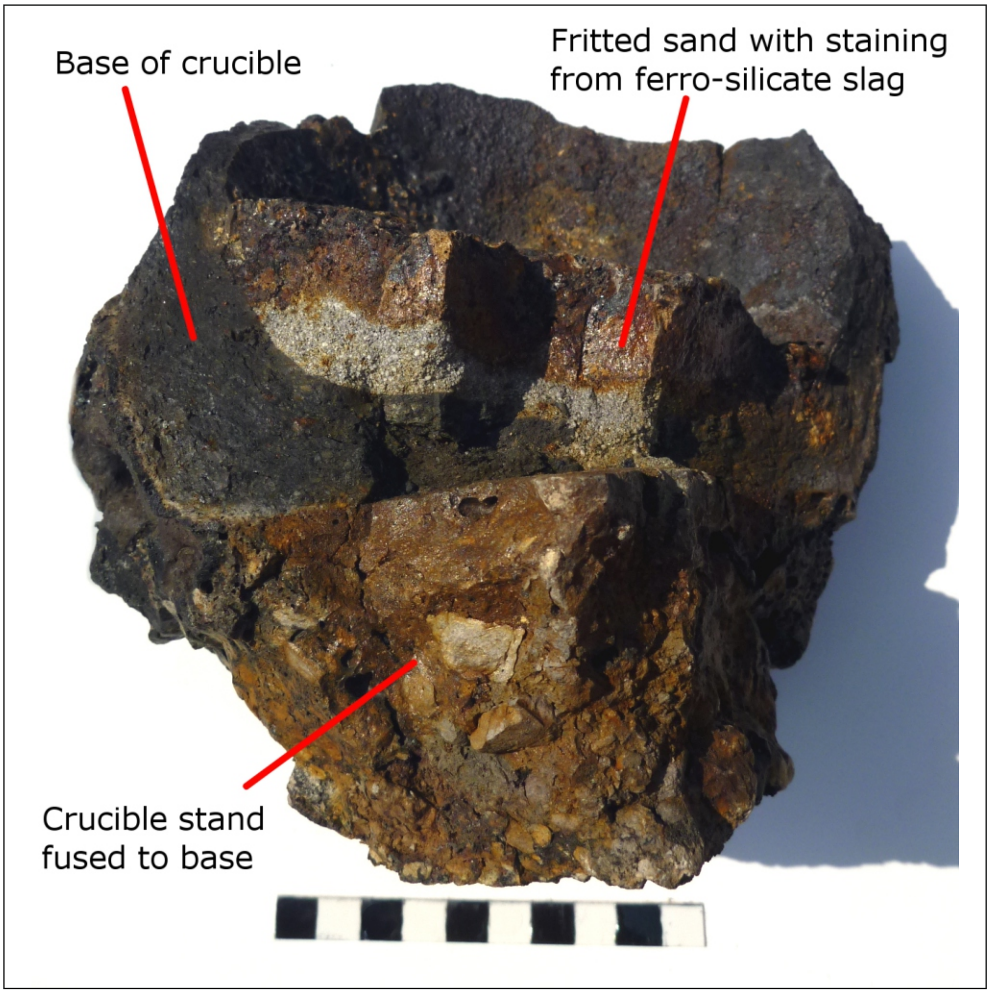
making sense of heritage

Hoyle Street, Sheffield

Specialist Report
Slag and crucibles recovered during
archaeological fieldwork



Ref: 87352
Specialist Report No 1
October 2014

wessex archaeology

Final report on slag and crucibles recovered during archaeological fieldwork at Hoyle Street, Sheffield (Arcus 930)

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Introduction

The post-excavation assessment report on the ferrous metalwork, crucibles and slag from Hoyle Street (Doonan 2009) made several recommendations for further work, based on a provisional identification of the excavated material.

During the excavation, at least two site visits were made by the author to advise on sampling and finds collection. During these visits, the author was able to see many of the finds and process residues whilst they were still in their respective contexts; this additional information has been used to reappraise the recommendations made in the original post-excavation assessment report.

The post-excavation assessment report identified finds and materials that suggested the former presence of an iron foundry on the site, and the evidence seen during the author's site visits backs up this interpretation. However, in the post-excavation assessment, some of the process residues appear to have been possibly misidentified as slag produced by a blast furnace rather than that from a cupola furnace.

Although both blast furnaces and cupola furnaces both produce cast iron, there are significant differences in the way that they produce the iron, the scale of production, and how and where they were used. Blast furnaces produce cast iron from the initial raw material, iron ore; the molten iron can be used to produce finished products, or it can be cast into ingots (or 'pigs') of iron that can be sold on for remelting in other furnaces. Cupola furnaces are used to re-melt scrap cast iron and steel to produce cast products. Blast furnaces are substantial structures and are often situated near a source of iron ore. Outwardly, cupola furnaces look similar to blast furnaces, i.e. a vertical tube/shaft; however, cupola furnaces are generally much smaller, and the smallest can be around the size of a domestic dustbin. Because of their smaller size, cupola furnaces are generally easier to accommodate in foundries, and they are can be especially useful where the demand for castings is variable.

As cupola furnaces are re-melting rather than smelting furnaces, they generate much less slag by-product than a blast furnace; this may explain the relatively small amounts of slag noted in the post-excavation assessment. There is some cross-over in the morphology of slag produced by blast furnaces and cupola furnaces; however, the assemblage does contain fragments of characteristic cupola slag and there is an absence of characteristic blast furnace slag. The casting moulds seen on site were small sized and would not have required a blast furnace. It is therefore most likely that the slag found on the site came from a cupola furnace, and further analysis to determine its origins is not justified.

The assessment also recommended potential characterisation work on the casting moulds, to give an insight into the range of products being produced. However during the site visits, the author saw several patterns for what appear to be automotive parts, including patterns to produce large brake callipers, presumably for commercial vehicles. It seems likely that these casting moulds relate to the more recent history of the site, and further scientific investigation is unlikely to extend understanding of the site or the artefacts produced, beyond that available in historical records.

The post-excavation assessment also noted the extensive crucible assemblage and suggested that the chemical composition of any residual metal in the crucibles could add to our understanding of the site, and it recommended that the full range of steel recipes are examined by the further study of the residues.

Given the resources available, a decision was made to focus further work on this recommendation and to only investigate the crucible steel residues.

Methodology

Initially the aim was to select crucible fragments that might contain metallic residues from contexts with a range of dates and locations within the site to investigate differences in steel recipes.

However, the inspection of the crucible fragment assemblage revealed that only a small number of fragments had traces of any metallic residues. Given that only two contexts (2101 and 2104) were represented, the focus of the analysis shifted from comparing steel recipes from to trying to determine whether there was any direct evidence of alloy steel production at the site. The scarcity of any obvious metallic residues in the used crucibles is, in the author's experience, not unusual. The reasons for this are covered in more detail in the discussion section of this report.

The metallic residues on the crucible fragments were in the form of small spots of corroded metal adhering to the slagged inner surfaces of the crucibles. Due to the small volume of solid metal typically found under the layers of corrosion, a Scanning Electron Microscope with Energy Dispersive X-ray Detector (SEM-EDX) was used to chemically analyse the metal.

Two samples from context 2101 and two from context 2104 were analysed.

Where necessary, the large crucible base fragments were fractured to enable samples of the metallic deposits to be removed. The samples were then set in 32mm epoxy resin sample mounts, before being prepared for metallographic analysis using established methods, as described by Vander Voort (1999). After a final polish with 1μm diamond paste, the surface of the samples was examined using a reflected light microscope before being carbon coated prior to analysis using the SEM-EDX.

The chemical composition of the metal was investigated by performing EDX analysis of at least three points within the samples.

Results

Out of the four fragments of crucible with traces of corroded metallic residues selected, only one piece from context 2101 provided a sample of analysable metal. The analysis of the sample found that it was plain carbon steel, with approximately 1.0 to 1.1% carbon and no detectable alloying elements present.

Discussion

Although at first sight, there may appear to be large quantities of potentially metal bearing residues present in the assemblage, the crucible steelmaking process was very effective and, it is unusual to find sufficient quantities of metal present to enable reliable results to be obtained from metallographic analysis.

The fragments of used crucible that commonly appear to have substantial residues are the large pieces from the base of the crucible. However a large part of what appears to be slag like residues in the base of the crucible is, in fact, refractory sand with a thin crust of slag on its upper surface (See Plate 1). The refractory sand was thrown into the preheated crucible by the furnace men before the metal was put in for melting, to plug a hole in the base of the crucible left over from the crucible manufacturing process. To stop the sand running out of the hole, the crucibles were sat upon a clay stand; also know by furnace men as a 'cheese' because of its shape. In the intense heat of the furnace (circa 1500-1650^{0}C), the sand would fuse to plug the hole and join the crucible and stand together (Barraclough 1984, 41).

The sample of metal analysed was from a crucible fragment that probably dates from the 1850-1900 period, when Sheffield 'was at the centre of exciting and often quite secretive developments of new alloy steels' (Keown 1985), with the production of high tungsten tool steel, silicon steel and manganese steel. Hadfield (1925) defines alloy steel as:

> 'Steels which owe their properties to the presence of elements other than carbon, even though the carbon still plays a vitally important part in determining the characteristics of the alloy. This definition does not include as alloy steels those to which a small percentage of manganese, silicon, aluminium, titanium or other element is added in order to eliminate objectionable constituents or mechanical defects, such as blow-holes, from carbon steel.'

The sample analysed was a plain carbon steel rather than alloy steel, this is perhaps not surprising, as carbon steel accounted for the majority of crucible steel production in Sheffield until the 20th century.

Conclusion

It should be noted that, due to the nature and routine operation of the crucible steelmaking process, used crucibles were typically discarded away from the furnace. To the author's knowledge, no complete used crucibles have so far been recovered from what could be described as their primary context i.e. the melting hole of a crucible furnace. Fragments of used steelmaking crucibles are a common find in made ground contexts on former industrial sites within Sheffield.

Given the nature of the archaeological contexts that the Hoyle Street crucible fragments were found in, and lifespan and proximity of the crucible furnaces that lay within the excavated area, it is difficult to tie the crucible fragments down to a specific works.

Although the results of this analysis have been disappointing, attempting to identify changes in steel recipes over time or between different furnaces is still a worthwhile line of enquiry. Steelmakers were extremely protective of their recipes, '...considerable secrecy and controversy surrounded most new developments. Large numbers of patents were filed and industrial processes were carefully guarded as the inventors strove to establish international recognition and create wealth' (Keown 1985) and archaeological evidence of early alloy steelmaking in 19th century Sheffield is extremely rare. To the author's knowledge, only one site in Sheffield has produced evidence of alloy crucible steel, and that was the former Osbourne steelworks (Mackenzie 2009).

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