Ancient Monuments Laboratory
Report 90/87

COPPERGATE, YORK METALLURGY REPORT NUMBER 8. KNIVES 1532, 2270, 4035, 5096, 5107, 5111, 5719, 6487, 7662, 8574.

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Summary

Ten further knives were examined metallographically. The structures noted are described and interpreted.

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METALLURGY RESEARCH (ARCHAEOMETALLURGY)

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COPPERGATE YORK METALLURGY REPORT NUMBER 8

(Knives 1532, 2270, 4035, 5096, 5107, 5111, 5719, 6487, 7662, 8574)

[NOTE. All terms are those used in other York Reports, and Vicker's Hardness Tests were carried out using 5Kgf, and Micro-Hardness Tests using 100gmf]

1 KNIFE 1532

Knife 1532 was ascribed to Backform E3. The X-radiography showed differential corrosion at the cutting edge giving a scalloped appearance (Figure 1). The overall condition of the knife was good. A single half-section was removed.

In the unetched condition two slag lines indicative of a Type 1 manufacture were observed. This structure was confirmed in the etched condition. The two external sheaths were ferritic (Hv=85, uHv=95 Grain Size ASTMS 4/5), and showed evidence of irregular wear or sharpening, because one of the sheaths ended higher up the section than the other (Figure 2). Some carbon diffusion into the sheaths had occurred from the core. The weld line between one of the sheaths and the core was a white/yellow weld line (with slag inclusions, observed in the unetched condition), indicative of nickel or arsenic enrichment. The core was a slow cooled low carbon steel with a ferrite plus pearlite structure (Hv=126, μHv=176).

Knife 1532 was a well manufactured knife, but a low carbon steel had been used as the cutting edge and it had not been quenched. The softeness of the cutting edge would have given rise to excessive wear.

2 KNIFE 2270

Knife 2270 (Figure 3) was an example of the pivoted type knife, presumably a specialist tool. It had two notches and a rivet/pivot approximately one third along its length, enabling the handle to have been pivoted to expose the working blade at either end.

X-Radiography showed some corrosion present, with slag lines running the length of the knife, but no other structural details. Half sections were cut from each cutting edge.

Both sections revealed the same overall-structure of a high carbon martensitic cutting edge welded to the knife back which was a predominantly medium grained ferrite (Figure 4). Some small areas of pearlite were present in the knife back. The weld line was delineated by a white/yellow line (cf. Knife 10556). Towards the weld line the martensite contains a small amount of ferrite, and at the weld it degraded into pearlite. Beyond the weld line pearlite plus ferrite was present, clearly indicating carburisation of the knife back during welding.

The hardness and micro-hardness values obtained for Edge 1 and Edge 2 are given in Table 1. These show that the ferritic back contained no significant levels of alloying elements. and that the cutting edge had been successfully slack quenched.

TABLE 1 KNIFE 2270 HARDNESS VALUES

	Knife Back (Ferrite)		Cutting Edge (Martensite)	
	Hv	µHv	Hv	µHv
Edge 1	105	148	532	620
Edge 2	120	145	560	500

The knife was of Type 2 manufacture, and of high quality. This would accord with it being a specialist tool. There was no difference in the quality of the two cutting edges and therefore it is probable that blade shape determined function rather than metallurgical quality.

3 KNIFE 4035

Knife 4035 was ascribed to Backform C, although it was slightly unusual and appeared to be unfinished (P.Ottaway pers. comm.). X-Radiography showed that there was little effect from corrosion, and no overall structural details except for the usual horizontally orientated slag lines in the tang, and small cracks (<5mm in length) running vertically down from the knife back (Figure 5). A single half section was removed.

In the unetched condition vertically orientated slag lines were observed, but there was no strong evidence of banding. In the etched condition the overall method of manufacture was not readily apparent, the entire section being tempered martensitic steel (Hv=400, µHv=379 [mean of four readings]), but showing some carbon content variation (probably due to the presence of localised areas containing phosphorus, Hv=180, μHv=233).

Knife 4035 was either of all steel manufacture (Type 3), or was a butt welded knife (Type 2) with the butt weld high up the knife back, but there was no evidence for such a weld in the X-radiographs. The presence of the micro-cracks in the knife back would support an all steel interpretation.

4 KNIFE 5096

Knife 5096 was ascribe to Backform E1. It was corroded and part of the cutting edge was absent, due either to wear/corrosion or fracture. X-Radiography confirmed that corrosion had penetrated the knife, and also showed extensive slag banding. A single half section was removed (Figure 6).

In the unetched condition vertically orientated slag lines were observed. In the etched condition the knife section was ferritic with some grain boundary carbides present. There was no evidence of a steel cutting edge. A second section was therefore removed, but it also had the same structure. The 'cutting edges' of both specimens were corroded, and there were sharp changes of angle in the cross-sectional profile of the cutting edge. It is therefore possible that a steel butt welded cutting edge had corroded or worn away. The irregular profile of the cutting edge of the knife (above) would suggest extensive wear or breakage of the cutting edge. The micro-hardness tests showed a slight increase from the back of the section (μHv=124) to the tip (μHv=157). The overall mean Vicker's Hardness was 93Hv. The grain size was consistent (ASTMS 4/5). There was no change in grain size at the tip of the knife indicative of it being used as the cutting edge. this lends further support to the argument for erosion by wear or corrosion of an applied cutting edge. These results indicate the use of a ferritic rather than a phosphoric iron.

Knife 5096 was ascribed to manufacturing Type 0, but there was some evidence to suggest that a butt welded cutting edge had been present. This would suggest that rather than being unfinished, the knife had been heavily used.

5 KNIFE 5107

Knife 5107 was ascribed to Backform E3. It had a concave profile at the tang/blade interface, possibly enhanced by corrosion. X-Radiography showed the presence of some corrosion penetration. A single half-section was removed (Figure 7).

In the unetched condition a pattern of slag inclusions indicative of Type 1 manufacture was present. There were no distinct slag lines that could be interpreted as weld lines, but the slag inclusions were concentrated in a central band. In the etched condition the Type 1 method of manufacture was confirmed (Figure 8). The two flanks were ferritic/phosphoric iron, but had undergone considerable carbon diffusion, thus giving a structure varying from ferrite/phosphoric (μHv=200) to tempered martensite and fine nodular pearlite (Hv=244, μHv=300). One of the flank/core weld lines was a white/yellow line (indicative of nickel or arsenic enrichment). The central core was a slack quenched steel with a tempered martensitic structure degrading to bainite in parts (Hv=353, μHv=454 to 366). It had undergone slight decarburisation near the flank welds.

Knife 5107 was a good quality knife manufactured according to the Type 1 method.

6 KNIFE 5111

Knife 5111 was ascribed to Backform E1, the tang was thick and only formed a shoulder with the blade at the knife back. X-Radiographs showed extensive corrosion midway along the cutting edge, and horizontal slag banding (Figure 9). A single half-section was removed.

Examination of the unetched specimen showed heavy corrosion penetrating inwards from the faces of the knife, especially in the lower part (cutting edge area) of the section. Slag inclusions were present throughout the section, and slag lines were present on one side of the knife. When etched the overall structure was that of two strips welded together in the vertical plane (Figure 10). The first iron contained the slag lines and was a piled structure of bands of ferritic/phosphoric iron (Hv=151, µHv=215) and ferrite plus grain boundary carbides (µHv=181). The second iron was a fine degraded (partially spherodised) pearlitic structure (Hv=186, µHv=260) that coarsened at the tip to pearlite plus ferrite (Hv=237, µHv=274).

Knife 5111 could either be considered to have been manufactured according to Type 3 (all steel) or half a Type 1. The presence of a distinct central weld line would indicate the latter method of manufacture. The knife had not been heat treated, and was therefore of poor quality.

Knife 5719 was ascribed to Backform C. It had a very long tang with respect to its overall length. It had a concave edge profile, probably due to wear. X-Radiography showed corrosion penetration at the cutting edge, the presence of slag lines and vertically orientated micro-cracks along the back of the tang, close to the tang/blade interface. A probable cutting edge/back weld line was identified (Figure 11). Two half-sections were removed.

The unetched condition showed the iron to be heavily slagged, with vertically orientated slag lines. There was a probable scarf weld, at a steep angle, joining the cutting edge to the knife back. In the etched condition the presence of a scarf welded cutting edge was confirmed (Figure 12). The cutting edge had a low carbon tempered martensite plus ferrite structure (Hv=252, µHv=420). The knife back was an irregularily piled or banded structure of phosphoric iron and ferrite plus pearlite, the banding resulting from segregation of the phosphorus and carbon. The pearlite occurred at the prior-austentite grain boundaries. The ferrite had a large grain size (ASTMS >1, except at the knife edges where smaller grains were present ASTMS 6 [de-phosphorisation?]), with a mean hardness value of Hv=190, uHv=185, confirming the presence of phosphoric iron rather than ferritic iron. The ferrite plus pearlite bands ranged in hardness from µHv=177 - 245, Hv=186.

Knife 5719 was of Type 2 manufacture (or possibly a half Type 1, i.e. only one flank). It had been successfully heat treated, although a low carbon steel had been used for the cutting edge. The knife back had been manufactured from a piled iron.

8 KNIFE 6487

Knife 6487 was ascribed to Backform E1. It was heavily corroded on the surface, X-radiography showed that corrosion penetration had occurred, and that a region mid-way along the blade had totally corroded, and had fractured (Figure 13). Initially a single half-section was removed, but the knife broke and therefore a complete cross-section was removed. In the unetched condition both sections showed vertically orientated slag lines down which there had been extensive corrosion penetration. In the etched condition neither section showed evidence for a steel cutting edge. The microstructure was large grained ferrite, with a mean hardness of Hv=110, μHv=136, and with Grain Sizes >ASTMS 1. This would indicate a very slow cool, and may therefore be interpreted as accidental, i.e. left in a hearth. There was some ferrite plus pearlite bands present, nucleated on slag lines. These probably arose from carburisation during the working of the iron, in particular folding and welding. A cutting edge may have been present, but was lost due either to wear or severe corrosion.

9 KNIFE 7662

Knife 7662 was ascribed to Backform C. It was badly corroded, and X-radiographs showed some metal loss, especially along the cutting edge. It was fractured across the tang and also at about 10mm from the knife tip. Slag lines were observed in the X-radiograph (Figure 14). Two half-sections were removed.

In the unetched condition vertically orientated slag lines were recorded, concentrated in the centre of the knife back section, suggestive of a Type 1 manufacture. Etching confirmed the method of manufacture (Figure 15), the steel core having a fine pearlite plus ferrite structure. The hardness results (Table 2) show no variation down the length of the knife, indicating that the effective cutting edge had not been heat treated, although the original edge may have been quenched, but its effect worn away. The evidence of extensive wear, being the difference in length of the two flanks. The two flanks were phosphoric/ferritic iron displaying some banding of varying grain size with some grain boundary carbide present in the ferritic bands and phosphoric ghost phasing present in other bands. There were fine precipitates, indicative of age hardening in the ferrite. The hardness results are shown in Table 2, and show that the largest grains were the hardest.

Knife 7662 was of Type 1 manufacture but had either not been heat treated when originally manufactured, or had been carelessly maintained as evidenced by the differential wear/sharpening of the flanks and the absence of a heat treated edge.

TABLE 2 HARDNESS VALUES FOR KNIFE 7662

		Hv	μHv
Ferritic Bands			
Ghost Phases Present			209
" " "			213
Large Grained		252	322
" "		223	274
Steel Core			
Pearlite plus Ferrite	(Back)	185	297
	(Middle)		210
	(Tip)	223	297

10 KNIFE 8574

Knife 8574 was ascribed to Backform E1. It was heavily corroded, the cutting edge being particularily effected (Figure 16). A single half-section was removed.

Despite positioning the section in the least corroded region of the knife blade much of the section was corroded. The surviving metal was heavily slagged, but there was no distinct banding observed. In the etched condition the surviving metal was phosphoric iron (ghost phases present, Hv=178). There was no evidence of a steel cutting edge.

Knife 8574 had to be ascribed to manufacturing Type 0, due to the absence of a cuting edge. The extensive corrosion could have removed a butt welded edge. The profile of the knife did indicate some wear (slight concave profile at the tang blade interface, Figure 16), and therefore a combination of wear and corrosion may have removed the cutting edge.

FIGURE 1 KNIFE 1532 INTERPRETATION OF X-RADIOGRAPHS (X1)

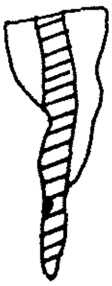

FIGURE 2 KNIFE 1532 CROSS-SECTION (X5)

FIGURE 3 KNIFE 2270 INTERPRETATION OF X-RADIOGRAPHS (X1)

FIGURE 4 KNIFE 2270 CROSS-SECTION (X5)

FIGURE 5 KNIFE 4035 INTERPRETATION OF X-RADIOGRAPHS (X1)

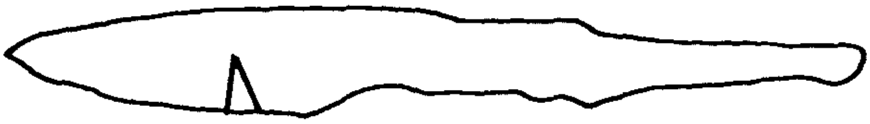

FIGURE 6 KNIFE 5096 INTERPRETATION OF X-RADIOGRAPHS (X1)

FIGURE 7 KNIFE 5107 INTERPRETATION OF X-RADIOGRAPHS (X1)

FIGURE 8 KNIFE 5107 CROSS-SECTION (X5)

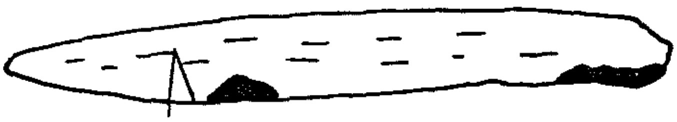

FIGURE 9 KNIFE 5111 INTERPRETATION OF X-RADIOGRAPHS (X1)

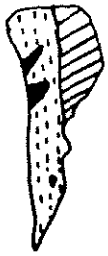

FIGURE 10 KNIFE 5111 CROSS-SECTION (X5)

FIGURE 11 KNIFE 5719 INTERPRETATION OF X-RADIOGRAPHS (X1)

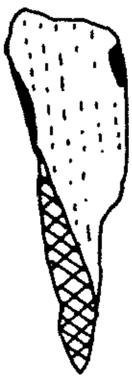

FIGURE 12 KNIFE 5719 CROSS-SECTION (X5)

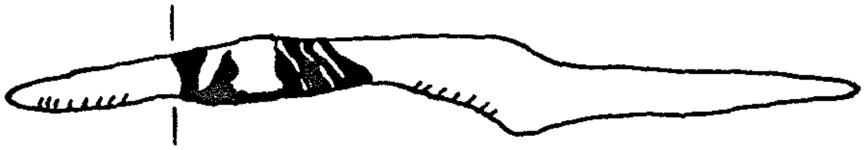

FIGURE 13 KNIFE 6487 INTERPRETATION OF X-RADIOGRAPHS (X1)

FIGURE 14 KNIFE 7662 INTERPRETATION OF X-RADIOGRAPHS (X1)

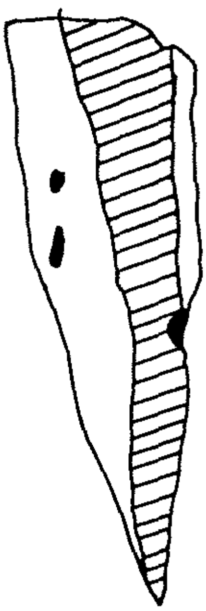

FIGURE 15 KNIFE 7662 CROSS-SECTION (X5)

FIGURE 16 KNIFE 8574 INTERPRETATION OF X-RADIOGRAPHS (X1)