Prehistoric iron smelting in London: evidence from Shooters Hill

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ABSTRACT: An archaeological excavation at Shooters Hill in south-east London revealed a ditch which contained a substantial quantity of iron smelting slag. The only dating evidence from the fill of the ditch is provided by Early Iron Age pottery. Shooters Hill is one of the earliest known iron production sites in Britain and suggests that this region (the lower Thames valley) may have played a significant role in the introduction of iron manufacture.

Introduction

The site in Eaglesfield Park, Shooters Hill lies in the south east of London in the Borough of Greenwich. The underlying geology comprises Eocene (*ie* part of the Tertiary) deposits including Bracklesham and Bagshot Beds, both of which have been reported as containing small deposits of iron ores (Tylecote 1962, 178-9; Potter 1977). The site was subject to archaeological excavation in July 2007 which unexpectedly uncovered a ditch containing prehistoric pottery and ironworking slag. The slag provides some of the earliest evidence for iron manufacture in Britain.

The excavation

In July 2007, a programme of archaeological fieldwork, including excavation, was carried out on Shooters Hill as part of a television programme (Channel Four's *Time Team*). The main focus of the television programme was the remains of Second World War defences; however, Trench 3 (NGR TQ 4391176647) revealed part of a much earlier ditch (context 306). Excavation was limited but the ditch produced a small assemblage of late prehistoric pottery (60 sherds, weighing 243g) from two of its fills (26 sherds from lower fill context 304; 34 sherds from upper fill context 303).

In terms of fabrics, just over half of this small assemblage (31 sherds) comprises sherds which are sparsely flint-tempered within a fine clay matrix with a smooth texture (fine quartz grains are only visible microscopically; flint inclusions are less than 1mm in size). A further 22 sherds have coarser matrices and contain sparse to moderate voids (up to 2mm), representing leached out inclusions, in this case probably calcareous (possibly shell), and also rare flint inclusions. Three sherds have a coarser sandy matrix with rare flint up to 2mm. Four sherds have been so heavily burnt that their original fabric cannot be determined, and several other sherds also appear to have been slightly burnt. Diagnostic pieces consist of three rim sherds, two in the fine sandy/flint-tempered fabric and one in the ?shelly/flint-tempered fabric. None are sufficiently large to determine overall vessel form, although at least two of the three appear to derive from vessels with some sort of neck constriction. There are also two body sherds with carinations, both in the ?shelly/flint-tempered fabric.

The dating of this small group of pottery is of particular significance given the presence of a quantity of ironworking slag in the same feature, although it has to be said that the fabrics and forms seen here do not lend themselves to particularly refined dating. Flint-tempered fabrics containing sparse, randomly sorted inclusions have a currency from the Late Bronze Age (*c*1000 BC to *c*700 BC) to the Early Iron Age (*c*700 BC to *c*400 BC) in the lower Thames valley, as do shelltempered fabrics. Both are paralleled, for example, in the large, recently excavated assemblage from Heathrow Terminal 5 (Leivers *et al* 2010, 28-9); at the same site, sparsely flint-tempered fabrics continued in use into the Middle Iron Age, but shelly fabrics disappeared. It is not often possible to distinguish Late Bronze Age from Early Iron Age ceramics successfully on fabric grounds alone; all that can be observed is that sandy fabrics become more prevalent, at the expense of flint-tempered fabrics, through the period (Longley 1991, 163). Some morphological traits of vessel forms can be identified as belonging specifically to the Early Iron Age, for example long-necked fineware bowls but, given the lack of diagnostic material in this small group, such distinctions are not possible here. In conclusion, the precise dating must remain uncertain, but the sparseness of the flint inclusions could be taken as indicating a date later in the period rather than earlier, perhaps 8th century BC or later, *ie* more probably in the Early Iron Age.

While there is sufficient overlap between the sherds from the two ditch fills to suggest that both context groups are broadly contemporary, some differences can be highlighted. Sherds from the lower fill (304) are larger and slightly less abraded than those from the upper fill (303) – mean sherd weight overall is 4.1g, that from 304 is 4.9g, and that from 303 is 3.6g. There are three sets of conjoining sherds from 304 (representing both old and fresh breaks). The fabric make-up of the two groups also differs: fine sandy/flint-tempered fabrics predominate in 304, while ?shelly/flint-tempered fabrics are more common in 303. No cross-context joins were noted. All the rim sherds came from 304, while the carinated body sherds came from 303. To conclude, the sherds from the upper fill appear to have undergone more re-working prior to eventual deposition, but there may also be a slight chronological difference between the two groups.

Charcoal was recovered from environmental soil samples taken from ditch 306 (Wessex Archaeology 2008); most of this was noted as being ring-porous and so most probably of oak (*Quercus* sp.). The same samples also produced some charred cereal remains, mainly of emmer wheat (*Triticum dicoccum*), and examples of both flake and spherical hammerscale (Wessex Archaeology 2008).

The iron smelting material

In total, just under 63kg of slag and related material was recovered from the ditch (context 306). The visual examination of the material showed no consistent differences in the types present in context 303 or 304 and all material from the ditch is treated together. The assemblage included a small amount of ceramic furnace lining and ore, but was dominated by ironworking slag. The slag has a relatively high density, consistent with a fayalitic composition, and was identified as the product of ironworking (Wessex Archaeology 2008). Much of the slag is black or dark grey in colour, often with a lustrous surface, although many pieces have 'rusty'

Figure 1: Shooters Hill run slag (5mm squared paper).

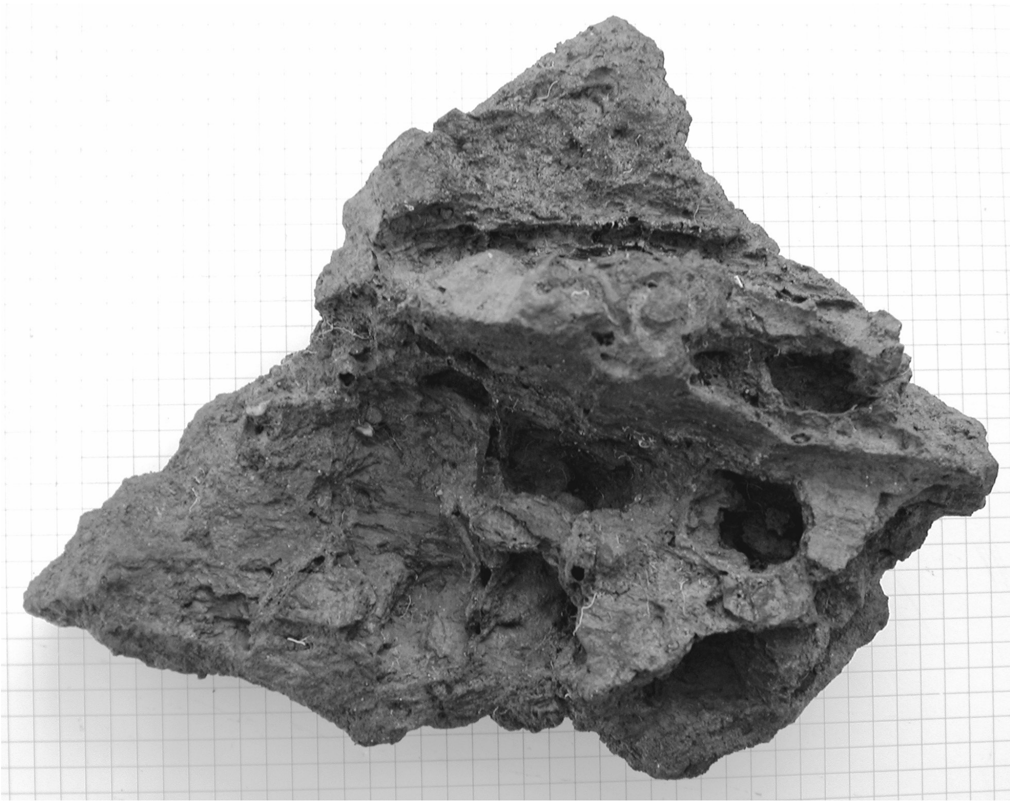

Figure 2: Larger lump of slag from Shooters Hill, possibly a fragment of slag cake (5mm squared paper).

surface deposits. The slag mostly comprises fairly small pieces (<100g) which appear to be more-or-less complete (there are few obvious fracture surfaces). Most of this slag shows signs of having been sufficiently fluid at some stage to have undergone a degree of flow (Fig 1). This flow or run slag is usually irregular in shape with a relatively high surface area, and there are frequent impressions of charcoal on the surfaces. The nature of the flow surfaces suggest that the slag flowed vertically (in contrast with the near horizontal flow characteristics of tap slag) and that this usually took place within a charcoal bed. This slag morphology closely resembles the Iron Age slag from Trevelgue Head (Nowakowski and Quinnell 2011; see also Paynter 2007). Other, larger fragments of Shooters Hill slag (up to 1.2kg in weight) appear to be less complete but are possibly fragments of slag cakes (Fig 2). Some of the run slag and most of the larger lumps of slag have fragments of fired or vitrified ceramic material adhering. The fired ceramic material probably derives from the lining or superstructure of the furnace but the fragments were too small to provide useful information about the size or shape of the furnace. The ore fragments comprise small (<40mm) lumps of maroon red rock with occasional quartz inclusions. The colour of the ore strongly suggests that it has been subjected to roasting. No samples of unroasted ore were identified.

The nature of the slag indicates that it formed, flowed and then solidified within a furnace; the absence of tap slag indicates that slag was never tapped from the furnace. The slag morphology is consistent with either a bowl furnace (cf Dungworth forthcoming; Nowakowski and Quinnell 2011) or possibly a slag-pit furnace (Paynter 2007; Pleiner 2000, 149-63). None of the slag lumps have an overall form that conforms precisely to those unambiguously linked to iron smithing, although the detection of hammerscale in environmental samples indicates that some smithing took place.

Scientific examination of the iron smelting materials

Following the visual examination of the slag, 23 samples were selected for scientific examination. The samples were selected to represent the range of materials present (ore, furnace lining and slag, with both small run slag and larger lumps represented). The samples were cut with a rock saw and embedded in epoxy resin. The embedded samples were ground and polished using standard procedures (Vander Voort 1999). The polished samples were examined using an inverted stage optical microscope (Zeiss AxioObserver) and a field emission scanning electron microscope (FEI Inspect F). The chemical composition of the samples was determined using an energy-dispersive X-ray spectrometer (Oxford Instruments X-act SDD) attached to the scanning electron microscope.

The assemblage of iron smelting debris recovered from Shooters Hill included several samples of iron ore. These samples generally show a rather vughy microstructure with circular or sub-circular pores and connecting channels and cracks. All theses vughs are infilled to varying degrees with radially distributed needles of iron oxide. The only occasional inclusions are quartz. This microstructure is consist with recent iron-rich formations forming at the top of the water table, in particular bog iron ores (cf Kaczorek and Sommer 2003; Kaczorek *et al* 2004; Landuydt 1990; Stoops 1983; Young 1993). The microstructure suggests that other sedimentary ironstones (*eg* Wealden claystone ironstones) are unlikely to be the source of this ore. XRD analysis confirmed the presence of haematite, however there are no significant sources of haematite in the region. Haematite is not a frequent component of bog iron ores which tend to contain amorphous iron, ferrihydrite and goethite (cf Kaczorek and Sommer 2003). It is likely that the ore was heated prior to smelting and so the original form

Table 1: Average iron ore compositions.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	FeO
19a	0.1	<0.1	<0.1	2.4	0.2	<0.2	<0.1	<0.1	<0.1	<0.1	96.8
21	0.1	<0.1	0.6	8.0	0.6	<0.2	<0.1	0.1	<0.1	<0.1	90.4
22	<0.1	0.4	2.6	3.1	0.9	<0.2	<0.1	0.6	<0.1	<0.1	92.3
23a	<0.1	<0.1	0.3	3.2	0.5	<0.2	<0.1	0.1	<0.1	<0.1	95.6
Potter	0.05	0.5	3.7	18.7	0.1	0.5	1.0	0.9	0.5	nr	74.0

Notes: 19, 21-23 = archaeological samples from Shooters Hill
Potter = average of three samples of sideritic ironstone from Bracklesham Beds (after Potter 1977)

Table 2: Average ceramic compositions.

	Description	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO
1a	Adhering ceramic	0.2	0.7	7.7	84.4	<0.2	1.6	0.2	0.4	<0.1	4.7
4a	Adhering ceramic	0.2	0.5	5.8	80.2	0.2	1.0	0.6	0.4	<0.1	11.0
8a	Adhering ceramic	0.3	1.2	13.9	74.3	<0.2	2.7	0.2	1.0	<0.1	6.2
10a	Adhering ceramic	0.2	0.4	5.2	68.6	0.7	1.9	0.8	0.3	<0.1	22.0
17a	Adhering ceramic	0.2	0.5	6.3	72.6	1.8	1.4	1.6	0.9	0.2	14.4
18	Furnace lining	0.3	1.3	13.9	74.5	<0.2	2.3	0.2	0.9	<0.1	6.4
23b	Adhering ceramic	0.2	0.4	4.4	75.0	<0.2	1.6	1.9	0.3	<0.1	16.1

Table 3: Average slag compositions.

	Description	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO
1b	Slag lump	0.2	0.7	2.4	19.6	0.5	0.3	3.0	<0.1	0.2	72.9
2	Slag lump	0.3	0.8	3.9	23.5	0.6	0.7	5.3	0.1	0.3	64.4
4b	Slag lump	0.3	0.6	2.8	29.1	0.6	1.1	4.8	<0.1	0.3	60.4
6	Slag lump	0.2	0.8	3.0	26.0	0.6	0.6	2.8	0.1	0.3	65.4
7	Slag lump	0.2	0.4	2.3	22.4	1.8	0.7	4.2	<0.1	0.1	67.7
8b	Slag lump	0.2	0.8	8.9	44.8	0.4	1.2	3.1	0.5	0.2	39.6
11	Slag lump	0.2	0.6	3.9	23.9	0.8	1.1	3.8	0.1	0.2	65.1
14	Slag lump	0.3	0.6	4.2	26.4	0.9	1.0	3.9	0.2	0.3	62.1
15	Slag lump	0.2	0.4	1.7	22.6	1.0	0.3	2.2	<0.1	<0.1	71.5
16	Slag lump	0.5	0.7	4.9	27.6	1.3	1.4	6.6	0.1	0.4	56.2
17b	Slag lump	0.2	0.6	3.9	23.0	0.7	0.7	3.6	0.1	0.2	66.8
19b	Slag lump	0.3	0.6	4.5	26.5	1.0	1.2	4.0	0.1	0.2	61.2
20	Slag lump	0.2	0.7	3.1	21.9	0.6	0.2	3.0	<0.1	0.2	69.8
10b	Furnace bottom?	0.1	0.3	1.6	19.3	1.3	0.5	3.3	<0.1	<0.1	73.5
3	Flow slag	0.4	0.5	5.7	27.4	0.8	1.1	4.5	0.1	0.3	59.0
5	Flow slag	0.2	0.4	4.0	24.1	1.0	0.6	1.5	<0.1	<0.1	68.0
9	Flow slag	0.1	0.4	4.3	27.2	1.0	0.7	1.2	0.1	<0.1	64.8
12	Flow slag	0.3	0.5	4.3	24.1	0.9	1.0	3.5	0.1	0.2	64.9
13	Flow slag	0.2	0.7	5.4	26.9	0.4	0.9	5.0	0.2	0.2	59.9

of the iron ore has been obscured. The nearest potential deposits which could have yielded the iron ore are the Bracklesham Beds which outcrop throughout the lower Thames Basin (as well as parts of Hampshire and the Isle of Wight). The Bracklesham Beds are of Eocene origin and comprise pyritous clays which contain sideritic clay ironstones (Potter 1977). Analysis of iron ore from the Bracklesham Beds shows a fairly poor correlation with the ore specimens from the archaeological excavations at Shooters Hill (Table 1, note the reported composition of the Bracklesham Beds ore has been normalised to 100wt% and the reported CO_2 and H_2O have been ignored). The archaeological specimens are all much richer in iron but the most striking differences are in the aluminium, potassium and titanium contents. Potter discusses earlier analyses of iron-rich deposits from the Bracklesham Beds but suggests that these were 'a true iron pan of hydrated iron oxides' (Potter 1977, 235). The weathering of sideritic ironstones within the Bracklesham Beds could have resulting in the formation of an 'iron pan' with a much lower clay component and a composition closer to that seen in the archaeological specimens.

Two samples of ceramic furnace lining were analysed and several fragments of slag included zones of ceramic material. All ceramic material/zones contained abundant silica polymorphs; in most cases these were relict grains with at least some heat-induced fractures but a few zones also contained some re-crystallised silica polymorphs. The matrix varied from only a slightly altered clay to a completely melted, glassy matrix. The ceramic is silica rich (Table 2) and so would have provided a reasonably refractory material for furnace construction. Two of the samples contain elevated levels of iron and probably represent fragments of clay which have begun to react with slag inside the furnace. The Al:Si ratios suggest the use of two different clays: the first (samples 1, 4 and 10) adheres to slag lumps and is likely to represent the lower portions of the furnace, while the second (samples 8 and 18) may represent fragments of the superstructure.

The slag displays a limited range of microstructures (Fig 3). Fayalite (Fe_2SiO_4) is the most abundant phase and in most cases is present as laths approximately 50-100 microns across and up to one millimetre long. Some samples (especially from larger fragments of slag) tended to have larger fayalite crystals and these tended towards being equiaxed (up to 1mm).

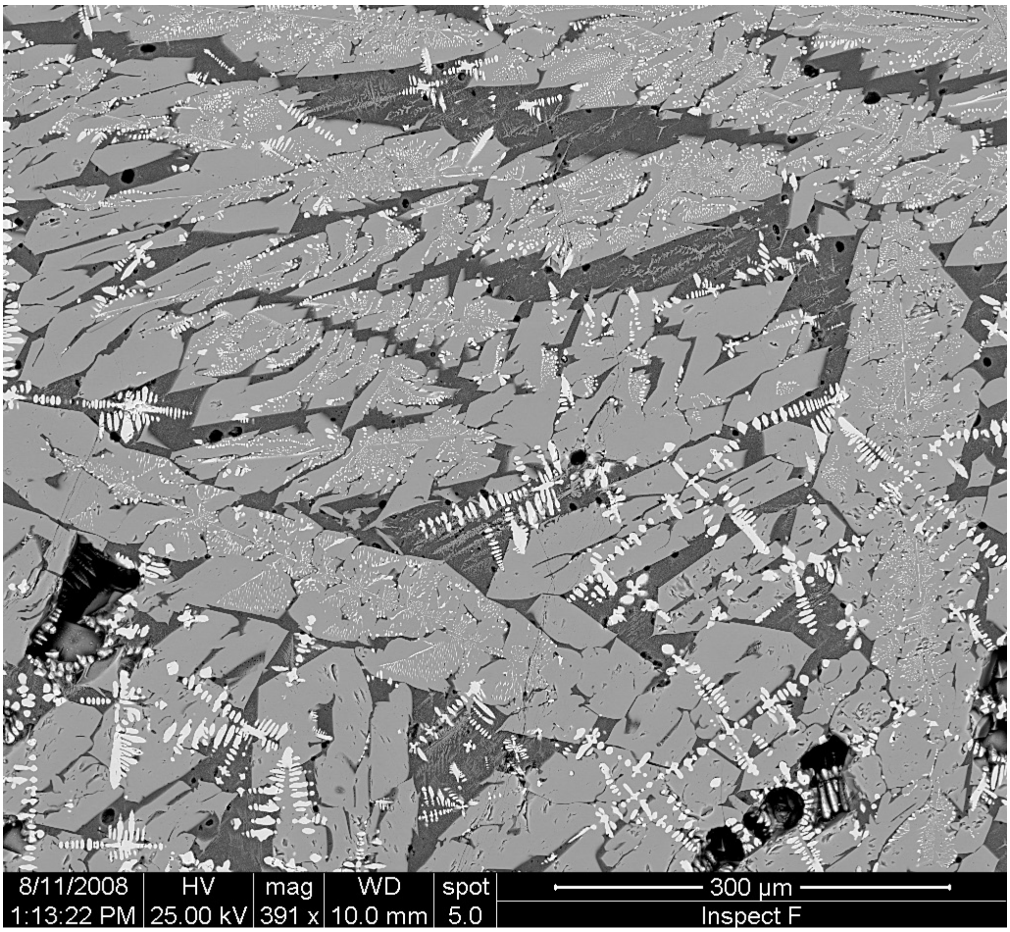

Figure 3: Microstructure of Shooters Hill run slag (SEM, back-scattered detector). The sample comprises rare wüstite (light grey) and abundant fayalite laths (mid grey, many with cotectic wüstite) in a partially glassy matrix (dark grey).

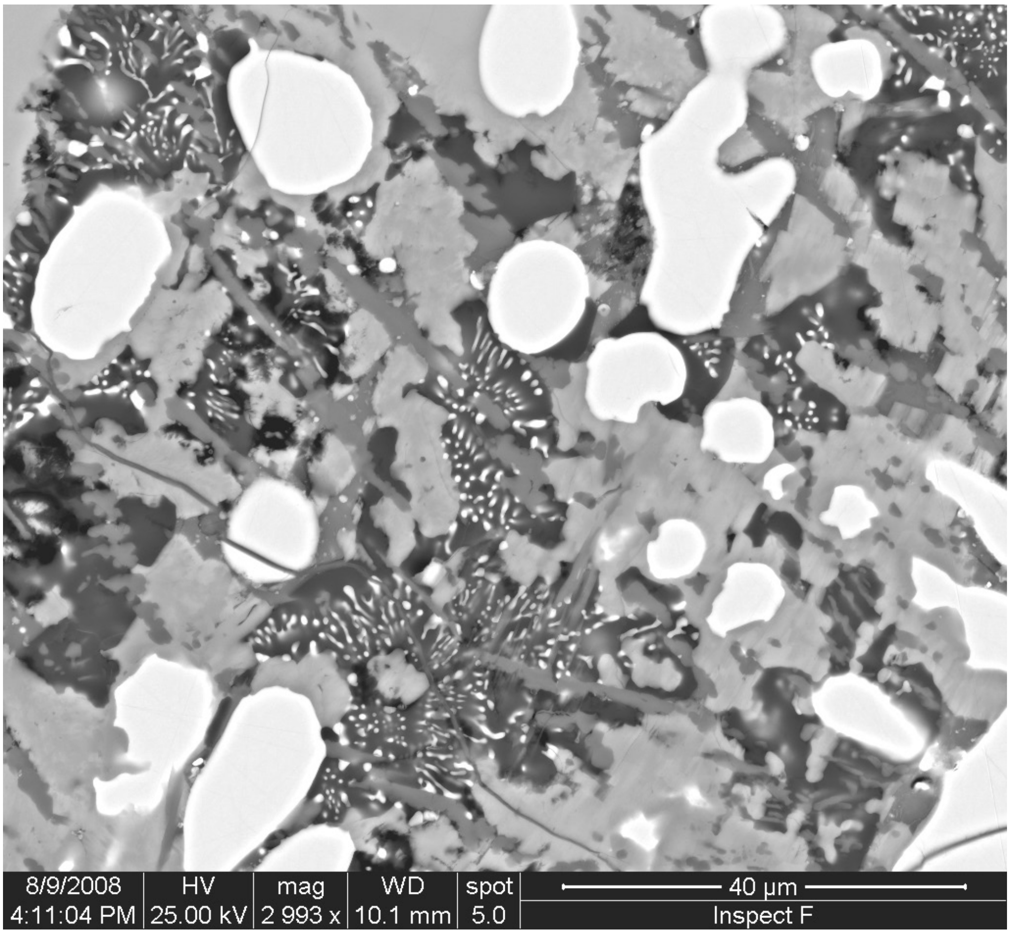

Figure 4: Microstructure of Shooters Hill slag lump (SEM, back-scattered detector). The image shows a magnified view of the matrix which is composed of small crystals of wüstite (light grey), fayalite (mid grey), kirschsteinite (dark grey) and leucite (black).

Wüstite was present as free dendrites and as a cotectic precipitation within fayalite; the former generally occurred when the fayalite was present as large equiaxed crystals and the latter when the fayalite was present as laths. These microstructural differences are likely to relate to slight differences in cooling rates. The samples examined also contain other rare to sparse minerals, including kirschsteinite ($CaFeSiO_4$), hercynite ($FeAl_2O_4$) and leucite ($KAlSi_2O_6$). These were often present as very small crystals within the glassy matrix. It is likely that other minerals are present but as crystals too small to allow SEM-EDS analysis. In some cases the matrix had almost completely devitrified (Fig 4); the devitrification of a glassy matrix suggests a rather slow cooling rate.

All of the slags contain high levels of iron and silicon (Fig 5) with varying levels of a range of minor elements (especially aluminium, calcium, phosphorus, potassium, magnesium, sodium, manganese and titanium; see Table 3). The aluminium and titanium in the slag probably derive for the most part from reactions with the ceramic furnace lining (Fig 6). Some of the minor elements in the slag (such as magnesium, phosphorus, calcium and manganese) are likely to derive (at least in part) from the charcoal ash (Fig 7).

The chemical composition of the Shooters Hill slag is broadly similar to prehistoric and Roman bloomery iron smelting slags found elsewhere in England (cf Paynter 2006) but the range of minor elements and their concentrations do not provide a perfect match with any of the data presented by Paynter (2006). The relatively low phosphorus and manganese contents compare well with the Forest of Dean slags but the magnesium and calcium concentrations in the Shooters Hill slag differ from the Forest of Dean slag. The exploitation of ore derived from Tertiary beds might suggest links with the Surrey and Hampshire sites, however, the slag from these sites contains much higher levels of phosphorus.

Discussion

The origins of iron production in prehistoric Britain are imperfectly understood. The first significant review was undertaken by Tylecote (1962, 175-201) who listed 30 sites with some evidence for iron smelting or smithing. This list has not fared well in the half a century since it was first published. Some of the iron smelting sites have since been reassessed and are now believed to be iron smithing rather than iron smelting sites, *eg* Glastonbury Lake Village, Somerset (Mortimer and

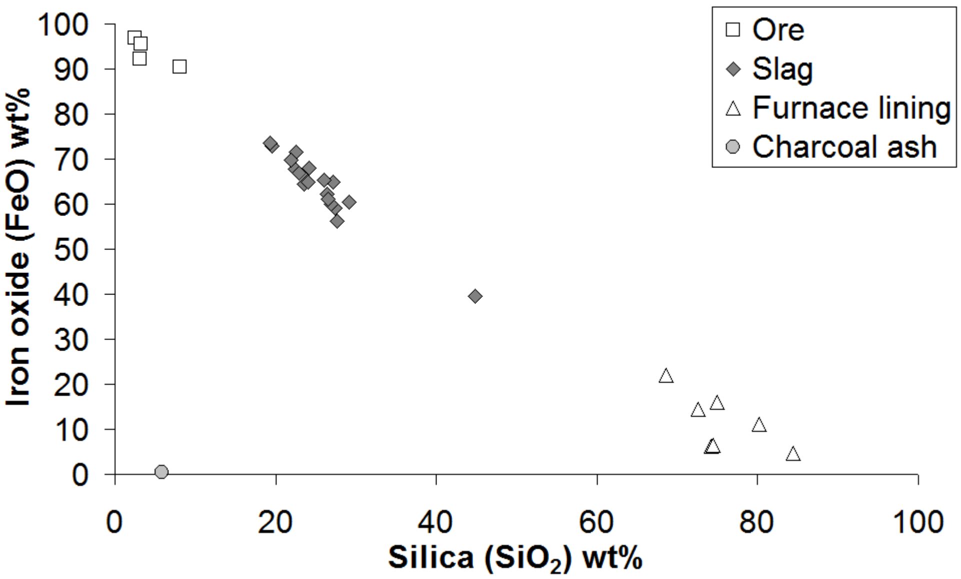

Figure 5: Plot of iron and silicon content of the analysed metalworking materials (the charcoal ash represents an average value for oak from the literature).

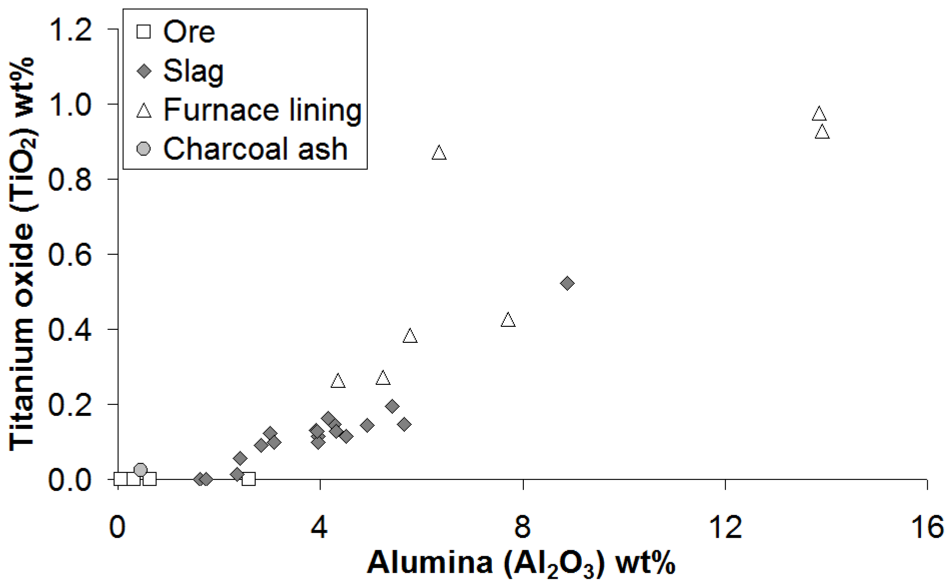

Figure 6: Plot of aluminium and titanium content of the analysed metalworking materials (the charcoal ash represents an average value for oak from the literature).

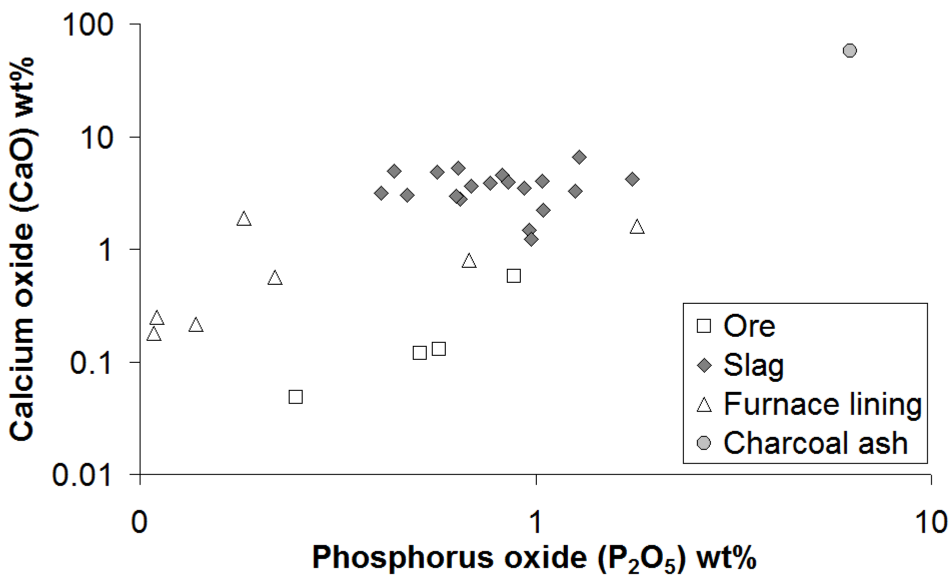

Figure 7: Plot of calcium and phosphorus content of the analysed metalworking materials (the charcoal ash represents an average value for oak from the literature).

Starley 1995) and Kestor, Devon (McDonnell 1986, 41). Other sites were excavated so long ago that some doubt must be expressed over the quality of the stratigraphic record, and in some cases the relevant archive material can no longer be located, *eg* All Cannings Cross and Swallowcliff Down, both in Wiltshire. Some sites have regularly featured in accounts of prehistoric iron smelting in Britain but have only been fully published quite recently, *eg* Trevelgue Head, Cornwall (Nowakowski and Quinnell 2011).

Subsequent fieldwork has located many more iron smelting sites and many of these have been excavated to a high standard: especially Welham Bridge, Yorkshire (Halkon and Millett 1999), Bryn y Castell, Gwynedd (Crew 1986), and Wakerley, Northamptonshire (Jackson and Ambrose 1978); in most cases, however, these sites have been dated to the Middle or Late Iron Age, as has Trevelgue Head which is now dated to the Middle Iron Age (Nowakowski and Quinnell 2011). The pottery from Shooters Hill is of Late Bronze Age or Early Iron Age date (8th to 5th centuries BC) suggesting that this site may be one of the earliest iron smelting sites in Britain. The lack of other securely dated Early Iron Age iron smelting sites in Britain means that the origins of this iron smelting technology will remain uncertain until more early sites are investigated.

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