Bloom refining and smithing slags and other residues

The smelting of iron by the direct process results in a bloom, which must be refined to produce forgeable iron stock. Blooms produced from bog ores in a non-tapping furnace would have had more entrapped slag and would have needed more refining than the cleaner blooms made from an ore which could be smelted by slag tapping. At least the initial stages of refining would be carried out at the smelting or primary production site, so that both smelting and refining residues can be found together.

Once refined the iron stock would be traded to the blacksmithing community and the smithing or forging of the iron would be carried out at a secondary production site, which could be a specialised workshop or a small forge attached to a settlement or a farm.

All the stages of refining and smithing produce broadly the same kinds of structural and residue evidence and there is little of it which is diagnostic of a specific stage of the process. The characterisation and interpretation of this kind of evidence depends mainly on the size and relative quantities of the different types of residue.

Any site with only a small quantity of slag, assuming that the range of debris is representative, should be presumed to be a secondary smithing site, unless it can be shown unequivocally to be otherwise.

Systematic sampling of the small residues can give good spatial information, to define the layout of a workshop and even the location of the anvil.

The weights and types of residues will vary with the chronology of the site and the technology used. Later water powered bloomeries will clearly produce considerably greater sizes and .quantifies of residues.

Few detailed studies of refining and smithing sites have been carried out. New variations of smithing debris are still being recognised and the terminology used is still evolving.

Structural evidence

Few refining hearths and smithing hearths have been recognised. Early refining hearths can be circular and could be confused with the basal remains of a furnace. Secondary hearths can be ephemeral structures, as essentially only a clay wall or some other device for separating the fuel and bellows is required. Bar hearths, for smithing long bars, are hardly known.

The evidence for tuyeres or blowing holes is also rare and is usually found as vitrified and broken fragments. 'Bellows protectors' or 'bellows plates' are, in effect, the baked or vitrified remains of the hot zone of the hearth, from above or around the blowing hole. Smithing hearth lining generally occurs in much smaller quantities than from smelting furnaces.

Later hearths can be set at higher than ground level, as shown in contemporary illustrations. Evidence for this can survive as circular or square stone footings.

Hearth slags

The most recognisable residue from both refining and smithing is the *smithing hearth cake* which forms just below the blowing hole, often still with part of the lining attached. Various terms have been used for these slag cakes but none are really adequate. The most common are PCB's, or *piano-convex bottoms,* and SHB's or *smithing hearth bottoms*. The slag cakes are more often convex-convex, with the upper surface hollow resulting from the air blast, or concave-convex, with an irregular upper surface, with the last formed slags not fully incorporated into the cake. The slags don't form in the bottom of the hearth, but stick to the hearth wall below the air inlet, resting on a bed of fuel, which is often entrapped in the base of the cake. Only occasionally, in a very shallow hearth, does the slag cake pick up clay or stones.

Smithing slag cakes are usually sub-circular in plan. Their size and weight can vary considerably, from 100g or so to more than 2kg, but the majority seem to be between 200 and 500g. The larger smithing hearth cakes can easily be confused with so-called 'furnace bottoms'. As a generalisation slag cakes from refining will be larger and heavier than those from secondary smithing, but much depends on the amount of iron forged, how much slag it contained, whether fluxes were used and how often the hearth was cleaned out.

Hearth slag cakes are usually magnetic, sometimes strongly so. They can contain fragments of iron broken from the bloom and hammer scale can sometimes be seen on the upper surface. The cakes can also have a varying degree of secondary corrosion products, which can incorporate other, not necessarily relevant, materials. Hearth slags do not always have a distinctive shape and the term SSL, *smithing slag lumps*, has been used. Such material may be slags which have not been incorporated into the slag cake, or a result of the hearth being cleaned when hot, so that the slag shape becomes distorted. It **is** obviously more difficult to decide whether such amorphous slags are from smithing or smelting.

Small quantities of slag can also escape from being incorporated in the smithing cake, resulting in *slag flows or prills*, with smooth upper cooling surfaces and contorted lower surfaces, characteristic of cooling in a bed of charcoal. These slags can be morphologically identical to slags which have formed in a smelting furnace.

Fuel ash slags' of small dimensions are frequently found in smithing debris. However, heavy smithing, with hard blowing, can result in high temperatures in the hearth, which can lead to considerable quantities of the clay wall melting, which forms *fluxed lining slags*. These have a contorted shape, are usually pale coloured and they can be in quite large pieces, up to several hundred grams. Their density is part way between that of fuel ash slags and the denser silicate slags. On some sites, this material can constitute a significant proportion of the total.

Some non-ferrous processes also produce slag cakes, which can be mistaken for smithing, but their formation process is not yet fully understood.

Anvil residues

In the early stages of refining the bloom can still contain or be surrounded by significant quantities of slag, which can result in a wide variety of irregular forms of anvil slag. The most easily recognisable, called *smithing flats*, have one surface flattened by contact with the hammer or anvil and one irregular surface where the slag has broken from the bloom. These flats can be up to 10mm across and 5mm thick and they are often distorted as the slag cools. Sometimes they are metal rich, though this would normally have been re-cycled. Highly carburised metal fragments can also be found, called *gromp* from the Polish term.

As the refining process continues, the bloom becomes more compact and it can be brought to welding temperature. Typical products of this stage are *slag spheres*, which can fly for a considerable distance from the anvil. These spheres can be vesicular, solid slag or even cast iron. Similar spheres also occur in smelting and when iron is welded. If the spheres are not cool when they hit a surface, the can be flattened or can disintegrate into *spatter*, with a very wide morphology.

When the iron is fully refined, or during secondary smithing, the main anvil product is *hammer scale*. This is usually flat and thin, though it can be distorted. It is very fragile and can disintegrate into magnetic dust. Scale is usually dull, though high temperature smithing and welding can produce a highly lustrous scale.

If a large amount of smithing has been carried out the anvil residues can become trampled into a *smithing floor* or *smithing pan*. This is usually lightly cemented together with secondary corrosion products and can be fragile. The anvil residues can also be cleared out from time to time, resulting in secondary *smithing concretions*, perhaps incorporating non-related materials. All these deposits are strongly magnetic and their character can be masked by secondary corrosion.

Related evidence

There is no evidence for the type of bellows from early sites, though their location can sometimes be inferred. Metal tools such as anvils, tongs and hammers do survive, but hardly ever in a workshop context. Stone anvils and hammer stones, with slagged surfaces, have been found. Isolated 'post-holes' may indicate the location of a wooden anvil or a wood block into which a small metal anvil had been inserted.

Fluxes may have been used, such as sand, crushed quartz or flint, though evidence for this would be difficult to recognise. Fragments of thin clay envelopes have been found, resulting from blade objects being partly coated with clay before re-heating and quenching, to harden the cutting edge.

The fuel used was mostly charcoal. There is some evidence for specific species being used, but much more work needs to be done. From Roman times onwards, there is growing evidence for the use of coal.

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