Historic England

Pre-industrial Ironworks

Introductions to Heritage Assets

Summary

Historic England's Introductions to Heritage Assets (IHAs) are accessible, authoritative, illustrated summaries of what we know about specific types of archaeological site, building, landscape or marine asset. Typically they deal with subjects which have previously lacked such a published summary, either because the literature is dauntingly voluminous, or alternatively where little has been written. Most often it is the latter, and many IHAs bring understanding of site or building types which are neglected or little understood.

This IHA provides an introduction to pre-industrial ironworks. Making an iron object involved several stages; the term 'ironworking' covers all of these and an 'ironworks' was where these activities took place. Descriptions of the asset type and its development along with a brief chronology are included. Ironworks generally required some form of shelter, and so are often found in association with post-holes, slots or other structural remains. Although there is great variation, archaeological remains of smithies are more likely to be sited within an associated settlement, whereas the locations of smelting furnaces were dictated largely by the availability of resources such as ore, fuel and water, and so they can be found in apparent isolation. A list of in-depth sources on the topic is suggested for further reading.

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Front cover
Mid-16th century illustration of smiths working at an anvil set in a wooden block. Behind is a waist-level hearth.

Introduction

The properties of iron have made it an invaluable material since it was first exploited in England around 2,700 years ago. The strength, hardness and toughness of the metal made it ideal for a wide range of applications, for example tools, weapons, nails, beams and horseshoes. Since iron does not soften or melt until it is very hot, ironworking took place at high temperatures and consumed large amounts of fuel.

Making an iron object involved several stages; the term ‘ironworking’ covers all of these and an ‘ironworks’ was where these activities took place. Each stage required the use of particular skills, raw materials (iron ore) and structures and also produced waste, commonly known as slag, which is often the most noticeable indicator of ironworking activity at archaeological sites.

The first stage of ironworking was smelting iron-rich stone, known as ore, to extract metallic iron. Historically, iron smelting has been associated particularly with the Weald, the Forest of Dean and Northamptonshire. In the more distant past, however, other types of more widespread iron ore were used and so archaeological evidence for iron smelting is abundant all over England. The ore was often prepared before smelting by roasting it in a fire, breaking it to the required size and removing unwanted material.

The earliest smelting method, known as bloomery smelting or the ‘direct method’, was used from around the 8th century BC. The tiny particles of iron metal formed during bloomery smelting did not melt, but instead stuck together to make a spongy lump known as a ‘bloom’.

The next stage of ironworking was to shape the iron by smithing (forging). The metal was heated in a hearth until it was red hot and malleable, and it was then hammered into shape on an anvil. Evidence of smithing is widespread and common at all periods.

Bloomery smelting continued into the post-medieval period but began to be superseded by blast furnace smelting, the ‘indirect method’ of smelting, from the late 15th century. Whereas bloomery furnaces operated one smelt at a time, blast furnaces were used on a semi-continuous basis with smelting continuing for months at a time between repairs. This much larger scale process marked the beginning of industrial iron production, and is not covered here.

1 Description and Chronology

Bloomery smelting took place in a furnace built from clay and sometimes also stone, chosen to better withstand the extreme temperatures involved. The walls of ancient bloomery furnaces rarely survive intact and often show evidence of damage and repair, so the original height of the walls is difficult to determine.

The design of furnaces appears to have varied chronologically and regionally but they all tended to have thick walls to retain the heat. To help reach the high temperatures needed (about 1,200 °C), bellows were commonly used to blow air into the furnace through one or more blowing holes in the side; sometimes ceramic tubes, known as tuyères, may have been inserted into the furnace to direct air inside. Charcoal was used exclusively as the fuel for smelting until the 1700s.

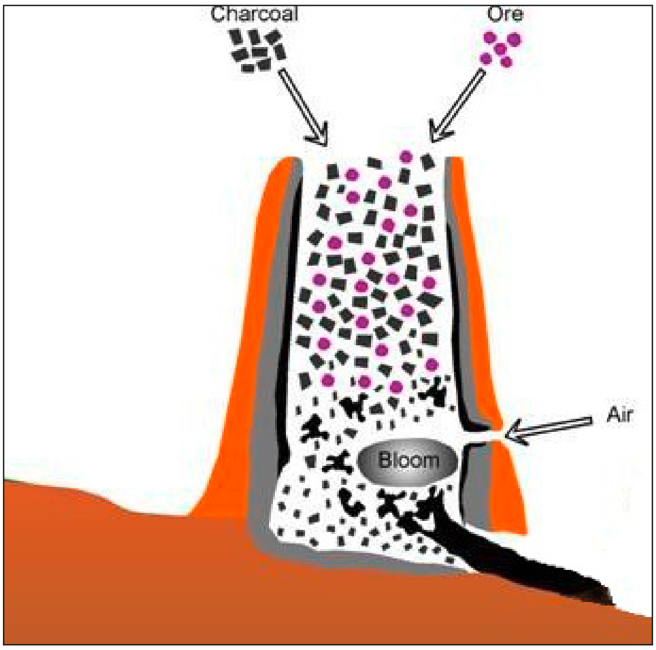


Figure 1
A Tapping Furnace. This type of bloomery smelting furnace had a hole near ground level that could be opened during the smelt, to release a flow of hot, molten waste slag (black), separating it from the solid metal bloom. Furnaces were variable, with an internal diameter at the base of 0.3 m to 1 m.

Figure 2
Tap Slag. This is waste from bloomery smelting, produced by a tapping furnace, and is easily identified by the flow patterns on the surface.

Each smelt is likely to have taken many hours and generated kilos of molten slag, which in itself also contained iron, and if this material was not then exploited for that iron content, making bloomery smelting would have been a fairly inefficient process.

This dense, black slag could be removed from the furnace in different ways. ‘Tapping’ furnaces, best known from the late Iron Age, Roman and medieval periods, had a hole at ground level in the furnace wall that could be opened during the

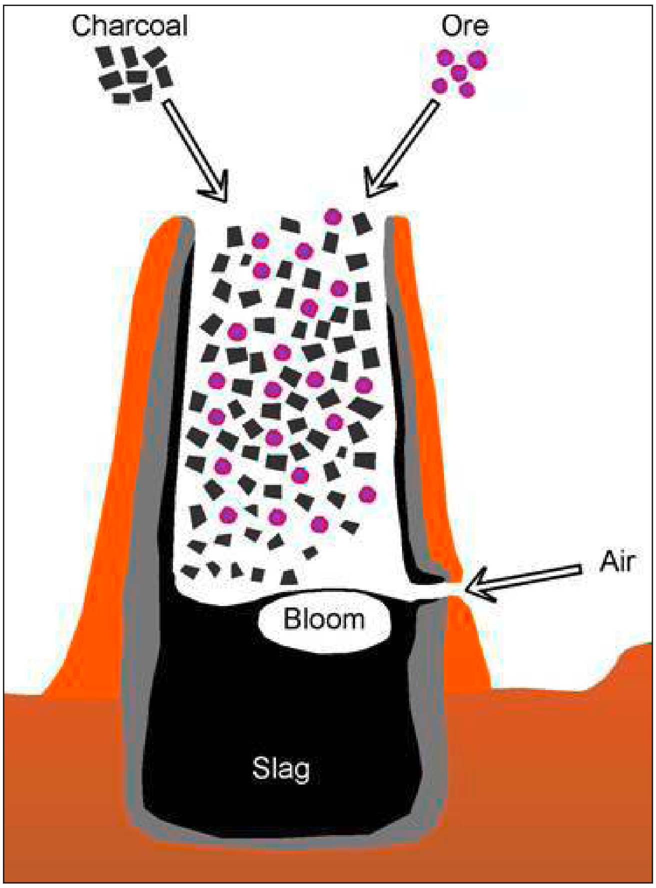


Figure 3
A diagram of the slag pit furnace. These non-tapping furnaces were used for bloomery smelting.

smelt so that the slag could run out (Figure 1). The resulting tap slag has a flowed appearance, like lava (Figure 2).

From the Iron Age and Saxon periods, 'slag-pit' or 'non-tapping' furnaces are known, such as the probable Pre-Roman example from Levisham Moor, North Yorkshire. During the smelt, the slag gradually drained into a pit beneath the furnace and cooled there, either as numerous small runs and lumps or as a large block of slag upwards of 10 kg in weight (Figure 3).

At the end of the smelt the iron bloom was removed from the furnace but still contained voids and trapped slag. The bloom was consolidated and shaped by smithing (forging), either into a bar or billet for trading (Figure 4) or into an object. Consequently some evidence of smithing is often found on smelting sites (Figure 5).

Figure 4
Iron billet. The iron blooms made by bloomery smelting had to be smithed before they could be used, to remove trapped slag and air. Then the iron was shaped into objects or a form of trade iron, such as a billet, ingot or bar. This is a billet of iron excavated from a Roman settlement at Westhawk Farm in Kent.

Blooms contained pure iron and also certain iron alloys, such as steel (iron containing some carbon from the charcoal) and phosphoric iron (iron containing some phosphorus from the ore). The alloy formed depended on the type of ore used and the smelting conditions. Steel and phosphoric iron are harder than pure iron and ironworkers learned how to exploit this for various applications, for example using steel for the cutting edge of knives.

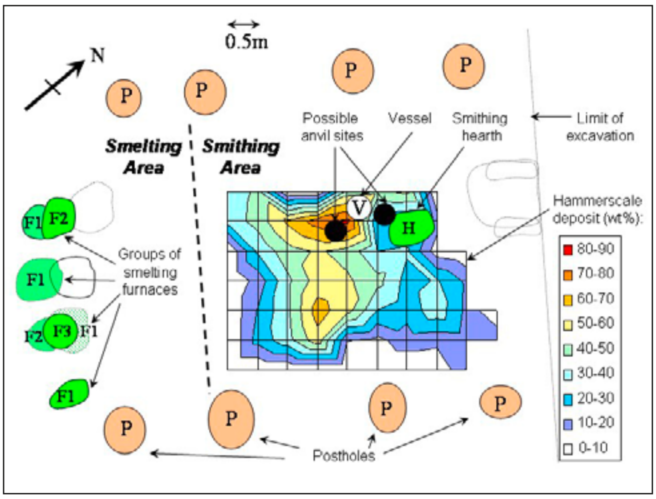


Figure 5
A plan of a Roman ironworks at Westhawk Farm in Kent where there were four tapping bloomery furnaces at the south-west end of the workshop, and a smithy at the north-east end with a floor-level hearth.

Smithing (forging) was the process of shaping iron. Smithies did not have to be located near to a smelting site and many weren't; the smith could obtain a stock of iron through trade links. The smith heated the metal in a hearth that was often fuelled by charcoal, although coal was also used where available as long ago as the Roman period.

The design of hearths varied; some were at floor level and others were waist high (front cover). As with furnaces, the hearths were generally constructed using clay and stone, and bellows were used to blow air into them, to produce high temperatures.

Smithing also generated slag waste, including bowl-shaped lumps of slag that collected in the smith's hearth, known as 'smithing heath bottom' slags (Figure 6). Tiny magnetic flakes of scale and droplets of slag were also dislodged from the metal surface during smithing and accumulated on the smithy floor (Figure 7). When this 'hammerscale' is found on archaeological sites it indicates the site of a smithy.

In the later medieval period, around the 14th century, water power began to be used in ironworking. Water was used to power the bellows of bloomery smelting furnaces making iron, and to power the hammers used during smithing to consolidate and shape the iron.

Figure 6
A cross section through a smithing hearth bottom (SHB) slag, which is a characteristically shaped lump of slag formed in a smith's hearth during iron smithing.

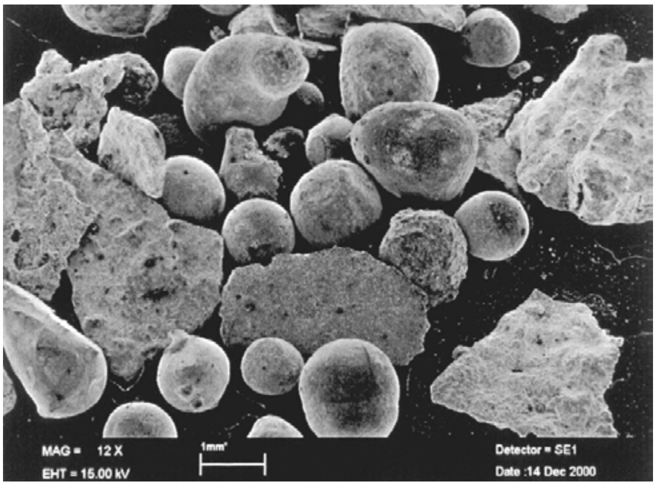
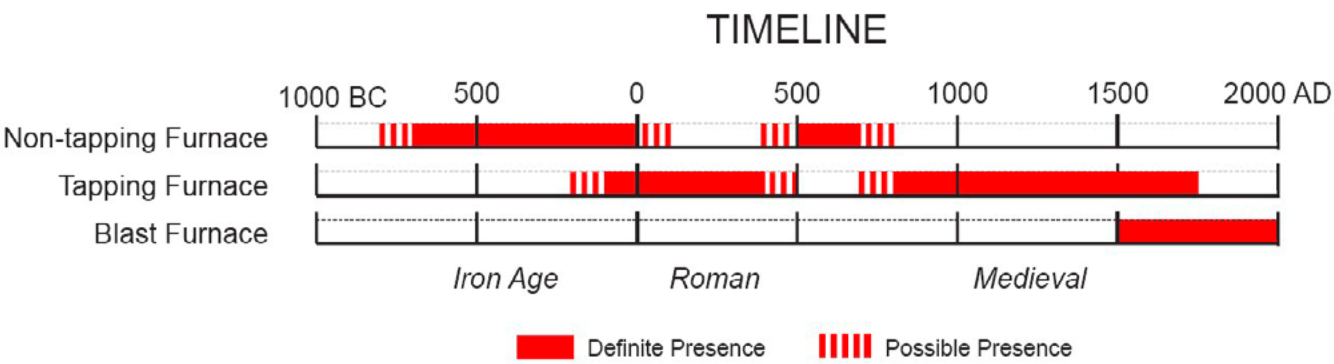


Figure 7
An enlarged picture of hammerscale, taken with an electron microscope, showing that it is made up of tiny flakes of iron oxide and spheres of slag.



2 Development of the Asset Type

Ironworks with good preservation, such as surviving furnace superstructures and in situ workshop floor deposits, are rare and so of greater importance.

Ironworking frequently generated large amounts of waste and so many methods were devised for disposing of, or re-using, the slag. Bloomery slag was used for road construction in the Roman period and more recently, for example a slag bank covering nearly 1 ha was quarried away in the 19th century from Beauport Park, East Sussex, a major Roman smelting site. Bloomery slag was also fed into post-medieval blast furnaces instead of ore so the remaining iron could be extracted. Consequently ironworking waste can be found large distances from where it was produced.

Nonetheless, slag dumps or slag-filled pits or ditches are often the first indicator that the remains of an ironworks are nearby. The appearance of the slag can indicate the type of ironworking taking place (smelting or smithing) and an estimate of the quantity of waste will suggest the scale of ironworking. The amount varies greatly, from a few kilos with early slag-pit furnaces or small-scale smithing, to routinely large amounts with tapping furnaces; the slag heaps at some Roman bloomery smelting sites, for instance are estimated to contain thousands of tonnes.

Waste from associated processes may be found at an ironworks site, such as charcoal-rich layers from charcoal preparation and storage, or deposits of burnt, iron-rich stone indicating ore roasting or storage. Iron objects, bars and off-cuts are also found, and can provide valuable information about the metal being made or worked at the site, and its products.

Geophysical surveys, especially using magnetic techniques, are ideal for detecting slag and the remains of smelting furnaces and smithing hearths, which give strong responses.

Unfortunately smelting furnaces rarely survive above ground level. It can be difficult to reconstruct precisely their form and function (Figure 8). With non-tapping furnaces often only the below-ground slag pit survives; these are of variable shape and size, from 0.3 m to about 1 m in diameter, and are not necessarily highly fired. These are less often identified and subsequently are under researched. Tapping furnace bases are generally 0.3 m to 1 m in internal diameter, with a grey-coloured, highly-fired, vitrified interior and a more friable, orange-coloured exterior.

The development of water-powered bloomery furnaces is poorly understood. Some were later converted to other types of mill and others were used as fineries, for refining the cast iron produced by blast furnaces, making the remains more difficult to interpret. However, evidence of water management, such as ponds, tail races and wheel-pits, is likely to survive at water-powered ironworks, for example at Newbridge blast furnace in East Sussex where there is also evidence of an earlier bloomery.

Ground level smithing hearths occasionally survive but can be difficult to identify, as they may be only lightly fired. Tools and anvils are rarely found. The most reliable indicator of smithing workshops is the presence of concentrations

Figure 8
The base of an Iron Age bloomery smelting furnace at Crawcwellt West, Merioneth. The remains of the furnace walls are about 0.3m thick. They are characteristically highly-fired and grey coloured on the inside surface but red coloured and lightly-fired towards the outside. The furnace superstructure has not survived.

of slag and hammerscale. Hammerscale can be extracted from soil using a magnet. If samples are taken at regular intervals over an area, the hammerscale concentrations can be used to reconstruct the layout of the smithy, as the highest concentrations indicate the likely site of the anvil (Figure 5).

Large pots sunk into the ground, or tanks, are sometimes found in smithing workshops and probably held water, for example to cool tools. Water was also used by smiths to rapidly cool, or quench, steel thereby making it harder. Evidence for water-management, such as wheel-pits, may survive if the forge hammer was water-powered.

Ironworks, and in particular smelting sites, are difficult to date in the absence of associated settlement or dateable artefacts. Oak charcoal was commonly used at earlier ironworks and carbon dates from samples of this long-lived species may not provide a precise date for the ironworking.

Archaeomagnetic dating of ironworks, particularly early ones, is also problematic since the results may be affected by the presence of iron metal. The archaeological significance of ironworking evidence is greatly increased if a precise date can be obtained for the activity.

Documentary evidence and place names can sometimes be an aid to identifying ironworks. If a site has good documentation this will enhance its significance.

3 Associations

Until early medieval times, iron ores were usually obtained by open-cast mining methods and evidence of this may be visible in the landscape, for example the scowles in Blake's Wood, Gloucestershire. Similarly, the extraction of clay, stone and sand for furnace or hearth construction sometimes leaves identifiable signs.

Large quantities of charcoal were consumed during ironworking and examination of samples from a site, or documentary sources, may provide evidence of woodland management, such as coppicing. As charcoal is fragile and therefore difficult to transport, ironworks were located near to the source of this fuel. The position of water-powered ironworks was also dictated by the need for water and features such as dams, leats, wheel-pits and tail races may survive.

Ironworks generally required some form of shelter, and so are often found in association with post-holes, slots or other structural remains (Figure 5). Although there is great variation, archaeological remains of smithies are more likely to be sited within an associated settlement, whereas the locations of smelting furnaces were dictated largely by the availability of resources such as ore, fuel and water, and so they can be found in apparent isolation.

4 Further Reading

Archaeometallurgy: Guidelines for Best Practice (Historic England 2015) summarises metalworking evidence for England until 1600.

A research agenda is outlined by J Bayley, D Crossley and M Ponting, *Metals and Metalworking: A Research Framework for Archaeometallurgy* (2008).

R Tylecote, *The Prehistory of Metallurgy in the British Isles* (1990) provides more technical detail.

David Crossley's *Medieval Industry* (1981) features a brief chapter on medieval ironsmelting, whereas his *Post-Medieval Archaeology in Britain* (1990) gives a comprehensive account of later industry.

Regional studies include H Cleere and D Crossley, *The Iron Industry of the Weald* (1985), and M Bowden, *Furness Iron: The Physical Remains of the Iron Industry and Related Woodland Industries of Furness and Southern Lakeland* (2000) which treats Cumbrian iron furnaces, forges and rolling mills.

An archaeological investigation of two ironsmelting and smithing workshops is described by P Booth, A Bingham and S Lawrence, *The Roman Roadside Settlement at Westhawk Farm, Ashford, Kent: Excavations 1998-9* (2008).

Guidelines on *Geophysical Survey in Archaeological Field Evaluation* (English Heritage 2006), the *EAC Guidelines for the Use of Geophysics in Archaeology* (EAC 2016) and *Archaeomagnetic Dating* (English Heritage 2006) are available via the Historic England website.

5 Where to Get Advice

If you would like to contact the Listing Team in one of our regional offices, please email: customers@HistoricEngland.org.uk noting the subject of your query, or call or write to the local team at:

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6 Acknowledgments

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Eygentliche Beschreibung Aller Stände auff Erden
(1568)

Figure 8: © Peter Crew

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