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Investigation of a bloom fragment from Cannop, Forest of Dean (Glos HER 37920)

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Abstract

The planned project to investigate the relationship between the composition of slag inclusions in a raw bloom fragment and that of the associated bulk smelting slags was curtailed because the bloom proved to be heavily corroded, with little or no metal remaining in the core of the bloom.

Instead, a quick investigation was undertaken of two fragments from the outside of the bloom using the scanning electron microscope. This revealed that the dense, uncorroded, outer part of the piece comprised partly-reduced ore particles bound by slag. The ore particles comprised dense blebs of wustite, with occasional blebs of iron, but with a discontinuous layer of iron on the outside. Across the specimen these particles show evidence for gradual dissolution in the slag, with slight thickening of the iron films, until a texture was reached with just the iron films in a slag matrix. The slag texture was coarsest-grained between the wustite-replaced ore, becoming finer into the more dominantly slaggy materials. This suggests that the core of the sample cooled more slowly.

The slag comprised a primary dendritic wustite, in a fairly low proportion, followed by elongate fayalite (up to several millimetres in length) with either glassy interstitial areas or a leucite-wustite cotectic.

The slag phase was thus similar in many respects to typical bulk smelting slags from the area and did not closely resemble other iron-rich (bloom fragment) materials.

This is an extremely interesting set of observations, but is difficult at present to place into context. The bulk smelting slags from the site are of a type seen in other major (military?) smelting sites in Dean and S Wales, which commonly contain large amounts of partly reacted ore in dense furnace slags, as well as more normal tapped slags. This may indicate that a different smelting technique was in use on these sites from that employed at other smelting sites in the area.

Contents

Methods & Rationale

Materials from this site (Glos HER 37920 – LIDAR-detected terrace features in the Cannop Valley: NGR 360950 213032) were assessed together with residues from other sites in Dean (Young 2011). The assessment recommended further investigation because the assemblage included a full range of smelting residues, together with a two objects believed to be bloom fragments. A project to attempt to determine the relationship between the bulk smelting residues and the slag inclusions in the iron of the blooms was set-up.

The reason behind the project was to attempt to provide data that would support the current research interest in provenancing iron artefacts through the analysis of their slag inclusions (e.g. Charlton *et al*. 2012). Much of this work, both the UK and abroad, has been undertaken by trying to compare bulk smelting residue compositions with slag inclusion compositions for ironwork possibly from a

particular source. Blakelock *et al.* (2009) compared inclusions in iron from experimental smelts with the corresponding bulk slag chemistry. The material from site 37920 appeared to offer the chance to compare bulk smelting slag chemistry with the inclusions present in uncompacted bloom from the same site.

When the supposed bloom fragments were cut, one (a 246g piece from 37920-105) was revealed not to be bloom, but was very dense slag with unreduced ore particles. The other (a 596g piece from 37920-101) was indeed a substantial bloom fragment, but the core of the bloom was completely corroded. Analysis of the slag inclusions was not possible. Two fragments from the slag-rich outer layer of the bloom fragment were sufficiently intact to be worth trying to mount (Plate 1). A reduced project, to just assess these fragments was then proposed.

The fragments were mounted (as samples F1 and F2), ground and polished in the Earth Science Department, The Open University. The samples did, in fact, prepare quite well, despite their weathering.

This report presents some very brief exploratory observations on the samples made on the scanning electron microscope (Plate 2).

Electron microscopy was undertaken on the Cambridge Instruments (LEO) S360 analytical electron microscope in the School of Earth and Ocean Sciences, Cardiff University. Microanalysis was undertaken using the system's Oxford Instruments INCA ENERGY energy-dispersive x-ray analysis system (EDX). All petrographic images presented in this report are backscattered electron photomicrographs.

Because of the constraints of the limited programme of work and because the slag attached to the outside of the bloom was not the target for the original project, no analyses were made in order to keep machine time, and therefore costs, to a minimum.

Throughout this report standard mineral terminology is applied to both natural and anthropogenic materials – although artificial phases are no longer strictly considered to be minerals.

This project was undertaken for Gloucestershire County Council Archaeology Service.

Results

Backscattered electron photomicrographs of the prepared specimens are presented in Plate 2.

The three areas examined in the two specimens represent a spectrum of textures from one in which partly-reduced ore particles are well preserved (Plate 2a) through to textures in which the ore has entirely reacted, leaving a thin metallic iron film.

The least altered ore particles (Plate 2a,b) are formed of rounded blebs of wustite, up to 100µm across, massed in irregularly shaped particles up to 5mm across, each with an intermittent blebby layer of metallic iron on its surface. Rare small blebs of iron occur with the body of the particles too. The particles have rounded bodies of secondary phases, probably representing infilled vesicles.

Outside the former ore particles is a slag comprising fayalite up to 3mm in length and 300 µm in width, following primary wustite dendrites and with variable interstitial material – either a leucite-wustite cotectic or a glass with fine-grained late stage olivines.

Where the ore particles have reacted further (Plate 2c,d), the iron rims have become continuous films, locally up to 50 µm thick. The amount of wustite in the former ore grains has decreased markedly and their place taken by further slag.

The slag in this area is noticeably finer grained than in the first area, with fayalite up to about 2mm x 200 µm. As well as a primary wustite similar to that in the first area there is a second generation of much more delicate dendrites, particularly in some interstitial areas. All the interstitial areas in this section of the sample were of glass plus olivine.

Where the wustite in the former ore grains has reacted entirely (Plate 2 e,f) they are replaced entirely by the slag phase, which is more finely-grained than the previous areas, with the fayalite up to 1mm x 40 µm and the wustite dominantly of the very fine dendrites.

The metallic iron rims to the ore particles are rather heavily weathered in this area, but appear to be thicker – in places possibly having formed more equant iron grains, now largely represented by corroded voids.

Interpretation

The material examined shows ore particles reacting to form mainly slag, with only rather filmy metallic iron. This material is not likely to be representative of typical bloom formation, rather this is a reaction zone adjacent to a bloom.

The material can be contrasted with a small fragment of poor bloom recently described from a site (Plot 430 of the Brecon to Tirley Gas Pipeline, immediately north of the Forest of Dean) recently (Young 2012). In this specimen (Sample D2 from context 86165; Young 2012 p7 and Plates A11 - A12) iron particles of up to 10mm across are partially coalesced and associated with a quenched wustite-rich slag.

The variable nature of the interstitial areas of the slag phase in the present material is similar to textures previously described for slags from the smelting of Forest of Dean ores (e.g. Thomas 2000) and can be paralleled best in the Gas Pipeline material in slags which originated inside the furnace. The leucite-rich areas are interpreted as showing greater influence of potassium-rich vapours arising from the burning charcoal.

The variation in grain size of the different areas can probably be related to the lower cooling rates of situations with the mass – where the ore is less reacted than on the outside.

In the assessment of materials from this site (Young 2011), attention was drawn to the similarity between the smelting residues and those of a group of sites in S Wales and the SW of Dean. These sites are characterised by thick, massive, dense, furnace slags, often with ore and roundwood charcoal inclusions (Caergwanaf, author's unpublished data; Cardiff, Young & Kearns 2011; Woolaston, Fulford & Allen 1992; and possibly Alvington, Young 2009). These sites include some that appear to have been 'official', or military operations (e.g. Cardiff and Caergwanaf; Young forthcoming). The occurrence of such a mass of unreacted/part reacted ore is in agreement with observations made on samples from these sites, but an interpretation in terms of the smelting technology is not yet possible. It seems likely however, that these sites were employing a different type of furnace to those used in other parts of the hinterland of the Forest of Dean.

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Plate Captions

Plate 1. Cut block of specimen.

Face of the sawn block (596g piece from 37920-101) with outlines of the two mounted samples.

Plate 2. BSEM photomicrographs.

a. F1 area 1. Scale bar 3mm. Low magnification view, showing patches of wustite (pale grey) with intermittent iron rims (bright), surrounded by slag (darker grey). The wustite patches are interpreted as incompletely reduced ore.

b. F1 area 2. Scale bar 600µm. Detail from centre of field of view in (a). Wustite (pale grey) shows as rounded blebs inside the former ore grains and as rather sparse dendrites outside. The ore grains bear rounded vesicles filled with secondary weathering products (mid grey). The iron (white) rims of the ore grains are intermittent and sometimes (just above centre) totally weathered. The slag in this area comprises elongate fayalite (mid grey) with interstitial or intergrown leucite-wustite cotectic (speckled) or interstital glass plus olivine (lower left).

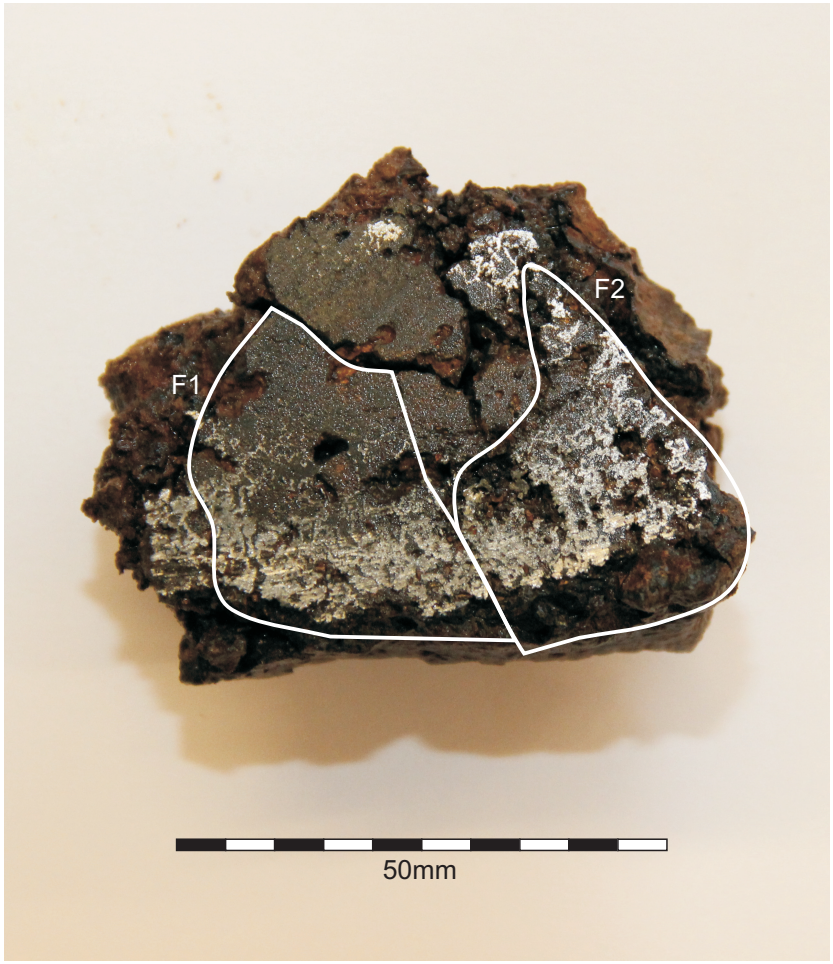
c. F1 area 3. Scale bar 3mm. Low magnification view of an area where the former ore grains are more thoroughly reacted. Explanation largely as (a).

d. F1 area 4. Scale bar 600µm. Detail from centre of field of view in (c). Iron rims on former ore grains are more continuous than in (b). Wustite inside the grains is reduced in volume and replaced by slag. The slag in this area shows primary wustite dendrites, followed by fayalite with an interstitial glass bearing further fine olivine.

e. F2 area 1. Scale bar 3mm. Low magnification view of an area where the former ore grains are almost entirely replaced by slag. Some of the voids have significant rims of secondary weathering products – some of these voids may indicate the former location of metallic iron particles.

f. F2 area 2. Scale bar 600µm. Detail from centre of field of view in (e). Iron rims of former ore grains are still present, but there is no little or no difference in slag texture inside and outside the rims. The slag shows a few coarse wustite dendrites, but most are very delicate and small. In general, the slag microstructure is finer grained than in (b) or (d). Patches of secondary weathering products (e.g. left and above centre) probably indicate further former iron rims.

Plate 1



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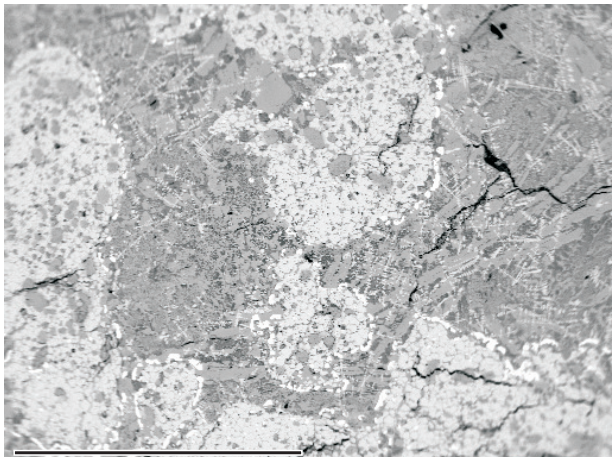

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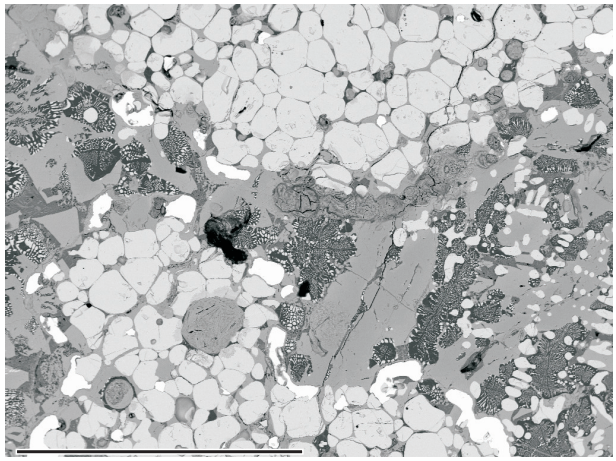

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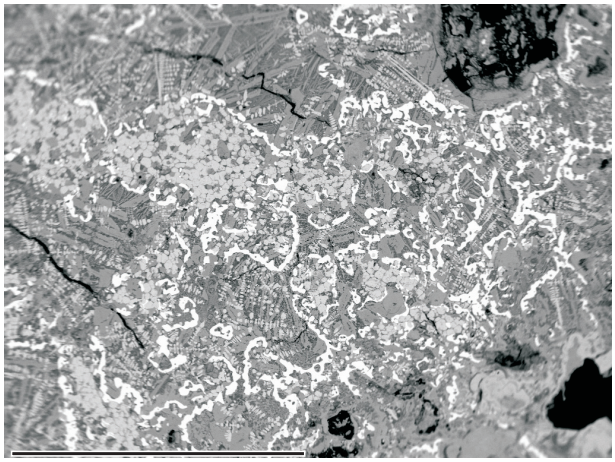

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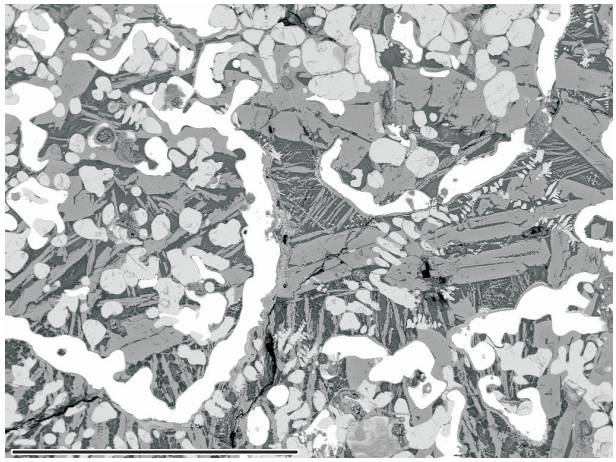

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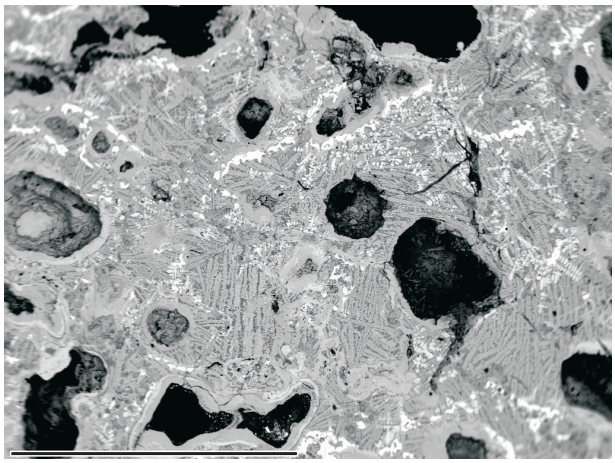

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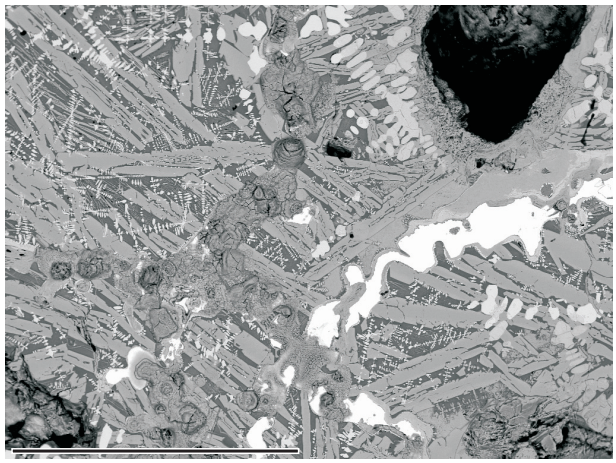

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