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Contents

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Field Notes

Brickhurst Stream Old Place Farm, Mayfield

In 1984 a report was received from Mr A.W. Fletcher on his researches 30 years before into ironworking in Mayfield. Visits were then made to relate the report to the present evidence on the ground.

Brickhurst Stream is a tributary of the Furnace Stream in Brickhurst Wood where are to be found the remains of Mayfield Furnace and Forge.[1] The two arms of the stream rise at TQ 586265 and TQ 589275 on the 115m and 100m contours and the stream carves a sinuous course, steeply banked, north eastward through the Ashdown Beds. When guns were cast at Mayfield Furnace a bay was built at TQ 593281 to impound water for the boring mill.[2] Upstream from the Boring Mill bay the shaw has recently been cleared. At TQ 591280 there is a large bay in good condition, 20.4m long, 2.8m high at the highest point above the water and 1.8m at the lowest. The upstream wall of the bay is sheer, while that downstream slopes at varying gradients. The present form of the land above the bay suggests a long, narrow pen pond for the boring mill.

Further up Brickhurst Stream near where Mr Fletcher found evidence of a bloomery[3] and near the junction of the two arms of the stream, the gill opens out into a more level area, perhaps revetted by the bank at TQ 590277. On this flat area, but not in the stream bed, can be found a considerable scatter of ‘dense’ slag, which is more concentrated round the western arm of the stream. The hedge between the two small streams was found to be on a slag bank, and further exploration of this boundary showed that the slag extends 27m into the pasture to the south of the shaw, in the form of a low mound of black soil and slag under the grass. This completely fills the area between the two arms of Brickhurst Stream. The slope of the eastern bank of the gill does not appear to be natural and could have been caused by quarrying for ore. The size of the slag heap that remains, with the amount of slag, bottoms and pieces of furnace lining indicates a large bloomery site. In 1955 I.D. Margary identified the slag as Straker's Type A, and a piece of pottery found by Mr Fletcher was identified by N.E. Norris as probably Romano-British.[4] A small piece of similar pottery was found in May 1984 on the surface of the hedge bank in the shaw. Samples of slag, bottoms and furnace lining were collected.

I am most grateful to Mr A.W.Fletcher for his notes on the area and for the piece of pottery, to Isabel Pike of Mayfield History Society and to Elizabeth Gibb, Margaret Tebbutt and Fred Tebbutt for their help and advice. I am also most grateful to Mr and Mrs Hulbert-Powell of Old Place Farm for permission to visit and for their interest in the ironworking remains on their property.

Anne Dalton

References and Notes

1. WIRG, *Wealden Iron*, 1st series **VI** (1973), p.31; 2nd series **2** (1982), pp 9-10.
2. ibid 1st series **XVII** (1980), pp. 17-18; 2nd series **2** (1982), p.10.
3. *S.N.Q* **14** (1956), p.173.
4. Information given to me by Mr Fletcher.

Blackfold Furnace, Handcross TQ 274294

The site was visited in October 1983. The area where the furnace stood is much overgrown by brambles but examination was made of the present bay. The spillway forms an overflow at the south-west corner of the pond and runs along the base of the bay, between it and a substantial bank. At a point about halfway along the present bay the stream turns south through quantities of slag. It was noticed that there was no evidence of slag on the present bay, nor on the downstream side until beyond the bank referred to above. It was suggested that this bank was the original bay of the furnace and that, rather than rebuild the old bay when the pond was landscaped, a new one was constructed upstream.

J.S.H.

Coushopley Furnace TQ 604302

Among the recent additions to the Camden papers deposited with the Kent Archives office in Maidstone is a book, dated 1815, of finely drawn and coloured maps (U840/2180/EB308). On page 122 is a map of Stonehouse and Bassett Farms, on the borders of Mayfield and Wadhurst parishes. The following names on the map refer to the furnace:

Upper Furnace Plat, Lower Furnace Plat, Upper Furnace Field, Lower Furnace Field, Furnace Plat, Furnace Wood and Old Ponds.

Coushopley Furnace is mentioned by Straker (*Wealden Iron*, pp. 110, 288) and in WIRG Bulletin (*Wealden Iron,* 1st series) **VIII** (1975) pp. 33 and 34.

Ann Dalton

Old Manor, Horam

A visit in September 1984 was occasioned by the invitation to WIRG to participate in the Sussex Farm and Museum Educational Trust, based at the Old Manor. The estate occupies both sides of the valley of a headwater of the River Ouse immediately west of the village of Horam. It was the site of bloomery experiments conducted in the late 1960s by Henry Cleere.

The junction of the Ashdown Sand and the Wadhurst Clay occurs on both sides of the valley and minepits were seen in considerable numbers on the south side, in the woods and in adjacent rough ground. The pits were both small, saucer-shaped depressions and large open-cast quarries up to 40m wide and 6m deep. There was a clear line beyond which there were no more pits.

The Field Group were told of two features which had been uncovered and then submerged during landscaping works in the past two years. One was an alleged ore-roasting pit and the other was a form of hearth. Of the latter, a large mass of slag had been dumped, during lake construction works, and left on the bank of the lake just downhill from the Old Manor House. It was concluded that the lump, measuring about 1.3m long by 80cm wide, had been a ‘bear’. This had formed at the tapping hole of a blast furnace and some had flowed into a depression in the sand for casting a sow: part of the ‘bear’ had a distinct ‘V’ section on what was judged to be its underside.

As no other reason could be suggested as to why this bear had been found in what the group were told had been a roughly square area of hard, burnt ground, it was concluded that a blast furnace could have existed on this site.

There was a total absence of slag elsewhere, except on the farm tracks, and the flow of water in the stream seemed wholly inadequate for the supply of water required by a furnace. Until other evidence can be brought to light, the question must remain open. Perhaps this is the 'Lower Chiddingly Furnace' searched for a few years ago (WIRG, *Wealden Iron*, 2nd series **1** (1981), p.22).

J.S.H.

Lurgashall Sussex SU 942261

This site has been variously described as a bloomery (Straker, *Wealden Iron* (1931), p.431), a possible water-powered bloomery (WIRG, *Wealden Iron*, 1st series **VII** (1974), p.10), and as a furnace (Schubert (1957), p.380). Some clarification seemed necessary, especially in the light of recent Group interest in water-powered bloomeries. The site is as described in WIRG, *Wealden Iron* **VII** and the area was re-examined in April 1984 by the Field Group together with members of the Haslemere Archaeological Group.

The position of slag agreed with earlier reports. The existence of an old water course was traced from the east end of the bay to a small bridge or culvert on the present stream. Contrary to the earlier report, the slag was found to be, without exception, from blast furnace working. It was highly silicaceous and varied between green and black in colour. Clearly this site should be re-designated as a blast furnace, corresponding with the documentary evidence quoted by Schubert.

The mill site (SU 941259) was also visited. Pieces of slag were found downstream of the pond, but not enough upon which to draw conclusions.

A concentration of minepits, each 5-6m diameter, was observed at SU 946236. The fill of each pit had settled, forming a marked depression in the once-coppiced woodland.

Pophole, Surrey/Hampshire SU874326

The visit to Pophole was occasioned by the documentary evidence of a furnace at the site in the eighteenth century (WIRG, *Wealden Iron*, 2nd series **2** (1982), p.35).

Pophole is a complicated site with large quantities of forge cinder over an extensive area. Some of the cinder resembles bloomery material, but samples will require further examination before clear conclusions can be drawn.

No evidence of a furnace was found.

Rackwell Gill, Crowhurst, Sussex

Straker (*Wealden Iron*, 1931, p.352) tentatively suggests a forge at TQ 763123, and in November 1984 the Field Group noted parts of two possible forge bottoms in the stream close to the bay, which is some 3-4m high. No other slag immediately associated with the site could be found, but samples were taken from the pieces found in the stream and, it is hoped, will be analysed. From the evidence it is impossible to enlarge upon Straker about the use of this site.

Further upstream at TQ 768127 a bay some 2-3m high was observed in a very dense thicket. This bay is recorded on the Ordnance Survey archaeological cards which note two breaches, one for the stream and another about 3m to the south east, the latter probably an overflow, the bay here being lower by about 1m. It was not possible to examine the ground adequately, and no slag was found apart from one piece about 10m downstream, which may have fallen from the footpath. All the tracks in Crowhurst Park are metalled with bloomery slag, much of which is believed to have been derived from the Crowhurst Park bloomery.

The Ordnance Survey cards also record a bay at TQ 769128, noted by B.H. Lucas, which has yet to be examined.

The Field Group took the opportunity of looking at the site of Crowhurst Park bloomery in the area of TQ 775127, and noted the heavy concentration of slag. The field known as Cinder Bank, recently ploughed, is, as Straker recorded, very dark on its lower slopes, and probing revealed a solid slag layer less than 0.5m below the surface. The Group also visited the ravine known as The Dell. Dell Cottage, a former gamekeeper's cottage at the southern entrance to the ravine, has recently been enlarged and the owners, Mr and Mrs Bland, reported that, in an attempt to find a secure footing for the foundations, their architect recommended that the builder dig down to the bed rock. Digging down through slag, the bed rock had not been reached after nearly 3 metres!

A Romano-British Ironworking Site at Crawley Down, Worth, Sussex

J.S. Hodgkinson

The site was discovered in 1980 during an investigation of the land along the Felbridge Water, upstream from the site of Warren Furnace, in an area known in the Middle Ages as Smythford and later as Smithfield.[1] Evidence of ironworking was noted at three locations: (A) TQ 3586 3898, (B) TQ 3584 3899 and (C) TQ 3602 3905, and, the excavation of the first two is the subject of this report. It should be noted that some 150m to the east there is a moated site, adjacent to a field once known as Bottle Field or Botley's. Here there is some surface evidence of habitation in the form of house platforms and hollow-ways, and the Roman road from London to Brighton (Margary 150)[2] passes through the field to cross the stream near the moat. (See Fig. 1)

The sites are in young woodland, on the gently sloping side of a small valley, just above a steep drop of 2-3m down to the stream. The geology of the area is Upper Tunbridge Wells Sand. On the north side of the valley a band of clay outcrops, and it has been suggested that this may have been the source of ore, as the same band outcrops beside the later Warren Furnace downstream, and may have been an ore source for that site.

The site has been given the name Smythford.

Site A Slag Heap

This site lies about 2m south of the stream. The stream has cut into the bank below the site, revealing a horizon of dark material,

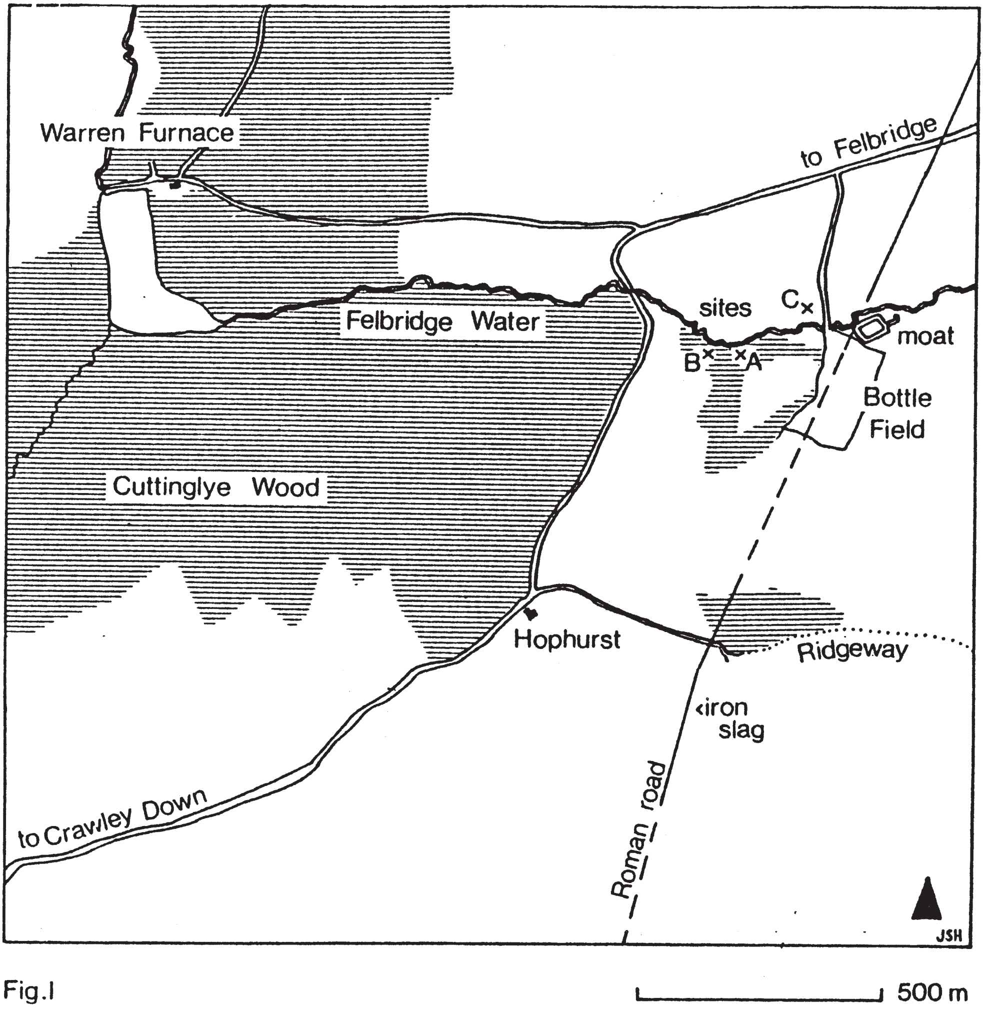
Warren Furnace
to Felbridge
sites
C
moat
Felbridge Water
B
A
Bottle
Field
Cuttinglye Wood
Hophurst
Ridgeway
iron
slag
Roman road
to Crawley Down
JSH
500 m

Fig.1

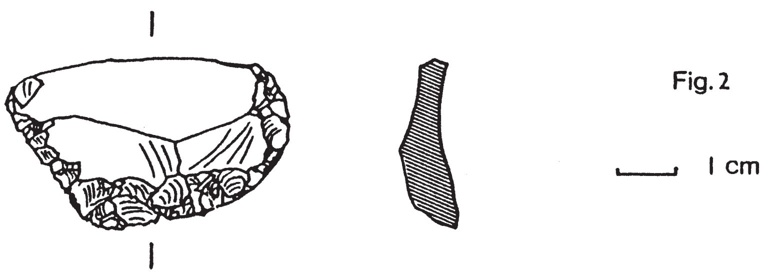
1 cm

Fig. 2

and several large lumps of slag and cinder (up to 240mm across) have been found in the stream.

Excavation showed this site to be a heap of furnace cinder and slag with a few pieces of furnace lining. However, no regular pattern was observed in the distribution of material excavated, nor was there any stratification. The slag heap extended over no more that $2.5m^2$ and was nowhere more than 300mm thick. It seems unlikely that such a small heap could be the sole waste dump for the smelting hearth excavated nearby, but despite an extensive search, no other heap was found.

Site B (see Fig. 3) Hearth 1

This site was discovered about 10m south of the stream. Initially, a trench 2m × 1m was dug, the object being to recover some dateable material, but it soon became apparent that beneath lay the remains of a hearth. Unfortunately, so unexpected was this that some of the upper remains were destroyed before it was possible to record them. Trowelling down revealed a roughly oval ring of sandstone and burnt clay, approximately 400m below the surface, with a gap at the north end. Within this ring, to a depth of 140mm, was a mixture of soil, charcoal, slag and small pieces of sandstone, together with pieces of burnt sandstone and clay. Beneath both the fill and the surrounding sandstone was a uniform layer of charcoal dust. Adjacent to this hearth and slightly to the north was found a small plug of slag 50mm long and 20mm in diameter corresponding closely with a similar object found at Chillies Farm;[3] it probably represents a slag blockage from the throat of a tuyere.

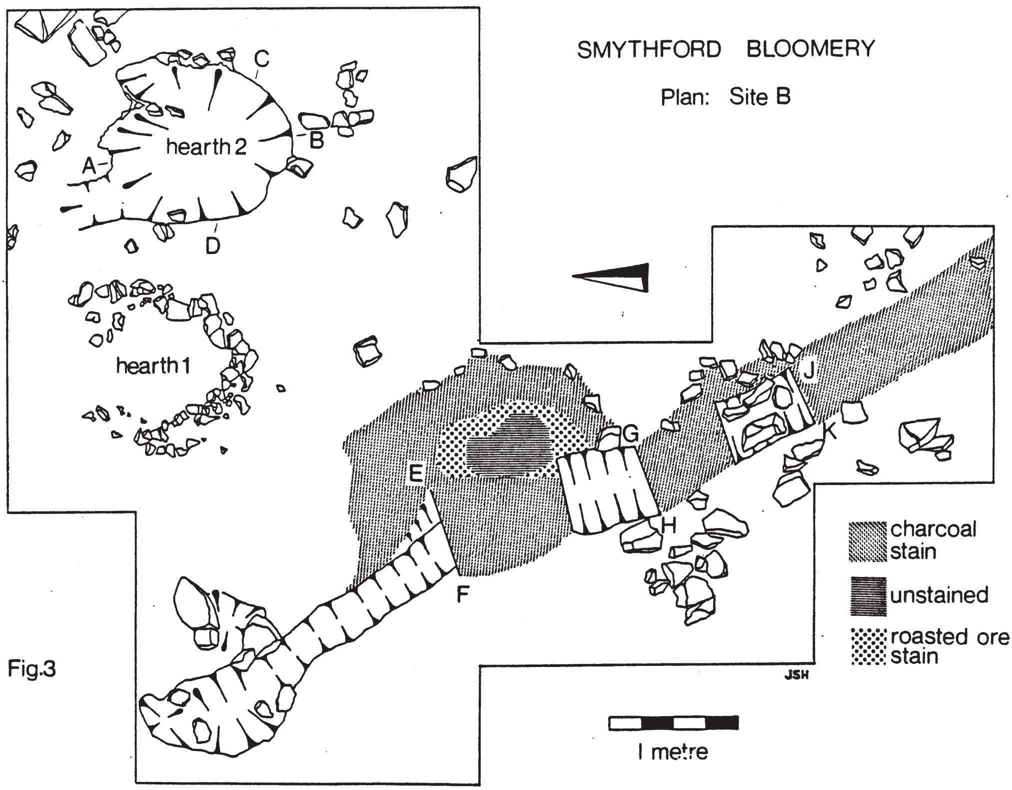
SMYTHFORD BLOOMERY
Plan: Site B
hearth 2
hearth 1
A
B
C
D
E
F
G
H
J
K
charcoal stain
unstained
roasted ore stain
JSH
I metre

Fig.3

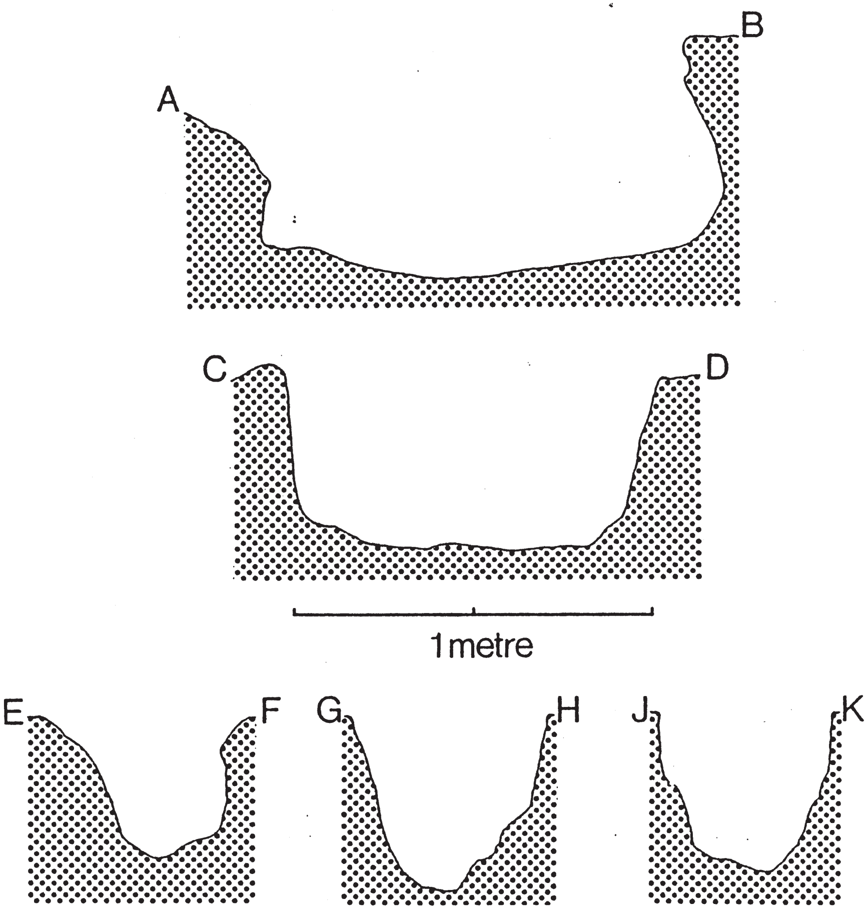

Fig.4

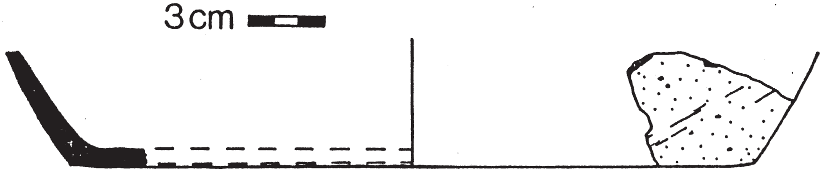

Fig.5

Despite its large size, the hearth would seem to have been a reheating hearth, as there is no evidence of roasted ore, nor was there any but the smallest sign of clay burnt to the grey colour which would indicate the higher temperatures necessary for smelting, and yet there was a sizeable quantity of slag present. The layer of charcoal dust beneath the structure may indicate some preliminary burning.

Hearth 2

To the east of Hearth 1, the remains of a second hearth were excavated. This was in the form of an oval pit 600mm deep, 1.5m long and 1.2m wide (Fig. 4). On the south side, the walls were formed of grey burnt clay, and were slightly concave, suggesting that any superstructure might have sloped inwards over the centre of the hearth. On the east side, the wall of the hearth was decayed and consisted of a few pieces of burnt clay with slag adhering to them. On the north side it was likewise very difficult to reconstruct any likely structure from the material that remained. On the west and north-west sides, however, the firm clay walls of the hearth graded into a hard slope which showed signs of having come into contact with hot material. The base of the earth was reddened clay, beneath which was a thin layer of charcoal dust. Exploration of the area immediately to the north of this hearth revealed nothing beyond the scatter of small pieces of slag found elsewhere on the working floor.

The material filling the hearth was a mixture of red and grey burnt clay, dripped slag and furnace lining. Most of the grey burnt clay and furnace lining was found at the southern end of the hearth, near the intact hearth wall.

The furnace lining was not in situ, parts being found in a variety of positions, mainly with the glazed side facing downwards, as if they had slipped from the side of the hearth. It was also noticed that the upper part of the filling of the hearth had the greater proportion of slag, perhaps indicating that this hearth was used to dispose of material from a hearth elsewhere. There was no 'bear', such as was found at Pippingford[4] and in two of the furnaces at Cow Park.[5] The conclusions that this hearth was a smelting hearth and that its decayed appearance on the north and east sides was due to its having been dismantled for relining and then abandoned seem the most plausible.

Other features

South west of the two hearths a shallow ditch was revealed, running in a NW-SE direction. It averaged 450mm in depth and appeared to widen and deepen to the south east (see Fig. 4). Due to the wooded nature of the site it was not possible to investigate the extent of the ditch, but it appeared to peter out at the north-west corner of the excavated area. There was a filling of charcoal-impregnated soil, slag, furnace lining, burnt clay and sandstone pieces in all the parts excavated.

Beside the ditch was an area of yellow subsoil devoid of the usual scatter of fragments of charcoal and slag, but bordered on three sides by fine sievings of roasted ore. There was a well-defined separation of the two surfaces suggesting that, on the area of pure clay, there had rested a container into which ore was sieved. The irregular line of stones bordering the area of ore sievings suggests some sort of enclosure, though no evidence of post holes was detected. In the area surrounding the ore sievings, the working floor was stained to a depth of about 40mm with charcoal dust.

Beside the north-west end of the ditch was a small depression bordered by blocks of stone, wherein was some evidence of burning; red and grey burnt sandstone were present. If this was a small hearth, it may possibly have been a roasting hearth, though there was no roasted ore present. Otherwise, the burnt material could have been dumped there with the rest of the fill of the ditch and, in view of the haphazard nature of the burnt material, this seems more likely.

Clearly the ditch predates much of the working, for the roasted ore sievings overlay the fill of the ditch which, in turn, was derived from ironworking. From its direction and gentle slope down to the north west, it seems to have been for the drainage of some feature uphill to the south east.

Discussion

From the nature of the fill of the hearths and the ditch, it seems that this small site had been disused for some time before it was abandoned, suggesting that there was further ironworking nearby, although apart from the slag heap and the third site noted but not excavated, there was no archaeological indication of this.

As to the type of smelting furnace, there is conflicting evidence. In appearance, it bears some similarity to those found at Pippingford and Cow Park, in that it was formed in an oval depression set below the working floor. No tapping arch remained nor was there any indication of the remains of one. There was however the slope with which the burnt material had come into contact, suggesting the removal of hot waste from the hearth. Only a very few samples of tap slag were found; the majority of the slag found in the hearth and in the slag heap being what can best be described as 'drip' slag, with the appearance of having cooled while adhering to or being suspended from some feature. In a number of samples there were the impressions of strips of wood, suggesting that the hearth superstructure had a wooden framework, as at Minepit Wood.[6] Flattened pieces of slag have been found in ploughing on the course of the Roman road at Hophurst Farm, 0.75km away, and Margary noted cinder to the north of the Felbridge Water crossing,[7] so if slag was tapped it may have all been removed for road metalling. On balance, the furnace would seem to have been of the tapping variety, probably identifiable, with Cleere's type B.1.ii[8] or, conceivably, Gibson Hill's type E.1.[9]

The dating of this site rests entirely on the evidence of archaeomagnetism. Three sherds of pottery were discovered at working-floor level and caused the preliminary dating of the site to be given as medieval; however, in the light of subsequent knowledge, there can be little doubt as to the early-Roman date, there being little confusion in the archaeomagnetic curve between the first century AD, and the thirteenth or fourteenth centuries with which the pottery is identified.

H.F. Cleere's exhortation to explore the Felbridge area[10] has borne fruit in that a connection has been established between the London-Brighton Roman road and adjacent ironworking, however circumstantial. The early date for the site does, however, question Margary's conclusion that the nearby Roman road was built later in the occupation,[11] unless the road builders took advantage of the waste from what was by then a long-disused site, to obtain some of their metalling.

Specialist Reports

Archaeomagnetic Dating

Nineteen samples of the fired clay from the south end of Hearth 2 were taken by Dr A.J. Clark of the Ancient Monuments Laboratory; their measurement gives an archaeomagnetic dating of AD 70 ± 20 at a 68% confidence level.

Pottery (Fig.5)

Mr A.D.F. Streeten writes that three probable medieval body sherds, including one base fragment, were submitted for examination.

The sand temper which includes coarse colourless grains is typical of medieval fabrics found in the northern part of the Weald. Examples of this type have been noted in the Hartfield area, and similar sands occur in medieval pottery from Reigate and among wasters from the neighbouring kiln at Earlswood. It is impossible to judge from such a small sample, however, whether or not these are products of that kiln.

In the absence of rim sherds, dating must remain tentative. The slightly sagging base of the cooking pot would be consistent with a thirteenth/fourteenth century date, but in view of the coarse fabric the material may belong to the earlier thirteenth century.

Discovery of these sherds on a Roman site draws attention to the problems of dating Wealden bloomery sites from surface finds alone. In this case, there is no proof that the sherds are associated with a medieval ironworking site.

Charcoal

Five samples from Hearth 2 and the ditch feature were submitted to Ms C.R. Cartwright, Research Officer at the London University Institute of Archaeology, Field Archaeology Unit, who identified them as *Quercus* sp. Oak (four samples) and *Crataegus* sp. Hawthorn (one sample).

Flint

One sample, found in the excavated material from Site B was shown to Dr A.G. Woodcock who described it as of a scraper type which it was not possible to date with any accuracy. The fine quality ripple flaking might suggest a Neolithic or Early Bronze date.

Acknowledgements

I am most grateful to A.L. Fenton, Esq., for permission to dig on his land; to Sandra Becker, Dorothy Hatswell, Valerie and Brian Herbert and Reg Houghton, foremost among others in the Wealden Iron Research Group, for doing most of the digging; to Dr H.F. Cleere, Mr J.H. Money and Mr C.F. Tebbutt for much-needed advice; to Dr A.J. Clark, Mr A.D.F. Streeten, Ms C.R. Cartwright and Dr A.G. Woodcock for specialist reports and advice; to Mr P. Becker for plastic sheeting; and to Mrs H. Wadey for the pottery drawing. The finds will be deposited with the Sussex Archaeological Society.

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The Introduction and Early Spread of the Blast Furnace in Europe

Alex den Ouden

Summary

The classical hypothesis that the blast furnace originated in the Walloon part of present-day Belgium in the 13th or early 14th century is incomplete. It is now postulated that (independent) indigenous developments in Sweden, Italy and Belgium took place almost simultaneously. The spread of the new technology from these centres was governed by various technical and economical factors and a rather complex pattern evolved. Matters are further complicated by the adherence, in some areas, to the direct process. This article traces, and tentatively explains, the development of the earliest blast furnaces and their adoption.

Prelude: the use of waterpower

In the early Middle Ages all iron production in Europe was by the direct process, i.e. wrought iron was made directly from the ores. Cast (pig) iron was unknown. Low shaft furnaces were used, blown with sets of bellows. These were hand powered or, in the more developed areas, by treading (Fig.1). Although in the Roman period waterwheels were known and in use for corn milling, water power then apparently never was applied to the blowing of smelting furnaces.

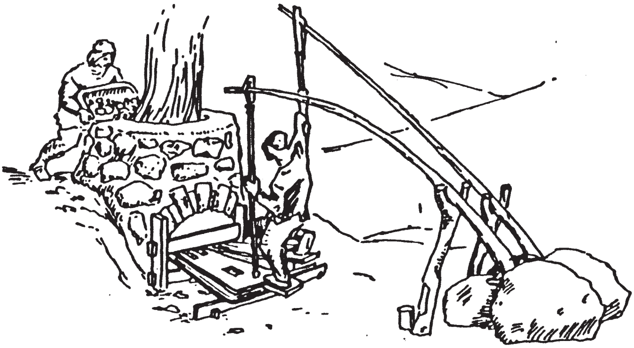

Fig. 1: A reconstruction of a 13th century** Trethütte **in Noricum (Austria) (based on: W. Schuster;** Das Alte Metall – und Eisenschmelzen;* ***Dusseldorf; 1969)

Entries in the Doomsday Book can be interpreted as referring to waterwheels driving (forge?) bellows, but presumably the first document explicitly mentioning their use in relation to iron production is the privilege given in 1197 to the Soro monastery (Halland, South Sweden). This mentions a hamlet Jarnvirke (ironworks) and a mill producing iron. Interesting in this conjunction is that the Cistercian order (founded in the period 1098-1110) is said to be closely connected with the spread of this new technology. Waterwheels were not adopted everywhere in iron production, however. Even in the 15th century tread-bellows were still in use in areas in Germany (*Trethütte*).

A new technology: the blast furnace

Applying waterpower to blowing allowed higher blast furnace pressure and/or flow. This could be combined with an increased section of the (low) shaft furnace. In this way the loups of wrought iron produced could be enlarged (from 8kg, Roman period, to approximately 75kg in the 13th century). Another possibility was, of course, to keep the shaft section small so increasing the air flow and the temperature in the furnace. Due to the quicker smelting attained and the increased speed of the reducing gases in the furnace shaft, the indirect reduction (ie, by carbon monoxide gas) in the upper part of the furnace decreased. Although at the higher temperature the direct reduction (ie, by solid-burning-charcoal) in the lower part of the furnace was more effective, this did not (fully) compensate for the loss of indirect reduction. This problem could only be solved by increasing the height of the furnace: the (high) blast furnace was born. Most European terms for a blast furnace refer to the height of the furnace: *haut fourneau*, *alto forno*, *Hochofen*, *hoogoven* – except the Swedish *masugn*.

In operation the blast furnace differed considerably from the (direct) low shaft furnaces. Both slag and iron could be taken – separately from the furnace in liquid form, hence a blast furnace would be operated 'continuously' – until the supplies of ore, charcoal or water ran out, or the shaft lining had to be repaired. The iron had absorbed much carbon during the last stage of smelting and reduction; indeed, only in this way was its smelting temperature sufficiently reduced to obtain liquid iron at all. The carbon, however, made the iron extraordinary brittle. To regain ductility, the pig iron had to be fined, either into steel (some carbon remaining) or into wrought iron (all carbon removed). The fining processes themselves were discontinuous and the iron obtained varied rather in quality. These factors certainly impeded the adoption of blast furnace technology in several countries.

The blast furnace profile considerations

The success of the blast furnace not only depended on the increase of temperature that could be realised by higher blast flows. An important problem that had to be solved was that of the inhomogeneous temperature distribution across the shaft section. The combustion of charcoal depends on the temperature at which the process takes place:

at low temperatures	$C + O_2 \rightarrow CO_2 + 8080$ kcal
at high temperatures	$C + \frac{1}{2}O_2 \rightarrow CO + 2420$ kcal

Theoretically, just in front of the tuyere, only CO should be formed as the temperature here is very high. Due to the excess of O_2 however, mainly CO_2 is formed – which is unstable. This is reduced to CO by charcoal:

$$CO_2 + C \rightarrow 2CO - 3240 \text{ kcal}$$

The latter reduction takes some time and, as it is endothermal, the temperature of the gas decreases. The flow pattern in a rather wide shaft is as shown in Fig. 2.

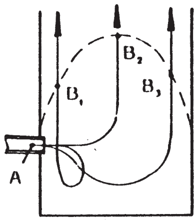

Fig. 2: Blast flow pattern in a wide shaft

It will be observed that the points where the $CO_2 \rightarrow CO$ transformation is complete are not all in the same horizontal section. At the outer edge, these points are much nearer to the tuyere plane than in the central column. In this way a cold outer zone is created. Heat losses due to convection further enhance the effect.

If the temperature of the outer zone remains below 1360°C, the final direct reduction of the ore is much less effective, as it will not melt. If this happens, two separate zones in the shaft exist. One, in the centre, where complete reduction is obtained and carbon-rich molten pig iron drips down into the crucible. The other, at the outer edge, where incompletely reduced ore – FeO – passes into the crucible. These two constituents react:

$$Fe_3C + FeO \rightarrow 4Fe + CO$$

The pig iron is (partly) decarburized by the ore, coalescing in the process. This in fact is exactly what happened in the so-called 'Stuckofen' – the 'direct' furnace that was used in parts of Austria up to the 1760s. It will be clear that such a furnace cannot be tapped but has to be operated discontinuously.

There are three ways in which the effect described can be evaded. If the shaft is made very narrow and high the isothermal plane will be quite flat. The overall temperature can be made sufficiently high for complete reduction if the crucible is fully closed. Such a solution has several disadvantages: the charge descends very quickly in the shaft, so indirect reduction is minimal. To obtain complete reduction the temperature must therefore be chosen relatively high (high wear of lining and consumption of fuel!). Furthermore the closed crucible is very small and has to be tapped quite often (at least once every two hours). The pig iron will be very grey and difficult to fine into wrought iron. A second possibility is to use a wide open crucible in combination with a tuyere high up in the shaft. In this case the blast flow will split into two portions, one going upwards, ensuring indirect reduction of the freshly charged ores; the other going down and leaving the furnace at the crucible. If sufficient charcoal is charged, enough will remain below tuyere level for the 'secondary' blast flow. In this way, the cooling effect in the upper zone is diminished as the gases in the outer zone are diverted downwards – and the metal in a large open crucible can be kept molten as a flame passes right over it. This kind of blast furnace requires relatively large blast volumes. Operation of the furnace must be difficult due to the high temperature at the open mouth. The third solution is to use a stepped shaft (Fig. 3).

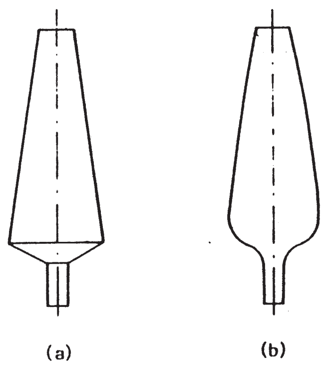

Fig. 3: The original discontinuous Walloon shaft profile (a) and a more rounded (German) version (b)

The very shallow boshes allow the charge from the outer zone to descend only slowly into the crucible, thus ensuring a very thorough indirect reduction before the material finally reaches the crucible. The sharp edges in the shaft (a) can only be maintained if a highly refractory lining material is available; otherwise a somewhat less discontinuous profile (b) must be chosen.

Of the three constructions described, the third is superior with regard to operating conditions (number of charges and tappings needed in a given period; wear of the lining; ease of working) and fuel economy. A high quality lining material is, however, essential.

The earliest blast furnace in actual use

Archaeological excavations and a very thorough study of available documents have shown, that – perhaps as early as the beginning of the 12th century – blast furnaces were operated in Sweden They had open crucibles and split blast flows. This fits quite well the facts that water power was abundantly available (large blast volumes) and that – at that period – very refractory lining material was unknown in the area. It is not very probable that the early Swedish blast furnace derives from the small local bloomeries (called ‘blaster’); there are many indications that it is based on contemporary copper furnaces. One of the most interesting similarities is that the blast furnace had three arches – one for blowing, one for slag tapping (straight into the tailrace for granulating and washing out iron particles) and one for iron tapping (with the open forehearth, with a sand dam).

Fig. 4 shows a reconstruction of this blast furnace. The separate slag arch rather weakened the construction and from about 1250 only two arches were used in the well-known manner.

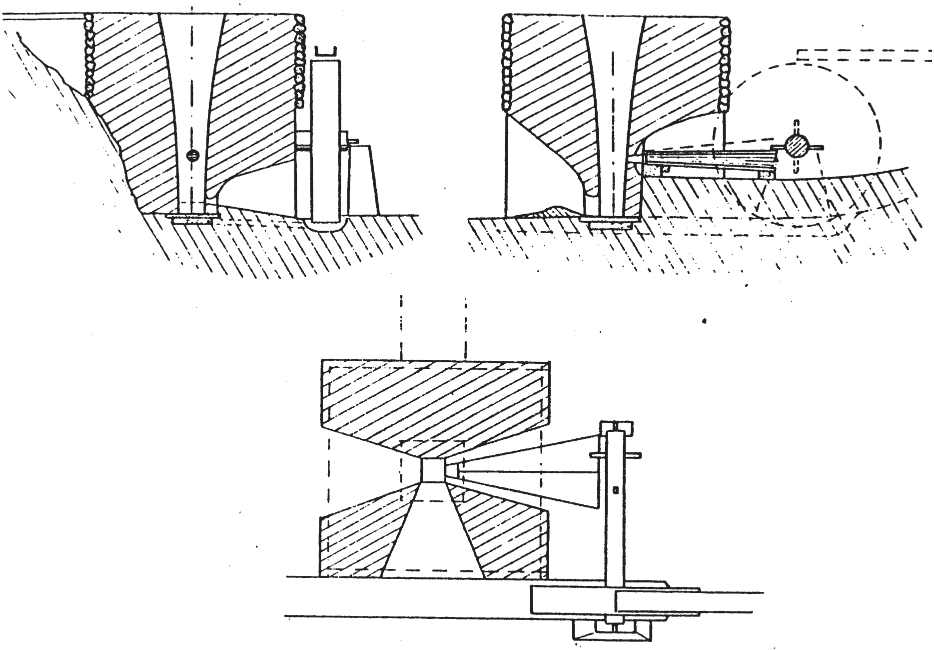

Fig. 4: Plan and sections of a reconstruction of the earliest Swedish blast furnace

The very first document mentioning a blast furnace now known dates from 1340 and relates to a site at Marche-les-Dames, near Namur in Belgium. The Walloon blast furnace was of the open crucible shallow boshes type, see Fig. 5. As far as can be ascertained it was built from the beginning with just two arches. It seems probable that the low shaft furnace (*bas fourneau*) used in the same area was its ancestor. In Italy, during the 15th century, both blast furnaces and *basso fuoco* (bloomery hearths) were producing iron. The blast furnaces had very high and narrow shafts and the crucible was closed, see Fig. 6.

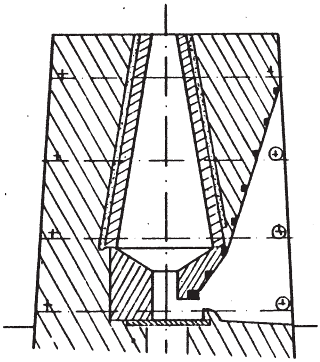

Fig. 5: Section of a Walloon blast furnace

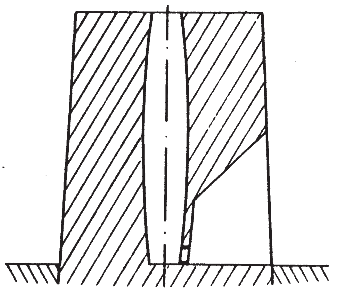

Fig. 6: Section of a Brescian blast furnace

There was only one arch in the main furnace body, for blowing as well as for tapping iron and slag. As described, the iron produced was very grey and it was mainly fined into steel. The bellows are described as 'having the shape of large wings, with a height (*altezz*a) of 3-4m'. They were water driven. The furnace and bellows show a strong Oriental influence, and in fact, it is postulated that the technology was imported from China. Particularly the travels of the Polo family (around 1300) would seem to be relevant in this respect, and presumably the first Italian blast furnaces were started in the first decade of the 14th century. They stood in the area of Bergamo and Brescia.

The introduction of the blast furnace technology was only possible under certain conditions. Quite apart from the well-known technical factors: sufficient supplies of quality ores and charcoal and a dependable source of water; others of a more financial character played an important part. Continuous smelting (for a certain period) meant storage of these commodities, and investment in storage sheds, water ponds, etc. The much higher production required more labourers. And of course the blast furnace itself was much more complicated and expensive to build and maintain. The considerably increased investments and running costs could only be paid if capital was forthcoming; and if a sufficiently large market existed for the iron(s) produced.

In Belgium, capital was mainly furnished by private persons operating the ironworks themselves. In northern Italy, bankers and gentry provided the capital, and the works were managed by (paid) overseers. In Sweden, usually a small group of ‘Bergmaster’ co-operatively owned and ran a blast furnace. Each owner mined his own ores and burned his own charcoal. Together they paid a furnace master and each Bergmaster in turn had his ore smelted – providing his own labourers for the assistance of the furnace master.

The Walloon country had a very well-established market for (wrought) iron products, long before blast furnaces were used. The increased productivity enabled Walloon producers to increase their hold on this market. Of course, most of the pig iron had to be fined before it could be sold, although cast iron plates and cannon were produced too. A special Walloon fining process gradually evolved. Prior to about 1420 single charcoal hearths were used for this, but later separate hearths for the fining proper and for reheating (for hammering into bar) came to be used (*affinerie* and *chaufferie*). A considerable industry existed in northern Italy in the late Middle Ages and this had a high intake of steel. The material was supplied from Austria and southern Germany, where it was produced in Stuckofen, directly from ores. Around 1400 all demand for steel was satisfied by locally fined metal. Sweden had no home market for iron at all, but already early in the 13th century the country was exporting iron via the Low Countries. This was made by the direct process. In the first quarter of the 14th century a new product, *osmund* iron (iron from the mouth – *mund* – of the *masugn*?) appeared. This quickly ousted the directly-produced iron and was exported in ever increasing quantities. Of course, there is a strong connection between this expansion and the use of the vastly more productive blast furnace.

The spread to other countries

The new blast furnace technology was not adopted in all European iron-producing countries, at least not immediately. In general terms, in those countries with a well established iron and, particularly, steel producing industry and with a reputation on the market, the new processes were not taken up. This was the case in large parts of Austria and southern Germany. In those countries where iron was made mainly for small-scale use, the old (direct) processes were continued, even into the 19th century in some cases.

Walloon entrepreneurial enthusiasm was considerable. Apparently not content with producing and exporting iron, many Walloon ironmasters left their country to start ironworks in other countries. In France the first Walloon type furnace was built in the Pays de Bray, in 1452. The work of Brian Awty, partly published in this Bulletin, will be well known to the present readers, so there is no need to describe the further introduction in northern France and the Sussex Weald here.

In Germany, several important iron producing areas existed in the Middle Ages:

Sachsen
Harz
Oberpfalz
Westfalen/Siegerland
Bohmen
Hessen/Odenwald

Prior to 1500, only the direct process was used in each of these areas. With the growing production of Belgium and Sweden, the established German export – also via the Low Countries – was threatened. In consequence, from about 1500 onwards, blast furnaces (of the Walloon type) were erected in the Siegerland; from about 1575 in Sachsen. These furnaces were, unlike the original Walloon furnaces, not fully stone-built to top level. The upper half of the shaft was enclosed in heavy timber bracing – resembling the construction apparently used in the Sussex Weald in the 16th and 17th centuries. This may well have been necessitated by lack of suitable stone. The shaft was shallow-boshed, although often rather more rounded than was usual in strict Walloon practice, again because of lack of suitable materials. In the eastern districts blast furnaces were first built in the period 1500-1560, but the direct process was continued here far into the 17th century, too. The blast furnaces were of the Walloon type, although in 1650 it was reported that they were only 4.5m high and had wide crucibles, quite unusual and in fact reminiscent of the Swedish type of furnace. The Oberpfalz, in southern Germany, was one of the suppliers on the Italian steel market in the 14th century and when it lost this market with the evolution of the Italian blast furnace and steel fining technology, new developments became necessary. In 1505 a Brescian furnace was erected at Pielenhofen in the Oberpfalz, but despite many experiments this failed. The local charcoal was too soft for use in the high, narrow shaft, large-flow type of furnace (although it was eminently suitable for the direct process due to its high reactivity). One of the modifications tried was to rebuild the furnace with two arches in the main body, the so-called 'German Flossofen'. The Oberpflaz iron industry never succeeded in remedying the backlog in technology and during the Thirty Years War (1618-48) it dwindled into obsolescence.

In southwestern Austria a similar situation existed. The market, for (Stuckofen-)steel had been lost, which was serious as most of the production of this part of Austria had long been exported via Italy. In 1540 a 'German Flossofen' (i.e. a Brescian furnace with an added arch for tapping and with a closed crucible) was built. This was a success (excellent lining stone and hard charcoal being available) and the Flossofen gradually replaced the (direct) Stuckofen. In eastern Austria however there was a marked difficulty in finding refractory material that could withstand the relatively high temperatures in a Flossofen. Quite apart from that, the district had for centuries been serving a very large market (the Levant, south-eastern Europe, Hungary, Russia, Poland, Germany, the Low Countries and Britain) with superior (tool) steel. There simply was no inducement to adopt the blast furnace: the original Stuckofen technology was perfected instead. Of course, the charcoal consumption of this process is quite extravagant and in the 1760s the Stuckofen were finally replaced by proper blast furnaces – by imperial decree.

With the gradual improvement and more or less general acceptance of the (Walloon) blast furnace in the main iron-producing districts in Europe, it became clear in Sweden that the original Swedish blast furnace could no longer compete. In 1610, with help from ironmasters from Sachsen, the first 'German' blast furnace (with open crucible, as it derived from the Walloon furnace) was constructed in Sweden; and in 1638 it was ordained that ‘this construction be generally adopted as it is so much more satisfactory’. The situation became still more complicated. Even in the 1580s Walloon ironmasters had been involved in Swedish fining experiments, trying to produce bar iron instead of osmund iron (which came in small lumps). When Sweden got engaged in the Thirty Years’ War, its export to the Low Countries (which ran mainly via the old Hansa ports on the Baltic) was cut off. Walloon capital and know-how were then used in establishing new – Walloon – ironworks in the Uppland district of Sweden, directly exporting to Britain and the Low Countries. In the light of the well-known predilection British steelmakers had for Uppland (Dannemora) wrought iron for making cementation steel, even in the earlier 17th century, one might wonder whether the introduction of the cementation process might have stimulated this new initiative? Anyway, the parallel existence of the German and Walloon blast furnaces after 1650 in Sweden (the old-fashioned ‘Old-Swedish’ furnace gradually disappeared) gives an excellent opportunity to see how the two countries – from the same ancestor – compare in that period, see Fig. 7.

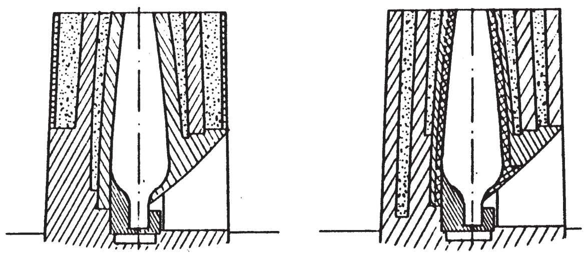

Fig. 7: The German (left) and Walloon (right) blast furnaces in Sweden in 1650

In Norway the first iron ores were mined in the 1530s. They were smelted in a direct process, by ironworkers from Sachsen. In the 1570s several smelters from England (Sussex Weald) came to Hakedal to erect a blast furnace and operate this; but they could not keep it in blast and left again shortly after 1580. Little is known about them in Norway, maybe more information could be found in England. The first successful blast furnace in Norway was built in 1625, presumably on Walloon lines.

In this short article it has not been possible to include details of the development of the fining of wrought iron and the production of steel. It should be kept in mind that in the period here covered, wrought iron and steel were in fact rather more important metals than pig iron, and that the evolution of their production processes certainly played a considerable part in the overall evolution of ferrous metallurgy.

For similar reasons it was impossible to describe the direct processes in any detail. These were continued in several countries until long after the establishment of the blast furnace. Spain, France and Italy were still producing direct iron in the 19th century. In England, bloomsmithies were still operated in the period that coke blast furnaces started being used. These classical processes have in their own way influenced the pattern of iron and steel development.

Further Excavations on Great Cansiron Farm, Hartfield, East Sussex

David Rudling

In 1983, a second season of excavations was undertaken on Great Cansiron Farm in order to follow up and complete the investigations of a Roman tile kiln and an associated drying shed which had been started in 1982, (Rudling, 1983). This second season of rescue excavations was able to take place as a result of generous grants from a modern handmade-tile company, Keymer Handmade Clay Tiles of Burgess Hill, Sussex, and East Sussex County Council. The project thus funded was able to finish the excavation of the kiln and drying shed, to reveal another building to the east of the kiln, to trial trench the flat, 'terraced' area which lies to the west between the 'shed' and the stream, to section the lynchet which appears on the 1982 survey of the site (Rudling, 1983) and to investigate a nearby iron bloomery furnace.

The kiln consists of several parts, a large stokehole from which the fire could be fuelled; a fire tunnel or flue, the front portion of which was constructed of Roman tiles; and a firing chamber or oven, the floor of which (made of flat tiles) was supported on a series of five closely-spaced cross-walls (of clay) which were carried across the main central flue by arches of clay. In between each cross-wall was a cross-flue with sloping floor which allowed circulation throughout the combustion chamber and forced the gases into the oven through holes or vents left in the oven floor which coincided with the sub-floor flues. Above the level of the oven floor nothing survived of the firing chamber superstructure. The walls of the chamber, however, are likely to have been taken up vertically to a height of one or two metres, and were probably constructed of crude clay bricks, traces of which were found in large quantities in and around the kiln. These walls may have been temporary structures and taken down after completion of each firing, thus making the task of unloading the kiln much easier. The kiln probably had a temporary roof, perhaps made of previously fired tiles, kiln wasters, or even turf. Such a roof, together with the type of vertical wall described above, would have the important effect of creating an up-draught of air through the kiln.

The plan of the firing chamber of the Hartfield kiln is similar to that of the only other Roman tile kiln to have been excavated in Sussex, that discovered at Wiston in 1848 (Figg, 1849) about which few details survive.[1] Another relatively local parallel is the tile kiln found on Wykehurst Farm, Cranleigh, Surrey (Goodchild, 1937).[2] Again the plan of this Surrey kiln is very similar to that at Hartfield, although there are a number of differences, such as it having six cross-walls.

The tiles to be fired would probably have been made in workshops, the location of which is still unknown, perhaps to the west near the stream, and then stacked and left to dry, possibly in the structure discovered to the west of the kiln, so as to remove as much moisture as possible prior to firing. When dry the 'green' tiles would have been neatly stacked on top of the oven floor, with spaces left between the tiles so as to ensure an even distribution of heat throughout the oven. Analysis of the charcoal samples collected during the excavation reveals that birch, oak and hazel were the main types of fuels used to fire the kiln.

The structure discovered in 1982 immediately to the west of the kiln is still interpreted as an open-sided drying shed. The tiled floor was lifted in 1983 and was shown to fill a rectangular terraced area, which had two post holes to the north and two others along each of the western and eastern sides. Immediately to the north of the tiled floor was a small oven, a feature first found in 1982.

To the east of the kiln was a roughly square area, 3m by 3m, of broken tiles and charcoal layers, bounded by post holes on its western side and containing a hearth made from six flat tiles. A similar hearth was found immediately to the north of the tile and charcoal spread. This spread is interpreted as the floor of a building, perhaps a workmen's hut; relatively large quantities of pottery were found in these deposits.

In addition to the structures already described, the trench also revealed other post holes, several large pits, and a post-medieval land drain.

The Hartfield Roman tilery produced a large range of tile types including both main varieties of roofing tiles (*tegulae* and *imbrices*) various sizes of flat tiles and heating system tiles, such as *pilae* box-flue tiles and *voussoirs*. Of great interest in 1983 was the discovery at Hartfield of box-flue tiles with roller-stamped decoration. The pattern, a W chevron, is of a type classified by Lowther (1948) as Group 1, Die 5A.[3] Tiles decorated with this pattern (Die 5A) have previously been found at Ewell (Surrey), Bradwell (Essex) and possibly also at Witham (Essex) and St. Albans (Hertfordshire). This wide distribution probably does not represent the market for the Hartfield tile kiln since tile production may have been carried out by itinerant craftsmen. It is to be hoped that in the future other Roman sites in the vicinity of Hartfield will also yield Die 5A tiles and thus indicate possible outlets for the kiln's products. One such outlet is likely to have been the large ironworking establishment at Blacklands (Tebbutt, 1972), which is situated only a short distance to the south west of the tile kiln.[5]

In addition to various forms of comb and roller-stamp decoration some of the tiles found at Hartfield had other forms of markings, including a number of impressions of the feet of animals (dog, cat and red deer) which must have walked over the drying tiles, finger-made semi-circular markings, which have sometimes been regarded as 'signatures' and two incised 'tally' marks: *CCXX* (220) and *CCXIIII* (214) – possible production batch marks. The results of the archaeomagnetic sampling of the kiln undertaken by Dr A. Clark in 1982 produced a magnetic date of AD 100-130 (at 68% confidence level). This date is consistent with the dating of the pottery and glass finds from the site (late first/early second century).

The flat terraced area which lies between the 'drying shed' and the stream to the west was trial trenched and revealed no archaeological features and very few finds (mainly pottery and iron-working slag). Unfortunately at the start of the excavation we had still not received a report on the geophysical survey carried out over the terraced area in 1982. An interim report however did arrive during the excavation and showed no anomalies in the trial trench (30 × 2 metres), and no major features in the rest of the area surveyed, although there may be some hearths and a possible gully/ditch (Tony Clark, pers. comm.) to the west of the trial trench.

The lynchet located in 1982 was sectioned and proved to have been virtually ploughed out. It was not possible to date the lynchet, which appears as a field boundary on an Ordnance Survey map of 1899.

The iron furnace found in 1982 to the north east of the kiln was relocated and excavated. Unfortunately the furnace itself was ploughed out, and was represented by a spread of burnt clay and bloomery slag. A small hearth, perhaps for re-heating, was found nearby, and C14 dating of the charcoal from this may be the only way of dating the furnace.

The final report on the Hartfield Roman tilery excavations will be submitted to the Society for the Promotion of Roman Studies, for inclusion in *Britannia*

I would like to take this opportunity to thank the various WIRG members who helped during the excavations.

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2. Goodchild, R.G. (1937) 'The Roman brickworks atWykehurst Farm in the parish of Cranleigh'. *Surrey Archaeological Collections* **45** : 74-96.
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5. Tebbutt, C.F. (1972) 'A Roman bloomery at Great Cansiron near Holtye, Sussex'. *Sussex Archaeological Collections* **110**:10–13.

References to Ironworks in Records at the Sussex Record Offices

Brian Phillips

(Mr Brian Phillips, of Uckfield, Sussex, has kindly supplied the following list of references, noted down during his researches. The information may include facts hitherto unrealised, and shed new light an the ownership or known working life of some works. We are most grateful to Mr Phillips for allowing us to publish these notes. J.S. Hodgkinson).

West Sussex Record Office (also faint microfilms at ESRO)

Archdeaconry Court of Lewes, Deposition Books

Ep II/5/3	f.19-38, 43-6	1585	One Glid sued for tithes due on furnace in Darvolle Wood, Battle. That or another in Battle owned by William Perchinge of Brightling. (Detailed case).
Ep II/5/3	f.64-55 (upside down) and f.92-4	1586	Well-known Panningridge Furnace tithe case.
Ep II/5/8	f.164	1611	Etchingham. Mr Anthony May's furnace.
Ep II/5/9	f.46	1612	Darvoll Furnace, Mountfield; scene of defamation case.
Ep II/5/9	f.48-50	1612	Worth tithe case. Charcoal supplied to Millplace Furnace.
Ep II/5/13	f.68	1629	"Mr Henry English hath two Iron Works in Salehurst."

East Sussex Record Office

Eastern Sussex Quarter Session Rolls

QR/E 9, m.108	1614	Richard James of 'Hackvill' (Hants) labourer, spent a night at a furnace in Brede and stole an iron pot.
QR/E 11, m.51	1614	John and Mercy Guler called at Cuesepleat and Old Mill Furnaces, while travelling around Mayfield and Wadhurst.
QR/E 12, m.106	1615	John Nicholas of Eastbourne, husbandman, travelling to Chiddingfold, spent one night at Shipley Forge.
QR/E 29, m.63	1628	John Tyler, the founder at Pounsley Furnace.
QR/E 29, m.65	1628	Pig thief visits Cowden Furnace
QR/E 33 ,m.2	1633	Vagrants frequented Freshfield and Sheffield Forges for past 2 or 3 years.
QR/E 35, m.91	1636	Buxted case involving John and William Luck's (of Rotherfield?) New Forge and Little Buxted Forge.
QR/E 35, mm.93, 105	1636	Thomas Symons of Frant, a forgeman at Mr.William Fowle's forge.
QR/E 38, m.105	1637	William Hud, alias Hoode, labourer, one of the fillers at Northiam Furnace under Thomas Gunter the founder.
QR/E 44, m.58	1639	Vagrant woman bought stolen linen at Ardingly Hammer.
QR/E 67, mm.67, 69, 70	1645	Vagrant/soldier thief apprehended at Dedisham Forge and Iron House at Rudgwick.

QR/E 78, m.104	1648	Meat thieves caught at the forgeman's house at Riverhall Forge at Rotherfield.
QR/E 79, m.7	1648	Woman servant stayed with her married sister at Glazier's Forge, Burwash.
QR/E 81, m.35	1648	Forgeman at Bibleham.
QR/E 122, m.26	1659	Watercourse past Tinsley Forge, Worth.
QR/E 129, m.39	1661	Theft of iron tools from the forgehouse at Benehale Forge.
QR/E 133, m.72	1662	John Hoth of Lampole in Maresfield obstructed the highway; the lands in question included a furnace demolished c.50 years previously, since when the traffic using the road had declined.

QR/EW 31, m.77	1632	Daniel Corke accused of stealing Nicholas Manners' sheep near Bivelham Forge. Accused was seen by Thomas Lucas at Darfould Furnace.
QR/EW 50, m.10	1640	Carriers of iron owing maintenance on highways included David Leader of Speldhurst, on the road from Snape Furnace, Wadhurst, via Ticehurst to Collines Forge, Burwash.
QR/EW 88, m.85	1650	Summonses, including for occupier of watermill and ironworks at Maresfield.
QR/EW 100, m.22	1653	Reference to road to Pounsley Furnace, Framfield.

Review

'The Organisation of the Iron Industry in the Western Roman Provinces in the Early Empire, with Special Reference to Britain'

by Henry Cleere. *OFFA* **40** (1983).

This paper, contributed to a German conference by Dr Cleere, is of especial significance to all WIRG members. It places the Roman iron industry of the Weald in its full context, with other Roman metallurgical organisations within the Empire.

The author discusses the main areas of Roman metallurgy in Europe, where there is a great deal of epigraphic evidence showing how the industry was organised. It is shown that there is direct or indirect evidence from Spain, Noricum (central Europe), Dalmatia and Gaul that when the Romans took control of a new province all minerals were put under central control, and the area in question was made into an Imperial estate. The industry was then greatly expanded and either leased out in various ways, sometimes to large or small entrepreneurs on a royalty basis, or put under direct state control.

In Britain there is almost no epigraphic evidence remaining for the Roman iron industry, but more archaeological evidence than on the continent. From this the author postulates at least two Imperial estates for the iron industry, one in the Weald, the other in the Forest of Dean. The Weald does seem a very likely candidate. It is undoubtedly true that there was pre-Roman iron working in the area, but the whole ore-bearing region could at first have remained under the client king Cogidubnus of Chichester, later being inherited by the Roman authorities, as at Noricum, on the death of the owner about A.D.80-90. Further arguments for the existence of an Imperial estate here is the characteristic lack of any large villa or Roman town in the area, but the presence of two Roman roads linking the area with London.

If we can assume an Imperial estate here towards the end of the first century, it appears to have been exploited in two ways, the eastern part with direct state working by the *Classis Britannica* (the fleet) and the western part by leasing to some civilian organisation, as existed in other continental Imperial estates, probably on a royalty basis. In the eastern Weald, Bardown and Beauport Park have both been partially excavated and proved to have been under state control. In the central Weald we have major industrial settlements at Garden Hill, Oldlands, Great Cansiron, Walesbeech, Ridge Hill, Saxonbury and Broadfields (Crawley), all under civilian control. Of these, Great Cansiron, Garden Hill and Oldlands are known to have had houses with some signs of luxury living. At Garden Hill a bath-house was attached to a simple house. These signs of an Imperial estate can be matched on the continent. Garden Hill, Crawley and Saxonbury had pre-Roman antecedents, perhaps under Cogidubnus. Several of these major industrial sites are known to have had satellite sites attached, each with one or more bloomery furnaces. Such would seem to have been the position in the Weald in the first and second centuries AD.

C .F. Tebbutt