



Map of Marshalls Manor 1653 showing Langleys Forge

Courtesy of East Sussex Record Office, SAS/AB/17a

Field Notes

- Exploring how factors influence iron yields** compiled by J. S Hodgkinson
- Genesis of bloomery iron – a note** Alan F. Davies
- Wealden iron, heretics and martyrs in Marian Sussex** Alan F. Davies
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FIELD NOTES

COMPILED BY J. S. HODGKINSON

A Bloomery site in Ticehurst, East Sussex

A dense concentration of bloomery slag has been found on the east bank of a gill stream in Stumblett Wood, Ticehurst (TQ 7087 2997). In the form of a mound, the slag extends over an area of about 250m². No tap slag has been noted but markings suggesting that the slag had flowed over lengths of wood are in evidence. Glazed furnace lining and unroasted siderite ore has also been found.

We are grateful to WIRG members, V. Kellett and J. Vesey, for informing us of this site.

A Middle Iron Age bloomery in Southborough, Kent

Investigations into the occupational history of Brokes Wood have revealed the site of a bloomery on the east bank of a small stream (TQ 5905 4229). Test trenches have revealed part of the remains of a furnace with pieces of slagged furnace lining. Bloomery slag, many pieces of which bear the marks of having flowed over lengths of wood, is scattered downhill from the furnace in disparate patches over an area of about 100m². A radiocarbon date of 2290±30BP (353-231BC) has been obtained from a sample of charcoal from the site, which lies within a kilometre of the contemporary hill fort at Castle Hill, Capel.

We are grateful to Nigel Stapple and his colleagues for notifying us of this discovery.

Bloomery furnaces in Crawley, West Sussex

As a result of Ifield Mill Pond being drained for remedial work to the pond bay of the mill, remains of two bloomery furnaces were discovered

at approximately TQ 2448 3636 by archaeologists from Archaeology South East. One furnace had been built into the remains of the other although little of the structure of either had survived. Assuming the stream flowing through the pond followed the course that had existed before the construction of the pond, the bloomeries were located on a typical site near to the west bank of the stream.

We are grateful to John Mills, Archaeologist for West Sussex County Council, for informing us of this discovery.

Fernhurst Furnace dendrochronology

This site, which is about 1km west of the village of Fernhurst, is one of the best preserved blast furnaces in the Weald. Partial excavation of the site took place in 1989.¹ Water flows past (and sometimes over) the remains via a concrete spillway constructed in the 20th century. However, a number of oak timbers from beneath the pond bay remain below the sluice, four being readily visible at the time of sampling, though others could be detected under the surface of the water (Fig 1.). The continuous wet/dry cycles and movement of the water poses problems with the timbers erosion. It was therefore decided that cutting a slice from some of the exposed timbers was a good opportunity to maximise the information from these timbers before they deteriorate further, with the possible option to further sample other timbers at a later stage if it is felt necessary.

Three timbers were sampled by Dr M. C. Bridge of the Oxford Dendrochronology Laboratory.² Each had been converted into a beam before use, and subsequently eroded, so showed no signs of sapwood on their outer surfaces. One had a short ring sequence (Sample 01; 41 rings measured) and could not be dated. The other two, both from the left bank, each had 132-year sequences which were firmly dated, Sample 03 to the period 1334-1465 and Sample 02 to 1406-1537. It is actually possible that these timbers are contemporaneous, though there is insufficient evidence at present. The earliest likely felling date, adding the minimum likely number of sapwood rings, for one timber is 1474, and for the other is 1546.

The early dating of these timbers would appear to be at odds with the

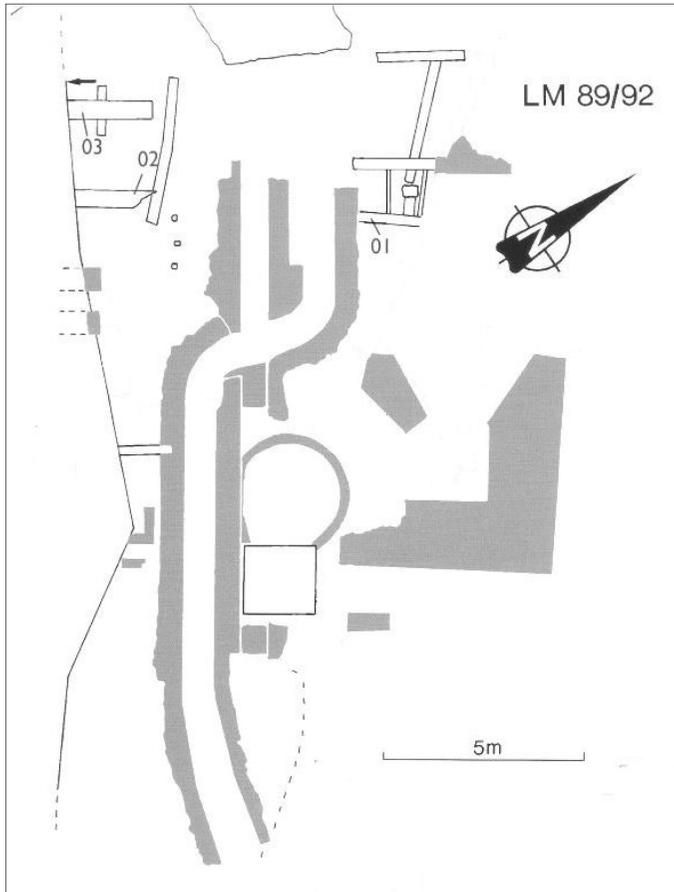


Figure 1 – Fernhurst Furnace; plan of excavated structures showing the location of tree-ring samples

earliest known date for the operation of the furnace in 1614. Possible interpretations are that the timbers, which from their position formed part of the underlying structure of the pond bay, were reused when the furnace was being built early in the 17th century; or that the pond bay was constructed much earlier for another water-powered operation such as a corn mill; or that the furnace was built at an earlier date than that stated in the Shulbrede Court Rolls.

A Late-Iron Age/Early Romano-British Bloomery at Catsfield, East Sussex

A geophysical survey and archaeological evaluation by Cotswold Archaeology on three fields at Eastlands Farm, Catsfield, has revealed evidence of bloomery smelting in the form of tap slag, fragments of burnt clay and oak charcoal, and a possible 'kiln-like' feature in three trenches targeted on strong magnetometer responses. Sherds of grog-tempered pottery dating from the 1st century BC - 1st century AD were found in association with the bloomery slag and in trenches dug in other parts of the same field.

We are grateful to Richard Greatorex for information about this site.³

Oaklands Park Romano-British bloomery site, Sedlescombe, East Sussex

Members of the Independent Historical Research Group, directed by David Staveley, have excavated six trenches in the remains of this ironworking site which is now part of land owned by the Pestalozzi Children's Village, following earlier geophysical surveying which had identified the possible site of a rectangular building. The aim was to establish whether there was evidence of occupation by the *Classis Britannica* (British Fleet) through the discovery of stamped roofing tiles, such as have been found at other sites in the Weald. Remains in the footprint of the building suggested possible use as a smithy but the little dating evidence suggested a late-Roman or even post-Roman date. Abundant pottery from the 1st and 2nd centuries, predominantly East Sussex Ware, was found in other trenches, in one of which was evidence suggesting a wooden building, and in others the extraction of clay for furnace construction and the dumping of metallurgical waste. No tile was found.

We are grateful to David Staveley for a copy of his report.⁴

Bloomery sites in Waldron and Chiddingly, East Sussex

Tim Smith

Three unrecorded bloomery sites have been located about 2.5km west of Horam, East Sussex, and a fourth visited approximately 1km further south near a Roman settlement and later moated house. This site was recorded in 1981.⁵ Two bloomery sites had previously been recorded in woodland to the north at TQ 5468 1757 and 5475 1736, known as Ralph Wood 1 & 2 respectively (see map RW1 & RW2). These sites are on the land of a convent. In woodland to the S and SE, on land now occupied by Little Dernwood Farm, the owner, Chris Bannister, had found various samples of iron related debris as well as possible charcoal platforms and evidence of mine pits.

Two proposed charcoal platforms in coppiced woodland in Summersbrook Wood (CP on map) were examined. One, near the wood's eastern edge, revealed a number of extruded bricks on the surface and was relatively small and almost square in plan. Finding some cinder, it was proposed to have been the site of a stationary steam engine rather than a charcoal platform. The second platform exhibited undulations towards the centre and a liberal scattering of charcoal fragments in the ground. It was of a sufficiently large diameter to accommodate a charcoal clamp, but the undulation in the surface leads to an alternative explanation, that it was a field kitchen established during the Napoleonic wars. Similar square and round platforms have been found on Ashdown Forest and are recorded to be for this purpose. The owner of Little Dernwood Farm understands that Napoleonic prisoners were camped in the area and employed to put in field drainage.

To the south-west, within woodland, was an area pitted with old minepits and a larger flooded excavation – with no spoil around its sides – (MP on map). Located within Wadhurst Clay and close to the border of Ashdown Beds, the large excavation was likely an ore pit and the shaft pits also dug for ore. The wood to the south is called Minepit Wood. Earlier Ordnance Survey maps show the wood extending south to join Coneyburrow Wood, but today there is a field isolating the two. Some 30 years back, when ploughing a field to the NW of the minepits, the land

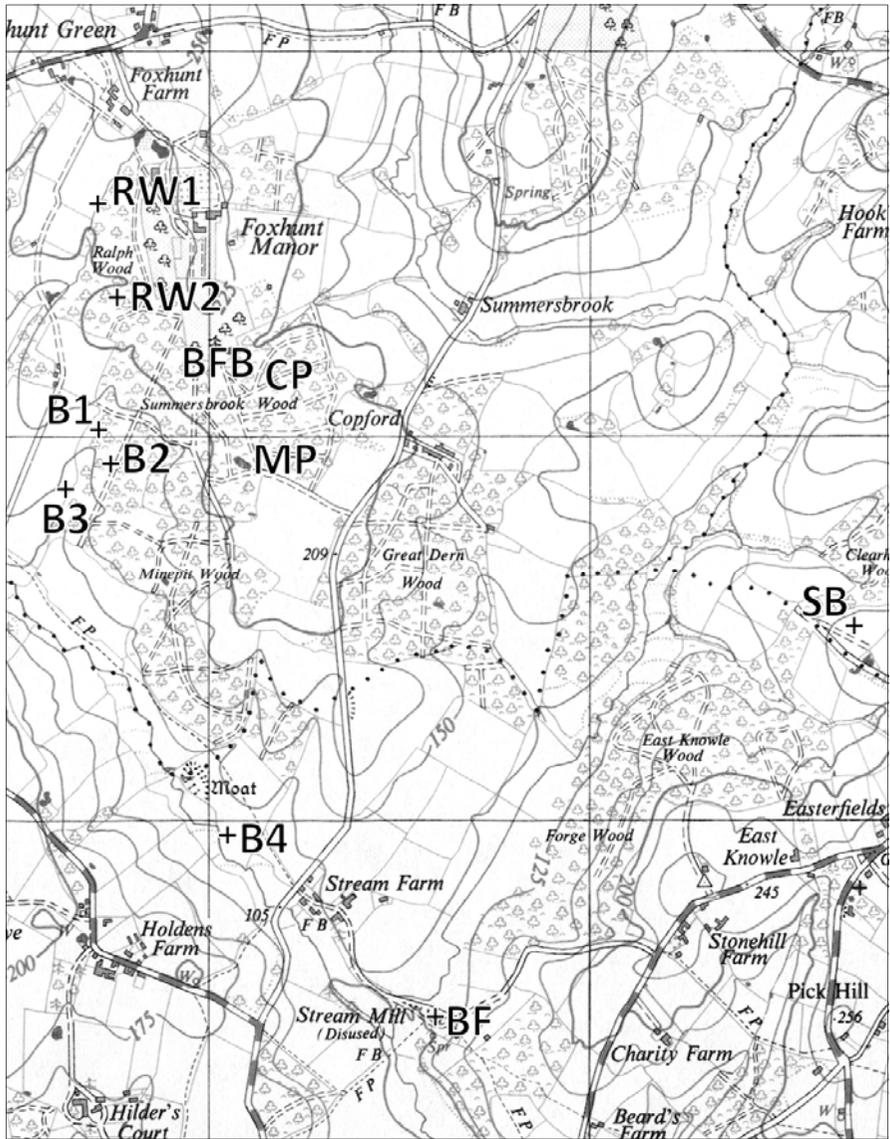


Figure 2 – Sites on 1km grid in area of Little Dernwood Farm north of Chiddingly village

Key to Figure 2

(IDs without crosses indicate general locations eg MP area of a number of mine pits)

- RW1 Previously recorded bloomery in Ralph Wood TQ 5468 1757
- RW2 Previously recorded bloomery in Ralph Wood TQ 5475 1736
- BFB Field in which fragment of a blast furnace bear was found about 30 years ago
- CP Possible charcoal burning platforms in Summersbrook Wood
- MP Mine pit hollows to west of larger flooded excavation
- B1 Bloomery at Badger's set TQ 54721 17023 (by GPS)
- B2 Bloomery at Holly tree TQ 54744 16977 (by GPS)
- B3 Bloomery to west of stream TQ 546 169 (estimated)
- B4 Bloomery to east of moated site in bank TQ 55037 15977 (by GPS)
- SB Bloomery recorded by Straker TQ 567 165
- BF Blast furnace, forge and boring mill dating from 1548 TQ 555 155

owner had found a large piece of what was revealed to be part of the bear from a blast furnace (approx. location BFB on map). Now used as a garden ornament, this was inspected back at the farm and consisted of ore, slag and metal. It had been roughly squared to about 50cm each side and had evidently been carried some distance to the field – most probably from Stream Furnace 1.5km to the SE (BF on map), or possibly from Waldron Furnace somewhat further to the NE (off map). It possibly served as a threshold stone for a small dwelling, (e.g. a hovel) which would leave little permanent trace.

To the SW, in coppiced woodland, is an area where bloomery slag had been found by the land owner. The site was located on a badger set surrounding an old coppiced hornbeam tree (B1 on map). Bloomery slag was found on the surface conveniently excavated by the badgers.

About 20m south and descending into the bed of a small brook, there was evidence of bloomery slag in the water. Probing and digging some 10m above the eastern bank revealed some atypical slag exhibiting a black central core. Similar slag has been found at Parrock and West Hoathly and dated as medieval. West of the brook a third concentration of bloomery slag was discovered about 25m from the water course (B3).

The fourth site (B4) is located about 1km SSE of these three bloomeries on Bull Stream – a head tributary of the Cuckmere. This site

had been previously recorded. Straker also reported a bloomery at TQ567 165 (SB on map) about 1.5km NE of B4 but this was not visited during this foray.⁶ Older OS maps show a moated site about 100m NW of this find. An excavation of the area led by Greg Chuter, Assistant County Archaeologist for East Sussex, had previously revealed artefacts ranging in date from a flint scraper, pottery identified as Roman (there was a settlement in the field about 200m to the north) and a more recent clay smoking pipe, indicating a long period of residence. Slag had been found during this excavation which was proposed to be Roman in view of the presence of pottery. Examination of the site located pieces of slag in an approximately 20m length of a boundary bank running parallel to the stream, and a single piece of blast furnace slag.

The slag find differed from that found at B1-3 being more dense and without the black central core previously described. Metallographic examination of this slag did not show the typical fayalite-wüstite phases frequently found in bloomery slags and exhibited 'halos' around voids suggested it could be forge slag. Correspondence with Tim Young of GeoArch – a specialist in slags – proved inconclusive on this matter so further samples were collected on a subsequent visit and analysed. One sample proved to be typical of a bloomery slag while another exhibited the trend towards a forging slag and a third proved to be slagged brick.

In view of the find of blast furnace slag on the site as well as slagged brick and possible forge slag it is suggested that these materials were transported to the site from Stream Furnace about 0.5km to the SE (BF on map) to improve the surface. A track linking the two sites is shown as a bridleway on present OS maps although no longer very evident on the ground to the west of Dern Lane.

With acknowledgments to Alan Davies for analysis of slags and Tim Young for correspondence on interpretation.

Ore Finds at Sites and Locations at Outwood, Surrey

Alan Davies and Tim Smith

A series of ore finds associated with bloomery smelts were examined

from various locations around Outwood, Surrey – some 10km NNE of Crawley. These were all found to be siderite ores in various states of having been calcined.

The samples were brought to the attention of WIRG in the belief by the finder that they were hematite due to the red colouration on the surface and cursory examination by a geologist friend.

Two samples were also analysed by wet methods to determine elemental content. These were the samples from Woolborough Farm and the Rainbow site. These respectively exhibited a silica (SiO₂) content of 15.16% and 11.8% and an iron content of 47.15% and 47.21%. These silica contents compare with around 9% in the Wealden ores presently used in the WIRG experimental bloomery furnace which are sourced from Beacon Wood, 1.5km east of Benenden, Kent. This indicates inferior yields of blooms in the Outwood samples due to the larger amount of slag produced resulting from the higher silica contents.

Since, in a bloomery, the iron acts as a flux to form the slag, to create a bloom under good furnace smelt management a calcined ore must provide greater than a 4:1 ratio of iron to silicon (Fe:Si). This ratio is a measure of bloom forming potential to ensure surplus iron over slag forming needs. The higher the ratio the greater is the bloom-forming potential.

| Map Reference: | Sample Location | Extent of Prior Calcining: |
|-----------------------|----------------------------|-----------------------------------|
| TQ 3210 4470 | Site 22 Ten Acre Wood | 94% - Highly |
| TQ 3187 4504 | Site C/L Burston Mount | None |
| TQ 3070 4575 | Site 10 Woolborough Farm | 67% - Partly |
| TQ 3148 4774 | Site 34 The Rainbow | 89% - Highly |
| TQ 3358 4538 | Site 13 Horne Ct. Bloomery | 65% - Partly |
| TQ 3165 4485 | Site 31 Coselands Shaw | 57% - Partly |
| TQ 3220 4450 | Site 24 Ten Acre Wood | 61% - Partly |

The Woolborough Farm sample has a calculated* Fe:Si ratio of 6.6:1 and the Rainbow sample 8.5:1. Additionally, some silica will arise from erosion of the furnace walls, so the ratio within the ore samples analysed can only be used as a guide as to the potential to produce a good yield. The degree of calcining will also influence the yield which is inferior in the case of the Woolborough Farm sample compared to the Rainbow.

Analysis is by Alan Davies. We are grateful to Robin Tanner for providing the ore samples.

*Note on calculation: Si in SiO₂ is determined by the ratio of atomic weight of each of the elements = $AWSi \div (AWSi + [AWO] \times 2) = 28 \div (28 + [16] \times 2) = 0.466$

So for Woolborough containing 15.16% SiO₂ the %Si = $15.16 \times 0.466 = 7.07\%$. Since the Fe content is 47.15%, the bloom potential is $47.15 \div 7.07 = 6.66$.

Notes and References

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EXPLORING HOW ORE BLOOM POTENTIAL AND OTHER FACTORS INFLUENCE IRON YIELDS

ALAN F. DAVIES

Introduction

Underpinning any bloomery smelting trial is the usual desire for a good yield of ‘useable’ iron. This evidence of smelting success can help to prove a furnace configuration, assess or compare ores or fuels, trial a smelting strategy or even replicate an historical finding of bloom or slag compositions and structures. However success can be unpredictable for many reasons.

Prus¹ reviews how management of the key operational factors of the bloomery process affect a good yield of iron. Bloomery smelting trials by WIRG led to evolutions in furnace design, temperature management, tuyere configurations and air flows, ore type, ore:charcoal ratios and smelting times.

Additional to these factors previous articles^{2,3} show how ore Bloom Potential – ratio of iron to silicon in calcined ore – can have a major influence on smelting success. The underlying premise is that to create a bloom a calcined ore must provide more than a 4:1 proportion of iron to silicon to give surplus iron over slag forming needs. This is a well-known aspect of bloomery iron smelting experienced from the time of ancient smelters of laterite ores,⁴ medieval smelters – Kronz⁵ – to more recent users of bog ores – see for example Espelund.⁶

However even for Wealden siderite ores with Bloom Potentials, typically in the range 7:1 – 14:1, clay furnace wall and tuyeres liquation or erosional losses raise melt silicon content. At excessive levels this will inhibit bloom production. Side effects include alumina from clay wall/tuyere increasing slag volume and viscosity. However viscosity may be reduced by lime in ore or added forming lower melting point calcium silicate over iron silicate. Overall bloomery slags are mostly fayalitic, low

in lime and usually with less than 10% alumina.

Yields are influenced also by the extent of prior siderite ore calcining conversion to ferric oxide and thereby ore iron weight proportion in a burden charge weight. Similarly variable total carbon and minerals content in charcoal may well be influential via the burden load.

This article explores, by modelling the underlying premise and examining data from smelting trials, how Bloom Potential and related factors alone and in combination influence bloom weight yield.

Background and Method

A working baseline is set for 'ideal' bloomery furnace conditions for reducing ore effectively. Against this changes in variables are assessed. Calcined ore reduction during descent in a bloomery furnace stack follows the sequence:



This is irrespective of whether some initial reduction is by solid carbon from charcoal or later by the predominantly upward flow of carbon monoxide gas produced from charcoal combustion or the reduction of carbon dioxide.

The overall Equilibrium Equation⁷ for ferritic oxide to complete reduction sequence is:



This shows a CO:CO₂ ratio of 12:3 = 4 (or 80%CO:20%CO₂ gas mixture) to be sustainable to achieve iron especially during last stage of smelt.

Conditions for reduction are shown by the phase diagram (Fig. 1) with CO:CO₂ ratio for temperatures. It shows iron produced from magnetite at relatively low temperatures. Importantly wüstite (FeO) exists only above 570°C and around 700°C+ is needed for gaseous reduction of FeO to iron.

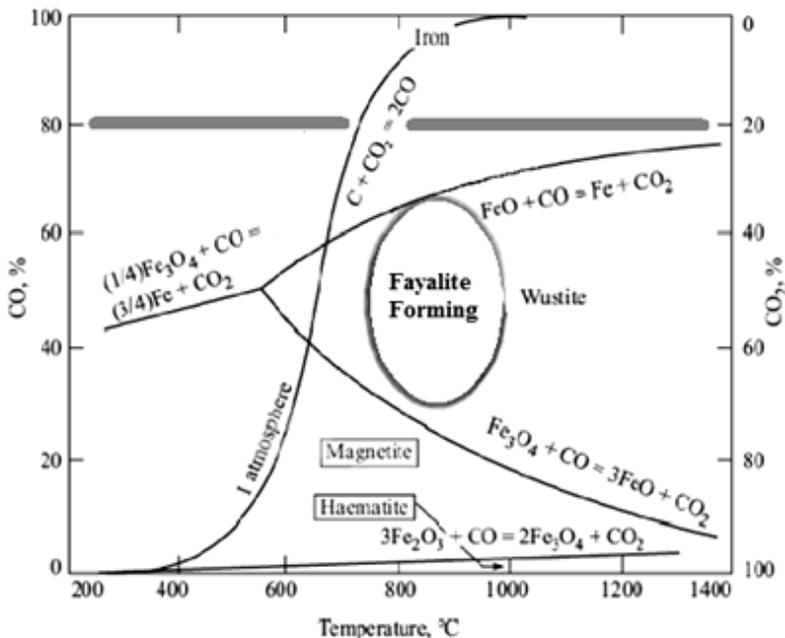


Figure 1 – Iron-Oxygen-Carbon Phase Diagram

The upper broad line shows critical gas ratio and margin to achieve final stage wüstite reduction to iron. A lower ratio of 3 (75%CO: 25%CO₂) for a furnace reducing zone of 1100°C would be borderline for completing this final reduction to ferrite. The margin is even less at 1200°C. However adopting a wider margin by increasing the CO:CO₂ ratio requires extra charcoal and air flow. This gives higher temperatures for the same smelt time, more melt minerals from charcoal and furnace walls increasing gas diffusion times, slower reduction and so a lower iron yield with possible higher iron carburisation from the reaction $3Fe + 2CO \rightarrow Fe_3C + CO_2 \uparrow$.

During latter stage reduction above 800°C wüstite combines (slagging) with ore silica to form fayalite, leaving some wüstite. Wüstite is only found in silica under-saturated melt compositions. Above the critical CO:CO₂ ratio available wüstite is reduced by CO gaseous diffusion through fayalite to form nucleated iron. However the premise is that any

additional silica entering the melt pre-empts this process by combining with the remaining wüstite to form more fayalite. In the extreme no wüstite is left for final stage reduction to iron and a silica saturated melt composition of fayalite + tridymite glass slag remains.

Model Aim

A CO:CO₂ ratio is used to set a constant reducing condition from ore and fuel mix and against which effects of melt silica content are assessed. All other operating parameters for good furnace management are fixed. The basic aim of the model is to represent relationships between total iron and total silica available in the melt for producing an iron bloom yield. Modelling using EXCEL helps explore how variability in:

Ore Bloom Potential

Ore calcining effectiveness

Charcoal fuel total carbon and mineral contents

Furnace structural clay mix composition and liquation losses

individually and in combination, in a well-run furnace, influence bloom metal yield.

Model Structure and Functions

Structure

Fig. 2 shows basic relationships between inputs, interrelated processes and outputs adopted for modelling. In this way output values can be assessed systematically against changes to inputs under selected reducing conditions.

Model Functions

Input Variables:

As mined ore composition for total iron%, silica%, alumina%, lime%

Ore calcining% and volatiles%

Charcoal total carbon%, silica%, alumina%, iron%

Furnace clay structures composition [silica%, alumina%, ferric oxide%]

Furnace structure loss kg/smelt

Target CO:CO₂ gas volume ratio

Ore charging rate kg/hour.

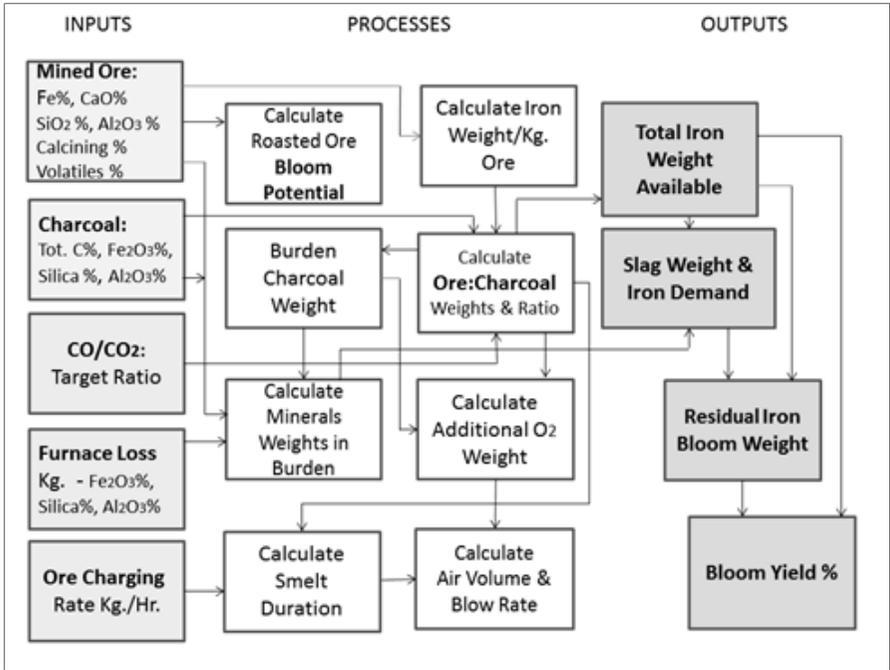


Figure 2 – Model Structure

Key Processes:

Calculate Bloom Potential from calcined ore composition

For a quantity of iron oxide within calcined ore burden weight calculate required weight of carbon monoxide for full reduction and maintain selected CO:CO₂ gas volume ratio

Calculate carbon monoxide weight from carbon content of unit weight of charcoal. Factor to supply the required weight of carbon monoxide to reduce fully the weight of iron oxide

Calculate required weight of burden charcoal to reduce the ore weight to iron and maintain target reducing conditions

Calculate total iron weight per unit of ore plus any from charcoal and furnace clay

Calculate total silica weight in burden from ore, charcoal and furnace clay. Furnace clay loss is input as a weight in kg and factored by clay

input composition

Calculate slag weight

Calculate oxygen weight to combust charcoal carbon weight to carbon monoxide. Deduct oxygen weight provided from ore(s). Calculate nett total volume of air to be blown for smelt duration and average blowing rate of litres per second (L/sec).

Outputs:

Total Iron weight kg available in melt

Slag weight kg produced and contained iron weight kg

Residual iron weight kg available to produce a bloom (value may be zero)

Bloom yield %

(Model includes an optional user selected ‘smithing loss’ factor to give a recovered post smithing consolidated bloom iron weight).

Model Assumptions:

Ore, charcoal, furnace lining plus oxygen from air are external reactants

Gaseous reduction of iron oxides

Any outstanding ore calcining completed in upper furnace stack

Fayalite slag produced with $2\text{FeO}.\text{SiO}_2$ composition

Alumina weight in solid solution added to slag weight, lime displaces wüstite in molecular weight proportions and stays (at low values) in solid solution

Input variables give linear additive effects on bloom yields.

The model determines gross iron yield weight as an available bloom of just iron. However bloom iron nucleates from reduced wüstite forming crystallites in fayalite slag. These merge, descend and coalesce to give a denser iron interspersed with some bloom slag. Subsequent bloom consolidation and smithing removes bulk attached slag but incurs some metal loss and some slag left in the bloom. Whilst the model calculates total available iron, applying an optional ‘smithing loss’ input factor gives a better estimate of useful iron yield.

Example Outputs

Table 1 – model results for two ‘smelt trials’ of 20 kg Beacon Wood Stream (BWS) ore (silica 6.0%, iron 37.6%, lime 1.5%, alumina 2.4%, volatiles 31.3%) in 80% silica clay furnace:

Trial A input values: Ore Calcining 100%, Charcoal C = 90%, No additional silica

Trial B input values: Ore Calcining 95%, Charcoal C = 90%, Additional clay 0.5kg

Trial B values show changes in yield% of iron from using slightly under-calcined ore with increased melt silica from furnace structure.

| INPUT RESULTS: | Trial A | Trial B |
|---------------------------------|----------------|----------------|
| Total Iron Available (kg) = | 10.96 | 10.41 |
| Silica Available (kg) = | 1.75 | 2.15 |
| Slag (kg) = | 6.01 | 7.39 |
| Iron in Slag (kg) = | 3.29 | 4.05 |
| Iron Available in Bloom (kg) = | 7.66 | 6.36 |
| Gross Bloom Yield % = | 70% | 61% |
| PROCESS RESULTS: | Trial A | Trial B |
| Effective Ore Bloom Potential = | 13.3 | 10.3 |
| CO:CO ₂ Ratio = | 4.00 | 4.00 |
| Ore:Charcoal = | 1.02 | 1.08 |
| Ore (Kg) = | 20.00 | 20.00 |
| Charcoal (Kg) = | 19.6 | 18.6 |
| Avg. Blowing Rate (L/Sec.) = | 7.0 | 6.7 |
| Smelt Duration (Hrs.) = | 5.0 | 5.0 |

Table 1 – Comparison of Model Outputs for Two Trials

Findings

Scenarios

This section compares bloom yields from individual and combination effects of different sources of silica input.

Charcoal 95% Carbon & No Additional Silica Pick up

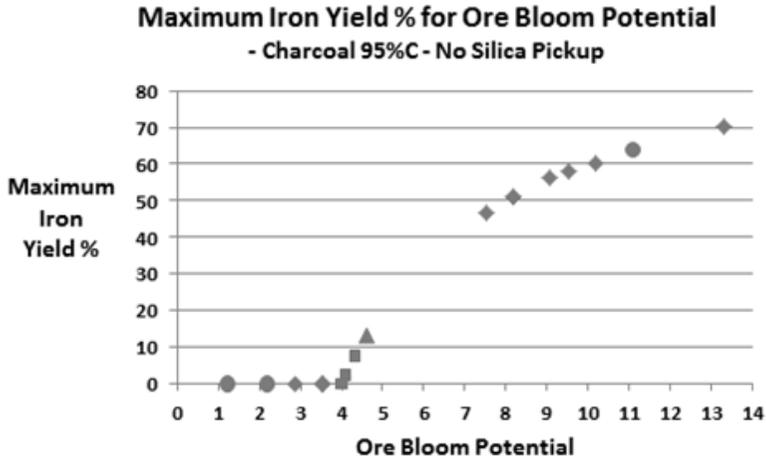


Figure 3 – Bloom Maximum Iron Yield% for Ore Potential

Fig. 3 shows how Bloom Potentials vary for a series of mostly Wealden ores. Of the seven ores with yields above 40% all are siderite except one limonite shown by the circle. Of the low potential ores the triangle marker represents a hematite laterite ore, circles limonite ores and the square markers ‘synthetic’ ores to indicate more clearly the lower cut-off point value of ‘4’ for producing a bloom. Iron and silica proportions in each ore give the differences in bloom yields.

Effect of Bloomery Structure Loss during Smelt

Prior WIRG smelting trials indicated that furnace repair required on average around 1kg of clay to patch smelting and tuyere zone wall erosion after a smelt.

Fig. 4 shows the effect on bloom yield from a loss of 1kg (= 5% of ore burden weight) of furnace structure during smelt adding 0.8 kg of silica and 0.2 kg of alumina to the melt. The result shows overall reduction in

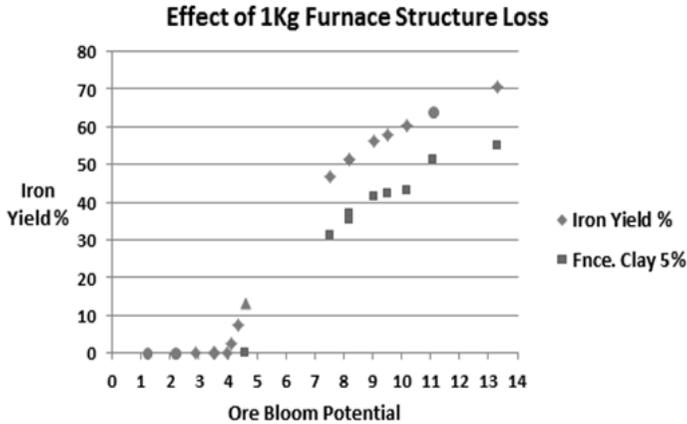


Figure 4 – Effect on Yield of 1 Kg of Furnace Clay Loss to Melt

bloom yield is about 20% – 21% over the range. Another view is this quantity of furnace clay loss degrades good ores by some 3 – 4 units in bloom formation capability.

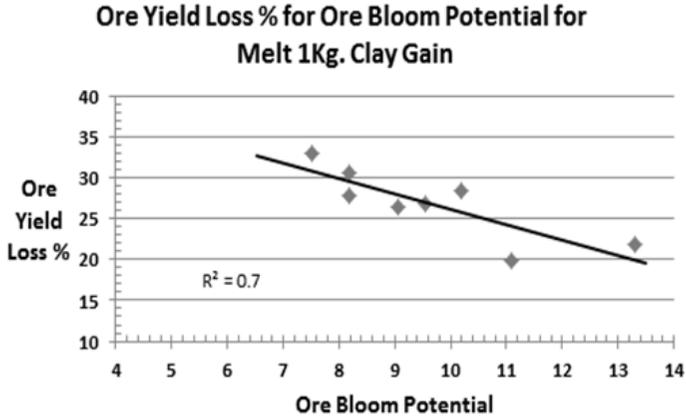


Figure 5 – Increasing loss of Bloom Yield for lower Bloom Potential Ores

Fig. 5 shows how lower Bloom Potential ores have proportionally higher

ore yield losses for a fixed weight of furnace structure clay loss.

Charcoal 95% Carbon with Compared Silica Additions

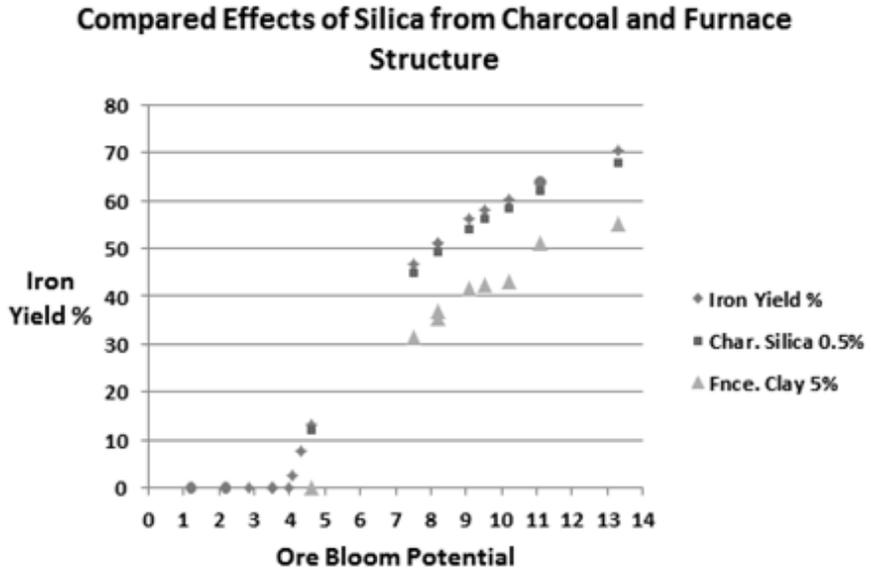


Figure 6 – Comparative Effects of Silica Pick-up

Fig. 6 introduces and compares the effects of minor quantities of silica in the charcoal burden (0.5%) against original yields shown in Fig. 3 and compared with the much larger effects from furnace structure loss shown in Fig. 4. The close values of the original and charcoal silica yield show around 3.2% – 3.4% reduction over the useful ore Bloom Potential range. So a small quantity of silica alone in charcoal causes only a minor reduction in bloom yield.

Effect of Ore Calcining

For under-calcined siderite ore Fig. 7 shows how the effect of lower iron quantity in a fixed weight of ore burden will reduce final ore yields. This shows up to 10% loss in bloom yield for the calcining effectiveness range shown.

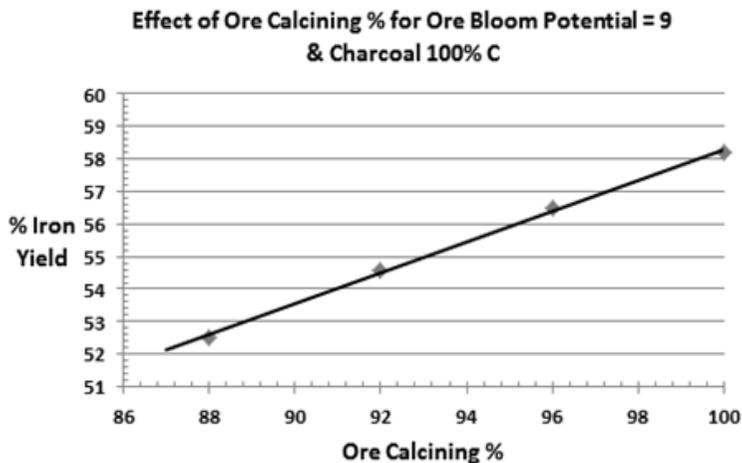


Figure 7 – Effect of Ore Calcining Completion on Bloom Yields

Summary of Findings

Table 2 shows a summary of findings for the relative rankings of effects on bloom yields.

Bloom Potential and furnace structure type losses to the melt are key variables affecting bloom yields. Ore under-calcining is significant from

| Individual Effect Trials | Effect on Range of Bloom Yield | Ranking |
|---------------------------------|---------------------------------------|-----------------------------|
| Bloom Potential (BP) changes | 47% - 70% | 37% Reduction over BP range |
| 1 Kg Furnace wall/tuyere loss | 31% - 55% | 16% - 26% Reduction |
| Ore Calcining (Ore BP = 9) | 52% - 58% | Up to 10% Reduction |
| Charcoal Silica of 0.5% | 45% - 68% | 3.2% - 3.4% Reduction |

Table 2 – Summary of Key Individual Findings

the input loss of iron content in the fixed weight of burden ore. In contrast low amounts of silica in charcoal have only a minor effect on yield.

‘Combined Cases’ Scenarios

In practice smelting invokes a varying mix of effects which the model can combine. Table 3 shows bloom yields% for trial combinations of input values.

| Trial Number | Bloom Potential | Wall/Tuyere Clay Loss kg | % Ore Calcining | Charcoal % Silica | Charcoal % C | Bloom Yield % |
|---------------------|------------------------|---------------------------------|------------------------|--------------------------|---------------------|----------------------|
| 1 | 13.3 | 0 | 100 | 0 | 100 | 70 |
| 2 | 13.3 | 1.5 | 90 | 0.15 | 90 | 43 |
| 3 | 8 | 1.5 | 90 | 0.15 | 90 | 21 |
| 4 | 8 | 0 | 100 | 0 | 100 | 50 |
| 5 | 8 | 2 | 85 | 1 | 85 | 5 |

Table 3 – Bloom Yield % for Combination Scenarios

High Bloom Potential ore used under ‘ideal’ conditions (Trial 1) gives the highest yield of 70%. In comparison a lower Bloom Potential ore under ‘identical’ conditions (Trial 4) gives only a 50% bloom yield – a reduction of 29% in output yield

However now adding a combination of ‘adverse’ variables values (Trial 2) reduces the best ore yield to 43% i.e. a reduction of 39%. For the lower Bloom Potential ore the similar ‘adverse’ effects combination (Trial 3) is a comparative reduction of 58% with bloom yield of just 21%

A possible ‘worst case’ scenario (Trial 5) is shown for the low Bloom Potential ore smelted under conditions of relatively low ore calcining effectiveness, low quality charcoal with extra silica and higher weight loss from furnace interior. In combination the overall effect gives a low 5% bloom yield – close to a ‘No Bloom’ condition.

These basic trials show how using known ore and charcoal compositions,

calcining effectiveness and furnace structural clay mix can help predict likely smelt iron yield.

Model Results Comparison

Kronz reports on medieval bloomery excavations in the Lahn-Dill area of Germany; in particular a tolerance by smelters for lower iron yields from high grade magnetite ores through the effects of furnace silica additions. He used a yield calculation method based on equivalent FeO contents of ore, slag and furnace lining (loam) weights. An example is given of an ore with 87% FeO mixed with 25% loam of ore weight yielding about 26% iron. His result was compared with model yield result using the same input data for loam weight, loam and ore mineral specifications given in his article. Table 4 compares yields from model parameters for magnetite ore. Loam 8% iron content alone adds 1.4% to iron yield %.

Results show a very close match. Moreover the model calculates ore

| | Ore FeO% | Ore Fe% | Ore BP | Loam Wt. : Ore Wt. | Iron Yield % |
|----------------------|----------|---------|--------|---|--------------------|
| Kronz (Given) | 87 | - | - | 25% Loam of: Silica 73%, Alumina 11%, iron 8% | ‘About 26%’ |
| Model | - | 67.6 | 16.9 | 4.5kg loam/18kg ore | 27.9% |

Table 4 – Summary Comparison of Kronz’ Method with Model Yield

maximum yield as 77% iron indicating around 66% smelting loss of iron. Kronz comments that ‘only a much lower quality ore or a much higher proportion of furnace lining would yield no iron’.

Smelting Trials – Temperature and Bloom Yield Variability

This section reviews smelting conditions and yields from a series of documented WIRG historical bloomery trials. The aim, using retrospective modelling, is to see whether widely variable bloom yields may be attributed to smelts’ silica contents and temperatures.

Original smelting trials used siderite ore with a Bloom Potential of 10:1 and with just under 4% each of alumina and lime using a fixed

ore:charcoal weight ratio of 1. Each smelting trial was between 4.75 to 5.83 hours and at one of four smelting temperatures. Bloom weight yields were within 6% to 43% for ore burden weights of 14kg to 20kg (a small quantity of added mill-scale was modelled as additional iron and oxygen weights to the melt). The furnace was 1000mm tall, 760mm circular diameter, cylindrical shaft chamber with 240mm clay walls (silica 80%:alumina20%). The furnace reducing zone temperature measured at 200mm above tuyere entry point and represents average value for last hour or so of smelt.

Examination of the smelt data showed:

No correlation between ore kg used and bloom kg

5% correlation between a lower bloom weight for longer smelting times

29% correlation between ore kg used and smelt duration hours

88% correlation between weight ratios of bloom:burden ore mapped against furnace temperature and shown as Fig. 8.

Smelt details were modelled in two stages to assess the effects of silica

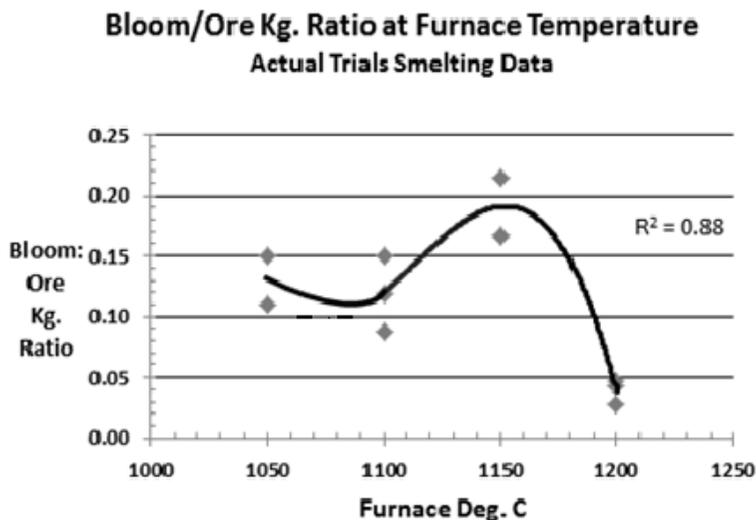


Figure 8 – Efficiency of Bloom Formation from Ore at Furnace Temperature

additions to the melts. Firstly each set of smelting variables was used to give an expected yield. The ore:charcoal ratio for each smelt gave consistent furnace CO:CO₂ ratios of 4.4. Whilst for each trial the model predicted a higher bloom yield than reported, overall there was no correlation with actual bloom yields. Added mill-scale quantity gave only a minor increase in yield.

Then each model trial for a temperature was repeated with successive increments of clay weight until the model gave the same bloom weight as that from the actual trial smelt. Mapping this simulated melt clay gain weight as a proportion of ore burden weight against temperature gives Fig. 9. This shows the highest clay ‘loss to the melt’ at the highest furnace temperature used.

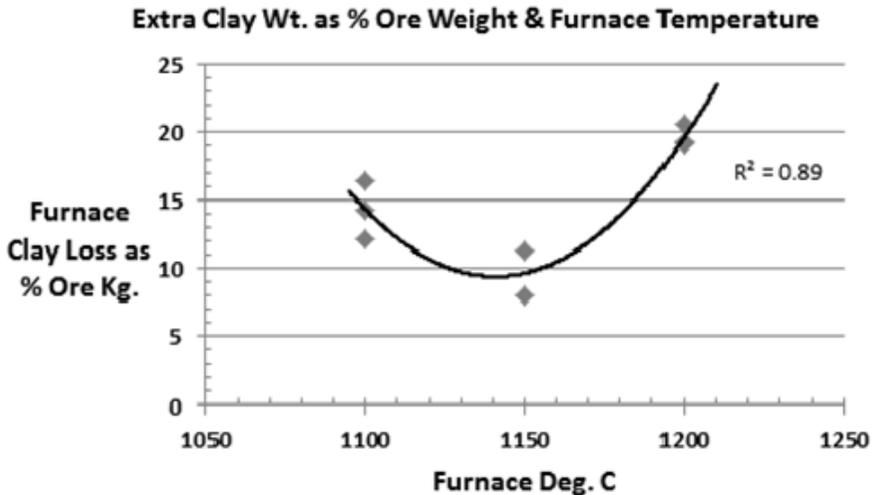


Figure 9 – Modelled Furnace Clay loss at Furnace Temperatures

This relationship suggests that clay loss at and below 1150°C, which is just below the FeO-SiO₂ phase diagram melting point of around 1170°C with some lime content, is more likely self-limiting solid diffusion rate controlled. With less than 29% silica, an essentially fayalite slag with wüstite for reduction gives bloom ratios shown in Fig. 8.

However a reducing zone of 1200°C becomes more critical for realising a good bloom yield. Clough,⁸ for example, referring to historical work, provides a comprehensive portrayal of how furnace conditions and burden transit times influence iron and bloom formation. He describes, for ore particles in contact with extra molten slag formed at this temperature, how ore reduction may be limited or even cease from longer gas diffusion times through extra slag. Moreover FeO-SiO₂ phase data shows that at 1200°C wüstite exists only with less than 22% silica in the melt. This means a comparable melt silica gain, say as for 1150°C, would now use proportionally more of the available wüstite to form fayalite leaving less or even none for reduction to iron. Combined effects are lower bloom:ore ratios shown in Fig. 8.

Thereafter, for either situation, Clough describes how descending iron and liquating slag separate in the hotter (oxidising) combustion zone. Depending on the rate of descent, gas ratios and temperature, any previously carburised iron may liquefy partially (such as for a 1½% carbon iron above 1300°C). This iron may drop lower or be partly decarburised and solidify with a lower carbon content. Some iron not protected by slag may re-oxidise and form more slag. Remaining iron will weld, entraining some slag, into a bloom of maybe varied iron content. Bloom yield depends on wüstite available for reduction to iron.

Empirical graphical findings suggest that for a low carbon bloom and maximised yield a bloomery reducing zone temperature should ideally be held to within 1160°C–1170°C.

Conclusions

This work shows, for a well-run furnace, how a Bloom Potential ratio of much more than 4:1 of iron to silicon weight content in calcined ore is needed to ensure forming a useful bloom yield. However variable burden quality specifications and liquated furnace structure additions to the melt can reduce ideal iron yield or even cause a ‘no bloom’ smelting condition.

Modelling as a technique helps to explore and especially quantify the effects of interactions within a system. Using this for smelt ‘trailing’ of an intended burden mix and temperature conditions can assess likely bloom yields and so expectations for smelting success. Findings from modelling some actual bloomery smelting burden and yield data suggest a

reducing zone temperature of 1160°C–1170°C may well support optimum bloom yield for a low carbon iron.

Importantly establishing likely yields for a specific burden mix and furnace structure gives baseline criteria against which to assess effects of other intended technical or operating changes in furnace smelting.

The technique, as much as helping to predict yields, offers support for assessing historical smelting conditions. Linking analyses of archaeological finds of ore type, related charcoal, furnace structure and slag morphologies may help in adding to knowledge about local and regional historical iron production efficiencies, throughputs and economics.

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GENESIS OF BLOOMERY IRON – A NOTE

ALAN F. DAVIES

The following micrographs show a snap shot example of early formation stages of bloom iron. They were recorded during analysis of slag sections from a laterite ore trial smelt giving an overall 10% iron content but no bloom.

Fig. 1 shows final iron globules and stringers, many formed around porosity boundaries and inner surfaces, from the reaction:

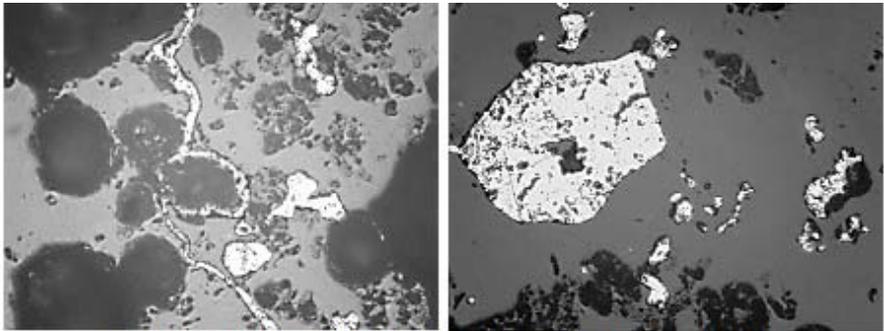


Figure 1 – Final Iron Globules and Stringers formed in Slag. (x100)

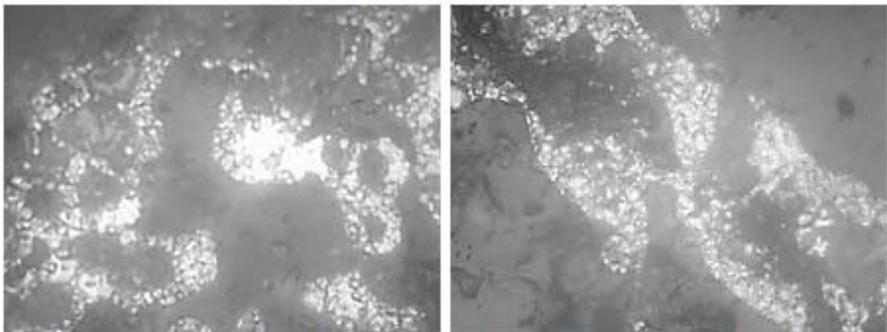


Figure 2 – Formation of Iron Crystallites around Slag Voids. (x400 & 2% Nital Etch)

$\text{FeO (as wüstite in slag) + CO (gas via porosity) } \rightarrow \text{Fe (nucleated) + CO}_2\uparrow$

Samples responded to a magnetic field so confirming presence of metallic iron.

However higher magnification (Fig. 2) shows iron formation as nucleated iron particles merging to form iron crystallites around micro porosity in slag. The right hand image shows a likely vestige of dendritic wüstite now reduced to iron in slag matrix.

These show that bloom consolidation processes were incomplete probably either from smelting conditions or insufficient iron present to descend the furnace, coalesce and form a bloom.

WEALDEN IRON, HERETICS AND MARTYRS IN MARIAN SUSSEX

M. J. LEPPARD

It is well-known that Richard Woodman, burnt at the stake for his Protestant beliefs at Lewes in 1557, was a ‘maker of iron’ from Warbleton. His autobiographical account of his controversies and trials was reproduced by John Foxe in his *Book of Martyrs*, first published in 1563, and the ironworking aspects of his life have been presented and discussed in this journal by Tim Cornish.¹ Less well-known is John Trewe, probably a son of John Trewe the founder at Robertsbridge furnace in the early 1540s, who was imprisoned in 1556 for his beliefs and, as of Hellingly, claimed compensation in 1559. His case has been discussed, and his 1556 statement and 1559 petition printed, by A. S. Gratwick and Christopher Whittick in the *Sussex Archaeological Collections*,² while his progress from ironworking in Sussex and Wales to civil engineering projects elsewhere in England has been outlined in these pages by Michael Chrimes.³ The probability of further links between religious dissent and Wealden ironworking seem not, however, to have been acknowledged, let alone explored in print, until now.

Before considering evidence, certain factors favouring this probability must be borne in mind:

1. From the time of Henry VIII there was considerable movement of people, ideas and literature between continental Protestants and their English sympathisers in both directions, much of it through the Channel ports.
2. As from the introduction of the blast furnace to the Weald, at Buxted in 1490, ‘alien’ experts in the new technology were brought in from northern France and the low countries to construct, operate and supervise them, the areas where all forms of Protestantism flourished and influenced developments in England.

3. Rye, the principal port through which Wealden iron, brought to it by road or river, was exported and probably the chief point of entry for the alien workers,⁴ had been a hotbed of religious and political strife and heresy-hunting from the 1530s and. was the home town of one of the martyrs.⁵

4. Although Woodman is the only ironworker among the 11 of the 37 Sussex martyrs whose occupations are known, the other ten are of much the same socio-economic status: a brewer, two carpenters (the builders of their day, one also a millwright), a currier, a husbandman (small farmer), two priests (unsurprisingly), a shoemaker, a turner, and (proving the rule?) a maidservant. Apart from the last, all ten callings required some level of formal education and precise, hard-earned, skills, pride in which would foster a sturdy independence of mind, in addition to whatever truth there may be in the stereotype of the obstinacy of Sussex folk. It is highly probable therefore that people involved with the Wealden iron industry were among the other martyrs and among the greater number suspected, accused or convicted of heresy in the county during the reign of Mary.

This *a priori* case is greatly strengthened when information is mapped. To avoid overstating it, I have limited what I have plotted: martyrs only, excluding ‘heretics’, some of whom might have been political dissenters rather than religious, or found blameless; and only parishes where there were the large-scale undertakings, water-powered furnaces or forges, with their sizeable workforces, as opposed to bloomeries or smithies. Relying on Cleere and Crossley’s gazetteer of water-powered sites,⁶ I have marked all parishes with evidence that one or more furnaces and/or forges were operating by c. 1560, or good reason to believe so. Statistically, five of the 27 parishes identified produced martyrs (18½%) and eight of the 38 martyrs came from those parishes (29%).

When researching for my entry, ‘Heretics and martyrs in Marian Sussex: networks and locations’, in the Sussex Archaeological Society’s recent history essay competition, I gathered all the information I could from every likely source about each person recorded by name as a heretic or martyr. In eleven cases (19%) I found some association with the Wealden iron industry, or the probability or possibility of it, mentioned it at the appropriate point, and decided to develop it elsewhere rather than make it a theme in the essay. The

prize-winning essay has been accepted as the basis of an article in a forthcoming issue of the Society's *Collections*. I will not therefore need to summarise it here, nor tell the stories of the people concerned; rather, I shall take them in turn, setting out the evidence, with source-references in the end-notes, and explaining my reasoning. To encourage readers to supplement, correct, refute or even endorse my findings, I have tabulated as an appendix the names of all the heretics and martyrs I studied, with source-references in the end notes for the heretics. Genealogists and family historians in particular should be well-placed to discover further cross-links. Even the people not living in the iron-working parishes might have had family or business connections there.

The statement issued from prison by John Trewe on 30 January 1556 had eleven counter-signatories,⁷ of whom **John Saxbye** could be the John Saxpes who by 1560 had married a half-sister of Alexander Hosmer,⁸ burnt in 1557, whose connection with the iron industry is discussed below. He might also be the John Saxpes in the Hundred of Hawksborough (embracing Burwash, Heathfield and Warbleton), two of whose alien servants are identified in the 1549 subsidy roll. One of them, Denys Lebbys, then appears in Richard Woodman's works in Warbleton in the next three years' rolls.⁹ By the 16th century the Saxbys/Saxpes name had spread into nearby parishes from Withyham,¹⁰ but rashly venturing conclusions from common names is offset by the likelihood that associates of John Trewe shared his involvement in the iron industry. Thus **John Guelle** might be John Gue, senior or junior, in Hawksborough Hundred in 1550, both servants of John Collyn,¹¹ of Burwash Forge, 1525-?74.¹² I can shed no light on **Cornelius Stevenson**, but, since his forename was not generally used in 15th-century England but brought in by aliens, he too could have been an ironworker.¹³

The biggest and best-documented burning took place on Tuesday 22 June 1557 in Lewes. As was customary in lists of persons, Brice (our earliest published authority¹⁴) and Foxe begin with the one of greatest substance or quality, **William Mainarde**, as substantiated by their next entries being his maid and his man (Brice) or servant (Foxe). M. A. Lower in his edition of Foxe's accounts of the Sussex martyrs says he was probably a member of a Mayfield family.¹⁵ It is arguable that he was the husband of Agnes Maynard of Mayfield against whom, by then widowed, proceedings were taken in Chancery in 1561 for taking seven tons of rough iron or sows

from John Relfe's place in Mayfield called the Olde Myll. C. S. Cattell regards this as possibly the un-named furnace in Mayfield held by John Baker in 1574 and Agnes as perhaps related to the deceased Richard Maynard named in 1618 as having had an interest in it; he does not notice the martyr.¹⁶ Cleere and Crossley give much information concerning Richard Maynard's involvement in the iron industry in Rotherfield, Mayfield's northern neighbour.¹⁷ Roger Davey, discussing three of the other Lewes martyrs of 1557, shows that none of the known contemporary William Maynards in Rotherfield can be the martyr and concludes 'he remains elusive'.¹⁸ If the martyr was Agnes's late husband, however, he can be integrated into larger stories and provide another connection between Wealden ironworkers and religious radicalism.

Alexander Hosmer ('Hosman' in Foxe), the next name, was Maynard's 'servant', the equivalent of employee, which could imply a responsible position in Maynard's business, not necessarily in the same parish; at death he owned a house and 60 acres. Of all the martyrs, he is the one for whose fate we have irrefutable contemporary evidence, in the court rolls of the manor of Rotherfield. A comprehensive account of the man and his family was constructed from the manor and parish records by Catherine Pullein and augmented from others by Davey.¹⁹ I can add only the possible family connection with the heretic John Saxpes discussed above.

Davey also assessed what can be known about the mother and son named next by Brice and Foxe, **Margery** and **James Morris**, both of Heathfield in Foxe's supplementary list. Margery's husband **John** was charged in 1552 with withholding tithes, but the case was dismissed on a compromise. Margery was cited for failing to attend communion for two years, given a penance which she did not perform, and then excommunicated. John was detected of heresy in 1556, a charge still outstanding in 1557, but his fate is unknown.²⁰ Davey also establishes that the martyrs left no surviving descendants, thereby tacitly correcting the family tree constructed earlier by Michael Burchall.²¹ An account of later holders of the surname by Susan Haines claims, but does not establish, their descent from the martyrs, to our knowledge of whom it adds nothing.²² One of John Morris's many namesakes worth noting, in case future research finds a connection, is the otherwise unknown and unlocated John Morys from whom sixty tons of iron were purchased for ironworks at Robertsbridge (some five miles east of

Heathfield) in 1563 and another thirty in 1567.²³

In 1555 the Privy Council had required Lord Abergavenny to put Rotherfield and its neighbour Frant in order. In the following year the rector of Rotherfield was deprived and the manorial court rolls record that **Edward Fyltnershe**, Robert Mason and Thomas Slowman were taken for heresy on 17 October but fled. In 1558 the first two re-appear in those records. Miss Pullein sets out the story in detail.²⁴ This Edward Fyltnershe, who died in 1581, could be the Edward Fyltnasse of Rotherfield Hundred assessed at £2 for lands in 1524²⁵ and/or the Edward Fyltness who in 1576 was to deliver charcoal at Maynards Gate Furnace in Rotherfield.²⁶

Although William Maynard cannot be conclusively connected with either the iron industry or Mayfield, that parish was selected for the burning on Thursday 24 September 1556 of four martyrs: Thomas Ravensdale of Rye (occupation unknown), John Hart (probably a shoemaker) and Nicholas Holden (probably a currier) both of Withyham, and one un-named. One reason for choosing Mayfield must have been its position at the heart of the largest concentration of parishes affected by religious radicalism, as the maps make clear. Whether it was their spiritual heart we cannot tell. Its central location among the iron-working parishes is equally apparent; though not necessarily a factor in its selection, it is a fact worth noting here.

APPENDIX: ALL KNOWN HERETICS AND MARTYRS IN MARIAN SUSSEX

Foxe, Brice and the Folger Library manuscript transcribed by Gratwick and Whittick²⁷ all deal with the martyrdoms in chronological order: the final column below therefore acknowledges them as sources by initial alone. Sources for heretics are indicated by endnotes to the second column.

| Name and sex | Heretic/ Excomm'd | Martyr Burnt at* | Parish/area | Sources for martyrs** |
|----------------------------------|----------------------|---------------------|--------------|--------------------------|
| 1 John ASHDOWN m | | M ? ? | Rotherfield | F |
| 2 William ASHDOWN m no.1? | H 1556 ²⁸ | | Rotherfield | |
| 3 ASHDON 's wife f | | M 1557 L | ?Rotherfield | B F Fm |

| Name and sex | Heretic/ Excomm'd | Martyr Burnt at* | Parish/area | Sources for martyrs** |
|---|-----------------------------------|-----------------------------|-----------------------|----------------------------------|
| 4 Thomas AVINGTON m | H 1556 ²⁹ | M 1557 L | Ardingly | B F Fm |
| 5 Denis (?Dionysia) BURGESS m/f | | M 1557 L | Buxted | B F Fm |
| 6 Henry BURGESS m | H 1556-7 ³⁰ | | ? | |
| 7 Dirick CARVER m | | M 1555 L | Brighton | B F Fm |
| 8 Thomas CHATFIELD jun. m | H 1556 ²⁸ | | Chiddingly | |
| 9 Thomas DUNGATE m | | M 1556 EG | E. Grinstead | B F Fm |
| 10 William FAYRWAYE m | H 1556 ²⁸ | | Hailsham | |
| 11 John FOREMAN m | | M 1556 EG | E. Grinstead | B F Fm |
| 12 Edward FYLTNERSHE m | H 1556 ³¹ | | Rotherfield | |
| 13 Stephen GRATWICK m | | M 1557 Southwark | Brighton | F Fm |
| 14 Christian GROVER m | | M ? ? | Lewes Archdeaconry | F |
| 15 GROVE 's wife f no.14? | | M 1557 L | | F Fm |
| 16 John GUELLE (? Jewel) m | H 1556 ²⁹ | | ? | |
| 17 Thomas HARLAND m | | M 1556 L | Woodmancote | B F Fm |
| 18 Richard HARMAN m | H 1554- 56 ^{29,32,33} | | West Hoathly | |
| 19 John HART m | | M 1556 M | Withyham | F Fm |
| 20 Richard HILLER m no.18? | H 1556 ²⁸ | | West Hoathly | |

| Name and sex | Heretic/ Excomm'd | Martyr Burnt at* | Parish/area | Sources for martyrs** |
|--|--------------------------|----------------------------|---------------|--------------------------|
| 21 Matthew HITCHERST m | H 1556 ²⁹ | | ? | |
| 22 Robert HITCHERST m | H 1556 ²⁹ | | ? | |
| 23 Nicholas HOLDEN m | H 1553 ³³ | M 1556 ? | Withyham | F Fm |
| 24 Richard HOOKE M | H 1555 ²⁸ | M 1555 C | Alfriston | B Fm |
| 25 Alexander HOSMER m | | M 1557 L | Rotherfield | B Fm |
| 26 Thomas (AT) HOTH m | H 1533 ^{34, 35} | M ? ? | ? | B F Fm |
| 27 Thomas IVESON m | | M 1555 C | Godstone, Sy. | B F Fm |
| 28 John JACKSON m | H 1556 ^{29,30} | | ? | |
| 29 -?- JUXON m | | ?M 1557 C ³⁷ | ?Chichester | |
| 30 Thomas KING m | | M 1557 ? | ? | F Fm |
| 31 John LAUNDER m | | M 1555 S | Godstone, Sy | B F Fm |
| 32 Henry LONDON m | H 1557 ³⁶ | | ? | |
| 33 Robert MASON m | H 1556 ³¹ | | Rotherfield | |
| 34 William MAYNARD m | | M 1557 L | ?Mayfield | B F Fm |
| 35 John MILLS m | | M 1556 ? | Hellingly | Fm |
| 36 Thomas MILLS m no.35? | | M 1556 L | ? | B F |
| 37 William MORANT m | | M 1557 ? | ? | F Fm |
| 38 James MORRIS m | | M 1557 L | Heathfield | F |
| 39 John MORRYS m | H 1556-7 ²⁰ | | ? | |
| 40 Margaret/Margery MORRIS f | (Ex 1552) ²⁰ | M 1557 L | Heathfield | B F Fm |

| Name and sex | Heretic/ Excomm'd | Martyr Burnt at* | Parish/area | Sources for martyrs** |
|------------------------------------|------------------------------|-----------------------------|--------------------|----------------------------------|
| 41 John NEWMAN m | H 1556 ²⁸ | | Rotherfield | |
| 42 Thomas NEWMAN m | H 1556 ²⁸ | | Rotherfield | |
| 43 John OSWALD m | | M 1556 L | Woodmancote | B F Fm |
| 44 Thomas RAVENSDALE m | | M 1556 M | Rye | B F Fm |
| 45 Thomas READ m | H 1556 ²⁹ | M 1556 L | ?Waldron | B F Fm |
| 46 Margery RUSSELL f | H 1556 ²⁹ | | ? | |
| 47 John SAXBYE m | H 1556 ²⁹ | | ? | |
| 48 Robert SKULTHORP m | H 1556-7 ³⁶ | | ? | |
| 49 Thomas SLOWMAN m | H 1556 ³¹ | | Rotherfield | |
| 50 John SMYTH m | H 1556 ²⁸ | | E. Grinstead | |
| 51 John SPRINGATE m | H 1556 ²⁸ | | Ticehurst | |
| 52 Thomas STANDEN m | H 1556 ²⁸ | | Eastbourne | |
| 53 George STEVENS m | | M 1557 L | Walberton | B F Fm |
| 54 Cornelius STEVENSON m | H 1556 ²⁹ | | ? | |
| 55 Joan THOMSET f | H 1556 ²⁸ | | East Hoathly | |
| 56 Ann (Mother) TREE f | H ? ³⁵ | M 1556 EG | E. Grinstead | B F Fm O |
| 57 John TREWE/ TRYE m | H 1556 ²⁹ | | ?Hellingly | |
| 58 William VESIE m | H 1555 | | ?Brighton | F |
| 59 John WARNER m | | M ? ? | (East)bourne | F O |

| Name and sex | Heretic/ Excomm'd | Martyr Burnt at* | Parish/area | Sources for martyrs** |
|------------------------------------|----------------------|---------------------|-------------|--------------------------|
| 60 Henry WICHAM m | H 1556 ³⁶ | | ?Surrey | |
| 61 Thomas WOOD m | | M 1556 L | ? | B F Fm O |
| 62 Thomasine A'WOOD f | | M 1557 L | ?Mayfield | B F O |
| 63 Richard WOODMAN m | | M 1557 L | Walberton | B F Fm O |
| ?64 <i>a shoemaker</i> m no.19? | | M 1556 ? | ? | F Fm |
| ?65 <i>a currier</i> m no.23? | | M 1556 ? | ? | F Fm |

* **C** Chichester, **EG** East Grinstead, **L** Lewes, **M** Mayfield, **S** Steyning

** **B** Brice, 1559, **F** Foxe, 1563, **Fm** Folger Library Ms., 1557 **O** Other

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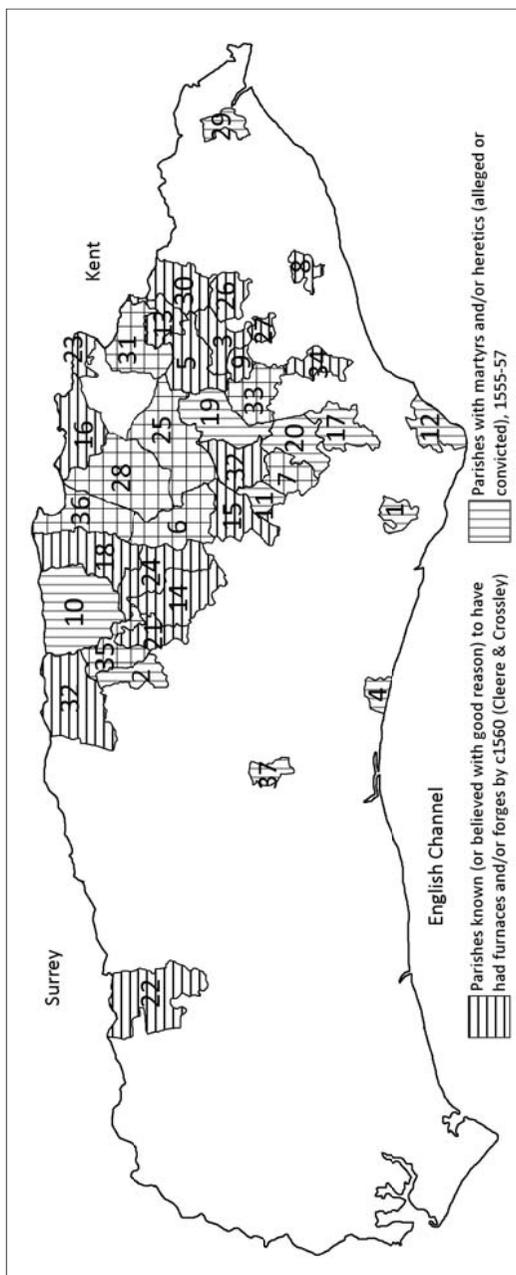


Figure 1 – Sussex Parishes where heretics and martyrs resided and where iron was being produced in the Marian period (for key see next page).

LIST OF PARISHES ON MAP, AND STATISTICS

| Parish | Iron works | Heretics/ martyrs | Parish | Iron works | Heretics/ martyrs |
|--|------------|----------------------|-------------------------|------------|----------------------|
| 1 Alfriston | | M1 | 20 Hellingly | | H1 M1 |
| 2 Ardingly | Yes | | 21 Horsted Keynes | Yes | |
| 3 Brightling | Yes | | 22 Kirdford | Yes | |
| 4 Brighton | | M2 | 23 Lamberhurst | Yes | |
| 5 Burwash | Yes | | 24 Maresfield | Yes | |
| 6 Buxted | Yes | M1 | 25 Mayfield | Yes | M1 |
| 7 Chiddingly | Yes | H1 | 26 Mountfield | Yes | |
| 8 Crowhurst | Yes | | 27 Penhurst | Yes | |
| 9 Dallington | Yes | | 28 Rotherfield | Yes | H6 M2 |
| 10 East Grinstead | | H1 M3 | 29 Rye | | M1 |
| 11 East Hoathly | | H1 | 30 Salehurst | Yes | |
| 12 Eastbourne | | H1 M1 | 31 Ticehurst | Yes | H1 |
| 13 Etchingham | Yes | | 32 Waldron | Yes | M1 |
| 14 Fletching | Yes | | 33 Warbleton | Yes | M1 |
| 15 Framfield | Yes | | 34 Wartling | Yes | |
| 16 Frant* | Yes | | 35 West Hoathly | Yes | H2 |
| 17 Hailsham | | H1 | 36 Withyham | Yes | M2 |
| 18 Hartfield | Yes | | 37 Woodmancote | | M2 |
| 19 Heathfield | | M2 | 38 Worth | Yes | |
| * also 'disturbances' (political or religious) | | | <i>Unknown parishes</i> | | M7 |

A BLOOMFORGE IN FRANT – THE CASE OF MARRIOTT’S CROFT

J. S. HODGKINSON

In the second half of the sixteenth century three forges operated along the two-kilometre stretch of the upper reaches of the Teise, which forms the Kent-Sussex border south east of Tunbridge Wells: Benhall, Melhill and Marriott’s Croft; a fourth forge, known as Dundle, Dundale or Derondale, lay close to Marriott’s Croft on a tributary of the Teise. Straker’s description of their operating history states, somewhat enigmatically, that ‘It is very probable that in their early history they produced the bar-iron direct from the ore, although later on Benhall was a conversion forge’.¹ He gives no further explanation for this assertion.

A fragmentary document in the archive collection of Columbia University, New York, lends support to Straker’s statement.² It is one of four documents which may be from the personal papers of John Wybarne, of Bayhall, Pembury, Kent. He was the son of William Wybarne who had occupied Bayham Forge from about 1525 until his death in 1549. John Wybarne (d. 1591) is associated with Marriott’s Croft Forge in partnership with Jeffery May of Frant, as tenants of the descendants of Roger Breecher, the forge’s builder. Wybarne had a brother, William, and sons, William, Edward and George, who may be the WW, EW and GW mentioned in the text. John Wybarne is noted as having been a litigious person, which may go some way to explaining the heated atmosphere surrounding the negotiations that are described below.³

The text takes the form of a memorandum of a series of discussions and arguments about a proposed agreement between Wybarne and an individual identified only as TP. The matter at issue concerned the setting up of a bloomforge, in which iron ore would be smelted to produce a bloom of iron in a single process similar, but on a larger scale, to that found in bloomeries that had been used in the Weald in the Middle Ages and earlier. This differed from the more typical Walloon process being employed across the Weald in the sixteenth century, which involved the

two stages of blast furnace and finery forge. There is no firm evidence of bloomforges from the Weald, although it is possible that several early sixteenth-century forges in the region may have been of this type, being subsequently converted to fineries. The last of these may have been the 'blomary' built by Edward Tanworth (or Tanner) in Haslemere in c1602, which became Sturt Hammer.⁴ However, they are better known in several other parts of Britain in this period. Among these are two areas mentioned in the text, Staffordshire and Yorkshire. 'Norris of Leeghe', a Staffordshire 'bloomer', is mentioned. Leigh is between Uttoxeter and Cheadle, and a 'hammer smithy' was noted before 1577 a mere seven miles distant at Oakamoor.⁵ 'Bloomers' are recorded around Madeley, west of Stoke on Trent, in the same period and later. Workers brought to assist in Wybarne's bloomforge came from Yorkshire. Between the 1530s and 1590s there were bloomsmithies active in the Barnsley and Sheffield areas as well as further north.⁶

THE TEXT

[f.63v?] *Note that on Tuesday night, the 14th of November,⁷ upon reading of an indenture the which the foresaid TP had caused to be drawn at London, as he said, between me on the one part and WW and the said TP on the other part, by reason of such communication as had been between us in this matter, we did differ and disagree so much, before we had read the third part of that paper draft, that the matter did grow to a great heat between us. And he said then, as he had said divers times before, that he came only to benefit me and my son, and not for any gain to himself. And therefore he would leave all the work un-finished, and go his way. To whom I answered, that I was well content he should so do, except he should mean better unto me, than by that paper draft of the indenture it seemeth to appear.*

After this talk he went out of the parlour and I remained there until 9 of the clock, about which hour I did use commonly to go to bed. And when I was laid in my bed he sent EW to me, persisting in his former request according to the draft of the indenture the

which, as I think, he did draw himself for it hath neither good form nor order in it, and is contrary to our former agreement. His request by EW was, that he might have 3 bloom hearths set up, where our agreement was only upon 2 bloom hearths. If I would not set up 3, then he required to be abated and discharged of the third part of the profit weekly, quarterly and yearly the which he had promised to me and to WW. And except I did agree hereunto, he would depart the next morning, leaving all undone. I sent him word by the said EW that if he would tarry and see the work finished and the workmen to work at it, before he did depart, though he neither did, nor was able to do any thing himself, but to direct others, and make provision at my charges, the which he did very unprofitably towards me, yet would I bear all his expenses, the which he had bestowed about my business only, and give him £6 13s 4d in his purse at his departing. All which might be finished within one week and four days then next following as he himself reported. And that if he did not like of this offer, I would give him 40 shillings for his expenses, and be well contented that he should depart the next morning. Yet had he caused a poor man and his son to come out of Yorkshire to my house, in hope that the said work should have been ready for them to work at, 32 or 33 days now past, for whose board and victual I have and must pay all this time and till the work be fully finished, besides some other extraordinary charges, they not being able to labour by the day, nor to do any other work to any purpose or profit.

[f. 63] *To the which offer, he sent me this answer by the said EW, that he did not come for my money, nor would not have any money of me, and that he would be gone in the morning, with which answer I was well content,*

He went from my house in the morning to the ale at Heyseden Green,⁸ and procured the workman, the which came out of Yorkshire as is aforesaid, to depart also from this country with him into Yorkshire. The honest-meaning workman was more willing to tarry than to go with him. I sent WW to him, willing him to consider that it would be to his discredit if he did depart

so, and more to his discredit if he did take the workmen with him. He sent me word by Stapleton, the carpenter, who worketh about the water-wheel and about other water-work at the aforesaid bloom-smithy that he would be content to tarry and see the work finished and the workmen to work thereat, and I should consider him as I did think good.

Whereupon he and WW went to the work, and workmen together that day, being Wednesday. And the next day WW informed me that the said TP would not tarry about the finishing of the work except he were in hope to have a lease made unto him, and to the said WW according to the intent of our former communication. And I willed him that day, being the Thursday the 16th of November, to say to the said TP that seeing the communication the which was between us touching a lease, and divers other weighty and material points were now relinquished, renounced and counted as void by our mutual consent, I will no more deal with him touching any lease to be made. And therefore, if his tarrying were in hope of a lease, that he should depart when he list, for I have now less mind to deal with him than ever I had before.

That afternoon, TP came to my house, and we commoned⁹ of this matter together in the hearing of WW the elder and GW, at which time the said TP would not by any means confess that he did mean to depart and to leave the benefit of his pretended bargain, nor the work unfinished, where indeed besides that the which is before written, he went about to get him a horse to ride away, and threatened the said John Nayler, the workman, the which came out of Yorkshire, that he should go back again with him though he were unwilling thereunto. This matter resteth upon trial between us, whether the matter be broken off or not. And now he offereth more reason, that if I will not charge him by reason of his grant to pay more than the blooms are worth, the which are a[n]d shall be there daily made <and burned with the burn-hearth>,¹⁰ he will be content with two bloom-hearths and a burn-hearth, pretending

yet unto me that one of the bloom-hearths cannot be altered to a burn-hearth and both of them work at once with one wheel, as both the bloom-

[f. 62v] *hearths may do, but the workmen say the contrary. He confesseth besides that he did mean indeed to have a third bloom more than the common account is towards his own expenses and his clerk's wages, and that might be easily gotten by his diligent seeing to the work, and by causing the workmen to work twice a week by night also. Norris of Leeghe, the which was a bloomer in Staffordshire, said unto me that if the mine be good and the workmen do their part, with spending of 16 or 18 bushels of mine at the most, a bloom of five hundredweight may be daily cast at every bloom hearth. If the mine be indifferent good, and not excellent, the bloom will weigh about four hundred and a half. Now if our blooms do weigh four hundredweight, TP may gain to himself the fourth part of the blooms there cast, after the reckoning and proportion that he hath set down to me, the which is after three hundredweight in every bloom, asking allowance of a load of coal and of a load of mine, wherewith the said stuff may be cast a bloom of five hundredweight or four hundred and a half at the least, ut supra, per Norris de Leeghe.¹¹*

And so note that TP dealeth <not> with me sincerely without shift of discount and therefore I have the more need to take good heed before I bargain with him. Since our former talk touching the indenture, the which he caused to be drawn at London as he saith, he hath reported that now we are fallen to a thorough agreement, and that I am come to his own request, and that now he shall have a lease by word, but not by writing, per Stapleton wherein he saith very untruly, for I never thought it, nor said it, neither will deal with him for any value by word only, who useth so many words in vain as he doth.

On Tuesday the 21st of November we differed so much and were so loud in our talk at dinner that TP departed in a pelting chafe, and afterwards my cousin Greene, William Wybarne and I did

talk of the matter more quietly, and the greatest deceit that I could lay against him was this, that he did set down for his proportion in coal for one week's work in the day time 20 loads of coals, where indeed 12 will serve, and by this means he might spend 8 loads of coals of my provision by night also weekly, and neither William Wybarne nor I should have any commodity of the gain Thereof, by amity or otherwise, but only be paid for the coal.

Likewise did he set down in his proportion, that every bloom should contain 3 hundredweight, or thereabouts, where by other men's estimation the bloom will contain 4 hundred weight and a half, and so should clearly the third part of every bloom to himself, all charges borne, for the workmen have their wages by the bloom, and by the hundred, the which doth amount to 18 pence at the bloom hearth, and other 18 pence at the burn hearth; yet did he affirm unto me that the whole charges at the bloom hearth and at the burn hearth was but 2s 6s for every bloom, and besides this, every workman hath of standing wages

[f. 62] *forty shillings yearly his livery cloth, or ten shillings his dwelling and fire. Hereunto he answereth now, that for all the coal and mine wrought out in the night time, I and WW shall have as much profit, rate- like, as we have for so much spent in the day time, over and besides that, the which is spent on the day time, of the said proportion of 20 loads of coals and 30 loads of mine, for one week's work. He sayeth further, that 2 bloom hearths and a hammer may work with one wheel. And that when his blooms be cast, and divided into smaller blooms, they may be heated in the bloom hearths, without any more coals spending then to the great blooms, and then wrought under the hammer without working of them in the bloom hearths. And hereupon as he sayeth, did he make his chief account of his private gains to rise. Inquire of this.*

The individual named as TP in the text clearly has connections with Yorkshire as the worker he has brought to assist in the bloomforge has come from there. This may be the key to his identity. In about 1574 Thomas Procter, a minor Yorkshire landowner, acquired property at

Warsill, about three miles from the former abbey at Fountains.¹² At some point in the next few years he seems to have set up an ironworks on his land. Whether this was a bloomforge or a blast furnace is not known. Bloomforges were established technology in the county, but the first blast furnaces in Yorkshire had already been set up in the 1570s near Sheffield and at Rievaulx. Procter was an enterprising proprietor and began to experiment with using coal instead of charcoal in ironmaking. However, he got into financial difficulties and in 1586 his ironworks were mortgaged to William Brokebank, a London Grocer, who had already purchased the neighbouring Brimham estate. What makes this particular venture relevant is that, although it failed, it provided the opportunity for the involvement of Thomas Dyke, who is described as ‘of Pembury’, in the spread of blast furnace technology in Yorkshire.

The Dyke family were, or became, involved with all three of the forges adjacent to John Wybarne’s at Marriott’s Croft. Dundle was already leased by Thomas Dyke from Henry Darrell before 1573, when the latter’s son, Christopher, sold it to him. It was still in his hands in 1588 but probably went of use by the time of his death in 1615. In 1598 Thomas Dyke acquired the manors of Sunningleigh and Frant, in which three of the forges were located.¹³ In 1633 Thomas Dyke’s son, William, acquired the Melhill and Benhall forges, the latter remaining in the family until the 1660s.

Thomas Dyke’s connections with Yorkshire were twofold: his second son, Robert, was established at Westwick, south-east of Ripon, having briefly lived at Brimham; and in the late 1580s he purchased the Brimham and Warsill estates from William Brokebank, who had acquired the latter in default of mortgage from Thomas Procter. Dyke went on to set up a blast furnace on the Thornton Beck where Procter had probably had his own works earlier.¹⁴ Robert Dyke’s presence in the North Riding would have enabled him to come into contact with other local landowners and to be acquainted with what was going on in the area, and to pass this on to his father.

After the financial failure of his enterprise in Nidderdale, in 1586 Thomas Procter went to London in pursuit of a patent for his new ironworking process, but he had not ceased direct involvement in ironmaking, for he became tenant of a bloomforge at Shipley, near

Bradford, where trials of his new process were undertaken.¹⁵

The coincidences of Thomas Procter's connections with the Dykes make a case for Thomas Procter being one of the parties concerned. The Dykes and Wybarnes would have been well acquainted both socially and through their common involvement in neighbouring ironworks, and would have been aware of Procter's probable presence in London in 1587, one of the years in which the extract above could have been written, and where TP was said to have drafted the document referred to in the extract.

The bloomforge process was akin to the bloomery that had been in use in the Weald since pre-Roman times. However, during the course of the Middle Ages the size of bloomforges, bloomhearths or bloomsmithies as they are variously known, increased. Also the shape of the hearth changed from the 'shaft' bloomery to a more open form akin to the Catalan forge, where the melting iron ore was worked with iron rods. Generally such works were separated into two operations: the bloomhearth and the stringhearth, the iron being smelted in the former and the resulting bloom consolidated and forged in the latter. Occasionally these operations were carried on at separate sites. Such separation of operations seems to have been proposed at Marriott's Croft in the reference to 'two bloom-hearths and a burn-hearth', the term 'burn-hearth' suggesting a forging hearth, equivalent to the stringhearths noted in other parts of the country.¹⁶

The second development was the increasing use of water power, particularly for smelting. The mechanisation of the bellows reduced the manpower required, the depopulation resulting from the Black Death making the use of machinery economically more necessary.¹⁷ Water power in iron making is often associated with the introduction of the blast furnace and the need for a more powerful blast of air and continuous operation, but its regulated use at lower pressure in a bloomforge made as much sense. Water power was clearly a consideration at Marriott's Croft, where the use of a single water wheel for two bloomhearths and a hammer was proposed, though it is difficult to see how the engineering of such mechanical economy might have been accomplished satisfactorily. Clearly no geographical separation of the operations was implied.

Output per bloomhearth of a 5-hundredweight bloom per day at

Marriott's Croft was considered worth aiming for, although lesser sizes of 4½ or 4 cwt were considered. No annual output is suggested. The Staffordshire bloomer, Norris, considered that 16 or 18 bushels of iron ore were enough to produce the largest bloom, though it is not known how well he knew the content of the Wealden ores, or whether the ore was roasted. 16 bushels (2 quarters) producing 5 cwt of iron equates to 2 tons of ore for 1 ton of iron. Given that, in the 18th century, John Fuller reckoned that about 2½ tons of roasted ore made a ton of iron in the more efficient blast furnace, and that ore lost about 30 percent of its weight in roasting, Norris's estimate may have been rather optimistic.¹⁸ A 3-cwt bloom, also mentioned, was probably more realistic.

Also of interest are the proposed costings. As at the fourteenth century ironworks at Tudeley, near Tonbridge,¹⁹ each worker was to be paid by the bloom 'and by the hundred', the average cost of a bloom at Marriott's Croft being estimated at 2s 6d (though the separate hearth costs totalled 3s). In addition each worker was to be paid a standing wage of £2 a year, and his (or her) uniform or 10s towards domestic expenses. No distinction between the roles of particular workers is mentioned, such as were defined at the bloomforge at Kyrkeknott, co. Durham, in the early-fourteenth century.²⁰

It is not known whether the proposals to set up a bloomforge at Marriott's Croft were ever carried out but the lack of other evidence of any other description of the works than as a forge suggests that they were not, and that Thomas Procter and his fellow Yorkshireman returned from whence they had come.

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7. Being in the Julian calendar, in which leap years occurred every four years without exception, it is possible to ascertain in which years of the sixteenth century the 14th of November fell on a Tuesday, based on a calculation back from the last day of the Julian calendar in England, which was Wednesday 2nd September 1752. These were: 1503, 1508, 1514, 1525, 1531, 1536, 1542, 1553, 1559, 1564, 1570, 1581, 1587, 1592 and 1598. Of these, the last two can be ruled out as John Wybarne died in 1591. According to the post-mortem inquisition of his father, John was born in about 1523, so the first seven dates, covering his childhood and adolescence, can be reasonably dismissed (S. F. Weyburn, 1911, *Weyburn-Wyborn Genealogy* (Frank Allen, New York), 127-8). He cannot have taken control of any of the ironworks of Roger Breecher until the latter's death in 1567, which leaves only the years 1570, 1581 and 1587 as possibilities.
8. A former hamlet about 1.75km SE of Leigh and 3km WSW of Tonbridge, in Kent.
9. communed?
10. Contemporary insertions in the text are shown between <> marks.
11. Trans. 'As above, according to Norris of Leegh.'
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Memoirs 1997, British Mining, **59** (Keighley, Northern Mine Research Society), 32-51.

15. Collinson, 'Enterprise and experiment', 195.

16. For an example *see* D. Crossley & D. Ashurst, 1968, 'Excavations at Rockley Smithies, a water-powered bloomery of the Sixteenth and Seventeenth Centuries', *Post-Medieval Archaeology*, **2**, 10-54.

17. Schubert, *History*, 134.

18. Blackman, H., 1926, 'Gun Founding at Heathfield', *Sussex Archaeological Collections*, **67**, 30.

19. Hodgkinson, J. S. & Whittick, C. H. C., 1998, 'The Tudeley ironworks accounts', *Wealden Iron*, Bulletin of the Wealden Iron Research Group, 2nd ser., **18**, 7-38.

20. Lapsley, G. T., 1899, 'The account roll of a fifteenth-century Ironmaster', *English Historical Review*, **14**, 509-17; P. W. King has pointed out that the name of the site should be read as Kyrkeknott rather than Byrkeknott as Lapsley had stated.

'KINIANS' FORGE – A SUGGESTED IDENTIFICATION

J. S. HODGKINSON

In a manuscript list, now lost, of ironworks operating in the Weald between 1653 and 1664, among the forges recorded as having ceased working between those dates is Kinians, for which no satisfactory identification has been suggested to date. First published by Lower in 1866, the list had been among papers preserved at Horam, the former seat of the Dyke family of ironmasters.¹ Lower relied on a transcription, which he reproduced with annotations. The forge appeared in the list between Tickeridge Forge, in Framfield, and Freshfield Forge, the list having some semblance of a geographical arrangement, east to west. In 1882, Parsons re-printed the list with some minor differences, although without annotation,² and in 1975 David Crossley produced a composite version of the list comparing the two previous transcriptions.³ He, too, was unable to suggest the identity of Kinians.

A forge in existence in 1653 is absent from the list. A measured survey of the demesne lands of the Manor of Marshalls, in Maresfield, by Anthony Cuerenden, was completed that year for the Revd. John Nutt.⁴ The Rector of Bexhill and of Berwick, and Prebendary of Chichester Cathedral, Nutt had purchased the manor from John Rootes in April of that year,⁵ only to die the following December. The map includes a small illustration of a forge building at the southern end of the 'Hamer Pond'. The drawing of the forge building has three chimneys (all with flames issuing therefrom), indicating that it had three hearths, presumably two fineries and a chafery, and two waterwheels are shown, probably for the two fineries, the remaining two waterwheels, for the chafery and hammer, being out of sight on the other side of the building. Straker had identified the site as Lower Marshalls but had failed to locate the pond bay.⁶ The WIRG Field Group found the pond bay with both furnace and forge slag and, from the place name evidence of 'Langle Felde' and 'Langlee Woode', adjacent to the site, identified it as the former Langleys Furnace,

one of the furnaces operated by Ralph Hogge in the late-sixteenth century.⁷ Its dual use was later confirmed by a site survey.⁸ The drawing of the forge, with its active chimneys, on the plan of 1653, is sufficient evidence to suggest the forge was operational at that time.

Aspects of the operation of Ralph Hogge's four ironworks have survived in a set of accounts, which largely concern the years 1576-8.⁹ Although the accounts were in the hand of John Henslowe, Hogge's brother-in-law, he makes reference to other books of accounts kept by two other individuals, George Kenyon and Samson Colestock. There is no indication whether either Kenyon or Colestock were specifically concerned with particular works but George Kenyon, who lived in the adjacent parish of Fletching, had become Hogge's 'servant' in about 1573, remaining so until about 1582. In 1584 he became embroiled in a Chancery action with Hogge that had not been resolved at the time of the latter's death the following year.¹⁰ In 1596 George Kenyon was one of the witnesses to the will of John Rootes, of Maresfield, the lord of the manor of Marshalls and Kenyon's would-be landlord.¹¹ Kenyon, who died in 1617, left no will and the administration indicated that his estate probably amounted to about £400, but no inventory has survived so whether it might have listed stock or equipment relating to an ironworks is not known.¹²

No records seem to have survived to suggest a closer connection, but given that George Kenyon resided in Fletching parish, whose boundary with Maresfield runs along the western edge of the Langleys site, could Kenyon have been particularly involved with Langleys, and perhaps more so after Hogge died, to the extent that the site became synonymous with Kenyon and was known as Kenyon's? It would not have been the first time that an ironworks had been known by the name of one of its former occupiers; Breecher's Forge (Marriotts's Croft), Paler's Furnace (Coushopley), and Glazier's Forge are examples. A simple mis-spelling by the author of the 1664 list could have rendered Kenyon's as Kinians.

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THURSLEY UPPER HAMMER POND (SU9157 4036)

DAVID AND AUDREY GRAHAM

Thursley Upper Hammer Pond is the first of the Thursley iron works and is listed as the site of a forge and furnace. The earliest reference comes in a deed of 1610 when the works were described as ‘lately erected and built’.¹

The exceptionally heavy rains of December 2013 overwhelmed the sluice system and the resulting overflow cut a section right through the dam, completely emptying the pond bay. This left a section exposed through the earthwork of the dam on the east side of the stream. This section was photographed and recorded by the authors with the kind permission of Natural England and James Giles, the local warden. The only caveat is that the section was unstable, had partially collapsed and, in places, the stream bed was soft and difficult to stand on. As a result of the potential hazards the results are not as clear as we would have wished, but while some detail may be lacking, we feel that the major elements of the stratigraphy are reasonably clear.

The pond bay dam, as it currently exists, is slightly over 11m wide (it was not possible to reach the front, pond side, of the dam) and about 3.5m high from the underlying natural gravelly sand to the highest point of the earthwork. As can be seen from the schematic section (Fig. 1), and perhaps on the photograph (Fig. 2), the core of the dam consists of a dump of clay about 38cm high at its thickest and roughly lying in the centre of the dam. This had been covered by a much thicker deposit of yellow sand interspersed with several bands of ash – no doubt the result of various episodes of tipping during the construction process. On the pond side of the dam the yellow sand had been covered and partially cut into, by two very hard packed layers of slag and ash partially separated from each other by a thin layer of grey sand, and butting, in the centre of the dam, on a deposit of black sand. The upper of the slag layers also contained quantities of vitrified material – possibly the discarded lining of

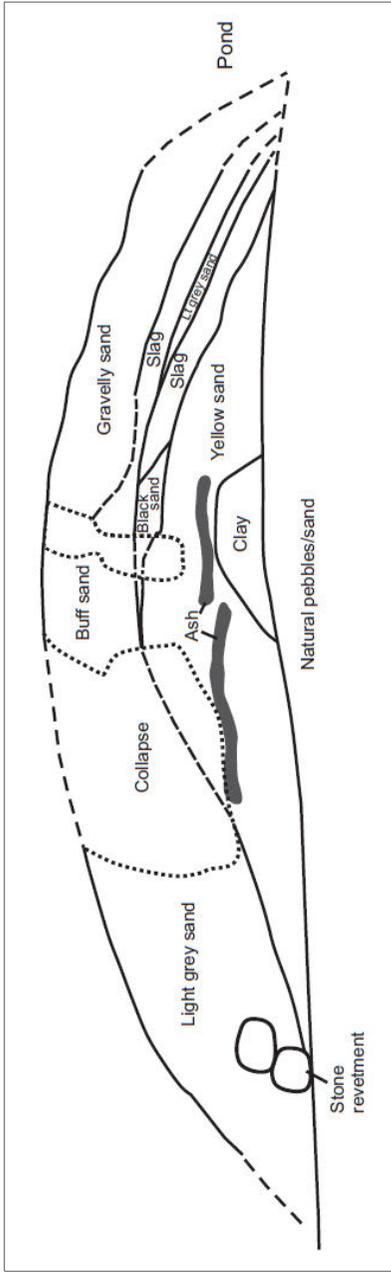


Figure 1 – Schematic section of east face of dam



Fig 2 Photograph of east face of dam



Fig 3 Photograph of west face of dam, showing the brick culvert

a furnace. These deposits presumably formed the face of the dam in contact with the water of the pond.

To the rear of the junction (the details of which were obscured by fallen soil and vegetation) between the yellow sand, black sand and the layers of slag, the yellow sand rose to be roughly level with the upper surface of the slag. Capping the front, pond side, of the dam was a thick layer of gravelly sand and to the rear this continued as relatively clean grey sand from which we recovered a few fragments of roofing slate. To the front of the dam was the remains of a post and horizontal plank sluice, the remains of part of which can be seen in the photograph. The timbers are of unknown date but may be of some antiquity and had been preserved by being underwater and, until recently, covered by silt. The timber work may perhaps have formed a temporary sluice when the 19th century brick sluice was installed (Fig. 3). It is also conceivable that it is of greater age yet and connected with the iron works themselves. To the rear of the dam the remains of a low revetment wall of stone showed in section and ran across the line of the stream. This probably also relates to the 19th century works.

It is, of course, unknowable how many times the dam was rebuilt during the lifetime of the works, but it seems likely that the now visible core of the dam relates to the period of iron working activity on the site.

Sadly no finds of pottery or other artefacts were recovered to confirm this.

The upper layers of gravelly sand and, to the rear, grey/buff sand may well then belong to a later repair of the dam. Slate does not commonly appear in the area until after the coming of the railways in the mid-19th century. The find of occasional pieces of slate in the capping layer of sand could therefore be taken to suggest that the pond was refurbished in the mid/late 19th century.

This suggestion is supported by the fact that on the opposite (west) side of the cut the flood had exposed a double-skinned brick wall fronting the dam and a brick-built domed culvert through the dam – all part of a sluice system that, from the use of bricks with no frogs, again probably relates to works in the 19th century. This was capped by layers of gravelly sand and cleaner sand, completely different from the layers in the opposite face of the dam. This perhaps implies that the 19th century works were carried out in a cut in the pre-existing dam.

The only other point noticed was that, on the downstream side of the dam, a causeway now carries the main footpath across the stream valley behind the pond bay dam itself. Again this had been partially eroded by the floodwater, which had caused a collapse of part of the upper rear section of the causeway. This consisted of dark sand and a mass of concrete rubble, which implies that, at least the upper level of the causeway, is fairly recent in date. The causeway itself is shown on the 1846 Tithe Map, so the concrete must relate to a modern repair, possibly connected with the use of the common as a military training area during or after World War 2.

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FULLER'S DESCRIPTION – NOT A WEALDEN BLAST FURNACE

DR TIM SMITH

The long held belief that a description of the operation of a blast furnace found amongst the Fuller papers refers to an 18th century English Wealden furnace is, I contend, the translation of a section of Emanuel Swedenborg's book '*Regnum subterraneum, sive minerale de Ferro*', published in Latin in 1734, and that it describes the operation of a Swedish charcoal blast furnace.

The original manuscript was transcribed by Richard Saville and published in the *Historical Metallurgy*, the Journal of the Historical Metallurgical Society under the title '*The operation of Charcoal Blast Furnaces in Sussex in the early Eighteenth Century*'.¹ It seems this title is the root of the misconception.

The manuscript of the account is held in the East Sussex Record Office (ACC 2449/5/1). It is undated and the writer unnamed. Its format is notebook size, approximately 150 x 200mm with pages formed by folding twice this size and loosely stitching together at the fold. A common hand appears to have been used throughout its 28 pages although page numbers have been added by a different hand, one number per open double page.

Found with papers held by the May family which contain papers identified as written by several members of the Fuller family, the curators of the Record Office have dated it at about 1740 in view of its context with the other documents associated with it, and likewise attribute it to a John Fuller because of this context.

Since the description was attributed to a John Fuller in the JHMS article, I will refer to it as the Fuller description.

Field Evidence

There have always been certain oddities in the text that did not seem to fit

the field evidence on the Weald. For instance, Fuller refers to the breaking of ore with a water powered hammer: *'The mine being first Burnt is broken partly in pieces partly into dust, by a Hammer which goeth with a waterwheel...'*. But excavations of blast furnace sites on the Weald have never shown evidence of water driven hammers to crush ore and the predominant siderite ore on the Weald is relatively soft and easy to break – particularly after roasting. In contrast, much of the Swedish ore is a hard magnetite which is not only more difficult to break but would also require crushing to a finer size than the Wealden siderite ore which, being a carbonate, becomes porous on roasting.

Further, Fuller refers to the colour of the slag being green indicates a good smelt

...If the colour of the drop be Green, and the fluidity everywhere equall, tis a sign the quantity of coal and mine is as it should be.'

But the blast furnace slags on the Weald are nearly always dark in colour, dark green and often close to black. In contrast, Swedish furnace slags are frequently light green and blue in colour. Also, Fuller refers to measuring charcoal in 'Lasts', the *läst* being a Swedish measure of weight: *'...a modern furnace holds about holds [repeated in manuscript] from 12 to 8 [a copy error? 18 in de Ferro] Lasts of Coales'*. In the margin, in the same hand, is a note that *'A Last of Coales about 12 Bushels.'* (Fig 1).

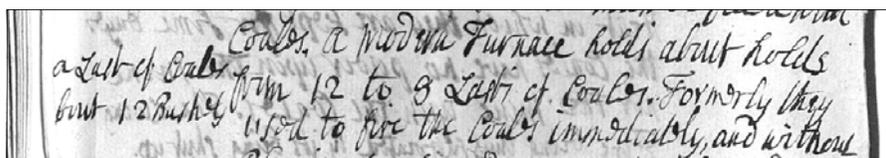


Figure 1 – Margin insert in Fuller's manuscript defining the Swedish *läst* as 12 bushels

Documentary Evidence

My suspicions were confirmed when I sent a copy of Saville's paper to Bosse Sundelin who is operating the replica 14C blast furnace at Nya Laphyattan in Sweden. He has a Swedish translation of *de Ferro* and

came back to say that large sections of the text are identical to what Emanuel Swedenborg wrote in *Regnum subterraneum, sive minerale de Ferro*, referred to as *de Ferro* for brevity in this article. What is more, Bosse says, Swedenborg first published this description in a paper in 1717.

This prompted me to look at the original document attributed to Fuller in the East Sussex Record Office and to compare this with a facsimile of Swedenborg's *de Ferro*; all 386 pages of the book have been scanned by Google and can be downloaded from the internet.

First, if the English version is attributed to John Fuller, any of four John Fullers could have accessed the work to translate it:

John Fuller (1652-1722) built Heathfield furnace, in Sussex in 1693;²

John Fuller (1680-1745) leased and later owned Heathfield Furnace 1722-45;³

John Fuller (1706 –1755) owned Heathfield Furnace 1745-55;

John Fuller (1757-1834) owned Heathfield Furnace 1777-93.

The first of these could have had access to Swedenborg's earlier paper of 1717. The later three to the paper or the book, *de Ferro*, published in 1734.

To ascertain if the work is a translation of the Latin text into English a number of sections of *de Ferro* have been translated into English by Anne Drewery, a Latin language scholar, for comparison with the Fuller work.

Fuller's account makes no reference to a Wealden blast furnace. It is titled,

How the melting work is begun and how the furnace is filled with coals from the bottom to the top and for some days shut up close

A similar sub head occurs on page 30 of *de Ferro*,

Quomodo opus liquefactorium inchoatur, & caminus ab imo ad summum adimpletur carbonibus & dein per aliquot dies occlusus tenetur

which translates today as:

How the work of melting [or the founders] is begun, and the furnace from the bottom to the top is filled with charcoal and then is kept closed up for some days

There are further substantial indications that the 'Fuller' account is a translation of *de Ferro*. On page 13 of the Fuller manuscript a section of

the English text is missing and indicated with dashes

The Crumbs are like to --- --- --- From the first day to the 12th...

In the margin is inserted the Latin which appears to read, *nibido sterili Glacici marias* (Fig 2). In *de Ferro* p. 40 this line is, *nitido sterili seu*

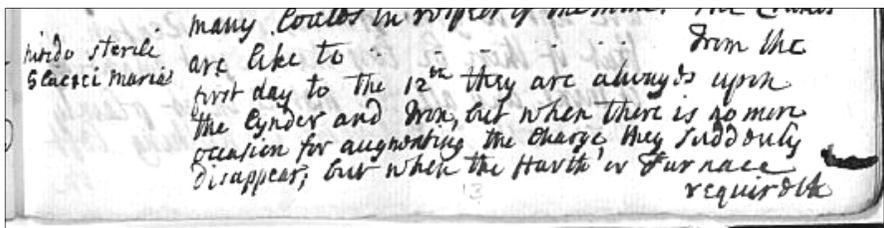


Figure 2 – Latin insert in margin indicating untranslated text in the line showing gaps

copiam carbonum in ratione ad venam esse. Micæ dictæ similes sunt nitido sterili seu glacii Mariæ, ut vocatur; primis diebus usque ad 12mum jugiter icorus & ferro inhiident: at vero cum nulla augmentatio amplius ne-

Figure 3 – The Latin phrase in De Ferro untranslated by Fuller (author's underlining)

glaciei Mariæ (Fig 3). This translates as: The said grains are similar to bright or pure glass of Mary. *Glacies Mariæ* is possibly selenite - a transparent form of gypsum - or possibly mica. This was used during the Middle Ages to protect icons of the Virgin Mary.

Further, commencing on page 40 of *de Ferro* is a list of 11 factors to look for when deciding if more ore or more charcoal is required in the charge. Fuller lists and numbers all 11 faithfully. For example we commence in Fuller's words with,

1 If there appears some Crumbs or scales sticking in the Cynders or dross, especially in those which come out of the Hearth with the cast Iron, sometimes such crumbs lye upon the Iron itself; as often therefore as the Cynders are scaly, or the Iron itself, is a sign that the Furnace wants more mine ...

The modern translation of this text in *de Ferro* reads:

1 If there appear some grains or scales clinging to the separated

recrements (cinders or dross) and especially in those which are accustomed to flow out from the hearth with the last iron - sometimes also similar grains lie upon the iron itself - as often, therefore, as the scoriae (slag) or the iron itself are scaly in this way, it is a sign that a portion of ore is needed...

In the second entry of the list Fuller records:

2 If the If the [repeated] Rerements comeing out of the Fire are a white Colour, especially in the Extremityes, or be white and Green, tis a sign more mine should be put up. The first day the Cynders are white, which seemeth to arise from the Lime stone, for the same quantity of this stone is put up att first, as att last, tho in the first dayesthere be put up but 4 Boshes to 12, the Last 24 Boshes; But if the mine be poor, ...

The modern translation of this text in *de Ferro* reads:

2 If the recrements coming from the hearth are of a white colour, especially in the extremities, or if at another time they become white and green, it is also a sign that a greater quantity of ore is to be put in. On the first days the scoriae [slag] become white, which seems to arise from the limestone [*lapide calcario*]; for the same quantity of this stone is added on the first days as the last, although on the first days only 4 to 12 vessels of ore are placed in each day, on the last 24. But if the iron ore is poor ...

Such similarities occur in all 11 of the listed factors.

11thly If the mass of Raw Iron be as it were polished and smooth, it signifieth the want of more mine: If the iron sparkle when it breaketh forth of the Harth, there wants more coales. I shall speak of more things hereafter, when I treat of Guessing att the Coction in the Harth.

The modern translation of this text in *de Ferro* reads:

11 If the mass of the raw iron outwardly is as if polished and smooth, it signifies that more of the ore is required: if the solid content of the iron sparkles when it bursts forth from the hearth, more charcoal is needed; and there are many other things, concerning which in the following, when the divination of the coction in the hearth is discoursed

Moreover, the Fuller account is incomplete, ending on page 50 of *de*

Ferro with a description of the activity of slag in the furnace

...*If the iron has been naked and all the Cynders taken of, so that then is a motion stirred up in the Iron, which doeth not cease, till the Fermentation is finished, and the Lighter parts are separated from the Heavier and the cooler from the Hotter parts*’. [End of account].

The modern translation of this text in *de Ferro* reads:

...if the iron is made bare, all the scoriae (slag) having been taken away, that heat and violent motion are easily set in motion: for the ore, sliding into the hottest and heaviest liquid, is not able immediately to unite both the heat and the weight, but a certain inharmonious harmony arises; whence the iron is also roused into motion which does not cease before the fermentation is complete and the lighter from the heavier, that is, those which are able to take in the lesser heat from those which are able to take in the greater, are separated.

The Latin text of *de Ferro* continues for a further 12 pages. Missing from the Fuller description is the tapping of the iron, the preparation for casting it and controlling the cast.

A Translation

Anne Drewery kindly translated these examples to greater length than included here as well as additional sections corresponding to 1400 words in English in total. She concludes that the English manuscript is indeed a translation of *de Ferro*.

Thus the question is, did Swedenborg copy Fuller or Fuller simply translate a section of *de Ferro* relevant to his interest in operating a Wealden furnace? Swedenborg was known to have visited England (as well as Germany and the Netherlands) to study iron production between 1710 and 1715. Indeed, he visited the Weald and other ironmaking regions in England and his description of English practices is included elsewhere in *de Ferro*. The part relating to blast furnaces and the casting of iron have been translated and published in the WIRG Bulletin of 1999.⁴

Not only do the anomalies between the description and the field evidence in the Weald indicate that what we have does not describe a Wealden furnace but the notes by the same hand in the margin referring to a ‘Last’ and the untranslated reference to *Glacies Mariae* indicate that the

manuscript is indeed a translation from *de Ferro*.

Attempts to attribute the handwriting of the manuscript to one of the John Fuller family from other papers identified as being in the hand of a John Fuller have only succeeded in eliminating John Fuller 1680-1745 as the author by comparison with a letter to his son, Rose, dated 3rd February 1735.

Nevertheless, the document makes a valuable contribution to the operation of an 18th century blast furnace and we should be grateful to Richard Saville for bringing it to our attention. Thirty five years after its publication, the advent of the internet is providing easy correspondence with a much wider international community and access to scanned documentation enabling us to expand our knowledge and make corrections where due.

Acknowledgements

With recognition to Bosse Sundelin for bringing the similarities of text to my attention, to Jeremy Hodgkinson for directing me to the translation of part of *de Ferro* in the WIRG Bulletin and the facsimile of *de Ferro*, Anne Drewery for her translation of the sections of *de Ferro* used here, Gerry Crawshaw in assisting Anne, and David Crossley for his confirmation that he found no evidence of the breaking of ore by water-driven hammers during his extensive excavations on the Weald.

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