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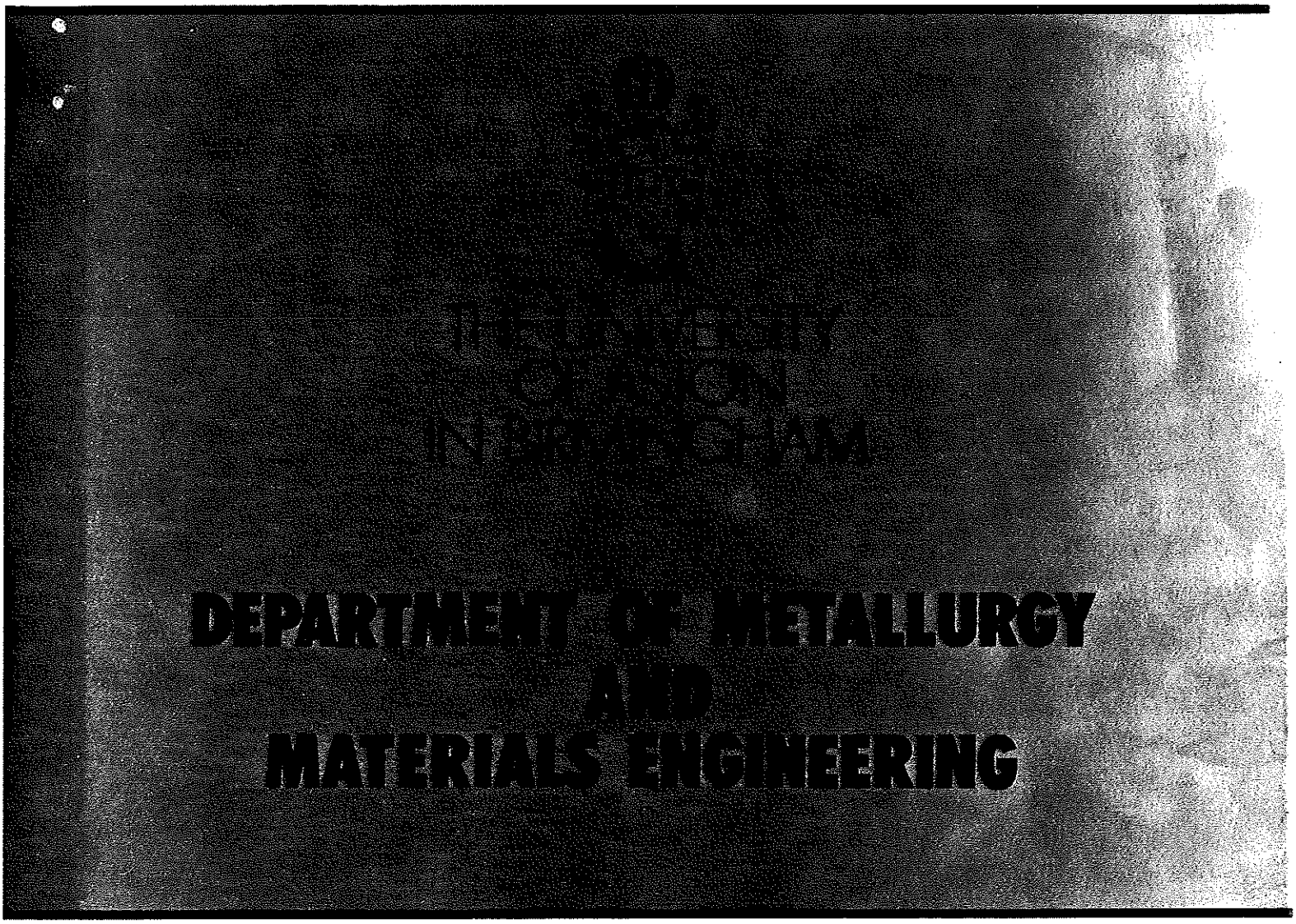

APPENDIX IV

A SURVEY OF THE IRONWORKING INDUSTRY IN ENGLAND 700 BC - AD 1600

by

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Introduction

This report is an attempt to assess the knowledge that has been gained from archaeological excavations and surveys, of the English ironworking industry, including both smelting and smithing. It spans the period from the first use of iron c.700 BC to the time of the supremacy of the charcoal blast furnace as the major source of iron, i.e. c.1600 AD. From the late 1960's onwards there has been a massive growth in excavation and fieldwork, accompanied by improved techniques both during excavation and in the post-excavation phase. It is from this published material that this report draws its main source of information, rather than from sites excavated and reported on more than twenty years ago.

The Sources

In common with many other surveys examining distributions of archaeological evidence, the study is severely limited by four factors. The first is the uneven emphasis on archaeological work on a national scale. It is an accepted fact that a national distribution map of certain archaeological aspects is more a representation of locations of active research in that particular topic, rather than one of real archaeology. Ironworking is no exception, and this can readily be appreciated by reference to two areas of major iron production in the past, namely the Weald and the Forest of Dean. The former has an active group specifically concerned with studying iron working in the area, (the Wealden Iron Research Group) which began before the Second War with the work of Straker [1]. In the Weald Cleere [2] lists thirty-six positively identified and

dated Roman sites. In the Crowborough area of East Sussex [3] an area of 170 square kilometres were fieldwalked and 300 bloomery slag heaps were recorded. Thirteen sites were examined in more detail of which ten were Roman, one was Medieval and two could not be dated.

The Forest of Dean has received scant attention in terms of ironworking studies. There is ample evidence for iron ore mining in the form of drifts, locally termed "scowles", e.g. at Bream, Noxon Park, Perrygrove [4]. There has been a little work on the distribution of slag heaps and the number of identified smelting sites is very few.

Since workable iron ores are so widely distributed in England (available in all Counties except six [5]), and both fuel and furnace building materials would have posed no serious problem there should be an underlying trend towards an even distribution of smelting sites, with higher concentrations in specific areas. With the widespread use of iron the number of smithing sites should be large and their distribution even over the whole country. As shown above, in the case of smelting sites this is clearly not so, and any inferences from the evidence presented as regards distribution must be taken as tennous.

The second factor affecting any discussion of site distribution over the two thousand year period between 700 BC - AD 1600 is the unequal number of sites excavated belonging to the various periods. This variation reflects the differences in society, settlement pattern, industrial and agricultural patterns, and technological level of the societies belonging to the various

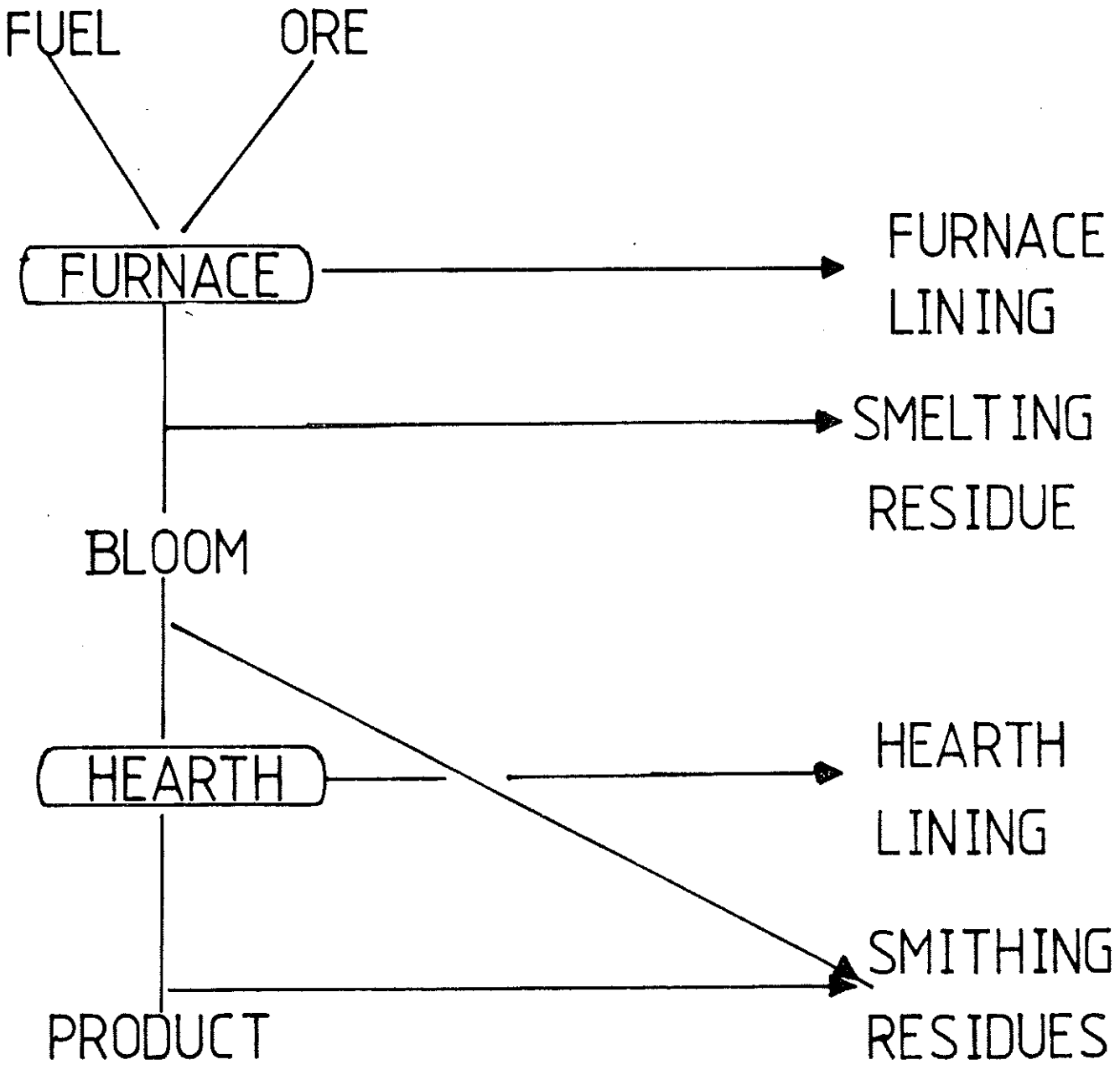
periods. The changes in settlement pattern (and therefore the industrial and agricultural patterns), throughout the prehistoric, protohistoric and historic periods have been discussed elsewhere, but they must be borne in mind when considering the varying evidence for ironworking. Evidence concerning the industrial patterns and the technological levels of the various periods from other, more comprehensively studied, industries, e.g. pottery, are worth considering.

The third factor is that of the delay occurring between excavation and publication. Interim reports may be published, as are short notes in the yearly sites and monuments form of register found in most of the leading national and county archaeological journals. Thus any survey of this type is several years out of date as it is written, and in two periods, the Iron Age and the Migration Period, just one site could alter dramatically the understanding we have of the ironworking industries of these periods.

The fourth factor limiting a study of ironworking and particular to this subject, is the lack of an established terminology when discussing the process itself, and the archaeological evidence left by the process. It is unfortunate that many archaeologists are ignorant even of a broad outline of the ironworking process, thus leading to a failure to identify and/or correctly interpret the evidence. Further, on publication, unless expert advice has been sought a wide, loose, and to some extent, technologically meaningless terminology has often been used. It appears that besides the use of general terms to describe areas of activity, e.g. 'industrial phase or working' and 'ironworking' the terms

FIG. 1

THE IRONWORKING PROCESS



'smithing' and 'smelting', 'hearth' and 'furnace' have been regarded as interchangeable, and that the misapprehension that "slag = smelting" has commonly been present.

It is therefore clear that though there is a substantial amount of evidence concerning ironworking, that which can usefully be used to construct a reliable picture of ironworking is but a portion of the evidence available.

The Ironworking Process

The direct ironworking process can be divided into two distinct processes (Fig. 1). The smelting process is the reduction of the iron ore by carbon monoxide to form a 'bloom' of sponge iron. It is carried out in a furnace, of which there appears to be a wide variety of types [6,7], though many of the interpretations of furnace superstructure are conjectural. The second process is the smithing process, which has been subdivided into primary and secondary smithing processes.

Primary smithing is the working of the raw bloom to drive out the excess slag, thus forming the worked bloom which is then ready to be made into tools. The primary process took place in a hearth probably on the smelting site. The secondary smithing process was either the working of the bloom into artefacts or the repair or reworking of tools. This again is carried out with a hearth, though any domestic or other hearth could be used, since only a moderately high temperature is required and oxidising conditions may prevail, as opposed to the much higher temperature and the reducing atmosphere necessary in the smelting furnace.

FIG.2.

OCCURRENCE OF SMELTING RESIDUES

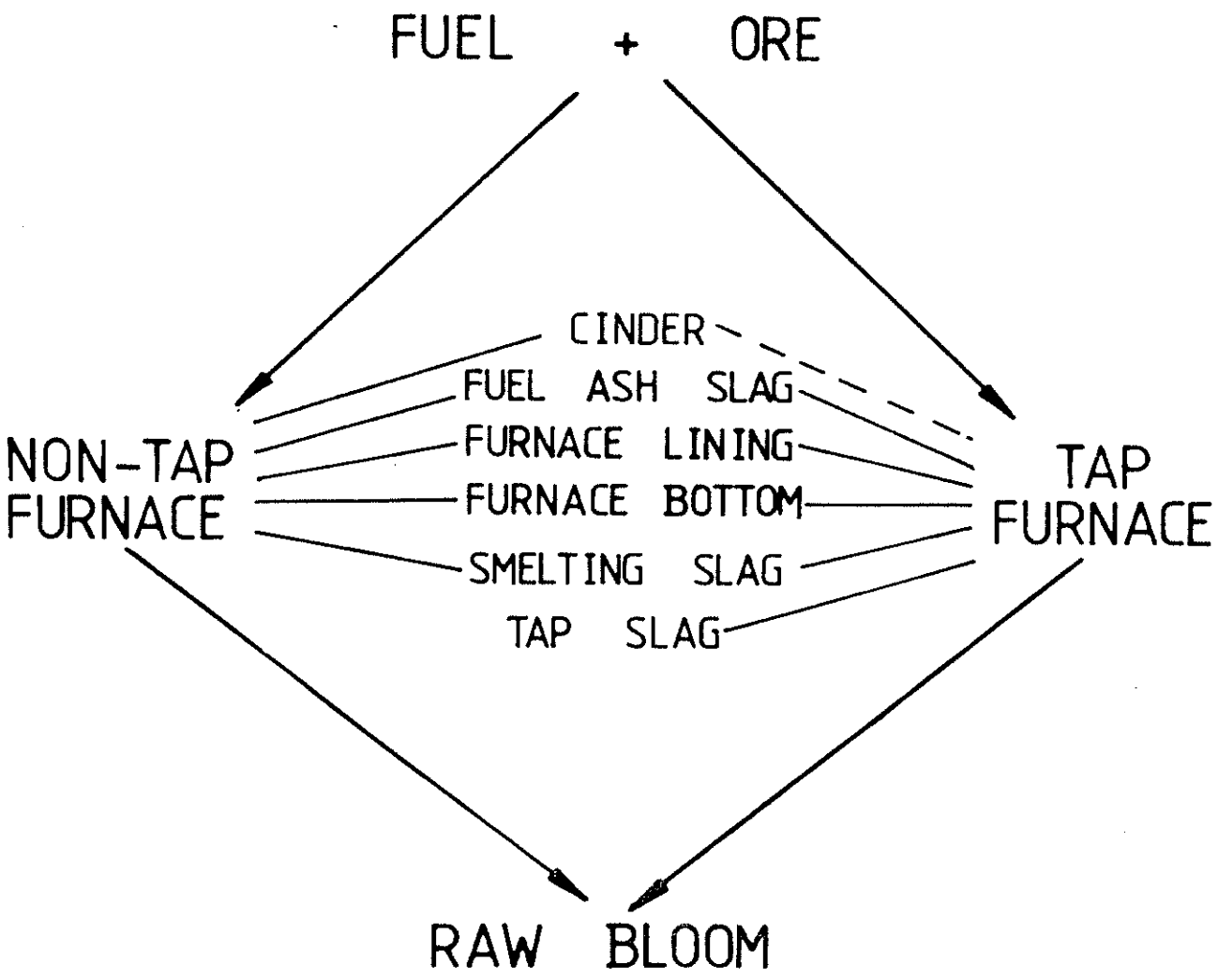
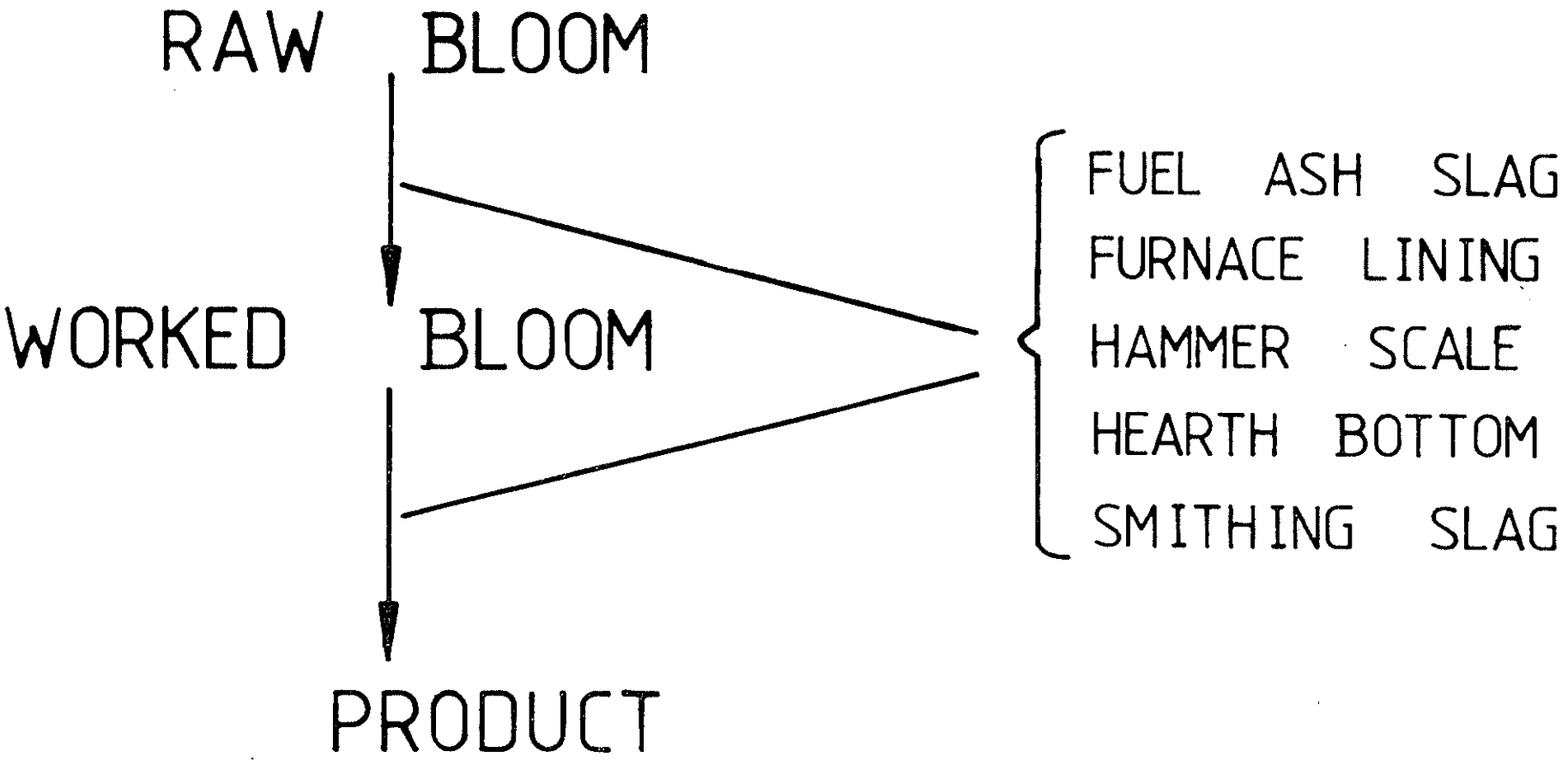


Figure 2 shows the evidence that may survive from the smelting process on an archaeological site, the amount of debris varies greatly depending on the technological level and on whether or not the evidence represents a "one-off" campaign or a series of campaigns that could be interpreted as a permanent or industrial iron smelting site. The greater part of the smelting residue is likely to be one of the forms of smelting slag rather than furnace lining or other residues. It is the recognition of the smelting slag that is likely to lead to identification of the feature as a furnace. In the case of tap slag this is straightforward visual identification, but in the case of non-tap slag (often in the form of furnace bottoms or slag 'cakes' or 'pans') its distinction from smithing slag can require extensive investigation. The furnace lining may show evidence of attack by the liquid slag in the lower portion of the furnace, and often in the tuyere zone, being the zone of highest hot face temperature, the lining will have a vitrified inner surface. The residues associated with smelting are commonly removed from the proximity of the furnace and may therefore be found dispersed across a site, in contexts not directly associated with the process.

Figure 3 illustrates the evidence that is associated with both the primary and secondary smithing process. As stated earlier, any hearth could be utilised though there is little doubt that hearths were commonly constructed specifically for smithing. Thus, for certain identifications, greater emphasis must be placed on the finding, sampling and identification of the residues derived from smithing, particularly the characteristic

FIG. 3

OCCURRENCE OF SMITHING RESIDUES



smithing slag and hammer scale. The latter is probably the most useful for identifying smithing on a site for two reasons. Firstly, hammer scale is found both in the hearth and in the vicinity of the anvil, e.g. on or in associated floor levels. Secondly, scale can be readily identified both in the field and in soil samples removed for further investigation. Smithing slag, (commonly in the form of hearth bottoms) is less widespread in a smithing working area than scale, and may be confused with non-tap slag when only visually examined.

The discussion so far shows that the ironworking process is complex and can be carried out on differently organised locations. Thus smelting and smithing may have occurred either on the same site or on separate sites. It may be expected that evidence for some level of smithing activity may be found on most settlement sites from the iron age onwards, such work being an essential service activity in the community.

The division of ironworking into two processes, and its widespread occurrence both temporarily and spatially would enable the present survey to be presented in a number of ways; but it seems most useful to arrange it on a temporal basis using the divisions of Iron Age (700 BC - c.43/80 AD), Roman (43/80 AD - c.400), Migration (c.400 - 1100), and Medieval (1100 - 1600). Within each period the evidence for smelting and smithing will be discussed separately.

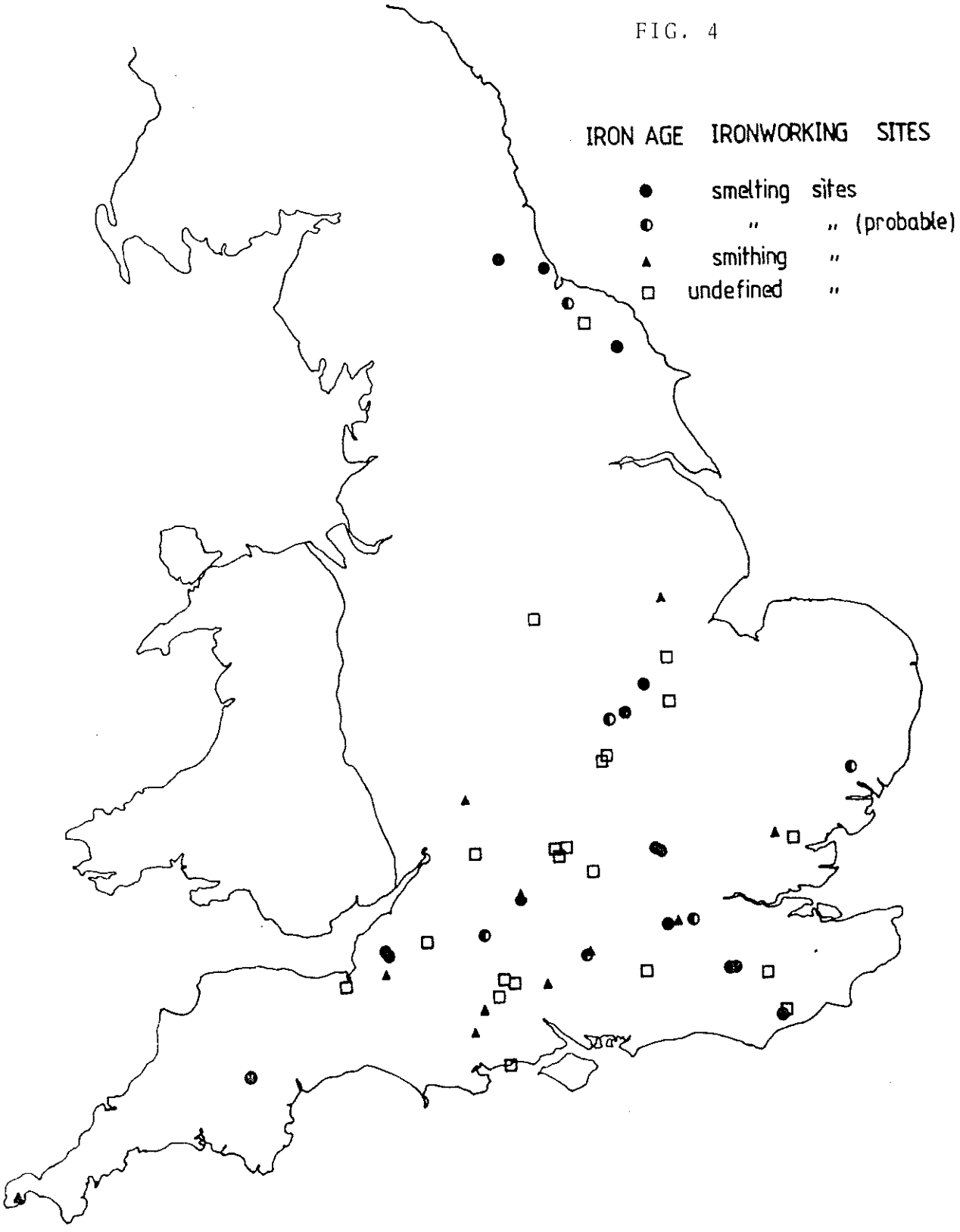
THE IRON AGE

The beginning of the Iron Age in Britain is generally regarded as having taken place in the seventh century BC. Hallstatt bronzes were being imported into this country and similar artefacts of iron, showing local adaptions, also appear (the notable site being Llyn Fawr in Glamorgan). The amount of iron occurring in this period is very small and the definition of the Iron Age is very dependent on innovations in pottery styles and the presence of Hallstatt bronzes (e.g. the late sixth century BC site of Staple Howe, East Yorkshire, produced only two small objects of iron [8]).

There appear to be two broad phases in the Iron Age [9], the first from c.700 - 500 BC is the period of the proliferation of hill forts, development of local pottery traditions and the continuation of continental links. In the second phase 500 BC - AD 43+ the highland zone appears to stagnate while in the lowland zone there are continuing strong continental influences and further recognisably local developments.

The actual date of the introduction into Britain of ironworking technology cannot be determined. The local variations of some ironwork from the continental Hallstatt type, e.g. in the Llyn Fawr hoard, indicate the local presence of the smithing process by the end of the seventh century BC, but does not necessarily imply that smelting was being practised here at this time. There is at present a total lack of direct evidence for either process before c.400 BC (Kestor, Devon [10,11] dated by association rather than physical methods), i.e. into the second phase or middle Iron Age period. At this point several loosely dated sites produce evidence for ironworking, though because of the

FIG. 4


IRON AGE IRONWORKING SITES
smelting sites
" " (probable)
smithing "
undefined "

lack of work done on the technology in this period few sites can be ascribed to a particular process. Tylecote [12] lists twelve English sites on which slag has been found, to these a further thirty can now be added, but with little increase of our knowledge concerning their technology (Fig. 4).

It has been generally accepted that ironsmelting was at a technological low level during this period and that the bowl furnace was the principal type used. Whether doomed or not, it may well be possible to show at a later date that shaft furnaces were introduced by the end of the Iron Age when there were other Belgic technological imports. This would lead to a reinterpretation of some poorly dates sites such as Dellfield, (Berkhamsted, Hertfordshire)[13].

Excations on settlement sites suggest that the amount of iron used in everyday life was small, and that it was reserved for larger, more durable artefacts, where other material would not suffice. There was therefore no requirement for large scale production until perhaps the later Iron Age. The mode of production would be of small scale, one-off operations often only producing a few pounds of iron (Tylecote [14] suggests blooms of the order of 4-5 lbs. maximum weight). The archaeological evidence for a small simple furnace is likely to be slight, and the correct identification of the slag may be the only available method for examining the occurrence and distribution of the smelting process in England.

There are only eight reasonably definite smelting furnace sites at present known to belong to the Iron Age in England, namely:-

Chelms Combe, Cheddar, Somerset; Kestor, Devon; Levisham Moor, North Yorkshire; Rowberrow Cavern, Somerset; Wakerly, Northants; Great Oakley, Northants; West Brandon, Durham; and Brooklands, Weybridge, Surrey. There are few details about any of these sites except for Wakerly and Brooklands.

The Chelms Combe, Kestor and Rowberrow furnaces were bowl shaped depressions, 30-45 cm in diameter and c.25 cm deep,[15,16,17] (though Rowberrow was c.40 cm deep). There are no details concerning any lining, etc. The fills seem to consist of soil, slag and charcoal. The Levisham Moor site produced what is believed to be an intact and possibly bowl shaped furnace, with a clay dome. The early site at All Cannings Cross produced[18] slag which has been termed tap slag. The mineralogy of the slag given in the report is typical of either an early smelting or smithing slag, consisting of fayalite, iron oxide (magnetite in the report) and a 'eutectic' (i.e. probably a glassy phase approximating to anorthite). The description of the fayalite suggests that the slag was slow in cooling; the amount of iron oxide present would suggest a relatively efficient process. Slag from Levisham Moor has also been examined but it is not known if it relates to the furnace or derives from a separate smithing area.

Two bowl furnaces were excavated at the second/third century BC enclosure at West Brandon (Durham).[19] They were approximately 30 cm diameter and 20 cm deep. The section through the furnace is very instructuve in that three layers can be distinguished, an upper layer consisting of broken furnace lining and fired clay (interpreted as collapsed dome), a middle layer of slag and a basal layer of charcoal containing some slag droplets.

A single similar furnace has been identified at Great Oakley [20] (Northants), the associated features again suggesting an early date. A group of six such furnaces were found at Brooklands, Surrey, three of which were considerably larger than those mentioned above, up to 80 cm diameter and 30 cm deep. Cleare suggests that these may have had a superstructure of a low shaft rather than a dome. [21]

The probable Iron Age furnaces from Wakerly, Northants, provide [22] the most recent excavation of a series of furnaces. Two of the three types of furnaces identified belong to the Iron Age. Type I were bowl furnaces, possibly covered by a dome. They varied in size from 60 cm to 130 cm diameter and were sunk up to 30 cm into the ground. Though they were not tapped there was a pit in front of the furnace to enable it to be raked out and the bloom removed. They are dated (doubtfully) to the first century BC. The second type is described as a sunken shaft furnace and resembles to some extent the slag-pit type furnace found on the Continent. The essential feature is a pit 40-75 cm deep, one side sloping steeply down to the front of the furnace, which was 30-70 cm diameter with an arch facing the pit, about 35 cm high. The shaft itself probably stood above ground level. The steeply sloping pit could not be used for tapping the furnace, though it probably served for raking out, and may also have helped to regulate the furnace atmosphere. This type has been dated to the Belgic period.

The evidence for pre-Roman smelting sites in the Weald is scant. Though a number of Roman sites were suggested to have had earlier origins [23,24] Cleere [25] has pointed out the discrepancies in

some of these arguments. A number of sites, in the region to the north of Hastings, e.g. Crowhurst Park and Footlands, have yielded Iron Age pottery but no firmly dated early furnaces have been discovered. The writings of Caesar [26] do suggest a relatively large industry in the first century BC, probably in the south east, i.e. the Weald, but it is likely that the remains of earlier activities have been removed or overlaid by the massive Roman and Medieval Industries that grew up in that region.

There are a further seven possible smelting sites of which two (the Cow Roast[27] and Dellfield[28] in the Bulbourne Valley, Herts.) are possibly Roman as are the furnaces at Garden Hill (Sussex)[29]. One at Harrington (Northants)[30] is also of uncertain date, while the slag from Roxby Low Moor, North Yorks. could be derived from either smelting or smithing. The 'furnace bottom' from Purberry Short, Ewell, Surrey as described [31] is more in keeping with a smithing hearth bottom. It is only a passing reference [32] to Catcote, Co. Durham, that suggests that it was a smelting site.

Of the eight sites identified as having smelting furnaces on them only two, Wakerly and Brooklands have more than two furnaces, but both these sites are relatively late in the Iron Age, being dated to about 50 BC - AD 50. The other sites are predominantly single occurrences. The overall furnace type (except for Wakerly Type II) is the bowl furnace with probably some sort of super-structure as described by Cleere's classification of early furnaces [33] (his A1 and 2 group). The evidence presented for iron smelting would suggest a growth from small, single isolated

furnaces, certainly present by the Middle Iron Age to an activity that may be classed as of small industrial scale, with larger furnaces occurring in groups.

The evidence for smithing in the Iron Age (in the form of slags and hearths) is meagre. The site at Beckford, Hereford had a concentration of smithing slag in middle iron age contexts, (with the possibility of smelting also occurring on the site). There is no evidence for specific smithing hearth, and no hammer scale was recovered from the site. (It is only at Gussage All Saints,[34] Wiltshire, that hammer scale has been found in an iron age context). At Beckford one pit contained a large amount of slag (1.26 kilos) out of a total of 3.6 kilos for the middle iron age phase. The meagre slags from Glastonbury and Liddington Castle are also derived from the smithing process, though there is a substantial quantity of possible ore (2 kilos) as compared with 0.5 kilos of smithing slag from the latter site.

There is further information on smithing in the iron age, (and to some extent the ironworking process as a whole) as evidenced by the finding of smiths' tools, blooms, and currency bars. Some attention has been paid to the distribution, size, function and composition of currency bars, and they need not be covered further here. A few blooms have been found and reported on: e.g. Wookey Hole, Somerset [35].

As has been pointed out [36] our knowledge of smiths' tools, (and techniques) of this period is severely lacking. They appear as grave goods, (Burton, Fleming and Garton Slack, East Yorks.), and the only other occurrence is in accidental finds, e.g. Waltham

Abbey where of a 23 piece hoard, 11 are blacksmiths' tools, (5 pairs of tongs, 3 anvils, sledge hammer, file and a poker).[37]

There are a further 19 sites that have produced slag from contexts dated to the Iron Age. The details concerning these finds are poor and no firm conclusions can be drawn, (though it should be noted that this is half of the total number of known smelting and smithing sites). If the trend in smelting sites (i.e. from isolated examples to a minor industrial status) is reflected in smithing evidence, the early period smithing evidence will be very slight indeed, being found as a few fragments of smithing slag and a scatter of hammer scale. It may only be in the latter part of the period that hearths, functioning solely as smithing hearths (perhaps accompanied by non-ferrous working) may be identified.

ROMANO BRITISH PERIOD

The Claudian invasion of 43 AD and the subsequent "Romanisation' of the larger part of Britain had a dramatic effect not only on society and the landscape but also on the industries of the late Iron Age, in particular the ironworking. From the limited evidence presented in the previous section it would seem that an embryonic iron industry probably existed in the lowland zone by the end of the first century BC. The requirements of the Roman armies, the building of new settlements, and the increase in the use of iron as an everyday material meant a massive demand for iron. This was met by the establishment of centres of iron production in areas such as the Weald, the Forest of Dean, and Northamptonshire.

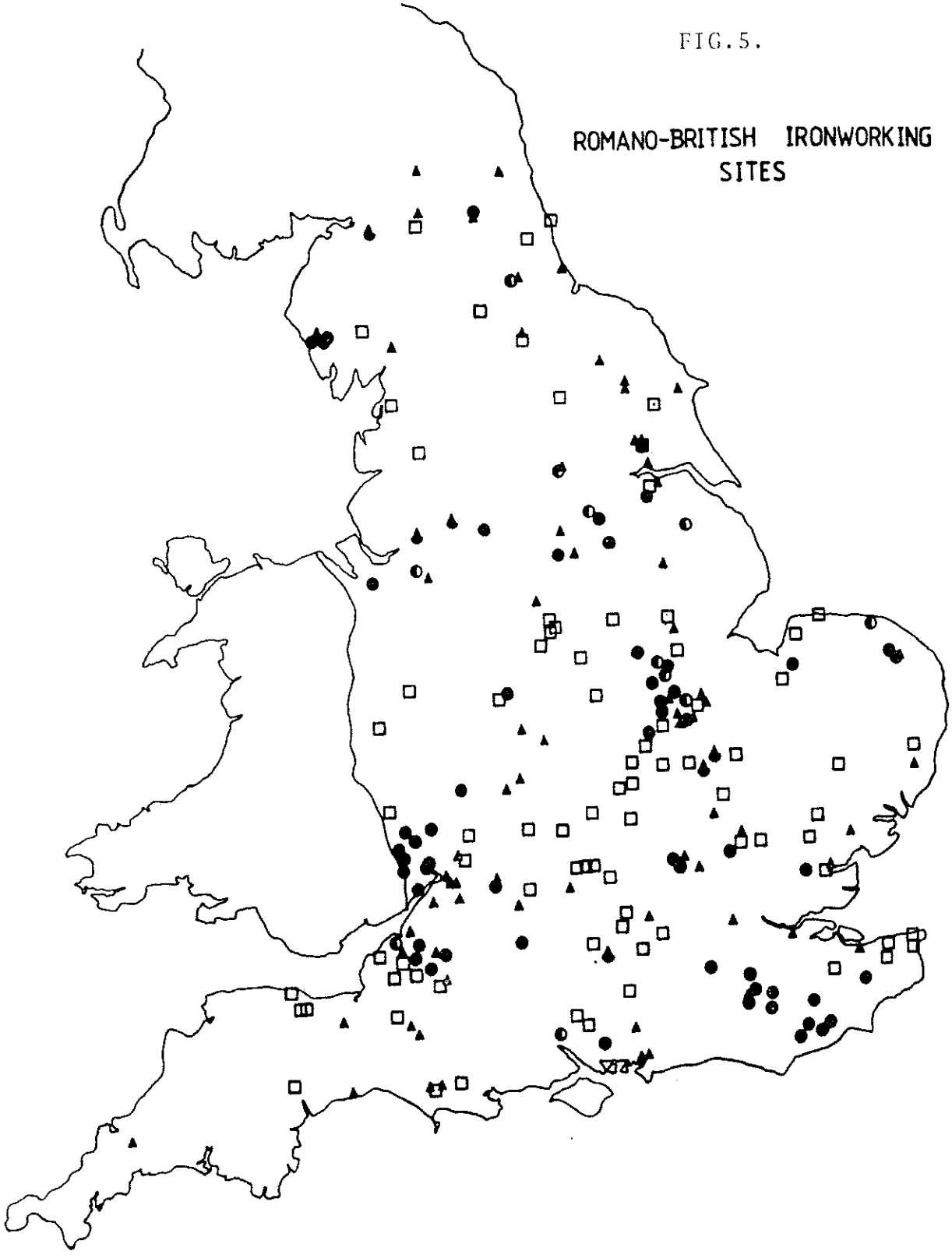
The evidence for Romano British ironworking has recently been listed by Aiano [38] and this section relies much on his work, though the number of sites has been expanded considerably.

The evidence provided by the late Iron Age smelting sites at Wakerly [39] and possibly Broadfield suggests that slag tapping furnaces were being used in lowland Britain prior to the Roman conquest. The more primitive non-tapping furnaces continued to be used in the highland zone, not only in the late Iron Age but possibly throughout the Roman period in the remoter regions.

The archaeological evidence of iron objects and the known distribution of the ironworking residues (Fig. 5) demonstrate the increase and widespread use of iron during the Roman period.

FIG.5.

ROMANO-BRITISH IRONWORKING SITES



The evidence suggests three major areas of iron smelting, namely: the Weald, the Forest of Dean, and Rockingham Forest (Northants). Only a few sites have been examined in the Forest of Dean, none in any great detail; a large number of sites have been noted in the Rockingham Forest area (e.g. E.T. Artis marked 60 'ironworks' on his map of the area of Durobrivae [40]), but only recently have several been scientifically excavated, many only on a rescue basis. The bulk of the evidence available for studying the iron smelting technology of the Roman period derives from the Weald, and has been examined by a number of workers [41], and several classifications of smelting furnaces have subsequently resulted. Table 1 lists the sites that have produced shaft or bowl furnaces (the discrepancy in the number of sites between those listed in Table and the total number of sites plotted as smelting sites arises from the fact that some smelting sites have been so identified by the presence of tap slag only, or there are insufficient details yet available to identify the type of furnace found on a site). This table again illustrates the southern bias of the information available, but more importantly shows that the two types of furnace are evenly distributed, though it must be recognised that the dating of some of the furnaces is dubious, and some, especially the bowl furnaces, may in fact be pre-conquest (if not first century BC). The available dating evidence of the listed furnaces suggests (Table 2) that the shaft furnace was used at least to the end of the second century (the Sacrwell site giving late dates for both the shaft and bowl furnaces), probably indicating the continuous use of shaft furnace technology throughout the Roman period.

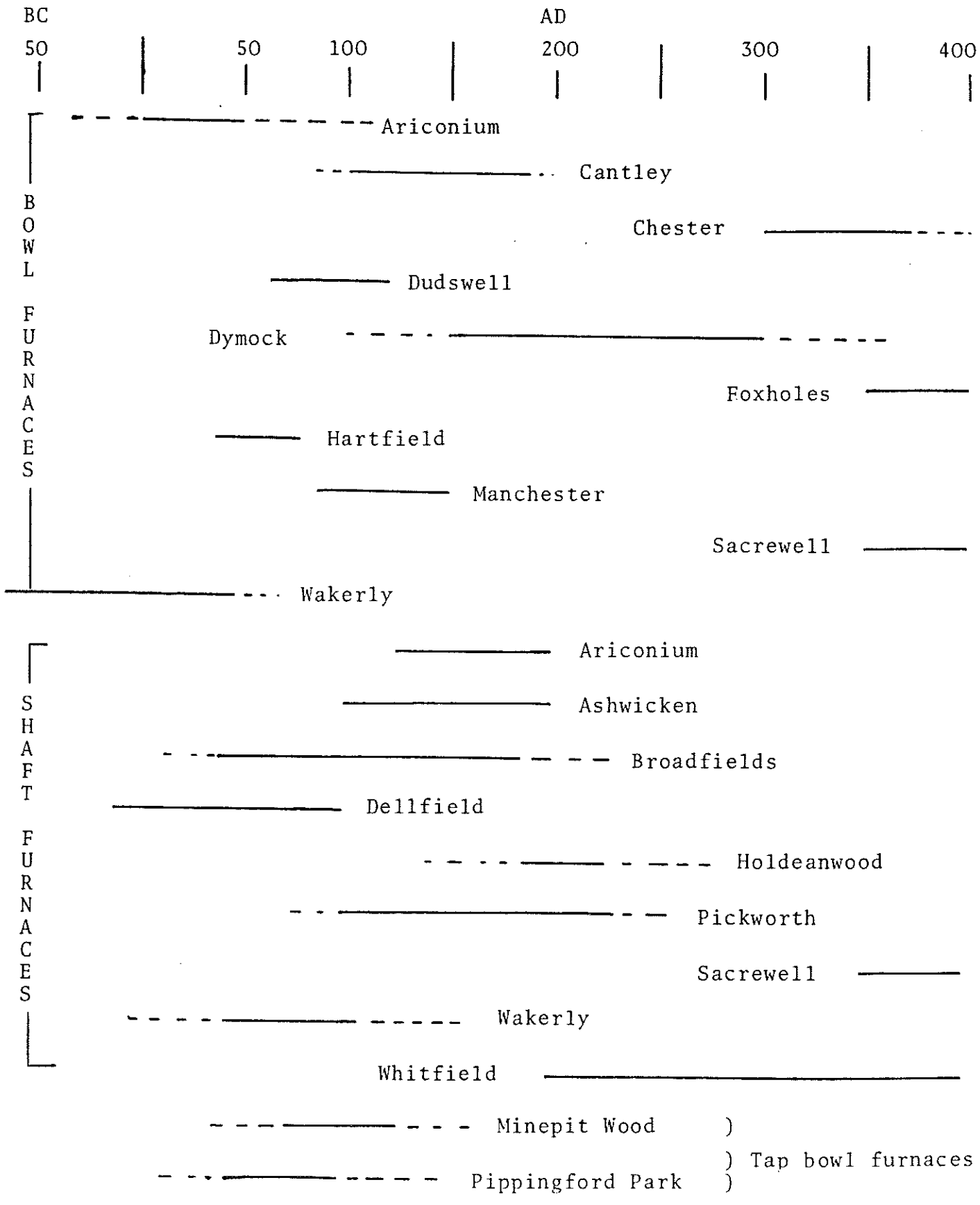
TABLE 1

ROMANO-BRITISH FURNACES

Bowl Furnaces Cleere Type A1	Number of Furnaces
Ariconium (Herefordshire)[42]	7
Cantley (Doncaster,Yorks)[43]	1
Castleford (Yorks)[44]	1
Chester (Cheshire)[45]	2+
Dudswell (Herts) [46]	6
Dymock (Glos.)[47]	2+
Foxholes Farm (Herts)[48]	40
Hartfield (Weald)[49]	1+
Manchester (Lancs)[50]	2+
Sacrewell (N'hants)[51]	7
Wakerly (N'hants)[52]	3

Shaft furnaces Cleere Type B1i	Number of Furnaces
Ariconium (Here)[53]	6
Ashwiken (Norfolk)[54]	6
Broadfields (Weald)[55]	36
Dellfield (Berkham-stead, Herts)[56]	4
Holbeanwood (Weald)[57]	4
Pickworth (N'hants)[58]	2
Sacrewell (N'hants)[59]	1
Wakerly (N'hants)[60]	4
Whitwell (Leics)[61]	1
Cleere type B1ii	
Minepit Wood (Weald)[62]	1
Pippingford Park (")[63]	1

TABLE 2 - DATING OF ROMANO-BRITISH FURNACES



It has been proposed [64] that by the end of the third century the major centre of production of iron had moved from the Weald to the Forest of Dean. The lack of identified and dated furnaces from this area precludes any discussion of this point, but it may well be that third and fourth century shaft furnaces will be found in that area.

The evidence available suggests a relative uniformity of dimensions for shaft furnaces (Table 3). The internal diameter is of the order of 30 cm, with a wall thickness of about 20 cm. The height can only be judged approximately due to the varying degrees of preservation. The Ashwicken site [65] would still appear to be a classic example, the best preserved furnace surviving to a height of 1.4 m, with a suggested full height of c.1.5 m (this was on the argument of the furnace depending on induced draught rather than forced draught which has since been rejected). Only the Pickworth site has a furnace standing to similar height, but the basic requirements, and ease of working of a shaft furnace would point to a height of the order of 1.5 m. Only at Sacrewell and Whitwell do individual shaft furnaces occur, small groups are more common indicating again the more organised industrial basis present in the Romano British period. Obviously the major sites in the Weald (and the Forest of Dean?) will have large numbers of furnaces, especially if they were supplying the military with iron. The size of some of the slag heaps would necessitate such numbers (e.g. at Beauport Park,(the Weald) the slag heap has been estimated to have originally held upwards of 100,000 tons of slag).

TABLE 3

DIMENSIONS OF SHAFT FURNACES

SITE	DIAMETER (INTERNAL)	HEIGHT (REMAINING)
Ashwicken	0.30 m	1.40 m
Broadfields	c.0.30 m	1.0 m (max)
Dellfield	0.28 m	0.60 m
Holdeanwood	c.0.30-0.40 m	-
Pickworth	0.30 m	1.0-1.20 m
Sacrewell	-	0.6 m
Wakerly	0.3-0.45 m	-

The furnaces so far excavated do vary in some respects, e.g. some are set into banks for support, as at Ashwicken, while others were free standing and some have sloping floors, (i.e. sloping down from the back furnace wall to the front arch). There is also variation in the number, size, and position of the pits into which the slag was tapped.

The Wakerly site illustrates a particular type of shaft furnace which has part of the structure sunk into a pit (Cleere type A2), varying in depth from 40-75 cm. They differ from the classic A2 type however in that the pit extended beyond the front of the furnace (in which there was an arch) and sloped steeply upwards to the surface, allowing no room for slag tapping to occur but probably enabling the smelter to rake out the furnace. Unfortunately, as with the other furnaces on the site very little of the superstructure remained, and so there is little to indicate whether the draught was induced above the pit through tuyeres, or whether the arch and pit was used to induce a draught though of the three one furnace (site 4, furnace 2) the authors suggest was blown from above ground level. These furnaces have been dated to the Belgic period but may have continued on into the early conquest period, to be superceded by the surface standing shaft furnace.

The second type of furnace found in the period, the bowl furnace, can be divided into two groups, the simple bowl type, and the developed type. The former conforms to Cleere type A1 while the latter has a pit in front of the furnace, used for raking the furnace out, though it is thought unlikely that the liquid slag was tapped off. There are few structural details available

at present, but the diameter of the bowl varies considerably from c.0.5 m up to 1.5 m. The depth is dependent on the state of preservation, and very little superstructure survives, often less than 10 cm. There is therefore no indication whether the furnaces were domed or were a 'low shaft' type, i.e. having a short (≈ 1 m?) cylindrical shaft. One feature that has been noted both in Iron Age and Roman bowl furnaces is that there is commonly a basal layer of unconsumed charcoal, several centimetres thick, the result of the blast failing to reach the lower levels of the charge; further, the lack of slag in this layer indicates that the slag had a high viscosity, and therefore the operation in these cases is primative.

The dates of these furnaces, as shown in Table 2 suggest two periods of use. The first period was probably a continuation of the Iron Age technology, running through the conquest and lasting until the end of the second century; the second phase occurring at the end of the Roman period in the fourth century. Only at Dymock (Gloucestershire) is there a bowl furnace loosely dated from 150-300 AD [66]. The presence of these furnaces at the end of the period would suggest a continuity of use throughout the Roman period. The developed bowl furnaces occur in both phases, at Hartfield and Wakerly in the early period and at Sactwell at the end of the Roman period.

Two distinctive furnaces, as yet unparalleled in this period, have been excavated, at Minepit Wood and at Pippingford - both in the Weald. Their construction and technology is typical of the medieval period, but they are both well dated to the first or early second centuries AD. They conform to Cleere type Blii,

typified by being a domed furnace with tap slagging facilities and were constructed in shallow pits. They were both 60 cm internal diameter, the walls being 30-40 cm thick. The Minepit Wood furnace was standing 60 cm high in the pit, the full height being estimated to 1.0 m. It was blown by three tuyeres set at 90° to each other, situated at ground level. There was no evidence of tuyeres from Pippingford in the structure as excavated and they must therefore have been placed either higher up the structure or more likely in the arch at the front of the furnace. It may be expected that further examples of this type will be found.

There are a number of furnaces or hearths from the Nene Valley (Rockingham Forest, Northants) that due to insufficient information cannot be ascribed to either the smelting or the smithing process with any certainty. Typical examples are found on sites such as Normangate Field (Castor), Longthorpe, and Lynch Farm, they have similarities to the developed bowl furnace but have longer 'necks' (the flue) which would be more typical of smithing hearths. Until an examination of the residues has been made no firm conclusion can be drawn as to their function.

The smithing process can be carried out on a number of levels, from primary smithing of the raw bloom to the repair of the single implement. The evidence left by these extremes of degree vary considerably. At the lowest level the "one-off" repair or alteration to an artefact can be done in the crudest of hearths, for example, a bonfire laid on the ground surface with a set of bellows would easily supply sufficient heat for

such working. The evidence for this activity would be virtually undetectable and unidentifiable in the archaeological record. Similarly, the domestic hearth could be usefully employed as a temporary smithing hearth. Larger smithing operations, or areas set aside for the intermittent smithing of iron may have had purpose built hearths. It has been suggested that permanently sites hearths might have been raised to waist level [67] and so the evidence from Gatcombe Villa is of interest [68]. During the second phase of the villa, in room 1 of building 5 was a 1.5 m long rectangular hearth with a flue leading into it half way down its length; Tylecote suggests this was used to hear a water boiler above. A similar feature was present in room 2 which Tylecote parallels with Tiddington (see later) and interprets as a smithing hearth. In neither room or feature was any smithing slag found, though in fact both rooms produced few finds of any kind. Both hearths were similar and therefore may have served the same function (either water heating or smithing). It is of interest to note that in the north-east corner of room 2 a platform was built approximately 3 m long and 2 m wide enclosing an open area which had fire debris in it; pottery and an iron knife blade were recovered from the surface of the platform. It is feasible to suggest that the platform was the base of a waist high smithing hearth. The massive hearth bottoms from Magiovinium (Milton Keynes) c.35 cm diameter by 15 cm deep, weighing 22 kilos, would require a more permanent structure in which to form, rather than a simple ground level hearth. At Illchester a smithy

was refurbished with several stone built structures. The absence of waist height hearths is probably more apparent than real, since their identification (when only a few courses may survive) is difficult and requires that the surrounding floor level and fill of the structure be examined for slag hammer scale, iron, etc.

The remaining evidence for smithing hearths is poor, since many of the references to them merely note the presence of a hearth (and perhaps may therefore be interpreted as intermittent smithing hearths, the smithing being only one of several functions of the hearth). The Tiddington hearth [69], originally interpreted as a smelting furnace (and the site a major smelting centre) consisted of a stone built hearth 70 cm long and 40 cm wide with a flue at one end 45 cm long by about 20 cm wide and 15 cm deep. There was a further possible side flue three-quarters of the way along one side. The floor of the hearth was a single slab of limestone with no adhering slag; there was no description of the fill. A similar hearth was found at Verulamium (St. Albans, Herts) [70] (1 m long, 45 cm wide narrowing to a 25 cm flue, and 55 cm deep), it was a clay built hearth and the floor was 'covered in slag'.

The apparently more common variety of smithing hearth, the simple depression or bowl shape has been examined scientifically at Manchester [71]. They are of the order of 1 m across and 20 cm deep, the most notable feature being that they were surrounded by 'perforations' the result of the location of a portable anvil (similar holes were recorded at Watercrook Fort [72] (Cumbria), though in this case the hearth was rectangular (1.1 m by 0.7 m)).

There are a number of other forms of hearth: oval (Frocester, Glos., 2 m x 1 m), half circle (Lufton, Somerset, limestone blocks in a half circle 2.4 m diameter), and a hearth intermediate between the rectangular and round bowl hearth, resembling a long necked bottle (this is the same form as those from the Nene Valley discussed earlier (p. 19), especially that from Lynch Farm [73]. This intermediate example is from the site of Lady Lodge, Orton Longueville (Nene Valley, Northants), and is believed to have been a smithing hearth. Again, only study of the slags found in association with these furnaces will reveal their exact function.

Smithing slags are commonly found in contexts not directly associated with the smithing process (in common with many other finds), e.g. ditches, pits, etc., and it can therefore only be said that smithing has occurred on the site. A typical site of this nature is Grimstock Hill (Coleshill, W. Midlands), a Romano-British farmstead and temple. The most distinctive type of smithing slag is the 'hearth bottom'; plano-convex in shape and formed by accretion of slag and other material, e.g. fuel in the base of the smithing hearth and of a size and shape dependent on the amount of smithing performed. Seventeen complete bottoms were found at Grimstock Hill, in a variety of contexts distributed across the site, and most occurring singly and they varied considerably in size and weight, the weight range being from 75 to 1000 grammes, the mean being 365 grammes. The inference from this site is therefore that smithing was practiced but not with such

regularity that a permanent smithy was established. In this respect Grimstock Hill will be typical of many sites.

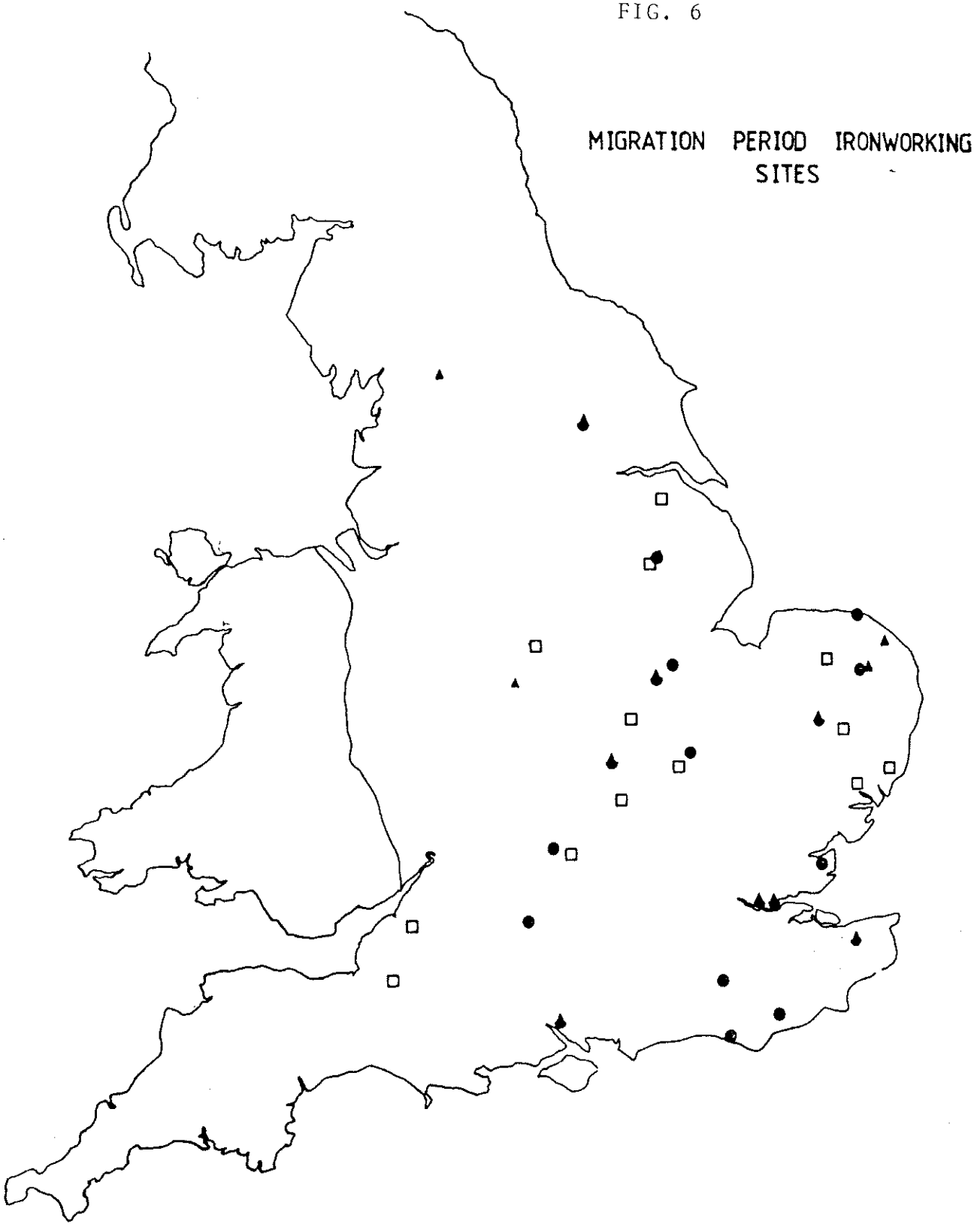
As would be expected, the distribution map (Fig. 5) of the Roman Ironworking sites shows for the smithing process a relatively even distribution. It should be noted that smithing residues would be expected to be found on smelting sites where the primary smithing process has occurred (i.e. the process of working the raw bloom into one suitable for use) though the iron rich slag derived from this process may have been recycled through the smelting process.

THE MIGRATION PERIOD

In this survey the Migration Period is taken to span the period from the end of the Roman Period (the early fifth century) until the mid-eleventh century. It covers a period of dramatic change, due to both internal (the growth of Kingdoms) and external influences (from the north, (Scandinavia, the Vikings), the Irish Sea Province (the Celtic Church and later the strong connections between Dublin and York in the Viking period), and both north and south Europe (the Saxons, etc., from north Germany and the Roman Church from southern Europe). It will be shown that some of these influences can be identified in the ironworking process. The post-Roman period in England has been described as the collapse of the industrial structure of the country. With the decline of the towns as market centres, the apparent break up of the communications network, and the fragmentation of society and withdrawal into a kingship structure, centralised industries could no longer function, and this is apparent and reliably observed in the pottery and glass industries. The ironworking industry was no exception, the evidence available suggesting the cessation of iron production on an industrial scale and the resort to local manufacture for local needs. The distribution of Migration Period ironworking sites is shown in Fig. 6.

In dealing with the Migration Period the problem of accurate dating of contexts is the greatest difficulty and it is only through scientific methods that chronologies can be established. Ironworking contexts offer suitable opportunities for the application of magnetic dating (though the calibration curve is lacking a totally satisfactory number of fixed points in this

FIG. 6



period) and the use of C^{14} dating on charcoal deposits. It is perhaps not surprising therefore that dates of contexts, especially from earlier excavations, are not exact, and commonly fall into either the early post-Roman phase (5th or early 6th centuries) or the later Saxo-Norman phase (late 10th to early 12th century).

The evidence for iron smelting in Anglo-Saxon Britain was summarised by D.M. Wilson in 1976 [73a] at which time the evidence had changed little since the publication of Tylecote's work in 1962 [73b] and amounted to four sites with smelting slag, two more sites, West Runton (Norfolk) and Stamford (Northamptonshire) had furnace remains. Further evidence in the form of unprovenanced and undated slags from East Anglia and an example from Mucking (Essex) is thought to derive from another different smelting technology. Fortunately three smelting sites, Ramsbury (Wiltshire), Millbrook (Kent) and Cherry Willingham (Lincs) have recently been excavated providing more evidence of furnace typology of this period. To deal chronologically with the evidence for smelting, there are two sites dated to the early period, firstly Cherry Willingham [74] (Lincs) - though its date is doubtful at present, and may in fact be Late Roman. It is a single furnace, poorly preserved but perhaps of a similar type to Minepit Wood and Pippingham (both Wealden) (see p. 18), i.e. a low shaft or domed furnace sunk into the ground with a pit in the front of the furnace for tapping off the slag. In the case of Cherry Willingham the slag was not tapped out but its appearance suggests high

viscosity and it may have been raked out. The second site is Turners Green (Sussex) a small bloomery site dated by C^{14} to the late 6th century [75], though no further details are available.

Furnace structures have not been found from the remainder of the Migration Period until the ninth century. There is evidence in the form of slag from the intermediate period which suggests that both tap furnaces (e.g. Shakenoak Farm, [76] 6/7th century) and non-tap furnaces (e.g. Ardale School,[77] Essex, 7/8th century) continued to be used at this time.

The evidence for smelting from the later Migration Period is more substantial. The early 9th century site of Millbrook (Weald) has been recently excavated [78], though under salvage conditions. It was probably a low shaft or domed non-tapping furnace, the slag accreting as small bottoms at the base of the furnace. From geophysical survey evidence it appears to be an isolated example, and the amount of slag would suggest that the furnace operated only for a short compaign.

The late 8th, early 9th century site at Ramsbury [79] provides a unique group of furnaces consisting of four non-tapping bowl furnaces and a slightly later tapping furnace of similar type to that from Cherry Willingham. The site clearly shows the continuation of the bowl furnace technology originating in the Iron Age, and operated throughout the Roman period. Whether the change to the slag tapping technology of the later furnace was due to local innovations or external developments cannot be determined. It is also of interest to note that the ore was

transported to the Ramsbury site; this has obvious implications for the improved organisation of the industry in that area.

Further evidence for smelting has been found at Northampton [80] of Mid-Late Saxon date, though the remains are fragmentary, and difficult to interpret.

A Saxo-Norman shaft furnace base was discovered at Stamford (Lincs) [81] with an associated slag heap over one metre high. A similar furnace structure was excavated at West Runton (Norfolk) [82] by Tylecote, again with a late date of 850-1150.

The types of furnaces described above (the bowl, the developed-bowl and the shaft furnace) all have earlier examples in the Roman Period. The developed bowl furnace continues through to become the principal type of the Medieval Period. During the Migration Period there is evidence for an intrusive furnace type. This is the slag block (or Schlackenklotz) furnace type. Their distribution and principles of operation have been previously studied [83,84,85] and are commonly found in North Germany and Scandinavia. It is therefore of interest that several slag blocks have been found in East Anglia (e.g. Aylesham (Norfolk) and Mucking (Essex)) of the type associated with the Schlackenklotz technique. Further examples have recently been discovered in the Orsett area of Essex, and the sparse evidence can be interpreted as direct evidence for Saxo-Germanic intrusion into East Anglia. The slag blocks are large, a complete example from Orsett (Essex) [86] measured c.40 cm diameter, 20 cm deep and weighs 38 kg. There is a further type of slag

probably of Migration date and so far the few examples that have been found occur in East Anglia. They are small (15 cm diameter, and cone shaped in section, up to 10-15 cm deep) but are a very dense fine grained fayalite slag. Unfortunately, neither the slag blocks nor the dense slag cones have been found in ironworking features; most are random, and often unprovenanced, finds.

There is little structural evidence for smithing hearths in the Migration Period, other than shallow oral or round hearths in the old ground surface, (e.g. Stamford (Lins), Ramsbury (Wilts), Gauber Cow Pasture (North Yorks)). This lack of evidence prevents any discussion of the smithing process in the Migration Period. Several sites have produced smithing slag (e.g. Hamwih (Southampton, Hants), York (Yorks), Tamworth (W. Midlands) and several ironworking tools have been found, e.g. Sibertswold (Kent) and Shakenoak (Oxfordshire).

The major Migration towns, e.g. Hamwih (Southampton), York, Canterbury, have all produced large quantities of slag, both smithing and smelting, but they all await full slag reports.

The evidence for Migration Period ironworking suggests that the smelting technology introduced and developed during the Roman Period was utilised throughout the Migration Period, though the change illustrated at Ramsbury from bowl furnace to developed bowl furnace may be representative of the trend present over the whole country. The evidence for smithing is

so meagre that no firm conclusions can be drawn, except that the structural evidence for hearths indicates that they were simple, which is confirmed to some extent by the small size of hearth bottoms, though there are large examples from Hamwih.

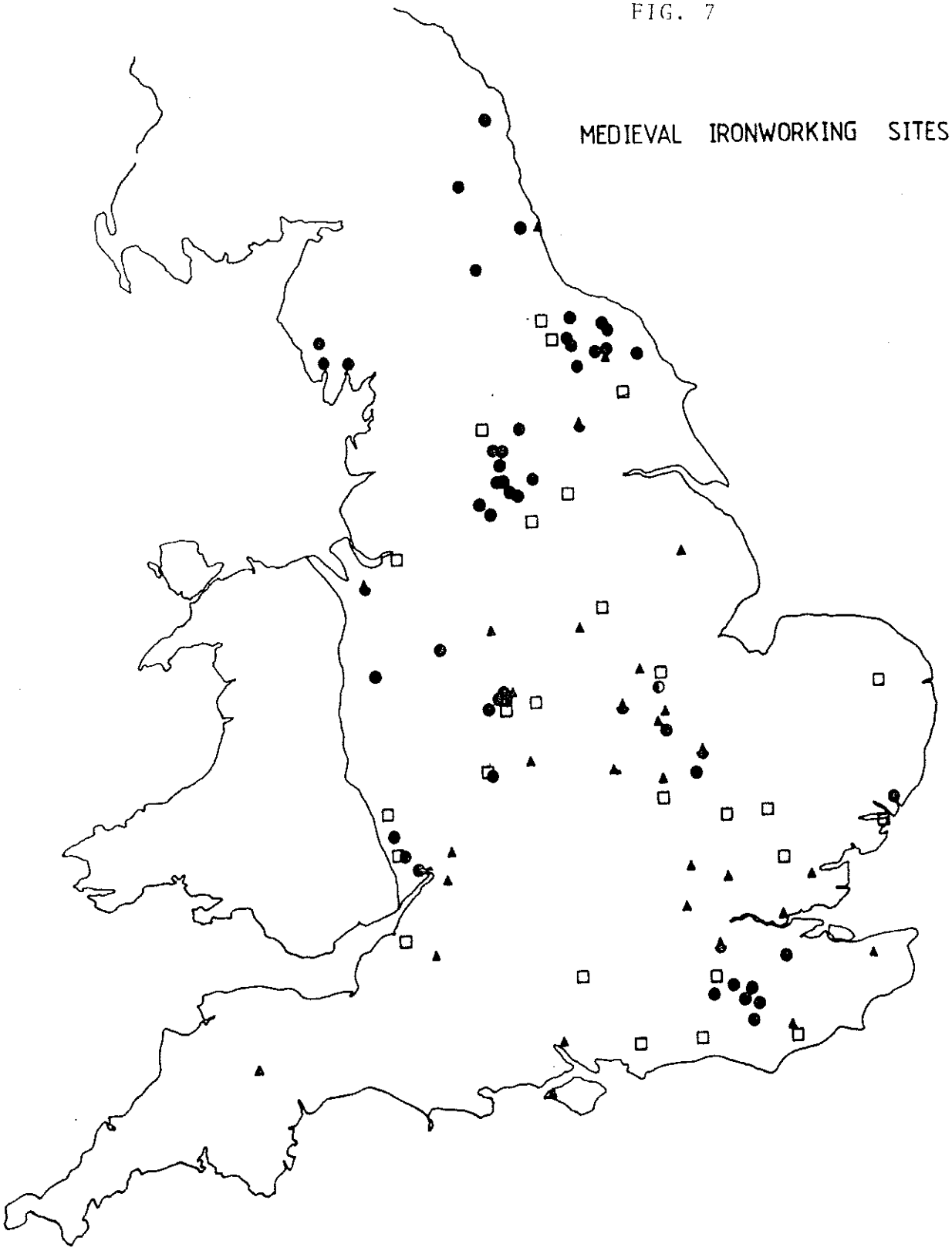
THE MEDIEVAL PERIOD

The Medieval Period extends from the mid-eleventh century, through to about 1600. It is the period in which the 'direct' wrought iron production methods, i.e. the bloomery process, was slowly replaced by the 'indirect' charcoal blast furnace producing pig iron, which had then to be processed through the finery and chafery forges to produce workable wrought iron. The bloomery process survived as the Catalan furnace until the 19th century in less industrialised areas of Europe, e.g. the Pyrenees.

The first purpose built blast furnace was at Newbridge (Sussex) in 1496 [87], and by 1576 the technology was being used at the Duke of Rutland's works at Rievaulx Abbey (North Yorkshire)[88]. The process rapidly became the major source of metal for wrought iron manufacture though the simple bloomery continued to be used in remote areas until the 18th or 19th century.

As a period of study the Medieval Period has a number of advantages. Firstly, field names, many of whose origins lie in the Medieval period, may refer to industrial activities, e.g. in Ryedale (North Yorkshire) [89], 'cinder' and 'black' were found to refer, virtually exclusively, to fields or areas of ironsmelting Secondly the documentary evidence available from the period, court rolls, etc., provides a vast source of information, especially when considering the laws concerning ironworking and that the lord of the manor (whether laity or religous) invariably held the mineral rights; there is therefore much legal documentation still available for study and analysis.

FIG. 7



To consider a full study of medieval ironworking is out of the question in this survey and a study of the excavated evidence will be made. In order to put the distribution map of medieval sites (Fig. 7) into perspective it is worth referring to the West Yorkshire Archaeological Survey [90] covering an area not so far noted for its ancient landscape, especially when viewed from the south. The area is suitable for study in that it contains both upland pastoral and lusher lowland regions, and has access to a variety of mineral resources, coal and iron in particular. The evidence for Iron Age, Roman and Migration ironworking is sparse and so the area, as yet, cannot be described as one of intense industrial exploration in these periods. The medieval documentary evidence identifies over 70 smelting sites in the area, of which only a few have been located on the ground; others have been found but have no accompanying documentary evidence. In the upland region of the Manor of Wakefield, during the late 13th and early 14th centuries, documentary evidence (principally surname evidence from the court rolls) shows that where a group of houses existed that settlement invariably possessed a blacksmith.

The evidence presented below is therefore a summary of the available archaeological evidence, which is clearly only a small sample of the medieval ironworking industry. The availability of ores and fuels for smelting, and the provision of smithies means that many of the medieval sites will still be ironworking sites today, i.e. the (often now redundant) village blacksmiths shop in today's villages and

towns will probably have origins in the early Medieval Period. Thus the opportunity to excavate such a site only rarely occurs, e.g. on destered village sites. It may therefore be only the remoter, technologically backward sites that are excavated.

The three major smelting furnace types are present in the Medieval Period. The simple bowl furnace, of which three were excavated at Alsted (Surrey) (91) dated to the mid-13th century. They were circular or sub-oval in plan, 25-50 cm diameter and 15-25 cm deep. There was evidence of slag tapping. Shaft furnaces have been dated to the 13th century at Godmanchester (Hunts) (92), where four had been built in the back yard of a smithy.

The developed bowl furnace is regarded as the typical Medieval bloomery furnace type, examples being known from St. Neots Hunts) (93), Baysale (94) and Glaisdale (95) (North Yorks), Minepit Wood (Weald) (96) and Weardale (Durham) (97).

The Minepit Wood site has been fully described and published. The furnace resembles very closely the example found nearby and dated to the Roman Period. In plan it was shaped like a horse-shoe, measuring nearly 2 m across. It was built of clay and stone, the mouth of the furnace, for tapping the slag and removing the bloom, faced south east, and the blast was introduced through tuyeres in the south side.

The furnace from Weardale is of similar type, though rather smaller, the tuyeres were also to one side of the taphole.

The evidence for smithing hearths indicates that both floor level and waist high hearths were used. The smithy at Goltho [98] contained two floor level hearths, both being simple pits containing ash and slag. There was evidence that coal had been used as a fuel. The larger of the two hearths measured 1.5 m long, 1 m wide and 45 cm deep. At Waltham Abbey (Essex) [99] the bases of two hearths were found surrounded by hammer scale, the original height of the hearths cannot be determined.

At Alsted (Surrey) in period 2b (late 13th, early 14th) there is evidence for smithing and possibly smelting. In one room there was a hearth base of sandstone blocks with a central channel; there are parallels to this construction in post-medieval hearth plans. During period 3b (end of the 14th century) a substantial waist high hearth was constructed which is as yet unparalleled in the archaeological record, and has many similarities to post-medieval hearths.

The archaeological evidence for ironworking does not reflect the scale on which it was practised. The documentary evidence for smelting would suggest that compaigns were for short periods only, e.g. in 1342 two 'forges' in the 'outwood' of Wakefield [100] were leased for a period of thirteen weeks and two days. Thus

furnaces need not have been of substantial construction, and a furnace for such a short period would be built for the campaign (it is likely that preparation of fuel, ore, etc., would take up a substantial part of the thirteen weeks). Thus one may expect to find a series of short term smelting sites, and this is a reasonable interpretation of the evidence from Ryedale (North Yorks) [101].

The evidence for smithing again depends a great deal on the correct identification of the slags. It is only in the complete excavation of self-contained communities (e.g. deserted Medieval villages and ecclesiastical centres) that established smithies may be found.

CONCLUSIONS

To draw conclusions in order to illustrate the gaps in the technological study of ironworking and to finish with a short prospective paragraph is by no means easy when approximately one third of the sites from all periods on which ironworking is known to have occurred can only be classed as 'undetermined'. The trends in smelting technology are apparent. The early simple bowl furnaces of the Iron Age are used into the Medieval Period, supplemented by the Belgic and/or Roman innovations of slag tapping furnaces, which also continue and develop into the blast furnace. The Migration Period brings a reversal in the market economy and a greater dependence on local manufacture, which can be exemplified by the introduction of the slag pit type furnace, and its apparent restriction to East Anglia. The Early Medieval Period appears confused with all three major types of furnace being used. There does not appear to have been the industrial centralisation and technological development that might have been expected at this period, and only in the 15th and 16th centuries with the introduction of the blast furnace does the industry start to concentrate in specific areas. (Most of the information concerning the introduction of the blast furnace is documentary). A large gap in our knowledge is the period between 1400-1600 when we know nothing of the technological development occurring in the developed bowl and shaft furnaces, and how they relate to the blast furnace.

We have no knowledge of the relationship between the different types of furnace in any of the periods, and serious appraisal must be given to structural features, in order that fuller

interpretations may be made. Investigations into variation of slag composition with furnace type are of interest. Tapped slag and non-tapped slag can be distinguished, but there may also be variations in efficiency between the two types of tapping furnace.

An assessment of knowledge in smithing technology is clearly restricted by the lack of available data. It is believed that more careful examination of "hearths, furnaces, etc." and especially of their fill may lead to some distinction between hearths used intermittently for smithing and those built to function specifically as smithing hearths. The occurrence and distribution of smithing residues, especially hearth bottoms and hammer scale, across a site may indicate whether smithing was a specialised craft, carried out in a specific area, or a general skill practised by many members of a society. The occurrence of smithies in the Manor of Wakefield in the Medieval Period described above should also be considered applicable to the other periods.

Only fuller recovery of ironworking residues, examination of all furnace and hearth structures, their analysis, and accurate description in a consistent terminology will enable a fuller understanding to be made of ironworking technology.

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