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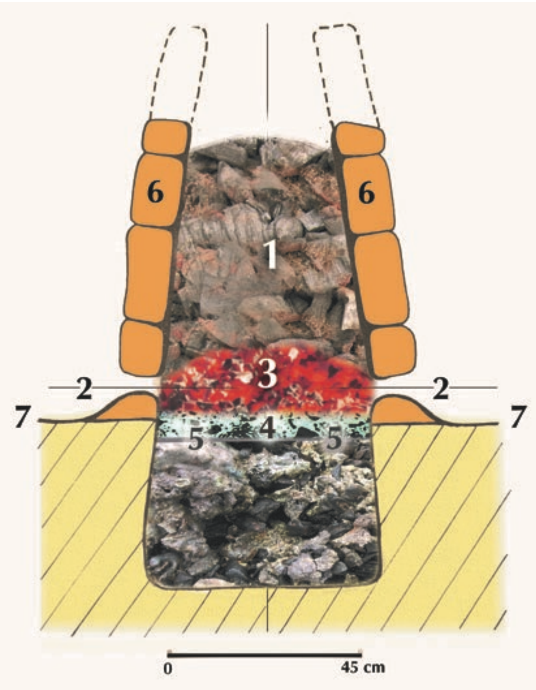
July 2018

Iron Smelting References

The following are extracts from dymarki.com - This site covers the Roman-period iron smelting industry in Poland. The technology described looks like the mid-Saxon smelting in Romsey that produced the large slag blocks. Note from the map that this process was also in use in Germanic areas.

Iron casting was performed in structures described in archaeological literature as slag-pit furnaces. This type of furnaces is known from the territories of Central and Eastern Europe and their spreading was connected with the Germanic peoples and eastern Celtic tribes. A furnace consisted of two main parts, the lower one called a pit and the upper called a shaft. A hollow was a simple hole dug out in the ground; it had 40-45 cm in diameter and not more than 50 cm in depth. Its main function was storing of slags coming from the reduction zone. Directly over the hollow a shaft was constructed which was a part of the furnace over the ground level. In the discussed region it was usually made of regular clay blocks – bricks strengthened with cut straw. Assuming that the driving force for the process was natural air blast, the height of this part of the furnace had to reach about 120 cm. A shaft was mainly used for feeding ore and charcoal to the furnace enabling their slow transfer to the reduction zone. Just over the ground, in the lower part of the shaft there were blast holes which provided air. In the Świętokrzystkie Mountains these were properly prepared 'blast bricks' with holes in the shape of a funnel.

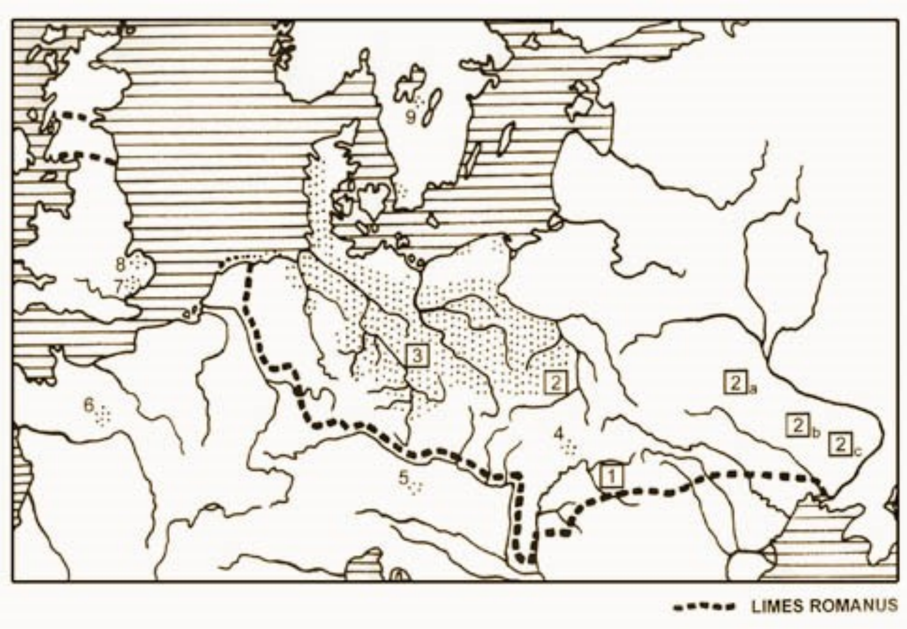


Schematic cross-section of a slag-pit furnace of the Świętokrzystki type according to K. Bielenin: 1. Input: iron ore and charcoal. 2. Air blast holes. 3. Reduction zone. 4. Sponge-like slag-pit furnace iron bloom. 5. The surface of a free solidification in the upper part of a slag block filling the hollow dug out in loess. 6. Furnace shaft constructed of shallow blocks – bricks. 7. Ground surface.

The iron casting process carried out in this type of structures is called in metallurgy a direct reduction process. It differs from the presently used technologies of obtaining iron called an indirect reduction process. It is worth highlighting that because of relatively low temperatures in slag-pit furnaces usually not exceeding 1250-1300°C iron reduction by means of liquefaction was impossible. Let's remind that the theoretical point of iron melting is 1537° C. Currently in large furnaces such temperatures are achieved with no effort and iron acquires form of liquid pig-iron which is then processed in oxygen furnaces called convectors to obtain iron or steel of various stages of carbonization. Contemporary iron casting consists of two stages hence its name – indirect reduction.This process was completely different when slag-pit furnaces were used. Reduction consisted in gradual deoxidization of ferrous oxides contained in ore until metallic Fe was obtained.
Reducer or an agent absorbing oxygen was ferrous oxide coming from the process of burning charcoal. Practically the process was conducted as follows. Through the mouth of a shaft layers of ore and charcoal were alternately fed. Ore transferred though zones of higher and higher temperatures underwent consecutive stages of reduction, that is the ferrous oxides it contained gradually disposed of oxygen finally to get rid of it at the level of blast holes and to turn to a metallic form. Sponge-like iron bloom created from microscopic pieces of reduced iron got stuck to the shaft walls over the blast holes. Metal, however, did not flow to the hollow as it was not yet liquefied. In a slag-pit furnace process only barren rock was melted which together with not fully reduced ferrous oxides created liquid slag.

It was calculated that in order to obtain a block of slags weighing about 100kg about 200kg of ore needed to be melted and 250-300kg of charcoal to be burned. The whole process would have to last almost 24 hrs. Semi-product obtained in such a process were an iron bloom contaminated mainly with slags and charcoal. Only after it was purified and its surface was melted was iron passed to smiths who used it for creating various useful objects.

The presented data are a slightly simplified version of a complex process which dependent on a variety of factors is very difficult to be reliably reconstructed. What we mean by that is the difficulty in establishing relation between ore used in the ancient process, the slags obtained in this process and expected effect of metallurgical activities – that is iron. On the basis of the slag-pit furnace slags it is impossible to define what type of ore was used by ancient metallurgists or to know what qualities the produced iron would have had. The latter we can find only in ready products which went through a number of processing stages. It is even more complicated if a mixture of ore types was used. The process itself was not the same in every slag-pit furnace thus while conducting research on their remnants preserved in the form of an underground part filled with slags, we can realize the complexity of the whole process. It is clearly visible in well-preserved slag-pit furnace sites which unfortunately are a scarcity. One of them has recently been discovered within the 'Wykus' range between Bodzentyn and Wąchock and still remains a subject of research. The mentioned problems impact experimental work on the reconstruction of the slag-pit furnace process so their long duration should not be surprising. Considering that the process was completely forgotten and only in the 50s of the 20th century its strenuous reconstruction started, one should not wonder why the current effects are still far from the results obtained by ancient metallurgists.



Metallurgical centers in Europe using slag-pit furnaces according to K. Bielenin.

Note: I have found a reference to an article in the Journal of Danish Archaeology, Vol 14 that says that slag-pit furnaces in Jutland were carbon dated to AD 250-610.

Excavations at Mucking, Vol 2, 1993, 93-94 (available on ADS)

Slags and ironworking residues
by Gerry McDonnell
Most of the eight slag deposits which can be dated with reasonable certainty to the Anglo-Saxon period are characterised by the presence of smelting slag, in particular slag blocks (SLB). Most of these deposits came from the fills of Grubenhauser, although two derive from pits and another from a group of pits. This follows the general pattern of slag distribution at Mucking, namely that the largest quantities of slag derive from large features. All these deposits represent dumping of ironworking residues, and not in situ ironworking.

Smelting slag occurred mostly in the form of slag blocks (Fig 49) except for the deposit in GH 202 which also contained 4kg of tap slag. Slag blocks recently excavated at Little Totham in Essex have been dated to the seventh century AD (Curr Archaeol 1989). The Grubenhauser from Mucking which contained ironworking debris likely to be Anglo-Saxon are also sixth- or seventh-century in date. The total weight of the slag blocks from the site (all of which are presumed to be Anglo-Saxon in date) is 118kg (Table 22). This could represent either a single phase of iron smelting activity or a series of smaller smelting operations carried out over a longer period. It does not, however, represent major iron smelting operations.

The evidence emerging from Essex indicates that ironworking during the Anglo-Saxon period took place on a small scale to satisfy local needs. It is not known which iron ores were used, but it is probable that they were extracted locally, probably from within a mile or so of the settlement. The most likely sources are either 'bog ores' from waterine environments (that is, the concentration of iron compound by precipitation from slow moving or stagnant waters) or ironstones from glacial deposits of clays or gravels, perhaps by-products of the clay extracted for pottery manufacture or daub. The smithing debris from pit group 14325was the only de posit large enough to indicate the location of a smithy. The others represent small individual dumps of debris.

Few ironworking sites are known from the Anglo- Saxon period, and this paucity of data hampers our understanding of ironworking technology in this period. The picture which emerges is of Anglo- Saxon smiths with the capacity for producing high quality objects, especially edged tools such as knives, but there is as yet no evidence for centres of iron and steel production. Furthermore, no smelting sites have been identified from the major centres of iron production in the Roman and medieval periods, such as the Sussex/Kent Weald or the Forest of Dean, where major ore deposits are located.

Slag block smelting was the main method of iron smelting used at Mucking, although slag tapping may also have been employed, judging from the evidence from pit 1002 and GH 72. Slag block smelting technology as been identified at Little Totham and at Romsey, Hants (McDonnell 1988), neither of which is sited near major iron ore deposits. The Romsey iron smelting activity is thought to date to the sixth or seventh centuries, but this has not yet been confirmed by independent dating methods. The quantity of slag recovered from Romsey is much greater than that from Mucking (SLB = 252kg, other smelting slag = 312kg, of which only 3kg was tap slag), and derives from a smaller area of excavation. This would strengthen the argument that the smelting slag from Mucking represents small-scale activity. No other contemporary sites producing significant evidence of iron smelting have been excavated.

The following are extracts from Archaeology in the Severn Estuary, Vol. 20, 2009 (available on ADS)
SAXON IRON SMELTING AT CLEARWELL QUARRY, ST. BRIAVELS, LYDNEY, GLOUCESTERSHIRE

The tap-slags occur in masses of up to many kilograms. A few of these are in the form of thin sheets, but most occur either as fragments from shallow, saucer-shaped masses or deep, basin-shaped lumps, the latter tending to be the heaviest. All show the characteristic flow structures. The range of forms suggests that more than one type of furnace was in use at Clearwell Quarry. The sheets, and perhaps also many of the saucer-shaped masses, suggest the use of shaft furnaces from which the slag could be tapped horizontally into a suitable depression to one side of the furnace. The deep, basin-shaped lumps weighing many kilograms are consistent with the employment of slag-pit furnaces, traditional from the Iron Age on the north-west European mainland, and therefore not unexpected on a Saxon site. In these the slag is allowed at the end of each smelt to fall for some decimetres into a hollow beneath the furnace, presumably after the bottom of the furnace had been broken through. The slag does not chill in contact with the charge (cf bowl furnace yielding furnace bottoms). In addition to the form of the larger masses, two other features of the slags are consistent with the uses of slag-pit furnaces: the abundance of slag pilules (drips of viscous material) and the presence of some dung-like slag accumulations (viscous slag that dripped for some time onto the same spot). Both shaft furnaces and slag-pit furnaces can in principle be relined, but there is as yet no direct evidence of furnace relining at Clearwell Quarry.

page 33:

Evidence for Saxon iron-making in Britain is rare. In contrast to the tappable furnaces used at Clearwell Quarry, those reported from Ramsbury, Wiltshire (Haslam 1980), Milbrook, Ashdown Forest (Tebbutt 1982), and Burlescombe, Devon (Reed et al 2006) were non-tappable types. The operation at Clearwell may therefore reprsesent a technological step up from what was practised regionally. The Burlescombe site lies in the Blackdown Hills, where there is extensive evidence for iron-making from the Roman period onwards.

Discussion (page 37-8):

Of much greater significance, regionally and nationally, is the discovery of iron-smelting unequivocally dated to the late 8th or 9th centuries AD. While only three of the 30 securely identified furnaces have been dated, this includes one from each ‘cluster’, and the similarity of the radiocarbon dates (Table 10), the features and the processes strongly suggests that they do not represent more than one period of use. Although the ranges for the calibrated radiocarbon dates are wide (AD 763–890 for the most likely dates, and wider still for the full range of possibilities) the raw determinations all come within a generation of one another, and a shortened timescale seems likely on all grounds, as smelting at all times until the introduction of the blast furnace would have been a partly mobile, probably seasonally shifting, process. In all probability, each ‘cluster’ represents one season’s work, and the three could all have been created in three years, or perhaps represent three visits to the same resource over the course of, say, ten or fifteen years. There is so far no evidence of a Saxon settlement at or near the Clearwell Quarry site.

While Saxon iron-production in the area has always been assumed, there has been no previous archaeological evidence for it, and indeed evidence of Saxon iron-working in general is very rare across the West Country and Wessex, with just Ramsbury to cite from the literature (Haslam 1980). A search of the British and Irish Archaeological Bibliography, the Archaeology Data Service (ADS) database of radiocarbon dates, and the ADS ‘grey literature’ database suggested no other securely dated metal-working sites of the period in these regions, and just two very tentative examples of sites in Wiltshire (Tidworth and Collingbourne Ducis) producing tiny quantities of slag amongst Saxon rubbish deposits, with no real evidence of production (Godden et al 2000; Pine 2001). There is only a little more evidence for this period from Somerset, Dorset and Devon (summarized by Webster 2007, 172; see also references cited above).

Note: Romsey has been missed out from the discussion due to the lack of published excavation reports.

Romsey is no longer the westernmost occurrence of the use of slag block technology.

N Fairburn et al. 2002. 'Birch Heath, Tarporley: Excavation of a Rural Romano-British Settlement', Journal Chester Archaeological Society 77: 58-114.
Note: This paper includes useful descriptions of smelting residues.

Industrial remains
Two types of metallurgical industrial waste were recovered on the site, ironworking waste and leadworking waste. The ironworking residues form the largest part of the metallurgical residue assemblage: only one piece of lead slag was uncovered and this was unstratified.
The ironworking residues were recovered from a number of contexts, but were particularly concentrated around Structure 3. They were diagnostic of both smelting and primary smithing.
Ironworking
A total about 8.5kg of material associated with ironworking (ore, slags and vitrified clay lining) was recovered from the excavation – a very small amount of material for a production site. Experimental work has shown that the smelting process to produce a bloom, followed by smithing, could be expected to produce a lot more waste – at least 7kg of slag waste per episode (Crew 1991). The Birch Heath material probably represents no more than two periods of activity, attested by pieces of vitrified clay lining which show evidence of repair or relining. New clay had been laid over an already-vitrified surface which itself then became vitrified from another episode of high-temperature activity.

The manufacture of an iron artefact from iron ore can be separated into three distinct processes: the smelting of the ore in a furnace, which will produce a bloom of iron as well as fayalitic slag residues; the primary smithing to consolidate the iron bloom into a billet; and, thirdly, secondary smithing, the shaping of the billet into an object.The evidence recovered from Birch Heath suggests that all of these processes were being carried out on the site.

The material from Structure 3 can be classified into seven different categories: roasted ore, bloomery slag, smithing slag, hammer scale, low-density slag, vitrified lining and amorphous slags.

Roasted ore
The ore was identified as haematite, one of the commonest iron ores. The source unknown, but the nearest known locations are in Lancashire. The ore that was recovered may not be representative of the ores actually smelted as it may have been discarded as of poor quality.

The bloomery slag constituted the largest amount of material recovered by weight. It was typical of furnace slag described by Tylecote (1986), containing partially reduced ore and charcoal. None of the slag that was recovered was tapped, suggesting that the Roman ironworking practices that produced tapped slags were no longer being used here.

Smithing slag
Amongst the recovered material were fayalitic slag lumps and pieces of plano-convex bottoms (PCBs) that are diagnostic of smithing, representing residues that consolidated in the bottom of the hearth as PCBs. The first are similar in composition to furnace slags but are distinguishable by their shape. Their production is still poorly understood.

Hammer scale
Smithing produces hammer scale when a hot iron object is struck. It is usually found in the area where the smithing was carried out.

Low-density fluxed lining slags
Low-density fluxed lining slag is usually described as fuel ash, but in fact it is clay which has melted and dropped away from the rest of the lining. It is a low-density vitreous, vesicular material that is very friable and easily fragmented. The fragmentary nature of the slag would account for the low quantity that was recovered. This slag is not diagnostic of any particular process, as it can result from any high-temperature activity, including smelting and smithing.

Vitrified lining
This material consists of clay that has been vitrified on one side in the high temperature area of the furnace or the smithing hearth. Vitrified lining is produced by a high- temperature reaction between the clay lining and the alkaline fuel ashes or slag. It can be difficult to identify if pieces of vitrified clay come from a furnace or a hearth structure. Smelting sites usually produce significantly larger quantities than smithing sites, because of the difference in the size of the structures. None of the pieces that were recovered were diagnostic of either furnace or smithing activities, as the clay from both of these activities would have similar characteristics. None of the pieces showed any sign of curvature.

The lining appears to have been made from the local clay and had oxidised to a purple- red colour. Where one face of this lining was exposed to high temperatures, it had started to vitrify to a slightly vesicular vitreous material. This vitrified surface varied in colour on different fragments from black through to olive green, reflecting the varying temperatures.

Some of the pieces show evidence of repairs, where a black vitrified surface had been covered with more clay, which in turn had vitrified again to a glassy black surface. This indicates two episodes of activity.

Amorphous slags
As with most assemblages there was a quantity of material that is difficult to classify, and this represented the largest proportion of the material recovered. These slags did not have any distinguishing characteristics and were amorphous in shape and were often small. They could have been from either the smelting or the smithing process, but it is more likely, as no smelting slag or ore was found, that they were from the smithing process. This does not mean that smelting may have been taking place in the vicinity.

Industrial activity in the early medieval period (Seventh century)

The Early Medieval period has produced very little evidence to suggest great centres of smelting comparable with the Roman occupation, even in the Weald (Cleere & Crossley 1986, 87), and not even documentary evidence provides much insight into the iron industry in this period.

The evidence generally suggests that Roman techniques for iron-smelting did not survive and that the native population returned to a pre-Roman Iron Age tradition of producing iron, using non-slag-tapping furnaces (Tylecote 1986, 179). The Birch Heath evidence supports this picture. The two possible explanations Tylecote gives for this reversal are that the old techniques were reintroduced by the migration of peoples from north-west Europe or, more likely, economic conditions not longer warranted the same large-scale production.

The amount of ironworking residue that was recovered indicated a very short period and/or small-scale production – perhaps only one or two episodes of work to meet the needs of the site – based on the repairs seen on a few of the pieces of the vitrified lining. The question clearly arises as to why a small site should bother with such production in an area where iron ore deposits are not known. It is conceivable that ironwork was urgently needed and it was easier to produce the necessary items on site rather than travel to any trading sites. This would at least explain why there was only a short episode of metalworking. However, the effort to transport ore and other raw materials does not make commercial sense.

The evidence for Early Medieval occupation is based on the result of one radiocarbon date and shows some positive evidence of settlement activity taking place in this period within the Cheshire landscape.

This is a smithing hearth bottom produced when a hot iron bloom was hammered to remove trapped slag, a process known as primary smithing. The lower surface is rounded and the upper surface is hollow. This example was provided by Phil Andrews from Wessex Archaeology to illustrate his talk on ironworking at Southampton Archaeological Society's Hamwic Study Day in June, 2018.

Plan from: Bulletin of the Wealden Iron Research Group, Second Series No. 1, 1981.

The non-tapping iron smelting furnace at Millbrook, Sussex was dated to the 9th century. It is the only known Saxon smelting site in the Weald.

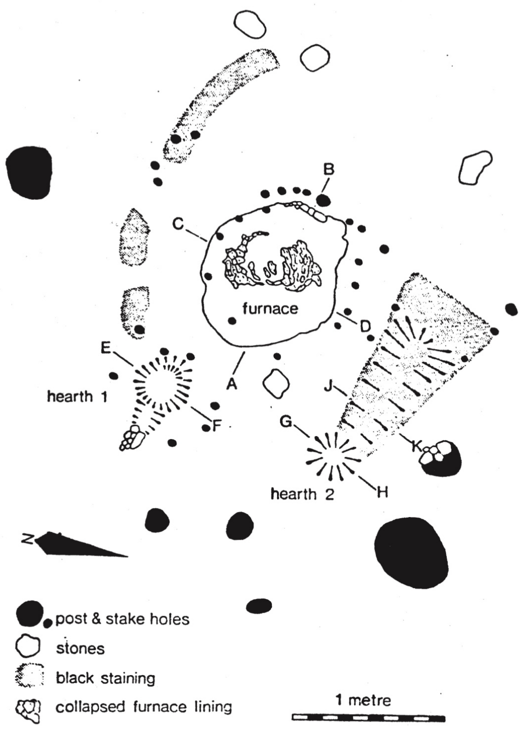


Fig.4: Millbrook Bloomery. Plan of site

South East Research Framework
Resource Assessment and Research Agenda for the Anglo-Saxon period
Consultation draft January 2013 (kent.gov.uk)

With regards to iron smelting, the site of Mersham excavated along the line of the CTRL south-east of Ashford stands as a significant addition to that previously discovered at Millbrook, East Sussex (Tebbutt 1982). Whilst the site of the furnaces were not located within the excavation, their close proximity was indicated by the discovery of fragments of furnace lining in a complex of pits, some of which also yielded diagnostic tap-slag and roasted ore (Willson 1999). Associated occupation and domestic refuse indicates that the site was active between 1050 and 1250 with a possible earlier phase commencing around 850. Located immediately to the south of a church first recorded in 1040, it is interesting to speculate on the historical context of this iron working and whether it represents ecclesiastical provisioning, perhaps for one of the Canterbury houses. In this connection, it may be noted that large quantities of iron working residue were recovered from Middle Saxon pits sampled by the unpublished Christ Church excavations in the outer court of St Augustine's Abbey (Bennett 1990). As attested historically by charters granting iron yielding estates to houses such as St Mary's, Lyminge, Kentish minsters had a stake in the industry's development from at least as early as the 8th century (Blair 2005: 246-87). A sidelight illuminating the production mechanisms associated with the Anglo-Saxon iron industry is also provided by a forging pit discovered at Friar's Oak, Hassocks, Sussex, which shows that the process of converting blooms for sale and redistribution may have occurred at some distance from source (Hodgkinson 2000: 18 Fig. 11 and 41-2).

The residues are indicative of iron smelting in a non- tapping bloomery furnaces. Non-tapping furnaces were typically employed in the Iron Age and early medieval periods, whereas slag tapping (in which the slag is encouraged to largely flow out of the furnace) was practiced in the Roman period, in some areas in the early medieval and more widely in Britain from the late 9th century onwards until bloomeries were replaced by the production of iron in blast furnaces in the early post-medieval period.

Certain discrimination of the residues from non-tapping furnaces of these different periods is not currently possible, but the present assemblage more closely resembles early medieval examples than collections of Iron Age date.

In detail, the presence of well-fluxed slag puddles provides a close comparison with the non-tapping furnaces of Churchills Farm, Hemyock (Young 2015b; Smart et al. in prep.). These furnaces had relatively shallow circular basal pits (0.4 to 0.5m diameter and mostly less than 300mm deep, one example being 450mm deep), which were packed with cereal steams prior to smelting. These furnaces show close similarity with examples in the Forest of Dean at Clearwell Quarry (Pine et al. 2009) and Yorkley (Young 2015c). These occurrences are all probably mid-8th-mid-10th century in age. It is possible that the cereal packing may indicate an Irish influence on the technology (Young 2011, 2012).

Wood packing was normal on a second group of sites, with larger basal pits to the furnaces, including those on the S side of Culmstock Road (Young 2014; Rainbird & Young in press) and at Burlescombe (Devon) (Reed et al. 2006), as well possibly as those at Ramsbury (Wiltshire) (Haslam 1980) and Millbook (Sussex) (Tebbutt 1982). These furnaces may include a few examples at around 0.5m diameter, but most are larger, ranging up to 1m diameter and have a broadly splayed prolife and a planar blowing wall. These examples also have given 8th-10th century dates, but are possibly just slightly earlier than the cereal packed examples.

At broadly the same period there are also examples of slag-tapping furnaces. These occur late in the sequence at Ramsbury, where the furnace has a splayed profile and a planar blowing wall, and contemporaneously with the cereal-packed non- tapping furnaces at Churchills Farm, where they are formed at one end of a small but elongate pit, as seen on 11th-13th century examples.

The samples produced no evidence for hammerscale. The site therefore parallels the two known early medieval sites in Hemyock in showing a remarkable lack of evidence for smithing. The raw iron produced must have been worked into usable iron elsewhere. A model of dispersed iron smelting (perhaps dependent on woodland resources) with centralised bloomsmithing seems likely. No centralised smithing facility has yet, however, been discovered in Hemyock.

Such a model is perhaps particularly significant given the likelihood that Hemyock was a royal estate in the late Saxon period. The abundant evidence for iron production, employing different and at times innovative smelting technology may hint at a specialised role for this estate. Although the evidence for iron smelting across the Blackdown Hills, drawing on the rich iron resources of the clay-wth-flints (Reed 1997; Young 2015a) is well established, this focus of early medieval activity at Hemyock appears unusual. Elsewhere in Wessex, there is evidence for iron production on other royal estates, for instance at Ramsbury (Haslam 1980) and Pucklechurch (Young & Young 2013).

Note: According to Wikipedia: [The church of] St Mary of Glastonbury holds Pucklechurch. There are twenty hides; in demesne are six ploughs and twenty three villans and eight bordars with eighteen ploughs. There are ten slaves and six men render 100 ingots of iron less ten and in Gloucester one burgess pays 5d and two coliberts pay 34d and there are 3 Frenchmen and two mills rendering 100d.