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METALURGICAL ANALYSIS OF THE COPPERGATE WEAVING SWORD.

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Summary

The report presents the results of the metallurgical examination of the 'weaving sword' recovered from the pit that included the Coppergate Helmet which is dated to the 8th century AD. The predominant microstructure was ferrite.

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The Metallurgical Analysis of the Weaving Sword from Coppergate, York (AM Lab Number 895413)

By Dr Gerry McDonnell

1 Introduction

During the watching brief on the Coppergate development site a group of objects were salvaged which included the Anglian "Coppergate Helmet" and a spear or spear-like artefact. Post-excavation examination suggested that it was a weaving sword rather than a weapon. Metallographic examination of the 'sword' might enable its true function to be determined.

No metallographic analysis of a weaving sword has been published, but a number of Anglo-Saxon/Viking Age (6th-11th century) weapons from England have been studied, especially by Gilmour (Tylecote and Gilmour 1986 p109-244), and Moir (1989). These results show that a wide range of manufacturing techniques and metals were used. However, Gilmour presented no results that showed a sword to be manufactured solely from ferritic/phosphoric iron, and that heat treated and un-treated steel cutting edges were present. The analyses of spears by Moir show that in general they were made from low carbon irons, which had not been heat treated.

2 Description of the 'Sword'

When complete the object was about 0.54m long. The sword is shown reconstructed in Figure 1. It was gently bent, midway along the blade, and in antiquity had been broken in two places. These are indicated in Figure 1 by increased corrosion. The break nearest the tip had possibly been repaired or contained by a rivet, however the evidence was inconclusive and it may have been a corrosion effect. Due to the waterlogged conditions in which the sword was buried, corrosion was restricted and the wooden shaft had been preserved in the socket. There was evidence for the welding-on of a tip section, again either repairing a break or the deliberate addition of a steel 'cutting' edge.

3 Methods of Analysis

The weaving sword had been X-radiographed and conserved by the Conservation Department of the York Archaeological Trust. It was radiographed again to investigate the weld line. A section was cut which traversed the weld line and therefore incorporated samples of both pieces of the 'sword'. The section was mounted in a thermosetting resin, ground and polished in the usual manner. A metallurgical microscope was used to examine the section in the unetched and etched condition (etchant 2% Nital). Microhardness measurements were recorded. A Scanning Electron Microscope with an attached energy dispersive analysis system was used to analyse the slag inclusions and examine the weld line.

Table 1 Coppergate Weaving Sword Microhardness and Grain Size Measurements.

Description	ASTM	HV0.1
phosphoric iron	<1	224
ferrite plus some grain boundary carbide	5	174
" " grain boundary carbide	6-7	113
ferrite	6-7	138
at the 'cutting edge'		
ferrite plus some grain boundary carbide	6	130
Welded-on length		
ferrite	7	130
ferrite plus grain boundary carbide	7-8	132
ferrite (phosphorus)	6-9	156
ferrite plus grain boundary pearlite	7	150
ferrite (phosphorus)	5-6	177
ferrite plus pearlite	8	203

(Note ASTM 1 is tha largest grain size)

4.3 The Elemental Analysis of the Slag Inclusions

The Scanning Electron Microscope with an attached energy dispersive X-ray analysis system was used to analyse the inclusions. (The operating conditions were accelerating Voltage =20kV, Working distance=26mm, filament run at saturation).

The majority of inclusions occurred as lines or swarms of inclusions running down the section in both pieces of iron. There were two main morphological types of inclusion present in both pieces of iron. The majority were small round or sub-round in cross-section with a maximum diameter of the order of 10 microns. The second group were thin lenticular inclusions with lengths of the order of 150 microns and maximum width of 40 microns, although some were only 5-10 microns wide.

The analyses are given in Table 2 and show a typical range of compositions. These results are part of a longer term project

TABLE 2

Weaving Sword Inclusion Analyses Component 1 (body of sword)
(oxide percent, INCL = Inclusion Number; n.d = not detected)

INCL	Na	Mg	Al	Si	P	S	K	Ca	Ti	Cr	Mn	Fe	Co	Ni	Cu	Total
1	0.2	0.2	0.3	14.6	1.7	0.0	0.0	0.2	0.1	0.1	0.1	83.7	0.2	0.0	0.1	101.5
2	0.2	0.0	0.8	15.5	2.1	0.0	0.1	1.1	0.0	0.2	0.1	83.0	0.0	0.0	0.0	103.1
3	1.0	0.2	0.9	20.9	6.6	0.0	0.8	6.1	0.0	0.0	1.1	70.2	0.0	0.0	0.0	107.8
4	0.8	0.5	1.1	26.6	5.9	0.0	1.8	5.5	0.1	0.0	1.4	61.0	0.0	0.0	0.0	104.7
5	0.6	0.2	0.2	28.4	0.9	0.0	0.1	1.2	0.0	0.0	6.1	65.7	0.0	0.0	0.0	103.4
6	0.6	1.4	6.4	37.6	2.2	0.0	2.3	5.7	0.5	0.2	0.8	43.8	0.0	0.0	0.0	101.5
7	0.0	1.5	7.6	37.6	6.1	0.0	1.8	5.8	0.7	0.0	1.9	40.6	0.0	0.1	0.0	103.7
8	0.4	2.6	6.8	36.8	1.3	0.0	1.4	3.5	0.3	0.0	0.3	52.8	0.0	0.0	0.0	106.2
9	1.1	2.4	10.2	53.0	0.7	0.0	4.4	5.8	0.8	0.0	0.5	25.6	0.1	0.0	0.1	104.7
11	0.4	0.5	0.8	19.5	3.5	0.0	0.0	0.2	0.0	0.1	0.0	80.0	0.0	0.0	0.0	105.0
12	0.3	0.4	0.7	5.7	31.3	0.0	0.2	1.3	0.0	0.1	0.1	63.4	0.0	0.0	0.0	103.5
13	0.0	0.0	0.0	82.3	0.4	0.0	0.0	0.8	0.1	0.0	0.0	15.1	0.1	0.1	0.0	98.9

Weaving Sword Inclusion Analyses Component 2 (welded-on tip)
(oxide percent, INCL = Inclusion Number; n.d = not detected)

INCL	Na	Mg	Al	Si	P	S	K	Ca	Ti	Cr	Mn	Fe	Co	Ni	Cu	Total	
1	1.0	0.0	1.4	7.2	0.9	0.0	0.5	0.1	0.0	0.0	0.0	113.7	0.1	0.0	0.1	125.0	(beam pen)
2	0.5	1.0	2.9	22.7	5.8	0.0	1.9	1.5	0.0	0.0	0.3	66.4	0.1	0.0	0.0	103.1	
3	0.3	1.3	4.3	26.2	6.5	0.0	1.0	3.8	0.3	0.2	0.6	56.8	0.0	0.0	0.0	101.3	
4	0.6	0.3	2.1	28.2	1.7	0.0	0.5	0.4	0.0	0.0	0.0	67.9	0.0	0.0	0.1	101.8	
5	0.2	0.1	0.8	19.2	2.2	0.0	0.1	0.5	0.0	0.0	0.6	75.6	0.0	0.0	0.2	99.5	
6	0.9	0.3	1.9	19.3	1.7	0.0	0.1	0.1	0.0	0.0	0.0	77.3	0.2	0.0	0.1	101.9	
7	1.1	0.3	1.5	30.0	4.0	0.0	1.2	0.3	0.0	0.0	0.0	63.0	0.0	0.0	0.0	101.4	
8	0.3	1.7	4.8	32.7	5.2	0.0	1.3	3.9	0.4	0.0	0.7	49.8	0.1	0.0	0.0	100.9	
9	0.6	0.9	2.1	10.7	4.1	0.0	0.2	1.3	0.3	0.2	0.2	105.4	0.0	0.0	0.0	126.0	(beam pen)
10	0.1	1.9	5.3	29.5	7.4	0.0	1.0	4.9	0.5	0.2	1.0	49.9	0.0	0.0	0.0	101.7	
11	0.3	1.5	5.8	33.6	6.4	0.0	1.8	4.2	0.3	0.0	0.5	52.7	0.0	0.0	0.1	107.2	
12	0.0	0.0	0.0	26.8	0.7	0.0	0.0	0.0	0.0	0.1	0.0	99.5	0.0	0.0	0.1	127.2	(beam pen)

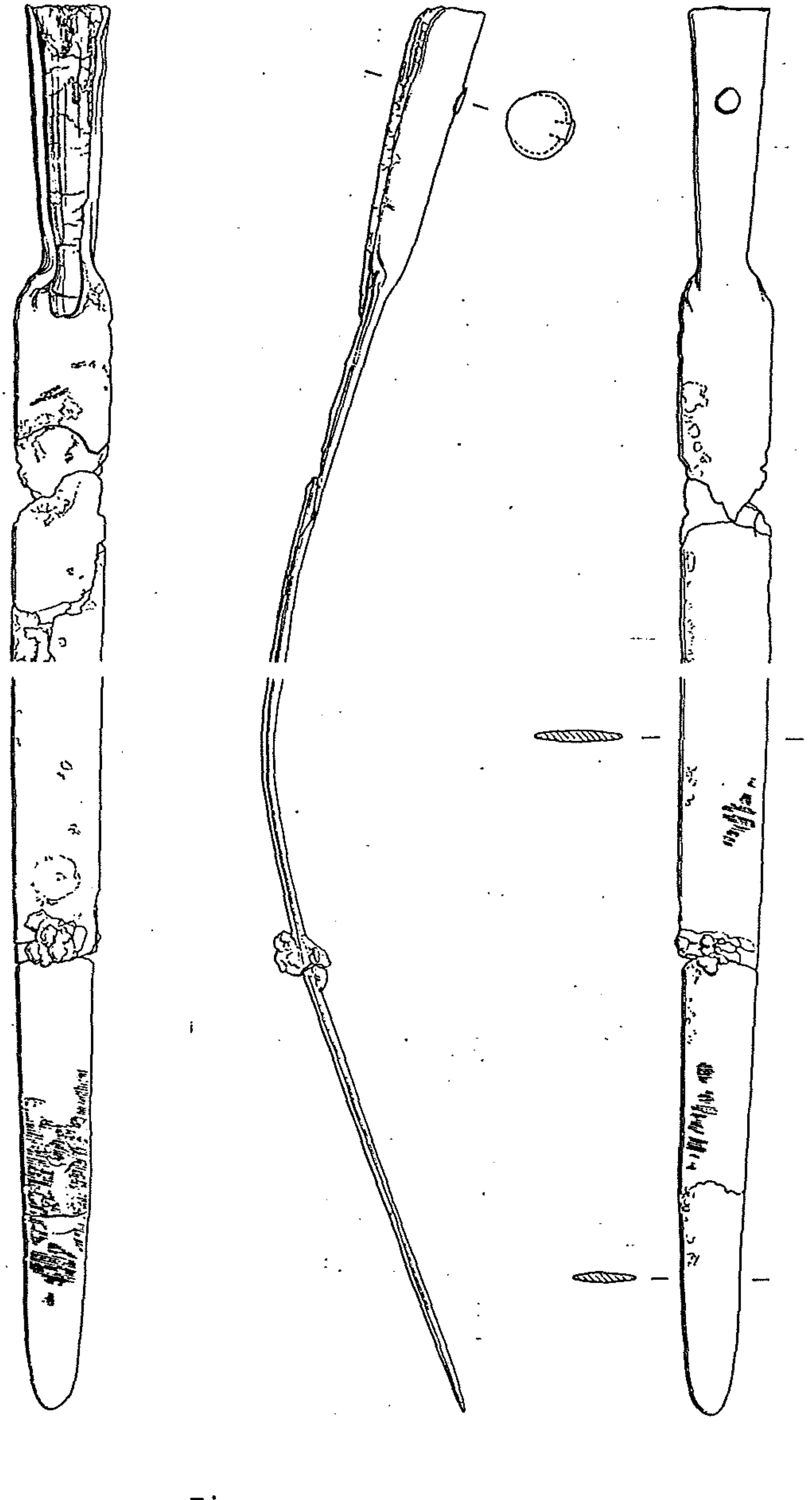

Figure 1 Coppergate Weaving Sword

0 10cms

Plate 3 Coppergate Weaving Sword. Micrograph showing the large grained phosphoric iron (top) and equiaxed ferrite plus grain boundary carbide (bottom) (Magnification x100)