				**9**		**1**			**8**	**10**	**5**	**1**	**7**	**3**	**1**	**4**	**1**	**0**	**0**	**6**	**10**	**5**	**9**
Early Saxon Cemeteries (excluding 7^{th})			**3**	**22**	**4**	**3**	**3**		**5**	**32**	**2**	**4**	**11**	**7**	**8**	**7**	**7**	**1**	**1**	**17**	**13**	**14**	**19**
Early Saxon Cemeteries 7^{th} Century			**1**	**4**	**3**	**1**			**6**	**10**		**2**			**1**				**2**	**6**		**1**	**4**

Table 2.3: Table summarising the heat-treatment methods and alloys used in the cutting edges and backs of the early Saxon settlement and cemetery knives from England.

		Heat-Treatments				White Weld Line	Knife Cutting Edges							Knife Backs						
		Martensite	Tempered Martensite	Tempered Martensite or Martensite with pearlite or ferrite	Bainite		Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron	Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron
Male Age	**15-20**	1	5				6										2	2	1	1
	20-30	1	2		1	1	4			1	1	1		2			2	2	1	
	30-40	2				1	2		1	1							2	1		1
	40-50		1				1		1	2			1	1			1		1	2
	50+								1	1							1			1
Female Age	**15-20**		1			1					1							1		
	20-30		2			2				1	1	1	2				2	2	2	1
	30-40		4			1	4				1	2	2	3		1	1		2	2
	40-50	1	1			1	2			2		2				1	3	1	1	
	50+		1				1					1					1			1
Male RAIC	**1-2**		3		1		4		1	3							3	1	1	3
	3-4	1	4		2	2	7		1		1	1		2			2	1	2	2
	5+	1	3				4		1	2			1	1			2	3	1	1
Female RAIC	**1-2**		3			1	3			2	1	1		1		1	3	2		
	3-4	1	2			1	3			1			1			1	3			1
	5-8		2				2				2	5	3	1			1	2	5	3
	9+		2				2						1	1						1
Male		2	10	0	3	2	15	0	3	5	1	1	1	3	0	0	7	5	4	6
Female		1	9	0	0	2	10	0	0	3	3	6	5	3	0	2	7	4	5	5
Under 15										2		1					2			1

Table 2.4 : Table summarising the heat-treatment methods and alloys used in the cutting edges and backs of the early Saxon cemetery knives, grouped by the sex, age and status of the individual buried.

	Heat-Treatments						Knife Cutting Edges							Knife Backs						
	Martensite	Tempered Martensite	Tempered Martensite or Martensite with pearlite or ferrite	Bainite	Overheated	Repair	White Weld Line	Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron	Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron
Fishamble Street	6	3	1		1		8	10		1	1				2		1	3	1	3	2
Winetavern Street	1	1		3			6	5				1								3	3
Christchurch Place	12	2	2	1		1	13	17		1					1		2	3	2	7	3
High Street	3	1					2	4						1					1	2	2

Table 2.5: Table summarising the heat-treatment methods and alloys used in the cutting edges and backs of the knives from Viking Dublin, grouped by the area excavated.

		Heat-Treatments							Knife Cutting Edges							Knife Backs						
		Martensite	Tempered Martensite	Tempered Martensite or Martensite with pearlite or ferrite	Bainite	Overheated	Repair	White Weld Line	Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron	Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron
	Early Saxon	3	31	4	4	3		13	21	9	4	9	2	1	6	2	2	2	9	5	10	21
Middle to Late Saxon Settlements	Rural	1	17	1	2		4	24	21	2	2	4	0	2	3	0	1	1	7	7	3	15
	High Status	0	19	1	1	1		17	53	9	3	11	5	3	0	5	1	1	11	38	8	17
	Urban	8	28	14	3	3	1	15	39	0	1	2	1	0	2	4	0	3	6	6	15	11
	Viking Dublin	23	8	4	4		1	29	21	9	4	9	2	1	6	2	2	2	9	5	10	21

Table 2.6: Table summarising the heat-treatment methods and alloys used in the cutting edges and backs of the knives from England and Viking Dublin. The middle and late Saxon settlements have been grouped by whether they are rural, high status or urban sites.

Site	Types	Heat-Treatments						Knife Cutting Edges							Knife Backs						
		Martensite	Tempered Martensite	Tempered Martensite or Martensite with pearlite or ferrite	Bainite	Overheated	Repair	White Weld Line	Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron	Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron
Early Saxon	**0**		1						1			6	8	7	3			1	7	7	6	4
	1	1	9	4	1	2		10	16	1	3	6		3	1	2		1	10	5	3	8
	2	3	13	1	2	2		6	19	2	2	1		2				1	10	5	4	10
	3		1		1			1	2	1		2	1		5					2	3	5
	4		6	1					7	1						1				2	4	
	5		5		1	2		2	6	2	2	7	1		5	5	1		9	2		6
Middle-Late Saxon	**0**						1	1			1	3	1		4				3	1		5
	1		4						4											1	2	1
	2	3	29	9	3		3	26	44	10	5	4	2	1	1	2	1		11	24	10	19
	3									1		4			1				1		1	4
	4		1		1				2		1								1	1		1
	5		2					1	2							2						
Late Saxon	**0**											1	6	3	1			1	1	5	2	2
	1	3	14	3	1			8	21	3	2	4	1	1		4		1	4	10	5	8
	2	2	12	2	1	1		9	17	2			1	1				1	1	8	3	8
	3											3			2				2	1		2
	4		1			1		1	1	1			1						1	2		
	5		2					1	2	2	1					2		2				1
Viking Dublin	**0**							2			1	1	1		2			1		1	1	2
	1	6	3	2	1			9	12											1	3	8
	2	14	5		1		1	14	19										5	4	5	6
	3							1				1							1			
	4																					
	5							4	7							3		3				1

Table 2.7: Table summarising the heat-treatment methods and alloys used in the cutting edges and backs of the knives first grouped by period but then also distributed by the knife manufacturing methods used to construct them.

Types	Back Shape					Tang Interface					Knife Wear				
	A	B	C	D	X	1	2	3	4	X	None	Slight	Some	Heavy	Unknown
0	6	31	1	4	4	19	5	6	5	3	10	8	13	5	5
1	7	32		16	3	24	3	12	4	2	6	12	21	4	1
2	47	66		11	10	47	7	28	8	16	24	37	32	6	8
3	3	7		3	7	6	5	2	2	1	2	2	6	2	4
4	2	8	1	2	1	4	1			1	2	2	1		1
5	4	10	1	8	2	11	3	3		1	5	5	6		2

Table 2.8: Table summarising the knife shape, tang interface and amount of wear based on the manufacturing types present.

	Knife Cutting Edges						
	Heat Treated	High Carbon Steel	Mid Carbon Steel	Low Carbon Steel	Ferritic Iron	Phosphoric Iron	Piled Iron
No Wear	28	4	3	6	1	3	4
Slight Wear	50	2	4	4	4	2	1
Some Wear	38	13	4	11	2	6	5
Heavy Wear	6	2		2	2	1	4

Table 2.9: Table showing the alloys present in the cutting edges compared to the wear observed.

		Manufacturing Types					
		0	**1**	**2**	**3**	**4**	**5**
Male Age	**15-20**			4		1	
	20-30	2	1	1			2
	30-40		1	1		1	1
	40+	1	4		1		1
Female Age	**15-20**	1				1	
	20-30	2	1		4		1
	30-40	1	2	2		2	2
	40+	3	2	3			
Male RAIC	**1-2**		2	3	1		
	3-4	2	2	2	1	1	2
	5+	1	2	2		1	2
Female RAIC	**1-2**	1	3	1	1		1
	3-4	1		3			1
	5-8	5	2	1	2	2	
	9+				1	1	1
Male		3	6	7	2	2	4
Female		7	5	5	5	3	3
Under 15		2		1			

Table 2.10: Table showing the distribution of different manufacturing methods by the sex, age and status of the individual buried.

		Knife Wear			
		None	Slight	Some	Heavy
Age	**15-20**	2	4	2	2
	20-30	4	6	6	4
	30-40	6	5	3	6
	40-50	4	2	4	4
	50+		1	2	
Male RAIC	**1-2**	1	1	3	1
	3-4	3	4	3	
	5+	3	2	1	
Female RAIC	**1-2**	1	4	2	
	3-4	3	2	1	
	5-8	2	5	5	
	9+	1		2	
Male		7	7	7	1
Female		7	11	10	
Under 15		1	1	2	

Table 2.11: Table showing the distribution of knife wear by the sex, age and status of the individual buried.

		Manufacturing Types					
		0	**1**	**2**	**3**	**4**	**5**
England	Middle-Late Saxon Settlements	9	4	67	6	3	2
	Anglo-Scandinavian	10	25	15	3	3	5
	Anglo-Norman Winchester	1	7	6	2		
Ireland	Pre-Viking, 6th-10th	2		2	1		1
	Dublin, 10th- Early 11th	3	3	9	1		1
	Dublin, 11th	1	9	7			4
	Dublin, 11th-12th	2	1	3			1
Viking Europe	Helgö, 5th-9th	3	3	4			3
	Iceland, 10th-11th		5		1		
	Denmark	8	26	1			1
	Novgorod, 10th		8				
	Novgorod, 11th		12		3		
	Novgorod, 12th	1	24	15	2		

Table 2.12: Table showing the distribution of different manufacturing methods in England, Ireland and the rest of Viking Europe, including the Viking knives from Denmark (Lyngstrøm 2008) and Novgorod (Thompson et al. 1967).

	Early Saxon	Middle to Late Saxon			Viking
	Gwithian	**Sedgeford**	**Wharram Percy**	**York**	**Helgö**
High Carbon	1			1	5
Mid Carbon				1	5
Low Carbon	1		2	3	8
Ferritic Iron			1		8
Phosphoric Iron	1	5	3	1	6
Piled Iron	2	3	3	3	6

Table 2.13: Table showing the distribution of different iron alloys in the stock iron at various sites including Wharram Percy (McDonnell 2000; McDonnell et al. Forthcoming), York (McDonnell et al. Forthcoming) and Helgö (Modin & Lagerquist 1978). The bars from Gwithian and Sedgeford were examined while studying the knives.

Chapter 3: Glossary of Terms

Alloy: A compound of two or more chemical elements of which at least one is a metal.

Age hardening: The precipitation of supersaturated carbon either by slight re-heating after quenching or during burial. The effect is indicated by the presence of small etch pits.

Annealing: A heat treatment process, that involves heating the metal to soften the material and remove deformation, resulting from cold working. Cooling at a suitable rate will produce discrete changes in microstructure and properties.

Austenite: A face-centred-cubic gamma-iron containing alloying elements in solid solution, in particular carbon, present in the iron-carbon phase diagram.

Bainite: A product of isothermal transformation of steel, formed between about 500°C and the martensitic transformation temperature. Upper bainite is distinguished by its feathery structure and lower bainite is indistinguishable from tempered martensite under the light microscope. The hardness range for bainite is between 200-600 HV.

Cementite (Fe_3C): A very hard and brittle compound of iron and carbon commonly known as iron carbide, the filaments of which only occur in steel with carbon above 0.8%.

Cold working: The plastic deformation of a metal at the temperature low enough to cause permanent strain hardening. The treatment usually consists of rolling, hammering, or drawing at room temperature when the hardness and tensile strength are increased with the amount of cold work, but the ductility and impact strength are reduced.

Carburisation: Absorption and diffusion of carbon into solid ferrous alloys by heating, to a temperature usually above the temperature at which ferrite begins to separate from austenite, in contact with a suitable carbonaceous material.

De-carburisation: Loss of carbon from the surface layer of a carbon containing alloy due to reaction with one or more chemical substances in a medium that contacts the surface (Samuels 1999: 432).

Diffusion: The migration of one alloy or metal into another. Usually heat is required for this process to occur.

Embrittlement: A weakness in metal due to trace elements or quenching without tempering.

Etching: Subjecting the surface of the metal to preferential chemical or electrolytic attack to reveal structural details.

Ferrite: Pure iron is in its single phase at ambient temperatures. This alloy may contain very low percentages of alloying elements in solid solution, some of which can precipitate out during burial. The ferrite grain size can vary owing to minor levels of alloying elements, heat treatments and if it has been worked. The hardness range for ferrite is between 120-160HV.

Ghosting: The appearance of some phosphoric iron microstructures after the section has been etched with nital**.**

Grain: In crystalline metals, the grain is an area or zone of crystal growth in a uniform and homogeneous form.

Heat treatment: Heating and cooling a solid metal or alloy so that desired structures and properties are attained. Heating for the sole purpose of hot working is excluded from the meaning of this term.

High Carbon Steel: Iron with over 0.7% carbon, but not a cast iron with over 2% carbon**.**

Hot working: Deformation of the metal or alloy above the temperature necessary for plastic deformation.

Low Carbon Steel: Iron with up to 0.3% carbon**.**

Martensite: Product of rapidly quenched steels. It is a meta-stable phase and the structure is normally relieved by tempering to produce the dark etching constituent, tempered martensite. The hardness range for martensite is above 700HV.

Mid Carbon Steel: Iron with between 0.3%-0.7% carbon**.**

Nital: Is a solution of alcohol and nitric acid commonly used for routine etching of metals.

Pearlite: Product of slow cooled steels, a lamellar structure of alternating plates of ferrite and cementite of eutectoid composition. The hardness range for pearlite is between 150-250HV although fine pearlite has a slightly high HV from 200-350HV.

Phase Diagram: A diagram showing the different phases of the structure of the metal over the range of conditions.

Phosphoric iron: Iron containing phosphorus (0.15% and above) as an alloying element. Signs of phosphoric iron include large grain sizes, resistance to carbon diffusion and 'ghosting' due to segregation. The hardness range for phosphoric iron is between 180-300 HV.

Piling (or banding): A process in which several bars are stacked and forged together. It is not possible to determine whether or not the piled structures are the result of deliberate manufacture or whether they were produced accidentally by the segregation of phosphorous or carbon during the smelting or refining processes.

Quenching: Is the rapid cooling to harden steel, with over 0.3% carbon, at such a quick rate that a substantial amount of austenite is transformed to martensite.

Spheriodisation: Heating and cooling to produce a spheroidal or globular form of carbide in steel, usually the result of prolonged holding at a low temperature.

Slag inclusions: A non metallic material in a solid metallic matrix.

Slag stringers: Small pieces of slag that have become incorporated into the metal and are elongated as a result of working the metal to shape it.

Steel: An iron based alloy usually containing carbon and other alloying elements.

Tempering: Reheating hardened steel for the purpose of decreasing the hardness and/or increasing toughness. The hardness range for tempered martensite is between 500-700 HV.

Welding: A joint between two metals made by heating and joining the separate parts with no solder applied.

Widmanstatten structure: A structure characterised by a geometric pattern resulting from the formation of a new phase along certain crystallographic planes of the parent solid solution.

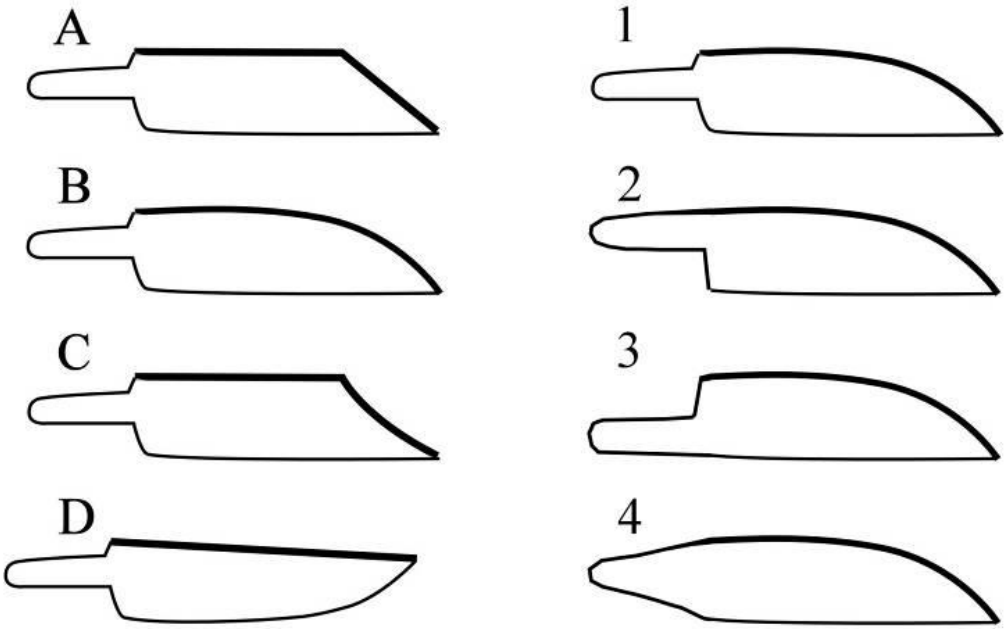


Figure 3.1: The new knife typology based on the shape of the knife back alone. Also included is the simple knife typology for the tang interface.

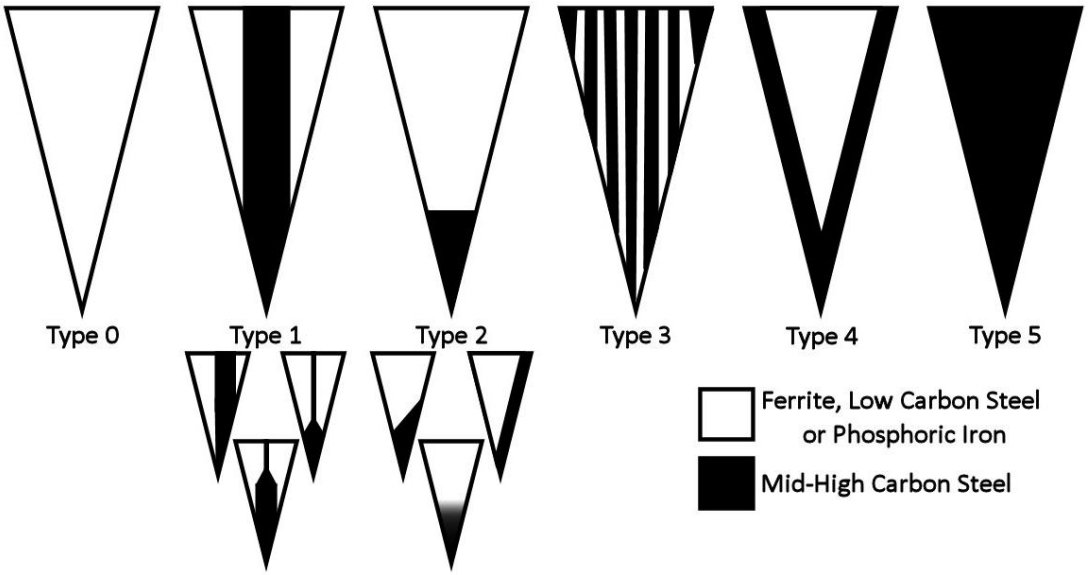


Figure 3.2: Simplified knife manufacturing typology based on blade cross sections (adapted from Tylecote and Gilmour 1986). Some of the variations on the type 1 and 2 blades are also shown below.

Chapter 4: West Stow

Knife Descriptions

Knife 72

The x-radiograph revealed no evidence for a weld line and only slight evidence of a spotted texture. A single section was removed from the broken end of the knife.

Figure 4.1: Photograph and x-radiograph of knife 72, the lines show where the sections were removed.

Un-etched there were lots of sub-rounded or sub-angular single phased inclusions throughout the knife and some of those present were large multi-phased. The inclusions were vertically elongated particularly in the knife back.

When etched the cutting edge consisted of medium to large grains of ferrite with some ghosting (*Average 183HV*). The back of the knife also consisted of medium to large grains of ferrite, again with some ghosting in areas (*Average 169HV, Range 148-192HV*), that in addition to the extremely hardness values suggest a phosphoric iron. SEM-EDS analysis confirmed the presence of phosphorus (0.3%-0.6%). There were vertical bands of mid carbon steel, ferrite with pearlite, and some Widmanstätten (*Average 169HV, Range 148-183HV*).

Knife 86

The x-radiograph of this knife revealed one dark striation, possibly indicating a type 2 knife. There was slight evidence for a spotted cutting edge. The knife was corroded, particularly at the end of the tang.

Figure 4.2: Photograph and x-radiograph of knife 86, the lines show where the sections were removed.

Two half sections were removed during cutting. The cutting edge section had few single-phased angular inclusions which were mostly small and spherical. There were also some larger sub-rounded inclusions. The knife back was similar to the cutting edge but also had larger sub-rounded inclusions which were multi-phased.

When etched the cutting edge was revealed to consist of very large grains of ferrite with ghosting (*Average 169HV, Range 127-221HV*), this and the high hardness values suggested that this was phosphoric iron. Confirmed by SEM-EDS analysis, which revealed between 0.3-0.5% phosphorus. There was a similar area of large grained ferrite at the back of the knife (*Average 182HV, Range 168-192HV*), again there was a high amount of phosphorus present (0.4-0.5%). Half way between these two areas there was a band of smaller grained ferrite where little ghosting was present (*Average 188HV, Range 161-201HV*). SEM analysis of this knife revealed up to 0.3% phosphorus in this area.

Knife 100

There was clear evidence for a weld line and a spotted texture was seen throughout the knife, but this is more likely due to the corrosion. This suggested a type 2 knife.

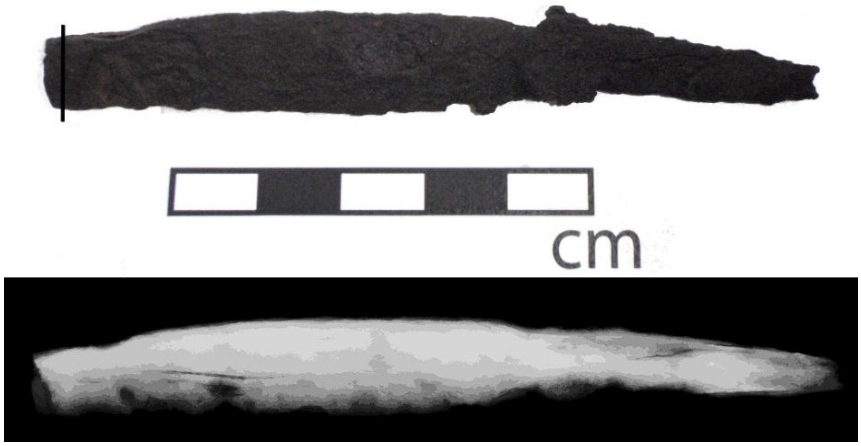


Figure 4.3: Photograph and x-radiograph of knife 100, the line show where the section was removed.

One section across the broken tip of the knife was removed. There were very few single phased inclusions all sub-rounded. A convex band of sub-angular and elongated single phased inclusions separated this cutting edge from the back. Above this there was another line of inclusions which were multi-phased and sub-angular, between these bands were small single phased sub-rounded inclusions. The back had many bands of elongated single phased inclusions separating areas of single phased sub-angular inclusions.

Once etched the section revealed that the cutting edge consisted of martensite (549*HV*, *Average 498HV, Range 412-593HV*). Above this area and the curved band of inclusions the microstructure transforms to pearlite with some ferrite (*Average 200HV, Range 148-244HV*) and the carbon content reduces up to the white weld line (*Average 209HV, Range 196-221HV*). SEM analysis of the weld line revealed the presence of arsenic (0.5-0.6%) and large quantities of Nickel (0.7-1.2%). Beyond this weld line the back consisted of ferrite with pearlite (*Average 143HV, Range 132-148HV*) throughout this area ghosting was seen suggesting some phosphorus is present, this was confirmed by SEM-EDS analysis (0.2%-0.4% phosphorus). Carbon also diffused from the higher carbon iron back which consisted from pearlite (*Average 293HV, Range 250-340HV*). The clear presence of a weld line suggests that this knife is a type 2 iron knife

with a piled back of ferrite and high carbon steel. As there were two weld lines it is possible that the knife was repaired in antiquity using a high carbon steel. This was then re-heat treated to create a hard cutting edge.

Knife 330

X-radiography of this knife revealed that it was badly worn and corroded, especially the cutting edge. There was no weld line or spotted texture.

Figure 4.4: Photograph and x-radiograph of knife 330, the lines show where the sections were removed.

Two sections were removed, one from the knife tip but as this does not always represent the microstructure of the whole knife therefore another section was removed from the cutting edge. Throughout the sections there were many single- and multi-phased inclusions which were mostly sub-rounded or rounded. The section from the knife tip had more angular inclusions especially at the grain boundaries.

After etching the knife appeared to consist of predominately tempered martensite and bainite. The cutting edge of the knife was tempered martensite (*Average 549HV, Range 362-549HV*). Near the cutting edge there was a band of small grains of ferrite (*Average 208HV, Range 183-323HV*) there were also areas of pearlite with ferrite, martensite and ferrite and tempered martensite (0.6% carbon, *Average 333HV, Range 201-841HV*). There were many bands of etched resistant areas which suggested enrichment in arsenic, this was confirmed by SEM-EDS which revealed up to 0.5% arsenic and 0.6% Nickel in areas.

Knife 433

The x-radiograph revealed no evidence for a weld line and only slight evidence of a spotted texture. Two half sections were removed from the knife.

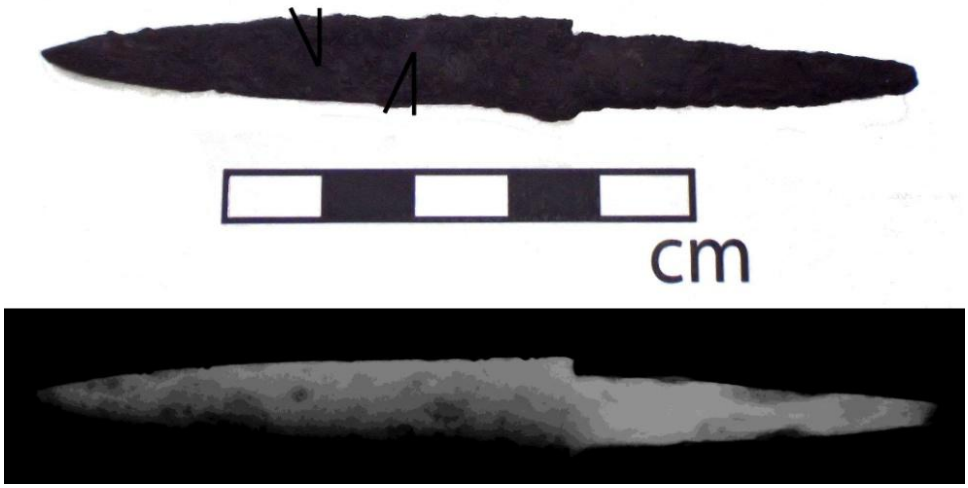


Figure 4.5: Photograph and x-radiograph of knife 433, the lines show where the sections were removed.

Un-etched there were lots of vertically elongated single phased inclusions. Between these bands there were many rounded or elongated inclusion present mostly single phased.

When etched the cutting edge consisted of a strip of tempered martensite (453*HV*, *Average 330HV, Range 321-509HV*) which ran throughout the length of the blade, although near the back this transformed to pearlite with ferrite (*Average 375HV, Range 321-441HV*). To one side of this strip there was a band of large grained ferrite with ghosting and no carbon diffusion (*Average 180HV, Range 114-321HV*), that in addition to the extremely hardness values suggest a phosphoric iron. SEM-EDS analysis confirmed the presence of traces of phosphorus in areas (up to 0.2%). The other side consisted of small grains of ferrite with some diffusion (*Average 262HV, Range 226-303HV*), SEM analysis again revealed phosphorus.

Knife 556

The x-radiograph of this knife revealed no evidence for either a weld line or the spotted appearance associated with steel. Two sections were removed, one from the knife tip but as this does not always represent the microstructure of the whole knife therefore another section was removed from the cutting edge.

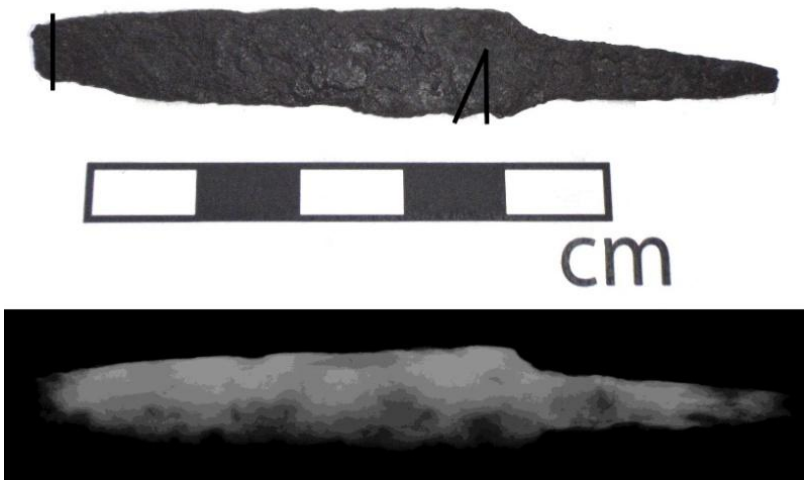


Figure 4.6: Photograph and x-radiograph of knife 556, the lines show where the sections were removed.

The cutting edge section had some single-phased sub-angular inclusions and sub-rounded which were mostly small. The same type of inclusions was also present throughout the knife back section. When etched the entire section consisted of ferrite with carbides (*Average 205HV, Range 183-257HV*). SEM analysis of this knife revealed some phosphorus in the sample (up to 0.4%). This knife was a type 0 knife with ferritic iron present throughout. The microstructure suggests that it might have been exposed to excessive temperatures for long periods of time.

Knife 659

The x-radiograph revealed a number of possible weld lines and also only evidence of a spotted texture. Two half sections were removed from the sample but the cutting edge sample was entirely corroded, but the back section extended beyond the lines seen in the x-radiograph.

Figure 4.7: Photograph and x-radiograph of knife 659, the lines show where the sections were removed.

Un-etched there was a clear convex band of single phased inclusions. These separated two areas, the cutting edge below had few small single-phased sub-angular inclusions. Above this band there were more bands of inclusions but between these bands there were few inclusions in the back, those present were single-phased and either sub-rounded or sub-angular in shape.

When etched the band of inclusions turned out to be a clear white weld line which was enriched in Nickel (0.6-0.9%). Below this line the cutting edge consisted of pearlite with ferrite ranging from 0.7% to 0.6% (154*HV, Average 165HV, Range 107-244HV*). There was carbon diffusion across the weld line into the piled knife back. This consisted of small grains of ferrite with some pearlite (0.1-0.2% carbon, *Average 140HV, Range 137-148HV*), there was no evidence for ghosting. SEM-EDS analysis confirmed the absence of phosphorus.

Knife 794

The x-radiograph of this knife revealed a heavily worn knife. There was no evidence for a weld line or the spotted appearance associated with steel cutting edges.

Figure 4.8: Photograph and x-radiograph of knife 794, the line show where the section was removed.

A single section was removed from the broken end of the knife. Prior to etching there were several features that were clearly visible, the first and most significant was the huge corrosion crack that runs vertically from the back to tip. There were also two clear lines of large elongated single-phased inclusions. There were very few slag inclusions in the metal and those that were present were small and single-phased.

When etched there were three different microstructures. The two bands of inclusions turned out to be white weld lines (*Average 271HV*) these separated the centre strip from the two ferrite flanks. The one on the left had small grained ferrite with very little carbon diffusion (*Average 196HV, Range 183-210HV*) while the one on the right was similar but there was some carbon diffusion (*Average 210HV, Range 171-232HV*). The centre strip and cutting consisted of bainite suggesting a heat-treated high carbon steel (303*HV, Average 297HV, Range 271-340HV*). The corrosion crack may originally have been a weld line but it did not seem to separate two different pieces of steel. SEM analysis of this knife revealed only traces of phosphorus (up to 0.1%).

Knife 828

There was no evidence for a weld line and no spotted texture seen in the knife, but the corrosion present in the knife may have hamper identification. Two half sections were removed from the knife.

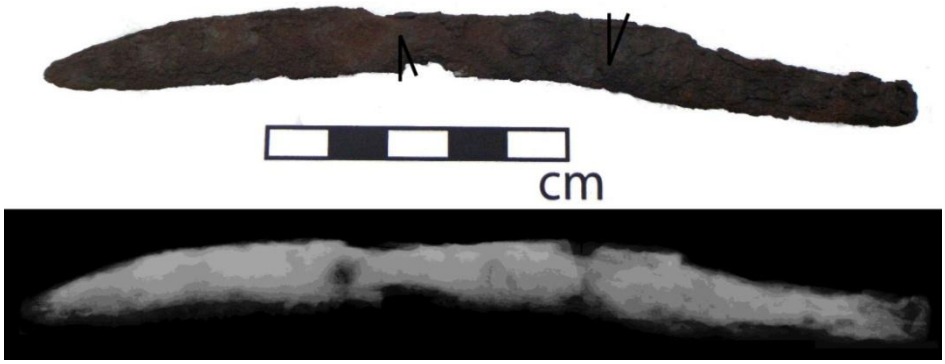


Figure 4.9: Photograph and x-radiograph of knife 828, the lines show where the sections were removed.

Prior to etching these sections revealed lots of slag inclusions present throughout the knife. The only exception was the cutting edge as no inclusions were present. A line of large single-phased sub-rounded inclusions separated this area from the back where a variety of inclusions of all shapes and sizes were present although most were single phased. Even so there were two distinct regions, just after the weld line there were elongated inclusions but beyond a corrosion band the inclusions were irregular and angular.

Once etched cutting edge consisted of pearlite to pearlite with ferrite, 0.8-0.6% carbon (*271HV, Average 245HV, Range 210-271HV*) which had diffused across the white weld line. The white weld line present in the knife back, this was enriched in arsenic and Nickel and had an increased hardness (*Average 210HV*). Beyond the white weld line the back seems to have been constructed from two different irons. The closest piece to the weld line had large grains with ghosting (*Average 164HV, Range 148-175HV*). There was some diffusion over the weld line but even so the ghosting and high hardness suggested some phosphorus is present, this was confirmed by SEM-EDS analysis (0.4-0.6% phosphorus). The area at the back on the other hand was a low 0.1-0.3% carbon steel with ferrite and pearlite, with less phosphorus present (*Average 171HV, Range 152-201HV*, 0.2-0.3%).

Knife 928

The x-radiograph of this knife revealed no dark striations suggesting weld lines. There was slight evidence for a spotted cutting edge but this may have just been the result of heavy corrosion.

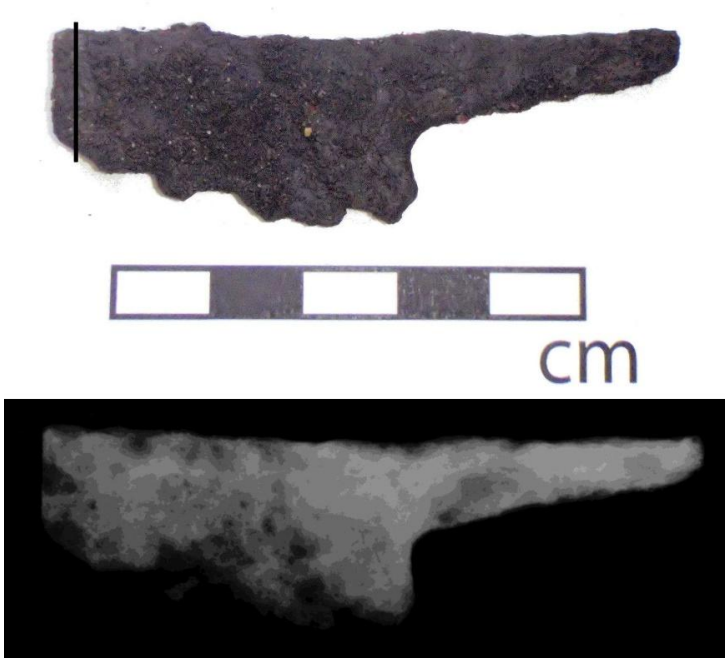


Figure 4.10: Photograph and x-radiograph of knife 928, the line show where the section was removed.

One section was removed but during cutting this split in two due to bad corrosion penetration. The slag inclusions present throughout both sections were either elongated vertically or sub-rounded and were mostly single phased.

When etched the entire knife looked very homogeneous with small to medium sized grains of ferrite (168*HV, Average 148HV, Range 107-175HV*). The cutting edge of the knife was particularly corroded but there was no evidence for a weld line. At the back of the knife there was an area of larger grains of ferrite. SEM analysis of this knife revealed only traces of phosphorus in areas (up to 0.2%).

Knife 973

The x-ray revealed a clear spotted texture and also slight traces of a weld line. There was also quite a lot of corrosion present at the cutting edge that hampered identification of weld lines.

Figure 4.11: Photograph and x-radiograph of knife 973, the lines show where the section was removed.

An attempt to remove one half section resulted in the knife breaking, therefore a full section was taken to reduce the stress on the knife. Prior to etching the section of the knife revealed at least three bands of inclusions which were small, single-phased and sub-rounded. At the cutting edge there were very few inclusions present, and these were single phased and sub-angular. Closer to the back of the knife there was a piece of metal that had many rounded and multi-phased inclusions.

Once etched, the cutting edge consisted of small to medium grains of ferrite with some pearlite, up to 0.2% carbon (*175HV, Average 165HV, Range 148-175HV*). The two bands nearer the back were white weld lines enriched in arsenic and copper and had an increased hardness (*Average 252HV, Range 232-271HV*). Between these white weld line the microstructure was small grains of ferrite with pearlite with areas of pearlite and ferrite (0.3-0.6% carbon, *Average 201HV, Range 183-232HV*). In the back were most of the slag inclusions were the carbon content had decreased dramatically to ferrite with some pearlite (*Average 151HV, Range 132-161HV*). There was some diffusion over both weld lines into the cutting edge and back but SEM-EDS analysis confirmed only traces in the cutting edge section (0.1%-0.2% phosphorus).

Knife 1135

The x-radiograph revealed a clear weld line and also only evidence of a spotted texture. Two half sections were removed from the sample.

Figure 4.12: Photograph and x-radiograph of knife 1135, the lines show where the sections were removed.

Un-etched there was a clear convex band of small, single phased, sub-rounded inclusions. These separated two areas, the cutting edge below which had few small single-phased sub-angular inclusions. Above this weld line there were more bands of sub-angular, single-phased inclusions but between these bands there were quite a number of single- and multi-phased inclusions in a variety of shapes and sizes.

When etched the band of inclusions turned out to be a clear white weld line (*Average 313HV, Range 321-399HV*) which was enriched in (0.4-0.5% arsenic). Below this line the cutting edge consisted of tempered martensite (473*HV, Average 502HV, Range 473-509HV*). There was carbon diffusion across the weld line into the piled knife back. This consisted of small grains of ferrite with some pearlite (0-0.2% carbon, *Average 195HV, Range 168-238HV*), there was no evidence for ghosting. The very back of the knife beyond the slag inclusion bands consisted of extremely large grains of ferrite but with no ghosting (*Average 147HV, Range 118-168HV*). SEM-EDS analysis confirmed the absence of phosphorus throughout the knife back.

Knife 1661

X-radiography of this knife revealed that it was badly corroded, especially at the tang interface. There was a possible weld line and the spotted texture below which suggested a heat-treated steel cutting edge.

Figure 4.13: Photograph and x-radiograph of knife 1661, the lines show where the sections were removed.

Two half sections were taken from the knife. In the un-etched there was no evidence for a transverse weld line. The corrosion had followed a line of slag inclusions that had penetrated the cutting edge, splitting it into two halves. In this area there were very few single-phased and sub-rounded inclusions. There were two bands of single-phased elongated inclusions. Between the bands there were a few single-phased inclusions, outside these bands the inclusions were sub-angular.

Once etched it was clear that the two bands of inclusions, which turned into white weld lines, separated a core from sheath surrounding the knife. There was lots of carbon diffusion across the white weld lines. The centre of the knife had extremely large to medium grains of ferrite (*Average 117HV, Range 103-132HV*). The large grains and low carbon content of this area suggested a phosphoric iron but SEM-EDS analysis revealed no phosphorus. The cutting edge had a pearlite with ferrite microstructure, 0.6-0.7% carbon (201*HV, Average 221HV, Range 201-244HV*), while the edges were a low carbon steel (0-0.3%), with ferrite and pearlite (*Average 166HV, Range 151-201HV*).

Knife 2191

The x-radiograph revealed a badly corroded knife, but there were hints of a weld line and also evidence of a spotted texture. A single section was removed from the knife, but this section broke in two due to corrosion penetration.

Figure 4.14: Photograph and x-radiograph of knife 2191, the line show where the section was removed.

In the un-etched condition the knife seemed very clean of slag inclusions. The back section was free of inclusions but the cutting edge had a few single-phased and rounded inclusions.

When etched there were no clear white weld lines or separation of microstructures. The cutting edge of the knife consisted of pearlite with ferrite (386*HV, Average 307HV, Range 286-386HV*). There was a decreasing amount of carbon as the carbon diffused from the cutting edge into the back (*Average 159HV, Range 123-205HV*). The back section of the knife had medium to large grains of ferrite with no ghosting. SEM-EDS analysis confirmed the presence of phosphorus in areas.

This knife was classified as a type 2 knife consisting of pearlite cutting edge with a ferritic iron back. This knife was either constructed by butt-welding a steel cutting edge on to the tip, possibly where the corrosion products are now or in an extremely clean way (as seen by the absence of other inclusions). Alternatively

the knife may have been carburised to increase the carbon content at the cutting edge. The knife was not heat-treated,

Knife 2208

The x-ray revealed a clear spotted texture and also a weld line. Two half sections were removed from the knife.

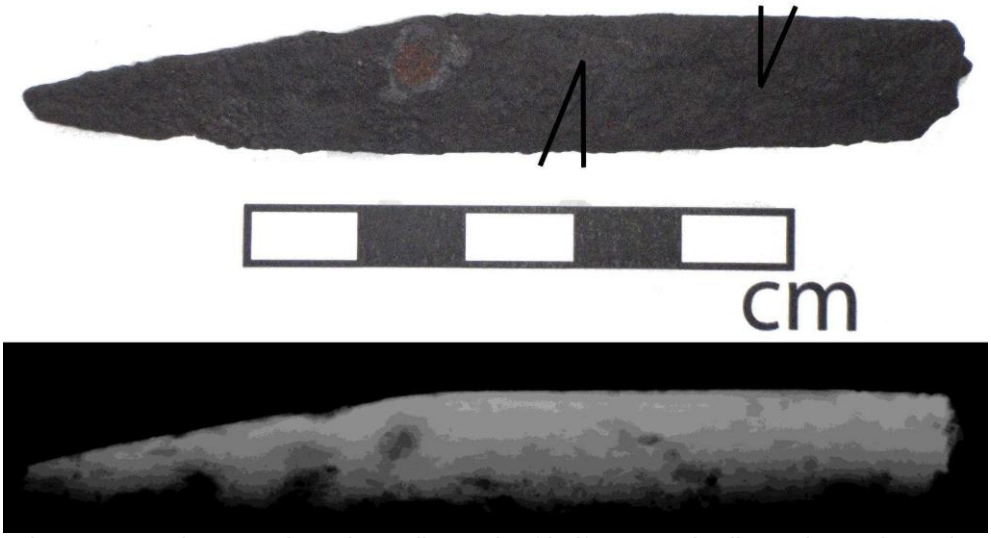


Figure 4.15: Photograph and x-radiograph of knife 2208, the lines show where the sections were removed.

Prior to etching these sections revealed lots of slag inclusions present throughout the knife. The only exception was the cutting edge where only a few single-phased, elongated inclusions were present. A line of small single-phased angular inclusions separated this area from the back where a variety of inclusions of all shapes and sizes were present.

Once etched cutting edge consisted of tempered martensite (*549HV, Average 469HV, Range 374-549HV*), with carbon diffusion across the white weld line. The white weld line was enriched in arsenic and had an increased hardness (*Average 280HV, Range 257-303HV*). Beyond the white weld line the back seems to have been constructed from heterogeneous iron. There were two distinctive microstructures the majority of the knife had medium to large grains of ferrite with ghosting (*Average 170HV, Range 152-201HV*). There was some diffusion over the weld line but even so the ghosting and high hardness suggested some phosphorus is present, this was confirmed by SEM-EDS analysis (0.2%-0.4% phosphorus). The other microstructure was bands and areas with pearlite and ferrite (*Average 139HV, Range 137-140HV*).

Summary Assemblage Knives

Knife No	Feature	Context	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
			Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
4	Layer 2	Ground Surface	B	3	110	80	30	12	8	slight			
47			B	3	55	20	35	6	5	heavy	x	y	
54	Layer 2	Ground Surface	A	3	120	76	44	16	8	slight	y	y	
57	Layer 2	Ground Surface	x	x	20	20	x	14	x	unknown	y	x	fragment
68	Layer 2	Ground Surface	D	1	72	34	38	16	5	none			broken at tip
72	Layer 2	Ground Surface	x	4	79	58	21	12	6	unknown	x	y	fragment
73			B	4	110	65	45	10	5	slight	y	x	
76	Layer 2	Ground Surface	A	1	108	70	38	10	6	none			
86	Layer 2	Ground Surface	B	2	100	50	50	14	10	none	y	x	
97	Layer 2	Ground Surface	B	1	104	64	40	12	7	none	x	y	broken at tip
100	Layer 2	Ground Surface	B	4	100	78	22	12	10	none	y	?	broken at tip
108	SFB 3	SFB	B	1	106	74	32	18	10	none			
147	SFB 8	SFB	C	1	114	30	84	12	8	slight			
263	Hollow 1	Hollow	A	3	80	56	24	10	7	none			notch in tang?
279	SFB 12	SFB	B	1	140	90	50	20	12	none			
300	Pit 44	Pit	A	1	128	90	38	12	5	some			
330	Pit 44	Pit	A	1	88	52	36	18	12	slight	y	x	
335	SFB 3	SFB	B	X	80	80	x	14	x	none			broken tang
336	SFB 15	SFB	D	1	54	40	14	9	6	none			
346	SFB 3	SFB	D	2	50	42	8	14	8	none			
403	Layer 2	Ground Surface	D	2	72	42	30	12	8	none	y	y	
433	Layer 2	Ground Surface	B	1	96	60	36	12	8	slight	x	y	
462	Layer 2	Ground Surface	A	3	86	50	36	10	7	some			
479	Layer 2	Ground Surface	x	4	70	40	30	18	4	unknown	?	y	fragment
486	Layer 2	Ground Surface	D	1	90	54	36	14	9	slight	x	y	
494	Building 2	Hall	B	1	140	80	60	22	10	none			
504	SFB 27	SFB	D	3	110	70	40	14	8	some	y	Y	
522	Layer 2	Ground Surface	x	x									
532			A	3	70	45	25	7	5	slight	x	Y	fragment
550	Layer 2	Ground Surface	A	1	146	96	50	22	14	slight			
556			B	4	76	48	28	10	6	none	y	x	
566	Layer 2	Ground Surface	D	1	84	56	28	12	8	none			
589	SFB 22	SFB	x	1	64	48	16	22	8	unknown			
641	SFB 22	SFB	A	x	60	60	x	12	x	slight			fragment

Table 4.1: Summary table of the knives from West Stow showing the measurements, typologies assigned and the results from the x-radiograph analysis.

Knife No	Feature	Context	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
			Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
655	SFB 21	SFB	D	2	170	120	50	38	16	none			broken tang
659	Layer 2	Ground Surface	B	1	132	86	54	16	8	none	?	y	
682	SFB 24	SFB	x	x	60	60	x	14	x	unknown			fragment
684	SFB 27	SFB	B	1	106	72	34	16	10	some			
720	Layer 2	Ground Surface	B	1	76	36	40	12	8	some			
741	Layer 2	Ground Surface	D	3	120	88	32	14	8	slight	y	y	
746	SFB 22	SFB	x	2	60	22	38	16	10	heavy			broken blade
780			x	3	145	35	110	10	5	some	y	y	broken blade
794	Layer 2	Ground Surface	D	3	78	48	30	12	8	slight			
807	Building 3	Hall	B	1	128	70	58	22	10	heavy			
828	Layer 2	Ground Surface	B	3	150	110	40	16	12	some	y	x	
928	Layer 2	Ground Surface	x	2	68	38	30	20	10	unknown	x	y	fragment
953	SFB 38	SFB	B	1	100	64	36	16	8	slight			
973	SFB 37	SFB	B	1	108	74	34	16	8	slight	x	y	
1084	Layer 2	Ground Surface	x	1	100	46	54	40	12	unknown			broken blade
1134	Ditch	Ditch	A	3	86	56	30	8	5	slight			
1135	Layer 2	Ground Surface	B	4	96	60	36	10	10	slight	y	y	
1138	Layer 2	Ground Surface	x	3	80	80	x	10	x	unknown	y	y	fragment
1200	Layer 2	Ground Surface	D	1	144	64	80	12	10	heavy			broken at tip
1201	Layer 2	Ground Surface	B	2	64	46	18	12	6	none	y	?	
1256	Building 5	Hall	x	1	60	20	40	12	8	some			broken blade
1398			x	1	35	20	15	9	5	unknown	y	x	fragment
1404	SFB 45	SFB	B	2	116	80	36	12	9	slight			
1409	SFB 45	SFB	x	x									fragment
1447	SFB 49	SFB	D	3	120	74	46	12	8	heavy			
1661			C	1	118	68	50	20	8	slight	x	y	
1672	Layer 2	Ground Surface	A	1	98	60	38	14	8	some	x	x	
1720			A	3	50	20	30	6	5	unknown	x	x	fragment
1826	SFB 59	SFB	C	2	136	96	40	36	12	none			
1882	Layer 2	Ground Surface	A	1	118	66	52	12	6	some			
1900	SFB 61	SFB	D	1	90	50	40	16	10	some	x	?	broken blade
2077	SFB 66	SFB	D	1	90	46	44	14	8	slight			broken blade
2109	Layer 2	Ground Surface	x	2	136	98	38	24	12	none			broken blade
2191	SFB 65	SFB	x	2	68	30	38	21	6	unknown	?	y	broken blade

Table 1.1 cont: Summary table of the knives from West Stow showing the measurements, typologies assigned and the results from the x-radiograph analysis.

Knife No	Feature	Context	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
			Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
2208	Layer 2	Ground Surface	A	X	90	90	x	13	x	none	y	y	Broken tang
2236	SFB 10	SFB	B	2	80	66	14	14	10	none			
3037	Layer 2	Ground Surface	B	2	88	64	24	12	10	slight	y	y	pivoting knife
3041	Layer 2	Ground Surface	A	3	66	30	36	10	6	some			
3047	Building 7	Hall	A	3	68	30	38	10	6	heavy			
3073	Layer 2	Ground Surface	B	2	110	60	50	12	6	slight			broken blade
3073	Building 7	Hall	B	2	110	60	50	12	6	some			
3088	Building 7	Hall	B	1	86	46	40	12	8	slight			

Table 1.1 cont: Summary table of the knives from West Stow showing the measurements, typologies assigned and the results from the x-radiograph analysis.

SEM-EDS Data

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
72		n.d.	0.4	0.1	n.d.	99.5	0.1	n.d.	n.d.	99.4
		0.1	0.41	n.d.	n.d.	99.5	n.d.	n.d.	n.d.	116.2
		n.d.	0.27	n.d.	n.d.	99.5	0.1	n.d.	0.1	101.4
		0.1	0.43	0.1	n.d.	99.4	n.d.	0.1	n.d.	114.1
		n.d.	0.59	n.d.	n.d.	99.3	n.d.	n.d.	0.1	119.5
		n.d.	0.45	n.d.	n.d.	99.3	0.1	n.d.	0.1	110.0
86	Large Grains	n.d.	0.48	n.d.	n.d.	99.4	n.d.	n.d.	0.1	116.5
		0.1	0.33	n.d.	n.d.	99.4	0.1	n.d.	n.d.	110.4
		n.d.	0.42	0.1	n.d.	99.5	n.d.	n.d.	n.d.	115.9
		n.d.	0.52	n.d.	n.d.	99.2	0.1	0.1	0.1	124.1
	Small Grains	n.d.	0.16	n.d.	n.d.	99.3	0.1	n.d.	0.4	127.5
		n.d.	0.32	0.1	0.1	99.3	n.d.	n.d.	0.2	111.0
	Large Grains	n.d.	0.41	0.1	n.d.	99.0	0.2	0.2	0.1	113.1
		n.d.	0.49	0.1	n.d.	99.0	0.1	0.1	0.2	118.9
100	Cutting Edge	n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	100.5
		0.1	0.10	n.d.	n.d.	99.5	0.2	0.1	n.d.	98.4
		n.d.	n.d.	0.1	n.d.	99.8	n.d.	n.d.	n.d.	96.0
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	101.0
	Cutting Edge 2	0.1	n.d.	0.1	n.d.	99.8	n.d.	n.d.	n.d.	101.2
		n.d.	0.14	n.d.	n.d.	99.7	0.1	n.d.	n.d.	99.2
		0.1	n.d.	n.d.	n.d.	99.7	0.1	n.d.	n.d.	96.8
	White Weldline	0.1	n.d.	n.d.	n.d.	98.5	0.7	0.1	0.6	98.4
		0.1	n.d.	n.d.	n.d.	99.6	0.1	0.1	0.1	104.1
		n.d.	n.d.	0.1	n.d.	98.1	1.2	0.1	0.5	99.6
	Knife back	n.d.	0.26	n.d.	n.d.	99.6	n.d.	n.d.	0.1	96.7
		0.1	0.27	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	97.4
		n.d.	0.20	n.d.	n.d.	99.6	0.1	n.d.	n.d.	106.6
		0.1	n.d.	n.d.	0.1	99.7	n.d.	n.d.	0.1	103.3
		n.d.	0.18	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	101.6
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	100.8
330		0.3	0.10	0.1	0.1	99.3	0.1	n.d.	0.1	102.4
		0.3	n.d.	n.d.	n.d.	99.5	0.1	n.d.	n.d.	99.5
		0.1	n.d.	n.d.	n.d.	99.0	0.3	n.d.	0.5	100.6
		0.1	n.d.	n.d.	0.1	98.8	0.6	n.d.	0.4	99.1
		n.d.	n.d.	n.d.	n.d.	99.1	0.3	0.1	0.5	100.5
		0.1	0.10	n.d.	n.d.	99.2	0.3	0.1	0.2	98.8

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
433	Tempered Martensite	0.1	0.10	n.d.	n.d.	99.4	0.1	0.1	0.2	101.5
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	101.7
		0.1	0.20	n.d.	n.d.	99.4	0.2	n.d.	0.1	104.0
	Small/Large Grains	n.d.	n.d.	n.d.	n.d.	99.7	0.1	n.d.	0.1	105.6
		0.1	n.d.	n.d.	n.d.	99.7	0.1	n.d.	0.1	104.5
		0.2	0.19	n.d.	n.d.	99.5	n.d.	0.1	n.d.	104.8
		0.1	0.16	n.d.	n.d.	99.6	n.d.	n.d.	0.1	104.9
	Small Grains of ferrite	0.1	0.16	n.d.	n.d.	99.3	0.1	0.1	0.2	100.6
		n.d.	0.13	n.d.	n.d.	99.5	0.1	n.d.	0.2	101.1
		n.d.	0.13	n.d.	n.d.	99.7	n.d.	0.2	n.d.	102.2
556		n.d.	0.11	n.d.	n.d.	99.6	0.3	n.d.	n.d.	92.5
		0.1	0.19	n.d.	n.d.	99.3	0.3	0.1	n.d.	95.0
		n.d.	0.18	n.d.	0.1	99.2	0.3	0.1	0.2	92.0
		n.d.	0.38	0.1	n.d.	99.1	0.2	0.1	0.1	99.4
		0.1	n.d.	n.d.	n.d.	99.5	0.3	0.1	n.d.	106.8
		n.d.	n.d.	0.1	0.2	99.5	0.1	n.d.	n.d.	93.8
659	Cutting Edge	0.1	0.12	n.d.	n.d.	99.6	n.d.	n.d.	0.1	120.3
		0.2	n.d.	n.d.	n.d.	99.7	n.d.	0.1	n.d.	97.9
		0.3	n.d.	0.1	0.1	99.3	0.1	n.d.	0.1	99.3
		n.d.	0.12	0.1	0.1	99.5	n.d.	0.1	0.1	101.2
		n.d.	n.d.	n.d.	0.1	99.7	0.2	n.d.	n.d.	102.9
	White Weld line	n.d.	n.d.	n.d.	n.d.	99.3	0.6	n.d.	0.1	99.6
		0.1	n.d.	n.d.	n.d.	98.7	0.9	0.2	n.d.	99.1
	Knife Back	0.1	n.d.	n.d.	n.d.	99.4	0.4	n.d.	n.d.	100.0
		0.1	n.d.	n.d.	n.d.	99.5	0.2	0.1	n.d.	98.0
		0.1	n.d.	n.d.	n.d.	99.4	0.3	0.1	0.1	99.5
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	96.1
		n.d.	n.d.	n.d.	n.d.	99.5	0.3	n.d.	n.d.	103.9
659	Cutting Edge	0.1	0.12	n.d.	n.d.	99.6	n.d.	n.d.	0.1	120.3
		0.2	n.d.	n.d.	n.d.	99.7	n.d.	0.1	n.d.	97.9
		0.3	n.d.	0.1	0.1	99.3	0.1	n.d.	0.1	99.3
		n.d.	0.12	0.1	0.1	99.5	n.d.	0.1	0.1	101.2
		n.d.	n.d.	n.d.	0.1	99.7	0.2	n.d.	n.d.	102.9
	White Weld line	n.d.	n.d.	n.d.	n.d.	99.3	0.6	n.d.	0.1	99.6
		0.1	n.d.	n.d.	n.d.	98.7	0.9	0.2	n.d.	99.1
	Knife Back	0.1	n.d.	n.d.	n.d.	99.4	0.4	n.d.	n.d.	100.0
		0.1	n.d.	n.d.	n.d.	99.5	0.2	0.1	n.d.	98.0
		0.1	n.d.	n.d.	n.d.	99.4	0.3	0.1	0.1	99.5
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	96.1
		n.d.	n.d.	n.d.	n.d.	99.5	0.3	n.d.	n.d.	103.9

Table 4.2: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

ample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
794	Bainite Core	n.d.	n.d.	n.d.	n.d.	99.6	0.1	0.1	0.1	96.6
		0.3	0.13	n.d.	0.1	99.1	0.2	n.d.	0.2	95.7
		n.d.	0.11	n.d.	n.d.	99.6	n.d.	n.d.	0.2	105.4
		n.d.	n.d.	0.1	n.d.	99.7	n.d.	n.d.	0.2	106.6
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	101.4
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	103.7
		0.2	0.16	n.d.	n.d.	99.3	n.d.	n.d.	0.4	102.2
		0.1	0.11	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	102.2
	Ferrite Flank 1	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	100.4
		n.d.	0.11	n.d.	n.d.	99.5	0.2	n.d.	n.d.	105.4
		n.d.	0.13	n.d.	n.d.	99.4	0.1	0.2	0.1	102.3
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	0.1	0.1	103.5
	Ferrite Flank 2	0.1	n.d.	n.d.	0.1	99.8	n.d.	n.d.	0.1	103.5
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	105.9
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	102.7
		0.2	0.11	n.d.	n.d.	99.4	n.d.	0.1	0.1	97.7
828	Cutting Edge	0.1	0.17	n.d.	n.d.	99.2	0.2	n.d.	0.3	97.5
		0.1	n.d.	n.d.	0.2	99.5	n.d.	0.1	n.d.	96.2
		0.1	n.d.	n.d.	n.d.	99.6	0.1	0.1	0.1	96.2
	White Weld line	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	104.2
		n.d.	0.14	n.d.	n.d.	96.6	2.4	0.2	0.6	102.9
	Large Grains	n.d.	0.42	n.d.	n.d.	99.4	0.1	n.d.	0.1	111.4
		0.1	0.48	n.d.	0.1	99.2	0.1	n.d.	n.d.	110.0
		n.d.	0.58	n.d.	n.d.	99.2	n.d.	0.1	0.2	95.3
		0.1	0.12	n.d.	n.d.	99.5	0.1	0.1	0.2	96.5
	Low Carbon Iron	n.d.	0.23	n.d.	n.d.	99.6	0.1	n.d.	n.d.	106.9
		n.d.	0.27	n.d.	0.1	99.6	n.d.	n.d.	n.d.	108.4
		n.d.	0.29	n.d.	n.d.	99.4	0.2	0.1	n.d.	103.1
928		n.d.	0.19	n.d.	0.1	99.3	0.1	0.1	0.2	96.1
		n.d.	n.d.	0.1	n.d.	99.7	n.d.	0.1	n.d.	101.3
		0.1	n.d.	n.d.	0.1	99.7	n.d.	0.1	0.1	97.4
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	118.9
		n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	117.9
		n.d.	0.25	n.d.	n.d.	99.4	0.1	n.d.	0.2	103.7
973	Small Grains of Ferrite	n.d.	0.16	n.d.	n.d.	99.6	0.2	n.d.	n.d.	107.8
		0.1	0.22	n.d.	n.d.	99.5	0.1	n.d.	0.1	109.2
		n.d.	0.17	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	111.2
		0.1	0.13	n.d.	n.d.	99.5	0.1	n.d.	0.2	100.5
		n.d.	0.13	n.d.	n.d.	99.6	0.1	0.1	n.d.	99.3
		n.d.	n.d.	n.d.	0.1	99.7	n.d.	n.d.	0.2	98.7
	Mid Carbon steel	n.d.	n.d.	n.d.	0.1	99.7	n.d.	0.1	0.1	105.4
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	114.5
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	100.9
	Small Grains of Ferrite	0.1	n.d.	n.d.	0.1	99.8	n.d.	n.d.	n.d.	106.3
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	n.d.	0.1	111.8
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	111.3
	White Weld line	0.1	n.d.	n.d.	n.d.	99.3	0.2	n.d.	0.3	110.5
		n.d.	n.d.	n.d.	n.d.	99.0	0.1	0.2	0.6	110.8

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
1135	Cutting Edge	0.1	n.d.	n.d.	n.d.	99.6	n.d.	0.1	0.1	102.6
		n.d.	n.d.	0.1	0.1	99.8	0.1	n.d.	n.d.	99.2
		n.d.	0.11	n.d.	n.d.	99.8	0.1	n.d.	n.d.	97.9
	White Weld line	n.d.	0.13	n.d.	0.1	99.1	0.1	0.1	0.5	103.3
		0.6	n.d.	0.1	n.d.	98.7	0.2	n.d.	0.4	100.0
	Ferrite	0.1	0.14	n.d.	n.d.	99.4	0.2	n.d.	0.2	99.0
		n.d.	0.26	n.d.	n.d.	99.4	n.d.	0.1	0.2	96.7
		0.1	0.10	n.d.	n.d.	99.5	0.2	n.d.	0.1	95.9
	Ferrite	n.d.	0.25	0.1	0.1	99.5	n.d.	n.d.	0.1	98.9
		n.d.	0.19	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	98.9
		n.d.	0.22	0.1	0.1	99.6	n.d.	n.d.	n.d.	103.0
	Large Grains	n.d.	0.20	n.d.	n.d.	99.6	0.1	n.d.	0.1	97.9
		n.d.	0.13	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	106.3
		n.d.	0.13	n.d.	n.d.	99.8	0.1	n.d.	n.d.	104.9
1661	Pearlite	n.d.	n.d.	n.d.	n.d.	99.7	0.1	0.1	n.d.	100.6
		n.d.	n.d.	n.d.	n.d.	99.7	0.2	0.1	n.d.	97.5
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	94.4
	Iron Core	0.1	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	99.0
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	96.9
		n.d.	0.14	n.d.	n.d.	99.7	n.d.	n.d.	0.1	96.2
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	98.0
	Side Flanks	n.d.	n.d.	n.d.	n.d.	99.6	0.2	0.1	n.d.	94.9
		0.1	n.d.	n.d.	n.d.	99.4	0.2	0.1	0.2	95.0
		n.d.	n.d.	n.d.	0.1	99.9	n.d.	n.d.	n.d.	92.2
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	94.6
2191		0.1	0.34	n.d.	n.d.	99.5	n.d.	n.d.	n.d.	122.3
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	104.7
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	114.8
		n.d.	0.27	n.d.	n.d.	99.6	n.d.	n.d.	0.1	111.0
		n.d.	n.d.	0.1	0.1	99.7	n.d.	n.d.	n.d.	112.2
		0.1	n.d.	n.d.	n.d.	99.6	0.1	0.1	n.d.	117.4
2208	Cutting Edge	n.d.	0.19	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	98.3
		0.1	0.19	n.d.	n.d.	99.5	n.d.	0.1	0.1	99.1
		n.d.	0.20	0.1	0.1	99.5	0.1	n.d.	0.1	95.4
	White Weld line	0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	92.6
		n.d.	n.d.	0.1	n.d.	99.6	n.d.	0.2	0.1	91.4
	Pearlite and Ferrite	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	101.6
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	99.5
		0.1	n.d.	n.d.	0.1	99.6	n.d.	0.2	n.d.	96.0
		0.2	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	96.9
	Large Grains	n.d.	0.27	n.d.	n.d.	99.5	0.1	0.1	n.d.	103.4
		n.d.	0.43	n.d.	n.d.	99.5	0.1	n.d.	n.d.	101.2
		0.1	0.29	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	96.6
		0.1	0.19	n.d.	0.1	99.5	0.1	n.d.	0.1	95.8

Table 1.2 cont: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

White Weld Lines

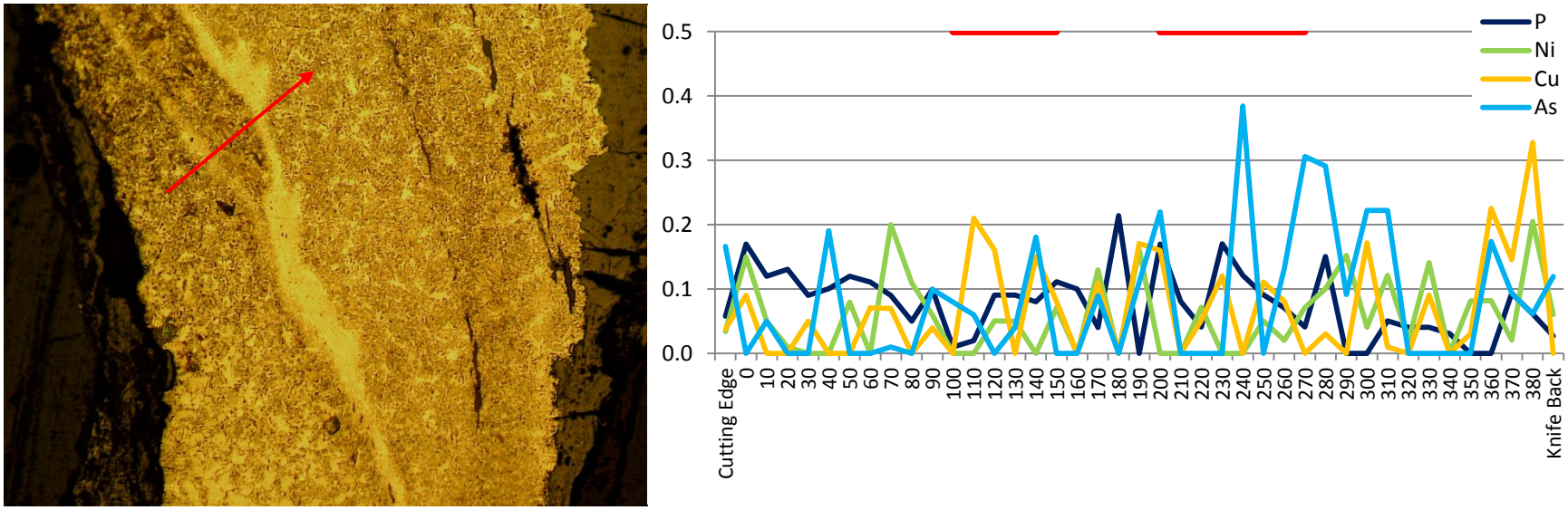


Figure 4.16: Line scan across two white weld lines in West Stow Knife 973

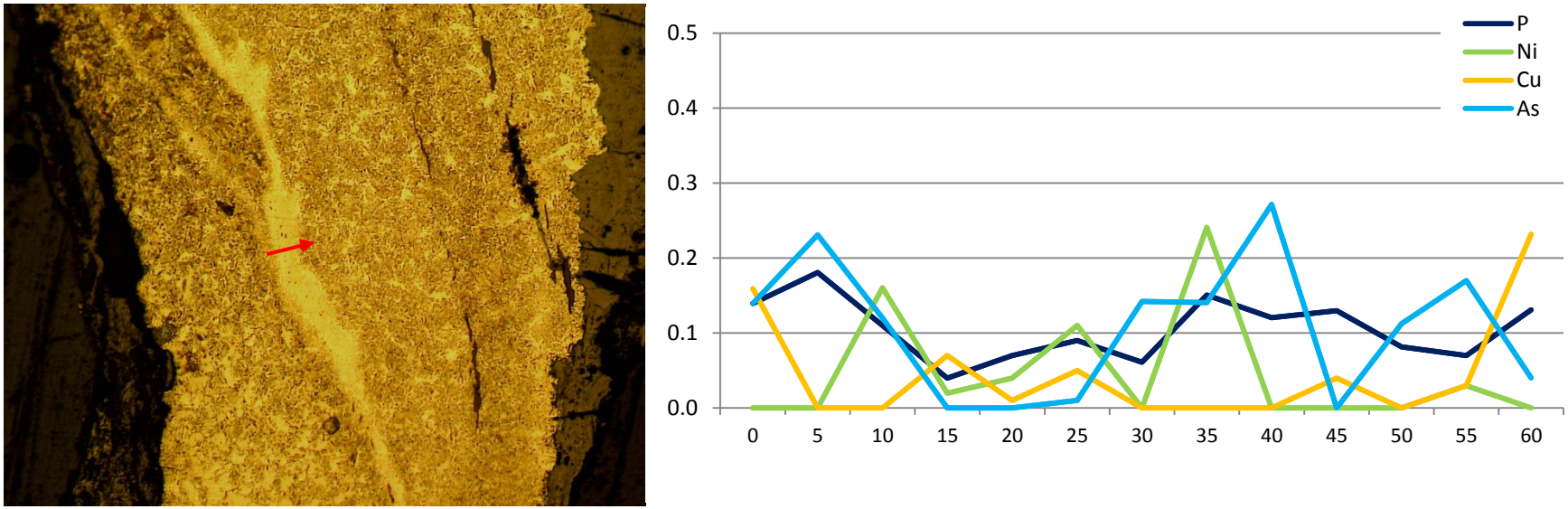


Figure 4.17: Line scan across the white weld line in West Stow Knife 973

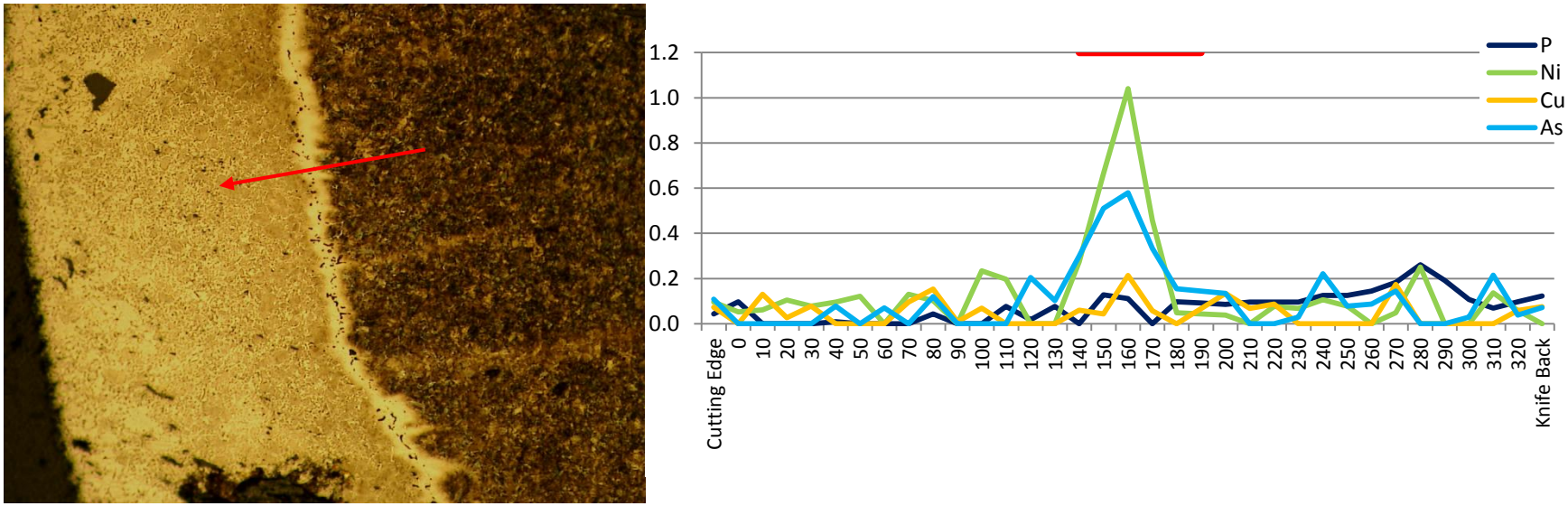


Figure 4.18: Line scan across the white weld line in West Stow Knife 1135

Chapter 5: Gwithian

Knife Descriptions

Knife GM/M/19

The x-radiograph revealed no evidence for a weld line or a spotted texture. A single section was removed from the knife as during sectioning the knife broke and the x-radiograph suggested that the knife would fragment too much if two half sections were removed.

Figure 5.1: Photograph and x-radiograph of knife GM/M/19, the lines show where the section was removed.

During sectioning the tip of the cutting edge became separated from the back due to corrosion penetration and was mounted in the same block. Un-etched there were few inclusions in the knife back and those present were large, due to corrosion penetration, single-phased and arranged in bands. The inclusions in the cutting edge were single-phased, small and angular.

When etched the cutting edge consisted of small grains of ferrite with some grain boundary pearlite or carbides (ASTM 7-8, *Average 330HV, Range 238-386HV*). The back of the knife consisted of bands of two distinct areas; nearest the cutting edge consisted of small to medium grains of ferrite with ghosting (ASTM 5-7, *Average 339HV, Range 271-412HV*), that in addition to the extremely hardness values suggest a phosphoric iron. SEM-EDS analysis confirmed the presence of phosphorus (0.3%-0.5%). The other area consisted of large grains of ferrite with ghosting (ASTM 1) this in addition to the high hardness suggested a phosphoric iron (*Average 317HV, Range 257-340HV*), again supported by SEM-EDS

analysis (0.4%). There was also a high proportion of arsenic (between 0.1%-0.5%) and copper (between 0.1%-0.4%) present throughout the knife, possibly explaining the higher hardness values seen.

Knife GM/M/37

The x-radiograph of this knife revealed many dark striations, possibly indicating a type 2 knife with a piled back. There was no evidence for a spotted cutting edge. The knife was badly corroded, particularly in the cutting edge.

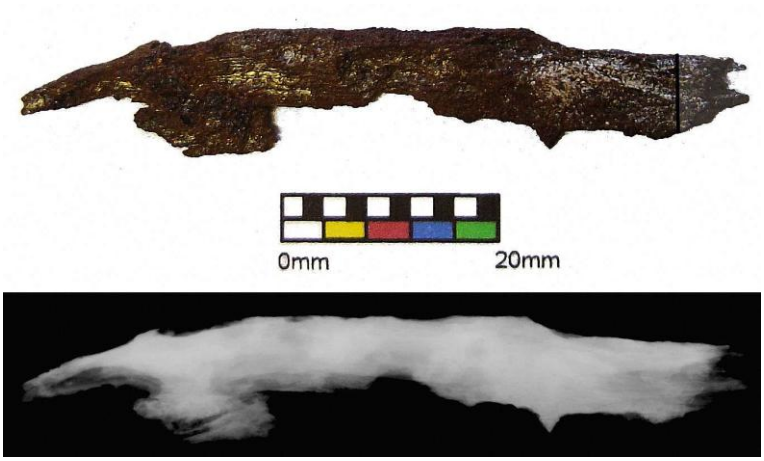


Figure 5.2: Photograph and x-radiograph of knife GM/M/37, the line show where the section was removed.

Two half sections were removed during cutting. The cutting edge section had few single-phased angular inclusions. The knife back on the other hand was heavily piled. There were many slag inclusions mostly small, single-phased, sub-rounded and formed bands. Between the bands the inclusions were small and rounded.

When etched the cutting edge was revealed to consist of pearlite or fine bainite, with the hardness values suggested bainite (*Average 407HV, Range 362-457HV*). This suggests that the knife had been heat-treated but slowly so as to result in bainite rather than tempered martensite. The slag inclusions in the back delineated a variety of microstructures; from small grains of ferrite with ghosting (ASTM 7-8, *Average 261HV, Range 192-321HV*), medium to small grains of ferrite with ghosting (ASTM 7-8, *Average 206HV, Range 179-244HV*) and also small grains of ferrite with some grain boundary carbides (ASTM 5-6, *Average 251HV, Range 244-264HV*). SEM analysis of this knife revealed only traces of phosphorus (up to 0.1%).

Knife GM/M/53

The x-radiograph revealed that this knife has been badly corroded. There was no evidence for a weld line and a spotted texture was seen throughout the knife, but this is more likely due to the corrosion.

Figure 5.3: Photograph and x-radiograph of knife GM/M/53, the lines show where the sections were removed.

Two small half sections were removed. Prior to etching these sections revealed heavy corrosion penetration resulting in a loss of the cutting edge. There were few slag inclusions which were mostly sub-rounded or elongated, small and single-phased with even fewer found in the cutting edge section. Occasionally some larger inclusions were identified.

Once etched the two sections revealed a fairly heterogeneous iron with varying amounts of carbon content up to 0.2%. The cutting edge section consisted of elongated grains of ferrite with some grain boundary pearlite (ASTM 5-6, *Average 286HV, Range 232-386HV*). This suggests that the knife had suffered dramatic amounts of cold working, and shock. The back also had small grains of ferrite with some pearlite (ASTM 7-8, *Average 274HV, Range 215-340HV*). Throughout the section ghosting was seen suggesting some phosphorus is present, this was confirmed by SEM-EDS analysis (0.1%-0.4% phosphorus). There was also a vertical white weld line present in the knife back, this was enriched in arsenic and copper and had an increased hardness (*Average 294HV, Range 221-330HV*).

Knife GM/M/61

X-radiography of this knife revealed that it was badly corroded, especially the cutting edge. There was a possible weld line and the spotted texture below suggests a heat-treated steel cutting edge, but could just be the result of bad corrosion

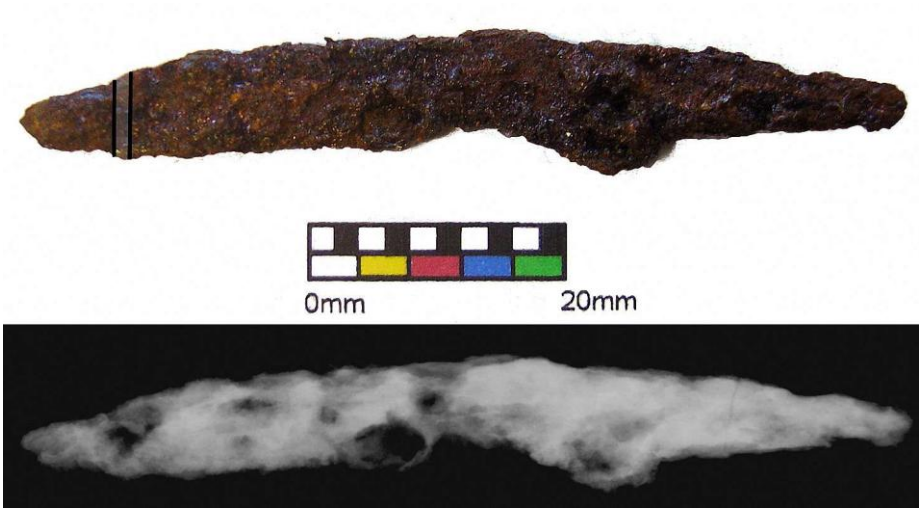


Figure 5.4: Photograph and x-radiograph of knife GM/M/61, the lines show where the section was removed.

During sectioning this knife broke, unexpectedly, and therefore the opportunity was taken to remove a full section. In the un-etched condition many of the slag inclusions were single-phased, sub-angular or sub-rounded and of varying sizes. There was no evidence for a transverse weld line.

After etching the knife appeared to consist of predominately ferrite. The centre of the knife had extremely large grains of ferrite (ASTM 1-2, *Average 250HV, Range 210-303HV*). Near the cutting edge there was a band of small grains for ferrite with grain boundary pearlite (ASTM 6-7, *Average 248HV, Range 201-278HV*) and there was a similar area near the back of the knife (ASTM 4-5, *Average 253HV, Range 232-286HV*). The extremely large grains and low carbon content of this knife suggests a phosphoric iron, this was confirmed by SEM-EDS (0.1%-0.4%). There was also a high proportion of arsenic (between 0.4%-0.9%) and copper (between 0.4%-1.2%) present throughout the knife.

Summary Assemblage Knives

Knife No	Site	Context	Phase	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
				Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
2	GMI	2225	2-4	x	2	53	20	33	23	5	Unknown	X	Y	Broken blade
18	GMI	2236	2-4	x	1	78	12	66	14	5	Unknown	?	?	Broken blade
19	GMI	2238	2-4	A	2	76	50	26	17	11	None	X	Y	
37	GMI	2232	2-4	B	2	65	53	12	11	3	Some	Y	X	
53	GME-N	2002/3	3-4	B	1	78	42	36	17	7	Very	X	Y	
54	GME-N	2002/3	3-4	B	4	80	50	30	9	6	Some	?	X	Fragment
61	GMA	2124	3	B	2	67	48	19	10	6	Some	Y	Y	
70	GMA	2126	3-4	x	x	27	27	x	11	x	Unknown	X	X	Fragment
72	GMA	2109	3	B	x	37	37	x	12	x	Unknown	X	X	Fragment
76	GMI	2270	2-4	D	2	50	40	10	12	7	Slight	X	X	
97	GMI	2209	2-3	B	2	55	38	17	13	8	None	X	Y	
103	GMI	2208	2-4	x	3	40	40	x	20	x	Slight	X	Y	Fragment
112	GMI	2210	2-3	B	x	40	20	20	20	9	Unknown	X	Y	Broken blade
45A	GMI	2202	3-4	x	x	35	19	16	10	5	Unknown	y	X	Bent

Table 5.1: Summary table of the knives from Gwithian showing the measurements, typologies assigned and the results from the x-radiograph analysis.

SEM-EDS Data

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
Knife 19	Ferrite with pearlite	n.d.	0.3	n.d.	n.d.	99.1	n.d.	0.2	0.5	104.7
		n.d.	0.4	0.1	n.d.	98.9	n.d.	0.4	0.1	105.5
		n.d.	0.4	0.1	n.d.	99.0	n.d.	0.3	0.3	105.3
		0.1	0.3	n.d.	n.d.	99.0	n.d.	0.2	0.3	105.7
	Small/medium grains	n.d.	0.4	n.d.	n.d.	99.2	n.d.	0.2	0.1	104.6
		0.1	0.4	n.d.	n.d.	99.3	n.d.	0.2	0.1	105.7
		n.d.	0.3	n.d.	n.d.	98.9	0.1	0.2	0.5	105.9
		0.1	0.3	n.d.	n.d.	99.1	0.1	n.d.	0.3	105.2
		0.1	0.4	n.d.	n.d.	99.3	n.d.	n.d.	0.2	104.5
		n.d.	0.5	n.d.	n.d.	98.9	n.d.	0.1	0.4	106.4
	Large grains	0.1	0.4	n.d.	n.d.	98.8	n.d.	0.3	0.4	104.5
		0.1	0.4	n.d.	n.d.	99.0	n.d.	0.3	0.2	103.8
		n.d.	0.4	n.d.	n.d.	98.7	0.1	0.3	0.5	102.6
		n.d.	0.4	n.d.	n.d.	98.9	n.d.	0.3	0.4	106.2
Knife 37	Pearlite	n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	102.8
		0.5	0.1	n.d.	n.d.	99.0	n.d.	n.d.	0.3	107.3
		0.1	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.1	108.0
		n.d.	n.d.	n.d.	n.d.	99.8	0.1	0.1	n.d.	107.3
	Small grains with ghosting	0.1	0.1	n.d.	0.1	98.9	0.2	0.4	0.2	110.1
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	0.2	n.d.	103.0
		0.1	0.1	n.d.	n.d.	99.3	n.d.	0.3	0.2	106.3
	Medium with ghosting	0.1	n.d.	n.d.	n.d.	99.2	0.1	0.2	0.3	108.6
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.3	0.1	103.2
	small grains with carbides	n.d.	n.d.	n.d.	n.d.	99.3	0.1	0.4	0.3	105.3
		n.d.	n.d.	n.d.	0.1	99.6	n.d.	0.3	n.d.	105.2
	Small grains with ghosting	n.d.	0.1	n.d.	n.d.	99.1	0.1	0.4	0.3	99.1
		n.d.	0.1	n.d.	0.1	99.7	n.d.	0.1	n.d.	105.7
		0.1	0.1	n.d.	0.1	99.3	0.1	0.2	0.1	109.5
		n.d.	n.d.	n.d.	n.d.	99.3	0.1	0.2	0.4	107.8
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	103.5
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	0.1	98.8
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.3	n.d.	99.1
		0.1	n.d.	n.d.	0.1	99.5	0.1	0.2	n.d.	99.5

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
Knife 53	Ferrite with some pearlite	0.1	0.2	n.d.	n.d.	99.0	n.d.	0.4	0.3	106.6
		n.d.	0.2	0.1	n.d.	98.9	0.1	0.6	0.1	108.6
		n.d.	0.2	n.d.	n.d.	99.2	n.d.	0.4	0.2	103.0
		0.1	0.3	n.d.	0.1	98.9	n.d.	0.4	0.3	97.4
		n.d.	0.1	n.d.	n.d.	99.1	n.d.	0.5	0.2	102.8
		n.d.	0.4	0.1	n.d.	98.3	0.2	0.5	0.4	95.2
	Ferrite with pearlite	0.1	0.2	n.d.	0.1	99.1	n.d.	0.4	0.1	99.8
		0.1	0.3	0.1	n.d.	98.4	0.1	0.6	0.5	9n.d.
		n.d.	0.2	n.d.	n.d.	99.4	n.d.	0.3	n.d.	99.9
		n.d.	0.4	n.d.	0.1	98.1	0.2	0.7	0.5	84.1
	White weld line	0.1	0.3	n.d.	n.d.	98.7	0.1	0.6	0.2	92.8
		0.1	0.3	n.d.	n.d.	98.6	0.1	0.5	0.4	90.2
Knife 61	Ferrite with some pearlite	0.1	0.4	0.1	n.d.	98.3	0.1	0.7	0.4	102.4
		n.d.	0.3	n.d.	n.d.	98.6	n.d.	0.5	0.7	103.0
		n.d.	0.1	n.d.	n.d.	98.7	n.d.	0.4	0.7	103.7
	Large grains	n.d.	0.1	n.d.	n.d.	98.6	n.d.	0.7	0.4	107.2
		n.d.	0.4	0.1	n.d.	97.7	0.2	0.8	0.9	104.9
		n.d.	0.3	0.1	n.d.	98.3	0.1	0.6	0.6	106.9
		0.1	0.2	n.d.	n.d.	98.2	0.1	0.7	0.7	11n.d.
		n.d.	0.4	0.1	0.1	97.9	0.1	0.7	0.8	110.8
		0.1	0.3	0.1	n.d.	98.1	0.2	0.5	0.8	112.8
	Ferrite with some pearlite	0.1	0.3	0.1	n.d.	98.0	n.d.	0.7	0.8	114.4
		0.1	0.1	0.2	n.d.	97.7	0.1	1.2	0.7	105.7
		0.1	0.1	n.d.	n.d.	98.7	n.d.	0.7	0.4	121.3

Table 5.2: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

Chapter 6: Quarrington Cemetery

Knife Descriptions

Knife 5

The x-radiograph revealed that this knife has been badly corroded. There was no evidence for a weld line and a spotted texture was seen throughout the knife, but this is more likely due to the corrosion.

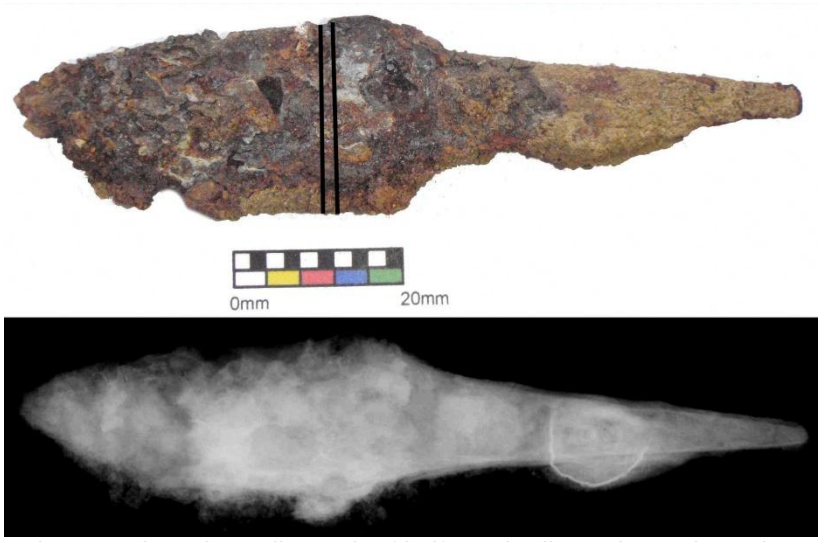


Figure 6.1: Photograph and x-radiograph of knife 5, the lines show where the section was removed.

Prior to etching these sections revealed heavy corrosion penetration. There were few slag inclusions which were mostly sub-rounded or elongated, single-phased. Once etched the section revealed a fairly heterogeneous iron with varying amounts of carbon content up to 0.2%. The cutting edge section consisted of elongated grains of ferrite with some grain boundary pearlite (*154HV, Average 164HV, Range 154-183HV*). The back also had large grains of ferrite with pearlite (*Average 161HV, Range 148-175HV*). SEM-EDS analysis revealed traces of phosphorus throughout the section, up to 0.1% phosphorus.

The absence of a weld line suggests that this knife is a type 0 heterogeneous ferritic iron and low carbon steel knife

Knife 9

The x-radiograph of this knife revealed no dark striations which suggested no weld line was present. There was also no trace of the spotted texture.

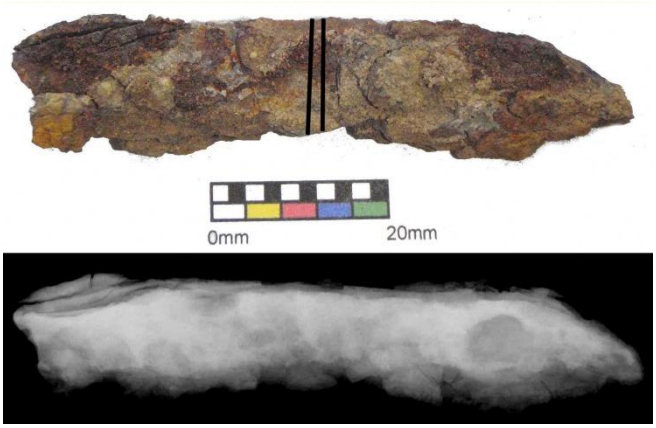


Figure 6.2: Photograph and x-radiograph of knife 9, the lines show where the section was removed.

A vertical line of single-phased separated one half of the knife from the other. The largest side had some very small rounded and single-phased slag inclusions. The other side had multi-phased, elongated and sub-rounded slag inclusions.

When etched the cutting edge consisted of pearlite with ferrite (*271HV, Average 212HV, Range 161-271HV*, 0.7%-0.8% carbon). There was lots of carbon diffusion into the knife back which consisted of bands of small grained ferrite (*Average 171HV, Range 148-175HV*). SEM-EDS analysis confirmed the traces of phosphorus and arsenic (up to 0.2%).

Knife 11

The x-radiograph of knife 11 suggested that it was badly corroded. There was no evidence for a weld line, and rather than the spotted texture seen in other knives this knife had a more grainy texture.

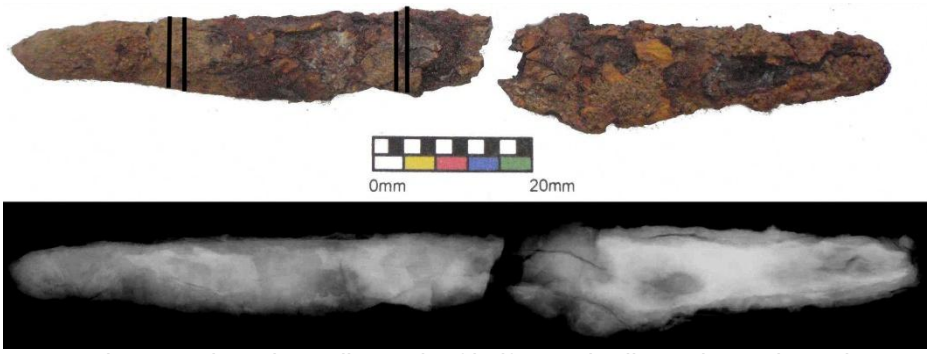


Figure 6.3: Photograph and x-radiograph of knife 11, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition, these were extremely corroded. But there was at least one clear vertical slag inclusion band, consisting of single-phased inclusions mostly elongated. Between these bands the inclusions were small, single-phased and sub-angular. Elsewhere the inclusions were elongated, spherical or sub-rounded and single phased

When etched the band separated a central strip was a white weld line which consisted of tempered martensite (*549HV, Average 357HV, Range 271-549HV*), with bainite and pearlite in areas. To either side of this band the microstructure consisted of large grains of ferrite with some pearlite (*Average 215HV, Range 154-257HV*). There was also very little carbon diffusion across the weld line suggesting that the two iron flanks may be phosphoric iron but the SEM-EDS analysis revealed only traces of phosphorus.

Knife 17

The x-radiograph of knife 17 suggested that it was badly corroded. There was no evidence for a weld line, although the spotted texture was seen in the cutting edge.

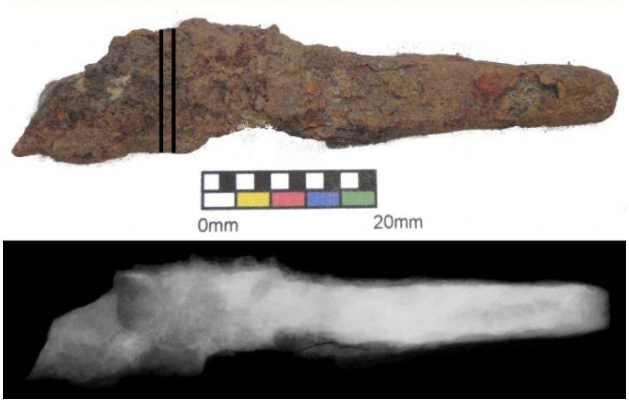


Figure 6.4: Photograph and x-radiograph of knife 17, the lines show where the section was removed.

The knife was extremely corroded with only a few small areas of metal surviving. The inclusions throughout the knife were single-phased and sub-angular. When etched the microstructure was homogenous with ferrite and pearlite throughout (183*HV, Average 181HV, Range 148-210HV*). Only traces of phosphorus were detected by SEM-EDS analysis, although arsenic and copper were present (up to 0.4%). The absence of a weld line and the homogenous microstructure suggests that this knife is a type 5 heterogeneous mid carbon steel knife

Knife 222

The x-radiograph revealed that this knife has been badly corroded. There was no evidence for a weld line although the spotted texture was seen throughout the knife. The knife was bent, presumably before it was placed in the grave.

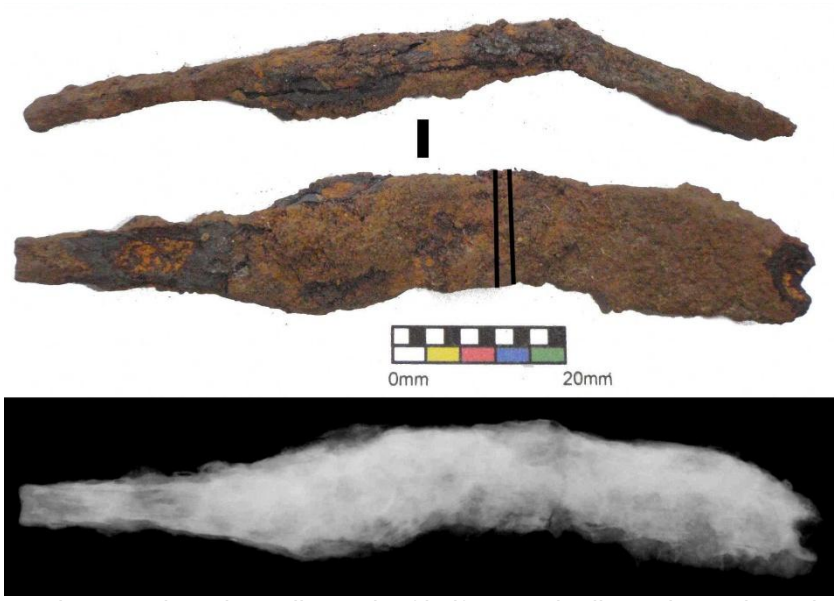


Figure 6.5: Photograph and x-radiograph of knife 222, the lines show where the section was removed.

There were few slag inclusions which were mostly sub-angular or elongated, and single-phased. Once etched the section revealed a fairly homogenous iron with medium to large grains of ferrite (*175HV, Average 172HV, Range 143-201HV*). Throughout the section ghosting was seen suggesting some phosphorus was present; this was confirmed by SEM-EDS analysis (0.1%-0.6% phosphorus).

Knife 230

The x-radiograph of knife 230 suggested that it was badly corroded. There was no evidence for a weld line, although the spotted texture was seen in the cutting edge.

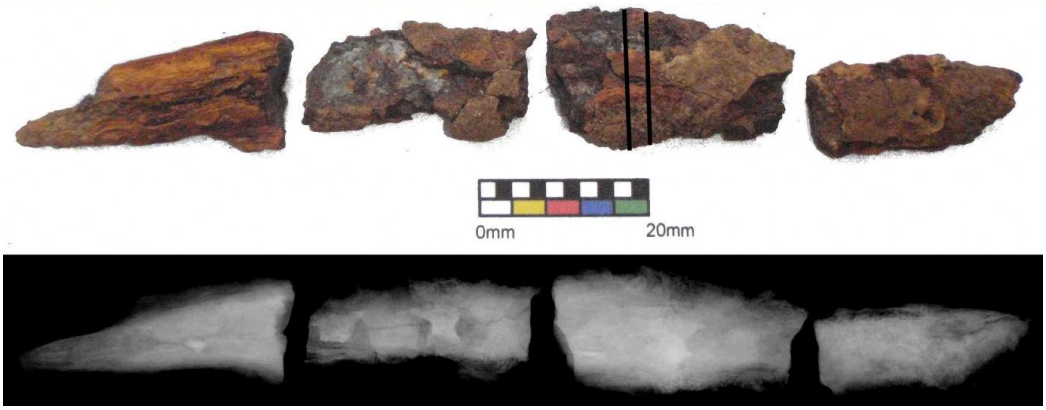


Figure 6.6: Photograph and x-radiograph of knife 230, the lines show where the section was removed.

The knife was extremely corroded with only a few small areas of metal surviving, in the back of the knife. The inclusions in these areas of the knife were single-phased and sub-rounded. When etched the microstructure was homogenous with small grains of ferrite with pearlite throughout (*Average 173HV, Range 161-183HV*). No phosphorus was detected by SEM-EDS analysis, although a trace of arsenic was present (up to 0.2%). Due to the amount of corrosion present it was impossible to determine how it was manufactured although ferrite with pearlite was identified in the knife back.

Summary Assemblage Knives

Knife No	Context	Feature	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
			Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
5	C1063	Grave 5	B	1	87	42	45	16	8	Some	X	X	
9	C1050	Grave 1	A	3	67	67		10		Slight	X	X	Broken
10	C1067	Grave 6	D	3	64	53	11	12	9	Some	X	X	Broken
11	C1058	Grave 4	D	4	99	44	55	11	9	Unknown	X	X	Broken
17	C1074	Grave 7	B	3	67	40	27	12	8	None	X	Y	Broken
222	C1061		B	1	85	55	30	14	5	Some	X	Y	
230	C1433	Grave 12	B	3	104	80	24	12	8	None	X	Y	Broken
231	C1422	Grave 8	B	1	90	61	29	15	6	Slight	Y	X	
238	C1433	Grave 12	D	4	73	73		24		None	X	Y	Broken
239	c1442	Grave 9	B	1	100	63	37	18	8	Slight	X	X	Broken but fairly complete
241	C1449	Grave 15	B	4	100	73	27	14	8	None	Y	Y	

Table 6.1: Summary table of the knives from Quarrington showing the measurements, typologies assigned and the results from the x-radiograph analysis.

SEM-EDS Data

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
5	ferrite (small)	0.1	0.1	0.1	n.d.	99.7	n.d.	n.d.	n.d.	104.0
		0.1	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.1	103.8
		0.1	n.d.	n.d.	n.d.	99.7	0.2	n.d.	n.d.	107.2
		0.1	n.d.	n.d.	n.d.	99.7	n.d.	0.2	n.d.	106.0
		n.d.	0.1	0.1	n.d.	99.8	n.d.	n.d.	n.d.	108.3
		n.d.	n.d.	0.1	n.d.	99.8	n.d.	n.d.	0.1	108.0
		0.1	0.1	n.d.	0.1	99.6	n.d.	n.d.	n.d.	99.4
		n.d.	0.1	n.d.	n.d.	99.6	0.1	0.3	n.d.	99.0
	large grains	n.d.	0.2	n.d.	0.1	99.5	0.1	n.d.	0.1	114.2
		0.1	0.1	n.d.	n.d.	99.4	0.1	0.2	n.d.	112.5
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	102.5
9	pearlite with ferrite	n.d.	0.1	0.1	n.d.	99.6	n.d.	0.1	0.1	101.9
		n.d.	0.1	n.d.	n.d.	99.5	0.1	n.d.	0.2	104.7
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.2	104.2
		n.d.	0.2	n.d.	0.1	99.7	n.d.	n.d.	n.d.	97.9
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.2	100.7
		n.d.	n.d.	0.1	n.d.	99.6	n.d.	0.2	0.1	104.1
	ferrite (small)	0.1	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.2	95.9
		0.1	0.1	n.d.	n.d.	99.7	0.1	n.d.	n.d.	98.9
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	101.9
		0.1	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	97.9
11	pearlite with ferrite	0.1	0.1	n.d.	n.d.	99.4	0.1	n.d.	0.3	94.2
		0.1	0.1	n.d.	n.d.	99.2	n.d.	0.1	0.5	91.8
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.3	99.0
		n.d.	0.1	n.d.	n.d.	99.4	n.d.	n.d.	0.5	114.4
		0.1	n.d.	n.d.	0.2	99.7	n.d.	n.d.	0.1	112.5
		0.1	n.d.	0.1	n.d.	99.4	n.d.	n.d.	0.4	109.9
	ferrite	n.d.	0.2	0.1	n.d.	99.2	n.d.	n.d.	0.5	92.2
		n.d.	0.1	n.d.	n.d.	99.4	0.1	n.d.	0.4	101.6
		n.d.	n.d.	n.d.	n.d.	99.5	n.d.	0.1	0.4	93.3
		n.d.	n.d.	0.1	n.d.	99.8	n.d.	n.d.	0.1	107.1
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	105.0
		n.d.	0.2	n.d.	n.d.	99.4	n.d.	n.d.	0.3	104.7

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
17		0.1	n.d.	n.d.	n.d.	99.5	n.d.	n.d.	0.4	103.9
		n.d.	0.1	n.d.	n.d.	99.4	0.2	0.3	n.d.	100.4
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	99.8
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	0.1	0.2	99.3
		n.d.	0.1	0.1	n.d.	99.7	n.d.	0.1	n.d.	100.5
		n.d.	0.2	n.d.	0.1	99.5	n.d.	0.1	0.2	99.0
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	98.7
222		0.1	0.4	n.d.	n.d.	99.4	n.d.	n.d.	0.1	97.4
		n.d.	0.3	n.d.	n.d.	99.4	n.d.	n.d.	0.2	102.9
		n.d.	0.8	n.d.	n.d.	98.9	0.1	0.1	0.2	103.3
		n.d.	0.5	0.1	0.1	99.2	0.1	n.d.	0.1	94.0
		n.d.	0.6	0.1	n.d.	99.2	0.1	0.1	0.1	95.1
		0.1	0.6	n.d.	n.d.	99.3	0.1	n.d.	n.d.	93.8
		0.1	0.1	n.d.	0.1	99.4	0.2	0.1	n.d.	92.6
		n.d.	0.3	0.1	n.d.	99.6	n.d.	n.d.	n.d.	94.8
		n.d.	0.5	n.d.	0.1	99.0	n.d.	0.1	0.2	94.9
		0.1	0.5	0.1	n.d.	99.0	0.1	0.1	0.1	103.3
		n.d.	0.3	n.d.	n.d.	99.6	n.d.	n.d.	0.1	103.0
		n.d.	0.3	n.d.	n.d.	99.6	n.d.	0.1	n.d.	100.4
		n.d.	0.2	n.d.	n.d.	99.6	n.d.	n.d.	0.1	100.3
		n.d.	0.5	0.1	0.1	99.2	n.d.	n.d.	0.1	96.5
		n.d.	0.6	0.1	n.d.	99.3	n.d.	n.d.	n.d.	97.5
		0.3	0.5	n.d.	n.d.	98.8	0.1	0.2	0.2	95.8
230		n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	0.1	102.4
		0.1	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	101.3
		0.1	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	101.5
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	0.1	101.4
		0.1	n.d.	0.1	n.d.	99.5	n.d.	0.1	0.2	101.3
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.1	101.4
		n.d.	n.d.	n.d.	0.1	99.9	n.d.	n.d.	n.d.	101.4

Table 6.2: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

Chapter 7: Twyford Cemetery

Knife Descriptions

Knife 100

X-radiography of this knife revealed that there was a possible weld line and the spotted texture below suggests a heat-treated steel cutting edge, but could just be the result of corrosion

Figure 7.1: Photograph and x-radiograph of knife 100, the lines show where the sections were removed.

In the un-etched condition many of the slag inclusions were single-phased and sub-rounded. At the cutting edge there were fewer inclusions. Also in the section wee some vertical bands of single-phased sub-angular and elongated inclusions.

After etching the knife appeared to consist of predominately ferrite with some pearlite. Near the cutting edge there was a band of small grains for ferrite with grain boundary pearlite (*143HV, Average 160HV, Range 143-175HV*) and there was a similar area near the back of the knife (*Average 167HV, Range 154-192HV*). The centre of the knife had a higher carbon content with pearlite and ferrite (*Average 182HV, Range 143-232HV*, 0.3%-0.7% carbon). SEM-EDS analysis revealed only traces of phosphorus present in the knife suggesting a ferritic and low carbon steel.

Knife 103

The x-radiograph of knife revealed near the back of the knife two clear dark striations which ran from the shoulder into the knife, suggestive of grooves. There was no evidence for a weld line, instead the classic spotted texture was seen throughout the knife.

Figure 7.2: Photograph and x-radiograph of knife 103, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. In the cutting edge section there was a clear raised weld line, with some multi-phased inclusions and corrosion. Below this weld line there were very few inclusions and those present were small, single-phased and sub-rounded. The back section consisted of many inclusions mostly single- and multi-phased and sub-rounded.

When etched the cutting edge consisted of predominately tempered martensite which degraded to ferrite with pearlite at the weld line (*509HV, Average 289HV, Range 168-509HV*). Etching revealed the presence of a clear white weld line, separating the back from the cutting edge, which SEM-EDS analysis revealed was enriched in arsenic and copper (*Average 146HV, Range 143-148HV*). There was very little carbon diffusion across the weld line. The knife back consisted of two types of microstructure. The majority had medium to large grains of ferrite with some pearlite and no ghosting (*Average 178HV, Range 148-221HV*). The other areas had smaller grains of ferrite with some pearlite and carbides. Apart from one area of this knife which had 0.8% phosphorus there was no phosphorus detected in the knife back, suggesting a ferritic iron.

Knife 110

The x-radiograph of knife revealed no evidence of a clear dark striation to suggest a weld line, although the cutting edge had a spotted texture throughout.

Figure 7.3: Photograph and x-radiograph of knife 110, the lines show where the sections were removed.

Prior to etching the knife was examined to reveal the presence of a weld line of small single- and multi-phased, sub-angular inclusions and corrosion. Below this weld line in the cutting edge there were a few small, sub-rounded, single-phased inclusions and above the weld line the inclusions were larger, both single- and multi-phased, and elongated or sub-rounded.

When etched the cutting edge consisted of predominately tempered martensite which degraded to ferrite with pearlite at the weld line (*441HV, Average 387HV, Range 271-441HV*). There was a white weld line, enriched in arsenic and nickel (*Average 264HV, Range 257-271HV*) separating the cutting edge from the knife back. There was some carbon diffusion across this weld line (*Average 279HV, Range 271-286HV*). The rest of the knife back consisted of larger grains of ferrite with no pearlite and some ghosting, suggesting phosphoric iron (*Average 159HV, Range 143-183HV*). This was confirmed by SEM-EDS analysis as up to 0.3% phosphorus was detected.

Knife 116

The x-radiograph of knife 116 suggested that it was badly corroded. There was no evidence for a weld line, and rather than the spotted texture seen in other knives this knife had a more grainy texture.

Figure 7.4: Photograph and x-radiograph of knife 116, the lines show where the section was removed.

Two sections were removed and examined in the unetched condition. There were two vertical slag inclusion bands, consisting of single-phased inclusions mostly elongated, visible in the back section, these seemed to continue into the cutting edge. Between these bands the inclusions were small, single-phased and sub-rounded and the inclusions in the two flanks were also sub-rounded but single- and multi-phased.

When etched the two bands separated a central strip which consisted of ferrite with pearlite (*168HV, Average 186HV, Range 154-221HV*). To either side of this band the microstructure consisted of large grains of ferrite with no pearlite and some ghosting (*Average 157HV, Range 148-168HV*). There was also very little carbon diffusion across the weld line suggesting that the two iron flanks may be phosphoric iron. Confirmed by SEM-EDS analysis which revealed only traces of phosphorus (up to 0.2%). This analysis also revealed the presence of arsenic in the knife (up to 0.3%).

Knife 127

X-radiography of this knife showed that it was well preserved although the cutting edge had been worn. There was a hint of the presence of a weld and the cutting edge had the classic spotted texture.

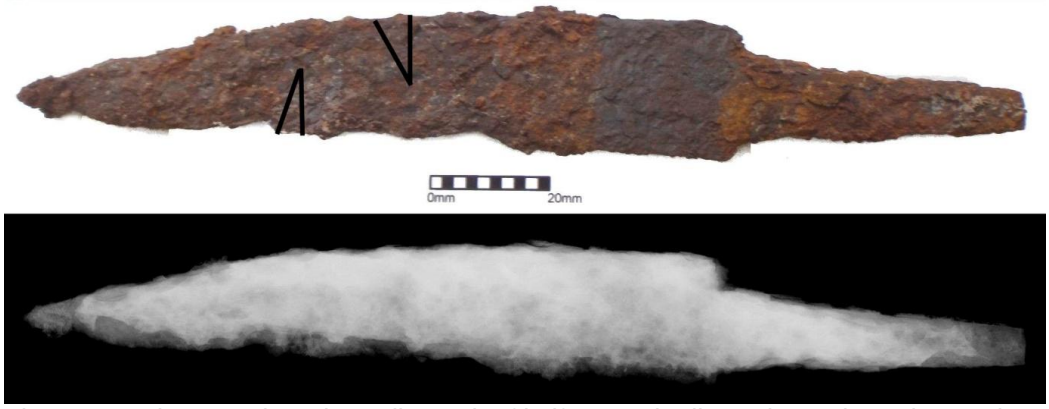


Figure 7.5: Photograph and x-radiograph of knife 127, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. In the cutting edge section there was a possible weld line made up of small, sub-angular, single-phased inclusions. Below this there were few inclusions which were small, rounded and single-phased. In the back section the inclusions formed bands of multi-phased, sub-rounded inclusions, between which the inclusions were single-phased and sub-rounded or elongated.

The possible weld line seen in the unetched condition did not become a white weld line, but was still clearly visible. This separated the tempered martensite cutting edge (*644HV, Average 452HV, Range 303-644HV*) from the piled iron back. There was carbon diffusion across the weld line. The back section consisted of predominately ferrite with pearlite, 0.2-0.4% carbon (*Average 193HV, Range 168-210HV*) although other areas had pearlite with ferrite (*Average 276HV, Range 221-412HV*). SEM-EDS revealed only traces of phosphorus, up to 0.2%.

Summary Assemblage Knives

Knife No	Context	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
		Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
100	1006	A	3	132	86	46	17	9	None	Y	Y	
103	1006	B	1	212	163	49	24	10	None	Y	Y	
110	1062	B	1	115	72	43	12	8	Slight	Y	Y	
116	1075	B	3	101	89	12	13	7	Some	X	X	
127	1143	B	1	164	113	51	21	12	Slight	Y	Y	

Table 7.1: Summary table of the knives from Twyford showing the measurements, typologies assigned and the results from the x-radiograph analysis.

SEM-EDS Data

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
100	ferrite (small)	0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	106.3
		0.1	n.d.	n.d.	0.1	99.6	0.1	n.d.	0.1	107.9
		0.1	0.1	0.1	n.d.	99.5	0.1	n.d.	0.2	110.1
		0.1	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.1	109.9
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	104.0
	pearlite and ferrite	n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	103.3
		n.d.	0.1	n.d.	n.d.	99.6	0.1	0.2	n.d.	104.0
		n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	108.8
		n.d.	0.4	n.d.	n.d.	99.4	n.d.	0.1	0.1	106.0
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	108.9
		0.1	0.1	n.d.	n.d.	99.5	n.d.	0.2	0.1	109.2
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	108.2
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.2	98.6
		n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	99.1
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	104.1
	ferrite with pearlite	n.d.	0.1	0.1	n.d.	99.7	n.d.	0.1	n.d.	103.8
		0.1	0.1	0.1	n.d.	99.5	n.d.	0.2	n.d.	101.1
		n.d.	0.2	0.1	n.d.	99.5	n.d.	0.2	0.1	98.9
103	cutting edge	n.d.	n.d.	n.d.	0.1	99.5	0.3	0.1	n.d.	106.2
		n.d.	n.d.	n.d.	n.d.	99.9	0.1	n.d.	n.d.	107.4
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	109.3
	white weld line	n.d.	n.d.	0.1	n.d.	99.8	n.d.	n.d.	0.1	108.8
		n.d.	n.d.	n.d.	n.d.	99.5	n.d.	0.1	0.2	109.6
		n.d.	0.1	n.d.	n.d.	99.3	0.1	0.2	0.3	110.2
	ferrite	n.d.	0.1	n.d.	n.d.	99.6	0.1	0.2	n.d.	107.4
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	0.1	109.0
		n.d.	n.d.	n.d.	n.d.	99.6	0.1	0.1	0.2	111.4
		n.d.	n.d.	0.1	n.d.	99.8	n.d.	n.d.	0.1	110.7
		n.d.	0.8	n.d.	n.d.	98.8	0.1	n.d.	0.2	109.0
	ferrite with pearlite	n.d.	n.d.	0.1	n.d.	99.8	n.d.	n.d.	0.1	108.9
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.2	n.d.	107.1
		0.1	n.d.	n.d.	0.1	99.5	n.d.	n.d.	0.2	104.9
		0.1	n.d.	0.1	n.d.	99.3	n.d.	n.d.	0.5	108.9
110	cutting edge	n.d.	0.2	n.d.	n.d.	99.6	n.d.	0.1	n.d.	95.1
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	0.2	0.2	115.5
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	111.9
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	102.0
	white weld line	n.d.	0.1	n.d.	0.1	96.4	1.6	n.d.	1.8	105.4
		n.d.	n.d.	n.d.	n.d.	98.1	0.9	n.d.	0.8	109.3
	large grains	n.d.	0.3	n.d.	n.d.	99.4	n.d.	0.1	0.2	107.0
		0.1	0.3	n.d.	n.d.	99.3	0.1	n.d.	0.1	102.3
		n.d.	0.2	0.1	n.d.	99.6	n.d.	n.d.	0.1	101.0
		0.1	0.3	n.d.	n.d.	99.4	0.2	n.d.	n.d.	100.0
		n.d.	0.2	n.d.	0.1	99.5	n.d.	0.1	0.1	104.5

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
116	ferrite with pearlite	0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	105.4
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.2	102.6
		n.d.	0.1	n.d.	n.d.	99.6	0.3	n.d.	n.d.	101.9
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.1	101.7
		n.d.	n.d.	0.1	0.1	99.8	n.d.	n.d.	n.d.	105.6
		0.1	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	105.4
		0.1	n.d.	0.1	n.d.	99.8	n.d.	n.d.	n.d.	105.2
	ferrite	0.1	0.2	n.d.	0.1	99.3	0.1	0.1	0.1	99.0
		n.d.	0.2	n.d.	n.d.	99.6	0.1	n.d.	0.1	97.9
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	104.4
		n.d.	0.2	0.1	0.1	99.5	0.2	n.d.	n.d.	103.9
		0.1	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	102.9
	ferrite with pearlite	n.d.	0.1	n.d.	n.d.	99.7	n.d.	0.1	0.2	101.9
		0.1	0.2	n.d.	0.1	99.6	n.d.	n.d.	n.d.	108.5
		n.d.	0.1	n.d.	n.d.	99.5	n.d.	0.1	0.3	107.1
127	cutting edge	0.1	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	101.0
		n.d.	0.1	n.d.	0.1	99.6	0.1	n.d.	n.d.	100.4
		n.d.	0.1	n.d.	0.1	99.8	n.d.	n.d.	n.d.	98.5
		0.1	0.1	n.d.	0.1	99.2	0.2	0.2	0.2	98.6
	pearlite and ferrite	n.d.	0.1	0.1	n.d.	99.5	0.2	n.d.	0.1	97.7
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	95.8
		n.d.	n.d.	0.1	n.d.	99.5	0.2	0.1	0.1	95.9
	ferrite with pearlite	n.d.	0.2	0.1	n.d.	99.6	n.d.	0.1	n.d.	95.9
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	95.1
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	0.1	n.d.	94.3
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	0.2	n.d.	94.3
	ferrite with some pearlite	0.1	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	93.7
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	101.9
		n.d.	0.1	n.d.	n.d.	99.8	0.1	n.d.	n.d.	106.7
		n.d.	0.1	0.1	n.d.	99.7	n.d.	0.1	0.1	107.6

Table 7.2: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

White Weld Lines

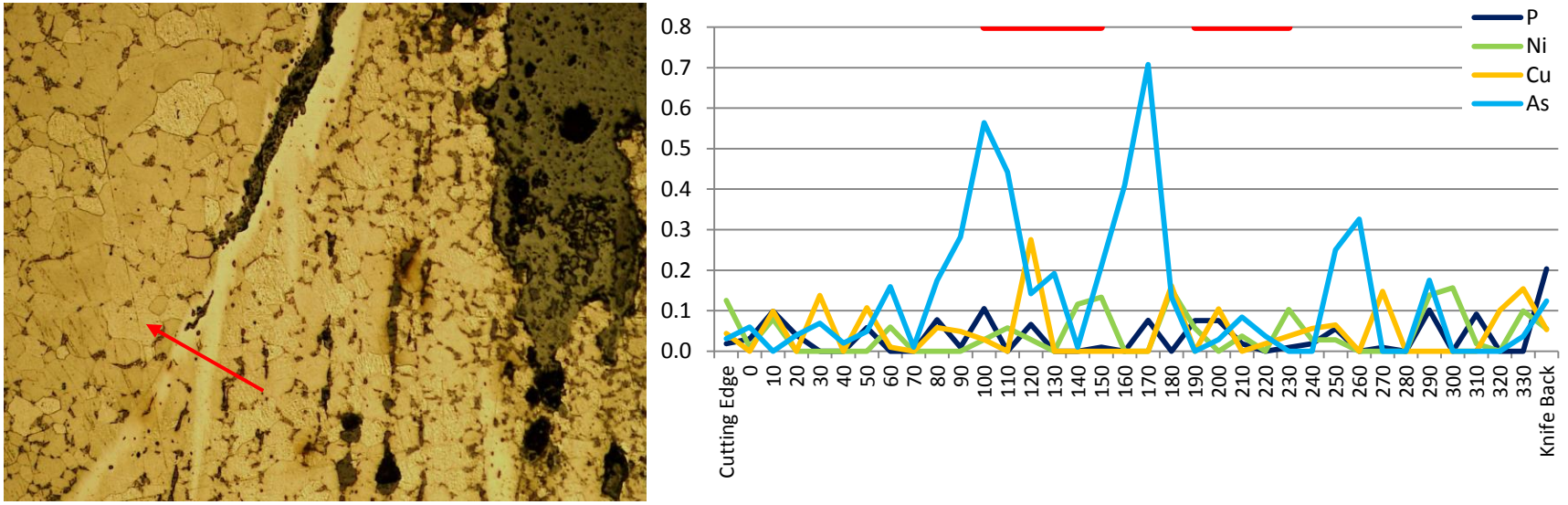


Figure 7.6: Line scan across the white weld line in Twyford Knife 103

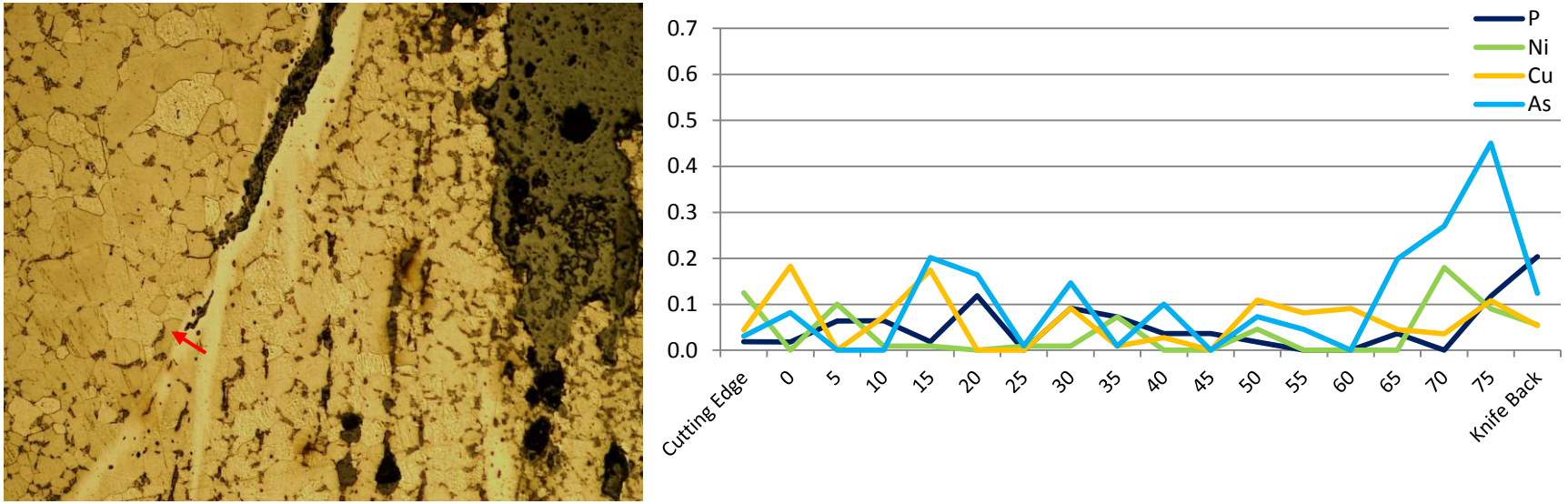


Figure 7.7: Line scan across the white weld line in Twyford Knife 103

Chapter 8: Collingbourne Ducis Cemetery

Knife Descriptions

Knife 12

There was a possible weld line and the spotted texture below suggests a heat-treated steel cutting edge.

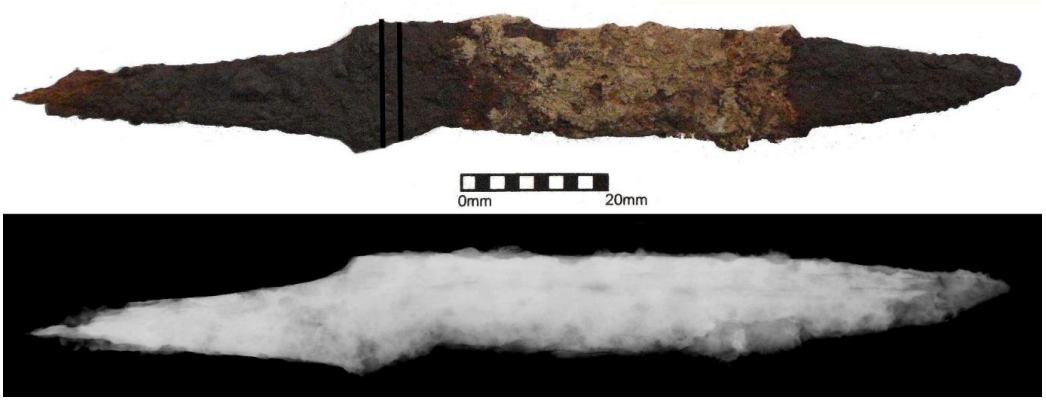


Figure 8.1: Photograph and x-radiograph of knife 12, the lines show where the section was removed.

During sectioning this knife broke, unexpectedly, and therefore the opportunity was taken to remove a full section. In the un-etched condition many of the slag inclusions were single-phased, sub-angular or elongated. There was no evidence for a transverse weld line.

After etching the knife appeared to consist of predominately ferrite. The centre of the knife had ferrite with pearlite and ghosting (*Average 141HV, Range 132-148HV*). Near the cutting edge there were large grains of ferrite with grain boundary carbides and ghosting (*132HV, Average 130HV, Range 110-143HV*) and there was a similar area near the back of the knife (*Average 124HV, Range 100-143HV*). The extremely large grains and low carbon content of this knife suggests a phosphoric iron, this was confirmed by SEM-EDS (0.1%-0.3%).

Knife 18

There was a possible weld line and the spotted texture below suggests a heat-treated steel cutting edge. Mineralised textiles were present on the blade.

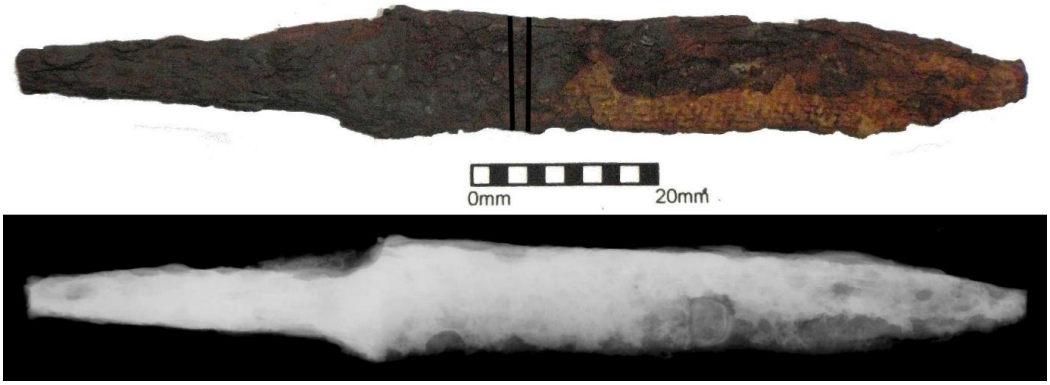


Figure 8.2: Photograph and x-radiograph of knife 18, the lines show where the section was removed.

A single section was taken to help preserve the mineralised textiles. There were very few slag inclusions present which were mostly sub-rounded and multi-phased. Once etched the two sections revealed a fairly heterogeneous iron with varying amounts of carbon content between 0.2%-0.4% (*240HV, Average 204HV, Range 161-271HV*). SEM-EDS analysis revealed traces of phosphorus (up to 0.2%). The absence of a weld line suggests that this knife is a type 0 heterogeneous low carbon steel and phosphoric iron knife

Knife 39

The x-radiograph of knife revealed a clear dark striation, suggestive of a weld line. Below this the cutting edge had a spotted texture.

Figure 8.3: Photograph and x-radiograph of knife 39, the lines show where the section was removed.

The knife had suffered from corrosion which had separated the two pieces of metal, explaining the dark striation, below this there was a white weld line with small sub-rounded inclusions. In the cutting edge there were a very few small, rounded, single-phased inclusions. Above the weld line the inclusions were sub-angular and multi-phased.

After etching the cutting edge turned out to consist of tempered martensite (*473HV, Average 505HV, Range 441-549HV*). There was a white weld line, enriched in arsenic and nickel (*Average 245HV, Range 232-257HV*) separating the cutting edge from the knife back. There was some carbon diffusion across this weld line (*Average 277HV, Range 232-321HV*). The rest of the knife back consisted of larger grains of ferrite with no pearlite and some ghosting, suggesting phosphoric iron (*Average 124HV, Range 100-137HV*). This was confirmed by SEM-EDS analysis although only traces up to 0.2% phosphorus were detected.

Knife 44

The x-radiograph of knife 44 revealed no evidence for the presence of a weld line but the classic spotted texture was present at the cutting edge.

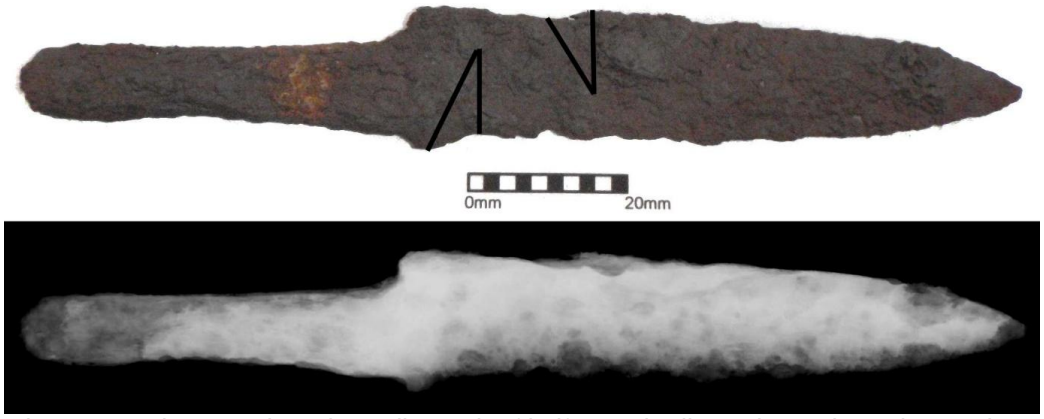


Figure 8.4: Photograph and x-radiograph of knife 44, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition, which revealed that there were two, or more vertical slag inclusion bands, consisting of single- and multi-phased inclusions mostly elongated, these bands seem to join together at several points. Between these bands the inclusions were small, single- and multi-phased, sub rounded and sub-angular. In the two flanks to either side were larger, sub-rounded and single- and multi-phased, in the back section these inclusions were larger.

When etched the two bands separated a central strip which consisted of small to medium grains of ferrite at the cutting edge (*192HV, Average 196HV, Range 175-221HV*), with ferrite with pearlite further back (*Average 227HV, Range 210-257HV*). This strip was again separated in two with the back consisting of large grains of ferrite (*Average 155HV, Range 143-168HV*). SEM-EDS analysis revealed the presence of arsenic and traces of some phosphorus. Many of the vertical bands turned out to be white weld lines. To either side of these bands the microstructure consisted of ferrite with pearlite (*Average 169HV, Range 137-201HV*), pearlite and ferrite (*Average 258HV, Range 221-321HV*) or medium grains of ferrite with some pearlite (*Average 143HV, Range 132-154HV*).

This knife was constructed by welding lots of pieces of heterogeneous iron and steel strips creating a type 3 piled knife. The cutting edge has not been heat-

treated. The piled nature of this knife suggested that it may have been made from recycled iron

Knife 96

There was no evidence for the presence of a weld line but the classic spotted texture was present in the cutting edge.

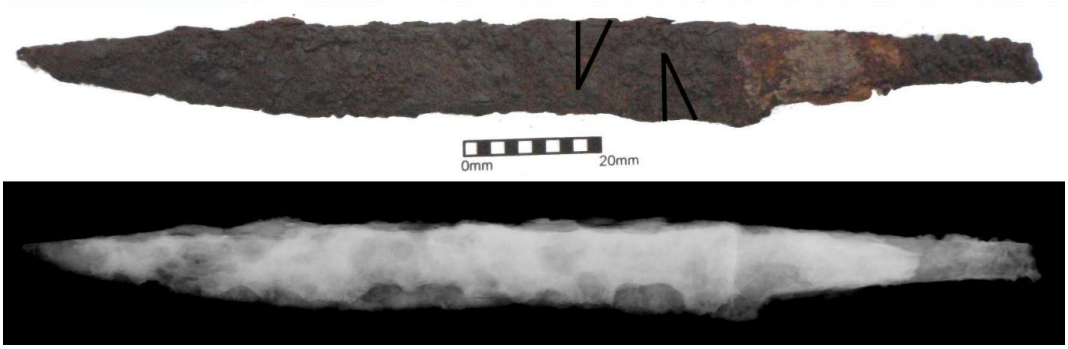


Figure 8.5: Photograph and x-radiograph of knife 96, the lines show where the sections were removed.

Un-etched there were few inclusions in the knife back and cutting edge. Those present were elongated and single-phased or rounded multi-phased. When etched the knife consisted of two phases, it was predominately large grains of ferrite with ghosting (*Average 339HV, Range 271-412HV*), that in addition to the high hardness values suggest a phosphoric iron. SEM-EDS analysis only revealed traces of phosphorus (0.1%). There was also a arsenic (up to 0.2%) and nickel (up to 0.2%) present throughout the knife, possibly explaining the higher hardness values seen. Throughout the knife there were bands of tempered martensite, which formed at the cutting edge (*593HV, Average 510HV, Range 412-644HV*)

Knife 116

The x-radiograph of this knife revealed a clear dark striation suggestive of a weld line. Below this the cutting edge had a spotted texture.

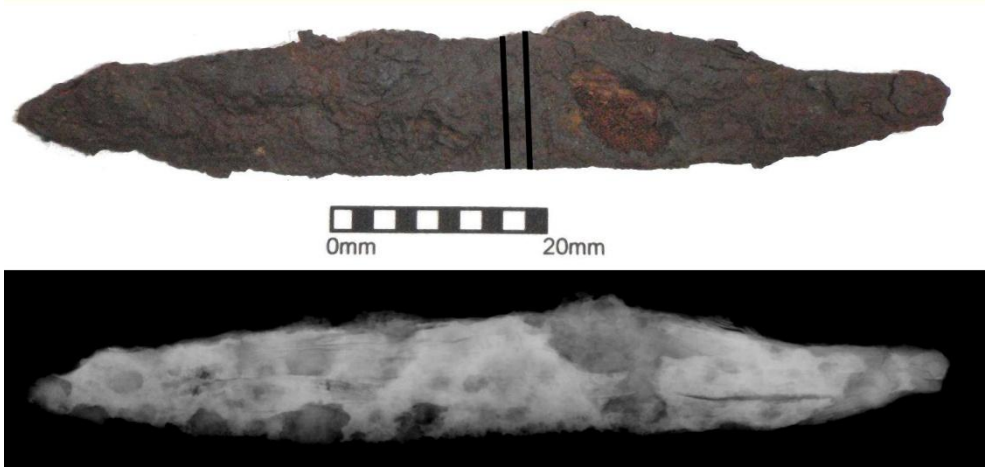


Figure 8.6: Photograph and x-radiograph of knife 116, the lines show where the section was removed.

Prior to etching, the knife was examined to reveal the presence of a weld line of sub-rounded, single-phased inclusions. There were very few slag inclusions in the cutting edge and those present were sub-rounded, single-phased inclusions. Above the weld line there were single-phased inclusions which were all rounded or sub-rounded or multi-phased and sub-angular inclusions, forming bands in the knife back.

This cutting edge is a lightly tempered martensite (473*HV, Average 396HV, Range 210-473HV*), which transformed into pearlite towards the weld line. There was some evidence for carbon diffusion across the weld line, although the back may already have been mild steel. The knife back consisted of heterogeneous bands of iron; the microstructures ranged from pearlite with ferrite around 0.2% carbon (*Average 195HV, Range 183-221HV*) to ferrite (*Average 160HV, Range 143-183HV*) and phosphoric iron (*Average 155HV, Range 143-168HV*) with only traces of phosphorus (0.1%).

Knife 118

The x-radiograph of knife 118 revealed the clear presence of a weld line and also the classic spotted texture was present throughout the knife.

Figure 8.7: Photograph and x-radiograph of knife 118, the lines show where the section was removed.

The weld line seen in the x-ray turned out to be the join between three pieces of metal that made up the knife. The three pieces of metal were similar with single-phased sub rounded inclusions in each, although there were fewer in the cutting edge.

When etched the cutting edge section predominately consisted of bainite (*321HV, Average 347HV, Range 286-386HV*). This knife section also seemed to have increased quantities of arsenic (up to 0.2%). The two pieces of iron that made up the back section of the knife were more heterogeneous, although the majority of the back bainite with ferrite (*Average 409HV, Range 340-473HV*). There were multiple white weld lines (*Average 480HV, Range 257-644HV*) seen in the knife, most were associated with the joins between the metals, but some extended into the knife cutting edge. These were enriched in large quantities of copper (up to 1.5%) and small amounts of arsenic (0.2%-0.3%).

Knife 123

The x-radiograph of knife 123 revealed the clear presence of a weld line and also the classic spotted texture was present throughout the knife.

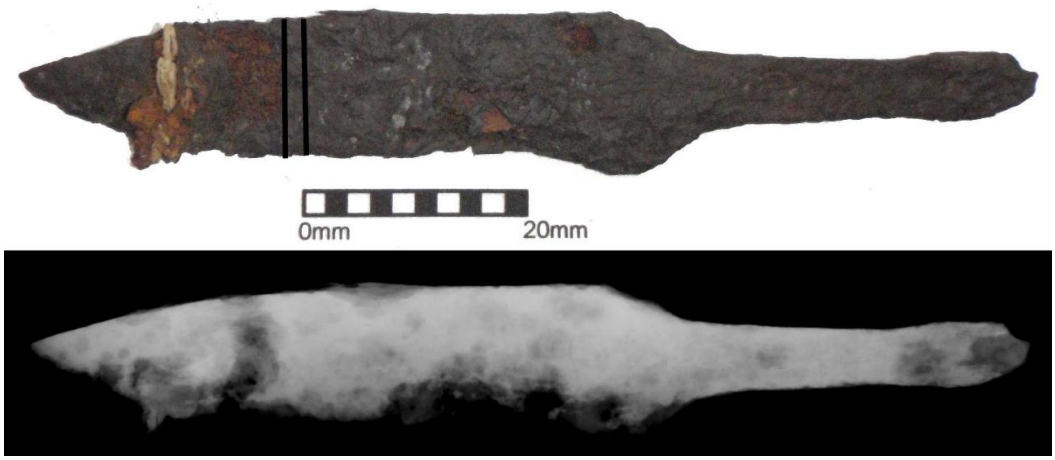


Figure 8.8: Photograph and x-radiograph of knife 123, the lines show where the section was removed.

Two etch resistant bands with single- and multi-phased elongated inclusions, which joined at the knife back, suggested that the knife was constructed of three pieces of iron. The central strip had multi-phased and elongated inclusions. To either side there were fewer inclusions which were small, sub-rounded or elongated and single-phased.

Once etched the central band turned out to be predominately ferrite with ghosting (*257HV, Average 230HV, Range 192-257HV*). SEM analysis of this metal revealed a high proportion of phosphorus, between 0.4% to 0.7%. There were two clear white weld lines, enriched in arsenic and nickel (*Average 571HV, Range 441-701HV*) separating the phosphoric iron core from the steel flanks. The two flanks to either side consisted of tempered martensite and bainite (*Average 442HV, Range 346-593HV*), although in some areas this became ferrite with pearlite (*Average 210HV, Range 168-286HV*) which had some traces of phosphorus (up to 0.2%).

This knife was constructed by welding one piece of phosphoric iron between two larger pieces of heat-treated steel, creating a ‘reverse’ type 1 knife. The phosphoric iron strip was not present throughout the knife, resulting in an upside down Y shape weld near the knife back. The knife had been heat-treated.

Knife 124

The x-radiograph of knife 124 revealed no evidence for the presence of a weld line but the classic spotted texture was present at the cutting edge.

Figure 8.9: Photograph and x-radiograph of knife 124, the line show s where the section was removed.

In the un-etched condition the few slag inclusions present were single-phased and sub- rounded. There was no evidence for a transverse weld line. After etching the knife appeared to consist of predominately ferrite. The centre of the knife had medium to large grains of ferrite (*Average 183HV, Range 161-210HV*) and near the cutting edge grains were large (*192HV*). The large grains and low carbon content of this knife suggests a phosphoric iron, this was confirmed by SEM-EDS (0.2%-0.4%).

Knife 175

The x-radiograph revealed no evidence for the presence of a weld line but the classic spotted texture was present at the cutting edge.

Figure 8.10: Photograph and x-radiograph of knife 175, the lines show where the sections were removed.

There were no clear weld lines instead the knife appeared to be fairly homogenous with few single- and multi-phased inclusions, mostly sub-rounded or elongated. The cutting edge had relatively more inclusions than the back, some of which were larger.

When etched the cutting edge section predominately consisted of pearlite with ferrite (*286HV, Average 268HV, Range 192-362HV*) which degraded to ferrite near the back. The back section of the knife was more heterogeneous and consisted of varying amounts of pearlite and ferrite. The centre of the knife consisted of ferrite with pearlite ranging from 0.3%-0.5% carbon (*Average 199HV, Range 168-221HV*) and ferrite at the back of the knife (*Average 169HV, Range 154-183HV*). SEM-EDS analysis of this knife revealed only traces of phosphorus, including in the ferrite region in the knife back (up to 0.2%).

Knife 177

The x-radiograph revealed that this knife has been badly corroded. There was no evidence for a weld line or the spotted texture.

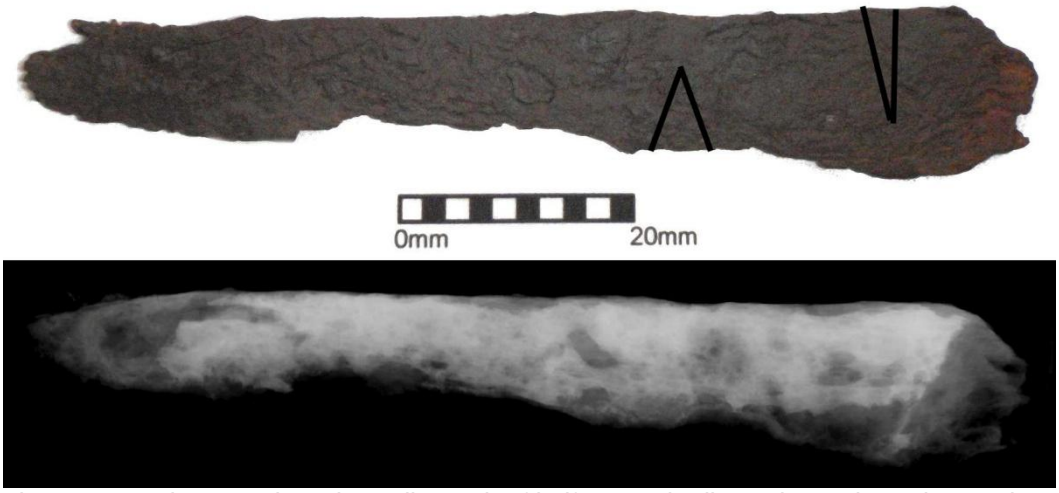


Figure 8.11: Photograph and x-radiograph of knife 177, the lines show where the sections were removed.

Prior to etching these sections revealed heavy corrosion penetration resulting in a loss of the cutting edge. There were few slag inclusions which were mostly sub-rounded, single- and multi-phased.

Once etched the two sections revealed a ferritic iron, with varying amounts of carbon, up to 0.2%. The remaining metal in the cutting edge section consisted of elongated grains of ferrite (303*HV, Average 239HV, Range 201-303HV*). The back also had small grains of ferrite with some pearlite (*Average 217HV, Range 192-244HV*) or in some cases medium to large grains of ferrite (*Average 188HV, Range 161-221HV*). No ghosting was seen suggesting no phosphorus was present, this was confirmed by SEM-EDS analysis where only traces were detected (0.1% phosphorus). The absence of a weld line suggests that this knife is a type 0 heterogeneous ferritic iron and low carbon steel knife

Knife 190

The x-radiograph of knife 190 suggested that the knife was badly corroded. There was no evidence for the presence of a weld line and the classic spotted texture was present throughout the knife.

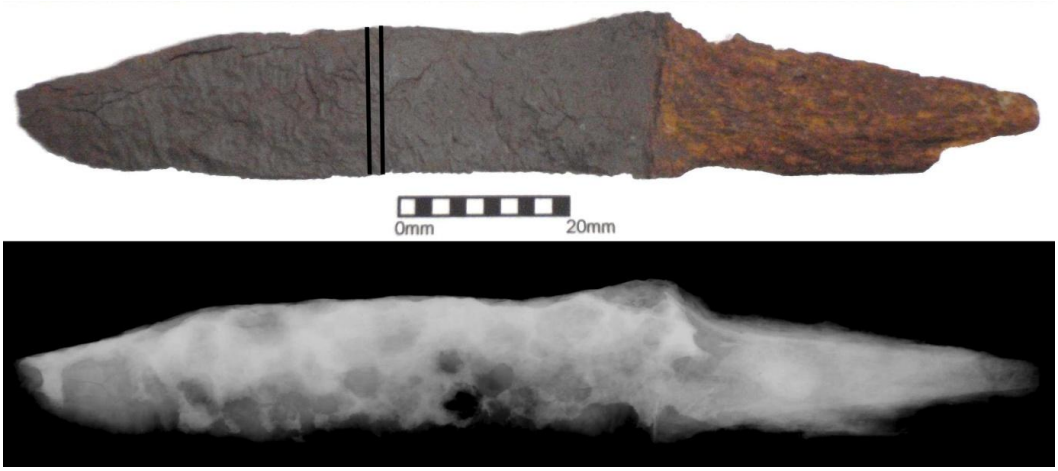


Figure 8.12: Photograph and x-radiograph of knife 190, the lines show where the section was removed.

One half of the knife was badly corroded, and had separated from the other half. The inclusions were elongated and sub-rounded, single-and multi-phased. At the cutting edge there were fewer single-phased, sub-rounded.

Once etched there were two clear vertical inclusion bands which appeared as white weld lines (*Average 233HV, Range 221-244HV*). The whole knife appears to have been constructed of pearlite with ferrite (*303HV, Average 278HV, Range 244-321HV*). At the back of the knife the microstructure changed into pearlite and bainite, with some ferrite (*Average 334HV, Range 210-412HV*). This is a type 5 knife constructed of heterogeneous pearlite with ferrite. It had not been heat-treated, although possibly the back was cooled slowly.

Knife 196

There was a no evidence for a weld line although the spotted texture suggests a heat-treated steel cutting edge. Mineralised textiles were present on the blade.

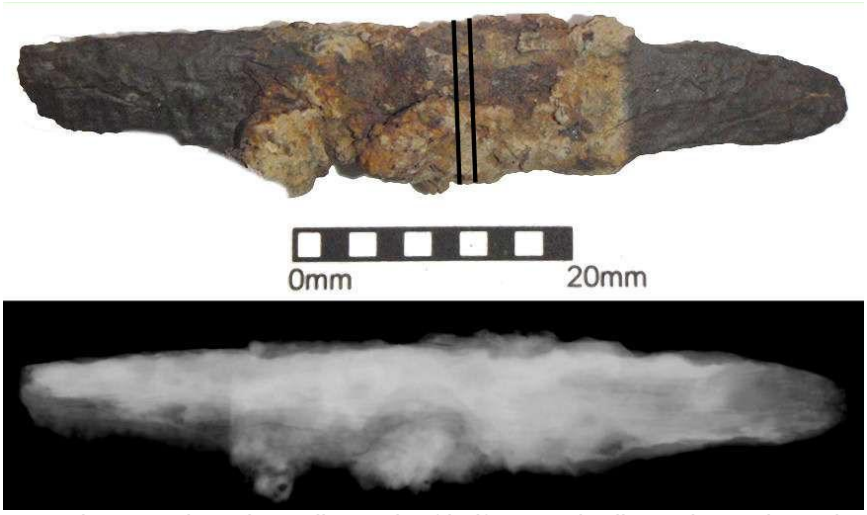


Figure 8.13: Photograph and x-radiograph of knife 196, the lines show where the section was removed.

A single section was taken to help preserve the mineralised textiles. There were two distinct areas of inclusions; the largest had few sub-angular, single phased inclusions while the other area had more multi-phased sub-rounded inclusions. Once etched the knife was revealed to be fairly homogeneous with varying amounts of carbon content between 0.1%-0.3% (*137HV, Average 147HV, Range 132-168HV*). Right at the back of the knife there was an area with medium grains of ferrite (*Average 105HV, Range 100-110HV*). SEM-EDS analysis revealed traces of phosphorus (up to 0.3%). The absence of a weld line suggests that this knife is a type 0 heterogeneous low carbon steel and low phosphorus iron knife

Knife 217

There was no evidence for a weld line or the spotted texture. Attached to the knife was a copper alloy sheet that presumably decorated the knife scabbard.

Figure 8.14: Photograph and x-radiograph of knife 217, the line shows where the section was removed.

A single section was taken from the broken end, but also a fragment of the copper alloy sheeting which fell off during sampling was also mounted in resin. There were no clear weld lines, although the corrosion was heavy in places, instead the knife appeared to be fairly homogenous with very few small, multi-phased sub-rounded inclusions.

When etched the cutting edge section predominately consisted of tempered martensite (*593HV),* this transformed to bainite and then pearlite as you moved further up the knife back *(Average 480HV, Range 286-644HV*). This knife was of type 5 manufacture constructed of steel. The cutting edge had been heat-treated.

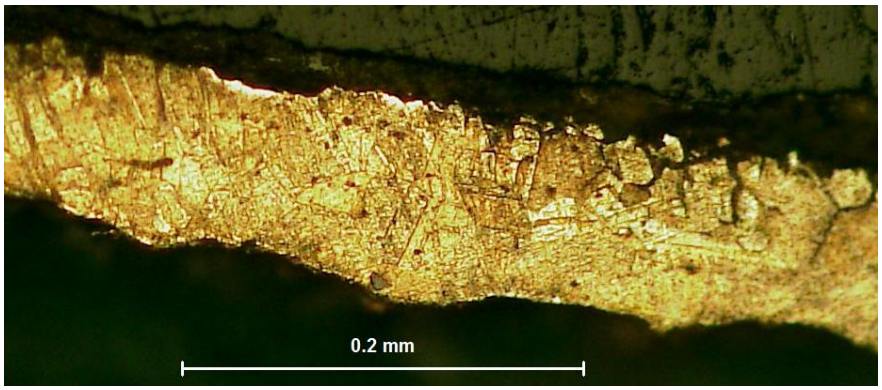


Figure 8.15: Micrograph revealing the microstructure of the copper alloy decoration present on the scabbard.

SEM-EDS analysis of the copper alloy fragment revealed a gunmetal with an average of 90% copper, 5.6% tin and 3.5% zinc. There were only traces of lead. After this was etched the microstructure turned out to consist of grains and annealed twins. This suggests that the metal was cast, then hot and cold worked into shape. There were no strain lines visible so the last activity carried out on the metal was to anneal it.

Knife 263

The x-radiograph of knife 263 revealed no evidence for a weld line or the spotted texture.

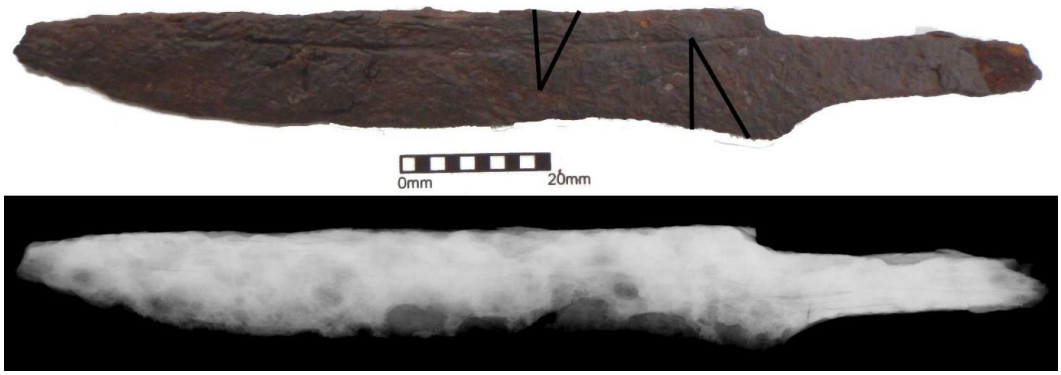


Figure 8.16: Photograph and x-radiograph of knife 263, the lines show where the sections were removed.

In the back section of the knife there was a clear transverse weld line of small sub-rounded single phased inclusions. Above which there were more, larger sub-rounded single phased inclusions. Below this weld line there were bands of vertical single- and multi-phased sub-angular and elongated inclusions. These separated areas with sub-angular, single phased inclusions. These vertical bands continued into the cutting edge section which was separated into two halve by corrosion. One side had sub-rounded multi-phased slag inclusions while the other side had more vertical bands with sub-rounded single-phased.

After etching the back of the knife turned out to be a medium to large grained ferrite *(Average 135HV, Range 123-154HV, up to 0.2% P*). The vertical bands separated three different pieces of iron. The piece that also formed the cutting edge had large grains (*161HV, Average 145HV, Range 123-161HV*), there were a few impurities, particularly arsenic (up to 0.2%). The centre strip was a pearlite with ferrite *(Average 135HV, Range 123-154HV, up to 0.1% P*) while the

remaining strip was small grains of ferrite with pearlite *(Average 135HV, Range 123-154HV, up to 0.2% P*).

Knife 128

The x-radiograph of knife revealed a possible dark striation suggestive of a weld line. There was no evidence for the spotted texture.

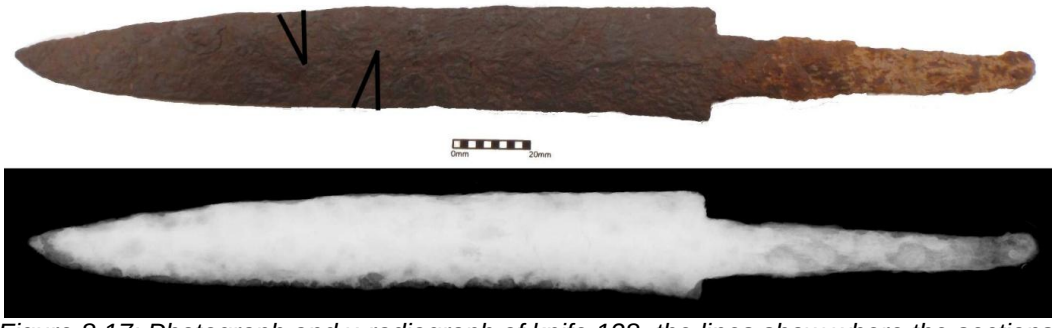


Figure 8.17: Photograph and x-radiograph of knife 128, the lines show where the sections were removed.

The inclusions in this knife were mostly sub-angular and single phased, except for the larger, multi-phased, sub rounded ones. After etching the cutting edge turned out to consist of pearlite with some ferrite (321*HV, Average 291HV, Range 221-340HV*). The carbon from the cutting edge diffused into the knife back resulting in small to medium grains of ferrite with pearlite (*Average 195HV, Range 168-221HV*). The rest of the knife back consisted of larger grains of ferrite with no pearlite and some ghosting, suggesting phosphoric iron (*Average 156HV, Range 143-175HV*). This was confirmed by SEM-EDS analysis as up to 0.6% phosphorus was detected.

Knife 252

The x-radiograph of knife 252 revealed the clear presence of a weld line and also the classic spotted texture was present in the knife.

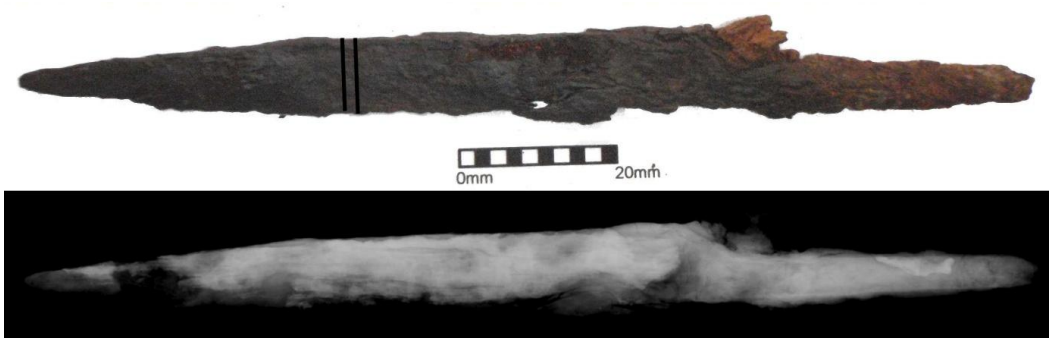


Figure 8.18: Photograph and x-radiograph of knife 252, the lines show where the section was removed.

There was a band of elongated single-phased inclusions near to the cutting edge suggesting a weld line. There were only a few inclusions in the knife back which were multi-phased and sub-rounded.

When etched the band of inclusions were revealed to be a white weld line and SEM-EDS analysis revealed that this weld line had traces of nickel and copper. Below this weld line the cutting edge was revealed to be tempered martensite (*549HV, Average 495HV, Range 441-549HV*). Just beyond this weld line the microstructure consisted of pearlite (*Average 197HV, Range 154-257HV*), which degraded into ferrite with grain boundary carbides (*Average 137HV, Range 132-148HV*). The back of the knife consisted of pearlite with ferrite (*Average 189HV, Range 175-201HV*). No phosphorus was detected in the knife.

This knife was of type 2 manufacture with a steel strip welded onto the knife back which was constructed of heterogeneous ferritic iron and steel. The cutting edge had been heat-treated, possibly gradient quenched using clay so as to preserve the pearlite microstructure in the knife back.

Knife 257

The x-radiograph revealed the clear presence of a weld line and also the classic spotted texture was present in the knife.

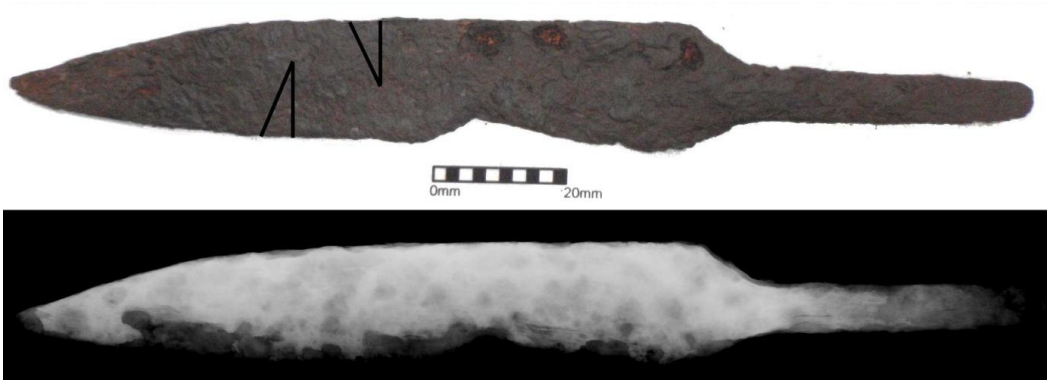


Figure 8.19: Photograph and x-radiograph of knife 257, the lines show where the sections were removed.

There was a band of spherical single-phased inclusions near to the cutting edge suggesting a weld line. In the cutting edge there were very few single-phased, sub-angular inclusions. The back was separated into two halve by single-phased, sub-rounded inclusions. Both sides had single- and multi-phased and sub-rounded and elongated inclusions.

When etched the band of inclusions were revealed to be a white weld line and SEM-EDS analysis revealed that this weld line was enriched in arsenic and had traces of nickel. Below this weld line the cutting edge was revealed to be tempered martensite (*644HV, Average 412HV, Range 303-644HV*). The two halves of the knife back consisted of ferrite with pearlite (*Average 191HV, Range 161-232HV*) with phosphorus (0.3%-0.4%) and on the other side ferrite and pearlite (*Average 140HV, Range 123-161HV*).

Knife 260

The x-radiograph revealed the clear presence of a weld line and also the classic spotted texture was present in the knife.

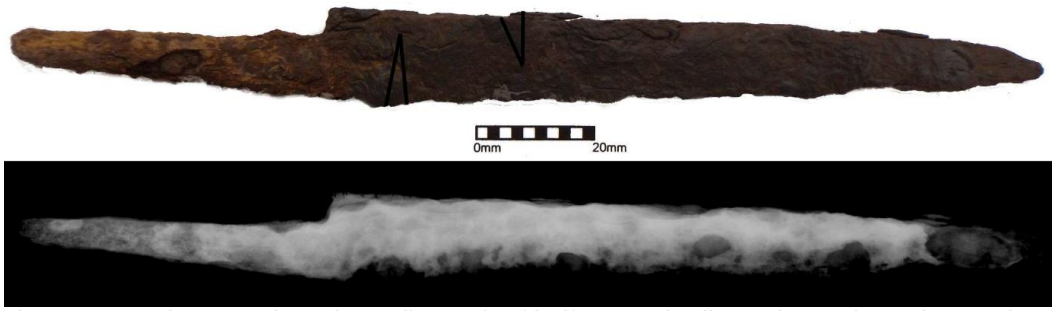


Figure 8.20: Photograph and x-radiograph of knife 260, the lines show where the sections were removed.

There was a band of sub-angular single-phased inclusions near to the cutting edge suggesting a weld line. In the cutting edge there were no visible inclusions. The back was consisted of two distinct areas; single- and multi-phased sub rounded inclusions and further towards the back single-phased and sub-rounded inclusions.

When etched the band of inclusions were revealed to be a white weld line and SEM-EDS analysis revealed that this weld line was enriched in arsenic and nickel (*Average 287HV, Range 271-303HV*). Below this weld line the cutting edge was revealed to be martensite with pearlite (509*HV, Average 339HV, Range 340-509HV*). The two areas of different inclusions turned out to be two distinct areas the first was ferrite and pearlite (*Average 174HV, Range 168-175HV*). Further towards the knife back the carbon content reduced and the grains got bigger (*Average 146HV, Range 127-175HV*). No phosphorus was detected in the knife. A vertical white line was also seen in the knife back, and this was slightly enriched in arsenic.

Knife 266

The x-radiograph of knife 266 revealed the clear presence of a weld line and also the classic spotted texture was present in the knife.

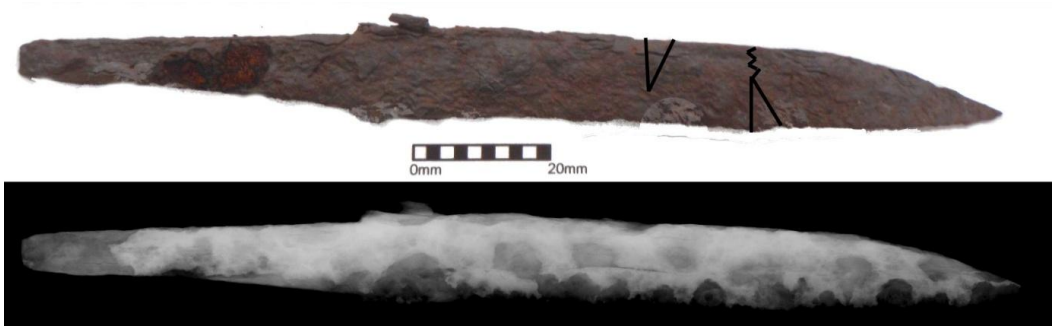


Figure 8.21: Photograph and x-radiograph of knife 266, the lines show where the sections were removed.

There were no transverse slag inclusion bands although in the back of the knife there were two raised lines, suggesting a white weld line. In the cutting edge there were very few single-phased, sub-rounded inclusions. The inclusions in the knife back were multi-phased, rounded and sub-rounded.

When etched the raised band was revealed to be a white weld line and which had nickel and arsenic (*Average 403HV, Range 257-549HV*). Below this weld line the cutting edge was revealed to be martensite which transformed into martensite and pearlite towards the weld line (*841HV, Average 693HV, Range 412-841HV*). Just beyond this weld line the microstructure consisted of ferrite with pearlite (*Average 286HV, Range 232-340HV*). The back of the knife consisted of medium to large grains (*Average 129HV, Range 114-148HV*). No phosphorus was detected in the knife.

Knife 271

X-radiography of this knife showed that it was well preserved. There was no evidence for the presence of a weld line but the cutting edge had the classic spotted texture.

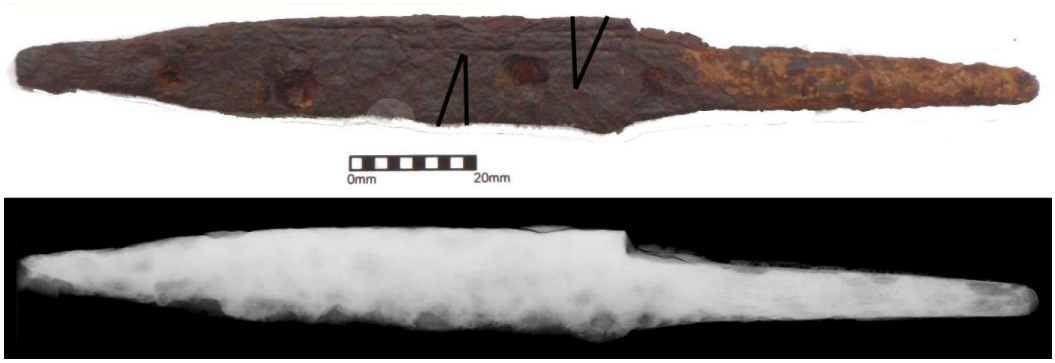


Figure 8.22: Photograph and x-radiograph of knife 271, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition, which revealed that there were two vertical slag inclusion bands, consisting of single-phased inclusions mostly elongated. Between these bands the inclusions there were few small, single-phased and angular but the inclusions in the two flanks were either large, sub-angular or elongated and single phased or they were sub-rounded and multi-phased.

When etched the two bands separated a central strip which consisted of tempered martensite at the cutting edge (*593HV, Average 649HV, Range 549-701HV*), with pearlite and ferrite towards the knife back (*Average 238HV, Range 232-244HV*). To either side of this band the microstructure consisted of large grains of ferrite with no pearlite and some ghosting (*Average 217HV, Range 148-386HV*). There was some carbon diffusion across the weld line suggesting that the two iron flanks may be phosphoric iron. SEM-EDS analysis confirmed that one side had between 0.3-0.6% phosphorus while the other only had traces.

Knife 272

The x-radiograph of this knife revealed many dark striations, possibly indicating a type 2 knife with a piled back. There was no evidence for a spotted cutting edge. The knife was badly corroded, particularly in the cutting edge.

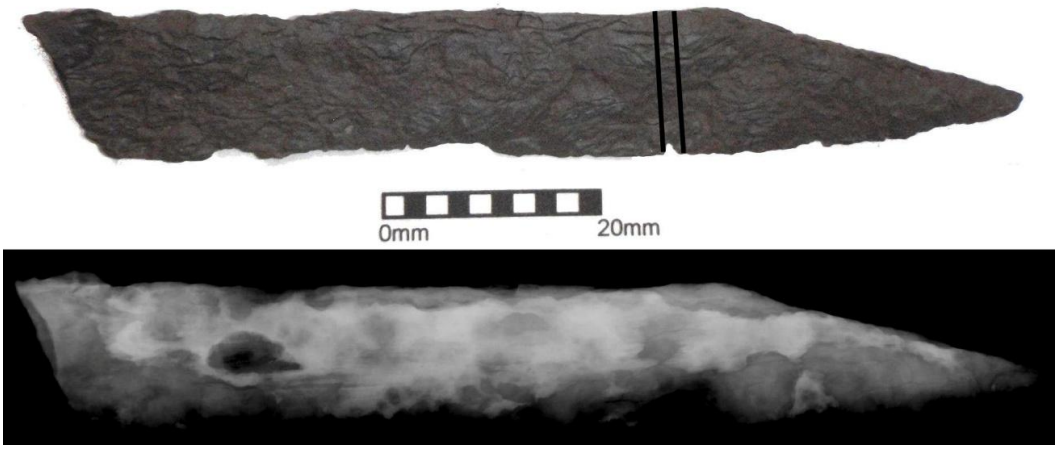


Figure 8.23: Photograph and x-radiograph of knife 272, the lines show where the section was removed.

The cutting edge had very few single-phased sub-rounded inclusions. The knife back on the other hand had many slag inclusions mostly small, single- and multi-phased, sub-angular. There was a clear weld line formed of sub-rounded single-phased inclusions.

When etched the cutting edge was revealed to consist of pearlite or fine bainite, with the hardness values suggested bainite (*303HV, Average 309HV, Range 303-321HV*). This suggests that the knife had been heat-treated but slowly so as to result in bainite rather than tempered martensite. This cutting edge was separated from the back by a white weld line enriched in arsenic, nickel and copper (*Average 199HV, Range 196-201HV*) with carbon diffusion across the line. The knife back consisted of small grains of ferrite (*Average 161HV, Range 137-192HV*), pearlite with ferrite (*Average 218HV, Range 201-244HV*) and medium grains of ferrite with ghosting (*Average 140HV, Range 123-148HV*). SEM analysis of this knife revealed phosphorus throughout the knife back (up to 0.3%).

Knife 280

X-radiography of this knife revealed that it was badly corroded, especially the cutting edge. There was a possible weld line and the spotted texture below suggests a heat-treated steel cutting edge, but could just be the result of bad corrosion

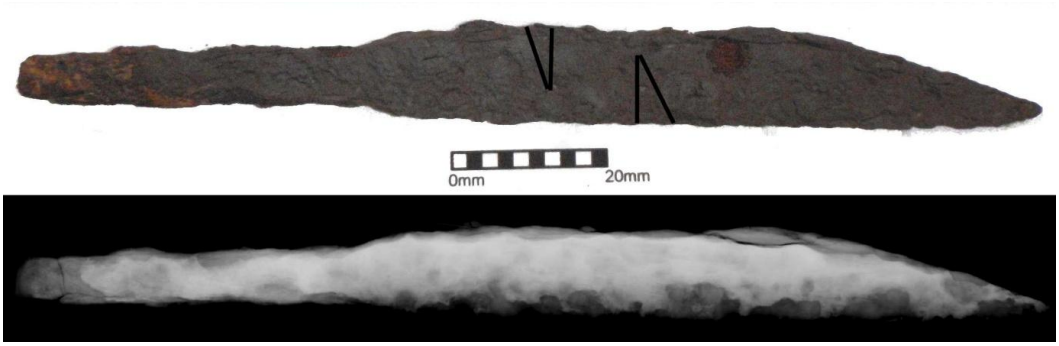


Figure 8.24: Photograph and x-radiograph of knife 280, the lines show where the sections were removed.

In the un-etched condition many of the slag inclusions were single- and multi-phased and sub-rounded or elongated. There was no evidence for a transverse weld line.

After etching the knife appeared to consist of predominately ferrite with pearlite with some bands of pearlite (*Average 168HV, Range 154-192HV*). Near the cutting edge there was a band of pearlite (*154HV*). SEM-EDS analysis detected traces of phosphorus (0.1%-0.3%). There was also a high proportion of arsenic (up to 0.3%) in the knife.

Knife 282

The x-radiograph of knife 282 revealed no weld line although the classic spotted texture was present in the knife.

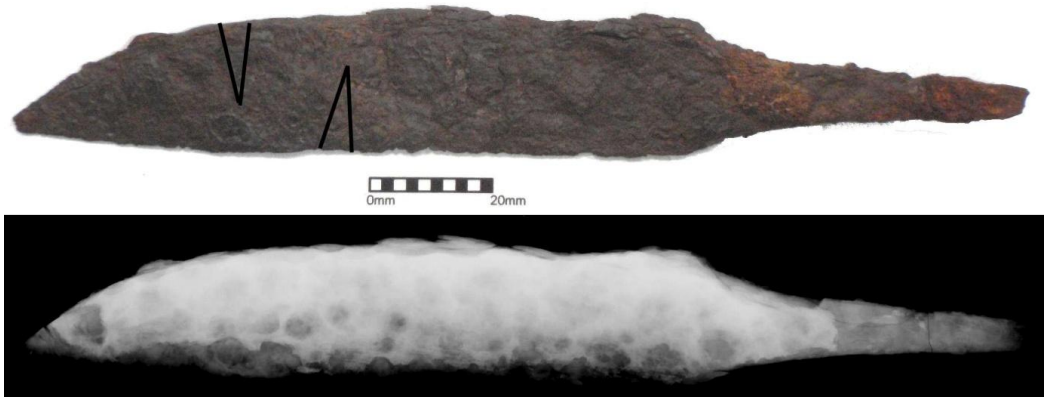


Figure 8.25: Photograph and x-radiograph of knife 282, the lines show where the sections were removed.

There was a transverse band consisting of multi-phased rounded slag inclusions. In the cutting edge there were few single-phased, sub-angular inclusions. The inclusions in the knife back were single- and multi-phased, sub-angular and sub-rounded.

When etched the weld line turned out to be a white weld line (*Average 265HV, Range 244-286HV*), this many smaller bands continued vertically from the weld line into the back. SEM-EDS analysis revealed that it was enriched in arsenic and nickel. Below this weld line the cutting edge was revealed to be temper martensite which transformed into tempered martensite and pearlite towards the weld line (*701HV, Average 629HV, Range 441-701HV*). The back of the knife consisted of pearlite with ferrite (*Average 210HV, Range 154-271HV*).

This knife was of type 2 manufacture with a steel strip welded onto the knife back which was constructed of mid carbon steel. The cutting edge had been heat-treated, possibly gradient quenched using clay so as to preserve the pearlite microstructure in the knife back.

Knife 285

There was no evidence for the presence of a weld line but the classic spotted texture was present in the cutting edge.

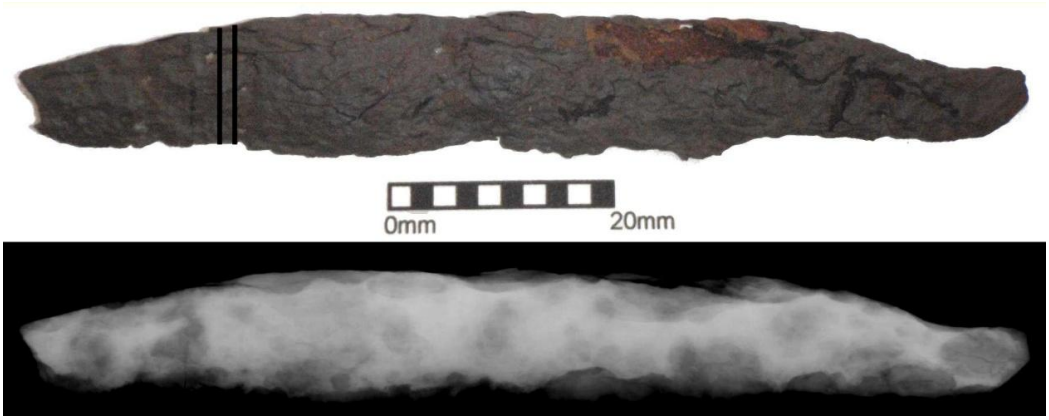


Figure 8.26: Photograph and x-radiograph of knife 285, the lines show where the section was removed.

A single section was removed and examined in the unetched condition, which revealed that there were two, or more vertical slag inclusion bands, consisting of single-phased inclusions mostly elongated or sub-rounded. Between these bands the inclusions were small, but also single-phased and elongated.

When etched two bands separated a central strip and cutting edge, which consisted of a pearlite with ferrite (*143HV, Average 138HV, Range 127-143HV*). The other bands consisted of ferrite (*Average 171HV, Range 148-183HV*). Near the back of the knife there were medium grains of ferrite with ghosting (*Average 151HV, Range 118-183HV*). There were also some vertical white bands in the knife (*Average 143HV, Range 132-154HV*). SEM-EDS analysis revealed the presence of phosphorus, but in the areas with ferrite (up to 0.5%) rather than the medium grains with ghosting.

This knife was constructed by welding lots of pieces of heterogeneous ferritic iron, phosphoric iron and steel strips creating a type 3 piled knife. The cutting edge has not been heat-treated.

Summary Assemblage Knives

Knife No	Grave	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
		Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
12	61	B	1	131	90	41	16	8	Some	Y	Y	
18	59	A	1	86	51	35	12	8	Some	Y	Y	
21	62	D	2	90	68	22	11	6	Slight	Y	Y	
29	51	B	1	101	74	27	12	8	Slight	Y	Y	Fragment
33	35	x	1	69	39	30	13	6	Very	X	X	Broken tang and blade?
34	54	B	3	194	150	44	19	12	Slight	Y	Y	
39	42	B	1	102	65	37	12	7	Some	Y	Y	
41	54											
43	55											
44	52	B	3	120	76	44	14	10	Some	X	Y	
53	40	A	2	116	76	40	10	8	Some	Y	X	
68	37	A	1	156	114	42	18	12	Some	X	Y	
71	58	A	4	106	71	35	13	8	Slight	X	Y	
87	49	A	1	140	97	43	13	9	Some	X	X	
89	45	B	1	114	84	30	14	9	Slight	Y	Y	
93	85	B	1	112	102	10	11	6	Slight	Y	Y	Broken tang
96	43	D	2	143	102	41	13	8	Some	X	Y	
97	87	D	2	85	60	25	12	7	Some	X	Y	
116	68	D	3	82	67	15	11	7	None	Y	Y	
118	83	D	1	125	75	50	14	8	Slight	Y	Y	
120	81	B	1	150	90	60	24	10	Some	Y	Y	
123	66	B	1	87	57	30	12	6	Some	Y	Y	
124	82	B	4	104	64	40	14	10	None	X	Y	
128	91	B	1	200	170	30	25	14	Slight	X	Y	
133	88	C	1	88	68	20	22	11	Slight	X	Y	
136	79	D	1	148	92	52	19	8	Some	X	Y	
138	67	x	1	115	75	40	16	8	Very	X	Y	Broken blade (deliberate)
161	93	B	4	120	82	38	13	8	Unknown	Y	Y	
162	69	x	x	19			17		Unknown			Fragment

Table 8.1: Summary table of the knives from Collingbourne Ducis showing the measurements, typologies assigned and the results from the x-radiograph analysis.

Knife No	Grave	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
		Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
175	74	B	1	144	124	20	15	7	Slight	X	X	
177	69	x	x	81	81		10		Unknown	X	Y	Broken tang
187	70	B	x	45	45		12		Unknown	Y	X	Fragment
189	69	x	x	54	54		13		Unknown	X	Y	Fragment
190	77	C	3	114	74	40	15	11	Slight	X	Y	
195	94	B	1	164	97	67	20	11	Some	X	Y	
196	71	B	2	55	40	15	9	6	None	X	X	
197	72	B	1	135	92	43	14	8	Some	Y	X	
217	38	x	2	62	36	26	12	6	Unknown	X	X	Broken blade (deliberate)
219	38											
252	104	A	3	123	84	39	8	6	Slight	Y	X	
257	106	A	1	145	105	40	15	7	Slight	Y	Y	
260	108	B	3	166	116	50	14	8	Slight	Y	Y	
263	76	D	1	133	95	38	14	8	Some	Y	Y	
266	110	B	3	137	90	47	11	9	None	Y	Y	
271	107	B	1	156	96	60	16	9	None	X	Y	
272	102	A	x	84	84		12		Slight	Y	X	Broken tang
277	103	B	3	99	63	33	11	5	Slight	Y	Y	
280	109	B	3	127	83	44	11	7	None	Y	Y	
282	101	B	1	154	111	43	20	12	Slight	X	Y	
285	97	B	4	86	63	23	11	6	None	X	Y	
287	100	B	3	136	84	52	14	10	Slight	Y	Y	
402	44	B	1	158	108	50	15	8	None	Y	Y	
1000	114	B	3	225	164	61	19	10	Some	Y	Y	
1002	116											
1004	115	B	1	113	77	40	13	7	Unknown	X	Y	

Table 5.1 cont: Summary table of the knives from Collingbourne Ducis showing the measurements, typologies assigned and the results from the x-radiograph analysis.

SEM-EDS Data

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
12	grains (large)	n.d.	0.2	n.d.	n.d.	99.6	n.d.	n.d.	0.1	95.1
		n.d.	0.1	0.1	n.d.	99.6	0.2	0.1	0.1	98.2
		n.d.	0.3	n.d.	n.d.	99.5	0.1	0.1	n.d.	96.7
	ferrite with pearlite	n.d.	0.3	n.d.	0.1	99.6	0.1	n.d.	n.d.	96.4
		n.d.	0.3	n.d.	n.d.	99.4	0.1	0.1	n.d.	100.4
		0.1	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	95.2
	ferrite with carbdes	0.1	0.2	n.d.	n.d.	99.5	0.1	0.1	n.d.	98.9
		0.1	0.2	n.d.	n.d.	99.6	n.d.	0.1	n.d.	98.7
		0.2	0.1	n.d.	n.d.	99.4	n.d.	0.2	0.1	99.1
18		n.d.	0.1	0.1	n.d.	99.6	n.d.	n.d.	0.2	101.9
		0.2	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	102.9
		0.1	n.d.	n.d.	n.d.	99.3	n.d.	0.1	0.4	102.4
		0.1	0.1	n.d.	n.d.	99.4	n.d.	n.d.	0.3	102.5
		0.1	0.1	0.1	n.d.	99.7	n.d.	n.d.	0.1	100.4
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	0.1	0.1	101.1
		0.1	n.d.	n.d.	0.1	99.6	n.d.	n.d.	0.1	99.8
		n.d.	0.2	n.d.	0.1	99.2	0.1	n.d.	0.3	99.3
		0.1	0.2	n.d.	n.d.	99.6	n.d.	0.1	0.1	98.3
		0.1	n.d.	n.d.	n.d.	99.6	0.2	0.1	n.d.	97.1
		0.1	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.1	96.4
		n.d.	0.1	0.1	n.d.	99.6	n.d.	n.d.	0.2	95.0
39	cutting edge	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	104.5
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	104.1
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	104.0
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	103.0
	large grains	n.d.	0.1	n.d.	0.1	99.5	n.d.	n.d.	0.2	103.9
		0.1	0.2	n.d.	n.d.	99.6	n.d.	n.d.	0.1	105.6
		n.d.	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.2	106.5
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	0.1	0.1	105.5
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	109.4
		0.1	n.d.	0.1	n.d.	99.3	n.d.	0.2	0.2	105.5
	white weld line	0.1	n.d.	n.d.	n.d.	98.8	0.2	0.1	0.7	107.3
		n.d.	0.3	n.d.	n.d.	98.6	0.1	n.d.	1.0	108.6

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
44	small grains	0.1	0.1	n.d.	n.d.	99.4	n.d.	0.2	0.2	97.7
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	0.1	n.d.	98.1
	medium grains	n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	0.2	100.5
		0.1	0.1	n.d.	n.d.	99.5	n.d.	0.1	0.1	99.6
		0.1	0.1	0.1	n.d.	99.6	n.d.	n.d.	0.2	98.7
	ferrite with pearlite middle	0.1	0.2	n.d.	0.1	99.5	n.d.	n.d.	0.1	100.5
		0.1	0.2	0.1	n.d.	99.3	0.1	n.d.	0.2	102.0
		0.1	n.d.	n.d.	n.d.	99.5	n.d.	0.1	0.2	100.3
	ferrite with pearlite	n.d.	0.3	n.d.	n.d.	99.7	n.d.	n.d.	0.1	100.9
		n.d.	n.d.	n.d.	0.1	99.9	n.d.	n.d.	n.d.	101.6
		0.1	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	104.2
	pearlite with ferrite	n.d.	0.1	n.d.	n.d.	99.5	0.1	0.2	0.1	100.9
		n.d.	n.d.	n.d.	0.1	99.5	n.d.	0.2	0.1	101.7
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	0.1	0.2	104.4
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	0.1	102.8
		n.d.	0.1	0.1	n.d.	99.6	n.d.	0.1	n.d.	106.5
	large grains	0.1	0.1	0.1	n.d.	99.5	n.d.	n.d.	0.2	103.4
		n.d.	0.1	n.d.	n.d.	99.3	0.2	n.d.	0.4	106.4
		n.d.	0.1	0.1	n.d.	99.5	0.1	0.1	0.1	108.6
		n.d.	0.1	n.d.	n.d.	99.5	0.1	n.d.	0.3	112.3
	medium grains	n.d.	0.1	n.d.	n.d.	99.5	n.d.	n.d.	0.2	106.2
		n.d.	0.2	n.d.	0.1	99.4	0.2	0.1	n.d.	110.9
		0.1	0.1	n.d.	n.d.	99.7	0.1	n.d.	0.1	112.0
		n.d.	0.2	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	111.8
	martensite	0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	112.7
		n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	0.1	112.8
		0.1	0.1	n.d.	n.d.	99.0	n.d.	0.1	0.8	113.4
		n.d.	0.1	n.d.	n.d.	99.0	0.3	0.1	0.6	106.5
96		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	97.2
		0.1	0.1	n.d.	n.d.	99.4	0.1	n.d.	0.2	107.1
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	n.d.	107.0
		n.d.	0.1	n.d.	n.d.	99.7	0.1	0.1	n.d.	107.3
		n.d.	n.d.	n.d.	n.d.	99.8	0.2	n.d.	n.d.	107.6
		0.1	0.1	n.d.	n.d.	99.5	0.2	n.d.	n.d.	108.4
		n.d.	0.1	n.d.	n.d.	99.8	0.1	n.d.	n.d.	104.5
		0.1	n.d.	n.d.	n.d.	99.4	0.1	0.1	0.2	99.2
		0.3	n.d.	0.1	n.d.	99.4	n.d.	n.d.	0.1	101.4

Table 8.2: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
116	cutting edge	n.d.	0.3	n.d.	n.d.	99.5	n.d.	0.1	n.d.	104.6
		0.1	0.3	n.d.	n.d.	99.3	0.2	n.d.	0.1	107.0
		n.d.	0.2	n.d.	n.d.	99.6	0.1	n.d.	n.d.	106.1
	ferrite (med)	n.d.	0.1	0.1	n.d.	99.6	n.d.	0.1	0.2	105.9
		n.d.	0.1	n.d.	n.d.	99.6	0.2	n.d.	0.1	108.6
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	107.4
	ferrite (small)	0.1	0.1	0.1	n.d.	99.6	0.1	n.d.	0.1	110.5
		0.4	n.d.	n.d.	n.d.	99.3	0.1	0.2	n.d.	110.7
		0.1	0.1	n.d.	n.d.	99.5	0.1	n.d.	0.1	111.1
	ferrite (med)	0.1	n.d.	n.d.	n.d.	99.5	0.1	n.d.	0.2	108.2
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	113.1
		n.d.	n.d.	n.d.	n.d.	99.5	0.1	0.1	0.3	113.1
	ferrite with pearlite	0.1	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	99.4
		0.1	0.2	n.d.	n.d.	99.7	n.d.	n.d.	0.1	100.2
		0.1	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	103.7
118	cutting edge	0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	107.0
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	103.6
		0.2	0.1	n.d.	n.d.	99.4	n.d.	0.1	0.1	104.3
		n.d.	n.d.	0.1	n.d.	99.7	n.d.	0.1	0.1	102.1
		n.d.	0.1	n.d.	n.d.	99.5	0.1	n.d.	0.2	108.4
		n.d.	0.1	n.d.	n.d.	99.6	0.1	0.1	0.1	105.6
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	102.0
	white weld line	n.d.	n.d.	n.d.	0.1	98.3	n.d.	1.5	0.2	104.6
		0.1	n.d.	n.d.	n.d.	98.5	0.2	0.9	0.3	104.9
	left flank	n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	n.d.	107.5
		n.d.	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.1	106.3
		n.d.	n.d.	0.1	n.d.	99.9	n.d.	n.d.	n.d.	103.0
	right flank	0.1	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.2	106.6
		n.d.	0.2	n.d.	n.d.	99.3	0.1	n.d.	0.4	109.7
		n.d.	0.1	n.d.	0.1	99.4	n.d.	n.d.	0.4	98.2
123	ferrite	0.1	0.5	n.d.	n.d.	98.9	0.2	n.d.	0.3	96.3
		n.d.	0.7	n.d.	n.d.	98.8	n.d.	0.1	0.3	95.7
		0.1	0.6	n.d.	0.1	98.6	0.1	0.3	0.3	95.5
		n.d.	0.4	n.d.	0.1	99.0	0.1	n.d.	0.4	96.9
	small grains	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	100.5
		0.1	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.1	102.0
		0.1	0.2	n.d.	n.d.	99.4	0.2	0.1	n.d.	107.1
		n.d.	0.2	n.d.	n.d.	99.6	0.1	0.1	n.d.	108.4
	martensite	0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	0.1	102.5
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.2	101.8
		n.d.	0.1	n.d.	n.d.	99.7	0.2	n.d.	n.d.	98.2
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	96.1
	weld line	n.d.	0.1	n.d.	0.1	98.4	0.2	n.d.	1.2	93.0
		0.1	0.6	n.d.	n.d.	98.8	0.1	n.d.	0.3	99.0
		n.d.	0.6	0.1	n.d.	98.8	n.d.	n.d.	0.5	100.2

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
124		n.d.	0.3	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	92.9
		n.d.	0.3	0.1	n.d.	99.5	n.d.	n.d.	n.d.	98.7
		n.d.	0.3	n.d.	n.d.	99.7	n.d.	0.1	n.d.	101.8
		n.d.	0.4	n.d.	n.d.	99.3	0.1	0.2	n.d.	95.3
		n.d.	0.2	n.d.	n.d.	99.5	0.1	n.d.	0.1	106.0
		n.d.	0.3	n.d.	n.d.	99.4	n.d.	n.d.	0.2	104.4
		0.1	0.3	0.1	n.d.	99.3	n.d.	0.2	n.d.	100.8
175	ferrite with pearlite	n.d.	0.1	n.d.	n.d.	99.4	n.d.	0.1	0.4	94.1
		n.d.	0.2	n.d.	n.d.	99.3	0.2	n.d.	0.2	90.4
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	90.4
		0.1	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	96.2
		0.1	0.2	0.1	n.d.	99.6	n.d.	n.d.	n.d.	95.3
		0.1	0.3	n.d.	n.d.	99.1	n.d.	0.2	0.3	93.0
		0.1	0.2	n.d.	n.d.	99.2	n.d.	0.2	0.2	80.5
		n.d.	0.2	0.1	0.1	99.4	n.d.	n.d.	0.1	105.1
		0.1	0.2	n.d.	n.d.	99.5	n.d.	n.d.	0.2	99.2
	medium grains	0.2	0.2	n.d.	n.d.	99.2	n.d.	0.1	0.3	101.0
		0.1	0.2	n.d.	n.d.	99.1	0.1	0.1	0.4	99.6
		n.d.	0.2	0.1	n.d.	99.4	0.1	n.d.	0.2	97.3
		n.d.	0.1	0.1	n.d.	99.2	0.1	0.2	0.4	97.9
177	small grains	n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	101.6
		n.d.	0.1	n.d.	0.1	99.7	n.d.	n.d.	0.1	100.6
		n.d.	0.2	n.d.	0.1	99.4	n.d.	n.d.	0.3	101.5
	ferrite with pearlite	n.d.	n.d.	0.1	n.d.	99.8	n.d.	0.1	0.1	103.7
		0.1	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.1	102.8
		n.d.	0.2	n.d.	n.d.	99.4	n.d.	0.2	0.2	102.4
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	101.6
	large grains	0.1	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	100.1
		0.1	0.1	n.d.	n.d.	99.3	0.2	0.3	n.d.	99.6
		0.1	n.d.	n.d.	0.1	99.6	0.1	n.d.	0.1	99.6
		n.d.	n.d.	0.1	0.1	99.8	n.d.	n.d.	n.d.	98.8
190	cutting edge	n.d.	0.1	n.d.	n.d.	99.6	n.d.	0.1	0.2	94.2
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.2	92.3
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	0.1	0.3	101.3
		n.d.	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.2	106.2
		0.1	0.2	n.d.	n.d.	99.5	n.d.	n.d.	0.3	105.0
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.2	102.4
		0.1	0.1	n.d.	n.d.	99.1	0.2	n.d.	0.4	110.3
	ferrite	0.1	0.2	n.d.	0.1	99.3	0.1	n.d.	0.2	109.0
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	105.3
		n.d.	0.2	0.1	n.d.	99.5	0.1	n.d.	0.1	108.3
		n.d.	n.d.	n.d.	n.d.	99.5	0.1	0.1	0.2	108.1
		0.1	0.2	n.d.	n.d.	99.6	0.1	n.d.	n.d.	108.7
	pearlite	n.d.	0.1	n.d.	n.d.	99.3	0.1	0.2	0.2	106.5
		n.d.	0.1	n.d.	n.d.	99.6	0.1	0.1	n.d.	100.1
		n.d.	0.2	n.d.	n.d.	99.7	0.1	n.d.	n.d.	93.6

Table 5.2 cont: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
196	ferrite with pearlite	n.d.	0.1	0.1	n.d.	99.6	0.1	0.1	n.d.	109.8
		0.1	0.3	0.1	n.d.	99.0	0.1	n.d.	0.3	109.2
		0.1	0.1	n.d.	n.d.	99.6	0.1	0.1	n.d.	106.5
		n.d.	0.2	0.2	0.1	99.6	n.d.	n.d.	n.d.	108.4
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	0.1	105.0
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	0.1	0.1	103.3
	ferrite with pearlite	n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	102.5
		n.d.	0.2	0.1	n.d.	99.6	0.1	n.d.	0.1	106.3
		n.d.	0.1	n.d.	n.d.	99.6	0.1	0.1	n.d.	101.5
217		0.1	n.d.	n.d.	0.1	99.6	n.d.	0.1	0.1	99.3
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	101.7
		0.1	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	100.4
		0.1	n.d.	n.d.	n.d.	99.7	0.2	n.d.	0.1	97.9
		n.d.	n.d.	n.d.	0.1	99.5	0.1	0.2	n.d.	101.7
		n.d.	0.1	0.1	n.d.	99.5	n.d.	n.d.	0.3	107.0
263	large grains (left flank)	0.1	n.d.	n.d.	0.1	99.4	0.1	0.1	0.2	102.5
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	102.4
		0.1	0.1	n.d.	n.d.	99.5	n.d.	0.1	0.2	105.9
	ferrite with pearlite	n.d.	n.d.	n.d.	n.d.	99.6	0.2	n.d.	n.d.	105.7
		0.1	0.1	n.d.	n.d.	99.3	0.1	0.1	0.2	107.3
		0.1	0.1	n.d.	n.d.	99.5	n.d.	n.d.	0.2	109.0
	pearlite with ferrite	0.1	0.1	n.d.	n.d.	99.5	n.d.	0.2	0.2	11n.d.
		0.1	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.2	95.4
		0.1	0.1	n.d.	0.1	99.5	0.1	n.d.	n.d.	96.0
	ferrite with pearlite (right)	0.1	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.2	92.9
		0.1	0.1	n.d.	n.d.	99.7	0.1	n.d.	n.d.	93.7
		n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	103.7
	large grains	0.1	0.2	n.d.	0.1	99.5	0.1	n.d.	n.d.	99.9
		n.d.	0.1	n.d.	0.1	99.6	0.3	n.d.	n.d.	99.1
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.2	96.4
128	pearlite with ferrite	0.2	0.2	0.1	n.d.	99.2	0.2	n.d.	0.1	97.2
		n.d.	0.2	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	109.3
		n.d.	0.3	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	108.0
	ferrite with pearlite	0.1	0.5	n.d.	0.1	98.9	0.1	0.2	0.1	107.8
		n.d.	0.3	0.1	n.d.	99.6	n.d.	n.d.	n.d.	107.8
		n.d.	0.3	n.d.	0.1	99.4	n.d.	n.d.	0.1	105.4
		n.d.	0.4	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	106.8
		n.d.	0.4	n.d.	0.1	99.3	n.d.	n.d.	0.1	103.5
		n.d.	0.3	n.d.	0.1	99.5	n.d.	0.1	n.d.	103.4
	large grains	n.d.	0.3	n.d.	n.d.	99.6	0.1	n.d.	n.d.	106.1
		0.1	0.3	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	108.1
		n.d.	0.2	n.d.	n.d.	99.5	0.1	0.2	n.d.	106.0

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
252	cutting edge	0.2	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.1	97.5
		n.d.	0.2	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	106.4
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	95.9
	weld line	n.d.	0.1	n.d.	n.d.	99.3	0.3	0.2	0.1	99.2
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	0.1	n.d.	98.1
	ferrite with pearlite	0.1	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	98.3
		n.d.	0.1	n.d.	n.d.	99.6	0.1	0.1	0.2	97.2
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	95.8
	pearlite with ferrite	n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.2	97.2
		0.1	0.1	n.d.	n.d.	99.6	n.d.	0.2	n.d.	98.6
		n.d.	n.d.	n.d.	0.1	99.7	0.1	n.d.	0.1	97.0
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	95.8
257	cutting edge	n.d.	0.1	n.d.	n.d.	99.9	0.1	n.d.	n.d.	88.2
		0.1	n.d.	0.1	n.d.	99.4	n.d.	0.1	0.3	92.0
		0.2	n.d.	0.1	n.d.	99.6	n.d.	0.1	0.1	96.8
		n.d.	0.2	n.d.	n.d.	99.5	0.1	0.1	0.1	103.8
	white weld line	n.d.	0.1	n.d.	n.d.	99.5	0.2	n.d.	0.1	96.9
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.2	94.7
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.2	92.1
	ferrite with some pearlite	n.d.	0.3	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	99.5
		0.1	0.4	n.d.	n.d.	99.3	0.2	n.d.	n.d.	100.6
		0.1	0.4	n.d.	0.1	99.3	n.d.	n.d.	0.1	99.2
	ferrite with pearlite	0.2	0.1	0.1	n.d.	99.5	0.1	n.d.	0.1	97.1
		0.1	0.1	n.d.	n.d.	99.6	0.1	0.1	n.d.	95.3
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	n.d.	0.1	94.5
260	cutting edge	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.2	90.2
		0.1	n.d.	0.1	n.d.	99.7	n.d.	n.d.	0.2	114.4
		n.d.	0.1	n.d.	n.d.	99.6	0.2	0.1	n.d.	113.3
	white weld line	4.9	0.1	n.d.	n.d.	92.4	1.3	0.1	1.2	93.2
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	97.1
	ferrite with pearlite	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.3	96.8
		n.d.	0.1	0.1	n.d.	99.9	n.d.	n.d.	n.d.	96.1
		0.1	0.1	n.d.	n.d.	99.3	n.d.	0.2	0.2	96.1
	large grains	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	95.9
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	104.9
		n.d.	0.1	n.d.	0.1	99.8	n.d.	n.d.	n.d.	102.6
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	102.6
	ferrite with pearlite	n.d.	n.d.	n.d.	0.1	99.7	0.1	n.d.	n.d.	102.7
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	0.1	103.9
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	103.1
		n.d.	n.d.	n.d.	n.d.	99.8	0.1	0.1	n.d.	100.8
	white weld line	n.d.	0.1	n.d.	0.1	99.8	n.d.	n.d.	n.d.	104.9
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.2	103.4
	small grains	n.d.	n.d.	0.1	n.d.	99.8	n.d.	n.d.	0.1	100.1
		n.d.	n.d.	n.d.	0.1	99.7	0.1	0.1	n.d.	102.3
		0.1	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	0.1	98.9

Table 5.2 cont: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
266	martensite	0.1	n.d.	n.d.	0.2	99.7	n.d.	n.d.	n.d.	105.7
		n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	104.8
		n.d.	0.1	0.1	n.d.	99.7	0.1	n.d.	n.d.	104.1
	martensite with pearlite	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.1	105.6
		0.1	n.d.	0.1	n.d.	99.8	n.d.	0.1	n.d.	107.4
		n.d.	n.d.	n.d.	0.1	99.6	n.d.	0.1	n.d.	108.8
	weld line	n.d.	n.d.	n.d.	n.d.	99.5	0.4	n.d.	0.1	109.8
		n.d.	n.d.	n.d.	n.d.	99.4	0.4	n.d.	0.1	108.3
	large grains	0.1	n.d.	0.1	n.d.	99.7	n.d.	n.d.	n.d.	101.7
		n.d.	0.1	n.d.	n.d.	99.4	0.1	0.2	0.2	101.4
		n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	102.2
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	100.5
271	tempered martensite	0.1	0.1	0.1	n.d.	99.7	n.d.	n.d.	n.d.	106.4
		0.1	0.3	n.d.	n.d.	99.4	n.d.	0.1	n.d.	104.4
		n.d.	0.2	0.1	n.d.	99.6	n.d.	n.d.	n.d.	103.3
		0.4	0.1	n.d.	n.d.	99.3	n.d.	0.1	0.1	96.5
		0.4	0.1	n.d.	n.d.	99.2	n.d.	0.2	0.1	96.7
		0.2	0.2	n.d.	n.d.	99.6	n.d.	n.d.	0.1	96.6
	left flank	n.d.	0.3	n.d.	n.d.	99.4	n.d.	0.1	0.1	98.0
		n.d.	0.6	n.d.	n.d.	99.2	n.d.	0.1	0.1	98.5
		0.2	0.3	n.d.	n.d.	99.4	0.1	n.d.	n.d.	97.8
	right flank	0.3	n.d.	n.d.	n.d.	99.1	n.d.	0.2	0.3	102.2
		0.2	n.d.	n.d.	n.d.	99.6	0.1	n.d.	0.1	99.7
		n.d.	n.d.	0.1	n.d.	99.6	0.1	n.d.	0.1	98.1
		0.2	0.2	n.d.	n.d.	99.3	0.3	n.d.	n.d.	97.3
		0.1	0.2	0.1	0.1	99.5	n.d.	0.1	n.d.	96.3
272	cutting edge	0.1	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	96.1
		0.2	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	106.6
		0.1	n.d.	n.d.	n.d.	99.5	0.1	0.1	0.1	108.7
	white weld line	1.7	n.d.	0.1	0.1	96.7	1.0	0.2	0.2	100.9
		0.1	n.d.	n.d.	0.1	97.9	1.1	0.2	0.6	104.8
	ferrite	n.d.	0.2	n.d.	n.d.	99.7	n.d.	0.1	n.d.	112.0
		n.d.	0.3	n.d.	n.d.	99.4	0.1	n.d.	0.1	108.0
		0.1	0.3	n.d.	n.d.	99.2	0.1	0.1	0.1	101.8
	pearlite with ferrite	0.1	0.2	0.1	n.d.	99.1	n.d.	0.1	0.4	98.5
		0.1	0.2	0.1	n.d.	99.3	0.2	0.1	n.d.	106.6
		n.d.	0.2	n.d.	n.d.	99.2	n.d.	0.3	0.2	106.1
	medium grains	0.1	0.2	0.1	n.d.	99.4	0.1	0.1	0.1	109.3
		n.d.	0.2	n.d.	n.d.	99.5	0.1	0.1	0.1	104.1
		0.1	0.1	n.d.	0.1	99.6	n.d.	n.d.	0.2	106.7

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
280		n.d.	0.1	n.d.	n.d.	99.7	0.2	n.d.	n.d.	97.4
		n.d.	0.1	n.d.	n.d.	99.7	0.1	0.1	0.1	97.3
		0.1	0.1	0.1	0.1	99.3	0.2	0.1	0.1	97.5
		0.1	0.3	n.d.	n.d.	99.3	n.d.	n.d.	0.3	96.2
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	98.2
		0.1	0.2	n.d.	n.d.	99.6	n.d.	0.1	n.d.	97.3
282	cutting edge	n.d.	0.1	n.d.	n.d.	99.6	n.d.	0.1	0.1	107.9
		n.d.	0.1	n.d.	0.1	99.8	n.d.	0.1	n.d.	100.9
		n.d.	n.d.	n.d.	0.1	99.9	n.d.	n.d.	n.d.	102.5
		n.d.	0.1	n.d.	0.2	99.5	n.d.	0.1	n.d.	99.9
	weld line	n.d.	0.1	0.1	n.d.	98.6	0.1	n.d.	1.1	102.1
		0.1	n.d.	n.d.	n.d.	99.0	0.2	n.d.	0.7	102.7
	pearlite with ferrite	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	103.8
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	101.1
		0.1	0.1	n.d.	n.d.	99.7	0.1	n.d.	n.d.	107.4
	ferrite with pearlite	n.d.	0.1	0.1	n.d.	99.6	n.d.	n.d.	0.2	100.1
		0.1	0.1	n.d.	n.d.	99.6	n.d.	0.2	n.d.	105.5
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.3	100.6
		0.1	0.1	n.d.	n.d.	99.7	n.d.	0.1	n.d.	104.3
	pearlite with ferrite	0.1	n.d.	n.d.	n.d.	99.7	n.d.	0.2	0.1	98.7
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.2	105.5
		0.1	0.1	0.1	0.1	99.3	n.d.	0.1	0.2	107.5
285	ferrite with pearlite	n.d.	0.2	n.d.	0.1	99.3	0.2	0.1	n.d.	96.4
		0.1	0.1	n.d.	n.d.	99.5	0.1	0.1	0.2	96.7
		n.d.	0.1	n.d.	0.1	99.7	n.d.	n.d.	n.d.	103.4
		0.1	0.5	n.d.	0.1	99.2	n.d.	0.2	n.d.	110.5
		n.d.	0.3	n.d.	n.d.	99.4	0.2	n.d.	n.d.	110.1
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	0.1	110.2
		n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	109.7
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	109.4
	medium grains	n.d.	n.d.	0.1	n.d.	99.5	n.d.	0.3	n.d.	99.9
		n.d.	0.1	n.d.	n.d.	99.7	0.1	0.1	n.d.	100.2

Table 5.2 cont Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

White Weld Lines

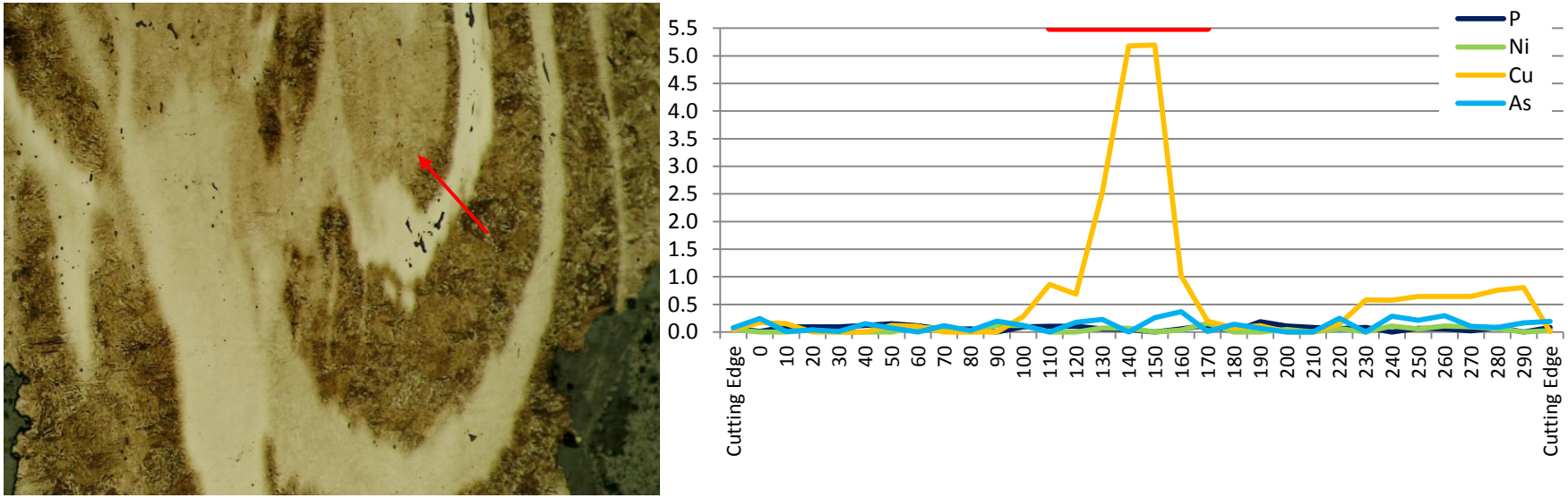


Figure 8.27: Line scan across the white weld line in Collingbourne Ducis Knife 118

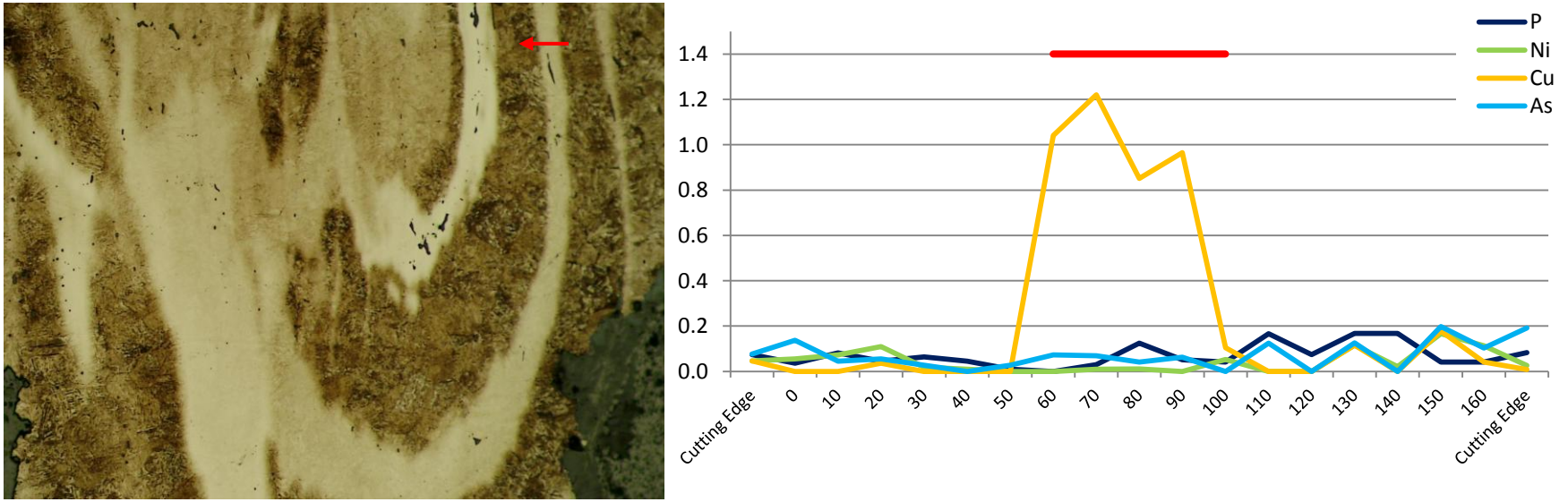


Figure 8.28: Line scan across the white weld line in Collingbourne Ducis Knife 118

Chapter 9: Wharram Percy

Knife Descriptions

Knife 110 (85)

The x-radiograph confirmed the extent of corrosion of knife 110 (85) with areas of the tang and blade being particularly affected. The un-corroded areas showed that the cutting edge had a characteristic steel texture although there was little evidence for a horizontal weld line. This suggests that the knife is of type 1 manufacture.

Figure 9.1: Photograph and x-radiograph of knife 110 (85).

This knife was badly corroded so the decision to cut a full section was taken. Un-etched this revealed a horizontal weld line made up of small spherical inclusions some of which were multiphase. The cutting edge was made up of a relatively clean metal with few small inclusions. A line of elongated multiphase inclusions separated two areas. The back of the knife had many elongated both single and multiphase slag inclusions orientated along the blade.

When the knife was etched a clear white weld line (206HV) was visible which indicates a type 2 knife. Above this weld line there was an area of pearlite indicating a high carbon steel (0.8%) which had an average hardness of 299. The elongated inclusions in the cutting edge separated an area of ferrite which ranged in size from ASTM 1 to 4 although there was no evidence of ghosting (average 200HV). The SEM-EDX analysis revealed the presence of phosphoric iron (0.2%) which explained the reduced carbon diffusion into the tip. At the very tip of the cutting edge the ferrite had a grain size of ASTM 7 to 8 and a hardness of 249. Across both weld lines there was evidence of carbon diffusion. The back of the knife consisted of large grains (ASTM 2) of ferrite with ghosting with an

average hardness of 151, suggesting a phosphoric iron. This was confirmed be the SEM-EDX analysis which revealed 0.4% phosphorous was present.

Knife 113 (82)

This fragment of knife 113 (82) compared with the other knives selected is badly corroded with corrosion penetration along the blade. The x-radiograph revealed the presence of possible horizontal slag stringers and a steel tip, suggesting a type 2 knife.

Figure 9.2: Photograph and x-radiograph of knife 113 (82).

A full section of knife 113 was taken as it was only a fragment. The slag inclusions indicated a piled structure with one band of elongated multi and single phased slag inclusions. The majority of inclusions on the left side of the band were small and spherical while those on the other side had slag inclusions ranging in size and shape. Some were small and spherical while others were larger and more irregular.

When etched the slag inclusion band seen before appeared to correlate with an area of large grains (ASTM 4) with little evidence for carbon and an average hardness of 181. The area of smaller spherical inclusions is an area of higher carbon resulting in a pearlite with ferrite (or cementite) structure (0.7 to 0.8% carbon). This area had an average hardness of 213. There is some evidence of carbon diffusion from this area into the large grained area. The other side of the band had a low carbon content indicated by the small grained ferrite (ASTM 6-8) with pearlite microstructure (0.1 to 0.2% carbon) and an average hardness of 169. The tip of the cutting edge consisted of large grains of ferrite (ASTM 3) with pearlite and had a hardness of 182, suggesting phosphoric iron. SEM-EDX analysis revealed the presence of phosphorous (0.2%) and copper (0.2%). This

knife was constructed of piled or heterogeneous iron (type 3). With bands of high-carbon steel and phosphoric iron. The tip of the cutting edge was phosphoric iron.

Knife 126 (53)

The x-radiograph revealed that knife 126 (53) is a curved back knife. The cutting edge was badly corroded in areas but the x-radiographs revealed the characteristic steel texture and possible horizontal slag stringers. The knife is most likely a type 2 butt or scarf welded knife.

Figure 9.3 Photograph and x-radiograph of knife 126 (53).

During cutting the knife unfortunately broke so the opportunity was taken to remove a full section. In the un-etched condition a possible weld line consisted of multi-phased elongated inclusions indicating a type 2 knife. Above this was an area of small spherical inclusions. The back of the knife appears to have two separate areas of inclusions. Below the weld line there were lots of large irregular inclusions, below this the area consists of few small spherical and irregular inclusions.

When etched the microstructure above the weld line consisted of small grains (ASTM 7-8) of pearlite (0.8% carbon) with an average hardness of 275 (HV). Below the weld line large grains (ASTM 1) of ferrite with evidence of ghosting, mostly around the slag inclusions, suggesting phosphoric iron. This was supported by the high average hardness of 232 and SEM-EDX analysis which revealed 0.6% phosphorous. Below this there is an area of small grained ferrite (ASTM 8) with some pearlite at the grain boundaries (0.1% carbon) which had an average hardness of 181.

Knife 126 seems to have been constructed mainly of piled or heterogeneous iron although there was a weld line near the tip of the cutting edge, suggesting a type 2 knife. Bands of phosphoric iron, low and high carbon steels were all present. At the tip of the cutting edge pearlite was visible

White Weld Lines

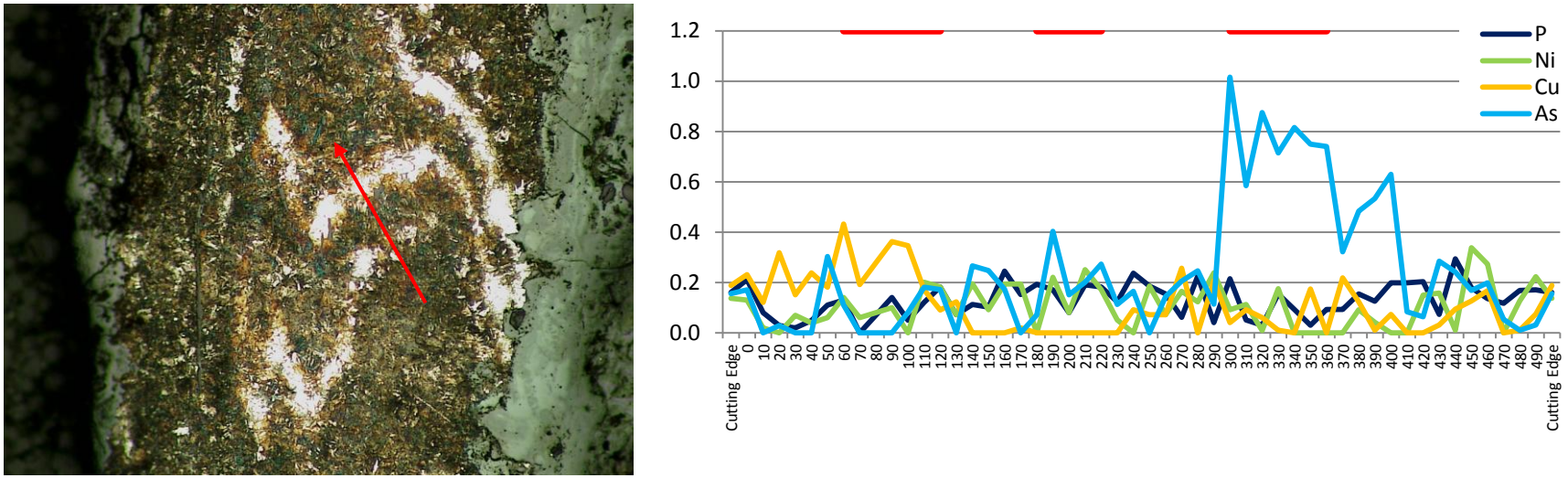


Figure 9.4: Line scan across two white weld lines in Wharram Percy Knife 159

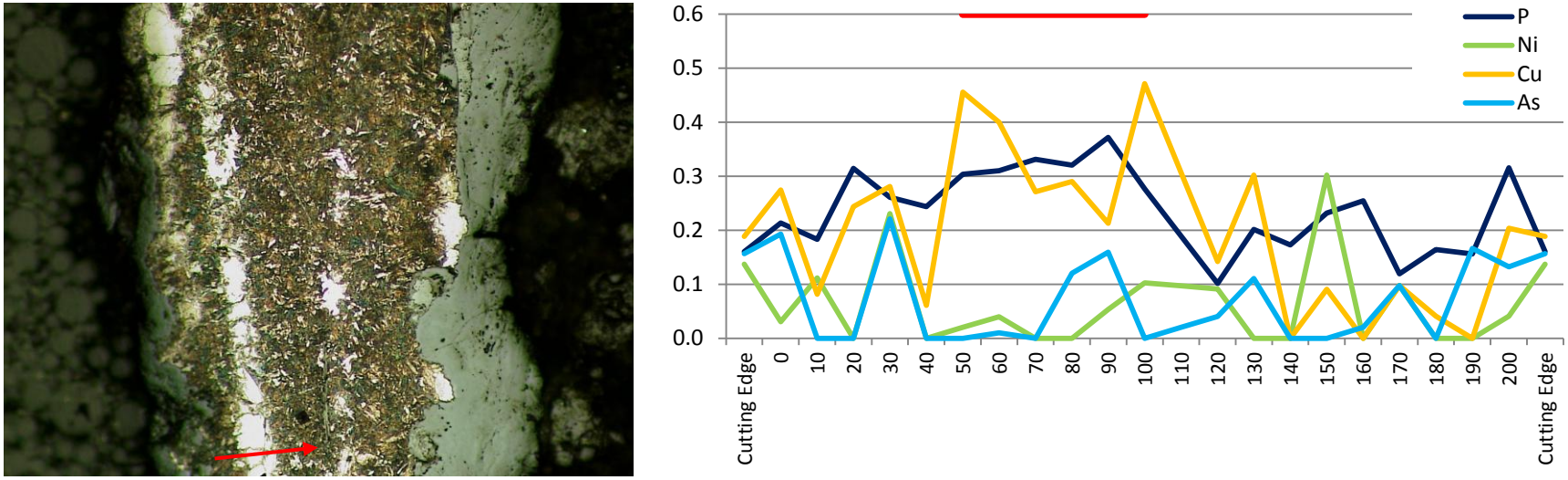


Figure 9.5: Line scan across another white weld line in Wharram Percy Knife 159

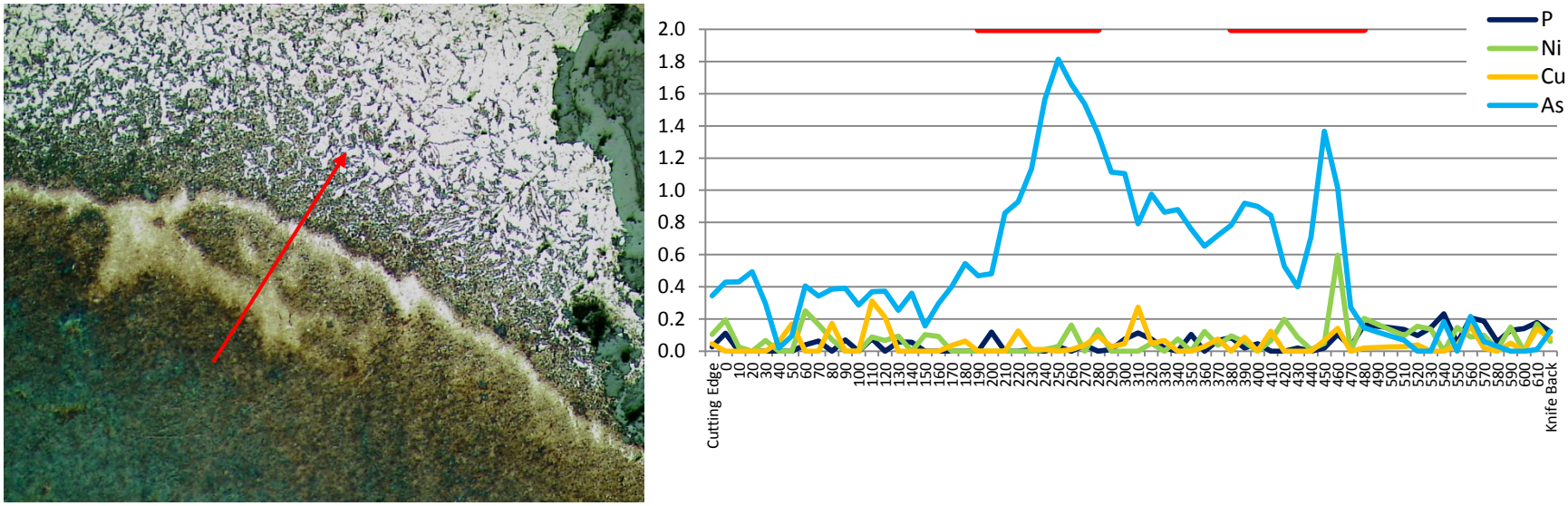


Figure 9.6: Line scan across the white weld line in Wharram Percy Knife 278

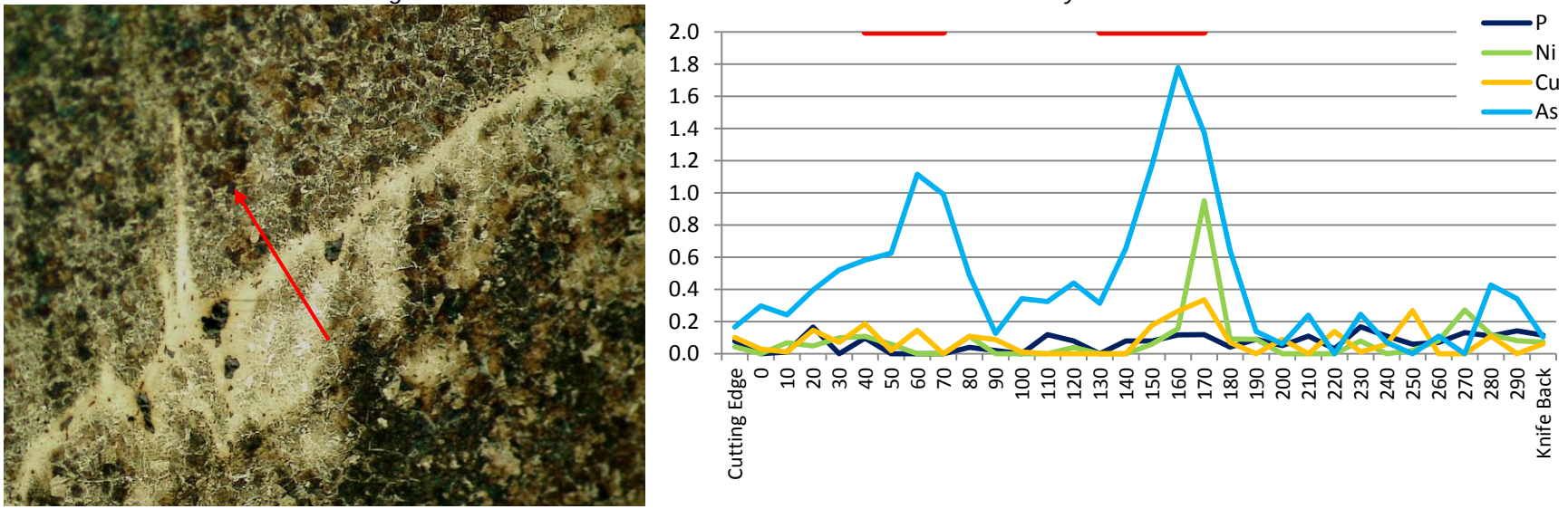


Figure 9.7: Line scan across the white weld line in Wharram Percy Knife 502

Chapter 10: Burdale

Knife Descriptions

Knife 64

The x-radiograph revealed a clear weld line but no evidence for a high-quality steel cutting edge. It also revealed that the back was most likely piled, as there were many dark striations clearly visible in the x-radiograph.

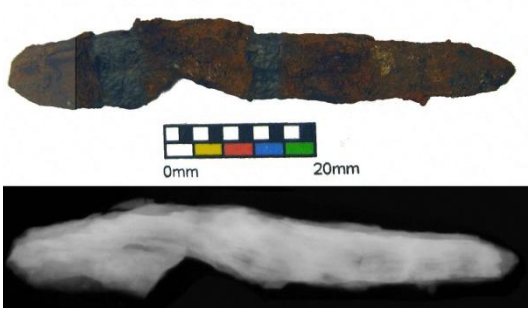


Figure 10.1: Photograph and x-radiograph of knife 64, the line shows where the section was removed.

Metallographic analysis of the full section in the un-etched condition revealed a horizontal, slightly convex, weld line consisting of many small spherical single-phased slag inclusions. Below this weld line in the cutting edge there were some fairly large sub-angular single-phase inclusions. The back consisted of many bands of differing inclusion types, suggesting a piled iron back. Some of the bands consisted of small spherical voids while other areas contained sub-angular single- and multi-phased inclusions. Many of the bands of inclusions had some corrosion penetration which was clearly seen on the x-radiographs.

When etched the cutting edge consisted of predominately tempered martensite with some pearlite at the weld line (*Average 490HV, Range 362-701HV*). At the very tip of the cutting edge there were areas that resembled martensite and the high hardness confirmed this (*701HV*). SEM-EDS analysis revealed the presence of small quantities of phosphorus in the cutting edge, up to 0.2%. The cutting edge also appeared to be separated by a faint vertical white weld line, although few, if any slag inclusions were present. There was significant carbon diffusion across the horizontal convex white weld line (*Average 234HV, Range 175-264HV*). The white weld line was particularly enriched in Nickel in areas, up to 2.4% but arsenic was also present in high quantities (0.2-0.3%). The back consisted of many bands of ferritic and phosphoric iron. Just above the weld line

the carbon diffusion had resulted in a mid carbon steel 0.3-0.4% carbon with grains of ferrite surrounded by pearlite, and some ghosting (*Average 162HV, Range 137-187HV*). The rest of the back consisted of heterogeneous bands of iron; ranging from small grains of ferrite (*ASTM 7-8*) with ghosting, to ferrite and pearlite (mid carbon steels with up to 0.3-0.4% carbon) with no evidence for ghosting but Widmanstätten structures (*Average 104HV, Range 91-116HV*). The bands which had many small voids had no grain boundaries but the ghosting present suggested phosphoric iron (*Average 139HV, Range 132-148HV*). SEM analysis confirmed that some of the bands in the back contained significant quantities of phosphoric iron (0.2-0.3%), while others were clearly ferritic.

Knife 65

The x-radiograph revealed a clear weld line present in this knife, below which there was also evidence for a high quality steel cutting edge.

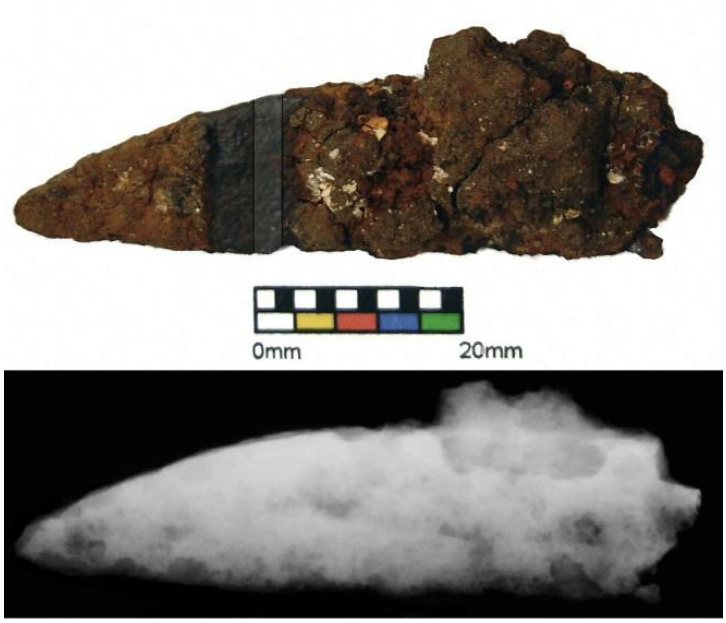


Figure 10.2: Photograph and x-radiograph of knife 65, the lines show where the section was removed.

In the un-etched condition there was evidence for a horizontal scarf weld line consisting of sub-rounded mostly single-phased slag inclusions. The back had a range of slag inclusion types ranging from small elongated single-phased inclusions to large sub angular single- and multi-phased inclusions. In addition there was ghosting present particularly in the top left part of the back. The cutting edge seemed to have two different areas of inclusions; near the weld line there

were few small single-phased inclusions, most of which were elongated. The other area closer to the tip of the cutting edge had both large, small, single- and multi-phased inclusions most of which appeared either sub-angular or elongated.

When etched the back had very large grains (*ASTM 1 and bigger*) with ghosting clearly visible (*Average 209HV, Range 161-244HV*), all these factors strongly phosphoric iron is present, confirmed by the extremely high phosphorus content detected during SEM Analysis (between 0.4-1%). There was no white weld line, instead the weld was very distinct with very little, if any, carbon diffusion, again supporting the presence of phosphoric iron in the knife back. The cutting edge was rather unusual as there were two different areas present. Just below the weld line there was an area of fine pearlite and tempered martensite, in areas there was even some lightly tempered martensite present (*Average 578HV, Range 362-766HV*). This area coincided with the small elongated single-phased inclusions, SEM analysis also revealed the presence of phosphorus (0.1-0.2%). Below this, near the tip of the cutting edge the microstructure changed dramatically from a well heat-treated blade to an area of phosphoric iron (0.2-0.3% phosphorus) with large grains (*ASTM 4-6*) and ghosting, this resulted in a lower hardness for the tip of the cutting edge (*210HV, Range 183-232HV*).

Knife 67

Analysis of the x-radiograph revealed a clear butt-weld line with a spotted texture below suggesting a steel cutting edge.

Figure 10.3: Photograph and x-radiograph of knife 67, the lines show where the section was removed.

In the un-etched condition the butt-weld line had many elongated multi-phased inclusions but was clearly visible due to its raised appearance suggesting enrichment from either phosphorus or arsenic. Below the weld line there were some small single-phased inclusions. The back consisted of two, maybe three, pieces of metal with different types of inclusions. Just above the weld line the inclusions were single-phased and elongated but further up into the back there were increasing numbers of single- and multi-phased elongated inclusions.

After etching the weld line was confirmed as a white weld line (*Average 178HV, Range 161-201HV*) which was enriched in arsenic (0.6-2.0%) but also in nickel up to (0.3%). Just below the weld the microstructure was pearlite with ferrite although some spheriodisation appears to have started to occur. About half way down the cutting edge the microstructure transformed into pearlite (*Average 178HV, Range 143-232HV*) and the very tip of the cutting edge was predominately tempered martensite (*549HV, Range 441-549HV*). There was some carbon diffusion across the weld line into the knife back. The back of the knife consisted of two different areas, possibly representing different pieces of metal. The first, closest to the weld line had small grains of ferrite (*ASTM 4-5*) with some grain boundary pearlite 0.1-0.2% carbon (*Average 111HV, Range 103-127HV*). Further in the back the carbon content decreases till there is no pearlite, in addition the grain size increases (*ASTM 2-3*), there is no evidence for ghosting and the low hardness suggests an absence of phosphoric iron (*Average 108HV, Range 91-137HV*), confirmed by SEM analysis.

Knife 69

There was a clear weld line present in this knife in the x-radiograph. The cutting edge did not have a spotted texture.

Figure 10.4: Photograph and x-radiograph of knife 69, the line shows where the section was removed.

The full section revealed a possible weld line of small spherical single-phased slag inclusions. Below this weld line, in the cutting edge the inclusions were small, single-phased and sub-rounded. The back consisted of bands of iron, some which had very few inclusions with those present sub-angular and single-phased while other areas had many angular and elongated multi- and single-phased inclusions.

When etched the entire knife appears to have been made from a mid to high carbon steel. The cutting edge is tempered martensite, with some areas of pearlite near the weld line (257*HV*, *Average 377HV, Range 183-457HV*). A white weld line (*Average 223HV, Range 187-244HV*) separates the cutting edge from the back. SEM analysis confirmed the presence of 0.2-0.3% As. There appears to have been some carbon diffusion over the weld line forming an area of roughly equal amounts of ferrite and pearlite (*Average 206HV, Range 201-210HV*). The inclusions had hinted at various bands of iron in the back which etching had confirmed. One band contained small grains of ferrite (ASTM 8) with some grain boundary pearlite 0.0-0.2% carbon (*Average 187HV, Range 183-187HV*), this coincided with the area with very few inclusions. Even so the predominate microstructure of the back consisted of pearlite with some grain boundary ferrite 0.6-0.8% carbon (*Average 230HV, Range 210-264HV*). Although there is a significant quantity of carbon in the back the presence of a clear weld line

confirms that this knife is of type 2 manufacture. SEM analysis revealed no presence of phosphorus or other elements.

Knife 70

Analysis of the x-radiograph revealed the presence of a clear weld line with a spotted texture suggesting a steel cutting edge particularly in the back of the knife.

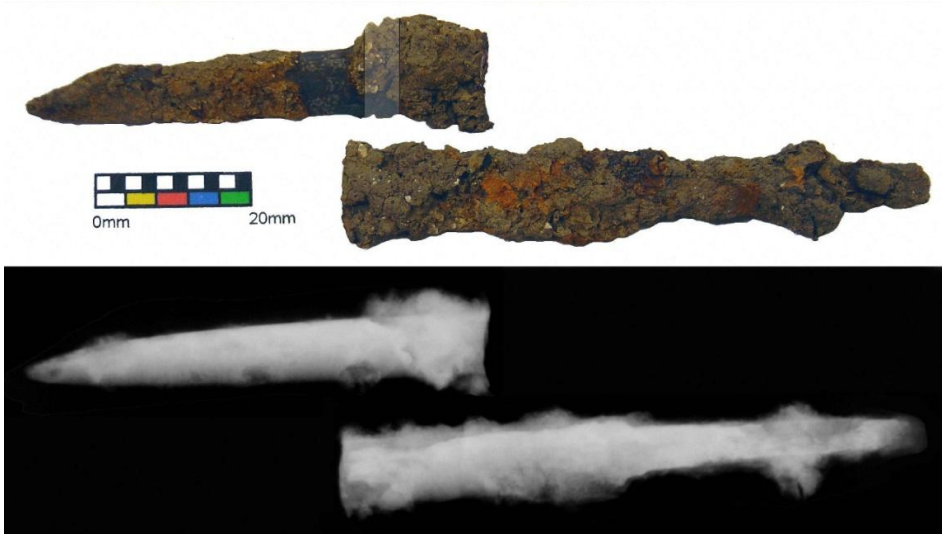


Figure 10.5: Photograph and x-radiograph of knife 70, the lines show where the section was removed.

In the un-etched condition there was a clear horizontal, slightly convex line of small single-phased inclusions. The inclusions present in the cutting edge were predominantly small, single-phased and elongated. While those present in the knife back varied in shape and size but were mostly multi-phased. The inclusions in the back formed bands, some of which had heavy corrosion penetration.

After etching the cutting edge appeared far more complicated than the inclusions originally suggested. A white weld line enriched in both arsenic and nickel *(210HV)* with some small, elongated, single-phased inclusions separated it into two halves. The microstructure varied, with decreasing carbon content, from a pearlite structure 0.8% carbon at the weld line to a ferrite with pearlite (0.4% carbon) structure at the edge of the knife (*Average 271HV, Range 210-362HV*). The tip of the cutting edge consisted of a tempered martensite (732*HV, Range 473-766HV*). There was a thin yellow weld line separating the cutting edge from the back, and some carbon diffusion into the back. The inclusions in the knife

back suggested a piled structure but the microstructure in the back was fairly homogenous with large grains of ferrite (*ASTM 3-4*) and no ghosting (*Average 137HV, Range 118-161HV*). SEM-EDS analysis confirmed that the back was mainly ferritic iron.

Knife 75

This knife was bent 30mm from the tip. The x-radiograph revealed the clear presence of a weld line and also the spotted texture that indicates a high quality steel. Two sections were removed from the knife, one near to the bent area while the second was taken from a straight section near the tang knife, this was to investigate the affect that bending the knife may have on the microstructure.

Figure 10.6: Photograph and x-radiograph of knife 75, the lines show where the sections were removed.

In the un-etched condition both sections were similar. There was a concave line of small slag inclusions concave in the section taken from the bent end but in the other section the weld was scarf. In the section furthest away from the bent tip there was particularly bad corrosion penetration, which was clearly seen in the x-radiograph. The cutting edge below was very clean with very few, very small spheroidal inclusions present. Just above the weld line the majority of inclusions were single- and multi-phased, but further in the back of the knife the inclusions present were much larger and angular, possibly suggesting that the back was constructed from two pieces of iron.

When etched there was no white weld line visible. The cutting edge in both knives was a high-quality, high carbon steel (1% carbon) as the grain boundary

cementite was clearly visible in the corrosion products (Notis 2002). In the section closest to the bent tip the pearlite with cementite (*473HV*) transformed into tempered martensite at the very tip (*549HV, Range 549HV*). The other section had very fine pearlite (*441HV*, *Average 380HV, Range 340-441HV*). The back of the knife consisted of two areas, corresponding well to the difference in inclusion types. Just above the weld line in both sections there was an area with medium to large grains (*ASTM 3-4*) with no pearlite or ghosting (*Average 159HV, Range 103-210HV*). The very back of the knife, with larger slag inclusions, had a microstructure consisting of small grains of ferrite (*ASTM 8*) with grain boundary pearlite 0.1-0.3% increasing to high carbon pearlite with ferrite 0.4-0.6% (*Average 208HV, Range 161-271HV*). SEM Analysis also revealed a difference between the two pieces of iron.

The act of bending the knife does not seem to have had an effect on the microstructure of the knife itself. There is no evidence for Neumann bands. Apart from tempered martensite at the tip of the knife the cutting edge has not been significantly heat treated, possibly the knife was possibly annealed prior to the bending suggested by the low hardness of the tempered martensite.

Knife 76

Again this knife had been bent. The x-radiograph revealed a weld line, which through corrosion penetration and possibly the act of banding has caused the knife to split at the weld line. In addition to this the knife was very blunt and may represent a stage between the bar and the manufacture of a knife.

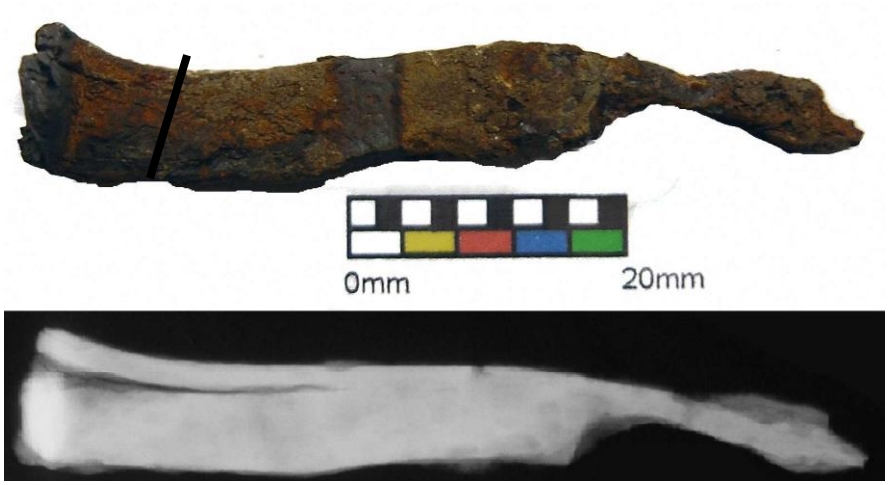


Figure 10.7: Photograph and x-radiograph of knife 76, the line shows where the section was removed.

During cutting the section broke, leaving two pieces, due to the corrosion present in the weld line seen in the x-radiograph. One section represented the cutting edge and the other was the knife back. In the un-etched state the back appeared to be three, possibly four, pieces of iron. One area of the knife was incredibly clean of inclusions while the others areas had lots of small single and multi-phased slag inclusions. A band of inclusions with corrosion penetration were noted forming a possible weld line. The cutting edge consisted of mostly small single phased inclusions. There was also a crack in the cutting edge but this did not seem to delineate between different pieces of iron. SEM analysis revealed an absence of phosphorus in the knife back.

When the back section was etched it appeared to consist of varying sized grains of ferrite with little carbon. One area consisted of large grains (*ASTM 2-3*) this coincided with the area that had very few inclusions (*Average 188HV, Range 154-221HV*). To the left of this area is a more heterogeneous region with medium to small grains (*ASTM 4-6*, *Average 190HV, Range 175-221HV*). Below this area the grain size decreased (*ASTM 6, Average 172HV, Range 137-201HV*). The possible weld line noted in the un-etched condition separated the above areas from a piece of metal which had medium sized grains (*ASTM 4, Average 182HV, Range 151-201HV*). The cutting edge was predominately pearlite (*Average 272HV, Range 244-321HV*) with a bit of pearlite with ferrite near one edge, presumably where the carbon had diffused over the weld line.

Knife 113

This knife was very badly bent which meant that x-radiographs would not reveal anything about its manufacture. In the un-etched condition this knife had many elongated single- and multi-phased slag inclusions orientated vertically, suggesting a piled knife. When etched the microstructure consisted of bands of large grains of ferrite (*ASTM 3-4, Average 163HV, Range 158-168HV*), to bands of small grained ferrite with grain boundary pearlite (*ASTM 6-7, Average 148HV, Range 116-176HV*). In the back of the knife possible neumann bands were identified suggesting that this knife was significantly cold worked, most likely when it was bent. This knife had no obvious deliberate welds and therefore is a type 3 piled knife.

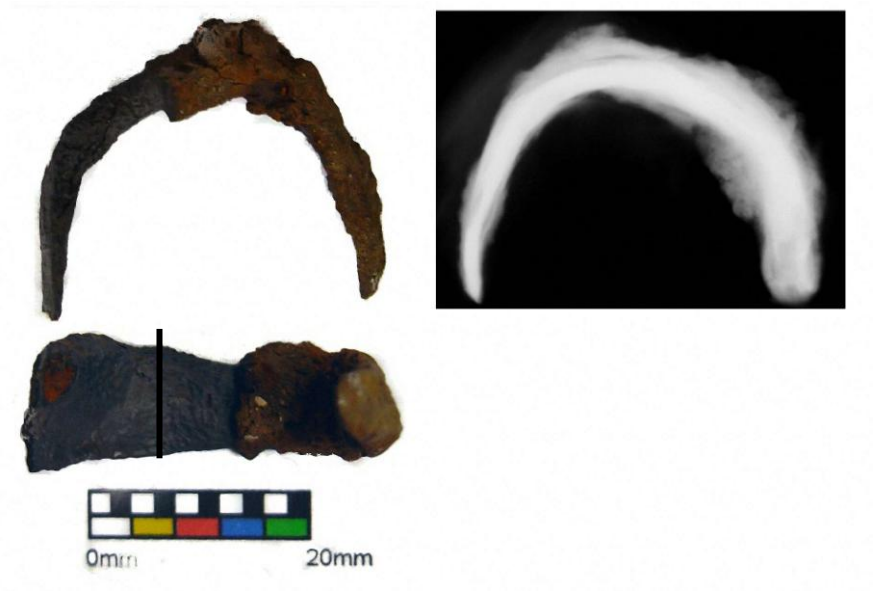


Figure 10.8: Photograph and x-radiograph of knife 113, the line shows where the section was removed.

Knife 200

X-radiography of this knife revealed that it was badly corroded, especially the cutting edge. There was a clear weld line near the tang and the texture below suggested a steel cutting edge.

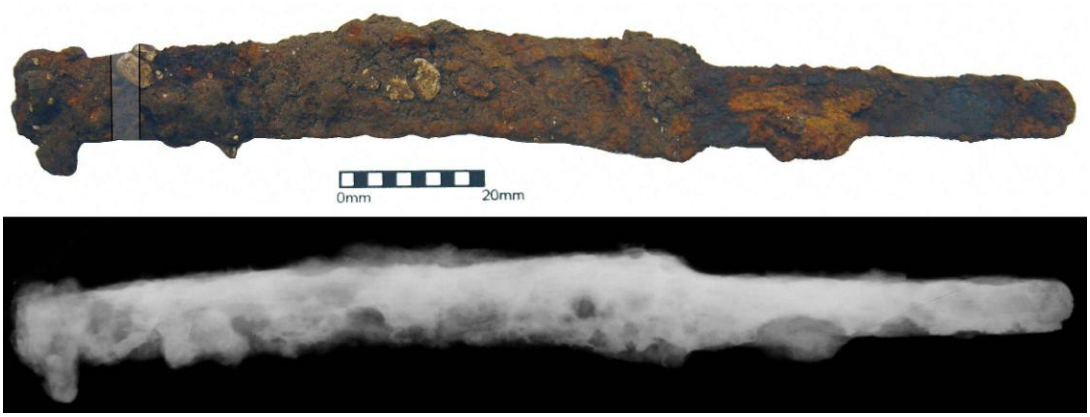


Figure 10.9: Photograph and x-radiograph of knife 200, the lines show where the section was removed.

Un-etched the section revealed the full extent of the corrosion, not only had much of the outside and cutting edge corroded but there was corrosion penetration within the knife, most likely from a weld line in the back of the knife. Even with the bad corrosion a second weld line, presumably separating the cutting edge from the back was visible consisting of many sub-angular and spheroidal single-phased inclusions. Below this line in the cutting edge there were very few inclusions which were all single-phased and angular. Above the weld line in the back of the knife there was a range of inclusions from large angular ones to smaller sub-angular, both single and multi-phased. Above the corrosion penetration there were fewer single-phased sub-angular inclusions.

After etching a white weld line, enriched in nickel (0.3%) and arsenic (0.1-0.4%), separated what remained of the cutting edge from the knife back. The cutting edge consisted of tempered martensite, with some martensite in areas (*671HV, Average 555HV, Range 386-701HV*). There was significant carbon diffusion across the weld line into the back resulting in small grains of pearlite, degrading to ferrite with pearlite (*Average 216HV, Range 196-232HV*). Above this the back consisted of very large grains with no pearlite (*ASTM 1-3*) and also no ghosting (*Average 155HV, Range 130-168HV*). Beyond the corrosion penetration the grain

sizes decreased (*ASTM 3-5, Average 128HV, Range 94-164HV*). SEM analysis of the iron revealed an absence of phosphorus, suggesting ferritic iron.

Knife 204

Analysis of the x-radiograph revealed the presence of a weld line half way up the blade, under this weld line the spotted texture suggested a steel cutting edge. There was also a possible indent in the back of the knife suggested by a line dark dense line.

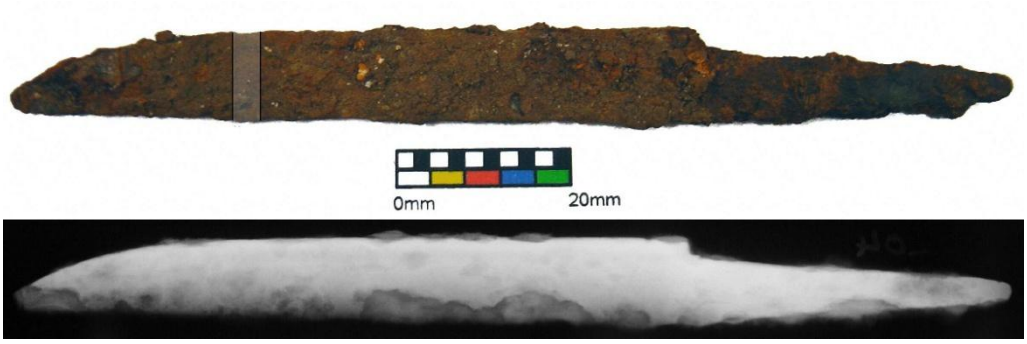


Figure 10.10: Photograph and x-radiograph of knife 204, the lines show where the section was removed.

Before the sample was etched a horizontal, convex line of very small single- and multi-phased spheroidal inclusions was clearly visible splitting the knife roughly in half. Below this weld line in the cutting edge there were very few inclusions most of which were small, elongated and single-phased. The inclusions in the knife back revealed that at least two pieces of iron had been used; one formed a core with the other, possibly piled iron, wrapped around the outside. The core like the cutting edge had few small single-phased inclusions most of which were sub-rounded. The iron surrounding it had lots of elongated single- and multi-phased inclusions.

The cutting edge of this knife consisted of fine pearlite or bainite, with no evidence for heat treatment (*441HV*, *Average 369HV, Range 303-441HV*). This cutting edge was separated from the knife back by a white weld line (*Average 239HV, Range 201-271HV*) which was enriched in arsenic (0.2-1.3%), there was a limited amount of carbon diffusion across the weld line. The back of the knife was constructed of two pieces of iron, the core consisted of small grains (*ASTM 6*) of pearlite with grain boundary ferrite degrading to pearlite and ferrite, i.e. high to mid carbon steel 0.7-0.4% carbon (*Average 172HV, Range 140-183HV*). SEM

analysis revealed the presence of some phosphorus in low quantities up to 0.2%. The iron surrounding this core was heterogeneous and appeared to be piled iron, but the microstructure was predominately large grains of ferrite (*ASTM 3-4*) with no evidence for ghosting even so it contained more phosphorus (0.1-0.3%) than the core (*Average 178HV, Range 143-215HV*).

Knife 208

This knife had been broken in antiquity. The x-radiograph did not reveal the presence of any weld lines but did suggest that there may be some corrosion penetration.

Figure 10.11: Photograph and x-radiograph of knife 208, the line shows where the section was removed.

The un-etched section revealed that the knife was badly corroded, on the outside but also within. There were no clear weld lines although vertical orientated elongated inclusions were present throughout. The inclusions present were mostly small single- and multi-phased inclusions. Many small spherical holes were identified, often forming bands across the knife section.

When etched there was no evidence for high-quality steel. There were occasional bands of pearlite which separated different microstructural areas; from small grains of ferrite with some pearlite and ghosting in areas (*ASTM 6, Average 380HV, Range 340-441HV*), large grains of ferrite (*ASTM 5-6)* to very small grains of ferrite with grain boundary carbides at the back of the knife (*ASTM 8,*

Average 341HV, Range 232-412HV). SEM analysis revealed the presence of phosphorus throughout the section (0.2-0.4%)

Knife 218

The x-radiograph did not reveal the presence of a weld line but did suggest the presence of steel in the cutting edge. There was significant corrosion visible, particularly in the cutting edge.

Figure 10.12: Photograph and x-radiograph of knife 218, the lines show where the section was removed.

In the unetched condition there were no clear horizontal weld lines instead many of the inclusions were elongated and vertically orientated, most were single-phased but some had multiple phases. The inclusions in the back of the knife were small and single-phased.

After etching the knife was revealed to be a type 4, with an iron core and a steel cutting edge wrapped around it. The steel cutting edge mostly consisted of pearlite in areas but also carbides (*Average 327HV, Range 232-386HV*), but near the tip of the cutting edge this became tempered martensite suggesting the knife had been heat treated (*Average 529HV, Range 509-549HV*). There was no carbon diffusion from the cutting edge into the back most likely due to the presence of phosphoric iron, as noted by the large grains, ghosting and high hardness (*Average 192HV, Range 148-232HV*). Confirmed by SEM analysis which revealed phosphorus was present throughout the sample, ranging from 0.2 to 0.4%. The back was fairly heterogeneous as there were pearlitic areas

particularly in the very back of the knife which had high carbon contents 0.3-0.7% carbon also had lower concentrations of phosphorus, 0.1-0.2% (*Average 269HV, Range 221-303HV*).

Knife 244

Examination of the x-radiograph revealed the presence of a weld line and the spotted texture which suggests a high-quality high carbon steel.

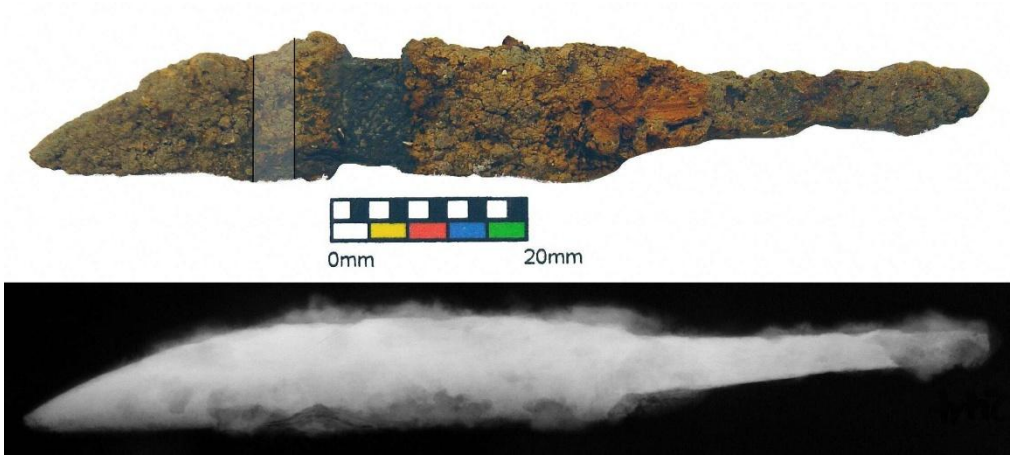


Figure 10.13: Photograph and x-radiograph of knife 244, the lines show where the section was removed.

In the un-etched state there was a clear convex horizontal weld line of small multi-phased inclusions. The cutting edge below had both small and large single-phased inclusions. The back of the knife appeared piled with many vertically orientated elongated inclusions, these separated areas with different types of inclusions but the majority were sub-angular, single- and multi-phased inclusions.

A white weld line clearly separated the cutting edge from the piled iron back, when analysed it was found to be enriched in arsenic (0.4-0.6%) and nickel (0.1-0.4%). There was very little carbon diffusion across the weld line but in the cutting edge there was an area of low carbon ferrite with pearlite at the grain boundaries (*Average 156HV, Range 137-175HV*). The rest of the cutting edge appeared to be particularly good quality as it was predominately tempered martensite but there was also some martensite and retained austenite present near the tip of the cutting edge (*766HV*, *Average 651HV, Range 441-927HV*). The back of the knife was piled with bands of varying microstructures; large grains of ferrite with ghosting (*ASTM 3-4, Average 159HV, Range 148-168HV*), small grains of ferrite with ghosting or pearlite and/or carbides(*ASTM 6-8,*

Average 201HV, Range 183-210HV) to medium sized grains with ghosting (*ASTM 5, Average 175HV, Range 168-183HV*). SEM analysis of the back revealed that phosphorus was present throughout the knife back (0.1-0.5%) but absent from the cutting edge, except in the area of low carbon ferrite which had 0.1% phosphorus.

Pivoting Knife 4

Pivoting knives are rare finds in Early Medieval Britain. Therefore this study offered the opportunity to analyse metallography of a pivoting knife. Sections were removed from both the knife back and the cutting edge, but also a section was taken from the pivoting point itself. The x-radiograph suggested a no evidence for a weld line, although the spotted texture was seen.

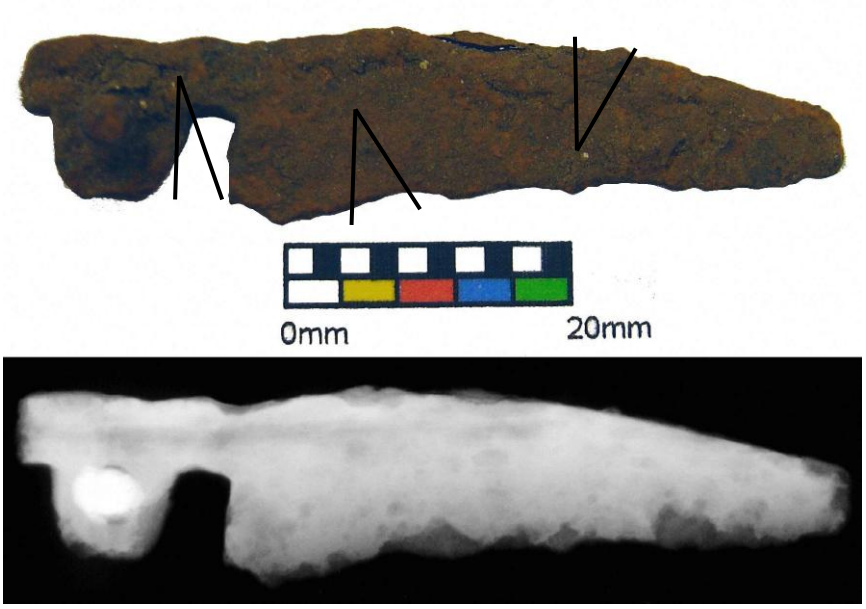


Figure 10.14: Photograph and x-radiograph of knife 4, the lines show where the sections were removed.

In the unetched condition there was a clear convex weld line made up of spherical single-phased slag inclusions. Below the weld line in the cutting edge there were very few inclusions all single-phased and angular. Above the weld line in the back there were two vertical bands of multi-phased inclusions, these bands also appeared raised in the un-etched condition. These separated three bits of iron with small single-phased inclusions, which were either elongated or sub-rounded.

Figure 10.15: Mapped section of pivoting knife 4 in the un-etched (left) and etched condition (right).

When etched the cutting edge was revealed to be predominately a fine pearlite or bainite (*Average 631HV, Range 618-644HV*), in some areas tempered martensite was also seen (*Average 438HV, Range 386-473HV*). The weld line separating the cutting edge from the back was a white weld line (*Average 323HV, Range 303-362HV*) enriched in arsenic. The back was split into three pieces of iron by the two bands of inclusions which also turned out to be white weld lines. One piece of iron (left side) consisted of large grains of ferrite (*Average 129HV, Range 107-143HV*, ASTM 5-6) with grain boundary pearlite up to 0.2% or in some cases carbides. The other two pieces of iron had smaller grains of ferrite (ASTM 8) and also higher carbon content up to 0.4% (*Average 186HV, Range 148-210HV*).

Figure 10.16: Mapped section of the pivot point in pivoting knife 4 in the un-etched (top) and etched condition (bottom).

The section of the pivoting point revealed that the whole of the back was constructed from the same piece of phosphorus free piled iron, This was particularly clear since both the two white weld lines and microstructures were the same, even with similar hardness for the large grained ferrite (*Average 143HV, Range 132-152HV*) and small grained mild steel (*Average 170HV, Range 148-192HV*). In the unetched condition the pin had similar inclusions to the knife back, with two clear bands of inclusions. When etched these bands appeared as white weld lines. The knife pin consisted of two different microstructures the first closest to the cutting edge consisted of a small grained (ASTM 7-8), mild steel with up to 0.4% carbon (*Average 298HV, Range 271-321HV*). The other was a large grained ferrite (ASTM 1-2, *Average 206HV, Range 183-232HV*). Unlike in the knife section the pin consisted of phosphoric iron with between 0.1 to 0.3% phosphorus. The pin was placed in a hole, which appears to have been pushed through from one side as the white weld lines in the knife back near the pivot have been distorted but this most likely while the iron was still hot as there are no neuman bands.

Summary Assemblage Knives

Knife No	Year	Context	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
			Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
4	2006	1000	A	x	57	43	14	13	4	Some	x	y	Pivoting, Angle starts 15mm from tip
8	2006	1001	x	2	85	40	45	15	10	Some	x	y	
26	2006	1010	B	3	90	60	30	10	6	Some	y	y	
123	2006	1088	x	4	64	44	20	18	4	Unknown	y	y	Broken tip
200	2006	6194	x	3	148	93	55	18	10	Some	y	y	
204	2006	6197	B	1	115	87	28	11	7	Some	y	y	
205	2006	6197	B	4	67	45	22	11	8	Some	y	y	Angle starts 15mm from tip
208	2006	I SE	x	3	50	37	13	12	6	Slight	x	y	Broken
210	2006	H SE	x	3	60	25	35	14	6	Unknown	y	x	Broken
217	2006	F SE	B	3	110	82	28	12	6	Some	x	y	
218	2006	E SE	B	1	100	65	35	14	7	Some	x	y	Angle starts 15mm from tip
52	2007	1046	x	1	36	28	8	12	4	Unknown			Broken just after tang interface
64	2007	1004	B	4	64	32	32	10	8	Very	y	x	
65	2007	1004	B	3	62	60	2	15	15	Slight	y	y	Broken just after tang interface
67	2007	1018	A	3	87	53	34	14	7	Slight	y	y	
68	2007	1018	B	4	102	85	17	12	6	Slight	y	x	Angle starts 30mm from tip
69	2007	1019	D	3	109	78	31	14	8	Some	y	y	
70	2007	1050	B	1	140	100	40	12	7	Slight	x	x	Angle starts 10mm from tip
72	2007	1066	x	2	70	58	12	14	5	Unknown			Bent, but also tang bent
74	2007	1100	A	3	110	65	45	14	7	Some	y	x	
75	2007	1157	A	1	148	110	38	10	7	Some	y	y	Bent
76	2007	1179	x	3	70	50	20	8	4	Some	y	x	Bent
77	2007	1180	A	2	90	55	45	20	7	Slight	y	y	
112	2007		x	x						Slight	x	x	Broken
113	2007	1018	x	1	52	10	42	10	8	Some			Bent
125	2007	1054	D	x	74	74		12		Unknown			Broken
190	2007	1002	A	1	112	84	28	16	10	No wear	y	y	
226	2007	1443	A	2	75	65	10	11	4	Slight	y	y	Broken tang
244	2007	1472	A	1	97	60	37	12	5	Slight	y	y	Angle starts 15mm from tip
295	2007	1494	x	1	35	5	30	12	5	Unknown			Bent and broken

Table 10.1: Summary table of the knives from Burdale showing the measurements, typologies assigned and the results from the x-radiograph analysis.

SEM-EDS Data

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
64	Cutting Edge	*n.d.*	0.1	*n.d.*	*n.d.*	99.6	0.1	0.1	0.1	***88.4***
		n.d.	0.1	*n.d.*	*n.d.*	99.8	*n.d.*	*n.d.*	*n.d.*	***88.0***
		0.1	0.1	*n.d.*	*n.d.*	99.5	*n.d.*	0.2	0.1	***87.4***
		n.d.	*n.d.*	0.1	*n.d.*	99.7	*n.d.*	0.2	*n.d.*	***85.8***
	Back	*n.d.*	*n.d.*	*n.d.*	*n.d.*	99.9	*n.d.*	*n.d.*	*n.d.*	***114.6***
		0.1	0.1	0.1	0.1	99.3	*n.d.*	0.2	0.2	***110.4***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.7	*n.d.*	0.1	0.2	***106.8***
		n.d.	0.2	*n.d.*	*n.d.*	99.7	*n.d.*	*n.d.*	0.1	***103.5***
		n.d.	0.2	*n.d.*	*n.d.*	99.5	*n.d.*	*n.d.*	0.2	***97.0***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.5	0.1	0.2	0.2	***96.7***
		n.d.	0.3	*n.d.*	*n.d.*	99.3	*n.d.*	0.2	*n.d.*	***92.2***
		n.d.	0.1	*n.d.*	*n.d.*	99.8	*n.d.*	*n.d.*	*n.d.*	***91.4***
		n.d.	0.1	*n.d.*	0.1	99.8	*n.d.*	*n.d.*	0.1	***89.1***
	White Weld Line	0.1	*n.d.*	*n.d.*	*n.d.*	96.4	2.4	0.3	0.8	***86.5***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.3	*n.d.*	*0.2*	0.5	***86.7***
65	Cutting Edge	*n.d.*	0.2	*n.d.*	0.1	99.6	*n.d.*	*n.d.*	*n.d.*	***112.6***
		0.1	0.3	*n.d.*	*n.d.*	99.2	0.1	0.2	0.1	***112.8***
		n.d.	0.1	*n.d.*	*n.d.*	99.7	*n.d.*	0.2	*n.d.*	***86.5***
		n.d.	0.1	*n.d.*	*n.d.*	99.8	*n.d.*	*n.d.*	0.1	***92.7***
		n.d.	0.1	*n.d.*	*n.d.*	99.9	*n.d.*	*n.d.*	*n.d.*	***97.9***
		n.d.	0.1	0.1	*n.d.*	99.6	*n.d.*	*n.d.*	0.2	***84.7***
		0.1	0.2	*n.d.*	*n.d.*	99.8	*n.d.*	*n.d.*	*n.d.*	***71.3***
		n.d.	0.2	*n.d.*	*n.d.*	99.8	*n.d.*	*n.d.*	*n.d.*	***74.5***
	Back	*n.d.*	0.8	*n.d.*	*n.d.*	99.1	*n.d.*	*n.d.*	*n.d.*	***80.6***
		n.d.	1.0	*n.d.*	*n.d.*	98.9	*n.d.*	*n.d.*	0.1	***82.5***
		n.d.	0.4	*n.d.*	0.1	99.3	*n.d.*	*n.d.*	0.2	***89.6***
		n.d.	0.4	*n.d.*	*n.d.*	99.3	*n.d.*	0.1	0.1	***94.9***
	Back (Ghosting)	*n.d.*	0.9	*n.d.*	*n.d.*	98.9	0.1	*n.d.*	*n.d.*	***85.1***
		0.1	1.0	*n.d.*	*n.d.*	98.7	0.1	0.1	*n.d.*	***86.2***
		n.d.	0.4	*n.d.*	*n.d.*	99.5	*n.d.*	0.1	*n.d.*	***123.7***
		n.d.	0.5	0.1	0.1	99.2	*n.d.*	*n.d.*	0.2	***130.4***
67	Cutting Edge	*n.d.*	0.1	*n.d.*	*n.d.*	99.8	*n.d.*	*n.d.*	0.1	***89.0***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.7	0.1	*n.d.*	0.1	***88.2***
		n.d.	*n.d.*	*n.d.*	0.1	99.8	*n.d.*	*n.d.*	0.1	***87.0***
		n.d.	0.1	*n.d.*	0.1	99.8	*n.d.*	*n.d.*	0.1	***87.1***
		n.d.	0.1	*n.d.*	*n.d.*	99.5	0.2	0.1	*n.d.*	***86.7***
	Back	*n.d.*	*n.d.*	*n.d.*	0.1	99.5	0.2	0.1	0.1	***99.5***
		n.d.	*n.d.*	0.1	0.1	99.7	*n.d.*	*n.d.*	0.2	***101.5***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.8	0.2	*n.d.*	*n.d.*	***98.5***
		0.1	*n.d.*	*n.d.*	*n.d.*	99.5	0.1	0.1	0.1	***97.4***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.8	*n.d.*	0.1	0.1	***94.5***
		n.d.	0.1	*n.d.*	*n.d.*	99.5	0.1	*n.d.*	0.3	***93.5***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.7	*n.d.*	0.2	0.1	***92.1***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.9	*n.d.*	*n.d.*	0.1	***90.1***
	White Weld Line	*n.d.*	*n.d.*	*n.d.*	*n.d.*	98.1	0.1	*n.d.*	1.8	***86.6***
		0.1	*n.d.*	*n.d.*	*n.d.*	98.0	0.3	0.1	1.5	***88.2***
		n.d.	*n.d.*	*n.d.*	0.1	97.7	0.2	*n.d.*	2.0	***86.4***
		0.2	*n.d.*	*n.d.*	*n.d.*	98.9	*n.d.*	0.1	0.6	***82.4***

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
69	Cutting Edge	0.1	*n.d.*	*n.d.*	*n.d.*	99.6	*n.d.*	*n.d.*	0.2	***67.5***
		0.1	0.1	*n.d.*	*n.d.*	99.7	*n.d.*	0.1	*n.d.*	***69.0***
		0.1	*n.d.*	*n.d.*	*n.d.*	99.7	0.1	*n.d.*	*n.d.*	***75.9***
		0.1	*n.d.*	0.1	*n.d.*	99.5	*n.d.*	0.1	0.3	***82.2***
		n.d.	0.1	*n.d.*	*n.d.*	99.9	*n.d.*	*n.d.*	*n.d.*	***84.0***
		0.1	*n.d.*	*n.d.*	0.1	99.8	*n.d.*	*n.d.*	*n.d.*	***89.5***
	Back	0.1	*n.d.*	0.1	*n.d.*	99.7	*n.d.*	0.1	*n.d.*	***114.4***
		n.d.	*n.d.*	*n.d.*	*n.d.*	100.0	*n.d.*	*n.d.*	*n.d.*	***120.1***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.8	*n.d.*	0.1	0.1	***118.7***
		n.d.	0.1	*n.d.*	*n.d.*	99.6	*n.d.*	0.2	0.1	***118.3***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.7	0.1	*n.d.*	0.1	***111.2***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.9	*n.d.*	*n.d.*	*n.d.*	***84.0***
		n.d.	*n.d.*	*n.d.*	0.1	99.7	0.2	*n.d.*	*n.d.*	***81.1***
		n.d.	0.1	*n.d.*	*n.d.*	99.9	*n.d.*	*n.d.*	*n.d.*	***72.2***
		0.1	*n.d.*	*n.d.*	0.2	99.7	*n.d.*	*n.d.*	*n.d.*	***73.7***
	White Weld Line	*n.d.*	*n.d.*	*n.d.*	0.1	99.5	*n.d.*	*n.d.*	0.3	***99.6***
		0.1	*n.d.*	*n.d.*	*n.d.*	99.5	*n.d.*	0.1	0.2	***107.1***
		0.1	0.1	*n.d.*	*n.d.*	99.4	0.1	*n.d.*	0.4	***115.7***
		0.2	*n.d.*	*n.d.*	*n.d.*	99.4	*n.d.*	*n.d.*	0.4	***117.9***
70	Cutting Edge	*n.d.*	0.3	0.1	*n.d.*	99.6	*n.d.*	*n.d.*	*n.d.*	***102.3***
		0.1	0.1	*n.d.*	*n.d.*	99.5	0.1	*n.d.*	0.2	***102.5***
		n.d.	0.1	*n.d.*	*n.d.*	99.7	0.1	*n.d.*	*n.d.*	***110.6***
		n.d.	0.2	*n.d.*	*n.d.*	99.6	0.1	*n.d.*	0.1	***100.7***
		0.1	*n.d.*	*n.d.*	*n.d.*	99.4	0.1	0.2	0.1	***100.8***
		n.d.	0.1	*n.d.*	0.1	99.8	*n.d.*	*n.d.*	*n.d.*	***111.0***
		n.d.	0.1	*n.d.*	*n.d.*	99.8	*n.d.*	*n.d.*	*n.d.*	***111.6***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.8	0.1	*n.d.*	0.1	***111.3***
	Back	*n.d.*	0.1	*n.d.*	*n.d.*	99.8	*n.d.*	0.1	0.1	***99.2***
		n.d.	0.1	*n.d.*	*n.d.*	99.8	0.1	*n.d.*	0.1	***98.1***
		0.1	0.1	*n.d.*	*n.d.*	99.8	*n.d.*	*n.d.*	*n.d.*	***116.5***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.9	*n.d.*	*n.d.*	*n.d.*	***117.7***
		0.1	0.1	*n.d.*	*n.d.*	99.3	0.2	0.1	0.1	***107.2***
		0.1	*n.d.*	*n.d.*	*n.d.*	99.8	*n.d.*	*n.d.*	0.1	***101.6***
		0.1	0.1	0.1	*n.d.*	99.6	0.1	*n.d.*	0.1	***110.5***
		n.d.	0.1	*n.d.*	*n.d.*	99.7	*n.d.*	*n.d.*	0.1	***108.2***
	White Weld Line	0.1	0.1	*n.d.*	*n.d.*	97.1	1.8	*n.d.*	0.9	***114.7***
75 (Bent)	Cutting Edge	*n.d.*	0.1	*n.d.*	*n.d.*	99.7	0.1	0.2	*n.d.*	***109.3***
		n.d.	0.1	*n.d.*	*n.d.*	99.4	*n.d.*	0.1	0.3	***111.3***
		n.d.	*n.d.*	*n.d.*	*n.d.*	99.8	*n.d.*	*n.d.*	0.1	***117.8***
	Back	0.1	0.1	*n.d.*	*n.d.*	99.4	0.1	0.2	*n.d.*	***105.5***
		0.1	*n.d.*	*n.d.*	*n.d.*	99.7	0.1	*n.d.*	0.1	***102.2***
		n.d.	0.1	0.1	*n.d.*	99.5	*n.d.*	0.3	*n.d.*	***99.3***
		n.d.	0.2	*n.d.*	*n.d.*	99.6	*n.d.*	*n.d.*	0.2	***99.5***
		n.d.	0.2	0.1	*n.d.*	99.6	0.1	*n.d.*	*n.d.*	***103.5***
		n.d.	0.1	*n.d.*	*n.d.*	99.8	*n.d.*	*n.d.*	0.1	***103.2***

Table 10.2: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
75	Cutting Edge	n.d.	0.1	n.d.	0.1	99.7	n.d.	0.1	n.d.	127.7
		0.1	n.d.	n.d.	n.d.	99.5	0.1	0.2	0.1	129.4
		n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	n.d.	110.0
	Back	n.d.	0.1	0.1	n.d.	99.4	0.1	0.1	0.2	126.1
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.2	115.4
		n.d.	0.2	n.d.	n.d.	99.8	0.1	n.d.	n.d.	100.5
		n.d.	0.2	n.d.	n.d.	99.7	n.d.	0.1	n.d.	77.4
		n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	67.5
		0.2	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	65.4
76	Cutting Edge	n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	86.5
		0.1	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	83.9
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	84.0
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	0.1	n.d.	85.0
		n.d.	0.1	n.d.	n.d.	99.7	0.1	0.1	n.d.	82.4
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	85.5
	Back	n.d.	0.1	0.1	n.d.	99.7	0.1	n.d.	0.1	96.9
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	0.2	0.1	100.6
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	0.1	109.0
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	105.4
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	0.2	n.d.	104.5
		n.d.	n.d.	0.1	n.d.	99.8	n.d.	n.d.	n.d.	106.6
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	108.4
		n.d.	0.1	n.d.	n.d.	99.4	0.3	0.1	0.1	100.4
113	Back	n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	n.d.	84.9
		n.d.	n.d.	n.d.	0.1	99.8	n.d.	n.d.	0.1	84.3
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	95.2
		n.d.	0.1	0.1	n.d.	99.6	n.d.	0.2	0.1	99.0
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	97.9
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	0.1	n.d.	96.8
		n.d.	0.1	0.1	n.d.	99.6	0.1	n.d.	0.2	96.8
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	0.1	96.2
		n.d.	n.d.	0.1	n.d.	99.8	n.d.	n.d.	n.d.	94.8
200	Cutting Edge	0.0	0.1	0.1	n.d.	99.8	n.d.	n.d.	n.d.	82.7
		0.1	n.d.	0.1	n.d.	99.7	0.1	n.d.	n.d.	79.3
		n.d.	0.1	n.d.	n.d.	99.8	0.1	n.d.	n.d.	80.8
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	78.9
	Back 1	0.1	0.1	n.d.	n.d.	99.5	0.1	n.d.	0.1	112.0
		0.1	0.2	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	115.9
		n.d.	0.2	n.d.	n.d.	99.6	0.1	n.d.	0.1	123.7
		n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	125.6
	Back 2	n.d.	0.2	n.d.	n.d.	99.6	0.1	n.d.	n.d.	93.6
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.1	0.1	92.7
		n.d.	0.1	0.1	n.d.	99.7	0.1	n.d.	n.d.	89.8
		0.1	0.1	n.d.	n.d.	99.4	n.d.	0.3	n.d.	88.7
	White Weld Line	0.1	0.1	n.d.	n.d.	99.4	0.3	0.1	0.1	88.2
		0.1	n.d.	n.d.	0.1	99.4	0.3	n.d.	0.1	87.7
		n.d.	n.d.	n.d.	n.d.	99.3	0.3	0.1	0.2	77.1
		n.d.	0.1	n.d.	n.d.	99.0	0.3	0.1	0.4	85.1

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
204	Cutting Edge	0.1	0.1	n.d.	n.d.	99.5	n.d.	0.1	0.2	111.1
		0.1	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	109.4
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.1	109.8
		n.d.	0.1	n.d.	n.d.	99.6	0.2	n.d.	0.1	109.5
	Back	n.d.	0.3	n.d.	n.d.	99.2	n.d.	n.d.	0.4	107.4
		0.1	0.1	n.d.	n.d.	99.2	0.1	0.1	0.4	114.3
		n.d.	0.3	n.d.	n.d.	99.0	0.1	0.1	0.5	125.8
		0.1	0.3	n.d.	0.1	98.8	n.d.	0.1	0.6	115.7
		0.1	0.1	0.1	n.d.	99.1	0.1	0.2	0.3	111.1
		0.2	0.2	0.1	n.d.	99.2	n.d.	0.1	0.3	116.6
	Back (Core)	n.d.	n.d.	n.d.	n.d.	99.4	n.d.	0.1	0.4	126.3
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.3	125.2
		n.d.	0.2	0.1	n.d.	99.4	n.d.	n.d.	0.4	115.2
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.3	114.0
	White Weld Line	n.d.	0.1	0.1	n.d.	98.6	n.d.	n.d.	1.1	109.8
		n.d.	0.2	n.d.	n.d.	99.3	0.1	n.d.	0.4	109.8
		0.1	0.2	n.d.	n.d.	99.4	n.d.	n.d.	0.2	110.6
		n.d.	0.1	n.d.	n.d.	98.4	n.d.	0.1	1.3	110.0
208	Back	0.1	0.2	n.d.	n.d.	99.4	0.1	n.d.	0.2	94.4
		0.1	0.2	n.d.	n.d.	99.7	n.d.	0.1	n.d.	93.5
		0.1	0.2	n.d.	n.d.	99.6	n.d.	n.d.	0.2	93.3
		n.d.	0.2	0.1	n.d.	99.6	0.1	n.d.	n.d.	93.1
		0.1	0.3	n.d.	n.d.	99.5	n.d.	n.d.	0.1	92.5
		0.1	0.4	n.d.	n.d.	99.1	0.2	n.d.	0.2	100.7
		0.1	0.2	n.d.	n.d.	99.5	0.1	n.d.	0.1	93.9
		0.1	0.3	0.1	n.d.	99.4	n.d.	0.1	0.1	99.3
		0.1	0.3	n.d.	n.d.	99.4	n.d.	n.d.	0.1	97.0
		n.d.	0.4	n.d.	n.d.	99.4	n.d.	0.1	n.d.	99.4
218	Cutting Edge	n.d.	0.3	n.d.	n.d.	99.3	0.1	0.2	0.1	124.4
		0.1	0.2	n.d.	0.1	99.6	n.d.	n.d.	n.d.	125.8
		0.1	0.4	n.d.	n.d.	99.5	n.d.	n.d.	0.1	122.7
		n.d.	0.3	n.d.	n.d.	99.6	n.d.	n.d.	0.1	124.1
		0.1	0.3	n.d.	n.d.	99.5	n.d.	0.1	0.1	129.4
		n.d.	0.3	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	121.7
	Back	n.d.	0.2	n.d.	n.d.	99.6	n.d.	0.2	0.1	98.6
		n.d.	0.3	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	96.3
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	113.9
		n.d.	0.2	n.d.	n.d.	99.7	n.d.	0.1	n.d.	120.0
		n.d.	0.4	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	122.1
		n.d.	0.4	n.d.	0.1	99.4	n.d.	0.1	n.d.	122.1
		0.1	0.3	n.d.	0.1	99.2	n.d.	0.3	n.d.	130.9

Table 7.2 cont: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
244	Cutting Edge	n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	n.d.	***110.1***
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	***105.2***
		n.d.	n.d.	n.d.	0.1	99.9	n.d.	n.d.	n.d.	***107.9***
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	0.1	0.1	***111.5***
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	***113.1***
	Cutting Edge (Ferrite Area)	0.1	0.1	0.1	n.d.	99.7	n.d.	n.d.	0.1	***117.1***
		n.d.	0.1	0.1	n.d.	99.8	n.d.	n.d.	0.1	***118.7***
	Back 1	0.1	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	***107.2***
		n.d.	0.4	0.1	n.d.	99.5	n.d.	n.d.	n.d.	***109.8***
		n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	***107.6***
	Back 2	n.d.	0.3	n.d.	n.d.	99.4	0.1	n.d.	0.2	***111.5***
		n.d.	0.2	n.d.	0.2	99.3	n.d.	0.1	0.1	***108.7***
		n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	***112.4***
	Back 3	0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	***113.0***
		n.d.	0.4	n.d.	n.d.	99.4	n.d.	n.d.	0.1	***111.1***
		0.1	0.3	n.d.	n.d.	99.5	0.1	n.d.	n.d.	***107.1***
	Back 4	n.d.	0.3	n.d.	n.d.	99.4	n.d.	n.d.	0.2	***105.8***
		n.d.	0.5	n.d.	n.d.	99.3	n.d.	0.2	n.d.	***113.6***
		n.d.	0.3	n.d.	n.d.	99.5	0.1	0.1	n.d.	***105.4***
		n.d.	0.2	n.d.	n.d.	99.7	n.d.	0.1	n.d.	***114.5***
	White Weld Line	n.d.	n.d.	n.d.	0.1	99.1	0.1	n.d.	0.6	***114.4***
		n.d.	n.d.	n.d.	n.d.	99.0	0.4	0.2	0.4	***114.9***
		0.1	n.d.	n.d.	0.1	99.3	0.1	n.d.	0.4	***116.1***
4	Cutting Edge	n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	***96.3***
		0.1	n.d.	0.1	0.1	99.3	0.1	0.1	0.3	***94.8***
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.1	0.3	***93.0***
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	0.1	0.1	***89.2***
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	***86.8***
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	0.1	n.d.	***85.0***
	Back Large Grains	n.d.	n.d.	0.1	n.d.	99.7	n.d.	0.1	0.1	***70.2***
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	n.d.	0.1	***67.9***
		0.1	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.1	***84.0***
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	***81.9***
	Small grains with P	n.d.	0.1	0.1	n.d.	99.7	n.d.	0.1	0.1	***78.5***
		n.d.	0.1	n.d.	n.d.	99.5	0.2	n.d.	0.2	***77.0***
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.1	0.1	***75.4***
		0.1	n.d.	n.d.	0.1	99.7	n.d.	0.1	n.d.	***73.7***
		n.d.	n.d.	n.d.	n.d.	99.8	0.1	0.1	n.d.	***91.5***
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	0.1	0.2	***90.4***
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	***89.1***
	Weld line 1 (Horiz)	n.d.	n.d.	n.d.	n.d.	99.7	0.1	0.1	0.1	***80.2***
		0.1	0.1	n.d.	n.d.	98.5	0.2	n.d.	1.1	***76.9***
	Weld line 2 (Verti)	0.1	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	***94.0***
		n.d.	n.d.	n.d.	n.d.	99.4	n.d.	n.d.	0.4	***93.4***
	Weld line 3 (Verti)	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.2	***80.1***
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.3	***78.8***

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
4 Pivot	Pin Large Grains	n.d.	0.1	n.d.	n.d.	99.6	0.1	0.2	n.d.	***95.7***
		0.2	0.3	n.d.	n.d.	99.2	n.d.	0.2	0.1	***82.9***
		0.1	0.1	n.d.	n.d.	99.6	0.2	n.d.	0.1	***88.3***
		n.d.	0.1	n.d.	n.d.	99.7	0.1	n.d.	0.1	***86.5***
		n.d.	0.3	n.d.	0.1	99.3	0.1	n.d.	0.2	***83.6***
		n.d.	0.2	n.d.	n.d.	99.3	0.2	n.d.	0.3	***82.6***
	Pin Small grains with Pearlite	0.1	0.1	n.d.	n.d.	99.5	0.2	n.d.	0.1	***81.1***
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	***78.0***
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.3	***74.6***
		0.1	0.2	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	***72.5***
		n.d.	0.2	n.d.	n.d.	99.4	0.1	n.d.	0.2	***69.8***
		n.d.	0.3	0.1	n.d.	99.6	n.d.	n.d.	0.1	***69.4***
	Back Large Grains	n.d.	n.d.	n.d.	0.1	99.7	n.d.	n.d.	0.2	***88.2***
		0.1	n.d.	n.d.	n.d.	99.7	0.1	0.1	n.d.	***88.2***
	Back Small grains with Pearlite	n.d.	n.d.	n.d.	0.1	99.5	0.2	0.1	0.1	***85.5***
		0.1	n.d.	n.d.	n.d.	99.5	0.1	0.1	0.2	***84.0***

Table 7.2 cont: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

White Weld Lines

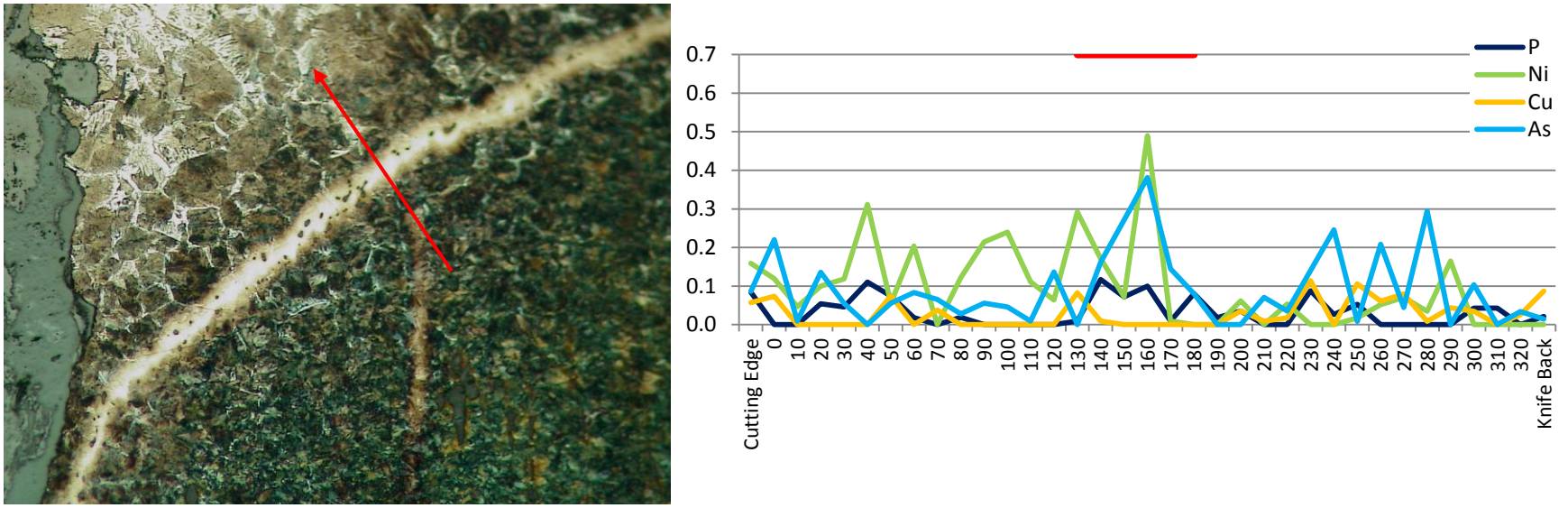


Figure 10.17: Line scan across the white weld line in Burdale Knife 64

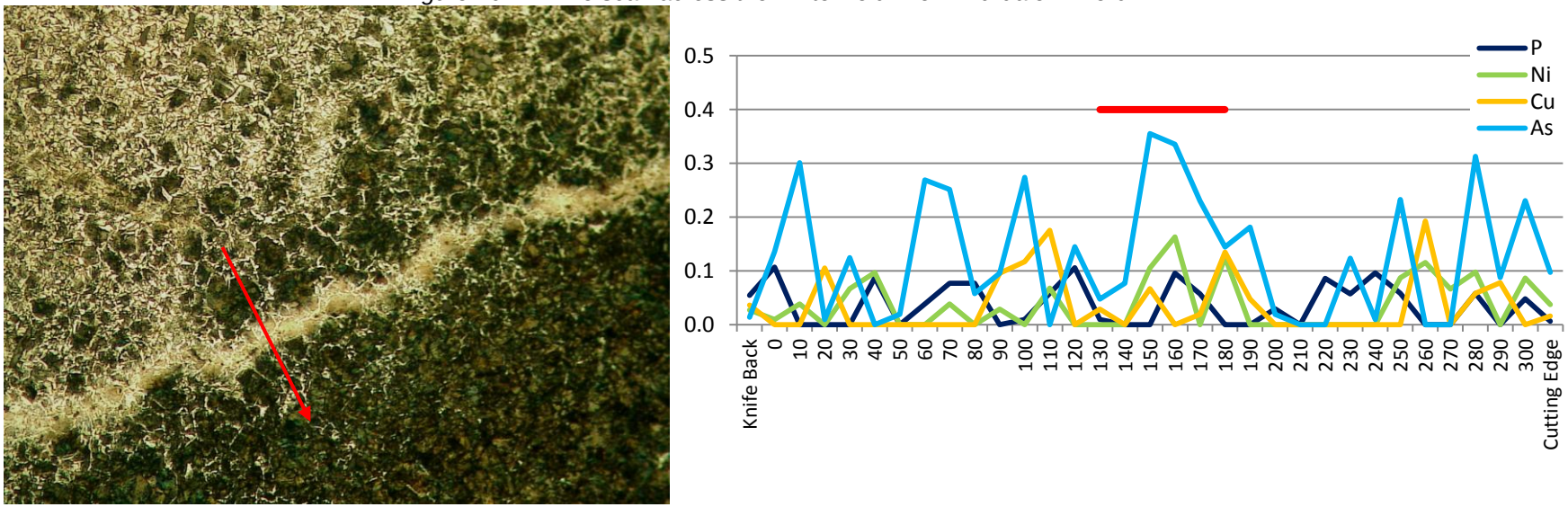


Figure 10.18: Line scan across the white weld line in Burdale Knife 69

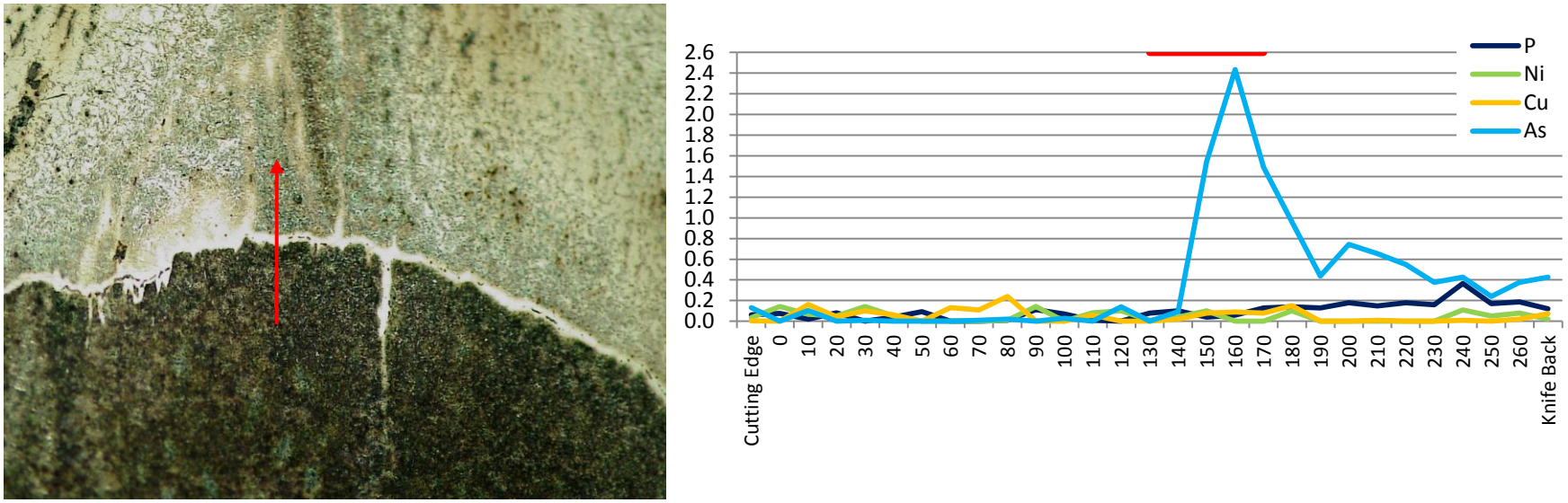


Figure 10.19: Line scan across the white weld line in Burdale Knife 204

Chapter 11: Sedgeford

Knife Descriptions

Knife 8 (Late Saxon)

X-radiography of this knife showed that it was well preserved although the cutting edge had been slightly worn. There was no evidence of a weld line although the cutting edge had the classic spotted texture.

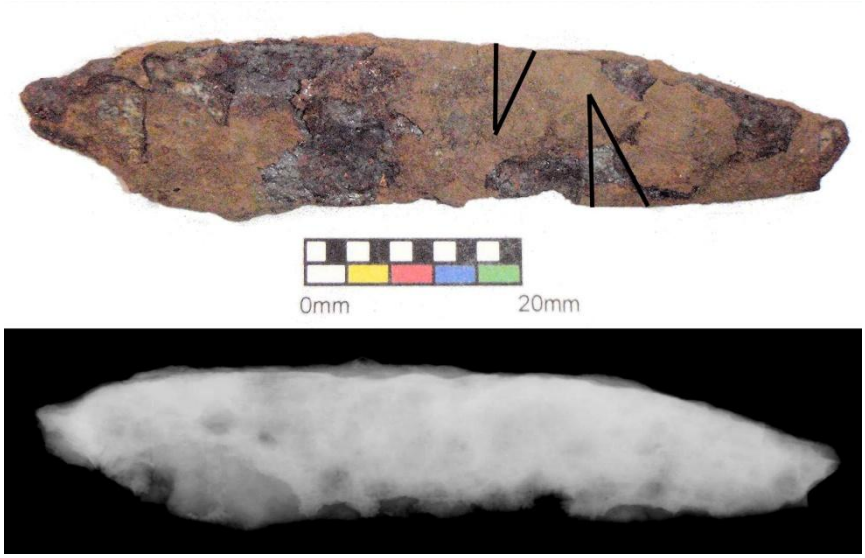


Figure 11.1: Photograph and x-radiograph of knife 8, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. In the cutting edge section there was a possible weld line made up of small, sub-angular, single-phased inclusions. Below this the inclusions were small, sub-angular and single-phased. In the back section the inclusions formed bands ranging from, small, elongated and single-phased near the weld line to multi-phased sub-angular inclusions seen in the back. Corrosion seems to have penetrated into the knife back forming a line.

The possible weld line seen in the unetched condition turned out to be a clear white weld line (*Average 227HV, Range 221-232HV*). This separated the tempered martensite cutting edge (509*HV, Average 469HV, Range 271-509HV*) from the iron back. There was carbon diffusion across the weld line resulting in a pearlite with ferrite structure. The back section consisted of predominately ferrite with pearlite, 0.2-0.4% carbon (*Average 161HV, Range 137-192HV*) although the

very back of the knife had larger grains, no carbon and some possible ghosting (*Average 211HV, Range 168-232HV*) suggesting a phosphoric iron, but no phosphorus was detected in this knife.

Knife 40 (Middle Saxon)

This knife was bent and the x-radiography of this knife revealed that it was badly corroded. There was a no evidence for a weld line although the spotted texture was seen.

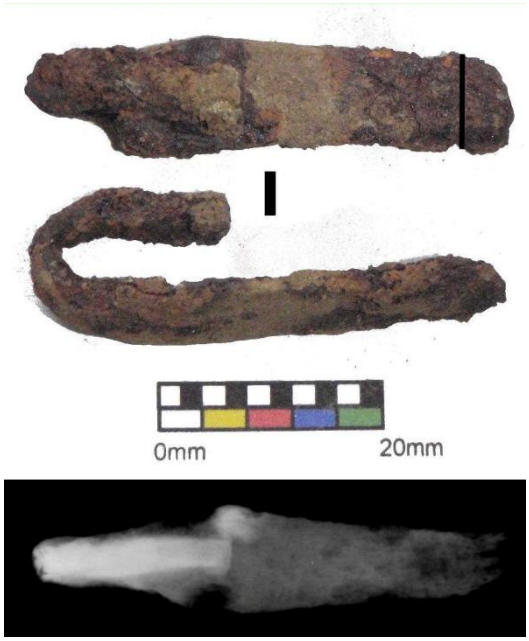


Figure 11.2: Photograph and x-radiograph of knife 40, the line shows where the section was removed.

Due to how the knife was bent a full section was removed. In the un-etched condition many of the slag inclusions were single-phased, elongated or sub-rounded and of varying sizes. There was no evidence for a transverse weld line.

After etching the knife appeared to be very heterogeneous but consisted of predominately ferrite with pearlite. Near the cutting edge there was a band of small grains for ferrite with grain boundary pearlite (154*HV, Average 154HV, Range 154-175HV*) near the back of the knife the carbon content had decreased (*Average 155HV, Range 123-192HV*). Analysis revealed very little phosphorus in the knife, apart from the very back (0.3%), although there were traces of arsenic

throughout (up to 0.2%). This possibly explains the white weld line seen in the knife section (*Average 158HV, Range 154-161HV*).

Knife 45 (Middle-Late Saxon)

This knife was bent and the x-radiography of this knife revealed that it was badly corroded. There was a no evidence for a weld line although the spotted texture was seen.

Figure 11.3: Photograph and x-radiograph of knife 45, the line shows where the section was removed.

Due to how the knife was bent a full section was removed. In the cutting edge section there were lots of single-phased sub-rounded inclusions. There was a line multi-phased, sub-rounded inclusions suggesting a weld line. The rest of the back consisted of elongated, sub-rounded or sub-angular single-phased inclusions.

When etched the cutting edge consisted of ferrite with some pearlite (*154HV, Average 157HV, Range 154-168HV*). The knife back consisted of large grained ferrite with no pearlite but with lots of ghosting around the inclusions (*Average 192HV, Range 148-221HV*). SEM-EDS analysis confirmed the presence of

phosphorus in the knife back (0.2-0.6%) and arsenic in the cutting edge (up to 0.4%). There was very little carbon diffusion across the weld line.

Knife 108 (Middle-Late Saxon)

The x-radiograph of this knife revealed some dark striations, possibly indicating a type 2 knife. There was no evidence for a spotted cutting edge.

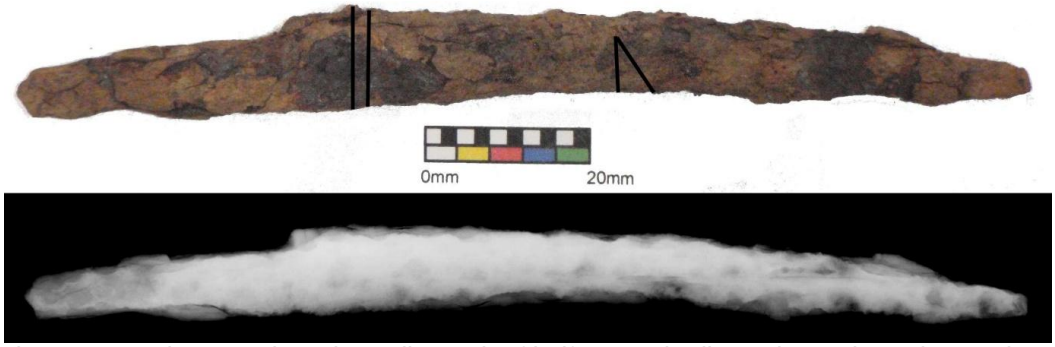


Figure 11.4: Photograph and x-radiograph of knife 108, the lines show where the sections were removed.

A single section was cut through the knife. The cutting edge had few single-phased sub-angular inclusions. There were many slag inclusions in the back mostly small, single-phased, sub-rounded, sub-angular or elongated. There was a band of single-phased sub-angular slag inclusions.

When etched the cutting edge was revealed to consist of pearlite (*362HV, Average 368HV, Range 321-441HV*). This suggests that the knife had not been heat-treated. The slag inclusions that formed a line which later revealed a white weld line enriched in arsenic (up to 0.2%). The knife back consisted primarily of medium to large grains of ferrite with no ghosting (*Average 117HV, Range 97-143HV*). There was an area which consisted of ferrite with pearlite (*Average 182HV, Range 161-192HV*). SEM analysis of this knife revealed only traces of phosphorus (up to 0.1%).

Knife 115 (Late Saxon)

The x-radiograph of this knife revealed a clear dark striation suggestive of a weld line. Below this the cutting edge had a spotted texture.

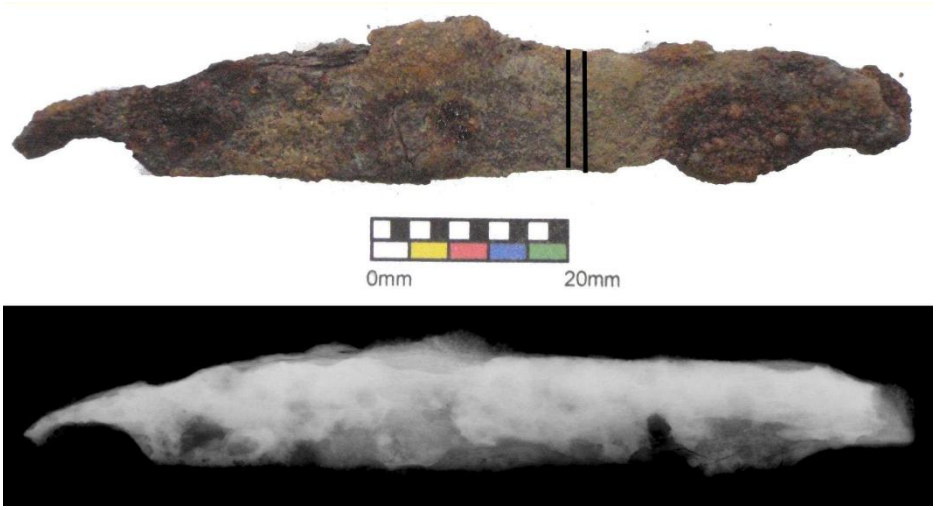


Figure 11.5: Photograph and x-radiograph of knife 115, the lines show where the section was removed.

Prior to etching, the knife was examined to reveal the presence of a weld line of sub-angular, single-phased inclusions. There were no inclusions in the cutting edge. Above the weld line, in the knife back, there were bands of single-phased inclusions which were sub-rounded or elongated.

The possible weld line seen in the unetched condition turned out to be a white weld line, enriched in arsenic and nickel (0.6-0.9% As, 0.3-0.5% Ni, *Average 399HV, Range 386-412HV*). This separated the tempered martensite cutting edge which transformed into pearlite towards the weld line (*509HV, Average 476HV, Range 362-509HV*). The knife back consisted of three heterogeneous bands of iron separated by faint white weld lines; the microstructures ranged from pearlite with ferrite up to 0.5% carbon (*Average 274HV, Range 244-303HV*), to ferrite with pearlite between 0.1-0.3% carbon (*Average 291HV, Range 232-321HV*) and large grains with some pearlite at grain boundaries and ghosting (*Average 198HV, Range 168-221HV*). Phosphorus was detected throughout the knife back.

Knife 116 (Middle-Late Saxon)

The x-radiograph of this knife revealed no evidence for a spotted cutting edge or weld lines.

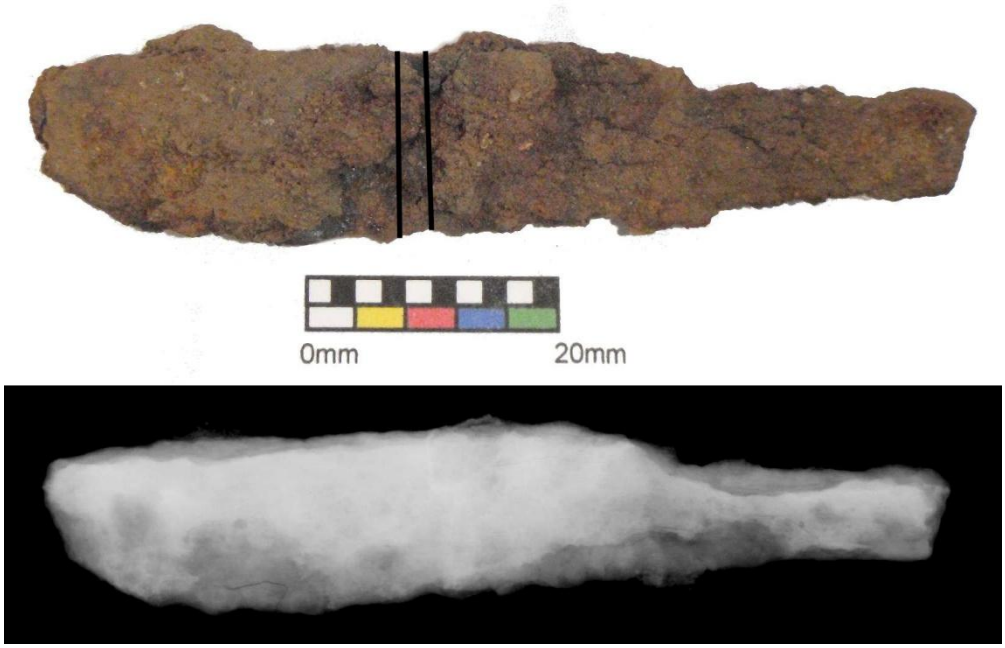


Figure 11.6: Photograph and x-radiograph of knife 116, the lines show where the section was removed.

A single section was cut through the knife. The cutting edge had few single-phased sub-rounded inclusions. There were many slag inclusions in the back were single- and multi-phased and elongated. There was a band of small single-phased spherical slag inclusions.

When etched the cutting edge was revealed to consist of pearlite with ferrite (*257HV, Average 270HV, Range 257-321HV*). This suggests that the knife had not been heat-treated. The slag inclusions that formed a line after etching were later revealed to be a white weld line (*Average 441HV*). The knife back consisted of heterogeneous bands of iron separated by slag inclusions. The microstructures ranged from pearlite with ferrite to ferrite with pearlite between 0.1-0.2% carbon (*Average 159HV, Range 132-201HV*). No phosphorus was detected in this knife.

Knife 120

The x-radiograph of knife 120 suggested that the knife was badly corroded in areas. There was no evidence for the presence of a weld line but the classic spotted texture was present in the cutting edge.

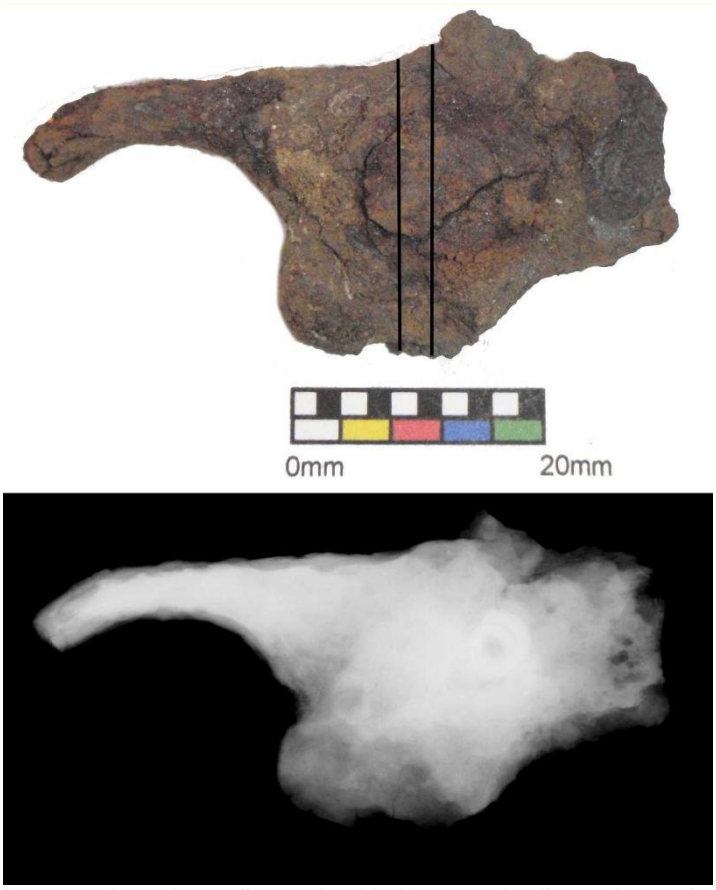


Figure 11.7: Photograph and x-radiograph of knife 120, the lines show where the section was removed.

A single section was removed and examined in the unetched condition. The corrosion had penetrated deeply into the knife, separating different areas. The inclusions were all elongated and single phased.

After etching two types of microstructures were visible. The first was ferrite with pearlite, located primarily by the cutting edge (*137HV, Average 156HV, Range 137-201HV*). The rest of the areas consisted of medium to large grains of ferrite, with some ghosting (*Average 171HV, Range 132-271HV*). This knife was constructed by welding lots of pieces of heterogeneous iron and steel strips creating a type 3 piled knife. The cutting edge has not been heat-treated.

Knife 128 (Late Saxon)

X-radiography of this knife showed that it was well preserved. There was no evidence for the presence of a weld line but the cutting edge had the classic spotted texture.

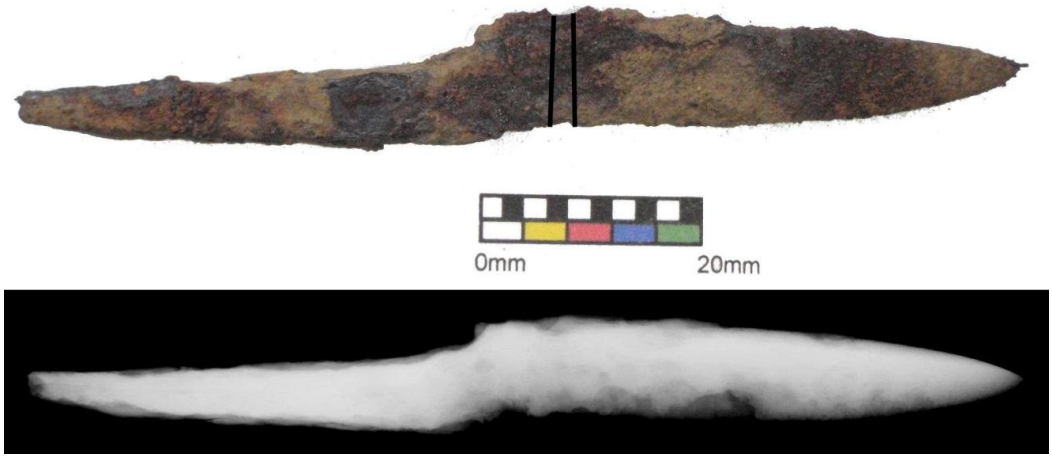


Figure 11.8: Photograph and x-radiograph of knife 128, the lines show where the section was removed.

A single section was removed and examined in the unetched condition, which revealed that there were two vertical slag inclusion bands, consisting of multi-phased inclusions mostly rounded and elongated. Between these bands the inclusions were small, single-phased and sub-rounded or sub-angular but the inclusions in the two flanks were large, sub-rounded or elongated and single phased. The corrosion had penetrated in to the cutting edge.

When etched the two bands separated a central strip which consisted of tempered martensite at the cutting edge (*490HV, Average 543HV, Range 303-701HV*), with pearlite in areas. To either side of this band the microstructure consisted of two types of metal; the majority is tempered martensite or pearlite (*Average 377HV, Range 286-644HV*) with some areas of large grains of ferrite with no pearlite and some ghosting (*Average 217HV, Range 210-221HV*). There was also carbon diffusion across the weld line but not into the large grained ferrite, suggesting phosphoric iron. This was confirmed by SEM-EDS analysis which suggested between 0.1-0.7% phosphorus.

Knife 188 (Late Saxon)

The x-radiograph of knife revealed a clear dark striation suggestive of a weld line. Below this the cutting edge had a spotted texture.

Figure 11.9: Photograph and x-radiograph of knife 188, the lines show where the section was removed.

Prior to etching the knife was examined to reveal the presence of a convex weld line of small single-phased inclusions. Below this weld line in the cutting edge there were a few small, sub-rounded or elongated, single-phased inclusions. Above the weld line the knife back consisted of two areas of inclusions; the left side had single- and multi-phased, sub-rounded slag inclusions while the right side had small, sub-angular, single-phased inclusions.

After etching the cutting edge turned out to consist of tempered martensite (*509HV, Average 610HV, Range 257-644HV*). There was a white weld line, enriched in arsenic and nickel (up to 0.4% As, 0.6%-0.7% Ni, *Average 234HV, Range 210-257HV*) separating the cutting edge from the knife back. There was some carbon diffusion across this weld line. The rest of the knife back consisted of larger grains of ferrite with no pearlite and some ghosting, suggesting phosphoric iron (*Average 199HV, Range 192-210HV*). This was confirmed by SEM-EDS analysis as up to 0.8% phosphorus was detected. The other side of the knife back had small grains of ferrite with some pearlite (*Average 192HV, Range 175-201HV*), phosphorus was also detected in this area (0.2%-0.3% P).

Knife 337 (Late Saxon)

The x-radiograph of this knife revealed a clear dark striation which ran along the knife, suggestive of a weld line. Below the weld line the cutting edge did not have the usual spotted texture.

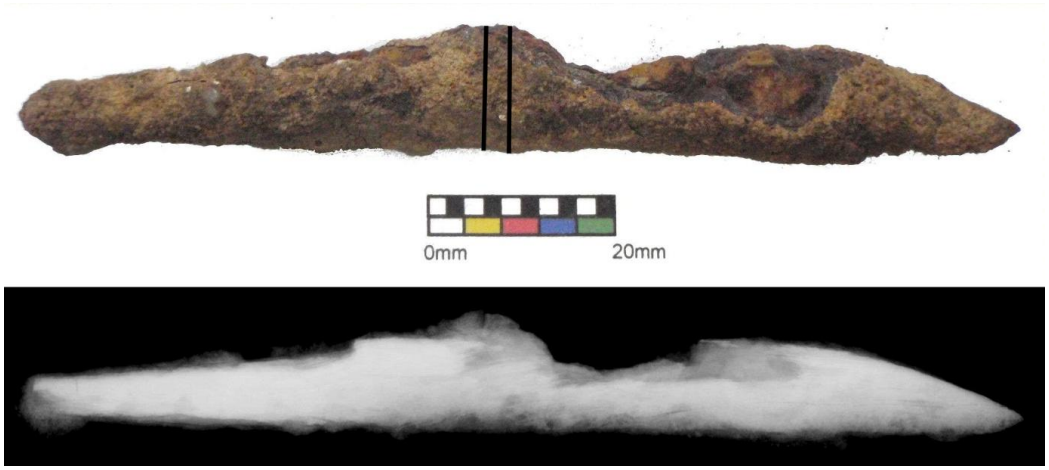


Figure 11.10: Photograph and x-radiograph of knife 337, the lines show where the section was removed.

A single section was removed and examined in the unetched condition. The cutting edge has single-phased, sub-rounded inclusions. The back of the knife had few single-phased angular slag inclusions.

When etched the cutting edge consisted of predominately large grains of ferrite (161*HV, Average 169HV, Range 148-201HV*). SEM-EDS analysis confirmed the presence of phosphorus (0.3%-0.6%). The back of the knife consisted of pearlite with ferrite (0.6%-0.8% carbon, *Average 340HV, Range 303-412HV*). This knife was a rather unusual type 2 manufacture with phosphoric iron welded onto a steel back.

Knife 344 (Late Saxon)

X-radiography of this knife revealed that it was badly corroded, especially the cutting edge. There was a possible weld line and the spotted texture below suggests a heat-treated steel cutting edge, but could just be the result of bad corrosion

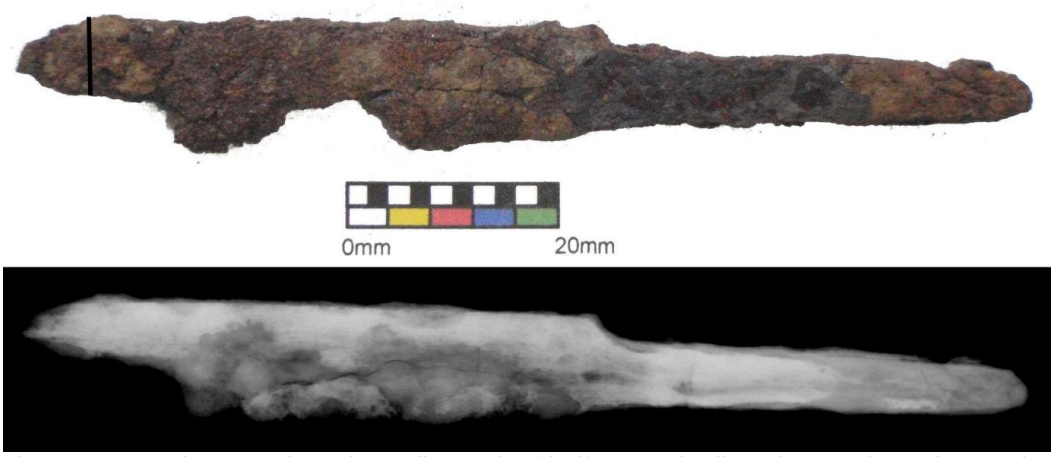


Figure 11.11: Photograph and x-radiograph of knife 344, the line shows where the section was removed.

During sectioning this knife broke, unexpectedly, and therefore the opportunity was taken to remove a full section. In the un-etched condition many of the slag inclusions were single-phased, sub-angular or sub-rounded and of varying sizes. There was no evidence for a transverse weld line.

After etching the knife appeared to consist of predominately ferrite. The majority of the knife had extremely large grains of ferrite (*Average 163HV, Range 132-192HV*). One side of the knife consisted of ferrite with grain boundary pearlite (*Average 197HV, Range 161-232HV*). The extremely large grains and low carbon content of this knife suggests a phosphoric iron, this was confirmed by SEM-EDS (0.2%-0.6%), while the other side had a smaller proportion of phosphorus (0.1%-0.2%).

Knife 429 (Late Saxon)

The x-radiograph of this knife revealed a dark striations, possibly indicating a type 2 knife, although there was no evidence for a spotted cutting edge.

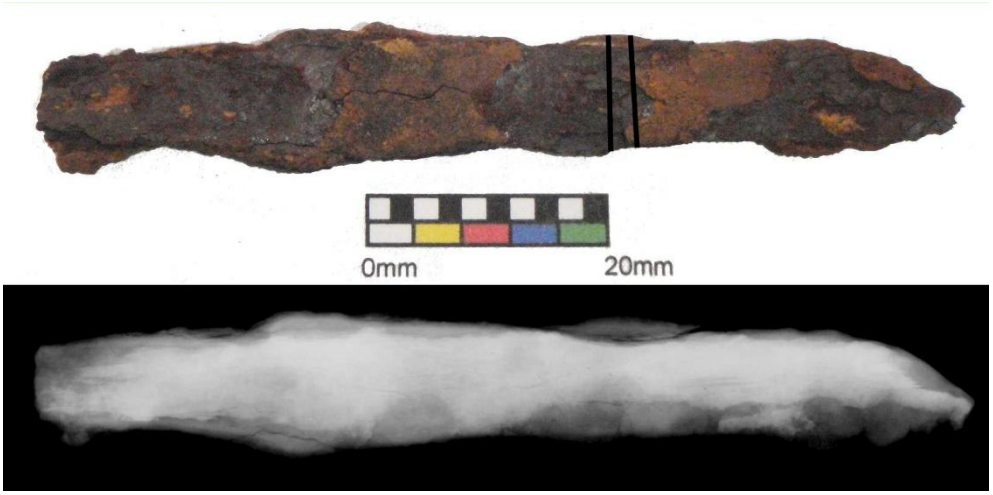


Figure 11.12: Photograph and x-radiograph of knife 429, the lines show where the section was removed.

A single section was cut through the knife. The cutting edge had few single-phased angular inclusions. There were many slag inclusions in the back including both multi- and single-phased, sub-rounded and rounded. There was a band of single-phased rounded slag inclusions.

When etched the cutting edge was revealed to consist of pearlite (*321HV, Average 272HV, Range 175-386HV*). This suggests that the knife had not been heat-treated. The slag inclusions that formed a line which later revealed a white weld line enriched in arsenic (up to 0.2%, *Average 279HV, Range 271-286HV*). The knife back consisted primarily of small grains of ferrite with no ghosting (*Average 163HV, Range 148-175HV*). There was an area which consisted of pearlite with ferrite (*Average 209HV, Range 192-221HV*). SEM analysis of this knife revealed only traces of phosphorus (up to 0.1%).

Knife 666 (Middle/Late Saxon)

There was no evidence for a weld line and the spotted texture was seen throughout the knife.

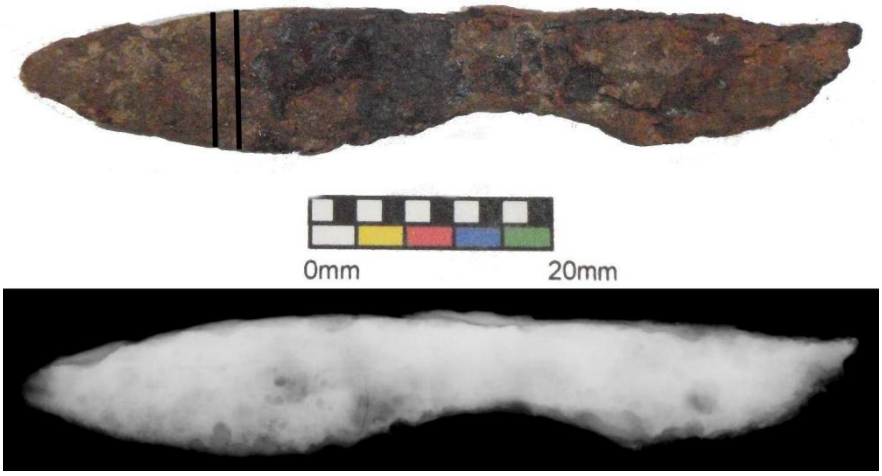


Figure 11.13: Photograph and x-radiograph of knife 666, the lines show where the section was removed.

A single section was removed. There was a few slag inclusions which were mostly sub-rounded and single-phased with even fewer found in the cutting edge section.

Once etched the two sections revealed a fairly homogenous iron, with varying amounts of carbon content (up to 0.1% carbon). The cutting edge section consisted of grains of ferrite with some grain boundary pearlite (*183HV, Average 154HV, Range 118-201HV*). The back consisted of larger grains of ferrite (*Average 122HV, Range 107-148HV*). Throughout the section no ghosting was seen, that plus the low hardness values, suggests no phosphorus is present, this was confirmed by SEM-EDS analysis which revealed only traces up to 0.1%.

Knife 705 (Late Saxon)

The x-radiograph of this knife revealed a dark striation, possibly indicating a type 2 knife, although there was no evidence for a spotted cutting edge.

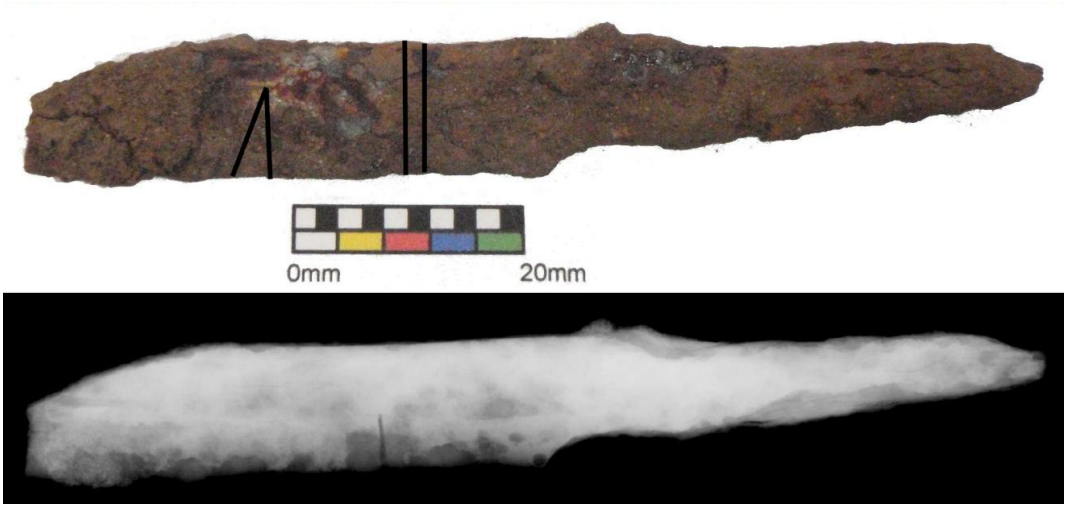


Figure 11.14: Photograph and x-radiograph of knife 705, the lines show where the sections were removed.

During sectioning the knife broke and therefore the opportunity was taken to remove a single section was cut through the knife. The cutting edge had a few single-phased sub rounded inclusions. The back was split into two pieces by the corrosion that had penetrated the knife back. The largest piece had very small single-phased, rounded inclusions. The other side had rub-rounded, single- and multi-phased slag inclusions.

When etched the cutting edge was revealed to consist of bainite and pearlite (*549HV, Average 468HV, Range 386-549HV*). This suggests that the knife had been quenched but slowly. The slag inclusions that formed a line which later revealed a white weld line enriched in arsenic (up to 0.2%) and nickel (0.3%-0.8%) with a hardness of *363HV*. The knife back consisted of two areas; the first was primarily of medium to small grains of ferrite with no obvious ghosting (*Average 145HV, Range 107-192HV*). The other area consisted of ferrite with pearlite (*Average 167HV, Range 148-192HV*). SEM analysis of this knife revealed only traces of phosphorus (up to 0.1%).

Knife 747 (Middle-Late Saxon)

X-radiography of this knife showed that it was well preserved, although the cutting edge had been slightly worn. There was no evidence for a weld line in the x-radiograph but the cutting edge had the spotted texture.

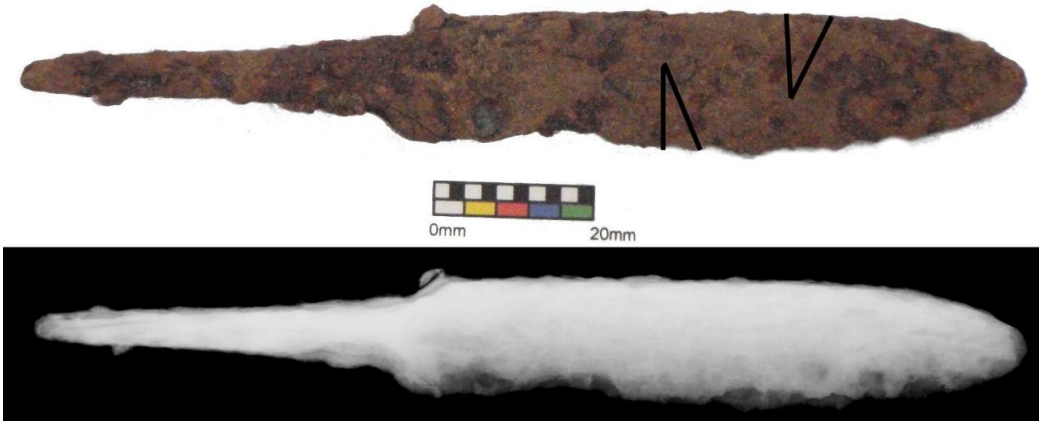


Figure 11.15: Photograph and x-radiograph of knife 747, the lines show where the sections were removed.

Two bands of single-phased elongated inclusions, joined at the knife back, suggested that the knife was constructed from at least three pieces of iron. The central strip had very few inclusions, those present were single-phased and elongated. To either side there were more inclusions which were larger, sub-angular or sub-rounded, single- and multi-phased.

Once etched the central band turned out to be predominately tempered martensite (*549HV, Average 385HV, Range 244-549HV*). There was some carbon diffusion across the weld lines into both iron flanks. The iron on one side was piled with areas of ferrite with pearlite and medium grains of ferrite (*Average 168HV, Range 137-201HV*). While the iron on the other side consisted of medium to large grains of ferrite (*Average 171HV, Range 137-221HV*). Neither iron flank had evidence for ghosting, and SEM-EDS revealed only traces of phosphorus, except for the areas of large grains which had between 0.4%-0.6% phosphorus.

This knife was constructed by welding one piece of steel between two larger pieces of ferritic and phosphoric iron, creating a type 1 knife. The steel strip was not present throughout the knife, resulting in an upside down Y shape weld near the knife back. The cutting edge was heat-treated.

Knife 1178 (Middle-Late Saxon)

The x-radiograph of knife 1178 suggested that the knife was badly corroded in areas. There was no evidence for the presence of a weld line but the classic spotted texture was present throughout the knife.

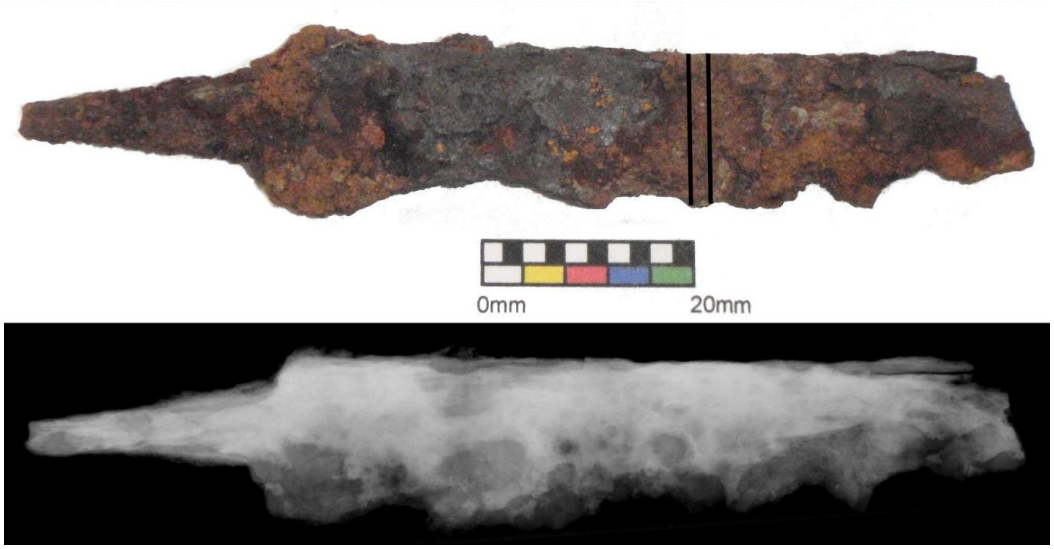


Figure 11.16: Photograph and x-radiograph of knife 1178, the lines show where the section was removed.

There were no clear weld lines instead the knife appeared to be fairly homogenous with very few single- and multi-phased, sub-rounded inclusions.

When etched the cutting edge was predominately consisted of tempered martensite (*509HV, Average 501HV, Range 386-644HV*). The rest of the knife consisted of pearlite and bainite throughout (*Average 339HV, Range 183-473HV*). SEM analysis revealed that phosphorus was present throughout, although in low concentrations (up to 0.3%). This analysis also revealed large quantities of copper in the metal with values between 0.6%-0.9%, and also some arsenic up to 0.2%. This knife was of type 5 manufacture constructed of steel. The cutting edge had been heat-treated, but quenched slowly to create the mostly bainite structure seen throughout.

Knife 1378 (Late Saxon)

The x-radiograph of knife revealed no evidence for a weld line but the cutting edge had a spotted texture.

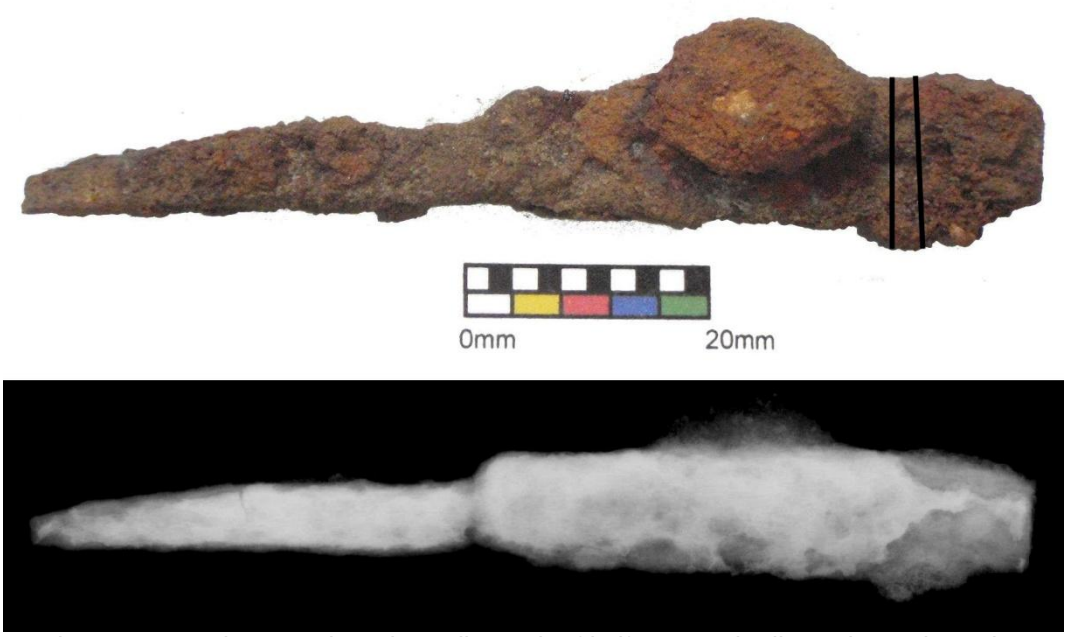


Figure 11.17: Photograph and x-radiograph of knife 1378, the lines show where the section was removed.

Prior to etching the knife was examined to reveal the presence of a weld line of small, sub-angular, single-phased inclusions. Below this weld line in the cutting edge there were a few small, sub-rounded, single-phased inclusions. Above the weld line the knife back consisted of two areas of inclusions; the left side had lots of single-phased, sub-rounded slag inclusions while the right side had fewer small, sub-angular, single-phased inclusions.

After etching the cutting edge turned out to consist of tempered martensite (*509HV, Average 495HV, Range 342-644HV*). There was a white weld line, enriched in arsenic (up to 0.1% As, *549HV*) separating the cutting edge from the knife back. There was some carbon diffusion across this weld line. The rest of the knife back consisted of small grains of ferrite with no pearlite but with no ghosting (*Average 175HV, Range 148-192HV*). SEM-EDS analysis revealed phosphorus in this are with between 0.3%-0.4% was detected. The other side of the knife back had small grains of ferrite with pearlite (*Average 325HV, Range 286-386HV*), again traces of phosphorus was also detected in this area (0.2%-0.3% P).

Knife 1384 (Late Saxon)

X-radiograph analysis of this revealed no evidence for a weld line or the spotted texture.

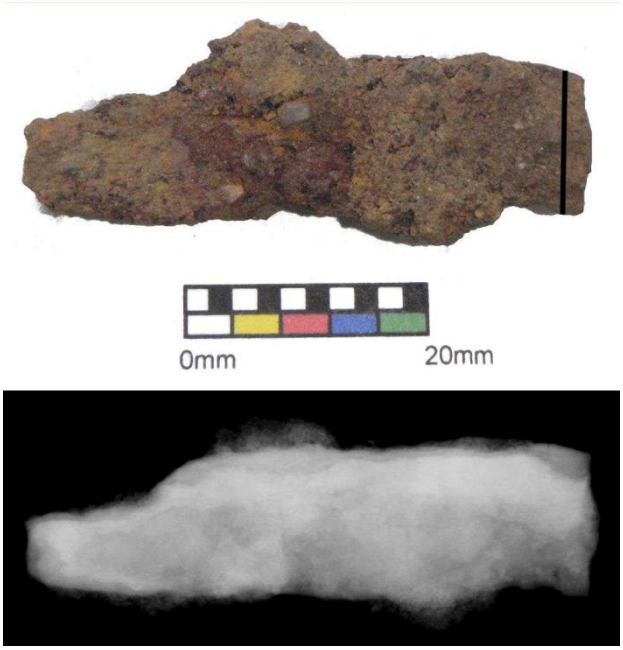


Figure 11.18: Photograph and x-radiograph of knife 1384, the line show where the section was removed.

A full section was removed from the broken end of this knife. In the un-etched condition many of the slag inclusions were single-phased, sub-angular or sub-rounded and of varying sizes. There was no evidence for a transverse weld line.

After etching the knife appeared to consist of predominately small grained ferrite with pearlite at the grain boundaries (*143HV, Average 149HV, Range 127-175HV*). The small grains and low carbon content of this knife suggests it was not a phosphoric iron, this was confirmed by SEM-EDS which only revealed traces of phosphorus up to 0.1%. There was also some arsenic (up to 0.3%) and nickel (up to 0.2%) present throughout the knife.

Knife 1513 (Middle Saxon)

X-radiography of this knife showed that it was not very well preserved. There was evidence for a weld line and the cutting edge had the classic spotted texture.

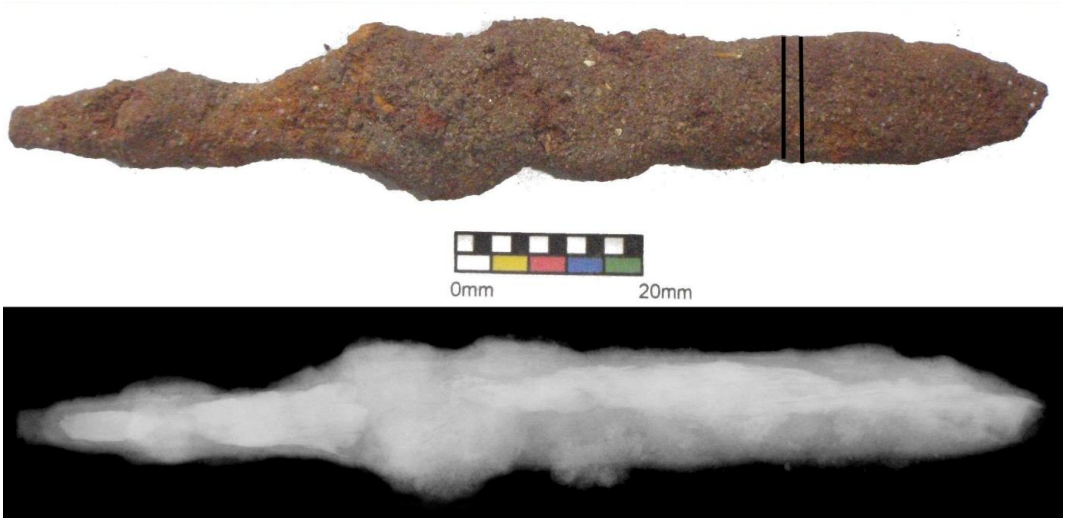


Figure 11.19: Photograph and x-radiograph of knife 1513, the lines show where the section was removed.

There was a possible weld line made up of small, sub-rounded, single-phased inclusions. Below this there were very few inclusions which were small, sub-angular and single-phased. In the back the inclusions formed bands ranging from, sub-angular and multi-phased near the weld line to multi-phased sub-rounded inclusions seen in the back. Corrosion seems to have penetrated into the knife back.

The possible weld line seen in the unetched condition turned out to be a clear white weld line (*Average 427HV, Range 412-441HV*) which was enriched in nickel (1.3%-1.8%). This separated the tempered martensite cutting edge (549*HV, Average 525HV, Range 509-549HV*) from the iron back, although within this cutting edge there was an area of lower carbon (*Average 211HV, Range 192-232HV*). There was carbon diffusion across the weld line resulting in a pearlite with ferrite structure. The back section consisted of predominately ferrite with pearlite, up to 0.2% carbon (*Average 187HV, Range 175-210HV*) although the very back of the knife had larger grains, no carbon and some possible ghosting (*Average 155HV, Range 137-175HV*) suggesting a phosphoric iron, but no phosphorus was detected in this knife.

Knife 2304 (Late Saxon)

The x-radiograph of this knife revealed no evidence for a weld line and the spotted texture was seen.

Figure 11.20: Photograph and x-radiograph of knife 2304, the lines show where the sections were removed.

Two half sections were removed. In the un-etched condition many of the slag inclusions were large, multi- and single-phased, sub-angular. There was no evidence for a transverse weld line.

After etching the knife appeared to be very heterogeneous but consisted of predominately ferrite. Near the cutting edge the structure consisted of large grains of ferrite (168*HV, Average 141HV, Range 114-168HV*). Near the back of the knife the carbon content increased resulting in a microstructure of ferrite with pearlite (0.2%-0.3% carbon, *Average 156HV, Range 132-210HV*). Analysis revealed phosphorus present throughout the knife (0.1%-0.3%), although there were traces of arsenic throughout (up to 0.2%).

Knife 2309 (Late Saxon)

The x-radiograph of knife 2309 revealed two notches in the back of the knife, near the tip. There was no evidence for a weld line, although the spotted texture was seen.

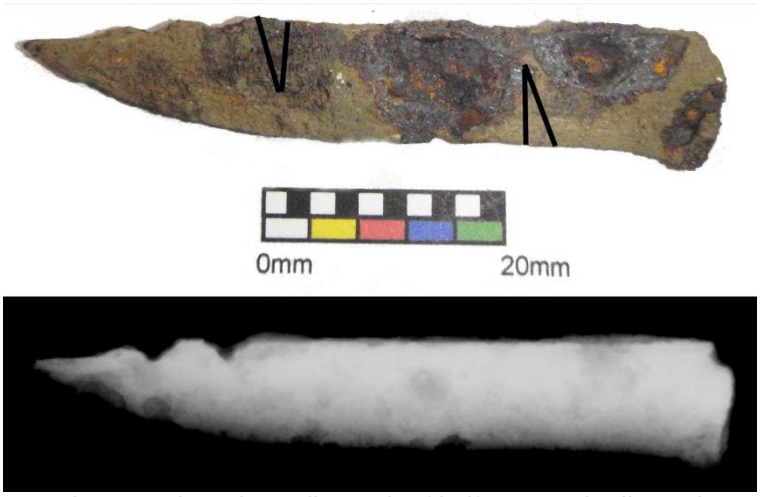


Figure 11.21: Photograph and x-radiograph of knife 2309, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. There were two vertical slag inclusion bands, consisting of single-phased inclusions mostly sub-rounded and elongated, visible in the back section, these seemed to continue into the cutting edge. Between these bands the inclusions were small, single-phased and elongated but the inclusions in the two flanks were sub-rounded or sub-angular and single phased.

When etched the two bands separated a central strip which consisted of tempered martensite and the cutting edge (*701HV, Average 614HV, Range 473-701HV*). To either side of this band the microstructure consisted of large grains of ferrite with no pearlite and some ghosting (*Average 216HV, Range 154-271HV*). There was also very little carbon diffusion across the weld line suggesting that the two iron flanks may be phosphoric iron. Confirmed by SEM-EDS analysis which revealed between 0.3-0.5% phosphorus, this analysis also revealed the presence of arsenic in the cutting edge (up to 0.3%).

Knife 2318 (Middle Saxon)

There was no evidence for the presence of a weld line but the cutting edge had the classic spotted texture.

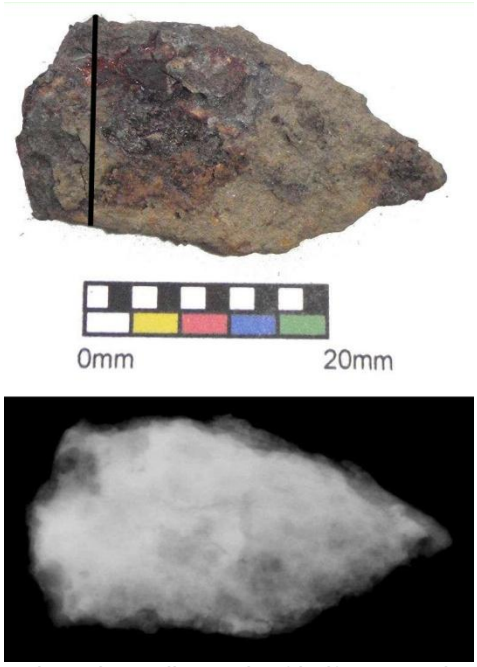


Figure 11.22: Photograph and x-radiograph of knife 2318, the line shows where the section was removed.

A single section was removed from the broken end of the knife fragment. In the unetched condition there was lots of corrosion which had penetrated lines of inclusions. This separated the metal into three distinct sections. The cutting edge section consisting of many single-phased, elongated inclusions. The metal above this had lots of angular and sub-angular, single-phased inclusions, while further towards the knife back the inclusions were elongated and single-phased.

Once etched the cutting edge piece of metal had a microstructure consisting of pearlite with ferrite (0.4%-0.6% carbon, *201HV, Average 245HV, Range 201-286HV*). There was some carbon diffusion from this piece of metal into the next one resulting in ferrite with pearlite (*Average 227HV, Range 221-244HV*). The final piece of iron further towards the back consists of medium to large grains of ferrite (*Average 212HV, Range 192-257HV*). Phosphorus was detected throughout the knife (0.1%-0.4%).

Knife 2401 (Late Saxon)

The x-radiograph of knife revealed no evidence for a weld line but the cutting edge had a spotted texture.

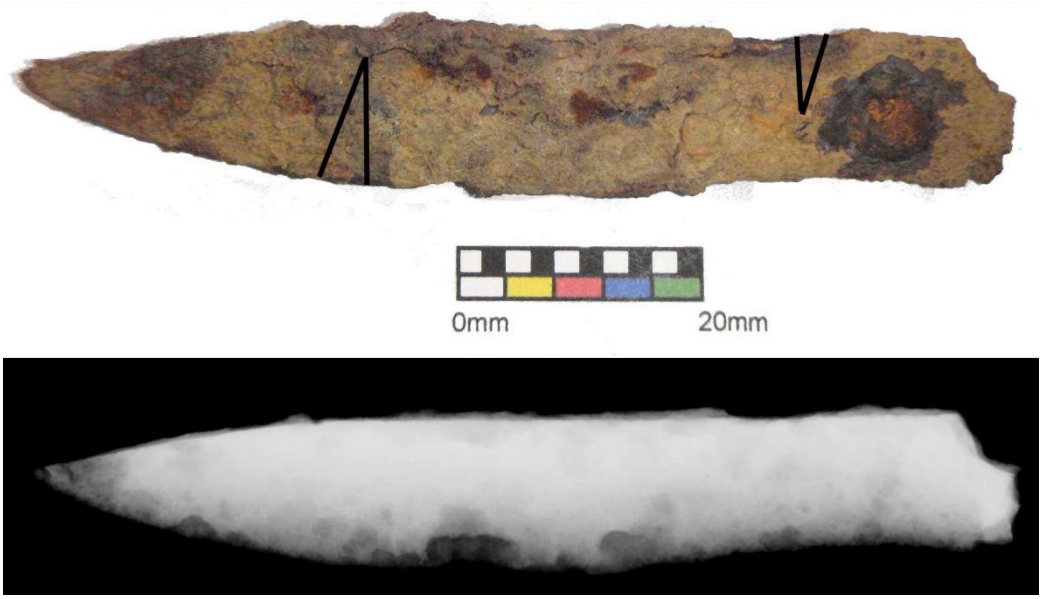


Figure 11.23: Photograph and x-radiograph of knife 2401, the lines show where the section were removed.

Two sections were removed and examined in the unetched condition. There were two vertical slag inclusion bands, consisting of single-phased inclusions mostly sub-rounded and elongated, visible in the back section, one of these lines seemed to continue into the cutting edge. Between these bands the inclusions were small, single-phased and elongated or angular but the inclusions in the two flanks were sub-rounded, multi- and single phased.

When etched the two bands separated a central strip which consisted of tempered martensite and the cutting edge, with pearlite with ferrite near the knife back (*644HV, Average 442HV, Range 286-644HV*). To either side of this band the microstructure consisted of large grains of ferrite with no pearlite and some ghosting (*Average 149HV, Range 107-244HV*). There was quite a bit of carbon diffusion across the weld line. SEM-Analysis revealed only traces of phosphorus in this knife (up to 0.1%).

Knife 3031

The x-radiograph revealed evidence for at least two weld lines and the classic spotted texture was present in the cutting edge.

Figure 11.24: Photograph and x-radiograph of knife 3031, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition, which revealed that there were two, or more vertical slag inclusion bands, consisting of single- and multi-phased inclusions mostly elongated. Between these bands the inclusions were single-phased and elongated.

When etched the cutting edge consisted of small grains of ferrite with some grain boundary pearlite (*110HV, Average 129HV, Range 110-168HV*). The back of the knife consisted of areas with small to medium grains of ferrite (*Average 114HV, Range 90-127HV*). SEM-EDS analysis revealed the presence of traces of phosphorus (up to 0.2%). This knife was constructed by welding lots of pieces of heterogeneous iron and low carbon steel strips creating a type 3 piled knife. The cutting edge has not been heat-treated.

Knife 3066 (Late Saxon)

There was clear evidence for a weld line, and the classic spotted texture was seen throughout the knife.

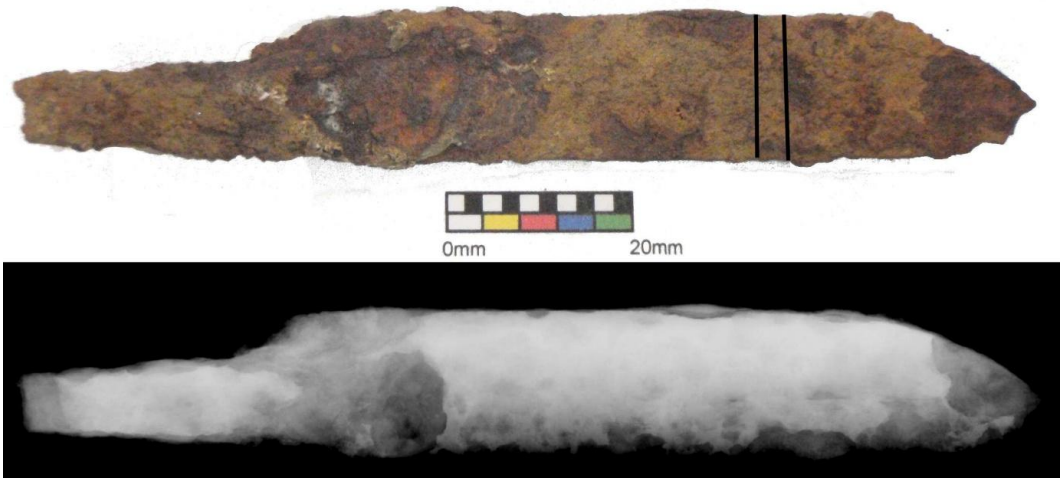


Figure 11.25: Photograph and x-radiograph of knife 3066, the lines show where the section was removed.

In the cutting edge section there was a clear weld line, with some single-phased and sub-angular inclusions. Below this weld line there were very few inclusions and those present were small, angular and single-phased. The back section consisted of many inclusions in bands, which were mostly single-phased and sub-rounded.

When etched the cutting edge consisted of predominately martensite with pearlite (441*HV, Average 528HV, Range 441-593HV*), which transformed to pearlite with ferrite towards the weld line (*Average 247HV, Range 201-321HV*). There was very little carbon diffusion across the weld line. The knife back consisted of medium to large grains of ferrite with no pearlite or ghosting (*Average 123HV, Range 107-143HV*), although traces of phosphorus was detected in some areas (up to 0.1%).

Knife 3136 (Late Saxon)

The x-radiograph of knife revealed no evidence for a weld line but the cutting edge had a spotted texture.

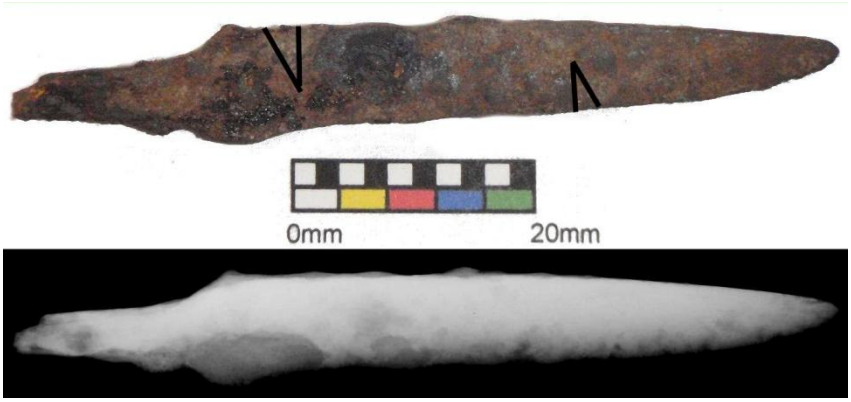


Figure 11.26: Photograph and x-radiograph of knife 3136, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. There were two vertical slag inclusion bands, consisting of single-phased inclusions mostly sub-rounded and elongated, visible in the back section, one of these lines seemed to continue into the cutting edge. Between these bands the inclusions were single-phased and angular but the inclusions in the two flanks were sub-rounded, single-phased.

When etched the two bands separated a central strip which consisted of tempered martensite and the cutting edge (*593HV, Average 502HV, Range 386-593HV*), with pearlite with ferrite near the knife back (*Average 246HV, Range 168-340HV*). To either side of this band the microstructure consisted of small to medium grains of ferrite with no pearlite and some ghosting (*Average 217HV, Range 148-62HV*). There was quite a bit of carbon diffusion across the white weld line. SEM-Analysis revealed only traces of phosphorus in this knife (up to 0.2%).

Knife 3138 (Middle-Late Saxon)

The x-radiograph of this knife revealed a clear dark striation which ran along the knife, suggestive of a weld line. Below the weld line the cutting edge did not have the usual spotted texture. Above this weld line another fainter line was also visible.

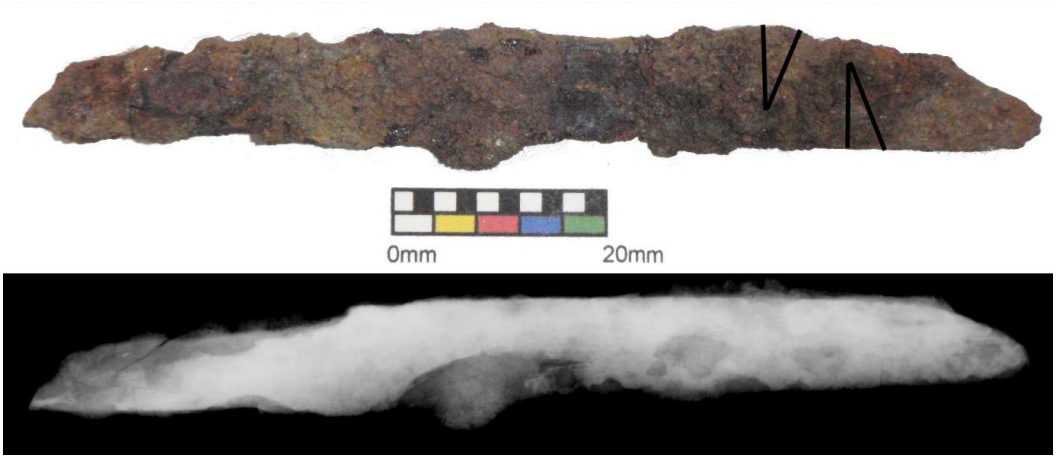


Figure 11.27: Photograph and x-radiograph of knife 3138, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. There was a line small multi-phased, rounded inclusions and a raised area suggesting a weld line. In the cutting edge there were lots of single-phased, sub-rounded and angular inclusions. The rest of the back consisted of single- and multi-phased, sub-rounded slag inclusions.

When etched, the cutting edge consisted of predominately martensite with pearlite, which transformed into pearlite close to the weld line (*644HV, Average 537HV, Range 340-644HV*). The knife back consisted of large grained ferrite (*ASTM 1*) with no pearlite but with lots of ghosting around the inclusions (*Average 211HV, Range 175-244HV*). SEM-EDS analysis confirmed the presence of phosphorus (0.1%-0.4%) and arsenic (0.1%-0.6%), but also traces of nickel (up to 0.2%). Etching revealed the presence of a faint white weld line separating the knife back from cutting edge, this was enriched in nickel and arsenic (*Average 216HV, Range 210-221HV*).

Knife 3140 (Middle-Late Saxon)

The x-radiograph of this knife revealed no evidence for a weld line although the spotted texture was seen.

Figure 11.28: Photograph and x-radiograph of knife 3140, the lines show where the section was removed.

In the un-etched condition the majority of the knife had very few inclusions, those present were single-phased, sub-rounded. Near the back of the knife there was an area with more sub-rounded and elongated single phased inclusions. There was no evidence for a transverse weld line.

After etching the knife appeared to be very homogenous and consisted of predominately of large grains of ferrite, with ghosting (175*HV, Average 199HV, Range 175-232HV*). Near the back of the knife the carbon content increased resulting in a microstructure of ferrite with pearlite at the grain boundaries (0.1% carbon, *Average 226HV, Range 192-286HV*). Analysis revealed phosphorus present throughout the knife (0.1%-0.6%), although less phosphorus was present in the back of the knife.

Knife 3141

X-radiography of this knife showed that it was well preserved, although the cutting edge had been worn and partially corroded. There was slight evidence for a weld line in the x-radiograph and the cutting edge had the spotted texture.

Figure 11.29: Photograph and x-radiograph of knife 3141, the lines show where the sections were moved.

Two etch resistant bands with small, spherical, single-phased inclusions, which joined at the knife back, suggested that the knife was constructed of three pieces of iron. The central strip had few inclusions, those present were small, single-phased and sub-rounded. To either side there were more inclusions which were larger, sub-rounded or elongated, single- and multi-phased.

Once etched the central band turned out to be predominately tempered martensite (*386HV, Average 623HV, Range 386-766HV*). There were two clear white weld lines, enriched in arsenic and nickel (*Average 571HV, Range 549-593HV*) separating the steel core from the iron flanks. There was some carbon diffusion across the weld line, particularly into one of the iron flanks, which consisted of small grains of ferrite with pearlite (*Average 189HV, Range 175-210HV*). The other piece of iron which was more resistant to carbon diffusion had larger grains (*Average 195HV, Range 168-221HV*). Neither iron flank had evidence for ghosting, although the SEM-EDS revealed phosphorus was present in both (0.2%-0.5%). This knife was constructed by welding one piece of steel between two larger pieces of phosphoric iron, creating a type 1 knife. The steel strip was not present throughout the knife, resulting in an upside down Y shape weld near the knife back. The cutting edge was heat-treated.

Summary Assemblage Knives

Knife No	Area	Context	Date	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
				Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
8	BYD/RDM	1047		B	x	74	69	5	13	8	Slight	X	Y	Broken tang
17	BYD/RDM	4	Medieval	B	3	128	47	81	8	5	Some	Y	Y	
18	BYD/RDM	4	Medieval	D	3	96	57	39	8	5	Some	Y	Y	
40	BYD/RDM	45	Middle Saxon	x	1	55	25	30	10	3	Unknown	X	X	Blade broken
45	BYD/RDM	65	Middle/Late Saxon	B			30		12	5	None	Y	Y	Bent & broken
108	BYD/RDM	1139		B	3	117	86	31	9	5	Some	Y	Y	
109	BYD/RDM	1139		B	3	40	32	8	7	4	Slight	Y	Y	
115	BYD/RDM	1185		B	2	86	76	10	12	7	None	Y	Y	
116	BYD/RDM	1132	Saxon?	D	1	70	47	23	14	8	None	X	Y	
120	BYD/RDM	1200		x	2	49	30	19	23	5	None	X	Y	Little blade, spiral of metal?
128	BYD/RDM	1189		B	3	86	46	40	9	6	Some	Y	Y	
130	BYD/RDM	1140	Modern?	x	1	55	16	39	26	9	None	?	Y	Broken blade
142	BYD/RDM	1227		x	x	88	88		26		Unknown	X	Y	Fragment
186	BYD/RDM	1130		x	x	53	53		20		None	X	X	Fragment
187	BYD/RDM	1140	Modern?	B	x	59	59		10		None	Y	Y	Broken tang
188	BYD/RDM	1180		B	2	66	48	18	10	5	None	Y	Y	
191	BYD/RDM	1227		x	x						None	X	X	Fragment
337	BYD/RDM	1419	C9+	B	3	99	67	32	10	6	Slight	Y	Y	
344	BYD/RDM	1663	C9+	D	3	92	52	40	10	6	Some	Y	Y	
348	BYD/RDM	0		B	x	52	52		12		None	Y	Y	Broken tang
366	BYD/RDM	0		B	3	87	67	20	11	6	Slight	Y	Y	
429	BYD/RDM	1573	C9-C10	B	x	74	56	18	8	7	None	Y	X	Broken tang
589	BYD/RDM	7004	Modern?	x	x	35	35		20		None	X	Y	Fragment
666	BYD/RDM	7015	Modern?	B	x	65	35	30	10	6	None	Y	Y	Pivoting?
705	BYD/RDM	7091	Modern?	A	1	86	56	30	12	8	Slight	Y	Y	
747	BYD/RDM	7091	Modern?	B	1	121	71	50	15	8	Slight	Y	Y	
1049			Modern?	D	2	114	48	66	13	3	None	X	Y	
1106	BYD/RDM	8006	C13+	x	x						None	X	X	
1178	BYD/RDM	0	x	D	1	90	68	22	16	7	None	Y	Y	
1378	BYD/RDM	8555	Late Saxon	B	1	78	43	35	11	5	None	X	Y	
1384	BYD/RDM	8543	C9-C10	x	3	45	35	10	12	6	None	X	X	
1511	BYD/RDM	0		A	1	130	79	51	14	8	Slight	Y	Y	
1513	BYD/RDM	8701	Middle	B	4	102	72	30	12	7	None	Y	Y	

Table 11.1: Summary table of the knives from Sedgeford showing the measurements, typologies assigned and the results from the x-radiograph analysis.

Knife No	Area	Context	Date	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
				Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
2304	CNE	303	Late	B	3	158	65	93	11	8	Heavy	Y	X	
2307				x	2	135	22	113	21	5	None	X	Y	
2309	CNE	310	C10/Late	D	x	55	52	3	10	8	Slight	X	Y	
2318	CNE	302	Middle	x	x	33	33		16		None	X	Y	Fragment
2401	CNE	404	Late	A	3	76	72	4	12	6	Slight	X	Y	Broken tang
3030	CNE	0		B	x	41	41		8		None	Y	Y	Broken
3031	CNE	0	x	B	1	110	69	41	12	8	Some	?	Y	Grooves
3066	CNE	10134	x	B	1	102	78	24	15	8	None	Y	Y	Broken tang
3076	CNE	0		A	1	117	87	30	16	7	Slight	Y	Y	Broken blade tip
3081	CNE	11026	Late?	x	x	26	26		8		None	X	X	Tang only
3130	CNE	0		x	3	74	46	28	11	10	Some	Y	Y	Broken blade tip
3136	BYD/RDM	1056		B	1	66	50	16	9	4	None	X	Y	
3137	BYD/RDM	2		x	x						None	Y	Y	
3138	BYD/RDM	1084	Modern?	B	3	91	62	29	10	7	Slight	Y	Y	
3139	BYD/RDM	3	Medieval	D	3	137	52	85	6	9	Heavy	?	Y	
3140	BYD/RDM	65	Middle/Late Saxon	B	2	46	32	14	9	6	None	X	Y	
3141	BYD/RDM	2	Modern?	D	3	78	72	6	10	8	None	Y	Y	Broken tang
3142	BYD/RDM	0		A	x	61	61		12		None	Y	Y	Broken tang

Table 8.1 cont: Summary table of the knives from Sedgeford showing the measurements, typologies assigned and the results from the x-radiograph analysis.

SEM-EDS Data

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
8	cutting edge	0.1	n.d.	0.1	n.d.	99.8	n.d.	n.d.	n.d.	97.8
		n.d.	0.1	n.d.	n.d.	99.5	0.1	0.3	n.d.	99.0
		n.d.	0.2	n.d.	n.d.	99.6	0.2	0.1	n.d.	98.4
		n.d.	0.1	n.d.	0.1	99.7	n.d.	n.d.	n.d.	99.4
	back 1	n.d.	0.1	n.d.	n.d.	99.7	0.2	n.d.	n.d.	97.4
		n.d.	n.d.	n.d.	n.d.	99.6	0.1	0.2	n.d.	99.7
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	101.5
		n.d.	n.d.	0.1	n.d.	99.6	n.d.	0.1	0.1	98.6
	back 2	n.d.	0.6	n.d.	n.d.	99.3	n.d.	n.d.	0.1	99.8
		0.1	0.4	n.d.	n.d.	99.2	n.d.	n.d.	0.3	99.4
		n.d.	0.3	n.d.	n.d.	99.5	n.d.	n.d.	0.3	99.5
		0.1	0.3	0.1	n.d.	99.3	n.d.	0.2	0.1	98.7
40	site 1	0.1	n.d.	n.d.	n.d.	99.6	0.1	0.1	0.2	115.2
		n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	n.d.	119.4
		n.d.	n.d.	n.d.	0.1	99.4	n.d.	0.1	0.2	102.1
		n.d.	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.2	97.8
		n.d.	0.1	0.1	n.d.	99.4	n.d.	0.2	0.2	94.1
		0.2	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.1	102.9
		0.1	n.d.	n.d.	n.d.	99.6	0.2	n.d.	n.d.	103.9
		0.1	0.1	n.d.	n.d.	99.4	0.2	0.1	0.1	102.5
	area 2	n.d.	n.d.	n.d.	0.1	99.8	n.d.	n.d.	n.d.	112.0
		0.1	n.d.	n.d.	n.d.	99.7	0.1	n.d.	n.d.	112.8
		0.1	0.1	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	113.5
		0.2	0.1	0.1	n.d.	99.5	0.1	0.1	n.d.	101.1
		0.4	0.1	n.d.	n.d.	99.2	0.1	n.d.	0.3	91.0
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	0.1	0.2	99.0
		0.1	0.3	n.d.	n.d.	99.5	n.d.	n.d.	0.1	99.5
		n.d.	0.3	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	96.1
	white weld line	0.1	0.2	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	102.9
		0.1	0.1	0.1	n.d.	99.5	0.1	0.1	0.1	108.4
45	cutting edge	0.3	0.1	n.d.	n.d.	99.5	n.d.	n.d.	n.d.	102.5
		0.4	0.1	n.d.	n.d.	99.2	n.d.	n.d.	0.3	108.7
		0.7	0.1	n.d.	n.d.	98.9	0.1	n.d.	0.2	103.6
		0.1	n.d.	0.1	n.d.	99.4	n.d.	n.d.	0.4	99.7
	back 1	0.1	0.3	n.d.	n.d.	99.2	0.1	0.1	0.2	93.0
		n.d.	0.3	n.d.	n.d.	99.4	n.d.	n.d.	0.1	81.8
		n.d.	0.2	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	94.7
		n.d.	0.2	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	100.7
	back 2	n.d.	0.6	n.d.	n.d.	99.1	0.1	0.1	n.d.	97.2
		n.d.	0.4	n.d.	n.d.	99.4	n.d.	0.1	n.d.	93.6
		n.d.	0.6	n.d.	0.1	99.2	n.d.	n.d.	n.d.	101.1
		0.2	0.5	n.d.	n.d.	99.1	n.d.	n.d.	0.1	102.2

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
108	cutting edge	0.1	n.d.	0.1	n.d.	99.6	n.d.	0.1	0.1	108.9
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	111.0
		0.1	0.1	n.d.	0.1	99.6	n.d.	n.d.	n.d.	110.8
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	107.7
	weld line	n.d.	0.1	n.d.	0.1	99.6	0.1	n.d.	0.1	109.8
		0.1	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.2	109.8
	back 1	0.1	n.d.	n.d.	n.d.	99.7	0.1	n.d.	0.1	109.2
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	0.2	n.d.	100.3
		n.d.	n.d.	n.d.	0.1	99.9	n.d.	n.d.	n.d.	98.1
		n.d.	0.1	n.d.	n.d.	99.6	0.2	n.d.	n.d.	98.2
	back 2	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.2	98.8
		0.1	0.1	n.d.	n.d.	99.5	0.2	0.1	n.d.	99.1
		n.d.	n.d.	0.1	n.d.	99.6	0.2	0.1	n.d.	101.7
		0.1	n.d.	0.1	n.d.	99.8	n.d.	n.d.	n.d.	102.2
115	Cutting edge	0.1	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	97.7
		0.1	n.d.	n.d.	0.1	99.3	0.1	0.1	0.3	98.8
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	0.1	0.2	96.2
	white weld line	n.d.	n.d.	n.d.	n.d.	98.7	0.3	0.2	0.6	94.1
		n.d.	0.1	n.d.	0.1	98.4	0.5	0.1	0.9	90.8
	Area 1	0.1	0.3	n.d.	n.d.	99.4	n.d.	0.1	0.1	88.4
		n.d.	0.3	n.d.	n.d.	99.4	0.1	0.1	n.d.	87.3
		n.d.	0.3	n.d.	n.d.	99.5	0.1	n.d.	0.1	110.2
	area 2	0.1	0.3	0.1	0.1	99.4	n.d.	n.d.	n.d.	107.0
		0.1	0.2	n.d.	n.d.	99.5	n.d.	n.d.	0.1	104.9
		n.d.	0.3	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	104.5
		n.d.	0.4	n.d.	0.1	99.2	n.d.	n.d.	0.2	101.4
		0.1	0.4	n.d.	n.d.	99.3	n.d.	n.d.	0.1	99.2
		n.d.	0.3	0.1	n.d.	99.6	n.d.	n.d.	n.d.	97.6
	area 3	0.1	0.1	n.d.	n.d.	99.4	0.2	n.d.	0.2	96.8
		0.1	0.1	n.d.	n.d.	99.6	0.2	n.d.	0.1	96.4
		0.1	0.2	n.d.	0.1	99.4	n.d.	n.d.	0.2	95.2
116	cutting edge	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.2	103.3
		0.1	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	102.6
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.1	0.1	104.4
		n.d.	n.d.	0.1	n.d.	99.6	n.d.	n.d.	0.2	103.7
	back 1	0.1	n.d.	0.1	n.d.	99.7	n.d.	n.d.	0.1	104.6
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	102.9
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	105.3
		n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	102.7
	back 2	n.d.	0.1	n.d.	n.d.	99.6	0.1	0.1	0.1	104.7
		n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	0.1	106.0
		n.d.	n.d.	n.d.	0.1	99.8	n.d.	n.d.	n.d.	103.3
		n.d.	n.d.	n.d.	0.1	99.9	n.d.	n.d.	n.d.	106.2

Table 11.2: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
120	site 1	0.1	0.2	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	105.8
		0.1	0.1	n.d.	0.1	99.7	n.d.	n.d.	n.d.	104.5
		0.1	0.2	n.d.	n.d.	99.3	0.1	0.1	0.3	104.2
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.2	101.0
	site 2	n.d.	0.3	n.d.	n.d.	99.4	n.d.	n.d.	0.2	102.5
		0.1	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	98.8
		n.d.	0.3	n.d.	0.1	99.4	n.d.	n.d.	0.2	97.1
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	99.5
	site 3	n.d.	0.2	n.d.	n.d.	99.5	n.d.	0.1	0.1	103.1
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	99.8
		n.d.	0.2	n.d.	n.d.	99.7	0.1	n.d.	0.1	101.0
	site 4a	0.1	0.6	n.d.	0.1	99.2	n.d.	n.d.	n.d.	100.9
		0.1	0.4	0.1	n.d.	99.3	0.1	n.d.	n.d.	102.7
		0.1	0.3	0.1	n.d.	99.3	n.d.	0.1	n.d.	106.8
	site 4b	0.1	0.3	n.d.	0.1	99.5	n.d.	n.d.	n.d.	99.6
		0.2	0.7	0.2	n.d.	98.7	0.2	0.1	n.d.	75.1
		n.d.	0.4	n.d.	n.d.	99.5	0.1	n.d.	n.d.	99.2
128	Cutting edge	n.d.	0.1	n.d.	n.d.	99.6	0.2	0.1	0.1	96.2
		0.1	0.1	n.d.	0.1	99.7	n.d.	n.d.	n.d.	103.3
		n.d.	0.1	n.d.	0.1	99.6	0.1	n.d.	0.1	103.0
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.2	99.2
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	0.2	n.d.	99.2
	weld line	n.d.	n.d.	n.d.	n.d.	99.7	0.1	n.d.	0.1	102.1
		0.1	0.1	n.d.	n.d.	99.6	0.1	n.d.	n.d.	101.5
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	100.7
		n.d.	0.1	n.d.	n.d.	99.8	0.1	n.d.	0.1	99.6
	Right Flank	0.1	0.3	0.1	n.d.	99.4	n.d.	n.d.	0.2	100.7
		0.1	0.2	n.d.	0.1	99.5	0.1	n.d.	0.2	100.4
		n.d.	0.2	n.d.	0.1	99.6	0.1	0.1	n.d.	100.2
	Left Flank (martensite)	0.1	0.1	0.1	n.d.	99.5	0.1	0.2	n.d.	98.2
		0.1	n.d.	0.1	0.1	99.5	n.d.	n.d.	0.1	98.4
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	98.7
		0.1	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.1	100.8
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	100.6
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.3	101.4
	Left Flank (ferrite)	0.2	0.4	n.d.	n.d.	99.4	n.d.	n.d.	n.d.	100.5
		n.d.	0.5	n.d.	n.d.	99.5	n.d.	n.d.	n.d.	100.6
		n.d.	0.7	n.d.	n.d.	99.0	0.3	n.d.	n.d.	102.8
		0.1	0.1	n.d.	n.d.	99.5	0.2	n.d.	0.1	102.2

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
188	cutting edge	0.1	0.1	0.1	0.1	99.6	0.1	n.d.	n.d.	107.1
		0.1	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.1	106.5
		0.1	n.d.	n.d.	0.1	99.7	n.d.	n.d.	n.d.	94.7
		0.1	n.d.	n.d.	n.d.	99.7	0.2	n.d.	n.d.	94.4
	weld line	0.1	0.1	n.d.	n.d.	98.7	0.6	n.d.	0.4	101.5
		0.1	0.1	n.d.	0.1	99.0	0.7	n.d.	n.d.	101.6
	back 1	0.1	0.2	n.d.	n.d.	99.0	n.d.	0.2	0.3	102.1
		n.d.	0.3	n.d.	0.1	99.5	n.d.	n.d.	n.d.	103.3
		n.d.	0.2	0.1	n.d.	99.4	0.2	n.d.	0.1	104.0
		n.d.	0.2	n.d.	n.d.	99.6	n.d.	n.d.	0.1	106.6
	back 2	0.1	0.8	n.d.	n.d.	98.9	0.1	n.d.	n.d.	105.2
		0.1	0.6	n.d.	n.d.	99.2	n.d.	n.d.	0.1	108.1
		n.d.	0.5	n.d.	0.1	99.3	0.1	n.d.	n.d.	109.0
337	Large grans	n.d.	0.4	n.d.	0.1	99.3	0.1	0.1	n.d.	109.1
		n.d.	0.6	n.d.	n.d.	99.1	0.2	0.1	0.1	110.7
		n.d.	0.5	n.d.	n.d.	99.4	n.d.	n.d.	0.1	111.5
		n.d.	0.3	n.d.	n.d.	99.5	n.d.	0.2	n.d.	109.2
	pearlite	n.d.	0.2	0.1	n.d.	99.5	n.d.	0.1	0.1	112.5
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	0.1	n.d.	113.8
		0.1	0.1	0.2	n.d.	99.6	0.1	n.d.	n.d.	112.0
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.3	110.8
		n.d.	0.6	n.d.	n.d.	99.4	n.d.	n.d.	n.d.	111.4
344	Large grans	n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	101.5
		0.1	0.3	n.d.	n.d.	99.4	n.d.	n.d.	0.2	105.6
		n.d.	0.3	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	101.4
		n.d.	0.6	n.d.	n.d.	99.1	0.2	n.d.	n.d.	107.9
	ferrite with pearlite	n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	104.4
		n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	106.6
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	0.2	n.d.	110.0
		0.1	0.2	n.d.	n.d.	99.3	0.1	0.2	0.1	113.6

Table 8.2 cont: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
429	**cutting edge**	0.1	0.2	n.d.	0.1	99.5	0.1	n.d.	n.d.	103.7
		n.d.	0.1	n.d.	0.1	99.6	0.2	n.d.	0.1	102.5
		n.d.	0.1	n.d.	n.d.	99.5	0.1	n.d.	0.2	103.4
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	102.3
	cutting edge 2	n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	104.1
		n.d.	n.d.	n.d.	0.1	99.7	n.d.	0.1	0.1	102.7
		0.1	0.1	n.d.	n.d.	99.6	0.1	n.d.	n.d.	101.6
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	103.9
	weld line	0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	102.1
		0.1	0.1	n.d.	n.d.	99.5	0.1	0.1	0.2	103.1
	back 1	0.1	n.d.	0.1	n.d.	99.6	0.1	0.2	n.d.	103.4
		n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	n.d.	104.0
		n.d.	0.1	n.d.	n.d.	99.7	0.1	0.1	n.d.	103.7
		n.d.	0.2	n.d.	n.d.	99.6	n.d.	0.1	n.d.	101.4
	back 2	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	0.1	102.2
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.4	n.d.	100.6
		0.1	n.d.	n.d.	n.d.	99.6	0.1	0.1	0.1	101.9
		n.d.	n.d.	n.d.	n.d.	99.4	0.2	0.2	0.2	102.7
666	**site 1**	n.d.	0.1	n.d.	n.d.	99.7	n.d.	0.1	n.d.	100.9
		n.d.	n.d.	n.d.	n.d.	99.3	0.3	0.1	0.3	90.7
		n.d.	n.d.	n.d.	n.d.	99.4	0.3	0.1	n.d.	81.4
		n.d.	n.d.	n.d.	n.d.	99.8	0.2	n.d.	n.d.	92.6
	site 2	n.d.	n.d.	n.d.	n.d.	99.7	0.1	n.d.	0.1	122.3
		n.d.	0.1	n.d.	n.d.	99.7	0.1	n.d.	0.1	112.7
		n.d.	n.d.	0.1	n.d.	99.5	n.d.	0.1	0.2	102.1
		n.d.	n.d.	n.d.	n.d.	99.5	0.1	0.2	0.1	100.4
705	**cutting edge**	0.1	0.2	n.d.	n.d.	99.6	0.1	0.1	n.d.	109.1
		n.d.	0.1	n.d.	n.d.	99.7	0.2	n.d.	n.d.	105.9
		n.d.	0.1	n.d.	n.d.	99.4	0.2	0.1	0.2	97.1
		0.1	0.1	n.d.	n.d.	99.7	n.d.	0.1	0.2	95.0
	weld line	n.d.	n.d.	n.d.	0.1	98.6	0.8	0.1	0.4	101.0
		n.d.	n.d.	n.d.	n.d.	99.5	0.3	0.1	n.d.	99.7
	back 1	0.1	0.1	n.d.	n.d.	99.6	0.1	n.d.	n.d.	92.5
		0.1	0.1	0.1	0.1	99.5	0.1	n.d.	n.d.	98.3
		0.1	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.1	101.2
		n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	104.3
	back 2	0.1	n.d.	n.d.	0.1	99.5	0.1	n.d.	0.2	101.4
		n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	104.4
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	n.d.	0.1	109.9
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	0.1	107.0

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
747	**cutting edge**	n.d.	n.d.	0.1	n.d.	99.6	0.1	n.d.	0.2	92.2
		n.d.	0.1	n.d.	n.d.	99.3	0.3	0.2	0.1	107.8
		n.d.	n.d.	n.d.	n.d.	99.6	0.3	n.d.	n.d.	100.9
		n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	92.8
	back 1	0.1	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.2	110.6
		0.1	n.d.	0.1	n.d.	99.6	0.1	0.1	n.d.	165.7
		n.d.	0.1	n.d.	n.d.	99.5	0.2	0.1	n.d.	106.7
		n.d.	0.1	0.1	n.d.	99.5	n.d.	0.3	n.d.	109.4
	back 2	n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	109.4
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	104.4
		n.d.	0.4	0.1	0.1	99.4	n.d.	0.1	n.d.	97.5
		0.2	0.6	0.1	0.1	98.9	0.1	n.d.	0.1	100.9
1178	**site 1**	n.d.	0.2	n.d.	0.1	98.7	n.d.	0.9	0.1	110.1
		n.d.	0.3	n.d.	n.d.	98.8	n.d.	0.9	0.1	114.5
		n.d.	0.2	n.d.	n.d.	98.9	0.1	0.6	0.1	114.3
		0.1	0.1	n.d.	n.d.	98.8	n.d.	0.9	n.d.	112.6
	site 2	n.d.	0.2	0.1	0.1	98.3	0.1	1.0	0.2	106.6
		n.d.	0.1	n.d.	n.d.	98.9	0.1	0.8	n.d.	101.9
		n.d.	0.2	n.d.	n.d.	98.7	n.d.	0.8	0.2	98.9
		n.d.	0.2	n.d.	0.1	98.5	0.1	0.9	0.2	100.0
	site 3	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	107.4
		n.d.	0.1	n.d.	0.1	99.6	n.d.	0.1	0.1	112.5
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	104.4
		0.1	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	102.4
1378	**area 1**	n.d.	0.4	0.1	n.d.	99.2	0.1	0.2	0.1	99.5
		n.d.	0.3	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	104.8
		n.d.	0.3	n.d.	n.d.	99.5	0.2	n.d.	n.d.	105.7
	area 2	n.d.	0.3	n.d.	n.d.	99.5	n.d.	0.2	n.d.	107.0
		0.1	0.3	0.1	n.d.	99.6	n.d.	n.d.	n.d.	109.7
		0.1	0.2	n.d.	n.d.	99.5	0.2	n.d.	n.d.	100.5
	weld line	0.1	0.1	n.d.	0.1	99.5	n.d.	n.d.	0.1	93.0
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	0.1	94.3
	cutting edge	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	93.0
		0.1	0.2	n.d.	n.d.	99.7	n.d.	0.1	n.d.	97.2
		n.d.	0.7	n.d.	n.d.	99.3	n.d.	n.d.	n.d.	94.8
		n.d.	n.d.	n.d.	n.d.	99.9	0.1	n.d.	n.d.	103.8
		n.d.	n.d.	n.d.	n.d.	10n.d.	n.d.	n.d.	n.d.	104.7
		n.d.	0.1	n.d.	n.d.	99.7	0.1	n.d.	n.d.	107.3

Table 8.2 cont: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
1384	**ferrite**	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	100.7
		0.1	0.1	n.d.	n.d.	99.7	n.d.	0.1	n.d.	104.8
		n.d.	n.d.	n.d.	n.d.	99.6	0.1	0.1	0.2	105.5
		n.d.	0.1	n.d.	0.2	99.6	n.d.	0.1	n.d.	106.1
		0.1	n.d.	n.d.	0.1	99.4	0.2	n.d.	0.3	106.5
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	0.1	0.1	115.1
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	116.6
		0.1	0.1	n.d.	n.d.	99.5	0.1	n.d.	0.2	115.9
1513	**tm**	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	110.7
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	102.9
		n.d.	0.1	n.d.	n.d.	99.5	n.d.	0.3	n.d.	101.1
	ferrite with pearlite	0.1	n.d.	0.1	n.d.	99.7	n.d.	n.d.	0.2	98.6
		0.1	n.d.	n.d.	n.d.	99.5	0.3	0.1	n.d.	96.2
		0.9	n.d.	n.d.	n.d.	98.8	0.1	0.1	n.d.	90.9
	white weld line	0.1	n.d.	n.d.	n.d.	98.4	1.3	n.d.	0.2	102.9
		n.d.	n.d.	n.d.	n.d.	98.1	1.8	0.1	n.d.	108.8
	ferrite with some pearlite	n.d.	0.1	n.d.	n.d.	99.5	0.2	n.d.	0.1	90.8
		n.d.	0.1	0.1	n.d.	99.6	n.d.	n.d.	0.2	91.5
		0.1	n.d.	n.d.	0.1	99.7	n.d.	n.d.	0.1	99.2
		n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	99.1
	ferrite	n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	95.4
		0.1	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	95.1
		n.d.	0.1	0.1	n.d.	99.8	n.d.	n.d.	n.d.	95.8
		n.d.	n.d.	n.d.	n.d.	99.6	0.2	0.1	n.d.	95.4
2304	**site 1**	n.d.	0.2	n.d.	0.1	99.4	0.2	n.d.	n.d.	94.6
		n.d.	0.1	n.d.	n.d.	99.5	0.2	n.d.	0.2	98.3
		0.1	0.3	n.d.	n.d.	99.4	n.d.	n.d.	0.1	99.9
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	108.5
	site 2	n.d.	0.3	n.d.	n.d.	99.6	0.1	n.d.	n.d.	105.7
		0.1	0.1	n.d.	n.d.	99.5	0.1	0.2	0.1	112.6
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	107.6
		n.d.	0.2	n.d.	n.d.	99.6	0.1	n.d.	0.1	108.1
2318	**pearlite with ferrite**	n.d.	0.2	n.d.	0.1	99.7	n.d.	n.d.	n.d.	108.0
		n.d.	0.2	0.1	n.d.	99.7	n.d.	n.d.	n.d.	110.4
		n.d.	0.3	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	110.1
	small grains of ferrite	0.1	0.2	n.d.	0.1	99.6	n.d.	n.d.	n.d.	106.3
		n.d.	0.1	n.d.	0.1	99.8	n.d.	n.d.	n.d.	108.7
		0.1	0.3	0.1	n.d.	99.0	n.d.	0.2	0.2	106.3
	large grains	n.d.	0.3	n.d.	n.d.	99.4	n.d.	0.2	0.1	105.0
		0.1	0.3	n.d.	n.d.	99.5	n.d.	n.d.	n.d.	104.6
		n.d.	0.4	0.1	0.1	99.2	n.d.	n.d.	0.2	104.4

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
2309	**cutting edge**	0.1	n.d.	0.1	n.d.	99.6	n.d.	n.d.	0.2	101.8
		n.d.	n.d.	n.d.	0.1	99.7	0.1	n.d.	0.1	101.7
		0.1	n.d.	n.d.	n.d.	99.5	n.d.	0.1	0.3	107.5
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	0.1	110.4
	weld line	n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	107.1
		0.2	0.5	n.d.	n.d.	98.8	0.1	0.1	0.2	107.1
	back 1	n.d.	0.4	n.d.	n.d.	99.5	n.d.	n.d.	n.d.	109.6
		0.1	0.3	n.d.	n.d.	99.1	n.d.	n.d.	0.3	114.7
		0.1	0.4	n.d.	0.1	99.3	0.1	n.d.	n.d.	117.5
		n.d.	0.5	n.d.	0.1	99.3	n.d.	0.1	n.d.	117.0
	back 2	n.d.	0.3	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	117.5
		n.d.	0.4	n.d.	n.d.	99.5	n.d.	n.d.	n.d.	113.8
		n.d.	0.5	n.d.	0.1	99.2	n.d.	0.2	n.d.	105.0
		0.1	0.5	n.d.	0.1	99.2	n.d.	n.d.	0.1	103.2
2401	**cutting edge**	n.d.	n.d.	n.d.	0.1	99.7	n.d.	0.2	n.d.	101.2
		0.1	n.d.	n.d.	n.d.	99.7	0.1	n.d.	0.1	100.0
		0.1	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.1	99.4
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	100.0
	back 1	0.1	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.1	101.7
		0.1	0.1	n.d.	0.1	99.6	0.1	n.d.	0.1	100.0
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	100.0
		n.d.	0.1	0.1	n.d.	99.6	n.d.	n.d.	0.1	100.4
	back 2	n.d.	0.1	n.d.	n.d.	99.7	n.d.	0.1	0.1	100.7
		n.d.	0.1	n.d.	0.1	99.6	0.1	0.1	n.d.	100.1
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	102.4
		n.d.	0.1	n.d.	0.1	99.5	0.1	n.d.	0.2	99.1
3031	**site 1**	n.d.	0.2	n.d.	n.d.	99.7	0.1	n.d.	n.d.	90.4
		0.1	0.1	n.d.	n.d.	99.5	0.2	0.2	n.d.	97.4
		0.1	n.d.	n.d.	n.d.	99.6	0.2	0.1	n.d.	102.6
		0.1	n.d.	n.d.	0.1	99.5	n.d.	n.d.	0.3	94.0
	site 2	n.d.	0.1	n.d.	n.d.	99.8	0.1	n.d.	n.d.	93.7
		n.d.	0.1	n.d.	n.d.	99.3	0.3	0.1	0.2	108.3
		n.d.	0.1	n.d.	0.1	99.7	0.1	n.d.	n.d.	96.1
		n.d.	0.1	n.d.	0.1	99.7	n.d.	n.d.	0.1	99.9
	site 3	n.d.	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.1	101.0
		n.d.	n.d.	n.d.	0.1	99.6	0.2	n.d.	0.2	102.6
		n.d.	0.1	n.d.	n.d.	99.5	0.3	0.1	n.d.	97.3
		n.d.	0.1	n.d.	0.1	99.5	0.1	0.1	0.1	93.2

Table 8.2 cont: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
3066	**cutting edge**	n.d.	0.2	0.1	n.d.	99.5	n.d.	0.1	0.1	101.9
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	0.1	n.d.	107.6
		n.d.	0.1	0.1	n.d.	99.5	0.1	0.1	n.d.	113.9
		0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	109.4
	back 1	0.1	n.d.	n.d.	n.d.	99.4	0.2	0.2	n.d.	105.7
		n.d.	0.1	n.d.	0.1	99.7	n.d.	0.1	n.d.	117.9
		n.d.	0.1	n.d.	n.d.	99.7	0.1	n.d.	0.1	105.9
		n.d.	0.1	n.d.	0.1	99.5	0.1	0.1	n.d.	108.9
	back 2	0.1	0.1	n.d.	0.1	99.5	0.2	n.d.	n.d.	112.5
		n.d.	0.1	0.1	n.d.	99.8	n.d.	n.d.	0.1	112.1
		0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	106.5
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	0.1	112.5
3136	**cutting edge**	n.d.	0.1	n.d.	n.d.	99.3	n.d.	0.3	0.2	94.8
		0.1	0.2	0.1	0.1	99.4	n.d.	0.1	0.1	95.4
		n.d.	0.1	n.d.	0.1	99.7	n.d.	n.d.	0.2	95.9
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.3	94.8
	back 1	0.1	0.1	n.d.	0.1	99.0	0.2	0.1	0.4	95.6
		0.1	0.2	n.d.	n.d.	99.0	0.3	n.d.	0.4	98.2
		n.d.	0.1	0.1	0.1	99.1	0.1	0.1	0.5	96.1
		0.1	0.2	n.d.	n.d.	99.3	0.3	n.d.	0.1	97.7
	back 2	n.d.	0.1	0.1	n.d.	99.8	n.d.	n.d.	n.d.	96.2
		n.d.	0.1	n.d.	n.d.	98.8	0.4	0.1	0.6	97.8
		0.1	n.d.	n.d.	n.d.	98.3	1.0	n.d.	0.6	99.0
		n.d.	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.2	99.3
3138	**cutting edge**	0.2	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.1	96.6
		0.1	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	97.2
		n.d.	n.d.	0.1	n.d.	99.5	0.3	0.1	n.d.	99.7
		n.d.	n.d.	n.d.	n.d.	99.5	0.1	0.1	0.2	98.5
	weld line	0.5	0.4	n.d.	n.d.	98.4	0.2	0.2	0.4	97.5
		0.1	n.d.	n.d.	n.d.	98.5	0.9	n.d.	0.6	98.4
	back	n.d.	0.3	n.d.	0.1	98.9	n.d.	0.2	0.6	97.5
		n.d.	0.1	n.d.	n.d.	99.3	0.1	0.1	0.3	101.8
		n.d.	0.2	n.d.	n.d.	99.0	0.2	0.2	0.4	100.7
		n.d.	0.4	n.d.	n.d.	99.3	0.1	0.1	0.1	96.7

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
3140	**site 1**	0.1	0.4	n.d.	n.d.	99.5	n.d.	n.d.	n.d.	88.6
		0.1	0.4	n.d.	0.1	99.2	n.d.	0.2	n.d.	83.9
		n.d.	0.6	0.1	n.d.	99.1	n.d.	0.1	n.d.	86.9
		n.d.	0.6	n.d.	0.2	99.1	n.d.	n.d.	n.d.	101.1
	site 2	n.d.	0.1	n.d.	n.d.	99.6	0.2	n.d.	n.d.	114.2
		n.d.	0.2	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	102.5
		n.d.	0.2	n.d.	n.d.	99.7	n.d.	0.1	n.d.	100.0
		0.2	0.1	n.d.	n.d.	99.4	0.1	n.d.	0.2	99.9
3141	**cutting edge**	n.d.	0.1	n.d.	n.d.	99.7	n.d.	0.1	0.1	102.4
		n.d.	0.2	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	102.2
		0.1	0.1	n.d.	n.d.	99.4	n.d.	0.2	0.2	104.5
		0.2	0.1	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	102.7
	weld line	0.1	n.d.	n.d.	n.d.	97.8	1.6	0.2	0.3	103.8
		n.d.	0.1	n.d.	n.d.	99.5	0.2	n.d.	0.1	103.0
	back 1	n.d.	0.4	n.d.	n.d.	99.4	n.d.	0.1	n.d.	103.6
		0.1	0.2	n.d.	n.d.	99.4	0.2	0.1	n.d.	102.7
		0.1	0.4	n.d.	n.d.	99.2	n.d.	0.1	0.2	100.6
		n.d.	0.5	0.1	n.d.	99.3	0.1	n.d.	n.d.	99.7
	back 2	n.d.	0.3	n.d.	n.d.	99.4	n.d.	0.1	0.1	105.2
		n.d.	0.5	n.d.	n.d.	99.4	n.d.	n.d.	n.d.	103.1
		0.2	0.2	n.d.	n.d.	99.4	0.1	n.d.	0.1	97.5
		n.d.	0.5	n.d.	n.d.	99.3	n.d.	0.1	n.d.	101.5
3140	**site 1**	0.1	0.4	n.d.	n.d.	99.5	n.d.	n.d.	n.d.	88.6
		0.1	0.4	n.d.	0.1	99.2	n.d.	0.2	n.d.	83.9
		n.d.	0.6	0.1	n.d.	99.1	n.d.	0.1	n.d.	86.9
		n.d.	0.6	n.d.	0.2	99.1	n.d.	n.d.	n.d.	101.1
	site 2	n.d.	0.1	n.d.	n.d.	99.6	0.2	n.d.	n.d.	114.2
		n.d.	0.2	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	102.5
		n.d.	0.2	n.d.	n.d.	99.7	n.d.	0.1	n.d.	100.0
		0.2	0.1	n.d.	n.d.	99.4	0.1	n.d.	0.2	99.9

Table 8.2 cont: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

White Weld Lines

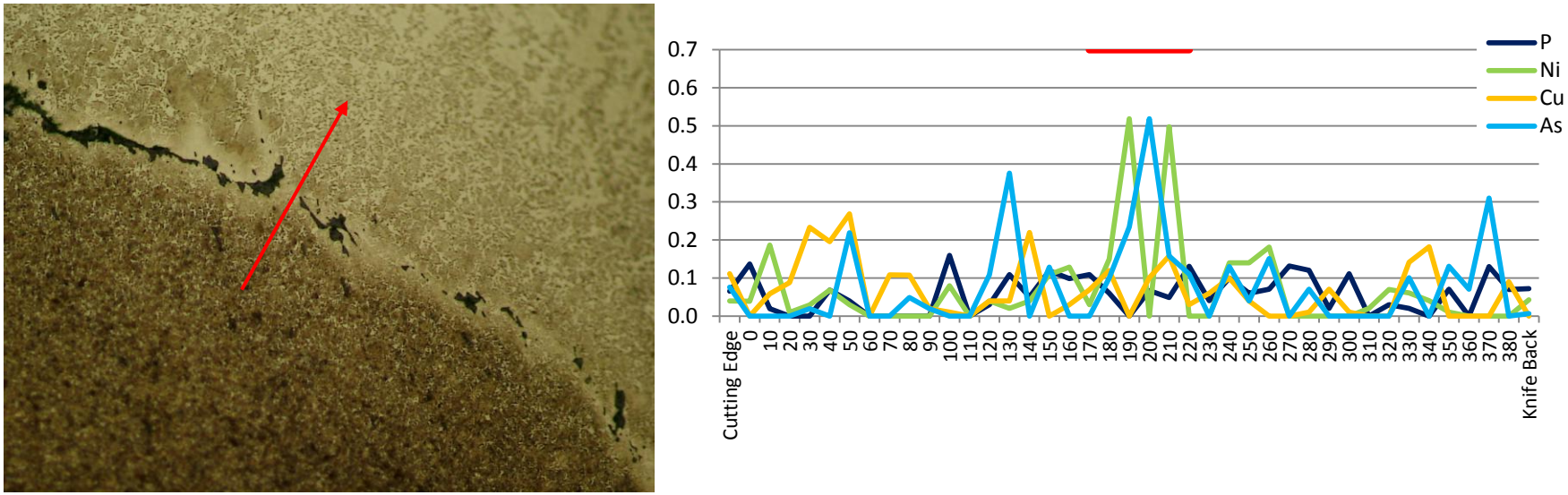


Figure 11.30: Line scan across the white weld line in Sedgeford Knife 8

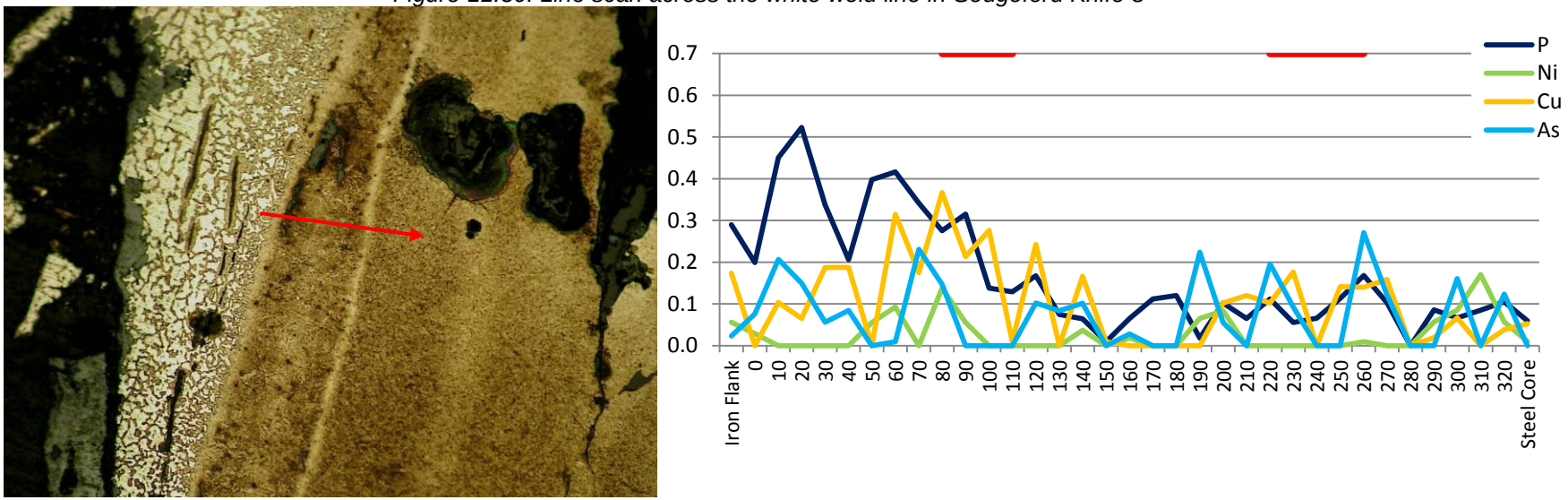


Figure 11.31: Line scan across the white weld line in Sedgeford Knife 18

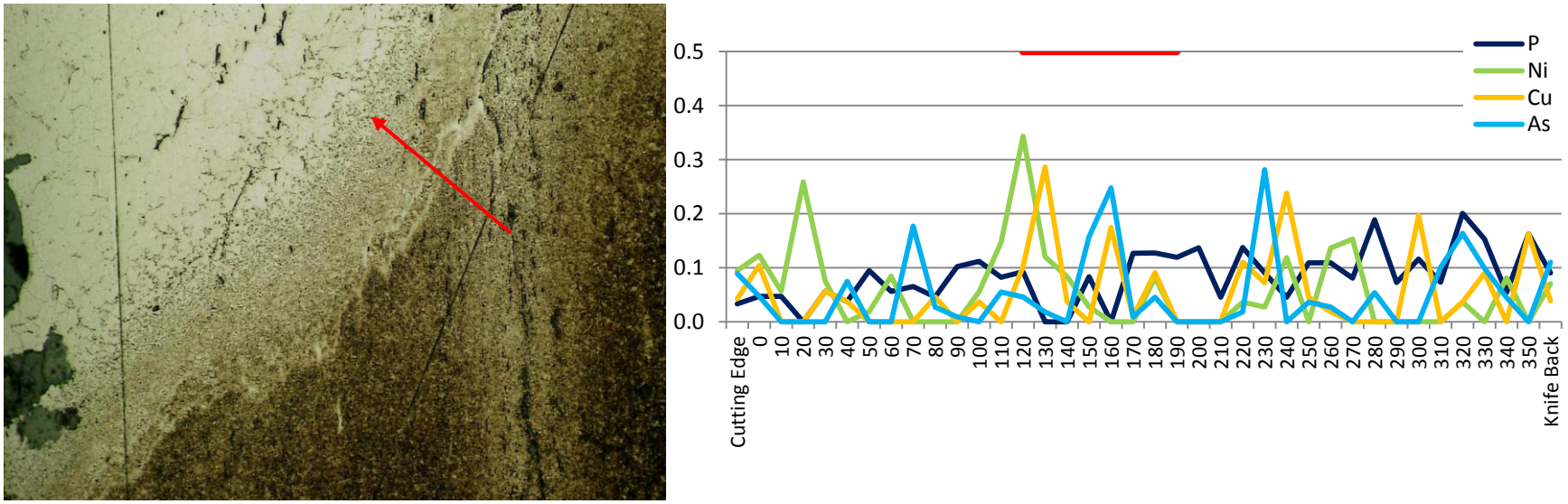


Figure 11.32: Line scan across the white weld line in Sedgeford Knife 108

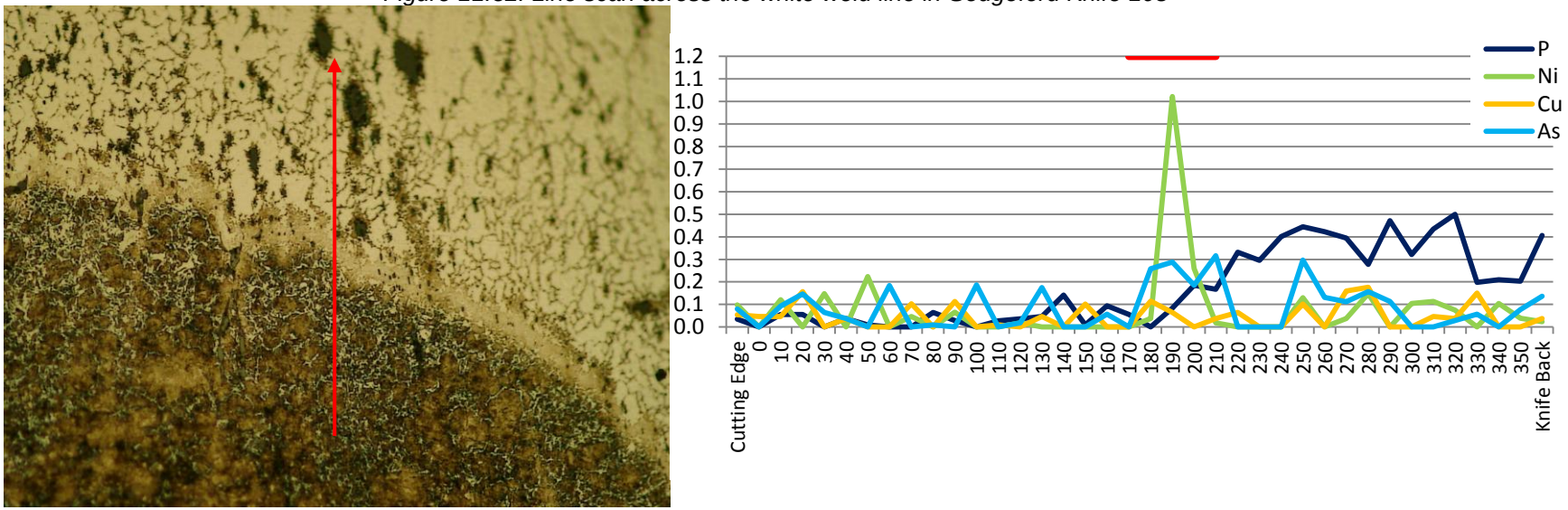


Figure 11.33: Line scan across the white weld line in Sedgeford Knife 188

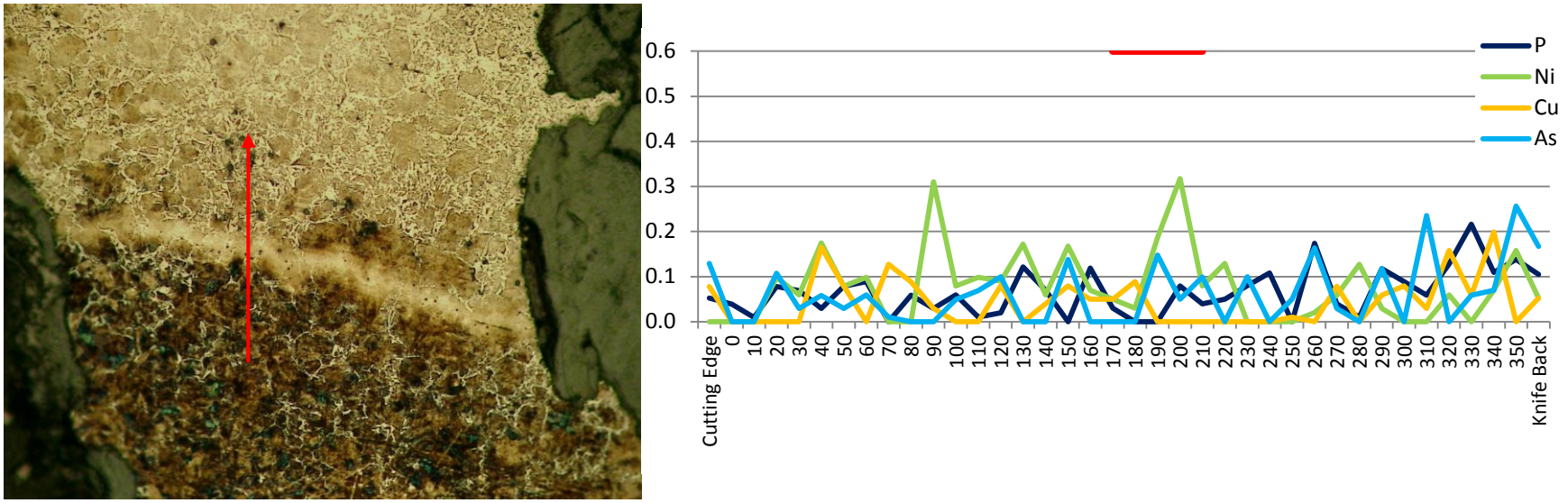


Figure 11.34: Line scan across the white weld line in Sedgeford Knife 429

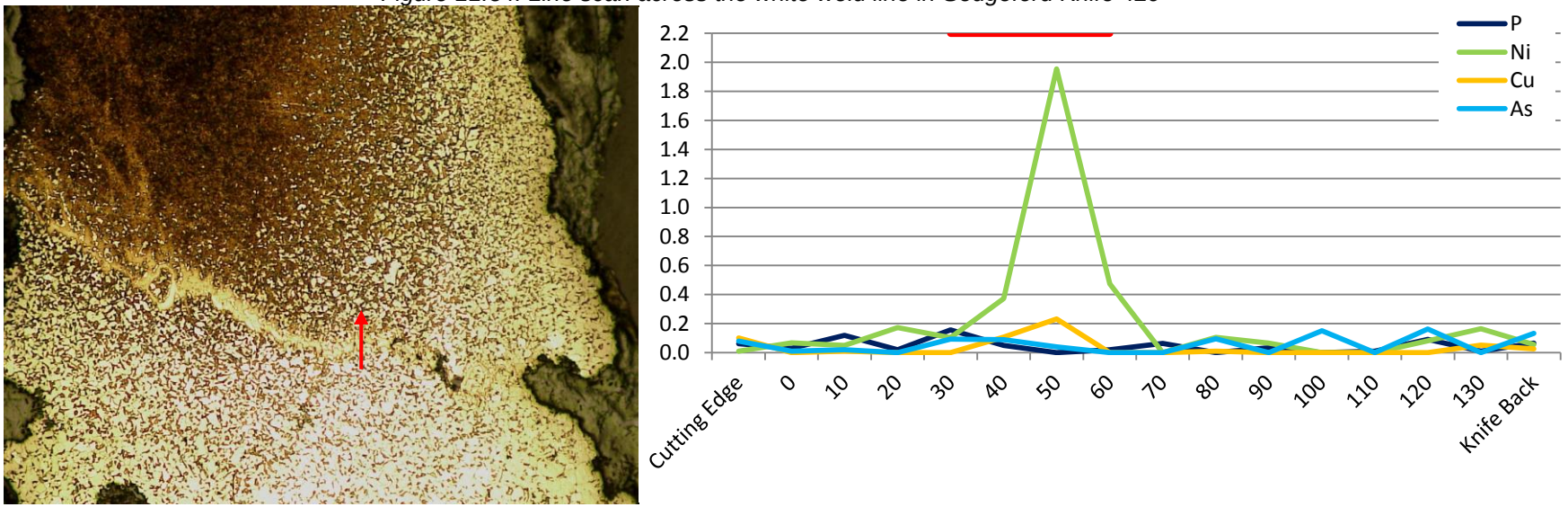


Figure 11.35: Line scan across the white weld line in Sedgeford Knife 1513

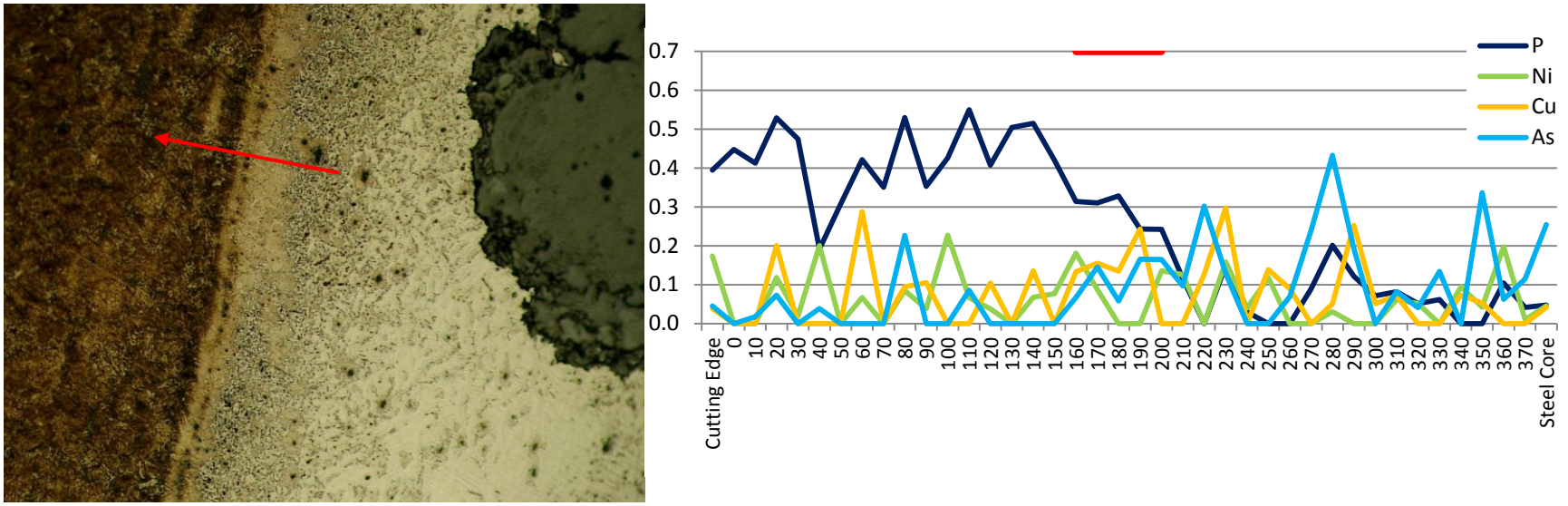


Figure 11.36: Line scan across the white weld line in Sedgeford Knife 2309

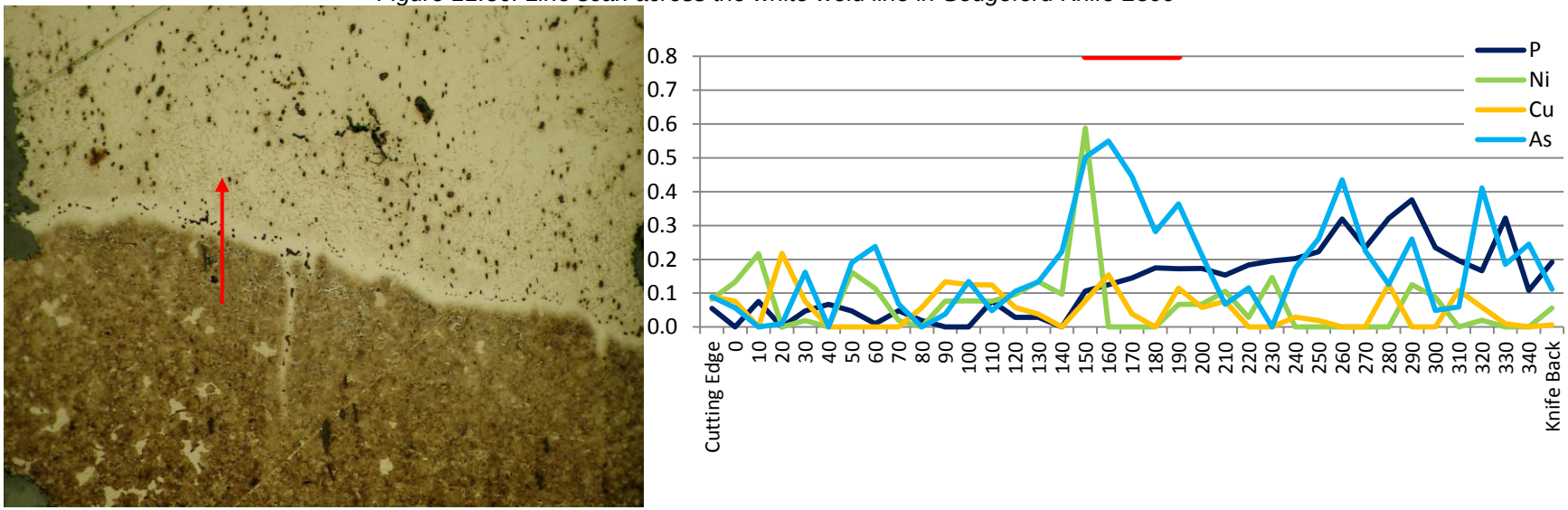


Figure 11.37: Line scan across the white weld line in Sedgeford Knife 3138

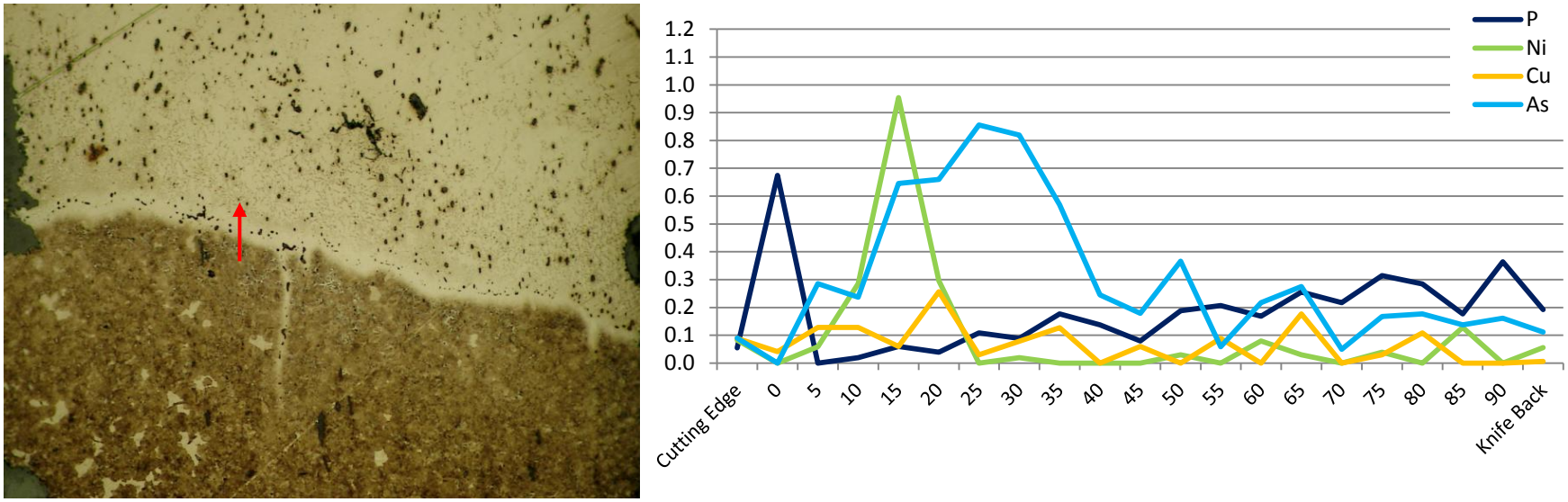


Figure 11.38: Line scan across the white weld line in Sedgeford Knife 3138

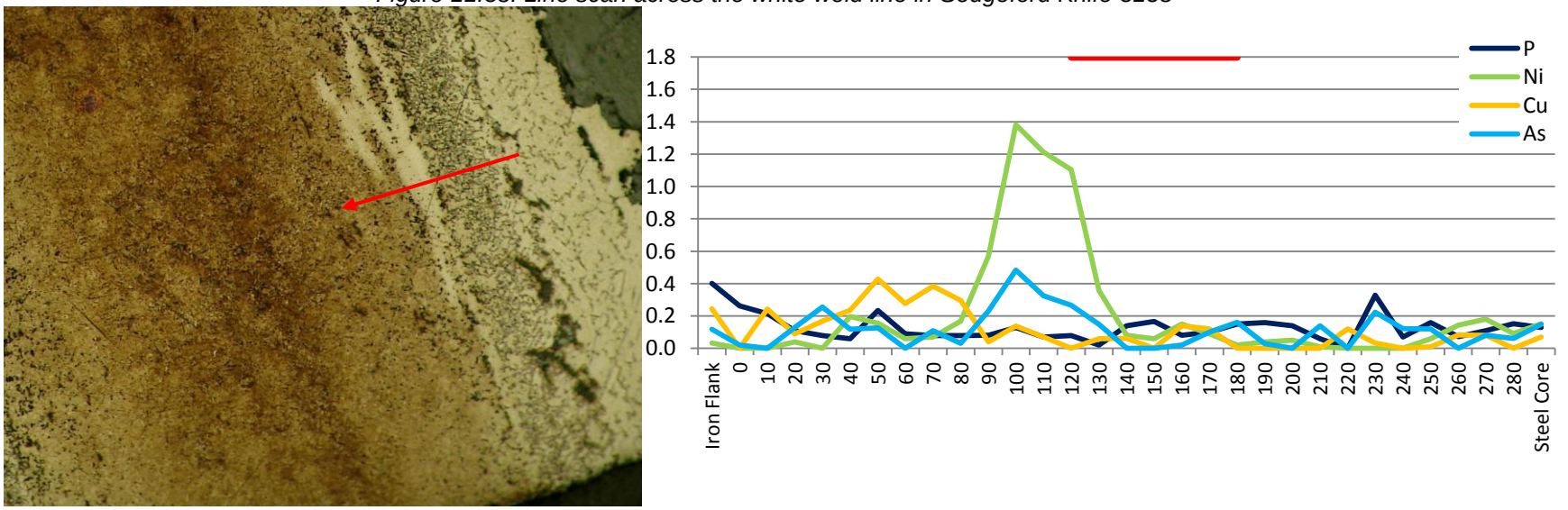


Figure 11.39: Line scan across the white weld line in Sedgeford Knife 3141

Chapter 12: Whithorn

Knife Descriptions

Knife 13737 (6th-8th Century)

The x-radiograph revealed a badly corroded knife, particularly the tip. There was no evidence for a weld line or spotted texture. A single section was taken from the knife.

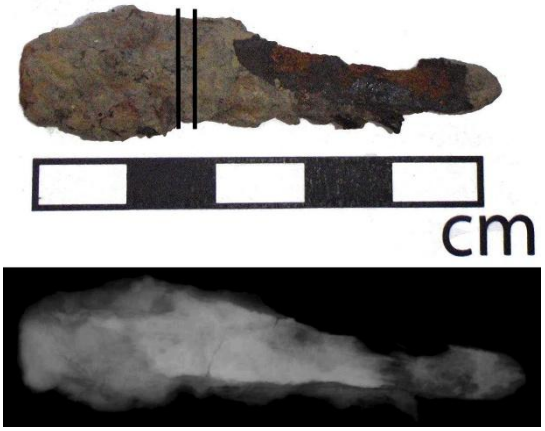


Figure 12.1: Photograph and x-radiograph of knife 13737, the lines show where the section was removed.

Un-etched there was a clear slightly concave line of rounded single-phased inclusions. These separated two areas, the cutting edge below which had many multi-phased sub-rounded inclusions, some of which were quite large. Above this line there was a vertical band, and many inclusions throughout in a variety of shapes and sizes but mostly sub-rounded or elongated and single phased.

When etched the line of inclusions turned out to be a clear white weld line (*Average 197HV, Range 183-210HV*) which was enriched in arsenic (0.2-1.1%). Below this line the cutting edge consisted of pearlite with ferrite ranging from 0.7% to 0.4% (210*HV, Average 260HV, Range 210-340HV*). There was little carbon diffusion across the weld line into the heterogeneous knife back. This consisted of two halves, split roughly down the centre. The left side had small grains of ferrite (*Average 285HV, Range 175-321HV*), and no evidence for ghosting. Whereas the right side had medium to large grains of ferrite, but again no ghosting (*Average 156HV, Range 127-210HV*). Throughout the sample there was evidence for grain boundary carbides. SEM-EDS analysis confirmed the absence of phosphorus in the area with small grains but there were traces of

phosphorus in the large grained side. In both areas arsenic was also present in the metal (ranging from 0.5-1%).

Knife 14373 (6th-8th Century)

The x-radiograph of this knife revealed no evidence for a weld line or the spotted appearance associated with steel cutting edges. The x-ray suggested the presence of metal throughout the knife but when sectioned the knife broke in many places, a single section was removed.

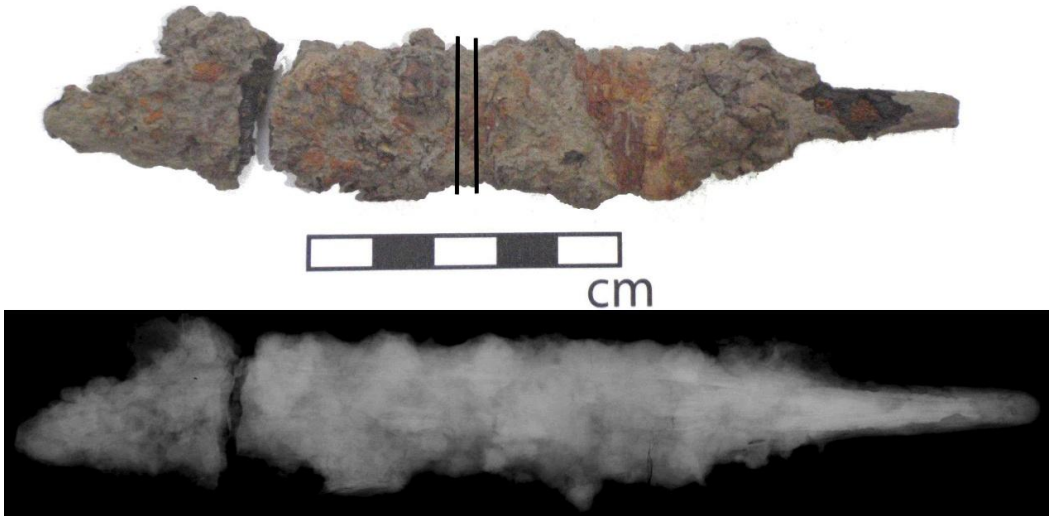


Figure 12.2: Photograph and x-radiograph of knife 14373, the lines show where the section was removed.

The knife section was almost entirely corroded, except for a couple of areas of iron still remaining. The inclusions in these areas were single phased, sub-rounded. There was no evidence for cementite in the corrosion products suggesting that little if any pearlite present. There were also no slag inclusions to suggest weld lines visible in the corrosion products.

When etched the microstructure in the different areas revealed a knife that was heterogeneous with ferrite and grain boundary carbides (*Average 169HV, Range 148-221HV*). There was no evidence for any weld lines. SEM analysis of this knife revealed only traces of phosphorus (up to 0.2%) and also arsenic in places.

Knife 4542 (8th-9th Century)

There was no evidence for a weld line and no spotted texture seen in the knife. As this knife fragment was very small a single section was taken across the centre of the knife.

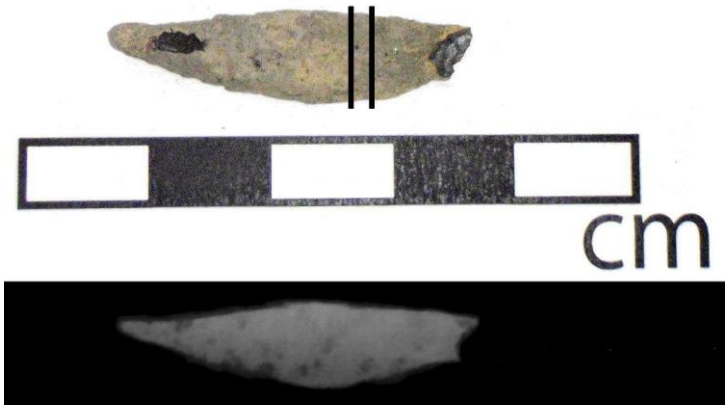


Figure 12.3: Photograph and x-radiograph of knife 4542, the lines show where the section was removed.

In the un-etched condition there were no clear weld lines but there was a stress crack. The inclusions present were single phased, sub-rounded and small, although there were also some large inclusions.

When etched the microstructure throughout the knife was fairly homogenous with ferrite with grain boundary carbides (*Average 217HV, Range 183-257HV*). SEM analysis of this knife revealed no presence of phosphorus. The microstructure of the knife suggested that it may have been a high carbon steel that was badly damaged by excessive heat. There were some vertically orientated white weld lines, which SEM analysis revealed were enriched in arsenic (0.3-1.2%) although arsenic was present throughout the knife (up to 0.6%).

This knife was a type 0 knife consisting of a single piece of ferritic to low carbon steel. This knife was possibly exposed to excessive heat, and therefore may have been originally been an all steel knife.

Knife 10070 (8th-9th Century)

The x-radiograph revealed a clear weld line and also some evidence of a spotted texture. A single section was taken across the knife.

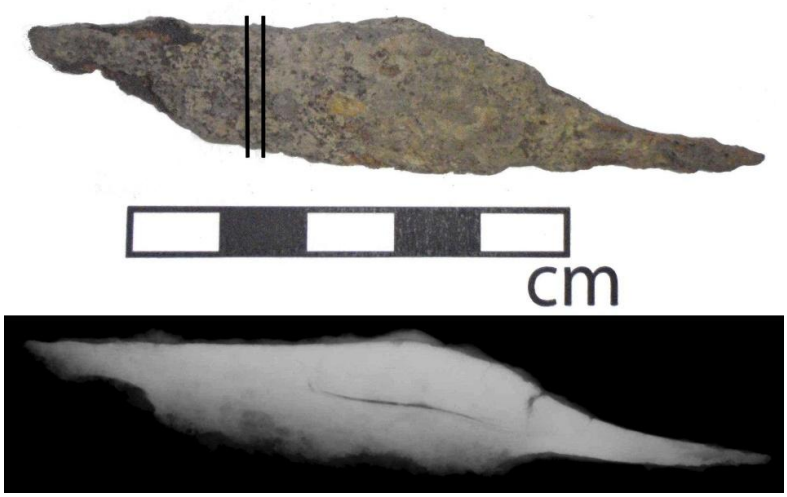


Figure 12.4: Photograph and x-radiograph of knife 10070, the lines show where the section was removed.

Un-etched there was a clear convex band of small, single phased inclusions. This separated two areas, the cutting edge below which had single-phased elongated inclusions. Above this weld line there were two bands of metal the one close the weld line had no inclusions while the inclusions near the back were mostly small sub-rounded, single-phased.

When etched the band of inclusions turned out to be a clear white weld line (*221HV*) which was enriched in arsenic (0.5-1.6%). Below this line the cutting edge was separated into two halves, the one on the left had pearlite with ferrite, around 0.6% carbon (321*HV, Average 322HV, Range 271-412HV*). The other side had small to medium grains of ferrite with some carbon diffusion from the other half (*Average 182HV, Range 161-215HV*). There was carbon diffusion across the weld line into the heterogeneous knife back. This consisted of small to medium grains of ferrite, with the carbon diffusion resulting in a ferrite with pearlite microstructure by the weld line (*Average 206HV, Range 175-232HV*), there was no evidence for ghosting. The very back of the knife consisted of pearlite, which had also diffused out into the centre of the knife back (*Average 257HV, Range 244-271HV*). SEM-EDS analysis confirmed the absence of phosphorus. Throughout the knife, associated with small grains, there was grain boundary carbides present.

Knife 84293 (8th-9th Century)

The x-radiograph of this knife revealed no evidence for a weld line or the spotted appearance associated with steel cutting edges. A single section was removed from near the end of the knife.

Figure 12.5: Photograph and x-radiograph of knife 84293, the lines show where the section was removed.

The knife section was badly corroded. There was no evidence for weld lines but instead there were two different areas of inclusions. The majority of inclusions were small, single-phased, rounded or sub-rounded. The other area of inclusions had many multi-phased sub-angular inclusions.

When etched the microstructure in the different areas revealed a knife that was heterogeneous with ferrite and grain boundary cementite (201*HV, Average 197HV, Range 175-244HV*). This cementite was also seen in the corrosion products. The other area of multi-phased inclusions had large grains of ferrite (*Average 171HV, Range 157-197HV*). SEM analysis of this knife revealed no traces of phosphorus in the areas with grain boundary cementite but in the large grained area there was up to 0.2% phosphorus.

Knife 1744 (9th-10th Century)

The x-ray revealed a heavily worn or broken knife, with corrosion penetration of the blade. It also showed no evidence for a weld line or the spotted texture. A full section was removed from near the tang to blade interface.

Figure 12.6: Photograph and x-radiograph of knife 1744, the lines show where the section was removed.

Prior to etching the section of the knife revealed lots of elongated inclusions which were also single-phased and sub-rounded. At the cutting edge there were many sub-rounded, single-phased inclusions some of which were quite large.

Once etched the cutting edge consisted of medium to large grains of ferrite with some ghosting (*148HV, Average 167HV, Range 137-215HV*), this and the high hardness suggested some phosphorus is present, this was confirmed by SEM-EDS analysis (0.2%-0.4% phosphorus). Near the back of the knife there was a thin vertical white weld line. The other side of the knife was ferrite with some pearlite and carbides (*Average 210HV, Range 175-232HV*). Phosphorus was also detected in this area.

This knife was clearly a type 3 piled iron knife. It was constructed from at least two pieces of iron, possibly more. The entire knife was constructed from phosphoric iron.

Knife 11202 (9th-10th Century)

The x-radiograph of this knife revealed no evidence for a weld line but there was the spotted appearance associated with steel cutting edges. Corrosion had badly corroded the cutting edge of the knife. A single section was removed.

Figure 12.7: Photograph and x-radiograph of knife 11202, the lines show where the section was removed.

The knife section was badly corroded, except for the knife back and an area of iron still remaining in the cutting edge. There was no clear weld line but then it is possible that the corrosion had obscured it. There were very few inclusions in the back. In the cutting edge the inclusions were elongated and single-phased.

When etched the microstructure in the knife back revealed a knife that was heterogeneous. It was predominately ferritic (*Average 168HV, Range 137-168HV*) but in the core there was an area that was pearlite with boundary ferrite, around 0.6%. The carbon from this area diffused across the entire back. There was still no evidence for any weld lines. The cutting edge of the knife consisted of small grains of ferrite, with no pearlite or ghosting, but there was grain boundary carbides present (*168HV, Average 153HV, Range 137-168HV*). SEM analysis of this knife revealed that phosphorus was present (up to 0.3%). This knife was a type 0 knife consisting of a heterogeneous piece of phosphoric iron with a high carbon content in areas.

Knife 12524 (9th-10th Century)

The x-radiograph revealed no weld lines and a slight spotted texture. A complete section was taken from the broken end of the knife.

Figure 12.8: Photograph and x-radiograph of knife 12524, the line show where the section was removed.

Un-etched there was a clear convex line of single phased inclusions. This separated two areas, the cutting edge below had few small single-phased, sub-angular inclusions. Above this line the many inclusions were large, sub-rounded and multi-phased. There was also a stress crack in the cutting edge.

When etched the band of inclusions turned out to be a clear white weld line (*Average 193HV, Range 164-221HV*) which was enriched in arsenic, copper and nickel (As 0.2-0.5%, Cu 0.8% and Ni 0.1-0.3%). Below this line the cutting edge consisted of bainite at the tip (0.8% carbon, 399*HV*) to ferrite and pearlite (0.4% carbon) at the weld line (*Average 313HV, Range 183-473HV*). There was carbon diffusion across the weld line into the homogenous knife back. This consisted of medium to large grains of ferrite with ghosting (*Average 158HV, Range 125-183HV*) this in addition to the high hardness suggested some phosphorus is present, confirmed by SEM-EDS analysis (0.1%-0.2% phosphorus).

This knife was classified as a type 2 knife consisting of a pearlite cutting edge with a homogenous phosphoric iron back. The presence of pearlite suggests that this knife was not heat-treated.

Knife 84343 (9th-10th Century)

The x-ray revealed a clear spotted texture and also a weld line. There was also quite a lot of corrosion present at the tip of the knife. A full section was removed.

Figure 12.9: Photograph and x-radiograph of knife 84343, the lines show where the section was removed.

Prior to etching the section of the knife, many bands were seen, orientated from the back corner diagonally across the knife. These inclusion bands were made up of elongated, single-phased inclusions. The few inclusions at the cutting edge were multi-phased and sub-rounded. The rest of the back consisted of more elongated single-phased inclusions except for the main band that ran across the knife as the inclusion there were mostly small and rounded, and were both single- and multi-phased

Once etched the cutting edge was revealed to consist of tempered martensite (*412HV, Average 412HV, Range 286-618HV*). Some of the bands of inclusions had white weld lines which were enriched in arsenic (0.3%). The rest of the knife back consisted of small to medium grained ferrite (*Average 147HV, Range 118-210HV*). There was some diffusion over both weld lines into the cutting edge and back but SEM-EDS analysis confirmed some phosphorus was present in the knife back (0.1%-0.2%).

Knife 813 (11th-13th Century)

The x-radiograph of this knife revealed no evidence for a weld line or the spotted appearance associated with steel cutting edges.

Figure 12.10: Photograph and x-radiograph of knife 813, the lines show where the sections were removed.

Two half sections were removed from the knife. Prior to etching it was clear that there were many slag inclusions throughout the knife. The cutting edge had some single-phased and angular inclusions. These inclusions formed a band that ran into the knife back. To either sides the inclusions were sub-angular, multi-phased and of varying sizes.

After etching, there were two clear bands of white weld lines, which corresponding to two bands of small, rounded single-phased inclusions (*Average 406HV, Range 303-509HV*), these were enriched in arsenic, nickel and copper (As 0.3-0.5%, Cu 0.1-0.2% and Ni 0.5%). The white weld lines separated the centre strip from the two ferrite flanks. Both consisted of medium to large grains of ferrite with some pearlite (*Average 130HV, Range 93-158HV*). The centre strip and cutting edge consisted of martensite and tempered martensite suggesting a heat-treated high carbon steel (841*HV, Average 586HV, Range 441-841HV*). SEM analysis of this knife revealed only traces of phosphorus (up to 0.1%) in the cutting edge, but between 0.2-0.4% phosphorus in the weld line and the two iron flanks.

Knife 1537 (11th-13th Century)

The x-radiograph of this knife revealed no evidence for a weld line or spotted texture. A single section was removed.

Figure 12.11: Photograph and x-radiograph of knife 1537, the lines show where the section was removed.

In the unetched condition there were no clear weld lines. The majority of inclusions present were single-phased, elongated or sub-angular, some were quite large.

When etched the microstructure throughout the knife was fairly homogenous with medium grains of ferrite (*137HV, Average 145HV, Range 137-171HV*). SEM analysis of this knife revealed that there was as much as 0.3% phosphorus. Near the back of the knife the microstructure changed to small grains of ferrite with grain boundary carbides. (*Average 186HV, Range 168-210HV*). There was less phosphorus in this area with only traces detected (up to 0.1%). This knife was a type 0 knife consisting of a single homogenous piece of phosphoric iron to low carbon steel.

Knife 1935

The x-radiograph of this knife revealed no dark striations suggesting weld lines. There was slight evidence for a spotted cutting edge but this may have just been the result of heavy corrosion.

Figure 12.12: Photograph and x-radiograph of knife 1935, the lines show where the section was removed.

A single section was taken from the knife. The slag inclusions present throughout the sample were both single- and multi-phased and in a variety of shapes and sizes.

When etched the entire knife looked very homogeneous with small to medium sized grains of ferrite with some carbides (123*HV, Average 130HV, Range 107-154HV*). SEM analysis of this knife revealed no traces of phosphorus. This knife was a type 0 knife with ferritic iron present throughout.

Knife 11988 (11th-13th Century)

In the x-radiograph there were some possible dark striations that could indicate weld lines. The cutting edge did not have the spotted appearance which is associated with heat-treated steel.

Figure 12.13: Photograph and x-radiograph of knife 11988, the lines show where the section was removed.

A single section was taken from the knife. There were very few slag inclusions present throughout the samples, those that were present were single-phased and sub-angular. There were also at least two, if not three cracks in the sample.

When etched the entire knife looked heterogeneous with pearlite and varying amounts of ferrite, with about 0.4% carbon at the cutting edge (183*HV, Average 184HV, Range 161-210HV*). Nearer the knife back there was much more carbon, with up to 0.8% carbon (*Average 184HV, Range 175-201HV*). Throughout the knife grain boundary cementite was present. SEM analysis of this knife revealed only traces of phosphorus (up to 0.1%).

This knife was a type 5 knife with mid-high carbon steel present throughout. There was no evidence to suggest that the knife had been heat-treated.

Knife 14622 (11th-13th Century)

The x-radiograph of this knife revealed a badly corroded knife, especially near the tip of the knife. There was no evidence for a weld line or the spotted appearance associated with steel cutting edges. A single section was removed from the knife.

Figure 12.14: Photograph and x-radiograph of knife 14622, the line shows where the section was removed.

Prior to etching it was clear that there were many slag inclusions throughout the knife, and there was a clear difference between the cutting edge and the iron flanks. The cutting edge had some single-phased, elongated and sub-rounded inclusions. The iron flanks were separated by weld lines made up of many, small, spherical, single-phased inclusions, this separated into two lines about half way down the knife. To either side the inclusions were a variety of shapes and sizes.

After etching, there was a clear white weld line, this formed an upside down Y shape, separating the two flanks from the cutting edge (*Average 254HV, Range 221-286HV*). SEM analysis revealed that these were enriched in arsenic, nickel and copper (As 0.3-0.4%, Cu 0.1% and Ni 0.4-1.1%). The iron flanks consisted of extremely large grains of ferrite with some ghosting and some carbon diffusion (*Average 210HV, Range 192-232HV*). This evidence and the high hardness suggested some phosphorus is present, confirmed by SEM-EDS analysis (0.7%-1.1% phosphorus). The cutting edge consisted of fine pearlite (264*HV, Average 279HV, Range 221-303HV*). SEM analysis of this knife revealed only traces of phosphorus (up to 0.1%).

Knife 84270 (11th-13th Century)

In the x-radiograph there was no evidence for a weld line. The cutting edge did not have the spotted appearance which is associated with heat-treated steel. A single section was taken from the broken end of the knife.

Figure 12.15: Photograph and x-radiograph of knife 84270, the line shows where the section was removed.

There were many slag inclusions present throughout the sample. These were in bands, and were single-phased and elongated or sub-rounded.

When etched the entire knife looked homogenous with tempered martensite throughout (*386HV, Average 416HV, Range 321-528HV*). SEM analysis of this knife revealed only traces of phosphorus (up to 0.1%). Some of the bands of inclusions corresponded to white lines which were enriched in arsenic and copper and had an increased hardness, possibly due to the high arsenic content of the metal (0.1-0.3%).

Knife 84298 (11th-13th Century)

The x-radiograph showed no evidence for a weld line but there was the spotted appearance associated with steel cutting edges. A single section was removed from the knife.

Figure 12.16: Photograph and x-radiograph of knife 84298, the lines show where the section was removed.

Prior to etching it was clear that there were many slag inclusions throughout the knife, and there was a clear difference between the cutting edge and the iron flanks. The cutting edge had some single-phased, elongated and sub-angular inclusions. The iron flanks were separated by weld lines made up of many, small, spherical, single-phased inclusions, this separated into two lines about two-thirds down the knife. As the weld line moved further to the back of the knife the inclusions became sub-angular and some were multi-phased. To either side the inclusions were multi-phased, in a variety of shapes and sizes.

After etching, there was a clear white weld line, this formed an upside down Y shape, separating the two flanks from the cutting edge (*Average 347HV, Range 221-549HV*). SEM analysis revealed that these lines were enriched in arsenic (0.5-0.6%). The iron flanks consisted of medium to large grains of ferrite with no ghosting and some carbon diffusion (*Average 121HV, Range 110-180HV*). Even so SEM analysis revealed that only traces of phosphorus was present (0.1% phosphorus) but on the other hand there was a fairly high quantity of arsenic present in the iron flanks (up to 0.4%). The cutting edge consisted of tempered martensite which transformed into tempered martensite and pearlite towards the back of the cutting edge (644*HV, Average 557HV, Range 257-701HV*). SEM analysis of this knife revealed no traces of phosphorus.

Summary Assemblage Knives

Knife No	Context	Feature	Period	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
				Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
91/14373	14475	Rubble	6th century to 730AD	A	1	142	102	40	24	8	Slight	N	N	
91/13737	14763	Rubble	6th century to 730AD	D	2	55	25	30	11	6	None	N	N	Broken blade
89/11424	13047	Surface	6th century to 730AD	x	x	38	28	10	18	9	Unknown	N	N	Fragment
91/13503	14163	Surface	6th century to 730AD	B	4	86	60	26	14	8	None	Y	N	
91/13516	14733	Surface	6th century to 730AD	B	2	104	70	34	21	11	Unknown	N	Y	
88/08499	9053	Layer	6th century to 730AD	B	x	40	30	10	12	6	Slight	N	N	Pivoting
91/14011	14273	Layer	6th century to 730AD	B	2	62	62	x	14	x	None	N	Y	Swivel knife
91/13654	14742	Layer/Burial	6th century to 730AD	A	3	54	44	10	12	5	None	Y	Y	Broken tang
91/14549	14164	Layer	6th century to 730AD	A	x	52	52	x	10	x	Slight	N	N	Broken tang
91/14360	14466	Rubble	6th century to 730AD	B	x	72	72	x	12	x	Unknown	N	N	
91/13651	14164	Layer	6th century to 730AD	x	x						Unknown			
89/10070	7297	Layer	730-845	A	1	86	58	28	16	4	Slight	Y	Y	
88/09529	1383	Building	730-845	B	4	42	42	x	12	x	None	N	N	Broken tang
90/12596	11859	Rubble	730-845	B	x	100	62	38	18	10	Slight	Y	Y	Broken tang
85/84293	84008	Layer	730-845	B	1	62	32	30	10	8	Some	N	Y	
87/04542	5358	Layer	730-845	B	x	30	30	x	6	x	None	N	Y	Broken tang
87/04448	6301	Layer	730-845	A	1	128	79	49	20	8	None	N	N	
90/12982	13504	Layer	730-845	B	x	49	49	x	14	x	None	N	N	Broken tang
85/84308	84073	Building	730-845	x	x						Unknown			
90/12805	13502	Layer	730-845	x	x						Unknown			
90/12524	11901	Building	845-1000	x	3	86	36	50	12	8	Unknown	N	Y	Broken blade
90/12089	11771	Building	845-1000	B	4	90	56	34	14	8	Some	N	N	
89/11202	13046	Rubble	845-1000	B	1	48	30	18	12	6	Slight	Y	Y	
85/84343	85052	Layer	845-1000	B	1	115	69	46	15	5	Heavy	Y	N	
86/01744	570	Rubble	845-1000	x	2	44	x	44	x	7	Unknown	N	N	Broken blade
87/04551	1365	Layer	845-1000	x	x						Unknown			Swivel knife
90/12478	9879	Rubble	845-1000	x	x						Unknown			

Table 12.1: Summary table of the knives from Whithorn showing the measurements, typologies assigned and the results from the x-radiograph analysis.

Knife No	Context	Feature	Period	Morphology		Length (mm)			Width (mm)		Wear	Manufacture Details		Other details
				Back	Tang	Total	Blade	Tang	Blade	Tang		Weld Line	Spotted	
91/14622	15144	Building	1000-1250	x	1	42	42	x	11	x	Some	Y	N	
91/15035	15055	Building	1000-1250	B	1	66	40	26	10	4	Slight	Y	Y	
87/04113	5502	Layer	1000-1250	B	3	83	57	26	15	6	Unknown	N	Y	
85/84270	82013	Layer	1000-1250	B	1	86	56	30	12	6	Some	N	Y	Broken blade tip
85/84298	84070	Burial	1000-1250	B	1	128	92	36	16	6	Some	N	Y	
90/12202	11754	Layer	1000-1250	B	1	72	46	26	12	6	Heavy	Y	N	
86/00813	540	Rubble	1000-1250	B	1	86	86	x	12	x	Slight	Y	Y	Broken tang
86/01537	1104	Building	1000-1250	D	2	79	73	6	16	5	None	Y	Y	Broken tang
86/01935	1065	Building	1000-1250	B	1	84	58	26	11	6	Slight	N	Y	
90/11988	11755	Building	1000-1250	B	2	52	52	x	14	x	None	Y	Y	Broken tang
86/00766	510	Rubble	1000-1250	x	x	44	44	x	10	x	Unknown	Y	Y	Fragment
86/01901	1052	Building	1000-1250	x	x						Unknown			
87/05251	5502	Layer	1000-1250	x	x						Unknown			
91/14415	15116	Building	1000-1250	x	x						Unknown			

Table 9.1 cont: Summary table of the knives from Whithorn showing the measurements, typologies assigned and the results from the x-radiograph analysis.

SEM-EDS Data

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
13737	Cutting Edge	n.d.	0.14	n.d.	n.d.	99.6	0.2	n.d.	0.3	87.8
		n.d.	n.d.	n.d.	n.d.	100.3	n.d.	n.d.	n.d.	102.2
		n.d.	0.16	n.d.	n.d.	99.8	n.d.	0.1	n.d.	97.1
	White Weld Line	n.d.	0.18	n.d.	n.d.	99.4	n.d.	0.1	0.2	90.1
		0.3	n.d.	0.1	0.1	98.5	0.1	n.d.	0.9	118.5
		n.d.	0.10	n.d.	n.d.	99.2	n.d.	n.d.	1.1	98.3
	Medium to Large Grains	n.d.	0.10	n.d.	n.d.	99.0	n.d.	n.d.	1.0	104.5
		n.d.	n.d.	0.1	n.d.	99.0	n.d.	0.1	0.8	99.8
		0.1	0.19	n.d.	n.d.	98.8	0.1	0.1	0.8	98.0
	Small Grains	n.d.	0.12	n.d.	n.d.	99.2	0.1	0.1	0.5	98.1
		n.d.	n.d.	n.d.	n.d.	98.8	n.d.	0.1	1.0	105.0
		0.1	n.d.	n.d.	0.3	99.2	n.d.	n.d.	0.5	103.4
14373		0.1	0.16	n.d.	0.1	99.5	n.d.	0.1	0.2	94.4
		n.d.	n.d.	n.d.	0.1	100.2	n.d.	n.d.	n.d.	93.5
		0.1	0.17	n.d.	n.d.	99.6	0.1	n.d.	0.2	102.0
		0.1	0.13	n.d.	n.d.	99.3	0.1	0.1	0.4	97.5
		0.1	n.d.	n.d.	0.1	99.8	n.d.	n.d.	n.d.	103.9
		n.d.	n.d.	n.d.	0.1	99.7	n.d.	0.2	0.1	93.2
4542		0.1	n.d.	0.1	n.d.	99.6	n.d.	0.1	0.3	99.8
		n.d.	n.d.	0.1	n.d.	100.0.	n.d.	n.d.	n.d.	109.4
		n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	0.1	97.0
		n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	0.1	99.8
		0.1	n.d.	n.d.	n.d.	99.5	n.d.	n.d.	0.6	92.9
		n.d.	n.d.	n.d.	n.d.	99.1	0.1	0.2	0.6	103.8
	White Bands	n.d.	n.d.	0.1	n.d.	98.6	0.1	0.1	1.2	102.0
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.3	104.1
		n.d.	n.d.	n.d.	n.d.	99.3	n.d.	0.1	0.6	105.2
10070	Cutting Edge (Pearlite)	n.d.	n.d.	n.d.	n.d.	99.5	n.d.	0.2	0.2	106.1
		n.d.	0.10	n.d.	n.d.	99.8	n.d.	0.1	n.d.	98.2
		0.2	0.20	n.d.	n.d.	99.6	n.d.	n.d.	0.2	96.0
	Cutting Edge (Ferrite)	0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	98.5
		0.1	0.18	n.d.	n.d.	99.8	0.1	n.d.	n.d.	89.5
		0.4	0.10	n.d.	n.d.	99.3	n.d.	0.1	n.d.	107.1
	White Weld Line	0.1	n.d.	n.d.	n.d.	98.0	0.2	n.d.	1.6	106.0
		0.1	n.d.	n.d.	0.1	99.4	n.d.	n.d.	0.5	104.4
	Small Grains	0.1	n.d.	n.d.	0.1	100.0	n.d.	n.d.	n.d.	100.4
		0.1	n.d.	0.1	n.d.	99.7	0.1	n.d.	0.1	96.3
		0.1	0.13	0.1	n.d.	99.7	n.d.	0.2	n.d.	101.4
	Medium Grains	n.d.	n.d.	n.d.	n.d.	100.1	n.d.	n.d.	n.d.	95.3
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	96.7
		n.d.	n.d.	n.d.	n.d.	100.2	n.d.	n.d.	0.1	91.0
	Pearlite	n.d.	n.d.	0.1	n.d.	100.0	n.d.	n.d.	n.d.	92.9
		n.d.	n.d.	0.1	n.d.	99.9	n.d.	n.d.	0.2	96.1
		n.d.	0.18	0.1	n.d.	99.8	n.d.	n.d.	0.2	97.7

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
84293	Ferrite	0.1	n.d.	n.d.	n.d.	99.9	n.d.	0.1	0.1	96.7
		0.1	n.d.	n.d.	0.1	100.2	n.d.	n.d.	n.d.	95.2
		0.1	n.d.	0.1	n.d.	99.8	0.1	n.d.	0.1	98.5
		0.1	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	0.2	106.2
	Large Grains	0.2	n.d.	n.d.	n.d.	99.6	0.1	n.d.	0.1	98.4
		0.3	0.19	n.d.	0.1	99.3	n.d.	n.d.	0.1	103.6
		0.1	0.18	n.d.	n.d.	99.6	0.1	0.1	n.d.	110.4
		0.2	0.16	0.1	0.1	99.3	0.1	n.d.	n.d.	105.3
1744	Medium to Large Grains	n.d.	n.d.	n.d.	n.d.	100.2	n.d.	n.d.	0.1	99.0
		0.1	0.31	n.d.	n.d.	99.7	0.1	n.d.	n.d.	100.0
		0.1	0.17	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	105.5
		n.d.	0.35	n.d.	n.d.	99.4	0.2	0.1	0.1	108.4
		n.d.	0.40	n.d.	n.d.	99.6	0.1	n.d.	n.d.	105.8
	Ferrite with some Pearlite	0.1	0.36	n.d.	n.d.	99.4	0.1	0.1	0.1	102.8
		n.d.	0.30	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	101.9
		0.1	0.15	n.d.	n.d.	99.7	n.d.	0.2	n.d.	99.4
		n.d.	0.32	n.d.	n.d.	99.8	0.1	n.d.	n.d.	94.4
		n.d.	0.28	n.d.	n.d.	99.5	0.1	0.1	0.2	91.9
11202	Ferrite	n.d.	0.16	n.d.	n.d.	99.5	0.1	0.2	0.1	95.9
		n.d.	0.22	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	102.1
		n.d.	0.28	n.d.	n.d.	99.7	n.d.	0.1	n.d.	97.9
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	0.2	0.1	102.6
		n.d.	0.12	n.d.	0.1	99.5	n.d.	0.2	n.d.	94.6
		n.d.	0.21	0.1	n.d.	99.7	n.d.	n.d.	0.1	94.1
	Pearlite	n.d.	0.29	0.1	n.d.	99.6	n.d.	0.1	n.d.	96.2
		n.d.	0.17	n.d.	n.d.	99.7	n.d.	0.1	0.2	95.6
		0.1	0.29	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	93.6
		0.1	0.19	0.1	n.d.	99.3	n.d.	n.d.	0.2	87.6
12524	Cutting Edge	0.1	0.12	n.d.	n.d.	99.7	n.d.	0.1	0.2	105.8
		n.d.	0.14	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	102.6
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	105.1
		0.1	0.13	0.1	n.d.	99.7	n.d.	0.1	0.1	97.8
		0.1	0.15	n.d.	0.1	99.7	n.d.	n.d.	n.d.	91.0
		n.d.	0.12	n.d.	n.d.	99.7	n.d.	n.d.	0.3	72.6
	White Weld Line	0.1	n.d.	n.d.	n.d.	98.5	0.8	0.3	0.2	110.4
		0.1	n.d.	n.d.	n.d.	99.3	n.d.	0.1	0.5	112.5
	Large Grains	n.d.	n.d.	n.d.	0.1	99.8	n.d.	0.1	n.d.	102.5
		n.d.	0.18	0.1	n.d.	99.6	n.d.	n.d.	0.1	106.1
		n.d.	0.13	0.1	n.d.	99.9	n.d.	n.d.	n.d.	116.2
		n.d.	n.d.	n.d.	n.d.	99.5	0.1	0.1	0.1	104.1
		n.d.	n.d.	0.1	n.d.	99.8	n.d.	n.d.	n.d.	97.3
		n.d.	0.19	n.d.	n.d.	99.8	0.2	n.d.	n.d.	105.4

Table 12.2: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
84343	Tempered Martensite	n.d.	n.d.	n.d.	n.d.	100.0.	n.d.	n.d.	0.1	103.1
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	0.2	102.7
	Medium Grains	0.1	n.d.	0.1	n.d.	99.3	n.d.	0.1	0.4	120.2
		n.d.	n.d.	n.d.	n.d.	100.2	n.d.	n.d.	n.d.	111.3
		n.d.	n.d.	n.d.	n.d.	100.1	n.d.	n.d.	n.d.	112.4
	Small Grains	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	0.1	100.8
		n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	0.1	101.4
		0.1	n.d.	0.1	n.d.	99.7	0.1	n.d.	n.d.	98.6
		n.d.	n.d.	n.d.	n.d.	99.6	0.1	0.1	0.2	108.3
		n.d.	0.20	0.1	n.d.	99.6	0.1	n.d.	0.1	93.4
		n.d.	0.10	n.d.	0.1	99.9	n.d.	n.d.	0.1	123.8
		n.d.	0.14	n.d.	n.d.	99.9	0.1	n.d.	n.d.	99.5
		n.d.	0.11	0.1	0.1	100.0	n.d.	n.d.	n.d.	93.3
		n.d.	0.11	n.d.	n.d.	99.8	n.d.	0.1	n.d.	105.7
	White Weld Line	0.1	n.d.	n.d.	0.1	99.6	n.d.	n.d.	0.3	112.8
		n.d.	0.13	n.d.	n.d.	99.8	n.d.	n.d.	0.3	117.0
813	Core	0.1	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	114.3
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	0.1	0.1	102.7
		n.d.	n.d.	n.d.	0.1	99.9	n.d.	0.1	0.1	99.4
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	110.5
		0.1	n.d.	0.1	n.d.	100.0.	n.d.	n.d.	0.1	101.8
	White Weld Line	0.1	0.15	n.d.	n.d.	99.1	0.5	0.1	0.3	107.7
		n.d.	0.16	0.1	n.d.	98.7	0.5	0.2	0.5	109.6
	Left Flank	0.1	0.43	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	104.4
		0.1	0.19	0.1	n.d.	99.8	0.1	n.d.	n.d.	110.0
		0.1	0.27	n.d.	n.d.	99.5	0.3	0.1	n.d.	109.5
	Right Flank	0.1	0.17	n.d.	n.d.	99.7	n.d.	n.d.	0.1	102.2
		n.d.	0.33	n.d.	n.d.	99.5	0.2	0.1	n.d.	112.5
		n.d.	0.37	0.1	n.d.	99.6	0.1	0.1	n.d.	112.3
1537	Medium Grains	0.1	0.11	n.d.	0.1	99.6	0.2	n.d.	n.d.	100.6
		n.d.	0.12	0.1	n.d.	99.7	n.d.	n.d.	n.d.	100.7
		n.d.	n.d.	n.d.	n.d.	100.0.	0.1	n.d.	n.d.	97.3
		n.d.	0.25	n.d.	n.d.	99.6	n.d.	0.1	n.d.	111.3
		0.1	0.23	0.1	n.d.	99.7	n.d.	n.d.	n.d.	106.7
	Ferrite with Pearlite	n.d.	0.10	n.d.	0.2	99.4	0.2	n.d.	0.1	107.1
		n.d.	n.d.	0.1	n.d.	100.2	n.d.	n.d.	n.d.	107.3
		n.d.	0.14	n.d.	0.1	99.5	0.1	n.d.	0.1	108.7
1935		n.d.	n.d.	n.d.	n.d.	100.1	0.2	n.d.	n.d.	97.7
		n.d.	n.d.	0.1	0.1	99.8	n.d.	n.d.	0.3	103.9
		0.1	n.d.	n.d.	n.d.	100.2	n.d.	n.d.	n.d.	103.1
		n.d.	n.d.	n.d.	n.d.	100.4	n.d.	n.d.	n.d.	100.0.
		0.1	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	0.1	103.5
		n.d.	n.d.	n.d.	n.d.	100.1	n.d.	0.1	0.1	98.3
		n.d.	n.d.	n.d.	n.d.	100.2	n.d.	n.d.	0.1	103.1

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
11988	Pearlite and Ferrite	n.d.	n.d.	0.1	n.d.	100.1	n.d.	n.d.	n.d.	97.2
		0.1	0.16	n.d.	n.d.	100.1	n.d.	n.d.	n.d.	97.1
		n.d.	0.13	n.d.	n.d.	100.2	n.d.	n.d.	n.d.	103.5
		0.1	n.d.	n.d.	n.d.	99.7	0.1	0.1	n.d.	108.4
		0.1	n.d.	0.1	n.d.	99.5	n.d.	0.1	0.1	95.7
		n.d.	n.d.	n.d.	0.1	99.9	0.1	n.d.	n.d.	94.4
		n.d.	0.13	n.d.	n.d.	99.6	n.d.	0.1	0.1	115.6
	Pearlite	n.d.	0.13	n.d.	n.d.	99.8	n.d.	0.2	0.2	84.3
		n.d.	n.d.	n.d.	n.d.	100.2	n.d.	0.1	n.d.	94.3
		n.d.	0.14	n.d.	n.d.	99.9	0.1	n.d.	n.d.	100.4
		0.1	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	0.1	97.8
14622	Cutting Edge	n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	n.d.	110.5
		n.d.	0.13	n.d.	0.1	99.8	0.2	n.d.	n.d.	106.5
		n.d.	0.13	0.1	n.d.	99.8	n.d.	n.d.	0.1	110.5
		n.d.	n.d.	n.d.	n.d.	100.0	n.d.	0.1	0.1	110.1
		n.d.	n.d.	n.d.	n.d.	99.6	0.1	0.1	0.2	106.3
	White Weld Line	0.1	n.d.	n.d.	n.d.	98.3	1.1	0.1	0.4	101.4
		n.d.	n.d.	n.d.	n.d.	99.2	0.4	n.d.	0.3	102.0
	Left Flank	0.1	0.70	n.d.	n.d.	99.2	n.d.	n.d.	n.d.	110.1
		n.d.	0.86	n.d.	n.d.	99.3	n.d.	n.d.	n.d.	108.3
		n.d.	0.66	n.d.	n.d.	99.4	n.d.	n.d.	n.d.	110.6
		n.d.	0.90	0.1	n.d.	99.1	n.d.	n.d.	0.1	99.6
	Right Flank	0.1	0.82	n.d.	0.1	99.2	0.1	n.d.	n.d.	110.4
		0.1	0.91	n.d.	n.d.	99.2	n.d.	n.d.	n.d.	97.1
		n.d.	1.07	0.1	n.d.	98.9	0.1	n.d.	0.1	99.8
		n.d.	0.98	n.d.	n.d.	99.2	n.d.	n.d.	n.d.	105.7
84270		n.d.	n.d.	0.1	n.d.	100.2	n.d.	n.d.	n.d.	100.0
		0.1	0.12	n.d.	n.d.	99.7	0.1	n.d.	0.3	100.5
		0.1	n.d.	n.d.	n.d.	99.9	n.d.	0.1	0.1	97.0
		n.d.	0.14	n.d.	n.d.	100.0	n.d.	n.d.	0.2	97.2
		0.1	n.d.	0.1	n.d.	99.6	n.d.	0.1	0.2	97.3
		0.1	n.d.	n.d.	n.d.	99.9	n.d.	0.2	n.d.	97.1
		0.1	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	0.3	98.2
84298	Cutting Edge	0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.2	103.6
		0.1	n.d.	0.1	n.d.	99.7	n.d.	0.1	0.1	102.6
		n.d.	0.12	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	103.9
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.2	n.d.	105.0
	White Weld Line	n.d.	n.d.	n.d.	0.1	99.1	n.d.	0.2	0.6	100.0
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.5	94.8
	Left Flank	n.d.	0.12	n.d.	0.1	99.5	n.d.	0.1	0.3	100.6
		0.1	0.11	n.d.	n.d.	99.8	n.d.	n.d.	0.3	105.8
		n.d.	n.d.	n.d.	n.d.	100.1	n.d.	n.d.	n.d.	101.8
		n.d.	n.d.	n.d.	n.d.	99.4	n.d.	0.1	0.4	98.3
	Right Flank	n.d.	n.d.	0.1	n.d.	100.1	n.d.	n.d.	0.1	96.2
		0.1	n.d.	n.d.	n.d.	99.9	0.1	n.d.	0.2	109.1
		0.1	0.11	n.d.	n.d.	99.5	n.d.	0.1	0.2	102.1

Table 9.2 cont: Full table of normalised results from SEM-EDS analysis. The total column shows the analysis total prior to normalisation.

White Weld Lines

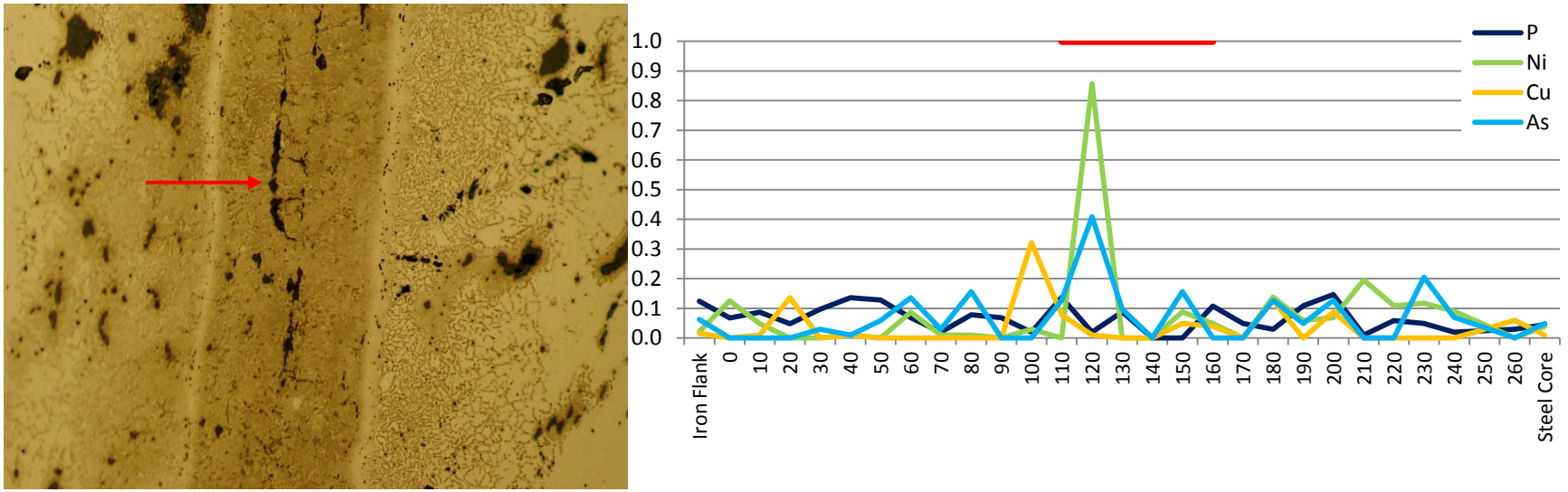


Figure 12.17: Line scan across the white weld line in Whithorn Knife 813

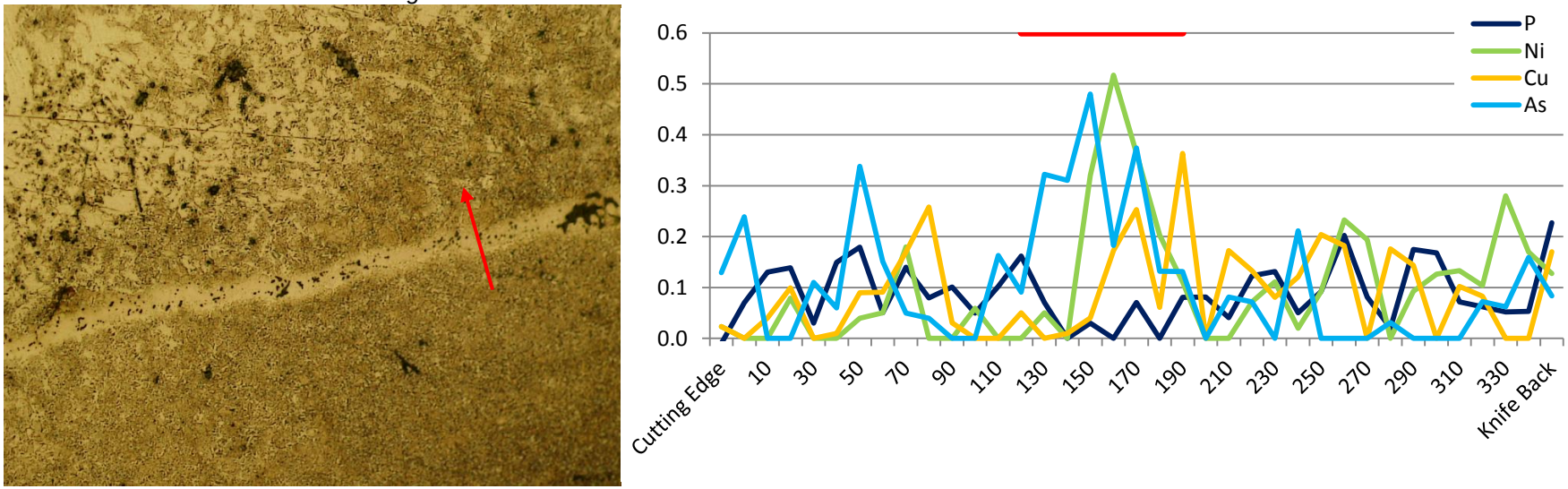
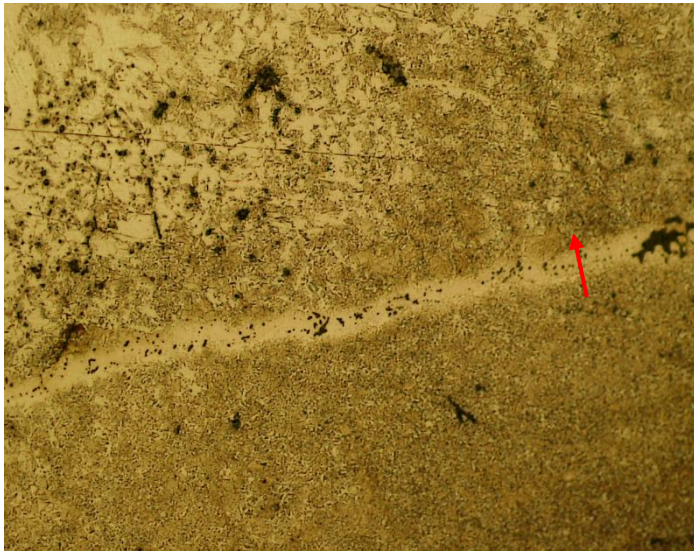


Figure 12.18: Line scan across the white weld line in Whithorn Knife 12524



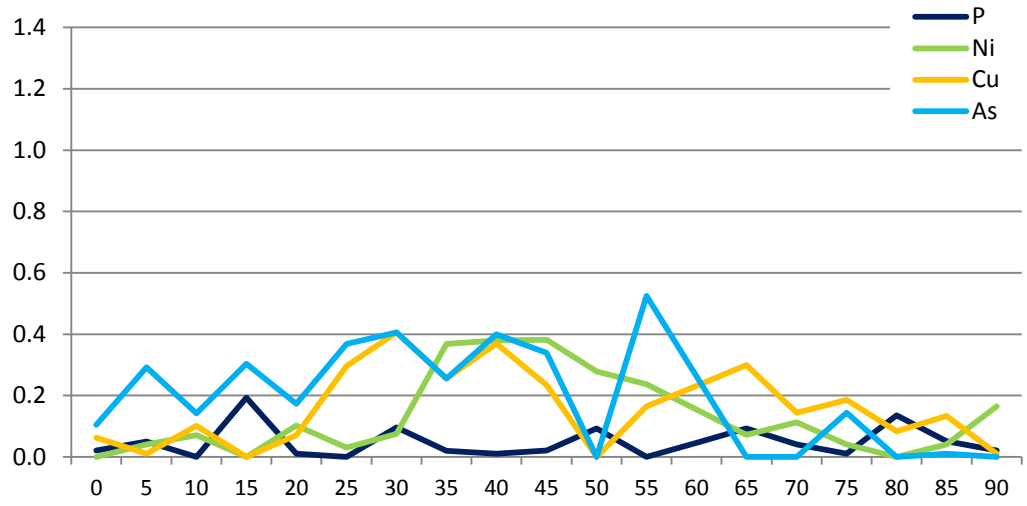
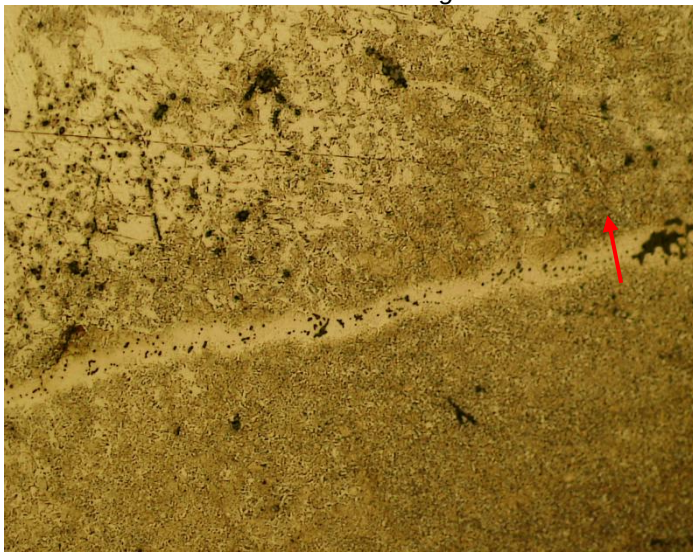


Figure 12.19: Line scan across the white weld line in Whithorn Knife 12524



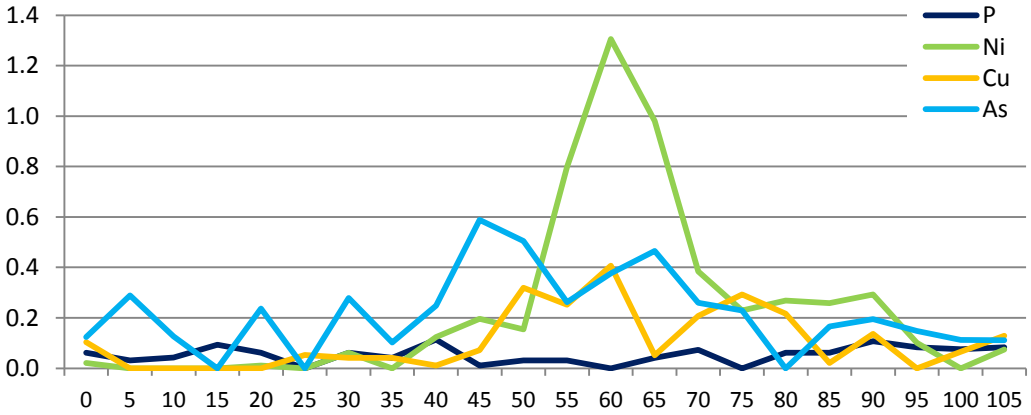


Figure 12.20: Line scan across the white weld line in Whithorn Knife 12524

Chapter 13: Dublin

Christchurch Place Knife Descriptions

Knife 1047

The x-radiograph of this knife revealed, near the knife back, a clear dark striation which ran from the tip to the shoulder, suggestive of a weld line. Below this the cutting edge had a spotted texture. The x-radiograph also revealed some possible damage to the cutting edge of the knife, near the tip.

Figure 13.1: Photograph and x-radiograph of knife 1047, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. Near the tip of the cutting edge there was a suspected weld line consisting of large single phased inclusions, this weld line seems to have been heavily distorted. Below this the cutting edge was clean of inclusions, while above there were very few single- and multi-phased angular inclusions. There was heavy corrosion penetration in the back section resulting in two large areas of corrosion. The largest seems to have formed due to the large number of multi-phased inclusions, which formed a band across the back. The rest of the back consisted of lots of bands of inclusions both single- and multi-phased.

When etched the cutting edge consisted of predominately martensite, with some tempering to one side of the knife (*549HV, Average 613HV, Range 549-766HV*). Near to the back of the cutting edge section the microstructure changes to a ferrite with grain boundary pearlite (*Average 203HV, Range 154-271HV*). The knife back consisted of bands of large grained ferrite (*ASTM 1-2*) with no pearlite or evidence for ghosting (*Average 123HV, Range 88-137HV*). No phosphorus

was detected during SEM-EDS analysis. Below the band of inclusions there were two white weld lines, enriched in arsenic and nickel (*Average 564HV, Range 509-618HV*), these separated the ferrite back from the martensite. There was some carbon diffusion across the weld line resulting in the area with the band of inclusions having small grains with grain boundary pearlite, up to 0.2% carbon (*Average 239HV, Range 221-257HV*). The suspected weld line in the cutting edge did not separate any different microstructures although there was a difference in the concentration of arsenic. Therefore considering the presence of a white weld line in the knife back this weld may in fact be a repair.

This knife was of type 2 manufacture with a steel strip welded onto the back of a ferrite strip. The cutting edge had been heat-treated. The second weld line suggests that this knife was repaired later in life, with materials similar but not identical to those of the original knife.

Knife 6255

The x-radiograph of knife 6255 revealed no evidence for a weld line, although the knife did appear to have a spotted texture. Examination of this knife revealed the presence of organic remains on the knife handle and SEM analysis showed the presence of a layered structure (Figure 10.3) similar to wood grain, indicative of either wood or possibly horn.

Figure 13.2: Photograph and x-radiograph of knife 6255, the lines show where the sections were removed.

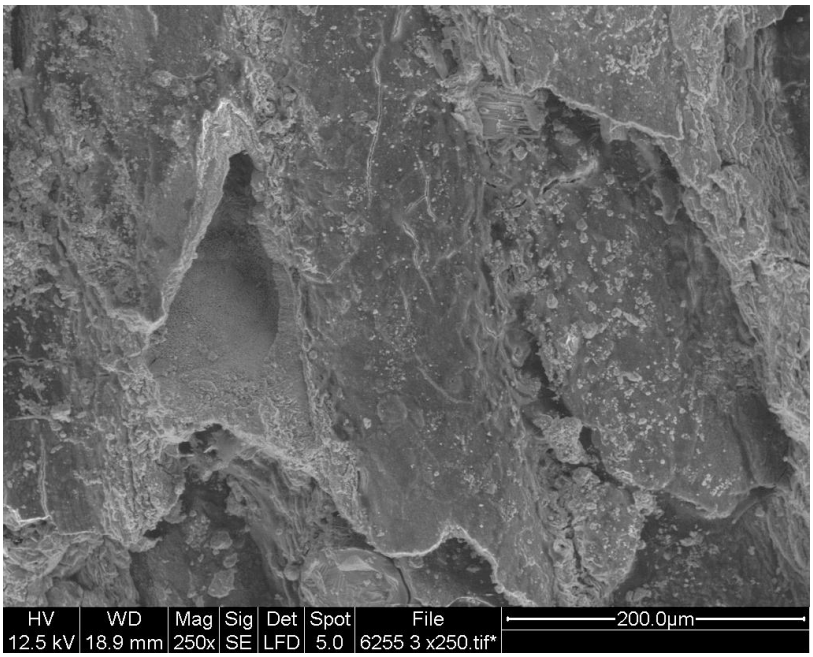


Figure 13.3: Secondary electron image of layered structure on the tang of knife 6255.

In the unetched condition there were few inclusions present most of which were small, single phased and angular or sub-angular. They appeared to be fairly homogenously spread across the sample. There was no evidence for any weld lines. When etched the microstructure also appeared to be homogenous, and was predominately pearlite with some ferrite, ranging in carbon content from 0.3% up to 0.6% (ASTM 7-8, *Average 327HV, Range 264-412HV*). The cutting edge had been heat treated to create a martensite with ferrite microstructure (*509HV, Average 577HV, Range 509-644HV*). Although mostly homogenous there were areas with lower carbon content (0.2-0.3%) particularly in the knife back (*Average 276HV, Range 210-321HV*). In the cutting edge there was also an area of lower carbon, with small grains of ferrite with some pearlite, which also had areas of ghosting (ASTM 6-7, *Average 301HV, Range 278-340HV*). SEM-EDS analysis of the knife revealed the presence of phosphorus in the cutting edge, not only in the low carbon areas but also in the quenched and higher carbon regions.

Knife 8891

X-radiography of this knife showed that the cutting edge had been heavily worn and corroded. There was no evidence for a weld line in the x-radiograph but the cutting edge had the classic spotted texture.

Figure 13.4: Photograph and x-radiograph of knife 8891, the lines show where the sections were removed.

In the unetched condition there were clear bands of inclusions running vertically down the knife, separating it into two halves. These inclusions were mostly small and single phased, but there were also several larger inclusions present. The inclusions differed to each side of this inclusion band; one side of the knife had few, small, single-phased angular inclusions while the other side had sub-angular multi-phased inclusions.

When etched these two halves were very different in microstructure; the first corresponding to the small single phased inclusions consisted of a pearlite with ferrite steel (0.6% carbon) which became a 0.4% carbon steel closer to the inclusion bands (ASTM 8, *Average 406HV, Range 244-509HV*). By the cutting edge this high carbon steel transformed into tempered martensite with some areas of pearlite with ferrite (*473HV, Average 466HV, Range 386-509HV*). The other half of the knife consisted of medium to large grains of ferrite, with no pearlite or ghosting (ASTM 1-3, *Average 255HV, Range 175-386HV*). SEM-EDS analysis revealed the presence of phosphoric iron, with up to 0.3% phosphorus. It also revealed that both arsenic and copper was present in relatively large quantities (Cu 0.1-0.3% and As 0.1-1.3%). There was some carbon diffusion across the slag inclusion bands and white weld line, which was highly enriched in arsenic (up to 1.9%), with traces of nickel and copper. (*Average 324HV, Range 257-412HV*) and slag inclusion bands.

Knife 11635

The x-radiograph of knife 11635 revealed that it was badly worn and also suggested that it was badly corroded. Even so there was a clear weld line, although no spotted texture beneath. The x-radiograph also revealed that the back was most likely piled, as there were many dark striations clearly visible throughout the x-radiograph.

Figure 13.5: Photograph and x-radiograph of knife 11635, the lines show where the sections were removed.

Prior to etching the knife was examined to reveal a clear weld line in the cutting edge section consisting of single-phased angular inclusions and a possible raised white weld line. Below this weld line there were some single-phased and angular inclusions, while above the weld line and in the knife back section there were many bands of inclusions. These were mostly single-phased and angular separating different areas with small single-phased inclusions.

Once etched the weld line was confirmed to be a white weld line (*Average 734HV, Range 701-766HV*), below which the microstructure consisted of martensite (*1027HV, Average 922HV, Range 701-1027HV*). SEM-EDS analysis revealed that the weld line was highly enriched in arsenic with 2.3-2.5%. There was extensive carbon diffusion across the weld line into the back resulting in a pearlite degrading into a ferrite with pearlite. Two other fainter white weld lines were found in the cutting edge section above the weld line. The back consisted of heterogeneous bands of iron; ranging from pearlite with ferrite (ASTM 6-7, *Average 354HV, Range 303-473HV*), to areas of ferrite with some pearlite at the grain boundaries (ASTM 4-6, *Average 302HV, Range 264-340HV*) and other areas with large grains of ferrite (ASTM 2-3, *Average 213HV, Range 148-278HV*). Chemical analysis of the knife back and cutting edge revealed the

presence of phosphorus, mostly present in relatively large quantities in the back (0.2-0.4%) but also traces in the cutting edge (up to 0.2%). This analysis also revealed the presence of arsenic in significant quantities in the knife back and cutting edge (between 0.2-0.8%).

Knife 12055

The x-radiograph of this large knife revealed no evidence for a weld line, although a clear spotted texture was seen in the cutting edge.

Figure 13.6: Photograph and x-radiograph of knife 12055, the lines show where the sections were removed.

During sectioning the back section of the knife split into two. When examined in the unetched condition this was revealed to be due to corrosion penetration. Even without etching it was clear that this knife was a type 1. The central weld line ran vertically down the knife and then split to two sides, delineated by single phased inclusions and an etch resistant white weld line. The cutting edge had small, angular single-phased inclusions while the two pieces of iron to either side had lots of single- and multi-phased inclusions, most of which were sub-rounded or elongated.

When etched the cutting edge consisted of martensite (1288*HV, Average 1089HV, Range 946-1288HV*), which transformed into tempered martensite closer to the weld line, and then pearlite at the weld line. There was some carbon diffusion across the white weld line which was enriched in arsenic and nickel (*Average 487HV, Range 401-572HV*). The two iron sheaths consisted of large grains of ferrite (ASTM 1-2, *Average 186HV, Range 123-254HV*), with no

pearlite. Ghosting was seen in some areas suggesting a phosphoric iron, confirmed by SEM-EDS analysis which revealed between 0.1-0.3% phosphorus.

This knife was constructed by welding one small piece of steel between two larger pieces of phosphoric iron, creating a type 1 knife. The steel was only inserted near the tip of the knife resulting in an upside down Y shape weld. The cutting edge was heat-treated.

Knife 12320

The x-radiograph of knife 12320 suggested that it was badly corroded. There was no evidence for a weld line, and rather than the spotted texture seen in other knives this knife had a more grainy texture.

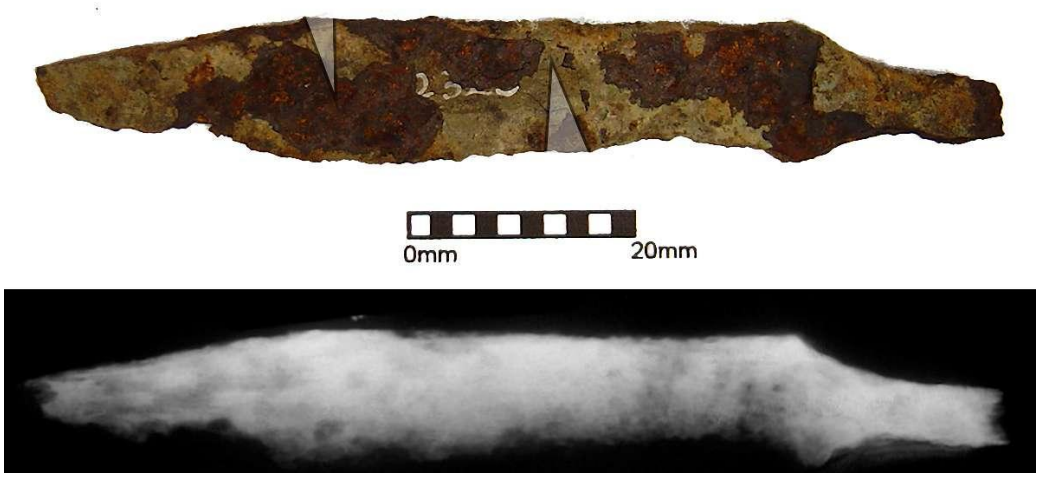


Figure 13.7: Photograph and x-radiograph of knife 12320, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. There were two vertical slag inclusion bands, consisting of single- and multi-phased inclusions mostly elongated, visible in the back section, these seemed to continue into the cutting edge. Between these bands the inclusions were small, single-phased and elongated but the inclusions in the two flanks were sub-rounded and single phased, some were very large. Some of these inclusions also appear to have suffered from corrosion, resulting in voids in the knife back.

When etched the two bands separated a central strip which consisted of martensite and the cutting edge (*1047HV, Average 838HV, Range 644-1047HV*), with pearlite and martensite towards the knife back. To either side of this band

the microstructure consisted of large grains of ferrite with no pearlite and some ghosting (ASTM 1-2, *Average 235HV, Range 175-286HV*). There was also very little carbon diffusion across the weld line suggesting that the two iron flanks may be phosphoric iron. Confirmed by SEM-EDS analysis which revealed between 0.2-0.5% phosphorus. This analysis also revealed the presence of arsenic in the cutting edge (up to 0.3%).

Knife 12477

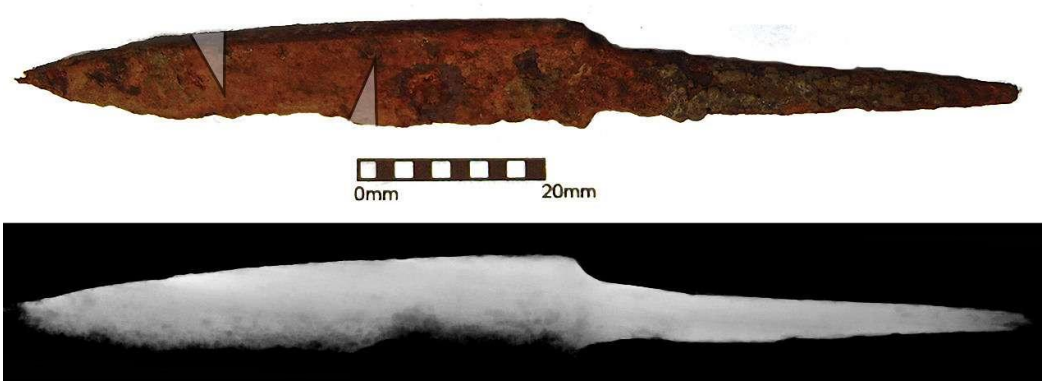


Figure 13.8: Photograph and x-radiograph of knife 12477, the lines show where the sections were removed.

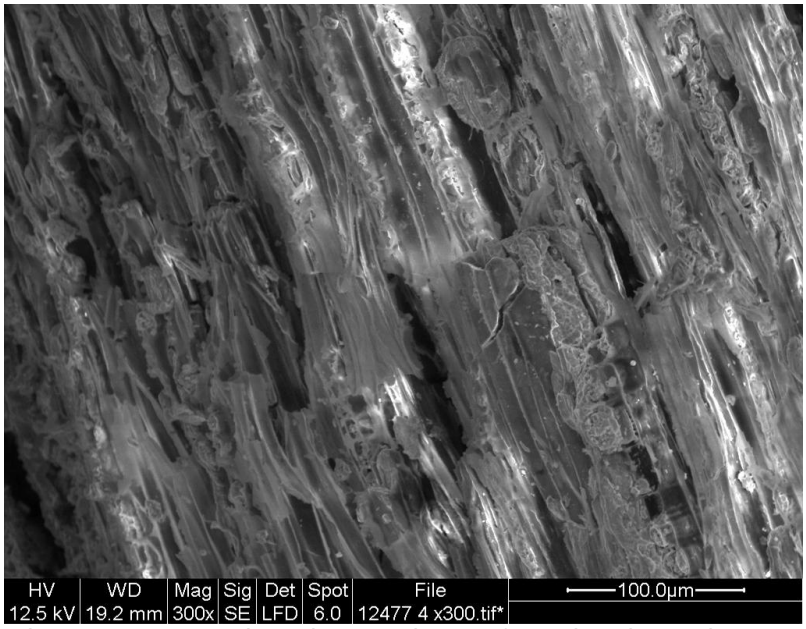


Figure 13.9: Secondary electron picture of wood scales and pores.

X-radiography of this knife showed that it was well preserved, although the cutting edge had been heavily worn and partially corroded. There was no evidence for a weld line in the x-radiograph but the cutting edge had the spotted texture. Examination of this knife revealed the presence of organic remains on

the knife handle, which under the SEM turned out to be wood, suggested by the presence of wooden scale and pores (Figure 10.15).

Two etch resistant bands with single- and multi-phased elongated inclusions, which joined at the knife back, suggested that the knife was constructed of three pieces of iron. The central strip had very few inclusions, those present were single-phased and elongated. To either side there were more inclusions which were larger, sub-angular and multi-phased.

Once etched the central band turned out to be predominately martensite with ferrite (*644HV, Average 456HV, Range 412-644HV*), and ferrite with pearlite near the knife back (ASTM 6-7). There were two clear white weld lines, enriched in arsenic (*Average 379HV, Range 321-441HV*) separating the steel core from the iron flanks. There was some carbon diffusion across the weld line, particularly into one of the iron flanks, which consisted of medium grains of ferrite (ASTM 3-4). The other which was more resistant to carbon diffusion had slightly larger grains (ASTM2-3). Neither iron flank had evidence for ghosting, and SEM-EDS revealed only traces of phosphorus, particularly in the right iron flank, corresponding to the carbon resistant larger grains (*Average 205HV, Range 168-271HV*).

This knife was constructed by welding one piece of steel between two larger pieces of ferritic and phosphoric iron, creating a type 1 knife. The steel strip was not present throughout the knife, resulting in an upside down Y shape weld near the knife back. The cutting edge was heat-treated.

Knife 12499

The x-radiograph of this knife revealed no evidence for a weld line, although a clear spotted texture was seen though out the knife.

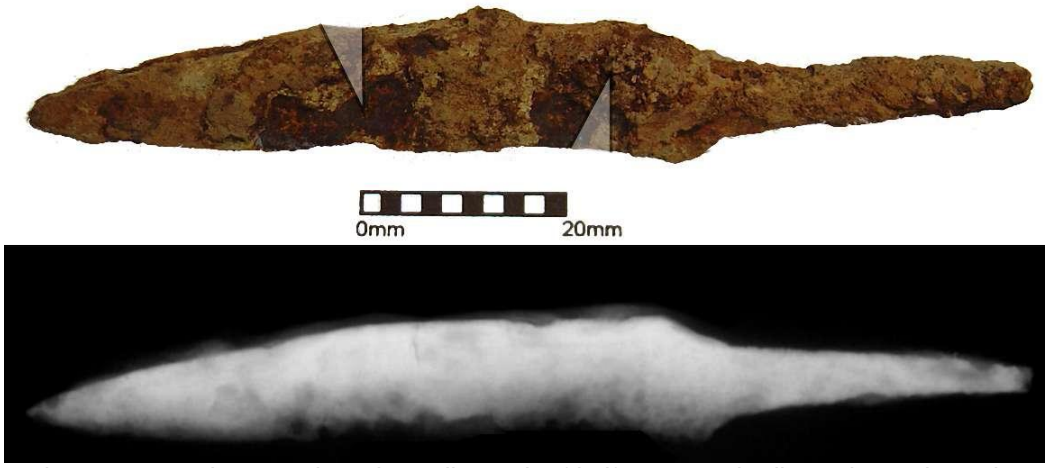


Figure 13.10: Photograph and x-radiograph of knife 12499, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. There were no clear weld lines instead the knife appeared to be fairly homogenous with very few single phased inclusions. The back of the knife had relatively more inclusions than the cutting edge, some of which were larger and angular.

When etched the cutting edge section predominately consisted of martensite (*927HV, Average 978HV, Range 766-1144HV*) which degraded to martensite with pearlite near the back. The back section of the knife was more heterogeneous and consisted of varying amounts of martensite, pearlite and ferrite. The centre of the knife consisted of ferrite with pearlite ranging from 0.3%-0.5% carbon (ASTM 6-7, *Average 252HV, Range 232-271HV*) and ferrite around a particularly angular inclusion in the centre of the back (ASTM 3, *Average 151HV, Range 148-154HV*). In the very back of the knife there was an area of martensite and pearlite (*Average 656HV, Range 386-1027HV*) with some white bands which resembled white weld lines, enriched in arsenic and copper (*Average 701HV, Range 701HV*). SEM-EDS analysis of this knife revealed no evidence for phosphorus, including in the ferrite region in the centre of the knife back.

Knife 12677

The x-radiograph of knife revealed a clear dark striation which ran from the tip to the tang interface, suggestive of a weld line. Below this the cutting edge had a spotted texture.

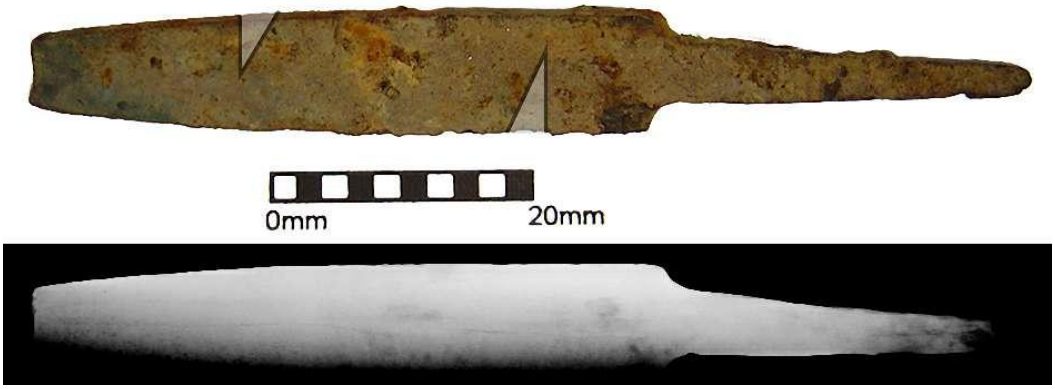


Figure 13.11: Photograph and x-radiograph of knife 12677, the lines show where the sections were removed.

Prior to etching the knife was examined to reveal the presence of a convex weld line of small single-phased inclusions. Below this weld line in the cutting edge there were a few small, angular, single-phased inclusions. There was also a crack in the cutting edge, with some corrosion penetration, which may possibly have resulted during quenching. Above the weld line the inclusions were larger and both single- and multi-phased, most formed bands.

After etching the cutting edge turned out to consist of martensite (*1027HV, Average 876HV, Range 593-1027HV*). There was a white weld line, enriched in arsenic and nickel (*Average 723HV, Range 701-766HV*) separating the cutting edge from the knife back. There was some carbon diffusion across this weld line (*Average 333HV, Range 271-399HV*). The rest of the knife back consisted of larger grains of ferrite with no pearlite and some ghosting, suggesting phosphoric iron (ASTM 1, *Average 229HV, Range 210-257HV*). This was confirmed by SEM-EDS analysis as up to 0.6% phosphorus was detected.

Knife 13135

The x-radiograph of knife 13135 suggested that the knife was badly corroded. There was a possible weld line in the knife back, and in some areas the spotted texture was identified.

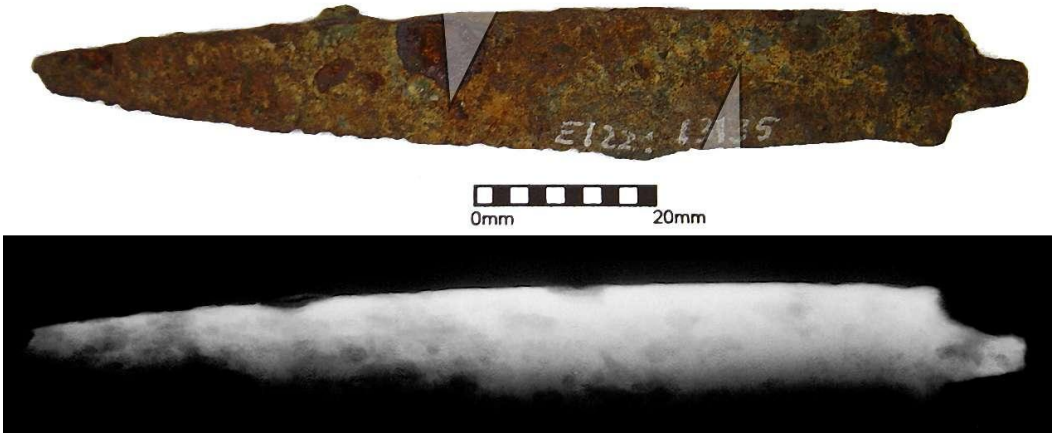


Figure 13.12: Photograph and x-radiograph of knife 13135, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. This revealed two vertical slag inclusion bands, consisting of elongated multi-phased inclusions. Between these bands the inclusions were small, single-phased and elongated. The inclusions to either side of this central strip ranged in shape, number and size; the majority were elongated and single-phased but towards the back of the knife there were more and large inclusions some of which were multi-phased and sub-rounded.

When etched the central band consisted of martensite (*701HV, Average 530HV, Range 232-701HV*) which turned into tempered martensite and then pearlite towards the knife back. There was considerable carbon diffusion across the weld lines into the two iron flanks which ranged in microstructures from; small grains of ferrite with grain boundary pearlite (ASTM 7-8, *Average 275HV, Range 210-321HV*), to ferrite with pearlite (ASTM 5-6, *Average 327HV, Range 314-340HV*) and large grains of ferrite with ghosting (ASTM 1, *Average 212HV, Range 201-240HV*). There were also bands of pearlite present in the knife back. This suggests that the two iron strips used were constructed of piled iron, confirmed by SEM-EDS analysis which revealed that both iron flanks had areas with varying amounts of phosphorus and arsenic.

Knife 14241

The x-radiograph of this knife revealed a clear dark striation suggestive of a weld line. Below this the cutting edge had a spotted texture. The x-radiograph also showed that some areas of this knife, such as the tip, were heavily corroded.

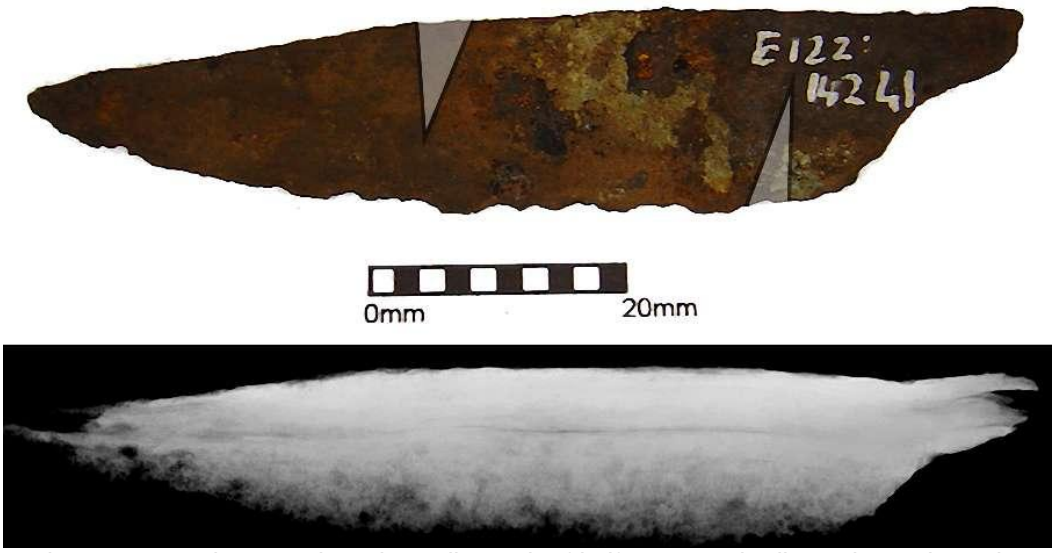


Figure 13.13: Photograph and x-radiograph of knife 14241, the lines show where the sections were removed.

This knife was heavily pitted and badly corroded with the corrosion had picked out the convex weld line, using the small single-phased inclusions as a pathway. Below the weld line in the cutting edge there were many elongated and sub-angular mostly single phased inclusions, some of which formed bands suggesting possible repairs. The knife back also had lots of single-phased slag inclusions, this time mostly sub-rounded.

Once etched the weld line which had suffered corrosion actually turned out to be a white weld line, enriched in arsenic (*Average 316HV, Range 232-412HV*). There was no carbon diffusion from the tempered martensite cutting edge into the back (*457HV, Average 475HV, Range 321-644HV*). Etching the cutting edge revealed an unusual watery effect created by multiple white weld lines. SEM-EDS analysis revealed the presence of arsenic possibly causing this affect. Above the weld line the microstructure consisted of small grains of ferrite with ghosting, suggestive of phosphoric iron (ASTM 7-8, *Average 177HV, Range 123-257HV*), although SEM-EDS analysis suggested that no phosphorus was present.

Knife 14491

X-radiography of this knife showed that it was well preserved although the cutting edge had been heavily worn. There was a hint of the presence of a weld and the cutting edge had the classic spotted texture.

Figure 13.14: Photograph and x-radiograph of knife 14491, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. In the cutting edge section there was a possible weld line made up of small, sub-angular, single- and multi-phased inclusions. Below this the inclusions were small, elongated or sub-rounded and single-phased. In the back section the inclusions formed many bands ranging from, very few single-phased near the weld line to many multi-phased sub-rounded inclusions seen in the back. Corrosion seems to have penetrated into the knife back forming a line.

The possible weld line seen in the unetched condition turned out to be a clear white weld line, enriched in arsenic (*Average 509HV, Range 350-605HV*). This separated the martensite cutting edge (*1288HV, Average 1189HV, Range 1097-1288HV*) from the ferritic iron back. There was carbon diffusion across the weld line resulting in a bainite and then pearlite with ferrite structure. The back section consisted of predominately ferrite with pearlite, 0.2-0.4% carbon (ASTM 6-8, *Average 213HV, Range 176-274HV*) although the very back of the knife had larger grains, no carbon and some possible ghosting (ASTM 5, *Average 175HV, Range 160-199HV*) suggesting a phosphoric iron, but no phosphorus was detected in this knife.

Knife 15910

The x-radiograph of this knife revealed very little evidence for manufacture, as there was no weld line or spotted texture.

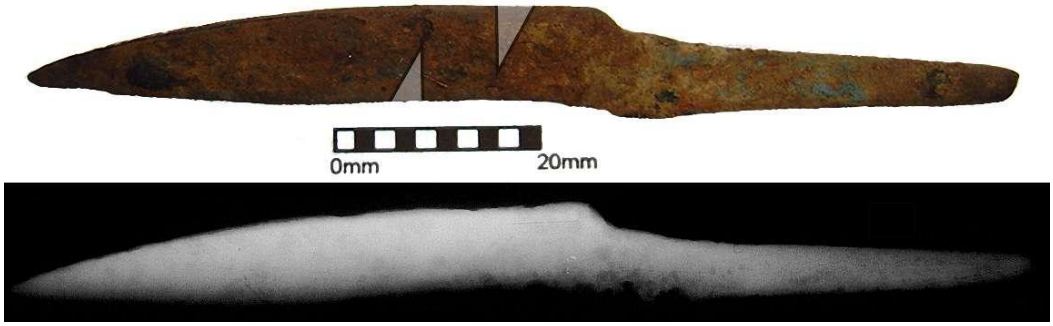


Figure 13.15: Photograph and x-radiograph of knife 15910, the lines show where the sections were removed.

Prior to etching the knife was examined to reveal the presence of a convex weld line of large, sub-angular, multi-phased inclusions in the knife back. The inclusions in the cutting edge section were elongated or angular and single-phased. Above the weld line there were very few small inclusions which were all sub-rounded and single-phased. There was also a line of multi-phased sub-rounded inclusions in the back running vertically up one side of the knife.

The cutting edge when etched was revealed to be martensite with pearlite in some areas (*509HV, Average 664HV, Range 509-927HV*). The vertical weld line of inclusions turned into a white weld line and separated the back. SEM-EDS analysis revealed that this weld line was enriched in arsenic but also with traces of copper. The majority of the back consisted of predominately medium grains of ferrite (ASTM 3-5, *Average 233HV, Range 192-321HV*). To the right of the weld line the microstructure was dominated by pearlite and pearlite with ferrite (0.8%-0.6% carbon, *Average 472HV, Range 399-528HV*), there was also a significant quantity of arsenic present (0.2-0.4%). There was significant carbon diffusion across the horizontal weld line into the ferrite back, and also across the vertical weld line.

Knife 16514

X-radiography of this knife showed that it was well preserved. There was no evidence for the presence of a weld line but the cutting edge had the classic spotted texture. The x-radiograph also revealed the presence of a notch just at the point where the knife angled down.

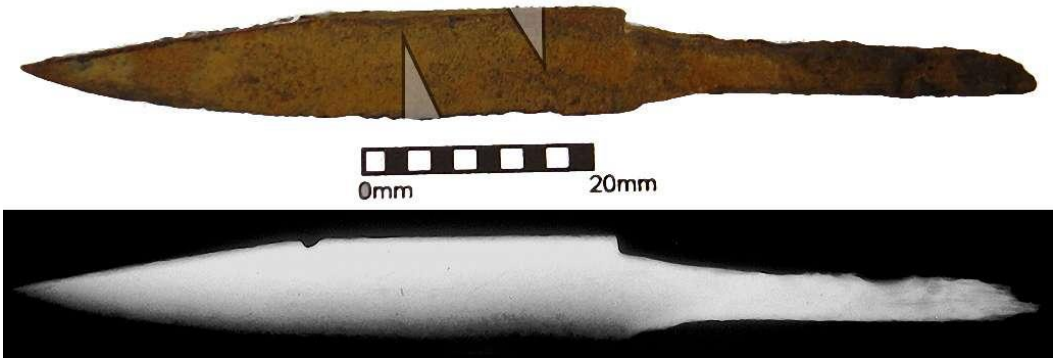


Figure 13.16: Photograph and x-radiograph of knife 16514, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition, which revealed that there were two vertical slag inclusion bands, consisting of single-phased inclusions mostly elongated. Between these bands the inclusions were small, single-phased and sub-rounded but the inclusions in the two flanks were large, sub-rounded and single phased

When etched the two bands separated a central strip which consisted of martensite at the cutting edge (*1144HV, Average 951HV, Range 644-1211HV*), with pearlite and martensite in areas. To either side of this band the microstructure consisted of large grains of ferrite with no pearlite and some ghosting (ASTM 1, *Average 260HV, Range 221-362HV*). There was also very little carbon diffusion across the weld line suggesting that the two iron flanks may be phosphoric iron. This was confirmed by SEM-EDS analysis which suggested between 0.2-0.4% phosphorus.

Knife 16557

This knife had a curve-backed with a distinct tang to blade interface. The x-radiograph revealed a homogenous structure with no evidence for weld lines or the spotted texture. There was only slight evidence for wear.

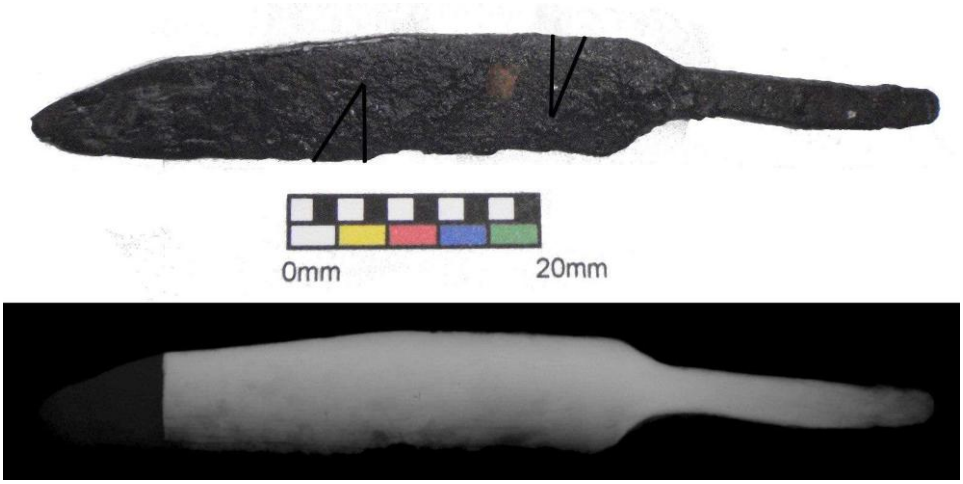


Figure 13.17: Photograph and x-radiograph of knife 16557, the lines show where the sections were removed.

There was a weld line made up of sub-rounded, multi-phased slag inclusions. Below this the cutting edge had very few small, single-phased inclusions. Above the weld line there were sub-angular, single-phased inclusions, some were quite large. Corrosion had begun to penetrate the knife. When etched the weld line turned out to be a white weld line (Average 261*HV,* Range 201-321*HV*). The cutting edge consisted of tempered martensite, which became pearlite or bainite at the weld line (441*HV,* Average 417*HV,* Range 257-593*HV*). The knife back consisted of several different areas, and the slag inclusions and corrosion suggest that it was piled. Just above the weld line there were small grains of ferrite and pearlite and bainite (Average 462*HV,* Range 386-549*HV*) while further up in the back the microstructure turned pearlite (Average 351*HV,* Range 340-362*HV*). Also in knife back there was a band of ferrite with pearlite (Average 285*HV,* Range 192-441*HV*) and ferrite and pearlite (Average 443*HV,* Range 412-473*HV*).

Knife 16808

The tip of the knife was most likely broken therefore it was not possible to determine the original shape. The tang to blade interface was distinct on both sides. There was an S-shaped curve and evidence of wear. The x-radiograph of this knife revealed no dark striations suggesting weld lines. There was slight evidence for a spotted cutting edge but this may have just been the result of corrosion at the cutting edge.

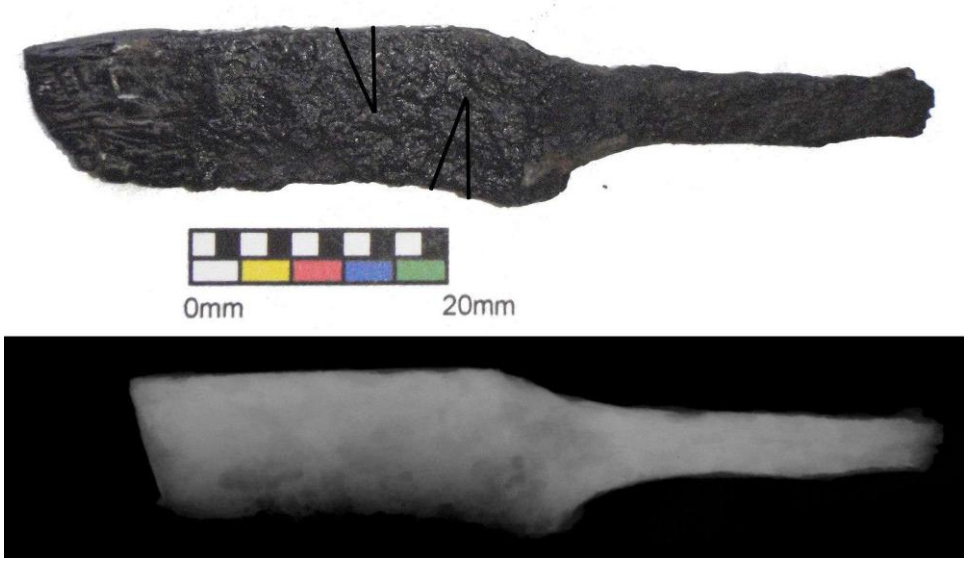


Figure 13.18: Photograph and x-radiograph of knife 16808, the lines show where the sections were removed.

Prior to etching the inclusions revealed a heavily banded knife. The middle section of the knife had elongated single-phased inclusions. Separating these bands were sub-rounded, multi-phased inclusions. To either side of this band there were many single-phased, sub-rounded and sub-angular inclusions.

When etched the middle band was revealed to be ferrite with pearlite (0.2-0.3% carbon*,* Average 480*HV,* Range 386-644*HV*). The strip which formed the cutting edge had martensite and pearlite (1027*HV,* Average 965*HV,* Range 841-1027*HV*) which turned into ferrite with pearlite (Average 412*HV*). To either side of the strips there were white weld lines these were enriched in phosphorus rather than arsenic (Average *734HV,* Range 701-766*HV*). The other band had ferrite with pearlite (0.2-0.3% carbon, Average *574HV,* Range 473-701*HV*). SEM analysis revealed traces of phosphorus in some of the bands to either side of the central steel strip.

Knife 16826a

The tip of the knife was most likely broken therefore it was not possible to determine the original shape. The tang to blade interface was distinct on both sides. The x-radiograph revealed no evidence for weld lines although there was a spotted texture. There was slight evidence of wear.

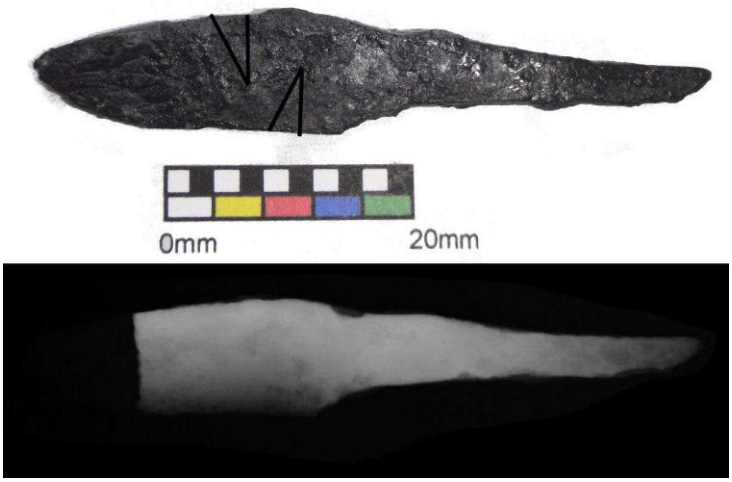


Figure 13.19: Photograph and x-radiograph of knife 16826a, the lines show where the sections were removed.

The cutting edge section had sub-angular and sub-rounded, single- and multi-phased inclusions. The back section also had many single-phased, sub-rounded inclusions or sub-angular multi-phased inclusions. There was no evidence for any weld lines. Once etched the sections were revealed to consist predominately of bainite (362*HV*, Average *416HV,* Range 362-473*HV*). There were many white bands which were not related to any slag inclusions. These bands were enriched in arsenic (0.6-0.7%) and had a lower hardness value than the surrounding microstructures (Average 1144*HV*). The back section consisted of two main areas. The first related was martensite with pearlite (Average *418HV,* Range 330-589*HV*) while closer to the knife back the microstructure changed to pearlite (Average 959*HV,* Range 701-1144*HV*). SEM analysis of this area revealed the presence of arsenic throughout the knife (0.2-0.4%).

Knife 16826b

The tip of the knife was most likely broken therefore it was not possible to determine the original shape. The tang to blade interface was distinct on both sides. The x-radiograph revealed no evidence for weld lines although there was a spotted texture. There was slight evidence of wear.

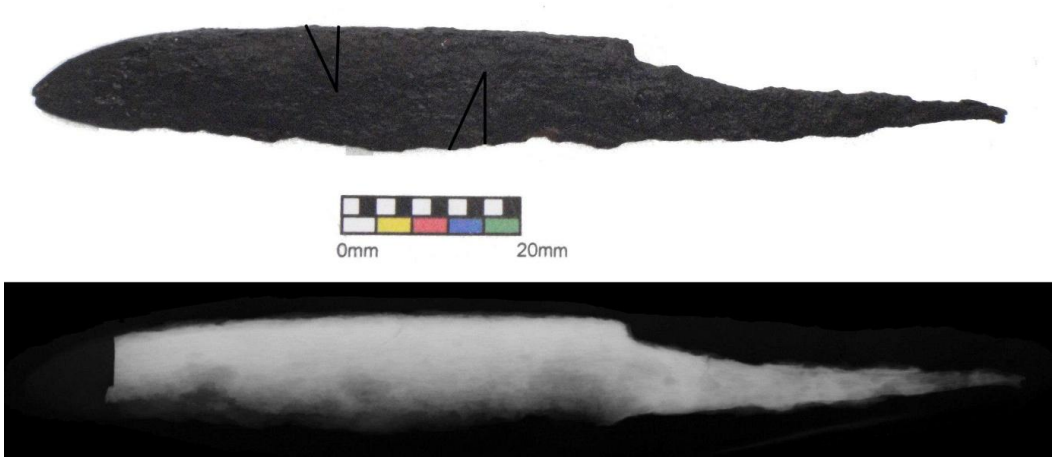


Figure 13.20: Photograph and x-radiograph of knife 16826b, the lines show where the sections were removed.

Prior to etching there were three different areas of inclusions. The central area had small single-phased rounded slag inclusions. The areas to either side had sub-angular, single-phased inclusions. When etched the sections revealed a clear type 1 knife with a martensite cutting edge (1144*HV)* which changed to martensite with pearlite closer to the knife back (Average *1018HV,* Range 766-1144*HV*). There were two white weld lines either side of the central strip which were enriched in arsenic (0.1-0.2%). The two flanks were similar in microstructure with some carbon diffusion across the weld lines into the large grains of ferrite and ghosting (Average 362*HV,* Range 303-412*HV*). SEM analysis confirmed the presence of large quantities of phosphorus (0.6-0.8%) indicating a phosphoric iron.

Fishamble Street Knife Descriptions

Knife 2041

This knife had a curved back with a distinct tang to blade interface on one side only. The x-radiograph revealed a spotted texture throughout the knife with no evidence for weld lines. There was evidence only slight wear visible.

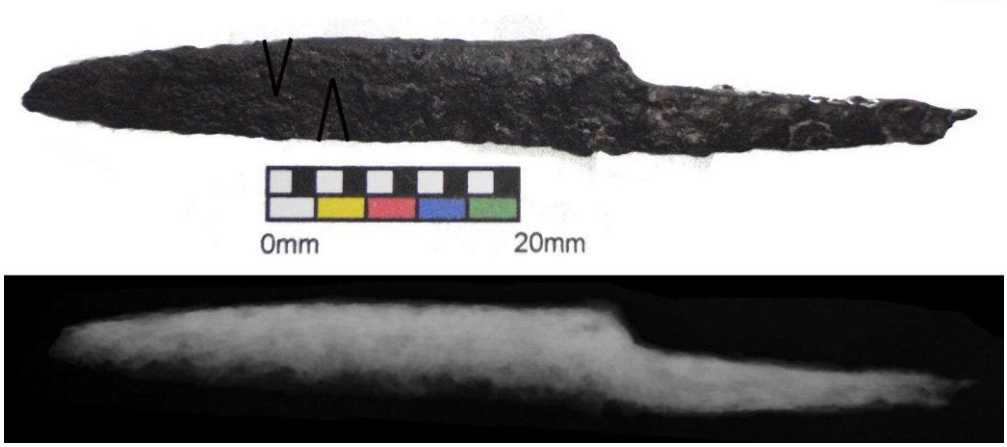


Figure 13.21: Photograph and x-radiograph of knife 2041, the lines show where the sections were removed.

Prior to etching there were two clear bands of sub-rounded single phased inclusions which separated a central strip with small, single-phased, rounded inclusions. The flanks to either side had lots of single- and multi-phased, elongated or sub-rounded inclusions some of which were large. When etched the sections revealed a clear type 1 knife with a tempered martensite core (644*HV,* Average 600*HV,* Range 441-766*HV*). The two bands of inclusions turned out to be white weld lines which were enriched in arsenic (0.2-0.3%). The two flanks were similar in microstructure with some carbon diffusion across the weld lines into the small to medium grains of ferrite, which also had ghosting (Average 385*HV,* Range 303-570*HV*). SEM analysis confirmed the presence of traces of phosphorus (0.1-0.2%) indicating a phosphoric iron.

Analysis of this knife has revealed a typical type 1 knife with a steel cutting edge sandwiched between two pieces of phosphoric iron. This knife has also been heat-treated, quenched and tempered, resulting in a tempered martensite cutting edge.

Knife 2555

The x-radiograph of knife 2555 suggested that the knife was badly corroded. There was no evidence for the presence of a weld line and the classic spotted texture was present throughout the knife.

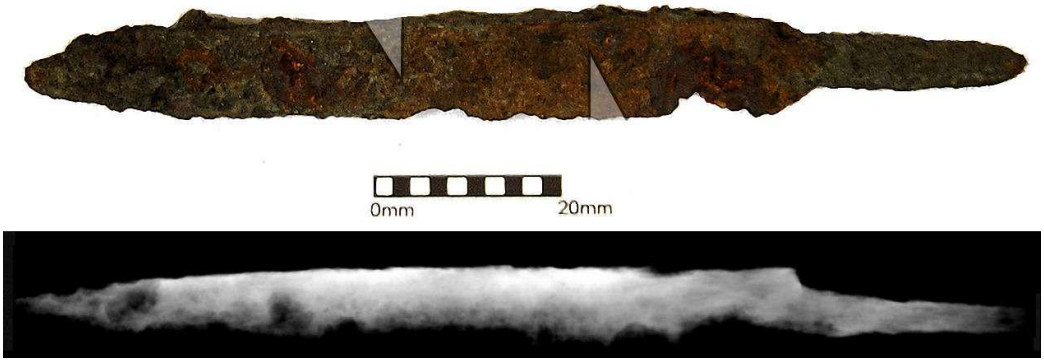


Figure 13.22: Photograph and x-radiograph of knife 2555, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. There were two vertical slag inclusion bands, consisting of small rounded and sub-rounded single-phased inclusions. Even though these bands are present there does not seem to be a difference in inclusion types between the areas, instead the inclusions throughout the sample are sub-rounded or elongated and both single- and multi-phased.

Once etched the two vertical inclusion bands turn out to be solid white weld lines, enriched in arsenic and nickel (*Average 648HV, Range 399-927HV*) but like the inclusions the different pieces of iron do not differ significantly. The whole knife appears to have been constructed of heat-treated steel, consisting of martensite with varying amounts of pearlite (*509HV, Average 575HV, Range 294-975HV*).

At first glance this knife appears to be an all steel type 5 knife which has been heat-treated. The presence of two vertical and central white weld lines on the other hand suggests that originally it may have been constructed as a type 1 sandwich weld. Perhaps using a high quality steel for the central strip and two lower carbon steels either side, but the resulting heat-treatment meant that this has been obscured.

Knife 2696

The x-radiograph of this knife revealed a clear dark striation suggestive of a weld line. Below this the cutting edge had a spotted texture.

Figure 13.23: Photograph and x-radiograph of knife 2696, the lines show where the sections were removed.

Prior to etching, the knife was examined to reveal the presence of a weld line of rounded, single-phased inclusions in the knife back section. The inclusions in the cutting edge section were sub-angular and single-phased. Near the tip of the cutting edge there were a number of large sub-angular single-phased inclusions, possibly suggesting a second weld line. Above the weld line, in the knife back, there were single-phased inclusions which were all sub-angular.

The possible weld line seen in the unetched condition turned out to be a white weld line, enriched in arsenic (*Average 223HV, Range 145-303HV*). This separated the martensite cutting edge (*1144HV, Average 1086HV, Range 1027-1144HV*), which transformed into martensite with pearlite and then pearlite towards the weld line. There was some evidence for carbon diffusion across the weld line, although the back may already have been mild steel. The knife back consisted of heterogeneous bands of iron separated by faint white weld lines; the microstructures ranged from pearlite with ferrite around 0.6% carbon to ferrite with pearlite between 0.1-0.2% carbon (ASTM 4-5, *Average 245HV, Range 143-286HV*). No phosphorus was detected in this knife.

Knife 2743

X-radiography of this knife showed that it was well preserved. There was no evidence for the presence of a weld line but the cutting edge had the classic spotted texture. The x-radiograph also revealed the presence of a series of notches, or possibly decoration, on the knife back.

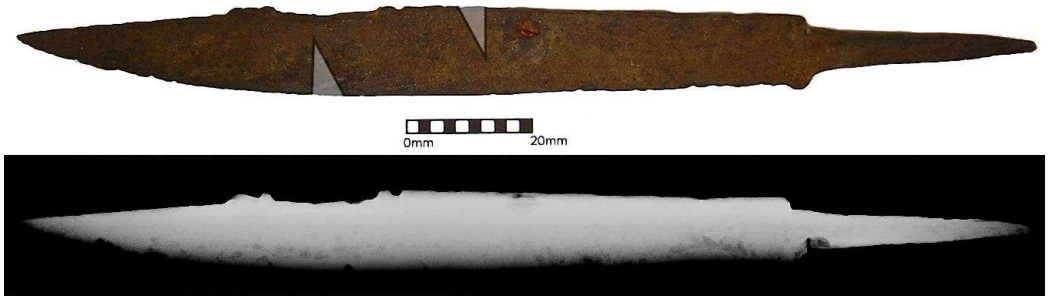


Figure 13.24: Photograph and x-radiograph of knife 2743, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. This revealed a clear weld line in the cutting edge section consisting of many single-phased sub-angular inclusions. Below this weld line there were some single-phased, sub-rounded inclusions. In the knife back section there was a band of inclusions which suggested another weld line. The centre of the knife back had few single-phased inclusions, while further towards the knife back the inclusions were larger, multi-phased and sub-angular.

Once etched the weld line was confirmed to be a white weld line, enriched in arsenic with traces of copper (*Average 977HV, Range 927-1027HV*), below which the microstructure consisted of martensite (*1144HV, Average 992HV, Range 841-11441HV*). SEM-EDS analysis also suggested the presence of arsenic in the cutting edge (0.1-0.2%). There was some carbon diffusion across the weld line into the back resulting in ferrite with pearlite. The back consisted of three pieces of iron. Closest to the weld line the iron consisted of medium grains of ferrite (ASTM 3-4, *Average 197HV, Range 175-232HV*). The central area consisted of small grains of ferrite with some pearlite at the grain boundaries, and in areas tempered martensite (ASTM 6-7, *Average 324HV, Range 210-509HV*). The final piece of iron further towards the back consists of medium to large grains of ferrite (ASTM 2-3, *Average 141HV, Range 120-201HV*). No phosphorus was detected in this knife.

Knife 2758

The x-radiograph of knife 2758 revealed no evidence for the presence of a weld line but the classic spotted texture was present at the cutting edge.

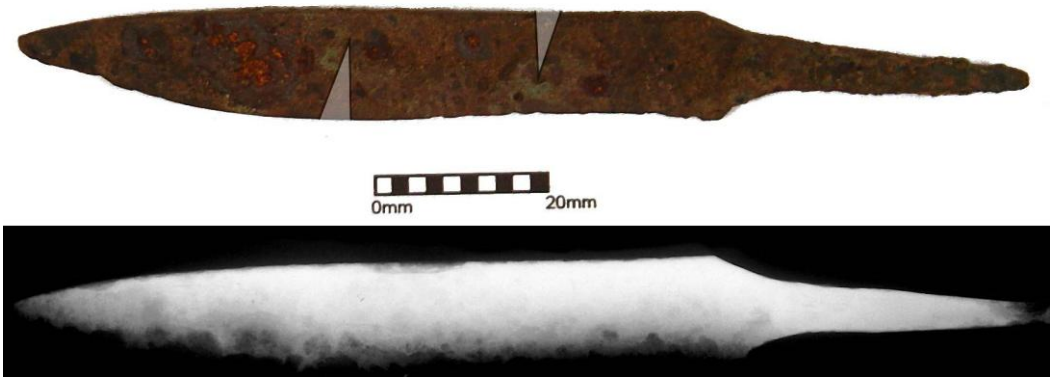


Figure 13.25: Photograph and x-radiograph of knife 2758, the lines show where the sections were removed.

Examination of the knife in the unetched condition revealed no evidence for a weld line. In the cutting edge there were very few inclusions, and those present were mostly small and single-phased. In the cutting edge needles were clearly seen prior to etching. The knife back seemed to consist of two strips of metal bent around a core, separated by elongated and sub-angular single-phased inclusions. The core like the cutting edge had very few inclusions. The other two strips of metal had small single-phased elongated or sub-rounded inclusions. Small filaments of metal were clearly seen prior to etching at the grain boundaries.

When etched the cutting edge appeared to have been constructed from two pieces of metal. The one that formed the tip of the cutting edge was a low carbon 0.2-0.1% small grained (ASTM 6) ferrite with pearlite (*232HV, Average 183HV, Range 143-232HV*) while the other half was ferrite with some grain boundary carbides and/or pearlite (ASTM 3-4, *Average 130HV, Range 114-148HV*). Needles were seen throughout the cutting edge section, but mostly in the second piece of iron. The inclusions in the back separated two different microstructures, the core which consisted of small grains of ferrite with a grain boundary filament, the same seen prior to etching (ASTM 4-5, *Average 130HV, Range 97-145HV*). The back of the knife had larger grains but the same filament (ASTM 1-2, *Average 117HV, Range 103-127HV*). Throughout the back section ghosting was

present suggesting a phosphoric iron, but SEM-EDS analysis revealed very little evidence for phosphorus, although traces of phosphorus were detected in the grain boundary filament. This knife was of type 3 manufacture with many pieces of iron welded together to create a piled knife. The needles suggest that the knife may have been exposed to extreme heat-treatment, although it is possible that they resulted from an accidental fire, i.e. house fire.

Knife 4485

The x-radiograph of knife 4485 suggested that the knife was badly corroded in areas. There was no evidence for the presence of a weld line but the classic spotted texture was present throughout the knife.

Figure 13.26: Photograph and x-radiograph of knife 4485, the lines show where the sections were removed.

There were no clear weld lines instead the knife appeared to be fairly homogenous with very few single phased inclusions. The back of the knife had more inclusions, often larger and more angular, than the cutting edge.

When etched the cutting edge section predominately consisted of martensite (*1283HV, Average 957HV, Range 509-1283HV*). This knife section also seemed to have increased quantities of arsenic (up to 0.3%). The back section of the knife was more heterogeneous, although the majority of the back consisted of martensite and pearlite. Even though there was no clear weld line, one area of the knife had a dramatically different microstructure consisting of ferrite with pearlite ranging from 0.2%-0.4% carbon (ASTM 3-6, *Average 229HV, Range 161-321HV*), although chemically no difference could be detected.

Knife 7306

The x-radiograph of this knife revealed a clear dark striation which ran along the knife, suggestive of a weld line. Below the weld line the cutting edge did not have the usual spotted texture. Above this weld line another fainter line was also visible.

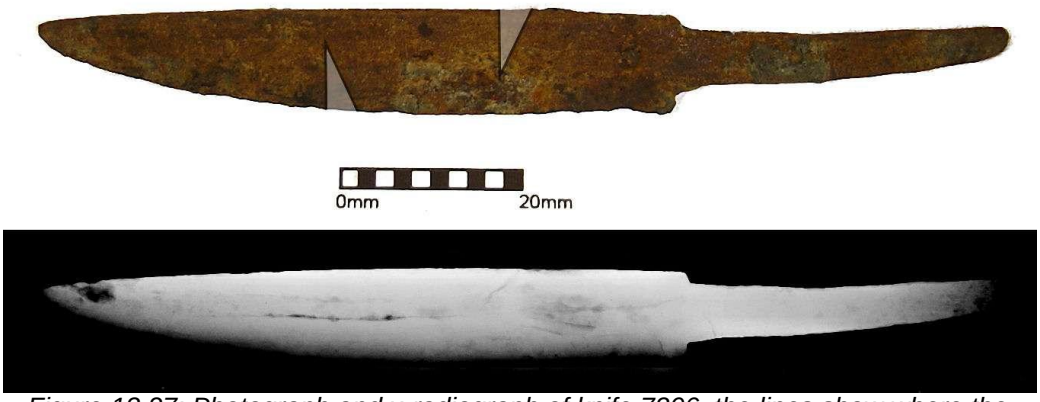


Figure 13.27: Photograph and x-radiograph of knife 7306, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. In the cutting edge section there were lots of single-phased angular inclusions. There was heavy corrosion penetration resulting in the back section being split into two. Below the area of corrosion there was a line single-phased, sub-rounded inclusions and a raised area suggesting a weld line. The rest of the back consisted of lots of bands of inclusions single-phased, between which the inclusions were smaller, rounded and single-phased.

When etched the cutting edge consisted of predominately martensite (*927HV, Average 906HV, Range 644-1027HV*). The knife back consisted of bands of large grained ferrite (*ASTM 1*) with no pearlite but with lots of ghosting around the inclusions (*Average 328HV, Range 271-426HV*). SEM-EDS analysis confirmed the presence of phosphorus and arsenic, but also traces of nickel. Etching revealed the presence of a faint white weld line separating the ferrite back from the martensite, although SEM analysis proved difficult and only phosphorus was detected (*Average 374HV, Range 303-457HV*). There was very little carbon diffusion across the weld line.

Knife 10627

The x-radiograph of knife 10627 suggested that the knife was badly corroded in areas. There was no evidence for the presence of a weld line but the classic spotted texture was present in the cutting edge.

Figure 13.28: Photograph and x-radiograph of knife 10627, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition, which revealed that there were two, or more vertical slag inclusion bands, consisting of single- and multi-phased inclusions mostly elongated, these bands seem to join together. Between these bands the inclusions were small, single-phased and elongated. In the two flanks to either side were larger, sub-rounded and single- and multi-phased, in the back section these inclusions were larger.

When etched the two bands separated a central strip which consisted of a pearlite cutting edge (*386HV, Average 343HV, Range 303-386HV*), with pearlite and ferrite in areas. SEM-EDS analysis revealed the presence of arsenic and traces of some phosphorus. One of the vertical bands also had a white weld line, enriched in arsenic (*Average 276HV, Range 257-294HV*). To either side of these bands the microstructure consisted of mild steel (up to 0.4%) of ferrite with pearlite (ASTM 5-6, *Average 194HV, Range 154-264HV*). Extensive carbon diffusion across the weld line had resulted in a higher carbon content in one piece of iron. The knife back was particularly heterogeneous with varying amount of ferrite and pearlite and grain sizes (0.2-0.4% carbon, ASTM 5-8, *Average 278HV, Range 192-386HV*)

Knife 10964

X-radiography of this knife showed that there was a hint of a weld and the cutting edge had the classic spotted texture.

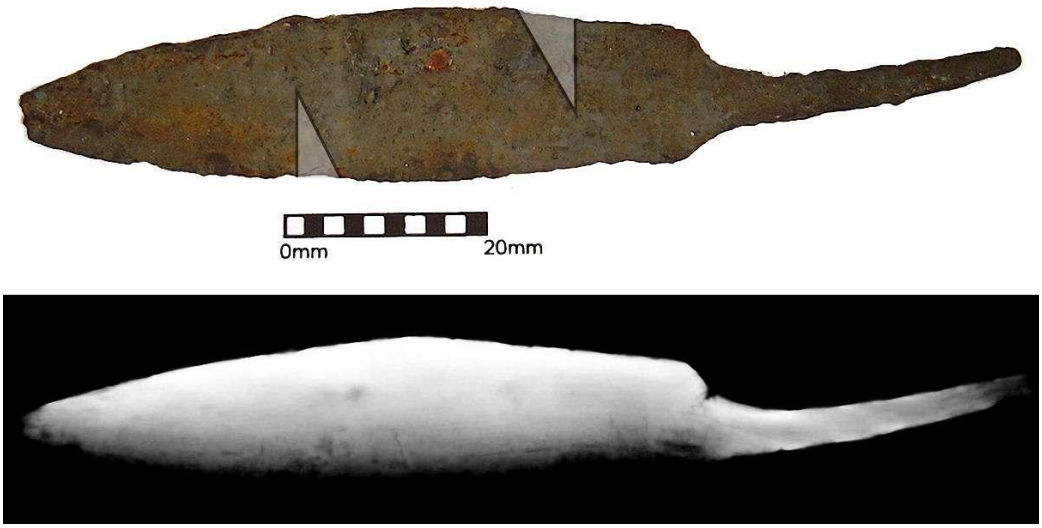


Figure 13.29: Photograph and x-radiograph of knife 10964, the lines show where the sections were removed.

Examination of the knife in the unetched condition revealed no evidence for a weld line in either section. The cutting edge section had many angular and elongated single-phased inclusions. The knife back had many areas with different types of inclusions, although no bands seemed to separate them. The majority of inclusions were single-phased and angular or sub-rounded. One area had a large number of inclusions, some of which were multi-phased.

After etching a weld line at the bottom of the knife back section became clear, due to the presence of a faint white weld line, enriched in arsenic and nickel (*Average 344HV, Range 330-362HV*) and a line of very small single-phased rounded inclusions. There was significant carbon diffusion across this weld line. The cutting edge section consisted of martensite (*1283HV, Average 868HV, Range 412-1283HV*). Above the cutting edge the knife back was heterogeneous with different bands of iron; ranging from large grains of ferrite corresponding to the multi-phased inclusions (ASTM 1-2, *Average 150HV, Range 132-168HV*), to bands of mild steel ferrite with pearlite (0.2-0.4% carbon, ASTM 7-6, *Average 228HV, Range 221-232HV*), and bands of medium grained ferrite with pearlite (ASTM 3-4, *Average 188HV, Range 179-201HV*).

Knife 13190

The x-radiograph of knife revealed near the back of the knife a clear dark striation which ran from the shoulder into the knife, suggestive of a groove. There was no evidence for a weld line, instead the classic spotted texture was seen throughout the knife.

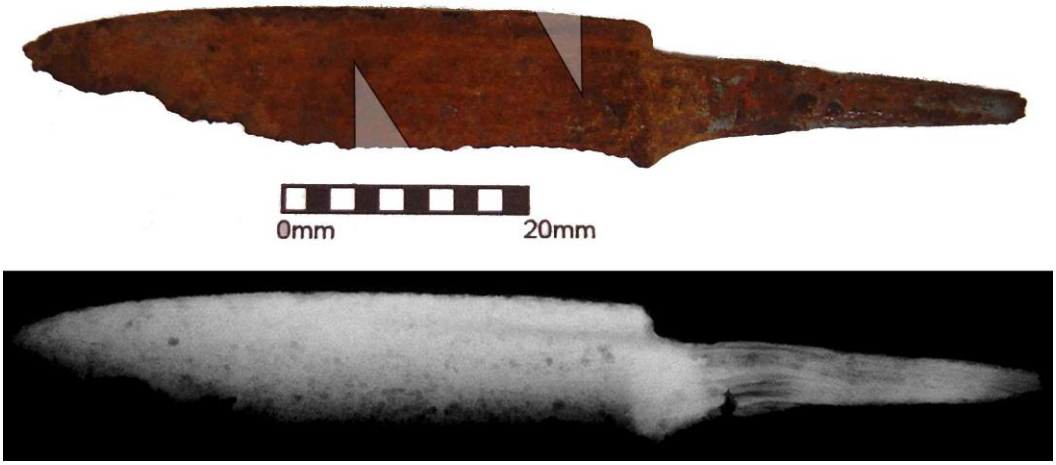


Figure 13.30: Photograph and x-radiograph of knife 13190, the lines show where the sections were removed.

Two sections were removed and examined in the unetched condition. In the cutting edge section there was a clear raised weld line, with some single-phased and sub-angular inclusions. Below this weld line there were very few inclusions and those present were small and single-phased. The back section consisted of many inclusions mostly multi-phased and sub-rounded.

When etched the cutting edge consisted of predominately martensite (*1027HV, Average 1040HV, Range 644-1283HV*). Etching revealed the presence of a clear white weld line, separating the ferrite back from the martensite, which SEM-EDS analysis revealed was enriched in arsenic and nickel (*Average 349HV, Range 286-412HV*). There was very little carbon diffusion across the weld line. The knife back consisted of medium to large grains of ferrite (*ASTM 2-3*) with no pearlite or ghosting (*Average 178HV, Range 148-221HV*), although low concentrations of phosphorus was detected in some areas (up to 0.2%).

Knife 16082

This knife had a curved back with a distinct tang to blade interface. The x-radiograph of this knife revealed multiple clear dark striations suggestive of a weld line. Below this the cutting edge had a spotted texture. There was no evidence of wear.

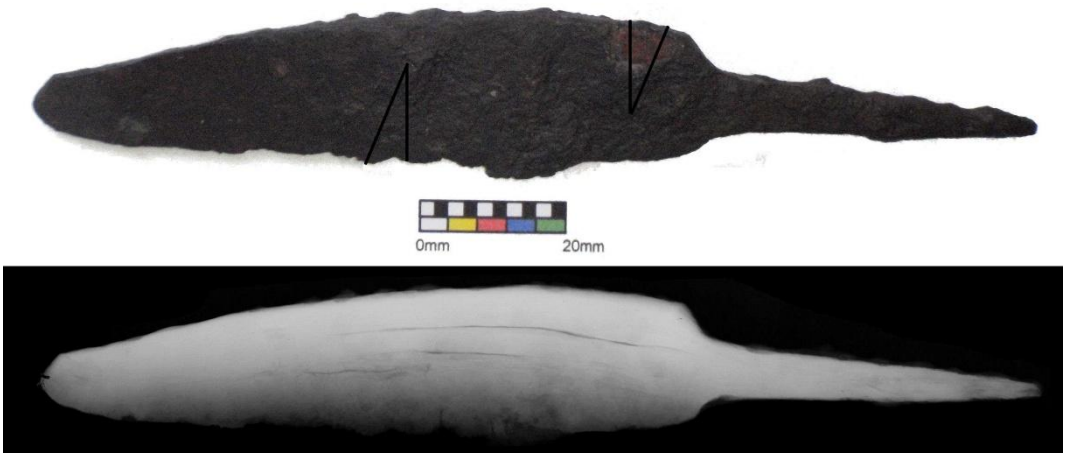


Figure 13.31: Photograph and x-radiograph of knife 16082, the lines show where the sections were removed.

The cutting edge section had sub-angular and sub-rounded, single-phased inclusions. Corrosion had penetrated the knife back following the weld line of small, rounded single-phased inclusions. The knife back had sub-angular slag inclusions. When etched the cutting edge was revealed to be tempered martensite which transformed into pearlite closer to the weld line (644*HV,* Average 510*HV,* Range 271-701*HV*). There was some diffusion across the weld line into the back of the knife which was medium grains of ferrite (Average 261*HV,* Range 192-321*HV*). SEM analysis of the knife back revealed the presence of phosphorus (0.1-0.2%).

This was a type 2 knife with a steel cutting edge scarf welded to a phosphoric iron back. The knife had been heat-treated resulting in a tempered martensite cutting edge.

High Street Knife Descriptions

Knife 1114

This knife had a curved back with a distinct tang to blade interface. The x-radiograph revealed a homogenous structure with no evidence for weld lines or the spotted texture. There was some evidence of wear resulting in an S-shaped curve.

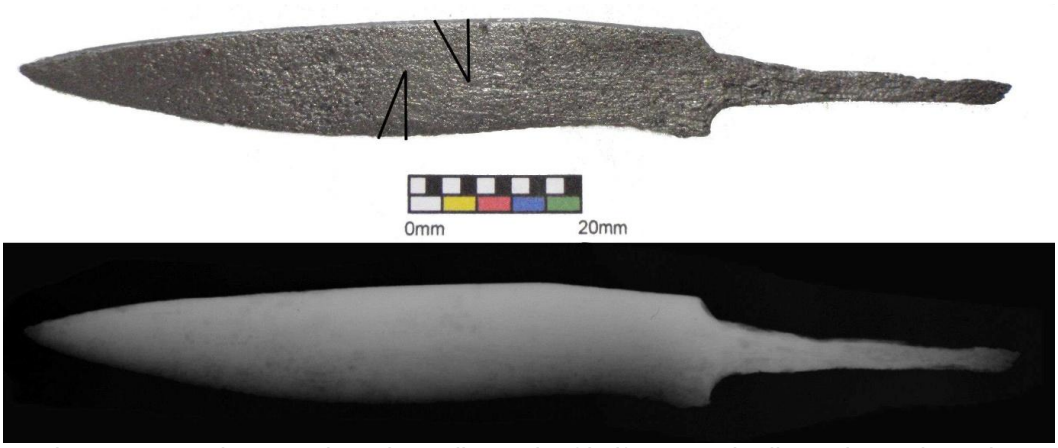


Figure 13.32: Photograph and x-radiograph of knife 1114, the lines show where the sections were removed.

The cutting edge section had many sub-angular and elongated single-phased inclusions. The back section also had many single-phased, sub-angular inclusions. There was no evidence for any weld lines. Once etched the sections were revealed to consist predominately of martensite (1144*HV*, Average 1022*HV,* Range 644-1144*HV*). In the cutting edge there were many white bands which were not related to any slag inclusions. These bands were enriched in arsenic (1.3-1.5%) and had a lower hardness value than the surrounding microstructures (Average 511*HV,* Range 473-549*HV*). The back section consisted of two main areas. The first related to the cutting edge was martensite with pearlite (Average *898HV,* Range 766-1144*HV*) which closer to the knife back was pearlite (Average 697*HV,* Range 473-1027*HV*). The other area had ferrite with carbides at the grain boundary, there was also pearlite in areas and large amounts of ghosting (Average 304*HV,* Range 257-362*HV*). SEM analysis of this area revealed the presence of phosphorus (0.3-0.4%).

Knife 1708

Knife 1708 had a curved back and a distinct tang to blade interface. The x-ray revealed a clear spotted texture at the cutting edge. There was no evidence for a weld line although near the tang interface there was more corrosion present. The x-ray also revealed a clear S-shaped curve suggesting some wear.

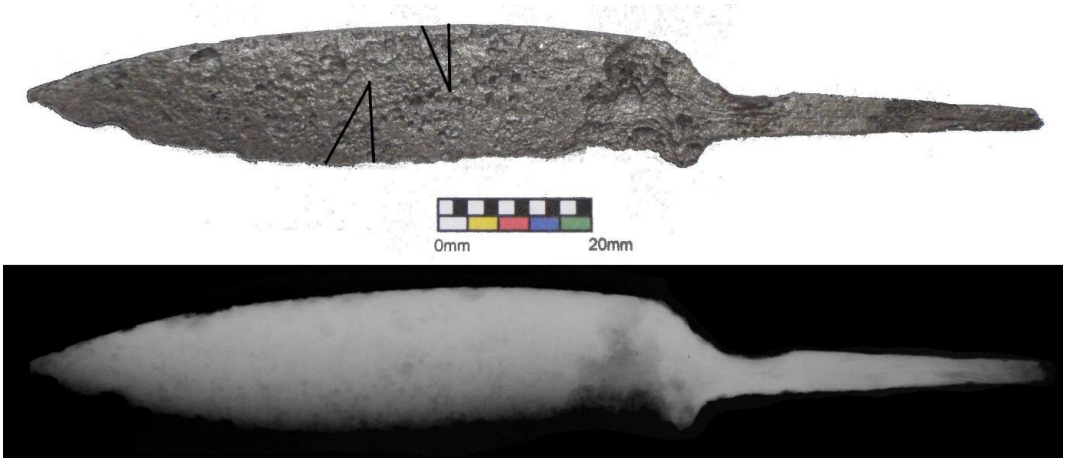


Figure 13.33: Photograph and x-radiograph of knife 1708, the lines show where the sections were removed.

In the un-etched condition there was a clear band of sub-rounded, multi-phased inclusions from the cutting edge to one corner of the knife back. To one side of these inclusions there were few sub-rounded, single- and multi-phased inclusions. The inclusions in the other side of the knife were large, sub-rounded, single- and multi-phased. When etched it was clear that there were two separate sides. The cutting edge side had martensite with some pearlite (1283*HV,* Average *1230HV,* Range 1144-1283*HV*). This reverts to pearlite, ferrite with pearlite (Average 559*HV,* Range 386-701*HV*) and then ferrite with grain boundary pearlite in the back section (Average 399*HV,* Range 340-509*HV*). The other side of the knife consisted of large grained ferrite with ghosting, this with the high hardness suggests a phosphoric iron (Average 377*HV,* Range 321-441*HV*). This was confirmed by SEM analysis which revealed (0.3-0.7%). Arsenic was present throughout the knife (0.1-4%) although no white weld lines were present.

Knife 10012

The knife had a straight back and the tang to blade interface is distinct on one side only. There was no weld line obvious in the x-radiograph or any spotted texture. The cutting edge had a slightly S-curved shape suggesting some wear.

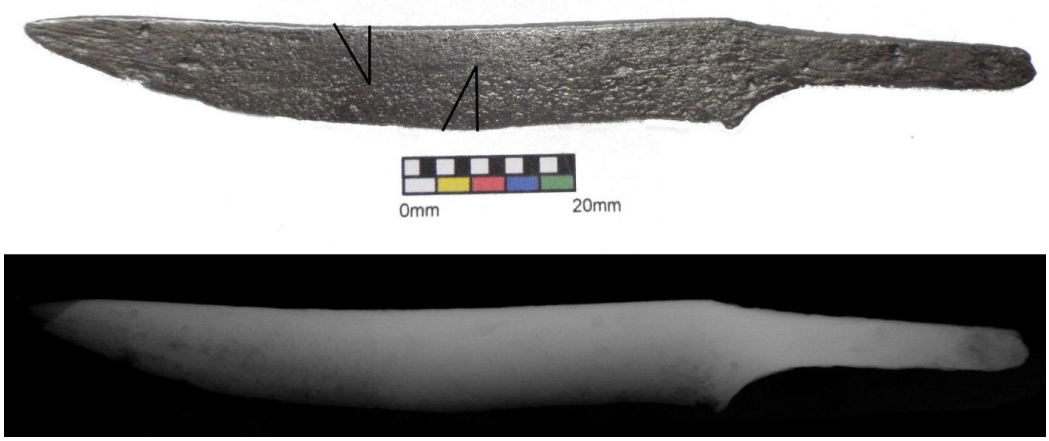


Figure 13.34: Photograph and x-radiograph of knife 10012, the lines show where the sections were removed.

There was no clear weld lines present in either section of the knife. The cutting edge section had a few sub-angular and single-phased inclusions. The back section had two separate areas of inclusions; there were predominately multi-phased, sub-rounded and spherical single-phased inclusions. The very back of the knife had fewer small sub-rounded, single-phased inclusions. Once etched the two half sections were clearly very different. The cutting edge consisted predominately of martensite and martensite with pearlite (Average 1041*HV,* Range 412-1283*HV*). SEM analysis of this area revealed the presence of nickel (0.1-0.2%), and traces of phosphorus and arsenic. The back section of the knife consisted of large grains of ferrite suggesting a phosphoric iron (Average 281*HV,* Range 183-412*HV*) confirmed by SEM analysis (0.2-0.3% phosphorus). Right at the back of the knife the microstructure of the knife changes to pearlite with bainite in areas (Average 414*HV,* Range 286-593*HV*).

Knife 10069

Knife 10069 was badly corroded and had a curved back and a distinct tang to blade interface on one side only. There was extensive wear of the cutting edge. The x-radiograph revealed corrosion throughout the knife.

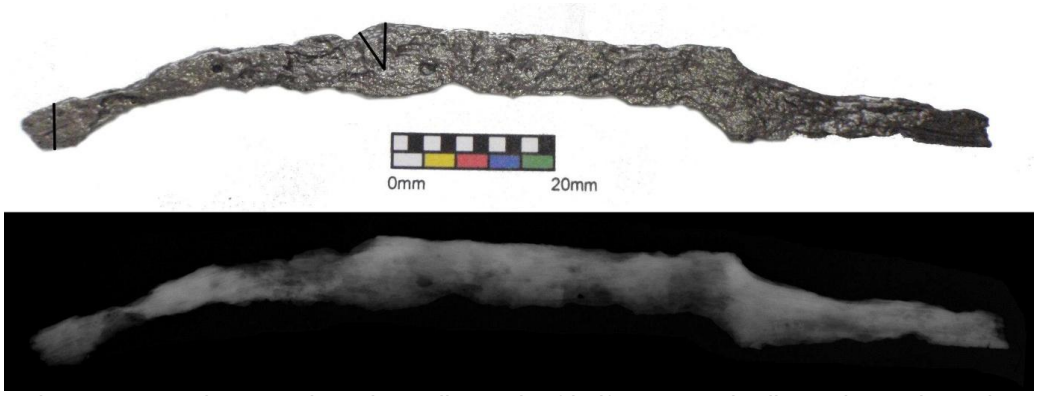


Figure 13.35: Photograph and x-radiograph of knife 10069, the lines show where the sections were removed.

The sections revealed two halves, separated by a band of small single- and multi-phased, rounded and sub-rounded inclusions. To one side the inclusions are elongated or sub-angular and single-phased. The other side had large single-phased, sub-rounded inclusions. When etched the two sides were both ferrite, one had small grains with some carbides (321*HV,* Average 322*HV,* Range 244-412*HV*) while the other had large grains (Average 372*HV,* Range 183-509*HV*). The SEM analysis revealed traces of phosphorus throughout the knife with more present in the half with large grains, confirming a phosphoric iron.

Knife 10369

This knife had a straight back and a distinct tang to blade interface on both sides. There was only slight evidence of wear. The x-radiograph of this knife revealed no dark striations suggesting weld lines. There was slight evidence for a spotted cutting edge but this may have just been the result of corrosion at the cutting edge.

Figure 13.36: Photograph and x-radiograph of knife 10369, the lines show where the sections were removed.

Prior to etching the inclusions revealed a clear type 1 knife. The middle section of the knife had no inclusions. To either side of this band there were many single- and multi-phased, sub-rounded and elongated inclusions. When etched the middle band was revealed to be tempered martensite (473*HV,* Average *429HV,* Range 340-549*HV*), which closer to the knife back was ferrite and pearlite (Average *266HV,* Range 192-362*HV*). To either side there were white weld lines these were enriched in phosphorus rather than arsenic (Average *342HV,* Range 321-362*HV*). To either side of this band there were multiple bands suggesting piled iron, ferrite with carbides (Average *171HV,* Range 127-210*HV*). SEM analysis revealed traces of phosphorus in some of the bands to either side of the central steel strip.

Winetavern Street and John's Lane Knife Descriptions

Knife 323

Knife 323 had a straight back with a distinct tang to blade interface. The x-radiograph revealed a badly corroded cutting edge, but also that the corrosion had penetrated areas of the knife. The corrosion picked out multiple striations suggesting a type 2 knife. There was no evidence for a spotted texture.

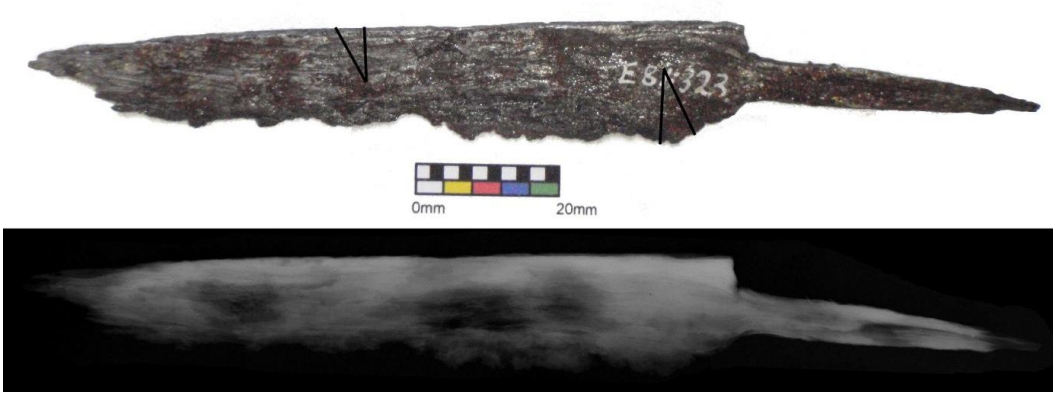


Figure 13.37: Photograph and x-radiograph of knife 323, the lines show where the sections were removed.

The cutting edge section had a convex curve of small spherical multi-phased slag inclusions. This separated the cutting edge which had very few single-phased, angular inclusions from the back of the section which had some sub-rounded single-phased slag inclusions. The back section was separated into three areas by corrosion which had penetrated the back. Each area had different slag inclusion distributions; the first area had no slag inclusions, the middle section had multi-phased, sub rounded inclusions and the third area had single-phased, elongated and sub-angular inclusions. When etched the cutting edge was martensite (1144*HV,* Average *1077HV,* Range 927-1144*HV*) this was separated from the back by a white weld line (Average *927HV*). SEM analysis revealed arsenic present in the weld line (0.3%). There was carbon diffusion across the weld line, resulting in martensite and pearlite. The back was constructed in two pieces of ferrite with some pearlite and the middle section had pearlite with ferrite (0.4-0.6% carbon, Average *402HV,* Range 362-473*HV*). SEM analysis of the pieces of iron in the back revealed that although both the sides were ferrite with pearlite, both were different, one containing arsenic (0.2-0.3%*,* Average *300HV,* Range 221-386*HV*) while the other didn't (Average *276HV,* Range 221-321*HV*).

Knife 589

This knife had a straight back with a distinct tang to blade interface. The x-radiograph revealed a badly corroded cutting edge, but also that the corrosion had penetrated areas of the knife. The corrosion picked out multiple striations suggesting a type 2 knife. There was no evidence for a spotted texture.

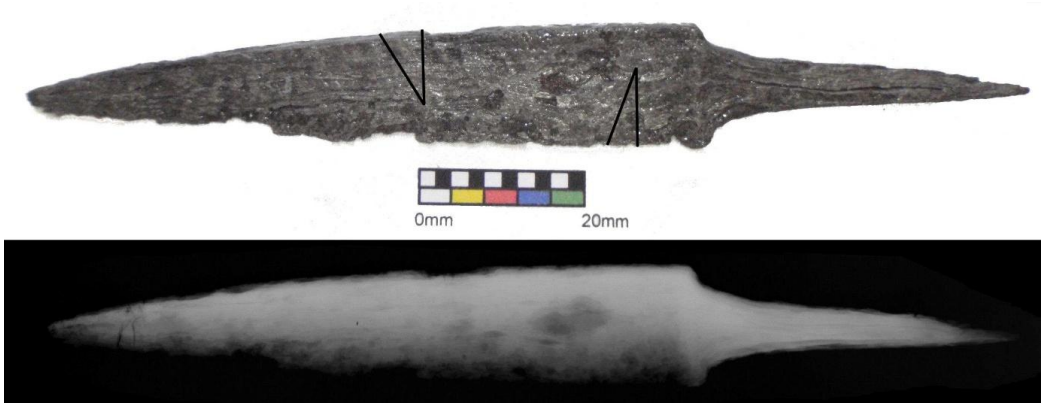


Figure 13.38: Photograph and x-radiograph of knife 589, the lines show where the sections were removed.

The cutting edge consisted of areas with different slag inclusions. The cutting edge had some large single-phased sub-rounded inclusions. Further up the knife the inclusions were small, elongated or sub-rounded and single phased. Right at the back of the knife the inclusions are sub-angular and single-phased. When etched the knife seemed to be the wrong way round. The tip of the cutting edge was medium grains of ferrite (161*HV,* Average *205HV,* Range 161-221*HV*). Above this area there were small grains of ferrite (Average *230HV,* Range 175-303*HV*) with ghosting in some areas suggesting phosphoric iron (Average *201HV,* Range 192-226*HV*). SEM analysis found only traces of phosphorus (<0.1%), although arsenic was found throughout the knife (0.1-0.4%) possibly explaining the white bands visible. The very back of the knife consisted of bainite with martensite in areas, suggesting the presence of a carbon steel (Average *807HV,* Range 473-1027*HV*). This knife was a type 0 plain ferritic iron knife, which had a high carbon content at the back. It has been heat-treated resulting in martensite forming.

Knife 3971

This knife had a straight back with a distinct tang to blade interface. The x-radiograph revealed a homogenous structure with no evidence for weld lines or the spotted texture. There was evidence of wear resulting in a slight S-shaped curve.

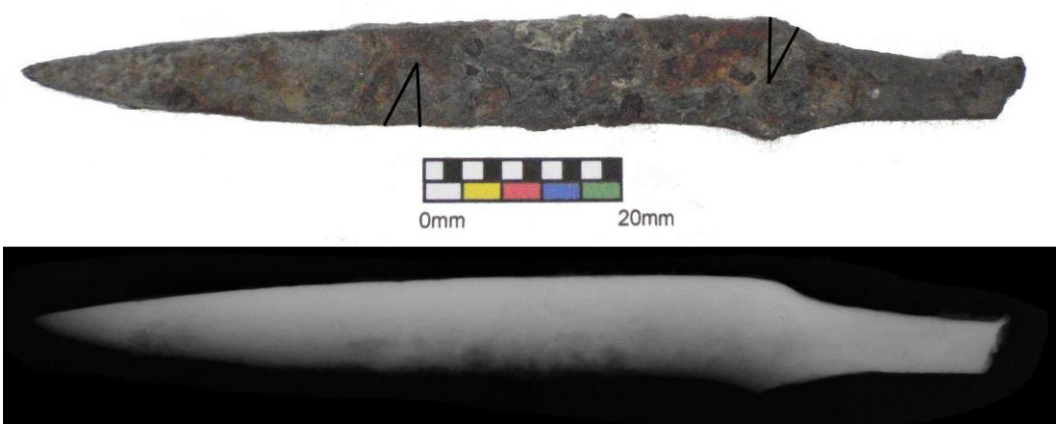


Figure 13.39: Photograph and x-radiograph of knife 3971, the lines show where the sections were removed.

Prior to etching there were two clear bands of sub-rounded single phased inclusions which separated a central strip with single-phased, elongated or sub-angular inclusions. The flanks to either side had lots of multi-phased inclusions some of which were large. When etched the sections revealed a clear type 1 knife with a tempered martensite (509*HV,* Average *556HV,* Range 412-841*HV*) core which changed to pearlite and then ferrite with pearlite closer to the knife back (Average *297HV,* Range 232-362*HV*). The two bands of inclusions turned out to be white weld lines which were enriched in arsenic (0.3%), nickel (0.2-0.3%) and copper (0.2%). The two flanks were similar in microstructure with some carbon diffusion across the weld lines into the large grains of ferrite, which also had ghosting (Average 302*HV,* Range 257-340*HV*). SEM analysis confirmed the presence of large quantities of phosphorus (0.4-0.6%) indicating a phosphoric iron.

Analysis of this knife has revealed a typical type 1 knife with a steel cutting edge sandwiched between two pieces of phosphoric iron. This knife has also been heat-treated, quenched and tempered, resulting in a tempered martensite cutting edge.

Knife 4974

This knife had a curved back with a distinct tang to blade interface. The x-radiograph revealed a possible spotted texture at the cutting edge but no evidence for a weld line. There was evidence of wear resulting in an slight S-shaped curve.

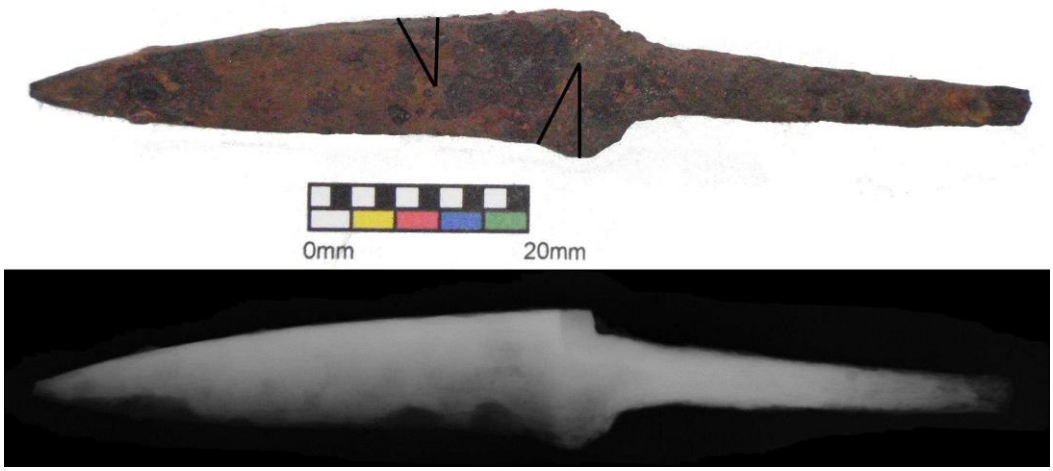


Figure 13.40: Photograph and x-radiograph of knife 4974, the lines show where the sections were removed.

Prior to etching there were three different areas of inclusions. The central area had small single-phased rounded slag inclusions. The areas to either side had sub-rounded or elongated, single-phased inclusions. When etched the sections revealed a clear type 1 knife with a bainite cutting edge (593*HV)* core which changed to pearlite with ferrite closer to the knife back (Average *339HV,* Range 286-593*HV*). There were two white weld lines either side of the central strip which were enriched in arsenic (0.5%). The two flanks were similar in microstructure with some carbon diffusion across the weld lines into the large grains of ferrite with some carbides at the grain boundaries, which also had ghosting (Average 362*HV,* Range 303-412*HV*). SEM analysis confirmed the presence of large quantities of phosphorus (0.4-0.7%) indicating a phosphoric iron.

Knife 604

This knife had an angle-backed with a distinct tang to blade interface on one side only. The x-radiograph revealed a homogenous structure with no evidence for weld lines or the spotted texture. There was some evidence of wear resulting in an slight S-shaped curve.

Figure 13.41: Photograph and x-radiograph of knife 604, the lines show where the sections were removed.

There was a clear concave weld line made up of elongated, sub-angular, multi-phased slag inclusions. Below this the cutting edge had elongated, single-phased inclusions. Above the weld line there were sub-angular, multi-phased inclusions, some were quite large which seemed to separate different areas. When etched the weld line turned out to be a white weld line (Average *312HV,* Range 303-321*HV*) which was enriched in arsenic (0.2-0.4%), nickel (0.2-0.4%) and copper (up to 0.2%). The cutting edge consisted of bainite, which became ferrite with pearlite at the weld line (509*HV,* Average 381*HV,* Range 286-509*HV*). The knife back consisted of several different areas, and the slag inclusions and corrosion suggest that it was piled. Just above the weld line there were small to medium grains of ferrite (Average 226*HV,* Range 201-271*HV*) while further up in the back the microstructure turned into medium to large grains (Average 182*HV,* Range 161-192*HV*). In one area of the knife back there was pearlite with ferrite (Average 355*HV,* Range 340-386*HV*). Traces of arsenic were present in the knife back (up to 0.2%) along with traces of phosphorus (up to 0.1%).

Knife 4437

This knife had an angle back with a distinct tang to blade interface. The x-radiograph revealed a corroded cutting edge. The corrosion picked out the spotted texture but no presence of striations. There was a slight curve to the cutting edge suggesting slight wear.

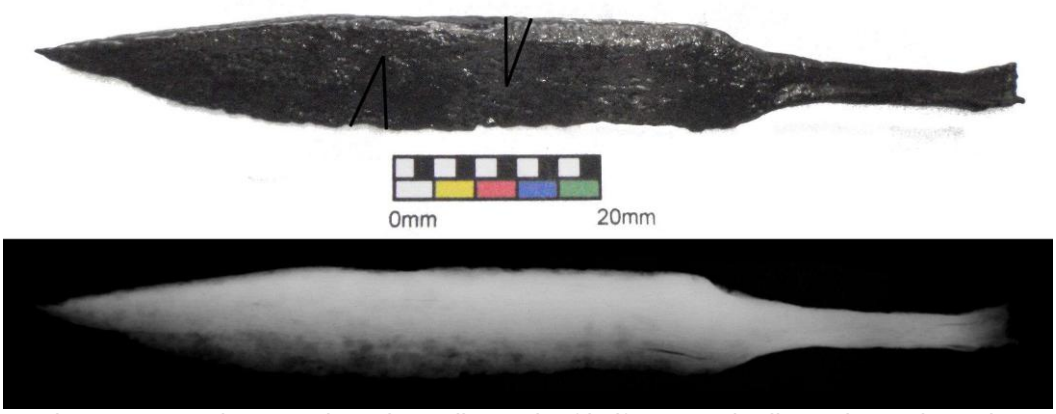


Figure 13.42: Photograph and x-radiograph of knife 4437, the lines show where the sections were removed.

The cutting edge had single-phased, sub-angular inclusions. Further up the knife there was two bands of small, sub-rounded and single phased inclusions. The tip of the cutting edge was small grains of ferrite with bainite in areas (490*HV,* Average *464HV,* Range 321-593*HV*). SEM analysis revealed the presence of phosphorus at the cutting edge (0.6-0.7%). Further towards the knife back the iron increased in carbon to ferrite with pearlite (0.1-0.2% carbon, Average 358*HV,* Range 340-412*HV*). Further towards the knife back the microstructure reverted to ferrite with carbides (Average 346*HV,* Range 321-386*HV*) and then ferrite with some pearlite (Average 362*HV,* Range 340-386*HV*). There were multiple white weld lines visible in the knife back, although there was no evidence for arsenic. Phosphorus was also present throughout the knife (0.1-0.3%). This knife was a type 0 plain low carbon iron knife, which had a slightly higher carbon content at the back. It has been heat-treated resulting in bainite forming at the cutting edge.

SEM-EDS Data

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
1047	Cutting Edge 1	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	104.6
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	107.7
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	0.1	n.d.	108.4
	Cutting Edge 2	n.d.	n.d.	n.d.	n.d.	99.6	0.2	n.d.	0.1	107.7
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	110.2
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	107.7
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	108.2
		n.d.	n.d.	n.d.	0.1	99.4	n.d.	n.d.	0.3	110.6
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	107.9
		n.d.	n.d.	n.d.	n.d.	99.7	0.2	n.d.	n.d.	107.2
	Knife Back 1	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	105.0
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	104.5
		2.6	n.d.	n.d.	n.d.	97.2	n.d.	n.d.	n.d.	95.4
	Knife Back 2	n.d.	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.2	98.0
		n.d.	n.d.	n.d.	n.d.	99.5	n.d.	n.d.	0.3	98.2
	Knife Back 3	0.1	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	93.6
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	93.1
6255	Cutting Edge	n.d.	0.2	n.d.	n.d.	99.4	0.1	n.d.	n.d.	101.9
		n.d.	0.3	n.d.	0.1	99.2	n.d.	n.d.	0.2	99.9
	Cutting Edge (Low carbon)	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	98.0
		n.d.	0.2	n.d.	n.d.	99.5	n.d.	n.d.	0.2	99.0
	Knife Back 1	n.d.	0.2	n.d.	n.d.	99.6	n.d.	n.d.	0.1	95.7
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.1	95.3
		n.d.	n.d.	n.d.	n.d.	99.7	0.2	n.d.	n.d.	92.8
	Knife Back 2	n.d.	n.d.	0.1	n.d.	99.8	n.d.	n.d.	n.d.	89.8
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	90.4
		0.1	n.d.	n.d.	n.d.	99.5	n.d.	n.d.	0.3	89.6
8891	Cutting Edge 1	n.d.	n.d.	n.d.	0.2	99.6	n.d.	n.d.	0.1	95.7
		n.d.	n.d.	n.d.	n.d.	99.5	n.d.	0.2	0.2	94.4
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.2	0.1	92.7
	Cutting Edge 2	n.d.	0.1	0.1	n.d.	99.1	n.d.	n.d.	0.6	90.2
		n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	89.8
		n.d.	0.2	n.d.	n.d.	99.3	n.d.	n.d.	0.4	87.0
	Knife Back 1	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.2	n.d.	82.7
		n.d.	n.d.	n.d.	n.d.	99.2	0.1	0.4	0.2	81.0
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.4	n.d.	0.1	0.3	80.6
		n.d.	n.d.	n.d.	n.d.	97.7	0.2	n.d.	1.9	76.6
	Knife Back 2	n.d.	0.1	n.d.	n.d.	98.2	n.d.	0.3	1.3	75.4
		n.d.	0.3	n.d.	n.d.	98.8	n.d.	n.d.	0.7	74.4
		n.d.	0.2	n.d.	n.d.	98.9	n.d.	0.2	0.6	74.8
	Knife Back 3	n.d.	0.1	n.d.	n.d.	99.3	n.d.	0.3	0.2	71.8
		n.d.	0.2	n.d.	n.d.	99.3	n.d.	0.1	0.3	70.9
		n.d.	n.d.	n.d.	n.d.	99.5	n.d.	n.d.	0.2	69.8

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
11635	Cutting Edge 1	0.1	n.d.	n.d.	n.d.	99.2	n.d.	n.d.	0.6	90.2
		n.d.	n.d.	n.d.	n.d.	99.2	0.2	n.d.	0.6	95.3
		n.d.	0.1	0.1	n.d.	98.5	0.1	0.1	0.8	106.0
		n.d.	n.d.	n.d.	n.d.	99.2	n.d.	0.1	0.6	104.1
	Cutting Edge 2	n.d.	0.2	n.d.	n.d.	99.2	n.d.	n.d.	0.6	102.3
		n.d.	0.2	n.d.	0.1	99.3	n.d.	n.d.	0.4	99.5
	White Weld Line	n.d.	0.1	n.d.	n.d.	97.0	0.2	0.5	2.3	77.0
		n.d.	n.d.	n.d.	n.d.	97.4	n.d.	n.d.	2.5	74.5
	Knife Back 1	n.d.	0.3	n.d.	n.d.	99.2	n.d.	n.d.	0.5	97.8
		n.d.	0.3	n.d.	n.d.	98.7	n.d.	n.d.	0.8	95.1
		n.d.	0.2	n.d.	0.1	99.2	0.2	n.d.	0.2	92.5
		0.1	0.2	n.d.	n.d.	99.3	n.d.	n.d.	0.3	89.6
	Knife Back 2	n.d.	0.4	n.d.	n.d.	99.0	n.d.	n.d.	0.5	87.2
		0.1	0.2	n.d.	n.d.	99.0	n.d.	n.d.	0.6	85.3
		n.d.	0.3	n.d.	n.d.	98.8	n.d.	0.2	0.7	81.8
		n.d.	0.2	n.d.	n.d.	99.0	n.d.	n.d.	0.7	80.5
12055	Cutting Edge 1	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	100.4
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	99.3
	Cutting Edge 2	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	98.6
		n.d.	0.2	n.d.	0.1	99.5	n.d.	0.1	0.1	98.5
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.3	96.9
		n.d.	n.d.	n.d.	n.d.	99.8	0.2	n.d.	n.d.	92.9
	Left Iron Flank	n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	90.8
		n.d.	0.1	0.1	n.d.	99.5	0.1	n.d.	n.d.	123.9
		n.d.	0.2	n.d.	n.d.	99.4	n.d.	0.3	n.d.	125.2
		n.d.	0.2	n.d.	n.d.	99.4	n.d.	0.3	n.d.	111.3
		n.d.	0.3	n.d.	0.1	99.3	n.d.	n.d.	0.2	96.6
	Right Iron Flank	n.d.	0.2	n.d.	n.d.	99.6	0.1	n.d.	n.d.	92.5
		n.d.	0.2	n.d.	n.d.	99.5	n.d.	0.2	n.d.	76.1
		0.7	n.d.	0.4	0.3	98.6	n.d.	n.d.	n.d.	122.8
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	97.0
		n.d.	0.2	n.d.	0.1	99.4	0.1	n.d.	n.d.	88.3
		n.d.	0.2	n.d.	n.d.	99.5	n.d.	n.d.	n.d.	95.0
12320	Cutting Edge	0.1	n.d.	n.d.	n.d.	99.3	0.1	0.3	0.2	97.6
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.1	94.9
		n.d.	0.2	n.d.	n.d.	99.2	n.d.	0.2	0.3	90.3
		0.2	n.d.	0.1	n.d.	99.5	n.d.	n.d.	n.d.	95.5
	Weld Line	0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	95.6
		0.1	n.d.	n.d.	0.1	99.6	n.d.	n.d.	n.d.	94.8
	Right Iron Flank	n.d.	0.3	n.d.	n.d.	99.3	0.1	0.1	n.d.	93.4
		n.d.	0.4	n.d.	n.d.	99.4	0.1	n.d.	n.d.	91.6
		0.1	0.2	n.d.	n.d.	99.5	n.d.	0.1	n.d.	91.1
	Left Iron Flank	n.d.	0.3	n.d.	n.d.	99.4	n.d.	n.d.	0.2	108.7
		n.d.	0.5	n.d.	0.1	98.9	0.1	0.1	0.1	108.2
		n.d.	0.3	n.d.	n.d.	99.4	n.d.	0.2	n.d.	99.7

Table 13.1: Full table of normalised results from SEM-EDS analysis of knives from Christchurch Place. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
12477	Cutting Edge	n.d.	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.1	104.1
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	103.6
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	103.2
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	102.6
	White Weld Line	n.d.	0.1	n.d.	n.d.	99.2	n.d.	n.d.	0.6	98.5
		n.d.	n.d.	n.d.	n.d.	98.8	n.d.	n.d.	1.1	97.8
	Right Iron Flank	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	100.7
		n.d.	0.1	n.d.	0.1	99.7	n.d.	n.d.	n.d.	99.6
		n.d.	0.2	n.d.	n.d.	99.5	n.d.	n.d.	0.2	98.4
		n.d.	n.d.	n.d.	0.2	99.5	n.d.	n.d.	n.d.	94.5
	Left Iron Flank	n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	102.2
		n.d.	n.d.	n.d.	n.d.	99.6	0.2	n.d.	0.1	102.4
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	99.8
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	n.d.	98.7
12499	Martensite Cutting edge	n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	83.5
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	83.9
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	83.0
	Ferrite	n.d.	n.d.	n.d.	n.d.	99.6	0.1	n.d.	n.d.	100.3
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	102.6
	Ferrite with pearlite	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.2	104.7
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	0.1	93.7
		n.d.	n.d.	0.1	n.d.	99.4	n.d.	n.d.	n.d.	90.7
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	92.0
		n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	n.d.	93.7
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.3	n.d.	0.3	0.2	93.6
		n.d.	n.d.	n.d.	n.d.	99.5	n.d.	0.2	0.2	96.0
12677	Cutting Edge	n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	104.3
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	104.1
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	100.5
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	98.3
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	95.7
	White Weld Line	n.d.	0.6	n.d.	n.d.	99.0	n.d.	n.d.	0.2	94.6
		n.d.	0.1	n.d.	n.d.	99.3	0.2	n.d.	0.4	81.9
	Knife Back 1	n.d.	0.3	n.d.	n.d.	99.4	0.2	n.d.	n.d.	92.0
		n.d.	0.4	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	91.8
	Knife Back 2	n.d.	0.4	n.d.	n.d.	99.3	n.d.	0.1	n.d.	88.4
		n.d.	0.4	n.d.	n.d.	99.4	n.d.	n.d.	n.d.	110.9
	Knife Back 3	n.d.	0.4	n.d.	n.d.	99.4	n.d.	n.d.	n.d.	122.3
		n.d.	0.6	n.d.	n.d.	99.0	0.1	n.d.	0.2	118.5

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
13135	Cutting Edge	n.d.	0.2	n.d.	n.d.	99.4	n.d.	0.2	n.d.	102.3
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	100.4
		n.d.	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.2	99.8
		n.d.	0.1	n.d.	n.d.	99.4	0.2	n.d.	0.2	98.1
		n.d.	n.d.	n.d.	n.d.	99.5	0.1	0.1	n.d.	87.9
	Right Iron Flank 1	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	94.2
		n.d.	n.d.	n.d.	n.d.	99.3	0.2	n.d.	0.2	91.0
		n.d.	0.1	0.1	n.d.	99.4	n.d.	0.1	0.2	89.0
	Right Iron Flank 2	n.d.	0.4	n.d.	n.d.	99.3	n.d.	n.d.	0.3	79.6
		n.d.	0.3	n.d.	n.d.	99.5	0.1	n.d.	n.d.	98.9
		n.d.	0.2	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	94.6
13135	Left Iron Flank 1	n.d.	0.3	n.d.	0.1	99.2	0.2	n.d.	n.d.	86.5
	Left Iron Flank 2	n.d.	0.5	0.1	n.d.	99.1	n.d.	n.d.	n.d.	83.6
		n.d.	0.5	n.d.	n.d.	99.3	n.d.	n.d.	n.d.	80.8
	Left Iron Flank 3	n.d.	0.2	n.d.	n.d.	99.5	0.1	n.d.	n.d.	96.2
		n.d.	0.4	n.d.	n.d.	99.5	n.d.	n.d.	n.d.	92.1
		n.d.	n.d.	0.1	n.d.	99.5	n.d.	0.1	n.d.	88.7
		n.d.	0.1	n.d.	n.d.	99.4	n.d.	n.d.	0.2	86.6
14241	Cutting Edge	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	97.3
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	96.9
		n.d.	0.1	0.2	n.d.	99.6	n.d.	n.d.	n.d.	105.7
		n.d.	n.d.	n.d.	n.d.	99.5	n.d.	n.d.	0.4	107.0
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.5	n.d.	n.d.	0.3	105.9
		n.d.	n.d.	n.d.	n.d.	99.1	n.d.	n.d.	0.8	105.0
	Knife Back 1	n.d.	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.2	103.8
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	104.7
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	100.0
	Knife Back 2	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	100.2
		n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	n.d.	100.3
14491	Cutting Edge	n.d.	n.d.	n.d.	0.4	99.6	n.d.	n.d.	n.d.	95.9
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	94.6
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	92.6
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	94.2
		0.2	n.d.	n.d.	n.d.	99.6	n.d.	0.2	n.d.	91.8
	White Weld Line	n.d.	n.d.	n.d.	n.d.	98.8	0.2	0.2	0.8	93.2
		n.d.	n.d.	n.d.	n.d.	99.5	n.d.	0.1	0.3	94.0
	Knife Back 1	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	91.0
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.1	89.7
	Knife Back 2	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	95.7
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	n.d.	95.6
	Knife Back 3	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	89.4
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	89.5
	Knife Back 4	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	92.2
		0.1	0.2	n.d.	n.d.	99.4	n.d.	n.d.	0.1	92.7

Table 10.1 cont: Full table of normalised results from SEM-EDS analysis of knives from Christchurch Place. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
15910	**Cutting Edge**	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	101.9
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	98.0
		n.d.	n.d.	n.d.	n.d.	99.4	n.d.	0.2	n.d.	105.7
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	94.8
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	95.8
		n.d.	n.d.	n.d.	n.d.	99.2	n.d.	0.2	0.4	96.4
	Knife Back 1	0.1	n.d.	n.d.	n.d.	99.5	n.d.	n.d.	0.4	97.0
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.2	96.7
		n.d.	n.d.	n.d.	n.d.	100.0	n.d.	n.d.	n.d.	99.0
	Knife Back 2	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	101.5
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	92.2
		n.d.	n.d.	n.d.	0.1	99.8	n.d.	n.d.	n.d.	94.2
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	89.6
	Knife Back 3	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.2	0.1	93.9
16514	**Cutting Edge**	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	n.d.	100.1
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	96.1
		n.d.	n.d.	n.d.	n.d.	99.4	n.d.	0.2	0.3	94.7
	Right Iron Flank	n.d.	0.3	n.d.	n.d.	99.4	0.2	n.d.	n.d.	98.1
		n.d.	0.3	n.d.	n.d.	99.2	0.2	0.2	n.d.	95.2
		n.d.	0.4	n.d.	n.d.	99.2	n.d.	0.2	0.2	96.3
		0.1	0.3	n.d.	n.d.	99.3	0.2	n.d.	n.d.	92.5
	Left Iron Flank	n.d.	0.4	n.d.	n.d.	99.4	n.d.	n.d.	0.1	100.5
		n.d.	0.3	n.d.	n.d.	99.5	0.1	n.d.	n.d.	93.6
		n.d.	0.3	n.d.	n.d.	99.5	n.d.	n.d.	n.d.	97.2
		n.d.	0.2	n.d.	n.d.	99.5	n.d.	0.1	n.d.	88.9
16557	**Cutting Edge**	n.d.	n.d.	n.d.	0.1	99.5	n.d.	n.d.	0.4	***93.0***
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	***100.1***
		0.1	n.d.	n.d.	0.1	99.8	n.d.	0.1	n.d.	***101.5***
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	0.1	***98.6***
		n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	0.1	***98.6***
	Back 1	n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	0.1	***96.3***
		0.1	n.d.	n.d.	n.d.	99.8	0.1	0.1	n.d.	***93.7***
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	***94.1***
	Back 2	0.1	n.d.	n.d.	0.1	99.8	n.d.	n.d.	n.d.	***92.2***
		0.1	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	***105.7***
		n.d.	0.1	0.1	n.d.	99.6	n.d.	0.1	0.1	***101.5***
	Back 3	n.d.	n.d.	0.1	n.d.	99.7	n.d.	0.2	n.d.	***106.7***
		n.d.	n.d.	0.1	n.d.	99.8	n.d.	n.d.	0.1	***111.3***
		0.1	n.d.	0.1	n.d.	99.6	n.d.	n.d.	0.2	***102.9***
	Back 4	0.1	0.1	n.d.	0.1	99.6	n.d.	n.d.	0.1	***107.3***
		n.d.	0.1	n.d.	n.d.	99.8	0.1	n.d.	n.d.	***102.2***
		n.d.	n.d.	0.1	n.d.	99.9	n.d.	n.d.	n.d.	***112.9***

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
16808	**Cutting Edge**	n.d.	n.d.	n.d.	n.d.	98.9	n.d.	0.2	0.9	***102.4***
		0.1	n.d.	n.d.	n.d.	99.0	n.d.	0.2	0.7	***102.7***
		n.d.	0.1	n.d.	n.d.	99.3	0.2	n.d.	0.3	***105.8***
		0.1	n.d.	n.d.	n.d.	99.0	n.d.	0.1	0.6	***105.7***
		n.d.	0.1	n.d.	n.d.	99.0	0.2	n.d.	0.7	***103.2***
		n.d.	n.d.	n.d.	n.d.	99.2	0.1	n.d.	0.6	***111.8***
		n.d.	0.1	n.d.	n.d.	99.4	n.d.	n.d.	0.4	***102.2***
		n.d.	0.1	0.1	n.d.	99.0	n.d.	0.1	0.7	***109.5***
	Left Flank	0.1	n.d.	n.d.	0.1	99.3	n.d.	n.d.	0.4	***98.4***
		0.1	n.d.	n.d.	n.d.	99.7	n.d.	0.2	0.1	***106.1***
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	***100.7***
	Right Flank	0.1	n.d.	n.d.	n.d.	99.5	0.1	0.1	n.d.	***92.1***
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	0.1	***102.0***
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	0.1	0.3	***112.8***
		n.d.	0.1	n.d.	n.d.	99.5	0.1	0.1	0.2	***111.2***
16826a	**Cutting Edge**	0.1	n.d.	n.d.	n.d.	99.5	n.d.	n.d.	0.4	***103.2***
		n.d.	0.1	n.d.	n.d.	99.5	n.d.	n.d.	0.4	***100.8***
		n.d.	n.d.	0.1	n.d.	99.6	n.d.	n.d.	0.3	***97.5***
	White Weld Line	n.d.	0.1	0.1	n.d.	98.9	0.1	n.d.	0.7	***100.7***
		n.d.	0.1	n.d.	0.1	98.9	0.1	0.1	0.6	***100.6***
	Back 1	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.2	0.2	***100.8***
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.3	***97.2***
		0.1	0.1	0.1	n.d.	99.3	n.d.	n.d.	0.4	***99.8***
	Back 2	0.1	0.1	n.d.	n.d.	99.3	0.1	0.1	0.3	***93.9***
		0.2	0.1	n.d.	n.d.	99.5	n.d.	n.d.	0.2	***103.9***
		0.1	0.1	n.d.	n.d.	99.3	0.2	n.d.	0.3	***103.2***
16826b	**Cutting Edge**	n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	0.1	***99.0***
		0.1	0.2	n.d.	n.d.	99.6	n.d.	0.1	n.d.	***97.7***
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	0.1	0.1	***102.4***
	White Weld Line	n.d.	0.2	n.d.	n.d.	99.0	0.4	0.1	0.3	***99.2***
		0.2	0.2	n.d.	n.d.	99.3	0.2	n.d.	0.1	***98.9***
	Left Flank	0.1	0.7	n.d.	n.d.	99.2	n.d.	n.d.	n.d.	***103.3***
		0.1	0.6	n.d.	n.d.	99.0	0.3	n.d.	n.d.	***97.3***
		n.d.	0.7	n.d.	n.d.	99.0	n.d.	n.d.	0.2	***100.3***
		n.d.	0.8	n.d.	n.d.	98.9	n.d.	0.2	n.d.	***106.2***
	Right Flank	0.1	0.8	n.d.	n.d.	98.9	n.d.	0.1	0.1	***103.3***
		n.d.	0.8	n.d.	n.d.	99.0	0.1	n.d.	0.1	***104.2***
		n.d.	0.8	n.d.	n.d.	98.7	0.1	n.d.	0.3	***101.6***
		n.d.	0.8	n.d.	n.d.	99.2	n.d.	n.d.	0.1	***97.8***

Table 10.1 cont: Full table of normalised results from SEM-EDS analysis of knives from Christchurch Place. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
2041	**Cutting Edge**	n.d.	n.d.	0.1	n.d.	99.5	0.1	0.2	0.1	***101.7***
		0.1	n.d.	n.d.	n.d.	99.5	0.2	n.d.	n.d.	***101.9***
		0.1	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.1	***97.0***
	Left Flank	n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	***100.4***
		n.d.	0.2	n.d.	n.d.	99.5	0.1	0.1	0.1	***98.6***
		n.d.	0.2	0.1	n.d.	99.7	n.d.	n.d.	n.d.	***100.8***
	Right Flank	n.d.	0.1	n.d.	0.1	99.7	0.1	n.d.	n.d.	***105.8***
		0.1	0.1	n.d.	n.d.	99.6	n.d.	0.1	0.1	***100.6***
		n.d.	0.1	n.d.	n.d.	99.5	n.d.	n.d.	0.3	***97.1***
	White Weld Line	n.d.	0.1	0.1	n.d.	99.5	n.d.	0.1	0.2	***102.0***
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	***104.6***
2555	**Cutting Edge**	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**105.4**
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	0.1	n.d.	**105.4**
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**104.7**
	Right Iron Flank	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.2	n.d.	**100.7**
		n.d.	0.2	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	**98.3**
		n.d.	n.d.	n.d.	n.d.	99.5	n.d.	0.1	n.d.	**97.1**
	Left Iron Flank	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**93.8**
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**91.3**
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.3	**98.9**
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.5	0.3	n.d.	0.1	**96.2**
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	**94.2**
2696	**Cutting Edge**	n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**100.2**
		0.2	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	**100.4**
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	**97.5**
		n.d.	0.2	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	**96.7**
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.2	**93.7**
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	n.d.	**90.7**
	Knife Back 1	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	**87.8**
		n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	**105.7**
	Knife Back 2	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**108.2**
		0.1	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	**105.6**
	Knife Back 3	n.d.	n.d.	n.d.	n.d.	99.6	0.2	n.d.	n.d.	**102.4**
		0.1	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**100.8**
	Knife Back 4	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	**97.8**
		n.d.	n.d.	0.1	n.d.	99.6	n.d.	n.d.	0.1	**96.5**

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
2743	**Cutting Edge**	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	**99.8**
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.1	0.2	**98.9**
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	**100.7**
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.1	**97.1**
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	**98.8**
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.2	0.1	**99.7**
	Knife Back 1	0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.1	**96.6**
		n.d.	0.2	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**93.3**
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	**97.4**
	Knife Back 2	0.2	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	**90.4**
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**88.9**
		n.d.	n.d.	0.1	n.d.	99.7	n.d.	n.d.	0.1	**98.8**
	Knife Back 3	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	**90.7**
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	**90.3**
2758	**Ferrite with needles**	n.d.	0.1	n.d.	0.2	99.7	n.d.	n.d.	n.d.	**105.1**
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	**104.4**
		n.d.	n.d.	n.d.	n.d.	99.7	0.1	n.d.	n.d.	**102.5**
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	**104.4**
	Knife Back 1	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**104.6**
		n.d.	n.d.	n.d.	n.d.	99.6	0.2	n.d.	n.d.	**102.1**
		n.d.	n.d.	n.d.	n.d.	99.4	0.1	0.3	n.d.	**99.9**
	Knife Back 2	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**98.2**
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	**96.4**
		n.d.	0.1	n.d.	n.d.	99.5	0.1	0.2	n.d.	**97.2**
4485	**Martensite**	n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	0.3	**98.2**
		n.d.	n.d.	n.d.	0.1	99.5	n.d.	n.d.	0.2	**96.1**
		n.d.	0.1	n.d.	0.2	99.5	n.d.	n.d.	0.1	**95.0**
	Pearlite	n.d.	n.d.	n.d.	n.d.	99.6	0.2	n.d.	n.d.	**94.4**
		n.d.	n.d.	n.d.	0.1	99.8	n.d.	n.d.	n.d.	**92.1**
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	0.1	n.d.	**90.8**
	Ferrite with Pearlite	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	**100.8**
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	**98.7**
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**97.4**
7306	**Cutting Edge**	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.1	n.d.	**99.0**
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.3	**98.4**
		n.d.	n.d.	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	**96.4**
		0.2	n.d.	n.d.	0.1	99.5	n.d.	0.1	n.d.	**94.9**
	Knife Back 1	n.d.	0.5	n.d.	n.d.	99.3	n.d.	n.d.	n.d.	**94.9**
		n.d.	0.7	n.d.	n.d.	99.1	n.d.	n.d.	0.1	**106.0**
	Knife Back 2	n.d.	0.5	n.d.	n.d.	99.1	0.1	n.d.	0.2	**105.3**
		n.d.	0.6	n.d.	n.d.	99.2	n.d.	n.d.	n.d.	**105.3**
	Knife Back 3	0.1	0.8	n.d.	n.d.	98.5	0.2	0.2	0.2	**106.8**
		n.d.	0.6	n.d.	n.d.	98.9	0.3	n.d.	0.2	**92.0**
	White Weld Line?	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	**101.0**
		n.d.	0.2	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**100.3**
		n.d.	0.5	n.d.	n.d.	99.1	n.d.	0.2	n.d.	**101.1**

Table 13.2: Full table of normalised results from SEM-EDS analysis of knives from Fishamble Street. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
10627	**Cutting Edge**	n.d.	0.1	n.d.	n.d.	99.0	0.2	0.4	0.2	**99.6**
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	**100.5**
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	**96.3**
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**98.7**
	White Weld Line	n.d.	n.d.	n.d.	n.d.	95.9	0.3	n.d.	3.5	**108.0**
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	**73.7**
	Back 1	0.1	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	**111.2**
		0.1	n.d.	n.d.	n.d.	99.4	n.d.	n.d.	0.5	**105.8**
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	**104.4**
		0.1	n.d.	0.1	n.d.	99.4	0.2	n.d.	0.2	**102.1**
	Back 2	n.d.	n.d.	n.d.	n.d.	99.7	0.3	n.d.	n.d.	**65.2**
		n.d.	n.d.	n.d.	0.2	99.7	n.d.	n.d.	n.d.	**95.4**
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	**95.0**
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	**94.9**
		n.d.	n.d.	n.d.	0.2	99.3	n.d.	0.1	0.3	**92.5**
10964	**Cutting Edge**	n.d.	n.d.	n.d.	n.d.	99.6	0.1	n.d.	0.2	97.8
		n.d.	n.d.	n.d.	n.d.	99.5	0.1	0.1	0.1	96.9
		n.d.	0.1	n.d.	n.d.	99.7	0.1	n.d.	n.d.	94.9
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	93.7
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.2	n.d.	91.4
		n.d.	0.1	n.d.	n.d.	99.4	0.2	0.2	n.d.	91.7
	Knife Back 1	n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	88.7
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	95.8
	Knife Back 2	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	98.0
		n.d.	n.d.	n.d.	n.d.	99.5	0.2	n.d.	0.1	100.9
	Knife Back 3	n.d.	n.d.	n.d.	n.d.	99.5	0.2	n.d.	0.2	95.3
		n.d.	0.2	n.d.	n.d.	99.6	0.1	0.1	n.d.	98.0
	Knife Back 4	n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	95.0
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	96.2

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
13190	**Cutting Edge**	n.d.	n.d.	n.d.	n.d.	95.9	0.3	n.d.	3.5	108.0
		n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	73.7
		n.d.	0.1	n.d.	n.d.	99.0	0.2	0.4	0.2	99.6
		0.1	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	100.5
	White Weld Line	n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	n.d.	96.3
		n.d.	n.d.	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	98.7
	Knife Back	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	n.d.	0.2	102.2
		n.d.	0.1	n.d.	n.d.	99.2	n.d.	0.1	0.4	98.7
		n.d.	n.d.	n.d.	n.d.	99.4	n.d.	n.d.	0.5	100.6
		n.d.	n.d.	n.d.	n.d.	99.2	n.d.	n.d.	0.5	96.6
		n.d.	0.1	n.d.	n.d.	98.5	n.d.	n.d.	1.1	100.2
		n.d.	n.d.	n.d.	n.d.	98.7	n.d.	n.d.	1.3	98.0
		n.d.	0.2	n.d.	n.d.	98.8	0.1	n.d.	0.9	114.2
		n.d.	n.d.	n.d.	n.d.	99.4	n.d.	n.d.	0.5	110.2
16802	**Cutting Edge**	n.d.	0.1	n.d.	n.d.	99.7	0.1	0.1	n.d.	***102.8***
		0.1	n.d.	0.1	n.d.	99.8	n.d.	n.d.	n.d.	***98.4***
		0.1	n.d.	0.1	n.d.	99.4	0.3	n.d.	0.1	***98.9***
	Back 1	n.d.	0.2	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	***99.1***
		0.1	0.2	n.d.	n.d.	99.6	0.1	0.1	n.d.	***94.8***
		0.1	0.2	n.d.	n.d.	99.5	n.d.	n.d.	0.2	***102.9***
	Back 2	0.1	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	***97.5***
		0.1	0.2	n.d.	0.1	99.5	n.d.	0.1	n.d.	***101.4***
		0.1	0.2	0.1	n.d.	99.0	0.1	0.2	0.4	***94.8***

Table 10.2 cont: Full table of normalised results from SEM-EDS analysis of knives from Fishamble Street. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
1114	Cutting Edge	0.0	0.1	0.1	0.0	99.6	0.0	0.0	0.2	***97.5***
		0.0	0.0	0.0	0.0	99.6	0.0	0.0	0.3	***90.9***
		0.2	0.0	0.0	0.1	99.2	0.0	0.0	0.5	***97.7***
	Back	0.1	0.0	0.0	0.0	99.5	0.3	0.0	0.1	***101.1***
		0.1	0.0	0.0	0.0	99.4	0.0	0.2	0.3	***98.8***
		0.0	0.1	0.0	0.1	99.3	0.0	0.1	0.4	***101.7***
		0.1	0.1	0.0	0.0	99.8	0.0	0.0	0.0	***97.6***
		0.1	0.1	0.1	0.0	99.7	0.1	0.0	0.0	***98.7***
		0.0	0.1	0.0	0.0	99.5	0.0	0.1	0.1	***92.6***
	Phosphoric Iron area	0.1	0.3	0.0	0.0	99.1	0.0	0.0	0.4	***103.1***
		0.0	0.4	0.0	0.0	98.8	0.0	0.1	0.7	***95.8***
		0.1	0.4	0.0	0.0	99.0	0.0	0.0	0.6	***105.5***
	White Weld Line	0.0	0.0	0.1	0.0	98.4	0.0	0.0	1.5	***99.6***
		0.0	0.1	0.0	0.1	98.4	0.0	0.2	1.3	***102.5***
1708	Cutting Edge	0.1	0.2	0.0	0.0	99.3	0.0	0.0	0.4	***105.8***
		0.1	0.1	0.0	0.1	99.2	0.1	0.0	0.4	***107.3***
		0.1	0.2	0.1	0.1	99.0	0.0	0.1	0.4	***105.2***
		0.0	0.3	0.0	0.0	99.6	0.0	0.0	0.0	***95.8***
		0.0	0.1	0.0	0.0	99.6	0.0	0.0	0.3	***106.8***
		0.1	0.1	0.0	0.0	99.2	0.1	0.0	0.3	***104.0***
	Back	0.0	0.7	0.0	0.0	99.1	0.1	0.0	0.1	***98.9***
		0.0	0.6	0.0	0.0	98.8	0.0	0.0	0.4	***105.3***
		0.0	0.7	0.0	0.0	98.9	0.1	0.1	0.2	***105.2***
		0.0	0.5	0.0	0.0	98.8	0.0	0.2	0.4	***101.7***
		0.1	0.3	0.0	0.0	99.2	0.0	0.2	0.2	***103.2***
		0.1	0.3	0.0	0.0	99.3	0.0	0.0	0.3	***100.3***
10012	Cutting Edge	0.1	0.2	0.0	0.0	99.3	0.1	0.2	0.2	***101.4***
		0.0	0.1	0.0	0.0	99.6	0.2	0.0	0.0	***103.7***
		0.0	0.2	0.0	0.0	99.4	0.2	0.0	0.2	***100.0***
	Back 1	0.0	0.1	0.0	0.0	99.8	0.1	0.0	0.0	***93.7***
		0.1	0.2	0.0	0.0	99.3	0.2	0.1	0.1	***93.4***
		0.0	0.1	0.0	0.0	99.5	0.1	0.2	0.0	***95.0***
		0.0	0.0	0.0	0.0	99.7	0.2	0.1	0.0	***101.8***
	Back 2	0.0	0.2	0.0	0.0	99.7	0.0	0.0	0.0	***105.8***
		0.0	0.3	0.0	0.0	99.4	0.2	0.1	0.0	***100.3***
		0.0	0.2	0.0	0.0	99.7	0.0	0.0	0.1	***91.4***
	Back 3	0.1	0.0	0.0	0.0	99.7	0.0	0.1	0.1	***103.6***
		0.1	0.0	0.1	0.0	99.8	0.0	0.1	0.0	***105.9***
		0.1	0.1	0.0	0.1	99.6	0.1	0.0	0.0	***97.8***
		0.0	0.1	0.1	0.0	99.7	0.1	0.0	0.0	***94.9***

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
10069	Cutting Edge	0.0	0.1	0.0	0.0	99.8	0.0	0.0	0.1	***103.1***
		0.0	0.1	0.1	0.0	99.6	0.1	0.1	0.0	***96.3***
		0.1	0.1	0.0	0.0	99.6	0.1	0.1	0.0	***94.0***
		0.0	0.4	0.0	0.0	99.1	0.1	0.2	0.1	***110.0***
		0.0	0.4	0.0	0.0	99.4	0.0	0.1	0.0	***104.0***
		0.0	0.3	0.0	0.1	99.2	0.1	0.1	0.2	***98.2***
	Back	0.0	0.4	0.0	0.0	99.5	0.0	0.1	0.0	***96.8***
		0.0	0.3	0.0	0.0	99.6	0.0	0.0	0.0	***105.5***
		0.0	0.3	0.0	0.0	99.5	0.1	0.0	0.0	***111.1***
		0.0	0.4	0.0	0.0	99.5	0.0	0.0	0.1	***105.5***
		0.0	0.4	0.0	0.0	99.3	0.2	0.0	0.1	***97.0***
		0.0	0.3	0.0	0.1	99.3	0.1	0.1	0.0	***101.0***
10369	Cutting Edge	0.0	0.0	0.1	0.1	99.6	0.0	0.2	0.0	***106.6***
		0.0	0.0	0.0	0.0	99.7	0.1	0.2	0.0	***99.9***
		0.0	0.0	0.0	0.2	99.4	0.0	0.1	0.3	***97.9***
		0.1	0.0	0.0	0.0	99.7	0.0	0.0	0.2	***98.3***
	White Weld Line	1.8	0.4	0.0	0.0	97.6	0.2	0.0	0.0	***102.5***
		0.0	0.2	0.1	0.0	99.7	0.0	0.2	0.0	***113.8***
		0.0	0.1	0.1	0.0	99.5	0.0	0.3	0.0	***105.8***
	Left Flank	0.0	0.3	0.0	0.0	99.6	0.0	0.0	0.0	***104.5***
		0.1	0.0	0.1	0.0	99.8	0.0	0.1	0.0	***115.4***
		0.0	0.1	0.1	0.0	99.8	0.0	0.0	0.0	***104.8***
		0.0	0.1	0.1	0.0	99.6	0.0	0.0	0.1	***103.8***
		0.0	0.0	0.0	0.0	99.7	0.2	0.2	0.0	***107.4***
		0.0	0.0	0.0	0.0	99.8	0.0	0.0	0.1	***107.3***
	Right Flank	0.0	0.1	0.0	0.0	99.8	0.0	0.0	0.0	***105.8***
		0.0	0.1	0.0	0.0	99.8	0.1	0.0	0.0	***100.8***
		0.1	0.1	0.1	0.0	99.7	0.0	0.0	0.0	***109.3***
		0.1	0.0	0.0	0.0	99.7	0.0	0.1	0.0	***110.7***
		0.0	0.1	0.0	0.0	99.8	0.0	0.1	0.0	***104.0***
		0.1	0.0	0.0	0.1	99.6	0.0	0.1	0.1	***110.8***

Table 13.3: Full table of normalised results from SEM-EDS analysis of knives from High Street. The total column shows the analysis total prior to normalisation.

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
323	Cutting Edge	n.d.	n.d.	n.d.	0.1	99.7	n.d.	0.1	0.2	***104.0***
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	***107.4***
		n.d.	n.d.	0.1	n.d.	99.9	n.d.	n.d.	n.d.	***113.6***
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.6	n.d.	0.1	0.3	***104.8***
	Back 1	n.d.	n.d.	0.1	n.d.	99.4	n.d.	0.2	0.3	***109.7***
		0.1	n.d.	n.d.	n.d.	99.5	0.1	0.1	0.2	***100.4***
		0.1	0.1	n.d.	n.d.	99.6	n.d.	n.d.	0.2	***102.7***
	Back 2	n.d.	n.d.	n.d.	n.d.	99.8	0.1	n.d.	0.1	***99.6***
		0.1	0.1	n.d.	n.d.	99.4	0.1	0.3	n.d.	***102.1***
		n.d.	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	***110.6***
	Back 3	0.1	n.d.	n.d.	n.d.	99.8	0.1	n.d.	n.d.	***103.0***
		n.d.	n.d.	0.1	n.d.	99.7	n.d.	0.1	n.d.	***101.8***
		n.d.	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.2	***10n.d.***
589	Cutting Edge	n.d.	n.d.	0.1	n.d.	99.7	n.d.	n.d.	0.1	***107.0***
		n.d.	0.1	n.d.	0.1	99.7	n.d.	n.d.	0.1	***102.3***
		0.1	0.1	0.1	n.d.	99.5	0.1	n.d.	0.2	***102.8***
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.7	0.1	n.d.	0.1	***96.7***
		n.d.	0.1	n.d.	n.d.	99.5	n.d.	n.d.	0.4	***101.3***
	Back 1	n.d.	n.d.	n.d.	n.d.	99.6	0.1	n.d.	0.3	***106.2***
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.2	***94.3***
		n.d.	0.1	0.1	n.d.	99.4	0.1	0.1	0.3	***101.1***
	Back 2	n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.2	***97.3***
		n.d.	0.1	n.d.	n.d.	99.5	n.d.	0.1	0.1	***100.5***
		0.1	0.1	n.d.	0.1	99.6	0.1	n.d.	n.d.	***95.3***
3971	Cutting Edge	0.1	0.1	n.d.	n.d.	99.3	0.1	n.d.	0.4	***90.2***
		n.d.	0.1	n.d.	n.d.	99.8	0.1	n.d.	n.d.	***97.6***
		0.1	n.d.	n.d.	n.d.	99.7	0.1	0.1	n.d.	***98.9***
		0.1	0.1	n.d.	n.d.	99.6	0.1	0.1	n.d.	***98.6***
	White Weld Line	0.1	0.1	n.d.	n.d.	99.2	0.2	0.2	0.3	***96.6***
		n.d.	0.1	n.d.	n.d.	99.1	0.3	0.2	0.3	***97.0***
	Left Flank	n.d.	0.6	n.d.	n.d.	99.0	0.1	0.4	n.d.	***102.9***
		n.d.	0.5	0.1	n.d.	99.1	n.d.	0.2	n.d.	***108.9***
		n.d.	0.5	n.d.	n.d.	99.3	0.1	n.d.	n.d.	***108.1***
		n.d.	0.6	0.1	n.d.	99.2	n.d.	n.d.	n.d.	***106.8***
	Right Flank	n.d.	0.5	n.d.	n.d.	99.2	0.1	0.1	n.d.	***106.4***
		n.d.	0.4	n.d.	0.1	99.4	n.d.	n.d.	n.d.	***104.6***
		n.d.	0.4	n.d.	n.d.	99.4	0.2	n.d.	n.d.	***107.3***
		n.d.	0.5	n.d.	n.d.	99.2	n.d.	0.2	n.d.	***107.4***

Sample	Area	Si	P	S	Mn	Fe	Ni	Cu	As	Total
4971	Cutting Edge	0.1	0.1	n.d.	n.d.	99.6	n.d.	0.1	0.1	***94.2***
		0.1	0.1	n.d.	n.d.	99.5	n.d.	n.d.	0.2	***99.2***
		0.1	n.d.	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	***100.9***
	White Weld Line	n.d.	n.d.	0.1	n.d.	99.3	0.1	n.d.	0.5	***102.1***
		n.d.	n.d.	n.d.	n.d.	99.3	0.1	n.d.	0.5	***103.1***
	Left Flank	0.1	0.7	n.d.	n.d.	98.9	n.d.	0.1	0.3	***101.3***
		0.1	0.6	n.d.	n.d.	98.5	0.1	n.d.	0.6	***103.7***
		0.1	0.6	n.d.	n.d.	98.6	0.1	0.1	0.5	***107.9***
		n.d.	0.5	n.d.	n.d.	99.1	0.1	n.d.	0.3	***108.1***
	Right Flank	n.d.	0.6	0.1	n.d.	99.0	n.d.	n.d.	0.2	***101.1***
		0.1	0.4	n.d.	0.1	99.2	n.d.	n.d.	0.1	***102.6***
		0.1	0.5	n.d.	n.d.	99.1	n.d.	n.d.	0.3	***109.6***
		0.1	0.4	n.d.	n.d.	98.9	n.d.	0.1	0.5	***107.3***
604	Cutting Edge	0.1	0.1	n.d.	0.1	99.5	n.d.	0.1	0.1	***108.0***
		n.d.	n.d.	n.d.	n.d.	99.9	0.1	n.d.	n.d.	***109.5***
		n.d.	0.1	n.d.	n.d.	99.6	0.2	0.2	n.d.	***111.8***
	White Weld Line	n.d.	n.d.	n.d.	n.d.	99.6	0.2	n.d.	0.2	***108.8***
		n.d.	n.d.	n.d.	n.d.	98.9	0.4	0.2	0.4	***111.0***
	Back 1	0.1	0.1	n.d.	n.d.	99.7	n.d.	0.1	n.d.	***112.1***
		n.d.	0.1	n.d.	n.d.	99.9	n.d.	n.d.	n.d.	***105.9***
		0.1	0.1	n.d.	n.d.	99.5	0.3	n.d.	0.1	***104.0***
	Back 2	n.d.	0.1	n.d.	0.1	99.6	n.d.	0.1	n.d.	***100.5***
		0.1	0.1	n.d.	n.d.	99.6	n.d.	0.2	n.d.	***104.4***
		n.d.	0.1	n.d.	n.d.	99.5	0.1	0.1	0.2	***111.2***
	Back 3	n.d.	0.1	n.d.	n.d.	99.5	0.1	n.d.	0.2	***106.6***
		n.d.	n.d.	0.1	n.d.	99.6	n.d.	0.1	0.2	***111.4***
		0.1	0.1	n.d.	n.d.	99.6	0.1	n.d.	0.1	***104.6***
		0.1	n.d.	n.d.	n.d.	99.5	0.1	0.1	0.1	***109.2***
4437	Cutting Edge	n.d.	0.7	n.d.	n.d.	99.1	n.d.	0.1	n.d.	***104.5***
		n.d.	0.6	n.d.	n.d.	99.2	n.d.	0.1	0.1	***104.7***
		n.d.	0.1	n.d.	n.d.	99.7	n.d.	n.d.	0.1	***101.7***
		n.d.	0.1	n.d.	n.d.	99.8	n.d.	n.d.	n.d.	***99.1***
	Back 1	n.d.	0.2	0.1	n.d.	99.6	n.d.	n.d.	n.d.	***95.5***
		n.d.	0.1	n.d.	n.d.	99.7	0.1	n.d.	n.d.	***98.9***
		n.d.	0.3	n.d.	n.d.	99.3	0.1	n.d.	0.2	***101.2***
	Back 2	n.d.	0.1	0.1	n.d.	99.6	0.1	n.d.	n.d.	***100.8***
		n.d.	0.2	n.d.	0.1	99.5	0.2	n.d.	n.d.	***96.2***
		n.d.	0.2	0.1	0.1	99.5	0.1	0.1	n.d.	***103.1***
		0.1	0.3	n.d.	n.d.	99.5	0.1	n.d.	n.d.	***95.6***

Table 13.4: Full table of normalised results from SEM-EDS analysis of knives from Winetavern Street and John's Lane. The total column shows the analysis total prior to normalisation .

White Weld Lines

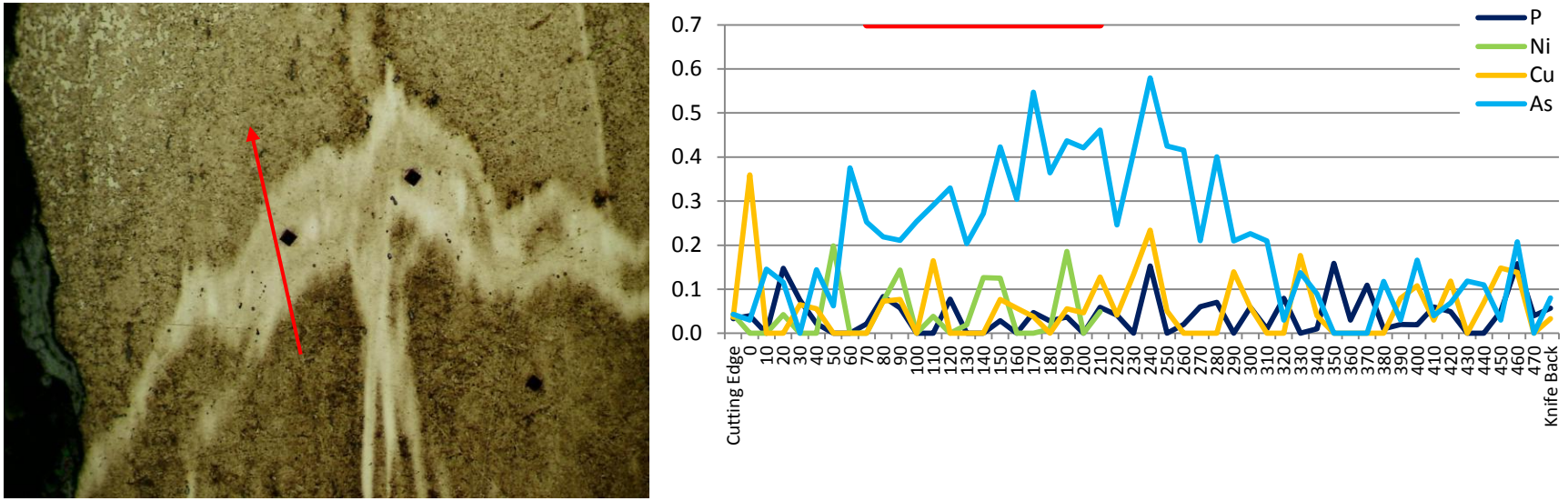


Figure 13.43: Line scan across the white weld line in Dublin Knife 323

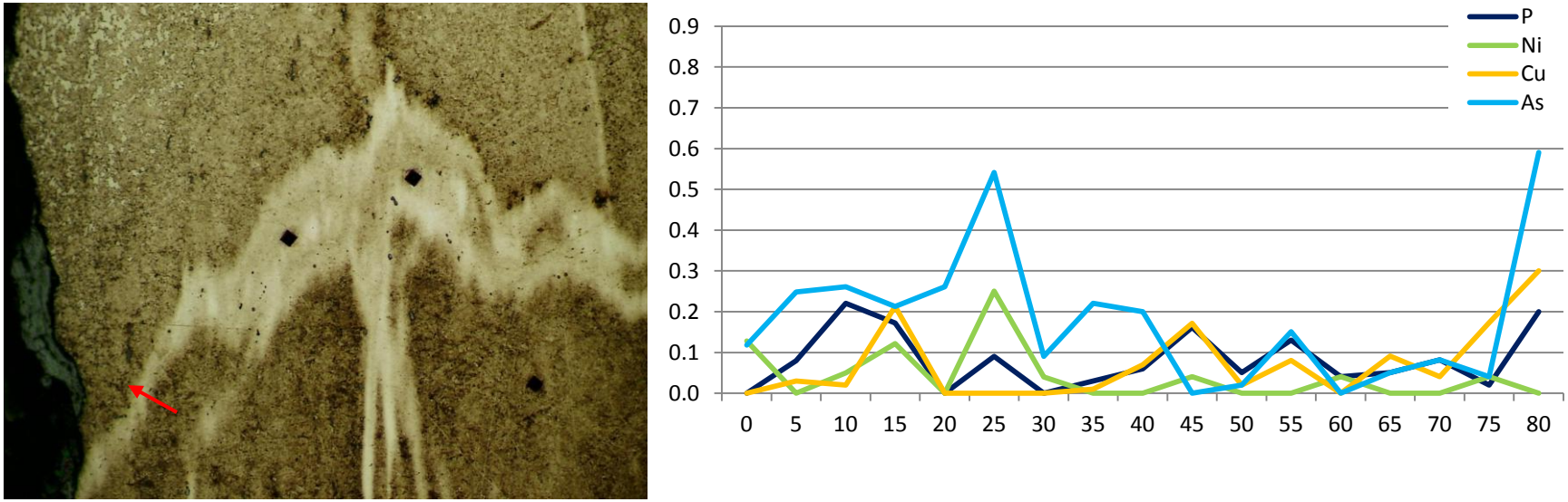


Figure 13.44: Line scan across the white weld line in Dublin Knife 323

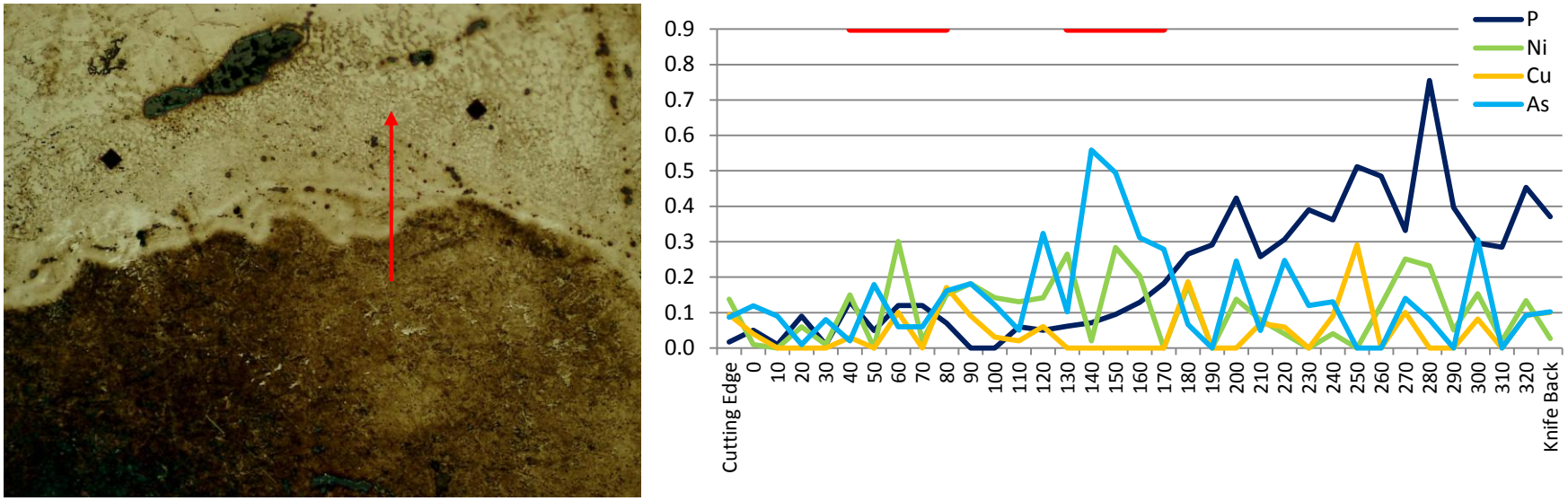


Figure 13.45: Line scan across the white weld line in Dublin Knife 12677

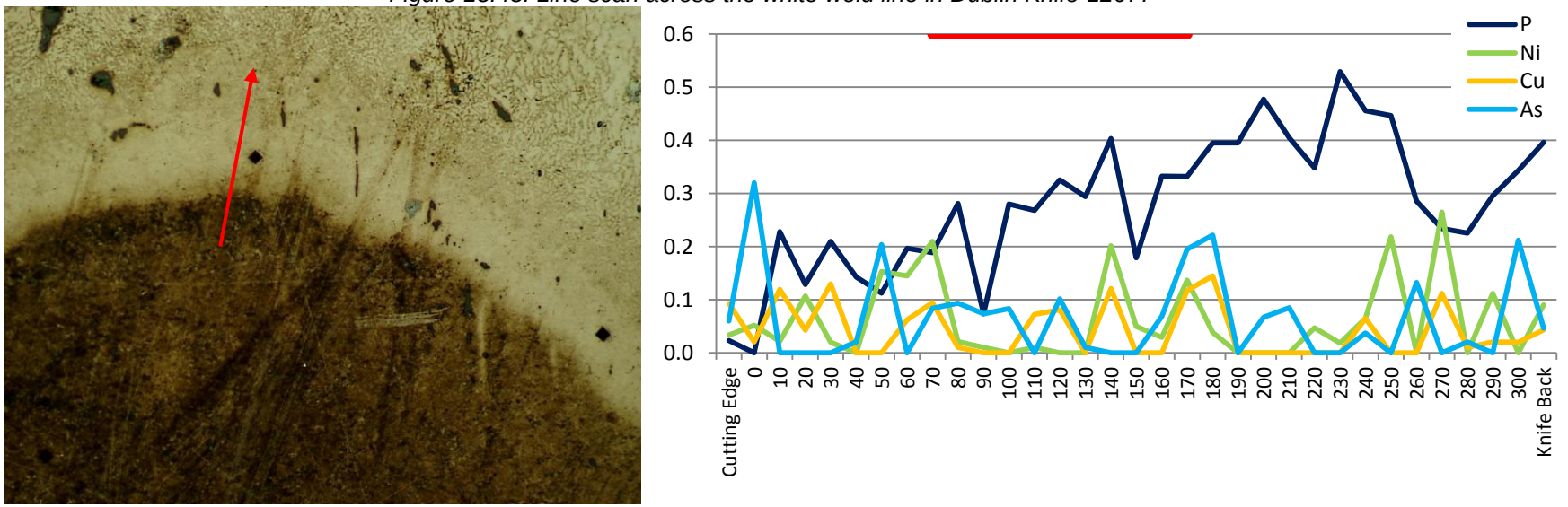


Figure 13.46: Line scan across the white weld line in Dublin Knife 12677

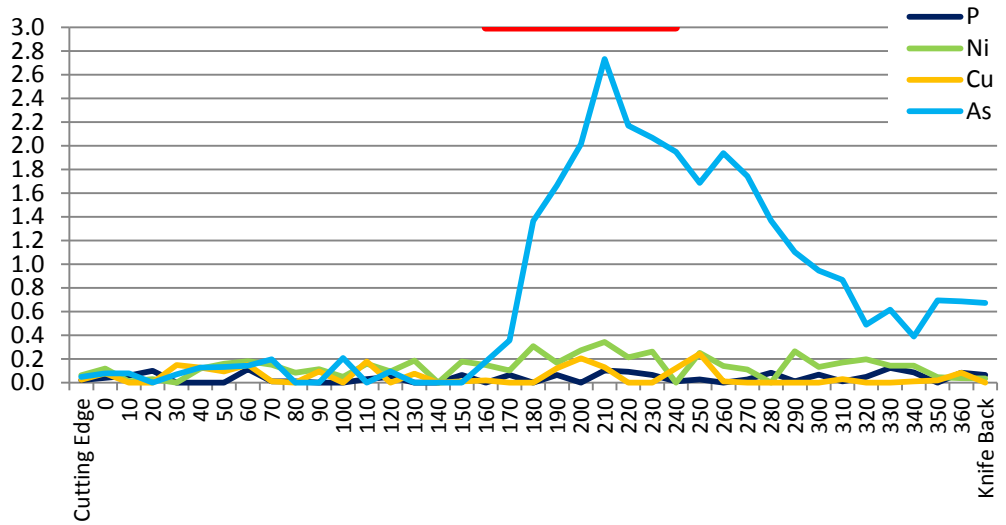
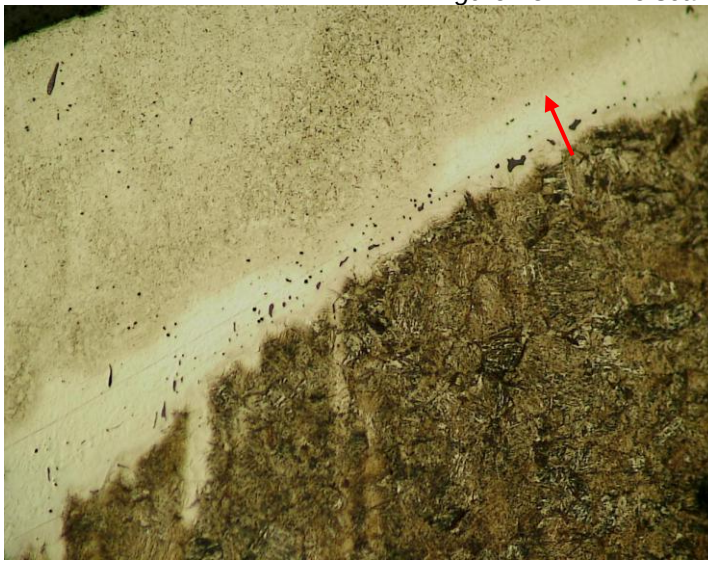


Figure 13.47: Line scan across the white weld line in Dublin Knife 13190



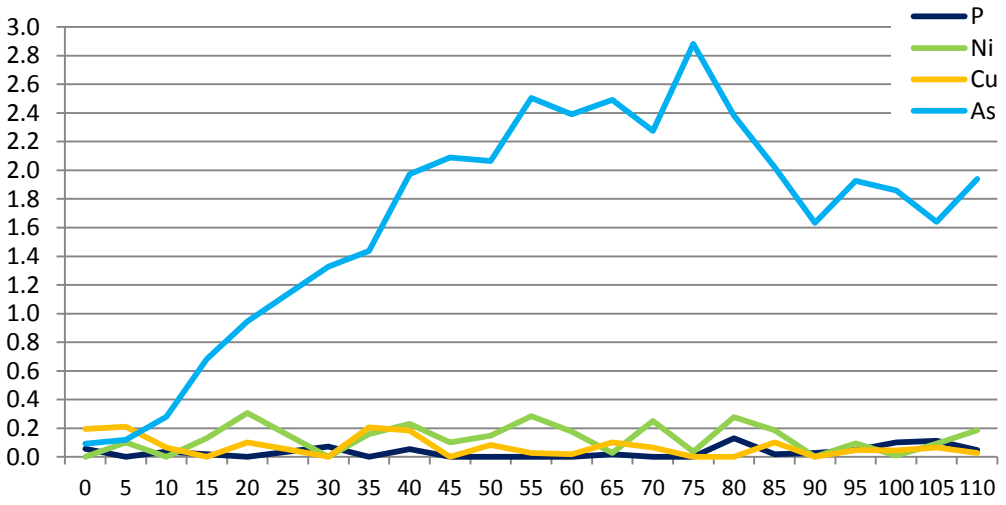


Figure 13.48: Line scan across the white weld line in Dublin Knife 13190

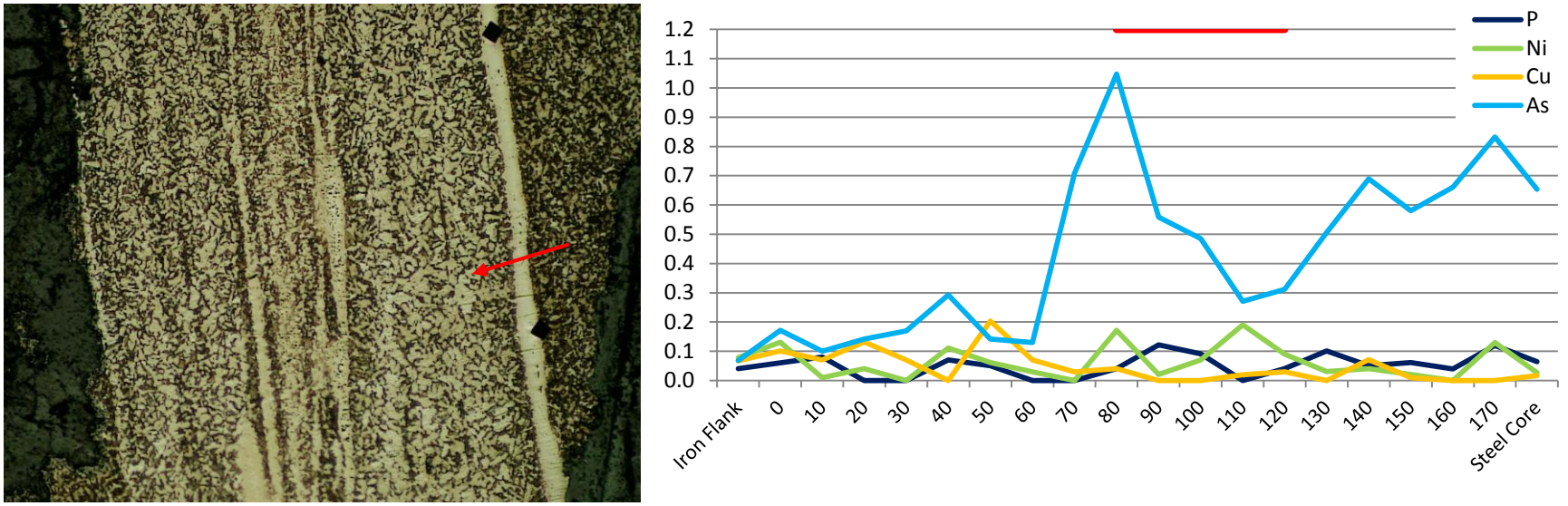


Figure 13.49: Line scan across the white weld line in Dublin Knife 16808

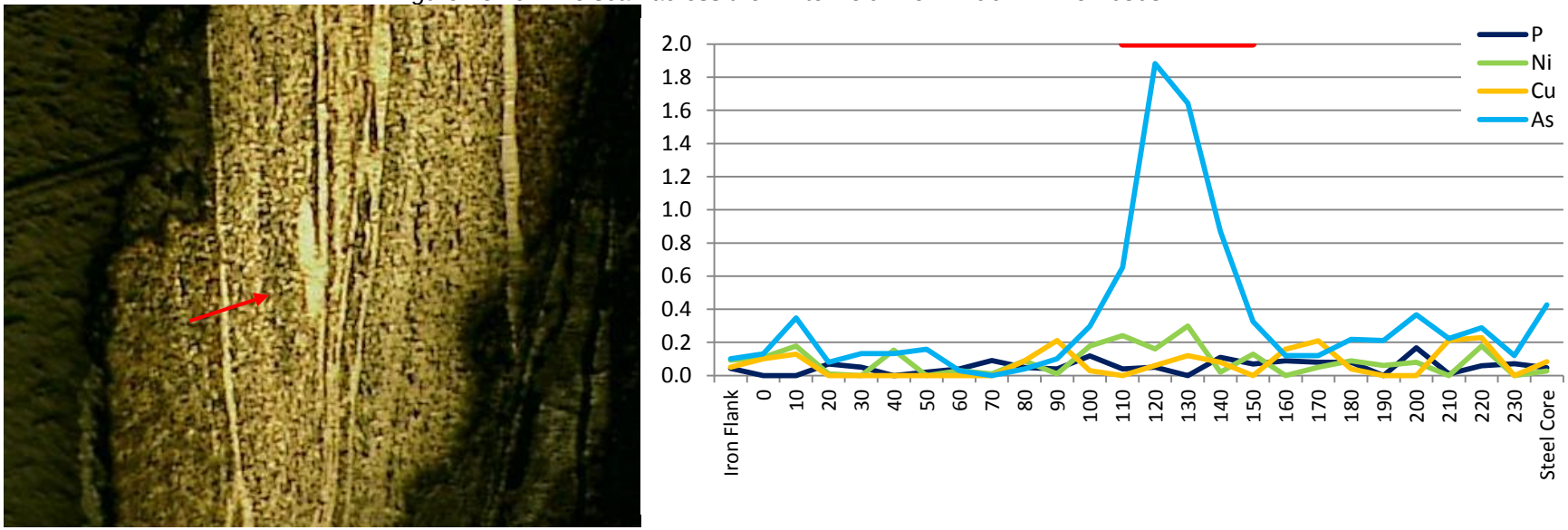


Figure 13.50: Line scan across the white weld line in Dublin Knife 16808

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