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METALLURGY RESEARCH (ARCHAEOMETALLURGY)

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HEYBRIDGE SLAG REPORT

1. INTRODUCTION

The manufacture of early iron artefacts was a two stage process. Firstly the extraction of the metal from the ore, the smelting process. Secondly the refining of the metal, the working into bar-iron, and subsequently artefacts, and any alteration or repair of artefacts is termed the smithing process. Both processes generate iron silicate slag as a by-product. Such 'slag' is found on most excavations of Iron Age and later settlement sites, both urban and rural. It is necessary to identify the slags as smelting or smithing, in order to establish which (or both) processes were practised on the site in antiquity.

The residues from ironworking (ie both smelting and smithing), can be classified into two broad groups, diagnostic and non-diagnostic slags. The latter are residues that are generated by both processes and cannot be ascribed to either process and may also be by-products of other pyro-technological processes. Furnace/hearth lining is the preserved fired clay fragments of the furnace or hearth structure. It is distinguished from ordinary fired clay by the vitrification of the inner face due to the high temperatures of the furnace or hearth. These conditions prevail in the tuyere zone of the furnace or hearth, and the tuyere mouth, a circular hole 1-2 centimeters in diameter, is often preserved. The second non-diagnostic residue is fuel ash slag, which is a product of the high temperature reaction between siliceous material and fuel ash. Characteristically it is light grey in colour, of low density, often vitrified and commonly occurs as fused globules.

The diagnostic residues are the silicate smelting and smithing slags. The latter occur as the characteristic hearth bottom or as randomly shaped lumps. The smelting slags occur in a number of different forms, characteristically as the flowed lava-like 'tap slag', but in many cases in forms which are difficult to distingush from smithing slags, eg. smelting slag cakes are similar to hearth bottoms.

HEYBRIDGE SLAG-CLASSIFICATION

The total quantity of slag retained from the excavation weighed 15.16 kilograms. The non-diagnostic slags totalled 0.345 kilograms, which was all furnace/hearth lining, in two cases fuel ash slag was fused to the lining. One piece [44, 12/00 *257/80] was a tuyere mouth 3 centimeters in diameter. Also recorded was a lump of ferruginous stone,([140, 33/60 * 273/7], weight o.24 kilos) that could be considered as a possible piece of ore.

The diagnostic iron silicate slag was predominantly smithing slag, and only 0.34 kilos was probable smelting slag. The latter comprised of less than ten pieces of probable tap slag from five contexts, and are considered to be residual or intrusive.

All the remaining slag (14.235 kilos, 94% of the total assemblage), was smithing slag, occuring as either the characteristic hearth bottoms or as randomly shaped lumps. Many of the latter were probably hearth bottoms in the early stages of formation. The hearth bottoms, (plano-convex accumulations of smithing slag) varied in size from 6.0 X 3.0 centimeters, (mean diameter X depth), to 9.5 X 5.0 centimeters and 10.0 X 4.0

centimeters, (mean values 8.0 X 4.0 centimeters). The weights varied from 0.12 to 0.55 kilos, (mean value 0.31 kilos).

3 SLAG DISTRIBUTION

Twenty-seven contexts produced slag, eight of which contained less than 100 gms, (including all the tap(?) slag, except for 140 gms of unstratified tap(?) slag, [layer 0, 36 X 290]. Eighteen contexts contained between 100-1000 gms of slag. Context 8 contained 6.695 kilos of smithing slag, (44% of the total), and 0.12 kilos of furnace/hearth lining. This context was a black soil layer with charcoal and burnt clay as well as slag, and it was associated witha possible pottery kiln. It was dated to the Roman Phase of the site, as were other slag containing features eg 2 and 2A (0.895 kilos), 79 (0.485 kilos). The possible tap slag was also of Roman date, (except for the unstratified layer, context 0 (0.14 kilos)). The slags deriving from the later Anglo-Saxon Contexts are probably the result of disturbance of Layer 8 or other contemporary (Roman) material.

The quantity of slag probably represents a small local smithing activity, and it is of interest to note its association to the possible pottery kiln.

4 SLAG ANALYSES

Five samples were selected for detailed analysis. A specimen was cut from each sample, mounted and polished for metallographic study to determine the mineral texture. Each sample was chemically analysed using the scanning Electron Microscope with an attached 'Link' energy dispersive analysis system. 'Bulk' analyses were obtained using a raster scan at 200X magnification, and individual phases using 'spot' analyses.

Iron smelting and smithing slags comprise of three phases, iron silicate, commonly Fayalite ($2FeO.SiO_2$), iron oxide, either Wustite (FeO) or Magnetite (Fe_3O_4), and a glassy phase containing the alkali oxides (CaO, K_2O), Alumina (Al_2O_3), and some silica and iron oxide.

The composition and texture of the phases present is indicative of the conditions of formation of the slag, and may therefore be used to discriminate between smelting and smithing slags, and to investigate differences between slags of different periods.

Samples were taken from three Roman contexts, [A8],[75],and [119], and two Anglo-Saxon Contexts [64] and [83A]. All samples were either typical hearth bottoms or randomly shaped lumps of smithing slag.

Sample A8, 75, and 83A showed typical smithing slag microstructures, massive silicate, free iron oxide dendrites (10-25 %), and interstitral glass (10-20%). Samples 64 and 119 contained less than 5% free iron oxide and the silicate occured as laths, the glass content was about the same. This type of structure is typical of fully liquid fast cooling slags, such as smelting slags, but also does occur in smithing slags.

A Bulk analyses of each sample is given in Table I,and are typical silicate slag analyses. The silicate was confirmed as fayalite by individual spot analyses. Samples 64 and 119 contain low percentages of iron oxide which is in aggreement with the low free iron oxide content observed in the optical study, and both samples have lath rather than massive silicate. The percentage of glass forming minerals (primarily potassium and calcium), is lower than expected from the observed glass content of 10-20%. The spot analyses of the glass phases showed a high silicon and iron oxide content indicating that the glasses contained a high silicate and/or quartz content.

TABLE I HEYBRIDGE SLAG BULK ANALYSES (% OXIDE)

SAMPLE	A8	64	75	83A	119
Na	0.0	0.3	0.2	0.2	0.1
Mg	0.8	0.2	1.0	0.3	0.8
Al	3.4	3.1	0.5	1.0	3.0
Si	22.2	30.0	18.4	23.9	35.6
P	0.6	1.1	0.4	0.6	1.9
S	0.1	0.1	0.0	0.0	0.0
K	2.6	3.6	0.0	0.3	2.7
Ca	3.2	8.4	0.8	0.7	8.3
Ti	0.0	0.3	0.1	0.0	0.2
V	0.1	0.0	0.0	0.0	0.2
Cr	0.0	0.5	0.1	0.0	0.0
Mn	0.1	0.4	0.0	0.3	0.6
Fe	63.5	54.3	77.4	64.1	47.9
Co	0.0	0.0	0.0	0.0	0.0
Ni	0.1	0.3	0.0	0.0	0.1
Cu	0.0	0.3	0.1	0.1	0.2
TOTAL	96.7	102.9	99.0	91.5	101.6

The analyses are typical of other smithing slag analyses, showing no single characteristic feature that would distinguish the Heybridge slags from smelting slags, nor do the analyses indicate any difference between the Roman slags (A8, 75, and 119) and the Anglo-Saxon slags (64 and 83A).

The identification of the slags as smithing slags rather than smelting slags relies on the morphology of the slags, the mineral texture, and the lack of smelting slag attributes, although slags 64 and 119 contain typical smelting slag silicate laths.

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