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Contents

The map which forms the cover illustration comes from William Waller's book 'An Account of the Cardiganshire Mines' printed in London in 1699.

Although at first glance it appears to be a rather stylised picture of the country inland from Aberystwyth, it will repay careful inspection as it forms an interesting catalogue of the more important lead mines in the area which the Historical Metallurgy Society's 1977 Annual Conference will be sited.

We are indebted to the National Museum of Wales for the reproduction from which our cover was made.

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The North Staffordshire Iron Industry 1600-1800

Peter Lead, ©

Writing in 1963, Professor S H Beaver stated that 'the history of the iron industry in North Staffordshire is known in broad outline but there are many details to be filled in, particularly before 1854.'[1] Since that date there have be comparatively few articles on the local iron industry, the major exception being the chapter entitled 'Iron', in the Victoria County History of Staffordshire, by Professor B L C Johnson and Dr A Birch.[2] Another significant contribution has been made by B M Hardman who has transcribed the Minute Book of the Silverdale Iron Company, for the period of its existence, 1792–1815.[3] Meanwhile in the eastern part of the area, H A Chester has been continuing his detailed studies of that part of the industry centred on the Churnet Valley and his book should appear within the next few years.[4]

In his paper Professor Beaver proposed a division of the history of the local iron industry into six chapters,[5] but in doing so he did not take into account the period before the introduction of the blast furnace to North Staffordshire. An increasing body of information points towards this being a serious omission, especially with regard to Newcastle-under-Lyme which was the centre of a flourishing iron working area by the thirteenth century.[6] Indeed the centuries before 1600 seem to have been characterised by a widespread industry based on the bloomery process and involving small units of production, associated with industrial hamlets rather than towns or villages. The late F W Dennis described many likely bloomsmithy sites, although there are many others which he did not locate and list.[7] The availability of water-power was the primary locational determinant, but a significant factor was the 'Oliver', a treadle-operated tilt hammer which Dr Plot saw at work in North Staffordshire smithies, during the late 1670's.[8] By this time the bloomery process had long since been abandoned in the area, but the 'Oliver' had been retained and adapted to other uses.[9] The period of the local industry which has received the most attention is that which might be termed the era of the charcoal blast furnace, between 1590 and 1790, although these are only approximate dates and change was a gradual process. Professor B L C Johnson produced a major study, based on the Foley papers; he examined the major sector of the local iron industry, during the rather restricted period, 1688–1712.[10] A complementary study was produced by B G Awty, whose study of the Cheshire and Lancashire iron industries between 1600–1785, also includes valuable information on certain North Staffordshire works and partnerships which often cannot be separated from those of adjacent parts of Cheshire.[11] Indeed, it seems pointless to separate the industry too strictly on administrative divisions and thankfully, few writers have attempted to do so.

Professor Johnson's paper has given rise to a somewhat distorted picture of the iron industry during the era of the charcoal blast furnace, the very title of his paper 'The Iron Industry of Cheshire and North Staffordshire, 1688–1712', is in itself rather misleading. It is in fact a paper concerned with the major grouping of ironworks, during a short period of time; and so, despite the title of the essay, the picture is in no way comprehensive. The realisation of these limitations is crucial, but they in no way detract from the immense value of the essay as an account of the majority of the local ironworks during the period in question.

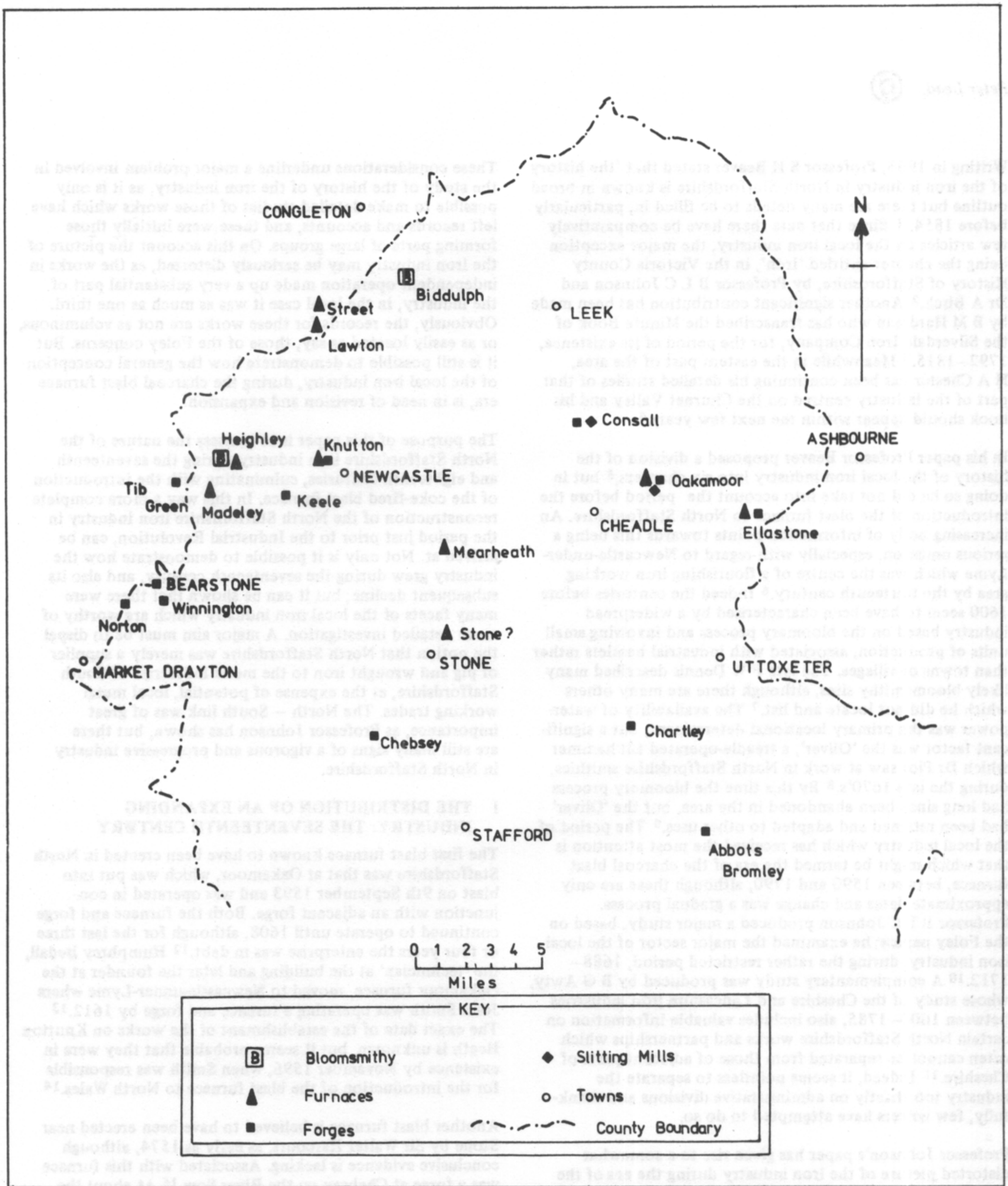
These considerations underline a major problem involved in the study of the history of the iron industry, as it is only possible to make detailed studies of those works which have left records and accounts, and these were initially those forming parts of large groups. On this account the picture of the iron industry may be seriously distorted, as the works in independent operation made up a very substantial part of the industry, in the local case it was as much as one third. Obviously, the records for these works are not as voluminous, or as easily located as say, those of the Foley concerns. But it is still possible to demonstrate how the general conception of the local iron industry, during the charcoal blast furnace era, is in need of revision and expansion.

The purpose of this paper is to reassess the nature of the North Staffordshire iron industry during the seventeenth and eighteenth centuries, culminating with the introduction of the coke-fired blast furnace. In this way a more complete reconstruction of the North Staffordshire iron industry in the period just prior to the Industrial Revolution, can be arrived at. Not only is it possible to demonstrate how the industry grew during the seventeenth century, and also its subsequent decline; but it can be shown that there were many facets of the local iron industry which are worthy of more detailed investigation. A major aim must be to dispel the notion that North Staffordshire was merely a supplier of pig and wrought iron to the metal industries of South Staffordshire, at the expense of potential, local metal working trades. The North – South link was of great importance, as Professor Johnson has shown, but there are still many signs of a vigorous and progressive industry in North Staffordshire.

I THE DISTRIBUTION OF AN EXPANDING INDUSTRY: THE SEVENTEENTH CENTURY

The first blast furnace known to have been erected in North Staffordshire was that at Oakamoor, which was put into blast on 9th September 1593 and was operated in conjunction with an adjacent forge. Both the furnace and forge continued to operate until 1608, although for the last three or four years the enterprise was in debt.[12] Humphrey Bedall, the 'technician' at the building and later the founder at the Oakamoor furnace, moved to Newcastle-under-Lyme where John Smith was operating a furnace and forge by 1612.[13] The exact date of the establishment of the works on Knutton Heath is unknown, but it seems probable that they were in existence by November 1596, when Smith was responsible for the introduction of the blast furnace to North Wales.[14]

Another blast furnace is believed to have been erected near Stone by Sir Walter Harcourt, as early as 1574, although conclusive evidence is lacking. Associated with this furnace was a forge at Chebsey on the River Sow.[15] At about the same time an ironworks was operating near to Trentham, and from 1580 to 1598 it was leased by the Leveson family to John Olcoatt of Talke.[16] This works was, in fact at Normacot, on the site later occupied by Mearheath furnace, and was probably one and the same as the 'iron mill' mentioned, in 1582 as being at Longton,[17] As the Normacot site was just inside the parish of Stone at this time, there seems to be a strong possibility that the so called Stone furnace was at Normacot. Should this prove to be the case,



The North Staffordshire Iron Industry During The Seventeenth Century

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then it will be necessary to revise the accepted idea that the first blast furnace in North Staffordshire was that at Oakamoor.

Another early furnace, again with an associated forge, was that at Ellastone, known to have been operating in 1607, when a Thomas Turneley, a founder is mentioned in the Ellastone Parish Registers.[18] Other references mention a John Maberye and a Richarde Jolley, both described as hammer-men, in 1603 and 1605 respectively.[19] In view of these earlier references to forge workers, and in the light of references to wood-colliers, as early as 1599, it seems reasonable to conclude that the furnace and forge were operational by 1600.[20] Professor Johnson has quoted a document which states that there was a furnace and forge at Ellastone in 1620,[21] and it is traces of these works which have been located by Dr A E Dodd in recent years.[22]

Despite the rapid spread of the blast furnace in North Staffordshire during the closing decades of the sixteenth century, the bloomsmithies were not immediately displaced. 'Bloomers are mentioned at Madeley in 1571,[23] 1587,[24] and 1617,[25] but in view of a reference to a 'bloomer' of Heighley in1591,[26] it would appear that the bloomsmithy was at Heighley rather than at Madeley. A late survival was in Biddulph, by the Mill, where during the Civil War, Mrs Biddulph had to rely heavily on the Committee at Stafford for assistance in running her husband's bloomsmithy and coalpits, whilst he was held prisoner in Eccleshall Castle.[27]

Judging by the number of identified sites of former iron-working, especially in the remote parts of North Staffordshire, there must have been other bloomsmithies operating into the seventeenth century. These smaller bloomsmithies may well have employed the treadle hammer known as the 'Oliver', first-described by Plot who saw it at work in smithies at Mow Cop, Betley and Caverswall during the late 1670's.[28] Indeed the use of this hammer could explain why sites such as those described by F W Dennis, at Cloud End, Mow Cop and Whitehough, apparently lack an adequate source of water power.[29] Rhys Jenkins believed that the 'Oliver' was used to produce blooms, even in one-man forges producing blooms of 20 to 30 pounds in weight.[30] By the time Plot saw the 'Oliver' at work it was being used by blacksmiths and he describes how one smith used an 'Oliver' to 'make a Horse-shooe, as they can also any other smaller sorts of wares, almost as quick as if another had struck the sledge to him.'[31]

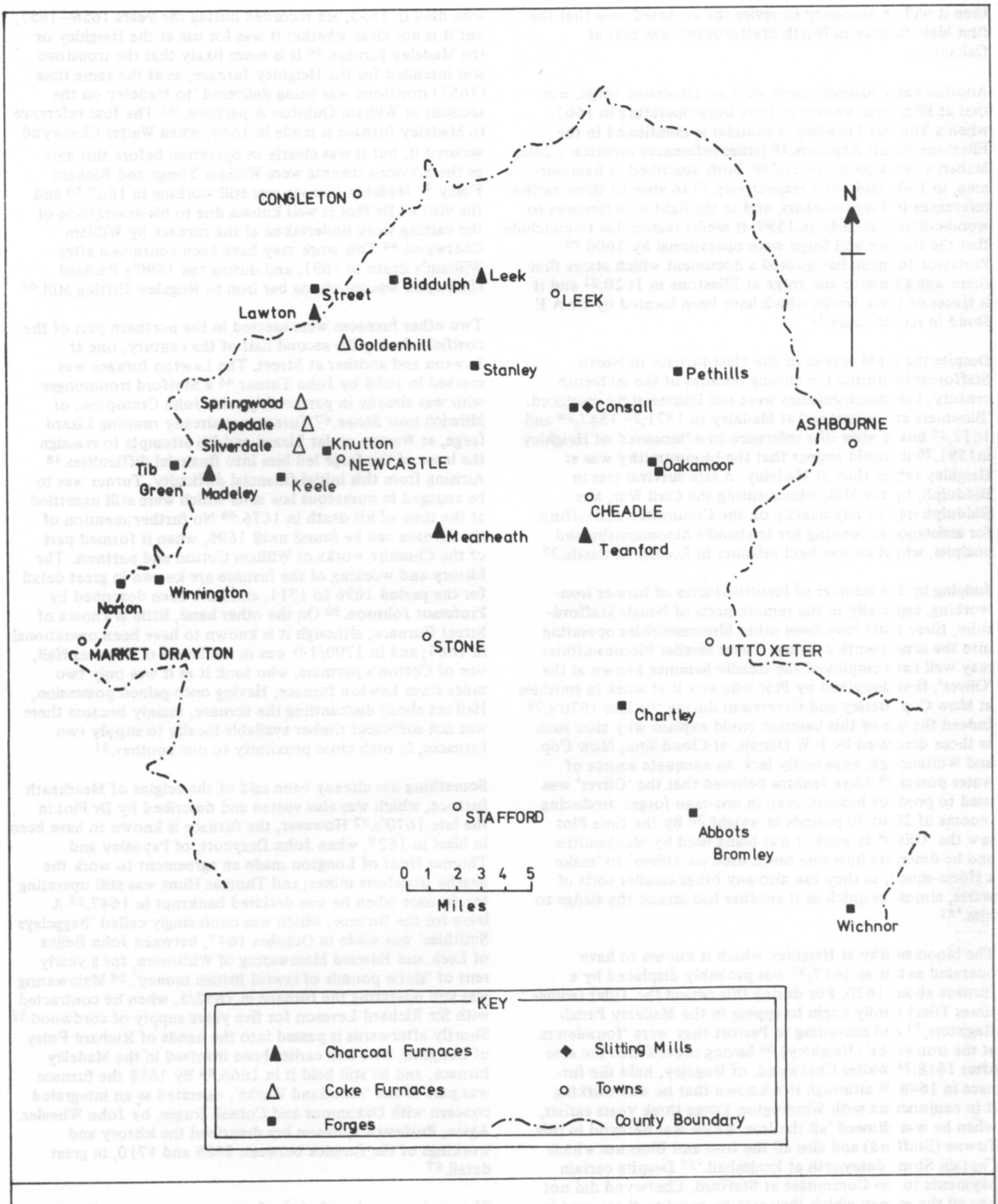
The bloomsmithy at Heighley which is known to have operated as late as 1617,[32] was probably displaced by a furnace about 1620. For during this period the Tyler (sometimes Tiler) family begin to appear in the Madeley Parish Registers,[33] and according to Parrott they were 'founderers at the ironworks' (Heighley),[34] having moved into the area after 1618.[35] Walter Chetwynd, of Rugeley, held the furnace in 1646,[36] although it is known that he was working it in conjunction with Winnington Forge three years earlier, when he was allowed 'all the Iron which was deteynd in this Towne (Stafford) and also all the Iron and Bloomes which Captain Stone deteyneth at Eccleshall.'[37] Despite certain payments to the Committee at Stafford, Chetwynd did not pay all the money which they said he owed to them, and in April 1644 the cordwood and coles (Charcoal) he had bought from Randulph Egerton, of Betley were seized until 'Mr Chetwind hath satisfied the committee for the monie it was sould for.'[38] Such treatment seems rather harsh, especially since Chetwynd had been supplying the garrison at at Stafford with 'Iron and bullett.'[39]

Sales of ironstone to William Chetwynd, nephew of Walter who died in 1653, are recorded during the years 1656–1657, but it is not clear whether it was for use at the Heighley or the Madeley furnace.[40] It is more likely that the ironstone was intended for the Heighley furnace, as at the same time (1657) ironstone was being delivered 'to Madeley on the account of William Quinton & partners.'[41] The first reference to Madeley furnace is made in 1649, when Walter Chetwynd secured it, but it was clearly in operation before this date as the previous tenants were William Yonge and Richard Foley.[42] Madeley furnace was still working in 1667,[43] and the visit of Dr Plot is well known due to his description of the casting work undertaken at the furnace by William Chetwynd.[44] This work may have been continued after William's death in 1691, and during the 1690's Richard Chetwynd was supplying bar iron to Rugeley Slitting Mill.[45]

Two other furnaces were erected in the northern part of the coalfield during the second half of the century, one at Lawton and another at Street. The Lawton furnace was erected in 1658 by John Turner,[46] a Stafford ironmonger who was already in partnership with John Crompton, of Milwich near Stone.[47] Turner was already running Lizard forge, at Weston under Lizard and his attempts to reassign the lease of the forge led him into financial difficulties.[48] Airising from this initial financial difficulty, Turner was to be engaged in numerous law suits which were still unsettled at the time of his death in 1676.[49] No further mention of the furnace can be found until 1696, when it formed part of the Cheshire works of William Cotton and partners. The history and working of the furnace are known in great detail for the period 1696 to 1711, and have been described by Professor Johnson.[50] On the other hand, little is known of Street Furnace, although it is known to have been operational in 1664; and in 1700/1 it was in the hands of Thomas Hall, one of Cotton's partners, who took it as it was only two miles from Lawton furnace. Having once gained possession, Hall set about dismantling the furnace, mainly because there was not sufficient timber available locally to supply two furnaces, in such close proximity to one another.[51]

Something has already been said of the origins of Mearheath furnace, which was also visited and described by Dr Plot in the late 1670's.[52] However, the furnace is known to have been in blast in 1627, when John Draycott, of Paynsley and Thomas Hunt of Longton made an agreement to work the nearby ironstone mines; and Thomas Hunt was still operating the furnace when he was declared bankrupt in 1647.[53] A lease for the furnace, which was confusingly called 'Baggeleys Smithies' was made in October 1647, between John Bellot of Leek and Edward Mainwaring of Whitmore, for a yearly rent of 'sixtie pounds of lawful British money'.[54] Mainwaring was still operating the furnace in 1652/3, when he contracted with Sir Richard Leveson for five years supply of cordwood.[55] Shortly afterwards it passed into the hands of Richard Foley of Longton, who had earlier been involved in the Madeley furnace, and he still held it in 1666.[56] By 1688 the furnace was part of the 'Moorland Works', operated as an integrated concern with Oakamoor and Consall forges, by John Wheeler. Again, Professor Johnson has described the history and workings of the furnace between 1688 and 1710, in great detail.[57]

The pig iron produced at the furnaces was not usable in its existing form, unless it was melted down to be used in casting work. The greatest demand was for wrought iron rod or bar, which could be forged and hammered by craftsmen into articles for domestic and commercial use. In order to obtain wrought iron from the cast iron pigs produced at the furnaces, it was necessary to work the pig iron at forges. This involved the subjection of the pig iron to the finery and chafery process, which involved repeated heating and hammering,



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before the iron emerged as more workable strips of wrought iron. Plot observed that:

'From the furnaces, they bring their sows and pigs of Iron when broken asunder, and into lengths, to the forges; which are of two sorts, but commonly (as at Cunsall) standing together under the same roof; one whereof they call the Finery, the other the Chafery: they are both of them open hearths.'[58]

Most of the forges worked in harness with a furnace, and some of these relationships have already been indicated, such as that of the Heighley furnace with Winnington forge. This forge was in existence by 1599, when it was in the hands of 'Sir Thomas Garrard' (Gerard?),[59] who was probably the 'Lord Gerrard' connected with the forge in 1613.[60] In view of this association it may well be significant that the Audley estates had been bought by Gilbert Gerrard, of Gerrard's Bromley in 1579; a man who has been described as being 'one of the band of wealthy lawyers and industrialists which was buying up the property of the old feudal nobility.'[61] As Heighley was part of the Audley estates, the Gerrard family may well have had the bloomsmithy and used it to supply Winnington forge.

Walter Chetwynd was working the forge at Winnington by 1643,[62] although it is doubtful that he held it as early as 1634, when it is also known to have been working.[63] There was another forge at Norton which Chetwynd also held in 1646 and may well have erected, as this is the earliest reference.[64] Surprisingly, a third forge was erected close to those at Winnington and Norton, on a site now occupied by Bearstone Mill and this has never been previously recorded, although there are frequent references to its existence between 1675 and 1699. Nothing is known of its ownership or operations, but the name Blewitt is common among the work-force, a name also associated with the two other neighbouring forges.[65]

Chartley forge was in existence by 1620, along with a 'furnace', although it is extremely doubtful if this was anything other than another bloomsmithy.[66] The forge formed part of the 'Moorland Works' between 1692–1710, when bar iron for slitting at Rugeley made up the greater part of the Chafery forge output. Consall and Oakamoor forges, owned by Philip Draycott and Dr John Foley respectively, were also part of the 'Moorland Works', between 1688 and 1710.[67] The history of both forges, however, goes back much further and already by the early seventeenth century the relationship between these forges and Mearheath furnace had been established. Consall forge was working in 1655–56,[68] although there are no details of the Oakamoor forge before it passed into the possession of the Foley family. The forge at Consall was visited by Dr Plot, who described it at length and who seemed to regard it as being typical of the forges at work in the area. Plot also describes the workings of a slitting mill, possibly that at work at Consall during the period, 1688–1710.[69] Oakamoor had also been the site of a slitting mill, but this was discontinued by 1694 and the work diverted to Consall.[70]

The forge at Abbots Bromley was in the hands of Thomas Chetwynd in 1623,[71] and the lease was later taken up by his son Walter, who held it in 1636–7.[72] It has been presumed that the forge was in the hands of the Chetwynd family, until the death of William in 1691, at which time it was leased to William Cotton and Dennis Heyford, who started sending pig iron there, to be refined before being forwarded to the Cannock Works.[73]

Over the Cheshire border, just south of Betley, stood Tib Green forge; first mentioned in 1619, when a Radulphi Jolley, hammerman is included in an entry in the parish register.[74] In 1646 Walter Chetwynd held the forge, which he presumably operated in conjunction with Heighley furnace, and possibly Madeley furnace after 1649.[75] The Egerton family owned the forge and they were operating it themselves later in the century. Their manager, a Richard Skinner was fining iron from the Forest of Dean in the 1680's, and this was also the source of charcoal for use in the finery hearth.[76]

The only other two forges known to have been operating in North Staffordshire at this time were the two belonging to the Sneyd family of Keele. The forge on Knutton Heath was originally worked by John Smith, who paid a yearly rent of £5 which was paid to the poor of the parish of Wolstanton.[77] Following the death of Smith, the furnace and forge passed into the possession of John Wright, who held them both in 1619.[78] The second forge was at Keele, in the Springpool area where a corn mill was converted into a plating forge by John Holland, a panmaker, in 1673. By the time Plot saw the works, Holland had also acquired the forge on Knutton Heath where the flat plates from Keele were taken to be worked into shape.[79]

II THE TRANSFORMATION OF AN INDUSTRY: THE EIGHTEENTH CENTURY

In view of the situation described in the preceding section, there seems to be no grounds for questioning B G Awty's assertion that 'the accounts in the Foley Manuscripts coincide almost exactly with the period when the industry was at its height.'[80] The seventeenth century had been a period of great expansion, although certain of the less viable units of production, such as the furnaces at Ellastone, Heighley and Knutton had disappeared during the century. In a similar fashion, Street furnace was to be dismantled in 1700/1 as, like Heighley, it was situated too close to another furnace, thus making diminishing supplies of wood even more precarious. Bearstone forge does not appear to have operated during the eighteenth century, but being sited so near to Winnington and Norton forges it would appear to have been the result of a boom period in the earlier days of the industry.

From the accounts of the Foley partnership some idea of the levels of production at the end of the seventeenth century, and at the beginning of the eighteenth century can be obtained. Evidence is available for the output of two local furnaces, namely Mearheath and Lawton furnaces during the period 1692; although the records of pig iron production are far from complete.[81] (see Figure 1) Of the two sets of furnace accounts, those for Mearheath are the most complete and from these it can be calculated that the average annual output of pig iron, for the period 1692 to 1700 was 764.4 tons; and that for the period 1702–1710, it had fallen to 543.9 tons. These figures and the trend shown in Figure 1, would seem to indicate a fall in production, which is possibly mirrored in the less complete figures for Lawton furnace. However, in the context of the National industry, the outputs of both the Mearheath and Lawton furnaces were extremely high and well above the national averages which were 300 tons per annum, for the decade 1690–9; and 315 tons for the decade 1700–9.[82] The figure of 1098 tons recorded for Mearheath furnace, during the campaign year 1693–94 is staggering, and on some days of the campaign production must have reached nearly four tons, for the twenty-four hour period. This is better than the capacity of most Stafford-

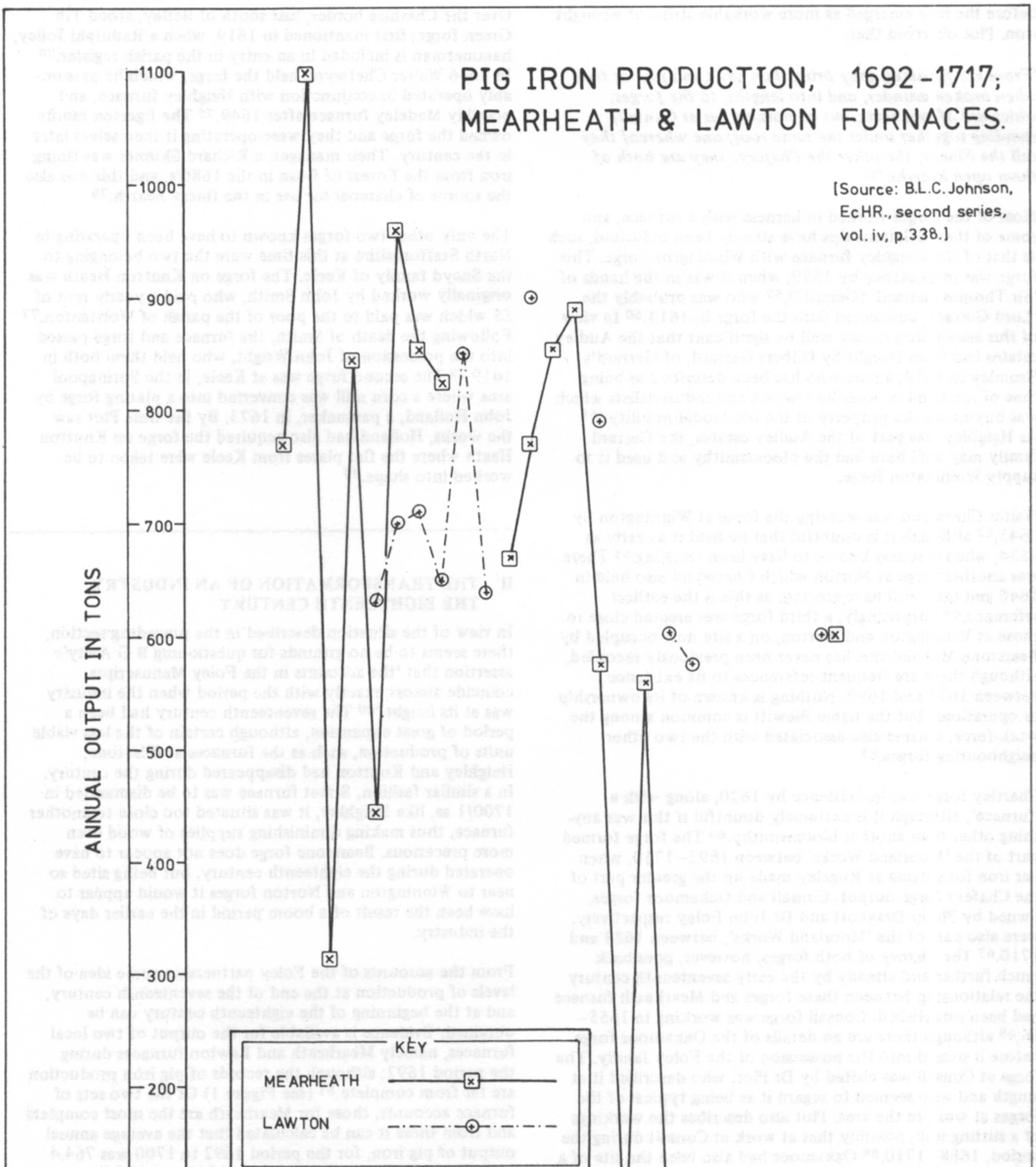

PIG IRON PRODUCTION, 1692–1717; MEARHEATH & LAWTON FURNACES.
[Source: B.L.C. Johnson, EcHR., second series, vol. iv, p. 338.]
ANNUAL OUTPUT IN TONS
1100
1000
900
800
700
600
500
400
300
200
100
0
NIL
PL
KEY
MEARHEATH
LAWTON
CAMPAIGN YEAR
92–93
93–94
94–95
95–96
96–97
97–98
98–99
99–00
00–01
01–02
02–03
03–04
04–05
05–06
06–07
07–08
08–09
09–10
10–11
11–12
12–13
13–14
14–15
15–16
16–17

FIG. 1

shire furnaces, which according to Plot was 'two or three tuns of cast Iron in 24 hours.'[83] It should, however, be noted that this was an exceptional campaign.

In 1717 the three local furnaces were all producing quantities of pig-iron which were well in excess of the national production average, which was 340 tons of pig iron,[84] per furnace, per year. Madeley furnace produced 400 tons; Lawton furnace 600 tons and Mearheath furnace 600 tons,[85] making a total of 1600 tons; or 6.4% of the total national production of 25,000 tons. This figure takes no account of Leek furnace which was almost certainly working by this date The figure expressing local production as a percentage of national production is important, as it illustrates how significant the local iron industry was in 1717. If it is considered that production had been greater towards the end of the seventeenth century, an estimate of 8 or 9% of the total national production would be a reasonable projection, for the period 1680–1700.

Some idea of the capacity of the forges can be obtained from the production figures for Consall, which dealt with about 282 tons of pig iron during the campaign year, 1693–94;[86] which was the year in which Mearheath furnace achieved its record production figure. Production at Consall forge had dropped to 150 tons in 1737, during the great depression in the industry;[87] but had increased to 300 tons in 1750, probably because most of the other local forges had been abandoned.[88] Abbots Bromley forge is believed to have had a more limited capacity of about 200 tons per year, which was akin to the capacity of Chartley forge.

Philip Riden has put forward a convincing case for a steady increase in the average output of British charcoal-fired furnaces during the eighteenth century,[89] but if this was the case then North Staffordshire does not seem to have shared in this general growth. If the figures for the output of local furnaces in 1717 are considered, then a more stable period may have existed in the industry, just prior to the great depression of 1737–38. Two new furnaces came into production during the early part of the century. The Leek furnace (at Horton) is first mentioned in 1719, and that at Teanford in a list of 1735.[90] The Leek furnace was in the hands of William Fallowfield in 1727[91] and 1731,[92] who was using prepared peat instead of charcoal. Fallowfield was probably still working the furnace in 1735.[93] Neither the Teanford or the Leek furnaces are referred to after 1735 and both were probably victims of the great depression in the industry between 1737–38 which, as B G Awty has demonstrated, seriously affected the local iron industry.

Foreign pig iron was being imported into England in considerable quantities during the early part of the eighteenth century, and due to its cheapness it undercut the English ironmasters who were being crippled by ever-increasing fuel costs. Sweden, Spain, Russia and the American Colonies were the chief suppliers and these were all countries where fuel was plentiful and relatively inexpensive. The English ironmasters were tied to their existing works, due to the inertia effect of their investment and the national shortage of timber. Faced with unfavourable market conditions, many ironmasters left off operating their works, especially during 1737–38, when the full force of foreign competition was felt.

The long established furnaces at Mearheath, Lawton and Madeley seem to have enjoyed better fortunes, with the possible exception of the Lawton furnace. For after 1717 nothing is known of its operation and it may well have been another victim of the depression; for on 24th April 1744, Thomas Adams of Ford Green and Stephen Stringer of Little Hassal, agreed that Adams should 'take, farme & Rent ye old ffurnace at Lawton & convert it into a fflint mill.'[94] Mearheath furnace was still operating in September 1754, when Charles Wood:–

call'd at Meer Heath Furnace (Mr. Smith, Clark) which makes cold short pigs with charcoal. They use Lancashire Mine when they cast uses. The charcoal costs them 38s. per dozen. But the Stone Lyes Near which makes amends for dearness of coal.'[95]

By 1763 the furnace was disused, although the name was perpetuated by the continued existence of the hamlet which had grown up around the furnace.[96]

The last charcoal-fired blast furnace in use in the North Staffordshire area was that at Madeley, which was described by Aikin (1795) thus:– 'Iron-stone is met with plentifully to the west of Newcastle: it is smelted at the Madeley furnaces, and yields a cold-short metal.'[97] Exactly when the Madeley furnace was abandoned is not known, but it would appear to have been between 1796 and 1800.[98] For most of the century the Madeley ironworks appears to have concentrated on casting work, as there are an uncommonly large number of ironfounders, including Edward Onions and Francis Lloyd associated with the works.[99]

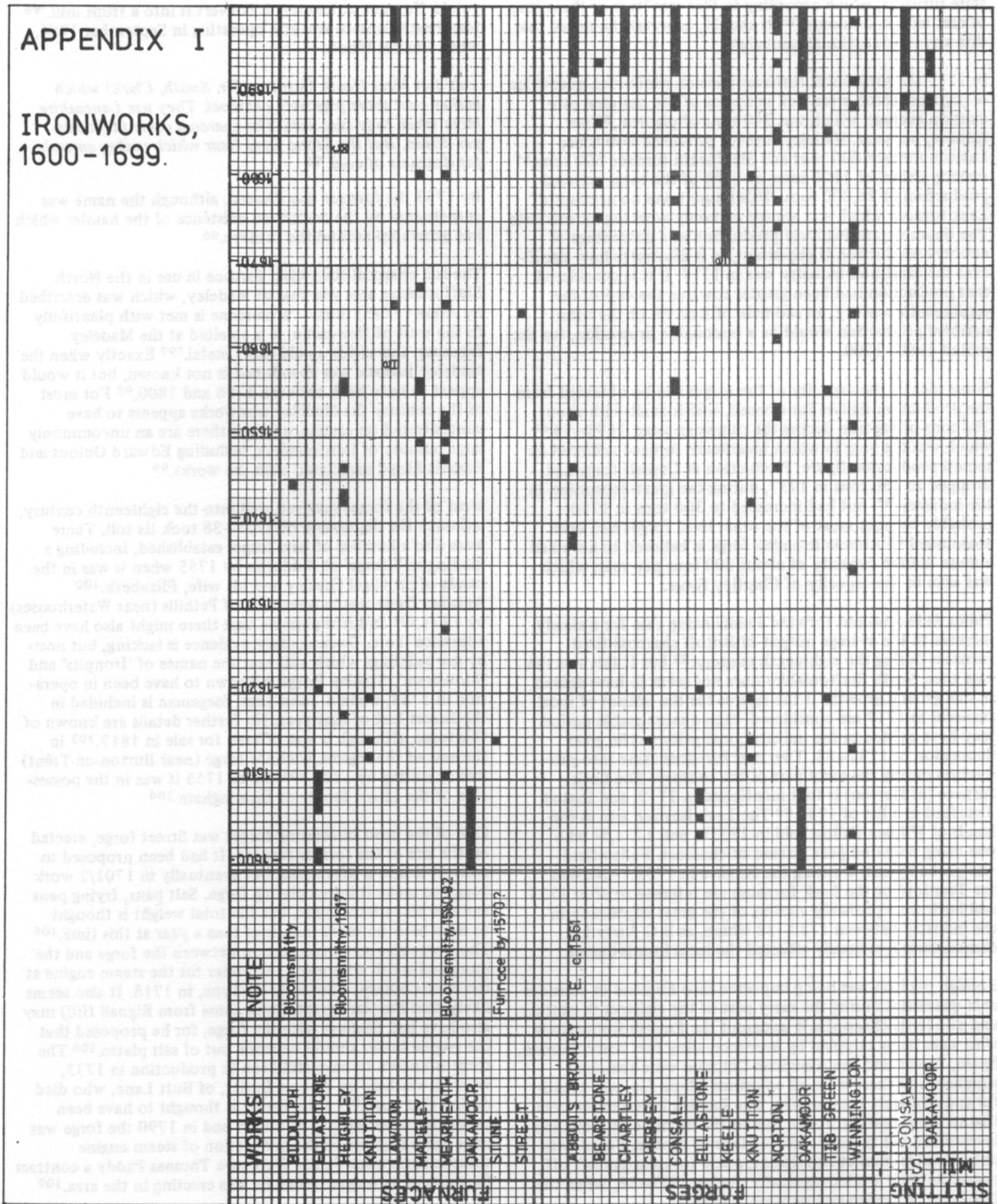
Most of the forges survived well into the eighteenth century, although the depression of 1737–38 took its toll. There were also a number of new forges established, including a 'plating-mill forge' at Biddulph by 1755 when it was in the hands of Sir Nigel Gresley and his wife, Elizabeth.[100] Another forge was in operation of Pethills (near Waterhouses) by 1771,[101] and it is possible that there might also have been a furnace there. Documentary evidence is lacking, but nearby are buildings which still bear the names of 'Ironpits' and 'Bloworam'. Stanley Forge is known to have been in operation in 1784, when a John Lees, forgeman is included in the Jurors List of that year. No further details are known of this forge, although it was offered for sale in 1817.[102] In the east of the region, Wichnor forge (near Burton-on-Trent) was operating by 1721,[103] and in 1755 it was in the possession of the Lloyd family of Birmingham.[104]

One of the most interesting forges was Street forge, erected on the site of the former furnace. It had been proposed to convert it into a wireworks, but eventually in 1701/2 work began to make it into a plating forge. Salt pans, frying pans and saw irons were made, but the total weight is thought to have been no more than four tons a year at this time.[105] There was also some connection between the forge and the unnamed smith who made the boiler for the steam engine at the Park Colliery, Newcastle-on-Tyne, in 1718. It also seems likely that Stonier Parrott (who came from Bignall Hill) may also have had dealings with the forge, for he proposed that the engine boiler should be made out of salt plates.[106] The forge is known to have still been in production in 1733, when it was held by Robert Butler, of Butt Lane, who died during that year.[107] John Paddy is thought to have been producing saws there in 1750;[108] and in 1790 the forge was once again engaged in the production of steam engine components, when James Watt gave Thomas Paddy a contract for parts of an engine which he was erecting in the area.[109]

The two plating forges at Keele and Knutton were further victims of the depression of 1737–38. They had been operated by the Holland family since 1673, and 1734 they were in the possession of John and William Holland, 'panmakers'.[110] Norton and Winnington forges were listed among the Cheshire works (along with Madeley furnace) by an advocate of the Trent and Mersey Canal in 1766,[111] but nothing is known of their operation during the eighteenth

APPENDIX I

IRONWORKS, 1600-1699.

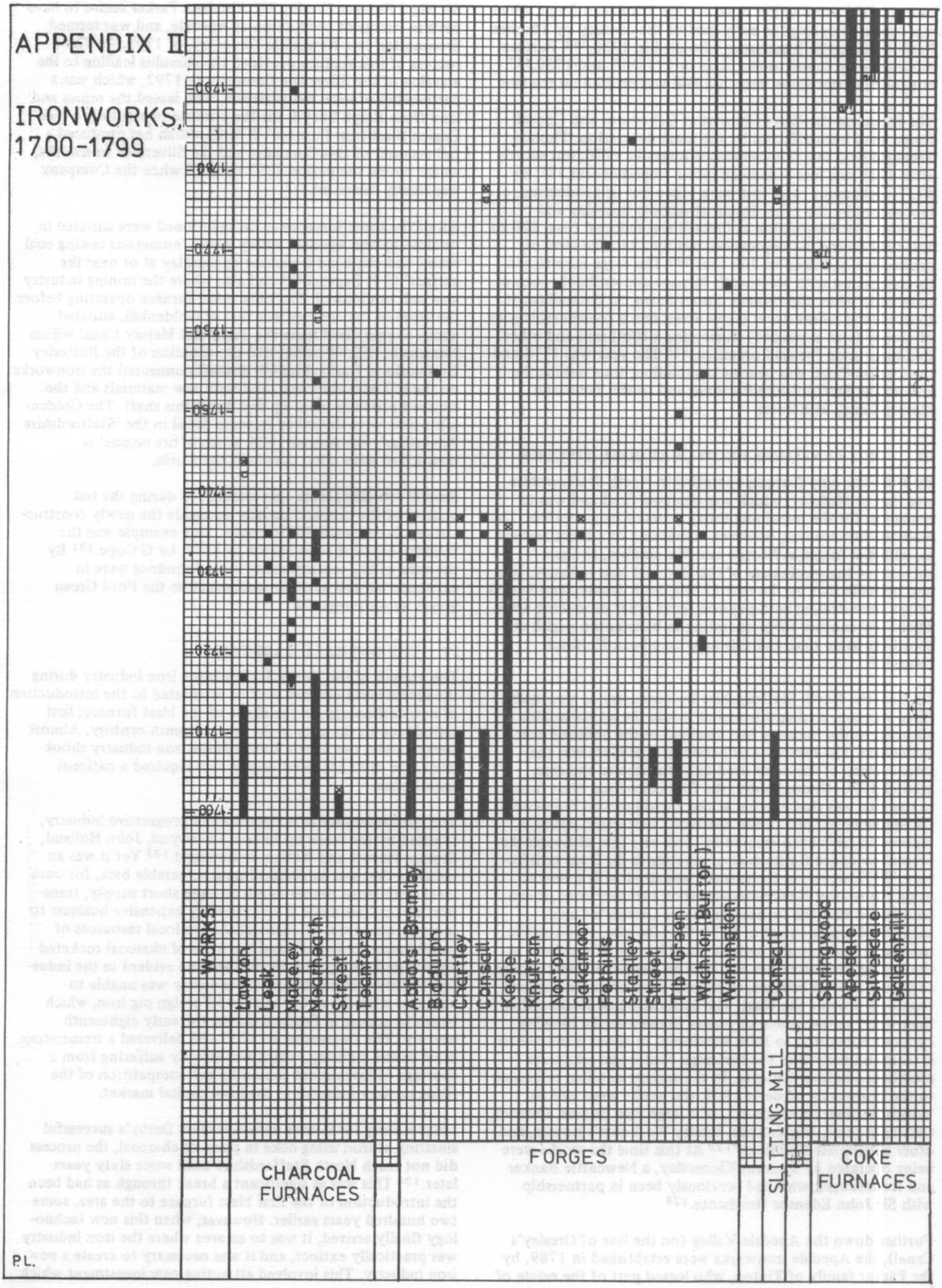


KEY TO APPENDICES I & II

- e — E & □ Erected
- ⊡ Re-erected
- ☒ Closed down
- ■ Known to have been operational
- a — ante
- c — circa

P.L.

APPENDIX II
IRONWORKS, 1700–1799



century. The same writer does not list Tib Green forge, which was operated during the early part of the century by Thomas Hart, a Newcastle Ironmaster who died in 1730.[112] Further references are found to the forge in 1732[113] and 1750,[114] but shortly afterwards Wrinehill Mill was erected on the site.

The forges on the River Churnet at Oakamoor and Consall Forge were both affected by the great depression. Thomas Tomkins held the two Oakamoor forges in 1730, but shortly after 1735 one was converted into a tinplateworks.[115] By 1737, Oakamoor forge had been taken out of production, a fate shared by the other forges at Abbots Bromley and Chartley.[116] Production at Consall was reduced from 200 to 150 tons during the depression, but by 1750 the level of production had risen to 300 tons.[117] The forge maintained its connection with Mearheath furnace and probably ceased to operate when the furnace closed down. At Consall (as at Lawton) the works were 'taken down and a considerable sum of money (was expended) in erecting a fflint mill and other Buildings upon the said premises.'[118] The year was 1778 and the Caldon Canal was nearing completion, thus linking the area to the Staffordshire Potteries and to the Trent and Mersey Canal, at Etruria.

III THE TRANSITION FROM CHARCOAL TO COKE

By 1765 the only furnace operating in North Staffordshire was that at Madeley, which was charcoal fired and was to remain so for the remaining thirty years of its useful life. The Madeley furnace was, however, something of a relict feature as, with the forges at Norton and Winnington, it was a survivor of the passing era of the charcoal iron industry. It is also possible that by the mid 1770's, both Stanley and Pethill forges were dealing with pig iron from other producing areas. There was another forge operating in Wolstanton parish at about the same time and this may have been Holditch forge.[119]

To view the North Staffordshire iron industry as a partially filled vacuum, during this period would be an acceptable allegory, as the industry had declined to the point of near extinction. The remedy and herald of a new era was the introduction of the coke fired blast furnace to the area, around 1770. Undoubtedly, the first coke-fired blast furnace in the area was that erected at the Partridge Nest Ironworks (at Springwood) just to the north of Chesterton, which is reputed to have been erected in 1768 or 1769, although the present evidence for its date of erection is far from satisfactory.[120] However, as the furnace was sited with a view to using the nearby Newcastle-Nantwich turnpike road, it can be inferred that the furnace pre-dates Gresley's Canal, authorised under an act of 1775.[121] Likewise, it is possible to suggest limits to the earliest possible date of erection, as the Springwood site does not have an adequate water supply to power a set of bellows, so it must have relied on a steam engine to provide the blast. The application of steam rather than water as the source of power to operate the blowing cylinder is credited to John Wilkinson, in about 1766;[122] so it seems unlikely that the Partridge Nest ironworks were established before this date. In the earliest detailed reference to the ironworks, made in 1801, the works were said to 'consist in their present state, of a large Fire Engine, Furnace, Casting Houses, Warehouses, sundry Workmen's houses, and other appropiate Buildings.'[123] At this time the works were being operated by Thomas Kinnersley, a Newcastle Banker and Ironmonger; who had previously been in partnership with Sir John Edensor Heathcote.[124]

Further down the Apedale Valley (on the line of Gresley's Canal), the Apedale ironworks were established in 1789, by the Parker family of Tipton, who leased part of the estate of Sir Nigel Bowyer Gresley.[125] Abraham Parker seems to have been in charge of production at Apedale, and was termed 'ironmaster' in a Newcastle Directory, of 1793.[126] The success of this venture provided the stimulus leading to the creation of the Silverdale Company in 1792, which was a partnership of local industrialists, who leased the mines and land from Ralph Sneyd, for the purpose of erecting 'a Fire Engine Blast Iron Furnace'. B M Hardman has produced a full account of this Company and the Silverdale ironworks, which covers the period 1792 to 1815 when the Company was finally dissolved.[127]

All of the three furnaces so far mentioned were situated in, or close by the Apedale Valley where 'numerous coking coal seams and clayband ironstone courses lay at or near the surface' (S H Beaver),[128] and also where the mining industry was well established. The only other furnace operating before the close of the century was that at Goldenhill, situated above a cross canal from the Trent and Mersey Canal within Harecastle Hill,[129] rather like the situation of the Butterley Ironworks in Derbyshire.[130] A shaft connected the ironworks on the hill with the canal, and both raw materials and the finished products went up and down this shaft. The Goldenhill works were described in some detail in the 'Staffordshire Advertiser', 4th August 1804, when a 'fire engine' is mentioned with other details of the works.

Several foundries were also established during the last quarter of the century, usually alongside the newly constructed canals of North Staffordshire. One example was the foundry established at Milton in 1782, by G Cope.[131] By the turn of the century many more foundries were in existence, as well as other works such as the Ford Green Steam Scrap Forge.[132]

IV THE OVERALL TABLEAU

The growth of the North Staffordshire iron industry during the seventeenth century may be attributed to the introduction of new technology, in the shape of the blast furnace; first introduced to the area in the late sixteenth century. Almost immediately, the North Staffordshire iron industry shook itself free of its localised origins and acquired a national importance.

The indications are of a vigorous and progressive industry, typified by the work of William Chetwynd, John Holland, Stonier Parrott and William Fallowfield.[133] Yet it was an industry that was established on a vulnerable base, for once local supplies of timber began to be in short supply, transport difficulites made it an extremely expensive business to import quantities of charcoal. As the local resources of wood began to dwindle and the price of charcoal rocketed up, so the first signs of decline become evident in the industry. In these circumstances the industry was unable to compete with cheap Colonial and Foreign pig iron, which began to appear in England during the early eighteenth century. The Depression of 1737–38 delivered a tremendous blow to the industry, which was already suffering from a shortage of investment caused by the competition of the rising pottery industry in the local capital market.

Despite early local links with Abraham Darby's successful smelting of iron using coke in place of charcoal, the process did not reach North Staffordshire until some sixty years later.[134] This was as significant a break through as had been the introduction of the first blast furnace to the area, some two hundred years earlier. However, when this new technology finally arrived, it was to an area where the iron industry was practically extinct, and it was necessary to create a new iron industry. This involved attracting new investment which was not easy at a time when there were great fluctuations and a great deal of uncertainty about the price of iron.

It has been demonstrated that the existing literature was responsible for a somewhat distorted view of the North Staffordshire iron industry, which it has been possible to redress in this paper, so that a more complete reconstruction has emerged. There is still room for detailed studies of various ironworks, like those in the Madeley area; and for a definitive work on the Partridge Nest or Springwood ironworks. Similarly, the North Staffordshire nailing industry is in need of a student of industrial history who is prepared to unravel the story of the rise and fall of this important industry.

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The writer also wishes to record his appreciation of the assistance of Miss Norma Hales, who kindly undertook the typing of the final draft of this paper.

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I remain, of course, solely responsible for any errors which may remain.

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134 In 1708, John Tyler, formerly of Heighley furnace, became the first founder employed by Abraham Darby I, at Coalbrookdale. (Arthur Raistrick, *Dynasty of Ironfounders*, London, (1953), pp. 32–33). Despite their removal to Shropshire, the Tyler family maintained their links with North Staffordshire and in 1766, William Tyler of Broseley married Jane Wiggin, a

widow of Madeley. It is also of interest to note that one of the witnesses was Francis Lloyd, an ironfounder at Madeley Furnace. (Madeley Parish Register, 12th October, 1766).

ABBREVIATIONS USED IN THE REFERENCES AND NOTES

Trans. NSFC	Transactions of the North Staffordshire Field Club
NSJ FS	North Staffordshire Journal of Field Studies
Trans. New. Soc.	Transactions of the Newcomen Society
VCH Staffs.	Victoria County History of Staffordshire
SHC	Collections for a History of Staffordshire
WSL	William Salt Library, Staffordshire
SRO	Staffordshire Record Office
PRO	Public Record Office

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The Technology of Wire Making at Tintern, Gwent, 1566 c.1880

H W Paar and D G Tucker ©

INTRODUCTION

The industrial archaeology[1] and general history[2,3] of the metal-working complex of the Angidy Valley near Tintern, Monmouthshire (now Gwent) have been reported upon, but little has so far been published on the technical processes used over the centuries following the opening of the first works in 1566. Indeed, little is known of most of the processes used, the evidence relating specifically to Tintern being very sparse and fragmentary. It is our purpose here to examine this evidence, and by relating it to known developments of technology elsewhere, to speculate on what processes were used at Tintern (and, of course, at its branch at Whitebrook), and to pose some questions to which answers are not at present forthcoming.

The great novelty involved at Tintern, so far as Britain was concerned, was the use of water power in the drawing operation. Before the Angidy wire-mills were established in 1566, men's bodily power alone was employed, although as will be seen, water power was a familiar adjunct in other countries.

BEFORE TINTERN

The primitive method of making wire was by hammering it manually;[4,5] we can also accept that use of the draw-plate or dies was of ancient origin.[6] More efficient man-powered machines had been developed by the early part of the 16th century. Judging by the relative sophistication, the earliest of these was of the form described by John Evelyn in 1675[7] as follows:–

"In this parish [Wotton, Surrey] were set up the first brass-mills, for the casting, hammering into plates, cutting, and drawing it into wire, that were made in England; first they drew the wire by men sitting harnessed in certain swings, taking hold of the brass thongs fitted to the holes, with pincers fasten'd to a girdle which went about them; and then with stretching forth their feet against a stump, they shot their bodies from it, closing with the plate again . . ."

This method of wire-drawing is illustrated by a woodcut showing a man sitting on a swinging seat, in front of a stump on which is mounted a multi-holed draw-plate; he is gripping the wire with hand-held tongs. No means of securing the operator to his seat is shown, but Evelyn states that he was "harnessed".[8]

Another means of using bodily power was a bench fitted with a die-plate at one end and a windlass at the other, with a belt, the free end of which was attached to tongs which gripped the wire; operation of the windlass wound the belt onto the shaft, and thus the wire was pulled through the die. Schubert discusses these early methods at some length.[9] He notes that the windlass bench was known as a brake, and its operators brakemen. (We have adopted the name "brake" for this type of machine and its derivatives, whether manually or water powered, although it was also called a draw-bench). "Compared with the brake, the girdle was a definite advance, as power was more advantageously distributed. The method did not compare favourably however with that of . . . the Tintern works, as the pincers used with the girdle as well as with the brake left impressions on the wire produced." There appear to be two objections to this statement: the girdle seems to have been a more primitive device altogether than the brake, and we feel that its use was confined to brass wire, as in Evelyn's description Furthermore (as will be shown later) one of the early objections to Tintern wire was that the pincers marked it.

A technical treatise published in 1540 by Biringuccio in Venice[10] illustrates and describes three methods of wire-drawing (see Figs 1 and 2) which may be summarised as follows:–

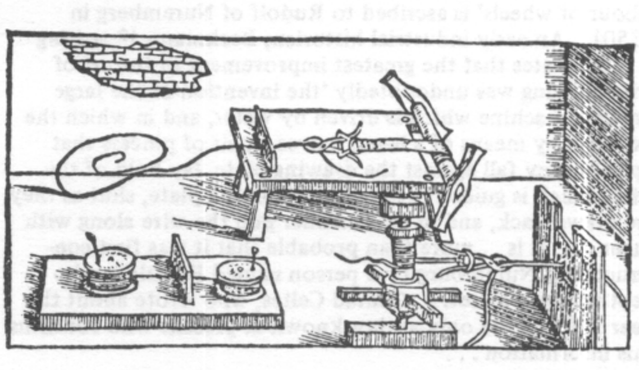

Figure 1 Three types of hand-operated wire-drawing machines, viz. the brake, the windlass, and the drum types, as shown by Biringuccio in 1540.

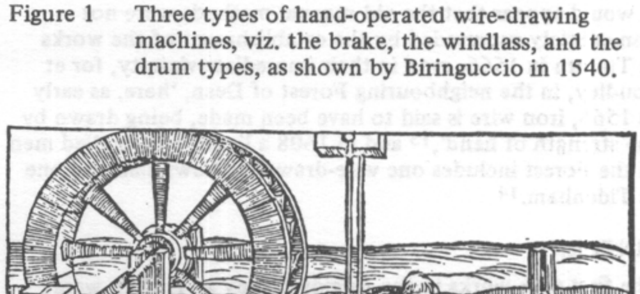

Figure 2 Water-powered machine for drawing iron wire, as shown by Biringuccio in 1540.

1 Bench windlass as described above. A similar mechanism, but with a capstan shaft arranged vertically between bearings at floor and roof is also shown.

2 Two drums mounted on vertical spindles on a base-plate, with a drawplate in between them. The wire was wound by hand off one drum and on to the other via the draw-plate.

3 A water-powered crankshaft, the throw of the crank pulling the wire through a draw-plate by means of

tongs moved by a driving band. The operator sat on a swing, 'his only care is to seize with the jaws of the tongs the end of the wire that issues from the draw-plate with every return that he makes". He moved with the work, and a pit was provided for his legs, which enabled the draw-plate to be floor-mounted, and kept short the bearing pedestals for the shaft.

Methods (1) and (2), and another not illustrated in which the force was applied by a screw device, were hand-operated. The drums were used for fine-drawing. The water-powered machine was stated to be for drawing 'heavy iron', and the author added that he had also seen iron wire drawn on horizontally-mounted drums, but then it had to be greatly thinned and well annealed; he added that this mechanism could be operated by water wheel, or by horse- or man-operated wheel.

It is probable that these methods described in 1540 were then by no means new, since 'the drawing of wire by the labour of wheels' is ascribed to Rudolf of Nuremberg in 1350[11]. An early industrial historian, Beckmann,[12] writing c.1800, states that the greatest improvement in the art of wire-drawing was undoubtedly 'the invention of the large drawing machine which is driven by water, and in which the axletree, by means of a lever, moves a pair of pincers that open as they fall against the drawing-plate, lay hold of the wire, which is guided through a hole in the plate, shut as they are drawn back, and in that manner pull the wire along with them . . . It is . . more than probable that it was first constructed at Nuremburg by a person named Rudolph, who kept it long a secret. . . Conrad Celtes, who wrote about the year 1491, is the only author known at present who confirms this information . . . '

It would appear that the old manual methods were not immediately superseded by the establishment of the works at Tintern in 1566, even in their immediate vicinity, for at Soudley, in the neighbouring Forest of Dean, 'here, as early as 1565, iron wire is said to have been made, being drawn by the strength of hand',[13] and in 1608 a list of able-bodied men in the Forest includes one wire-drawer at Newnham and one at Tidenham.[14]

TINTERN

The first wire works in the Angidy Valley at Tintern were being erected in November 1566, furnished with four water wheels, two annealing furnaces and two forges, and reckoned to be capable of dealing with one ton of metal per week: iron, steel, or brass.[15] This raises the question of whether brass wire was ever made at Tintern, because the original proprietors undoubtedly were authorised, inter alia, to make wire from brass, iron and steel.[16] In December, Schutz, the technical partner, was promising a weekly production of 25 cwt (1270 kg) of wire, and also latten (brass) wire at a rate sufficient to repay the building charges speedily.[17]

Humfrey, the commercial partner, reported on 23 July 1567 that the works were ready to start[18] and on 1 February 1568 he announced the production of latten at Tintern.[19] Yet on 11 July he wrote that the hammer house for latten, the foundry, the forge for Osmond iron, the rollers, and the casting stones for the brass were still to be made or obtained.[20] Moreover, a statement of expenditure at Tintern in its first five years (ie to 1570) mentions, so far as brass is concerned, only searching and mining for calamine (zinc carbonate ore), burning, and making pots for trials of latten;[21] and John Brode, in 1596, said that when he visited Tintern he was told that one Hinckens and his sons had built furnaces for making brass, their product being of the right colour but incapable of being rendered malleable; the small amount of calamine stone remaining was eventually used for repairing a fishing weir.[22] As to copper, the other constituent of brass, the arrival at Tintern of five tons is recorded by Humfrey, but apparently more of an embarrassment than anything else because it had to be paid for.[23]

Regarding brass at Tintern we may therefore repeat in part Hamilton's findings[24] that " . . . failure and disappointment are writ large over their efforts with brass . . . The Company was concerned with two different projects – the manufacture of iron wire and the making of brass, and the initial success of the former appears to have led to the neglect of the latter". From the facts known, the closing down of the brass-making experiments, far from being due to the success of the iron wire manufacture, was due to the failure of the experiments themselves, coupled with the great difficulty encountered in the making of iron wire, upon which all available resources had to be concentrated. It is safe to conclude that no brass wire was ever made at Tintern.

There is no doubt that iron wire was drawn in the Angidy Valley from the earliest period, but with limited success at first due to unsuitable iron and unskilled labour according to the list of expenditure already mentioned; this period would be from September 1565 (since the cost of the Letters Patent giving the necessary privileges is included) to 1570. We have no specific contemporary description of the wire-drawing machinery used in this early period (or indeed for the next century), save that it involved the use of water power by means of wheels. It is also safe to assume that tongs were used to grip the wire, as in 1596 there were complaints as to the quality of Tintern wire, centred upon bad smithing under the hammers, oversizing, and pinching with the drawing tongs.[25] According to Hamilton, the main reason was that the works had been let on lease since 1570 and the lessees had tried to maximise profits by raising prices and lowering quality.[26]

Whatever the details, within the first five years it was necessary to bring over from Germany Barnes Keyser, who 'caused all the engines in the house for drawing of wire to be altered into a new forme' and spent two and a half years in training operators.[27] It is probably significant that Keyser was described specifically as the only wire drawer there, whereas there must be considerable doubt about the talents of Christopher Schutz, if only by the very slow progress in the early years. Owen[28] describes him as an 'engineer and inventor, who claimed to possess the secret to the modernisation and enhanced efficiency of the wire industry . . . (he) had conducted experiments in the extraction and utilisation of iron ore in Saxony, and had discovered a revolutionary technique in the use of calamine for mixing metals, and in rendering iron more malleable for industrial purposes'. Rees is much more cautious,[29] saying that 'neither Schutz nor Humfrey were fully competent in iron work'. Humfrey was a goldsmith, and assay master of the Royal Mint,[30] while Schutz was most likely as Grey-Davies[31] says, 'skilled in the smelting and extraction of non-ferrous metals, but knew nothing of the vagaries of iron working and smelting'. Hamilton describes him as the manager of the zinc mining company of St Annenberg, Saxony.[32] Certainly the early correspondence between Humfrey and Cecil (Secretary of State) spoke much of calamine, and little or not at all of iron, and if Schutz had real mechanical skills in wire drawing it is indeed strange that Keyser had to be brought over, and had to spend so much time rebuilding the new machinery; there is also some reason for believing that another German, Corslett, played the major role in establishing production of Osmond iron, essential for the production of good iron wire.[33]

It is reasonable to speculate upon the necessity for modifying the original machinery. It seems unlikely that the equipment was obsolescent or needed major repairs, and it could be concluded that it was in fact unsuitable for its purpose; it is tempting to think that it was intended for the drawing of brass wire, and had proved unsuitable for iron, a less ductile material of greater tensile strength. It may be, indeed, that Schutz, with his bias towards non-ferrous metals, had installed drums, which would probably not have been suitable for drawing iron wire in its heavier gauges.

We suggest that the means first used for drawing wire at Tintern were twofold: a modified form of Biringuccio's water-wheel machine for heavy-gauge drawing, and drums for fine gauges. The evidence which follows is circumstantial and slender, but not without weight. These two methods were clearly well-established on the Continent twenty-five years before Tintern, and it was from the Continent that Tintern's first mechanics came; moreover, 25 years was a very short time in the history of technical advance in the 16th century, and the rate of advance in the wire industry seems to have been notably slow. Apart from this, there is another reason for believing that Biringuccio's water wheels were used at Tintern, although the evidence does not appear until 1803, when Charles Heath of Monmouth published a description of the then old method of wire drawing at Tintern, which he said was based upon a handed-down description, all those who had practised it having passed away.[34] The full text is reproduced in Appendix 1, but the essentials were a long beam carrying the operators, who were secured by girdles to seats in pairs facing one another with the draw-plate between them, the wire being gripped with pincers and the beam being reciprocated by a water wheel. This is simply what we may term the 'Biringuccio machine', enlarged to accommodate several men. Whilst the first wireworks building was under construction in 1566 it was described as about 50ft x 30ft in size, and 'in the same cometh as many works as four wheels can drive'; it appears that if such a small building needed four wheels to power its machinery, that machinery was probably of a ponderous nature, which description would appear to fit Heath's swinging beams very well.

As to our contention that drums, almost certainly mounted on vertical spindles on each side of the draw-plate, were also used, clearly the full power of the water wheel would not have been needed for drawing fine wire, and again Biringuccio shows that these drums were well-known by the time the Tintern works were started. In 1569 Humfrey Cole, a die-engraver at the Royal Mint, was sent to Tintern for 'justifyinge the rolars'.[35] This has been interpreted by Rees[36] as indicating the presence of a rolling machine for flattening the plates prior to cutting them into rods by means of shears, but this is contrary to the generally-understood history of rolling mills. Rhys Jenkins has said[37] of Plot's reference (1686) to 'the new invention of slitting mills'[38] that this is 'the earliest indication that we have of the use of rolling mills in the English iron industry'; and the earliest reference he finds to the water-powered cutting of iron into rods is the patent granted to Bevis Bulmer in 1588, itself apparently unused for many years. Of the Saugus ironworks in Massachusetts, established in 1646, it is said that it embodied the most advanced iron-making technology of its day, and its rolling and slitting mill was one of the few then existing in the world.[39] So the 'rolars' were unlikely to be part of a rolling mill.

There is, however, another possible explanation of the rollers of 1569, because the term roller was also applied to the small hand-operated drums described by Biringuccio,[40] and it seems most likely that such machines were used at Tintern from the beginning, as the finer wires could not have been made with the heavier machines, whilst equally the converse was true. The relationship of the rollers on their spindles with the draw-plate and with one another was clearly fairly critical if breakage of the wire was to be minimised, and the choice of a toolmaker rather than a millwright to remedy their defects suggests that the equipment concerned was of a relatively delicate nature, which could hardly be said of even a small rolling mill.

The virtues of wire drawing on drums were, according to Abraham Rees (1819),[41] that they eliminated the marks left by the tongs, and being small and cheap they could be used by out-workers in their cottages, or by small craftsmen who bought relatively coarse grades and reduced them to the finer sizes they required in their own premises. Biringuccio says that for iron-drawing such drums could be worked by water or other power, although he does not say that this had actually been done. There is no evidence of out-working at Tintern, and as water-power was the feature which distinguished Tintern wire-making from previous English operations, it is likely that the drums there were water-powered. Abraham Rees illustrates multiple-drum units arranged for power drive, although he also shows hand-operated drums, and it is known that such equipment was still in existence in Yorkshire in 1913.[42]

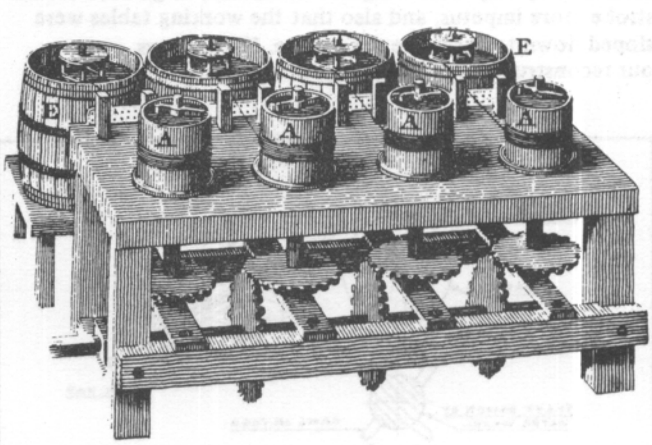

Figure 3 A battery of powered drums for wire-drawing, as shown by Abraham Rees in 1819.

RAY'S BARRELS

The first description of one type of machine used at Tintern was published in 1674 by John Ray, FRS, son of an Essex village blacksmith and later to be dubbed the Father of Natural History. The description[43] is reproduced in Appendix 2, but briefly the equipment consisted of a barrel mounted horizontally on an eccentric axis, rotatable by water power through a quadrant, after which the offset of its centre of gravity returned it to its original position; during its working cycle the barrel drew back a pair of tongs which gripped the wire and pulled it through the draw-plate. This was a major advance upon Heath's beam method, using the power more economically because the heavy beam was eliminated, and the operators themselves were no longer moved to and fro, but stood beside the machine as minders, feeding the wire into the die and adjusting the tongs as required.

Ray was born in 1627 and went to Trinity College in 1644; assuming that he saw the machinery for himself, as seems likely from his description of it, and assuming that he had little or no opportunity for travel before completing his studies, it can be taken that he visited Tintern at some time between say 1650 and 1674. There has been some tendency to assume that 'Ray's barrels' were the original machines employed at Tintern, but they embody mechanical sophistication so far advanced beyond that of Biringuccio that they appear to us to be more credible as a development near 1674 than of 1566.

We find no mention or illustration of a machine resembling 'Ray's barrels' in any of the other literature examined, which suggests that it may have been peculiar to Tintern. However, apart from the eccentric barrel, there is little real departure from the brake in its power-operated form, of which several illustrations exist (see Appendix 3), except that in the latter, the return of the tongs to the gripping position was achieved by an overhead spring beam linked to the operating lever, and possibly by sloping the work-table downwards to the draw-plate as appears in several illustrations, whereas the swing of the barrel re-positioned the tongs positively. The 'lazy-tongs' linkage described by Ray is illustrated in use on a sloping-table type of brake, with water pov er, in a work of 1839.[44]

It is, we feel, highly likely that the barrels of the machines described by Ray were weighted internally, to give the return stroke more impetus, and also that the working tables were sloped down towards the draw-plate. Fig 4 shows our reconstruction of the method.

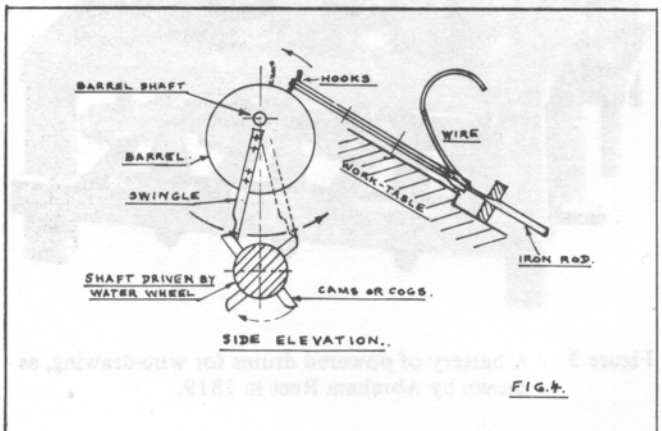

Figure 4 Authors' reconstruction of eccentric barrel type of wire-drawing machine, based on John Ray's description of 1674.

THE OVER–HOUSE MEN

Ray refers to another mill, for fine-drawing, having three floors with a driving shaft on each floor, driven by one water wheel, the wire-drawers being called 'over-house men', probably because they worked in an upper room. It appears that here the machinery was of relatively light weight, as it could be placed on upper floors, and it probably took the form of drums. The Schedule of 1821[45] includes a building named 'Gig Mill' in which one wheel worked three 'blocks' in the lower loft and five in the upper loft. This was the only building listed as having upper floors (and clearly two of them), so that there is no reasonable doubt that this was the single mill of that type mentioned by Ray, and the fact that 'blocks' was another name for 'drums' reinforces our belief that the fine-wire drums at Tintern were water-powered.

THE AGREEMENT OF 1747

In 1747 Rowland Pytt proposed to introduce new machinery at the Tintern wireworks, and it was such a fundamental departure from that in use before that he had to negotiate new rates of pay with his workmen.[46] The Agreement gives no indication of the nature of the innovation; Llewellin says that 'the ingenious apparatus employed at other establishments had placed their proprietors in a position to diminish the cost of production, and enabled them to undersell . . . Tintern'.[47] It was ostensibly to rectify this position that the Agreement was made.

There is a remarkable paucity of information available about what went on at Tintern in the 18th and 19th centuries, but there is certainly support for Llewellin's view that the Tintern wireworks, after their initial success under monopoly conditions in the 16th and early 17th centuries, had failed to respond to the growing competition from other works, and were backward and unsuccessful. The account books[48,49] for the last part of the 17th century, when the works were, for a time, under Foley management, show a surprisingly small scale of operation, with only about 30 men in total at Tintern (ie. including all trades, not merely wire-drawers), and even fewer at Whitebrook. Holland[50] says that 'in the 17th century the wire-drawing business . . . took deep root in the neighbourhood of Barnsley [Yorkshire] . . . the first workmen, it is supposed, came thither from Wales' [from Tintern?]. So there may have been an exodus of skilled men from Tintern to join competing organisations. Holland goes on to say, of wire-drawing generally, that 'grooved rollers' (ie. rolls) superseded hammering for making the iron rods, and referring to the brake with lazy tongs (which he illustrates) describes it as 'now [1839] rarely to be seen in the large wire-mills of this country . . . still to be met with in some of those old establishments where expensiveness, or want of convenience, preclude the adoption of rollers, and where the rippers . . . care little about modern improvements'.

Could a rolling mill with grooved rolls have been the new machinery which was being discussed in 1747? This would have replaced either the old process of tilting (ie. hammering) the bars into rods or the old processes of ripping and slipping the rods into wire – or both. However, if it had been the former, the 'hammermen' or 'handmen' would have been included in the 1747 Agreement, and they were not; had it been the latter, the rates for ripping and slipping (see p.24) would have been reduced or might even have disappeared; but in fact they were hardly changed. The rate for ripping was increased 12% as compared with 1698–9, and slipping was decreased 14%, so that the changes here were quite insignificant. It was indeed the rates for 'upperhouse wire', as the finer grades were called at the end of the 17th century, which were decreased by the 1747 Agreement, thus:–

Size	Rate per stone 1698–9	1747	% Reduction	
Reevin	3d	2d	33	(this size called Kleven in 1747)
Clavant	4d	3d	25	
Bastard	7d	4d	42	
Coarse fine	10d	5d	50	
Fine fine	12d	6d	50	
Super fine	18d	9d	50	

These very substantial decreases indicate that it was in this area that the great increase in efficiency was expected to take place. Heath (1803)[51] says that with the new methods 'less than one half the former number of hands became necessary'. But drums were still the normal system for fine-wire drawing in the 19th century, so it is hard to see what the great improvement could have been.

There is one possible explanation of the situation which appeals to us, namely, that the changes in machinery envisaged by the 1747 Agreement, did not, in fact, take place. Prior to the Agreement, the workmen had guaranteed security of employment; the real purpose, or at any rate, the real effect, of the Agreement may have been to change this situation by giving the employers greater freedom in deploying their workers at more suitable rates of pay. There is really no firm evidence that new methods were actually introduced within some decades after 1747; Heath's actual words were 'when the *present* method of making wire was introduced . . . less than one half . . . ' [Heath's italics]. As he was writing in 1803, the 'present' method may have been introduced quite late in the 18th century, or even in the first year or two of the 19th. We know that a rolling mill existed at Tintern in 1821,[52] situated at the Lower Works, although none was mentioned in an admittedly rather abbreviated description of 1798,[53] which did, however, include three tilt hammers. It is thus very possible that Heath's "*present* method' referred to the introduction of rolls without any implication that rolls were associated with the 1747 Agreement.

It may be presumed that the three hammers just mentioned were housed in the tilting mill which, by the evidence of surveys of 1763 and 1821, was built between those years. Tilt hammers had been used from the beginning of the wireworks for 'straining' or drawing down the iron bar into rods. (In 1583 reference was made to the straining of iron rods in the hammer houses built by Christopher Schutz,[54] and earlier, in 1580, when Richard Martin took a lease of the works, he promised to erect two hammers in addition to the four already there.[55]) The construction of new tilt hammers between 1763 and 1798 infers that no great changes had been made in this part of the wire-making process at that time, thus supporting our suggestion above.

TONGS AND BLOCKS

In the two descriptions of the wireworks dated 1798 and 1821, the wire-drawing machinery is described partly by the term 'tongs' and partly by the term 'blocks'. The following numbers of each were recorded:–

	1798	1821
Tongs	10	12
Blocks	10	23

In the period concerned, capacity had been increased by a total of two tongs and 13 blocks, yet in this period New Tongs Mill was built at Pont-y-Saeson, housing 11 tongs, one more than the total in 1798. The tongs were evidently still a well-established and indispensible means of production which had been concentrated in new premises rather than expanded, perhaps to make room for the considerable increase in the number of blocks. We are certain that the blocks were drums or developments thereof. The tongs would have been for relatively heavy drawing, where marking did not matter; they were probably still of the 'Ray's barrels' type, or possibly of the type of brake illustrated by Abraham Rees (see Fig 5) in 1819.[56] They were certainly not Heath's beams, pronounced long-extinct in 1803.

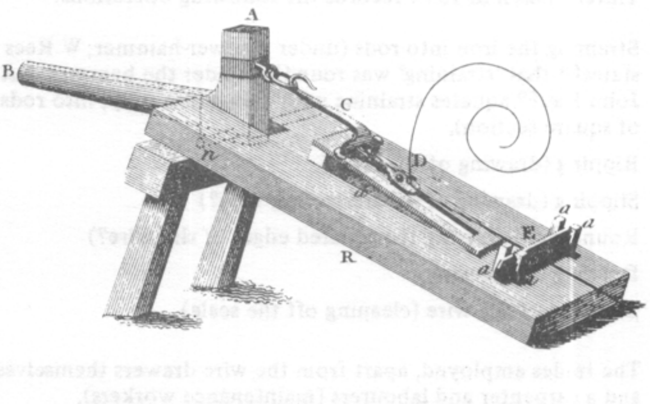

Figure 5 A brake for wire-drawing, as shown by Abraham Rees in 1819; the water-powered drive and spring-beam return are not shown, but are mentioned in Rees's text.

The fact that a great increase in the number of blocks was not accompanied by a corresponding increase in the number of tongs, coupled with the provision of a rolling mill which we have already mentioned, suggests that an increased demand for wire was being met by the substitution of rolling (with grooved rolls) for part of the wire rod making process. That the rolls were not plain rollers for rolling iron plate is indicated by the fact that we have found no record of slitting mills ever being used at Tintern, and without such mills to make bars from the plate, there could have been no purpose in making plate there.

We have discovered no technical information concerning the equipment used at Tintern in the 19th century; it is surprising that, limited though the accounts of earlier centuries are, they are generous compared with those for the most recent period. After the first quarter of the 19th century, the works appear to have been generally on the decline, and it is unlikely that any technical innovations were made after the installation of the rolling mill.

Considering wire making generally, not just at Tintern, an examination of available illustrations through the years indicates remarkably little change in the mechanics of wire production. We believe that this is partly attributable to the separation of the processes into the two quite distinct parts: (a) the production of wire rod (ripping, or 'rumpling' in some places), and (b) the drawing of this into fine wire. It is the second part that receives attention in most accounts, and changes in the first part may have escaped note.

The known illustrations are listed in Appendix 3.

OTHER ASPECTS OF THE WIRE–MAKING PROCESSES AT TINTERN

We have concentrated attention on the wire-drawing methods because these embodied the more refined and novel mechanical equipment; but the whole wire-making process involved other operations, and these will now be noticed.

Given the billet of Osmond iron, it was necessary to heat it, work it under a hammer to a thickness suitable for the wire contemplated, take off the four corners or edges, and bring each rod to a taper at one end so that it could be offered into the die with sufficient protrusion for it to be gripped by the tongs. During these operations, it was necessary to place the iron in water for varying periods (see below).

In the earliest period, a list of labour and material charges at Tintern taken in 1574 records the following operations:—[57]

Straining the iron into rods (under a power-hammer; W Rees states[58] that 'straining' was rounding under the hammer, but John Ray[59] equates straining with elongation only, into rods of square section).

Ripping (drawing of wire rod)

Slipping (drawing of square-section wire?)

Rounding (removing the squared edges of slip wire?)

Drawing of the wire

Scouring of the wire (cleaning off the scale).

The trades employed, apart from the wire drawers themselves and a carpenter and labourers (maintenance workers), comprised two smiths and their two strikers, nealers, and 'one to scale'. The definitions above are those given by W Rees, Schubert, and others, and which can be deduced from Ray's work. The sizes of wire made were given distinctive names, as listed in Appendix 4. There is some suggestion, as from the distinction between 'round' and 'slip' wire, that some was of square section.

The raw materials mentioned, apart from the iron, are given as train (oil), tallow, candles, 'sea coal and wood to neal', and steel and iron to mend tools and make new ones. The first two were clearly lubricants (Ray mentions train oil as such).

THE WATERING PROCESS

The immersion of the wire in water at various stages of drawing, detailed by Ray, has been the subject of some speculation in recent years. Ray offers no explanation of it, and Rogers, quoting the workmen's terminology in 1857,[60] says it was intended to 'purge and purify away the sulphur', and that the indication that the process was complete was a thin scum rising to the surface of the water.

The other contention is that the object of the watering process was to promote the formation of a rust coating, which acted as a carrier for the lubricant, thus permitting easy and continuous drawing. The formation of this coat, and its preservation by dipping into slaked lime, was described in 1913,[61] but the writers were silent as to its purpose. Professor Hugh O'Neill has briefly described this process, adding that the reason, according to the 'Steel Wire Handbook' (USA) of 1965 was that the calcium hydroxide acts as a solid lubricant carrier.[62] Mr K Gale adds that rusting also helped to break up hot-rolling scale which, being very hard, would quickly damage the dies.

It appears to us that even the early practitioners must have known that they did not need to water the iron for weeks and even months, simply to produce a coating of rust, also that total immersion in water was not the best way to achieve this. The presence of air would hasten the matter, so that far from making special 'water-holes' like tan-pits for the purpose, as Rogers states, it would have served better to have put the wire into a flowing stream, with its better aeration. We suggest that the original purpose of the watering was as Rogers states; that the formation of a rust coating used to carry lubricant was a useful by-product of the process; and that in later years, with the use of improved annealing methods in a sulphur-free environment, only the coating was required, and was obtained following tumbling in the scouring barrels, to which we can now turn our attention.

SCOURING BARRELS

These items of equipment were in use at Tintern in 1798[63] and the fact that they were not mentioned by Ray, coupled with Rogers's note of 1857 to the effect that the traditional watering process was regularly practised at Tintern more than fifty years before to his own knowledge, suggests that their introduction can be placed in the last quarter of the 18th century. The barrels were used for removing the scale produced by air-cooling following annealing, and their use was probably the same as described for works at Thurgoland, Yorkshire, as follows:—[64] The charge, ranging from 5 to 10 cwt, was packed with broken blast-furnace slag into a barrel, the end of which was removed for loading and then screwed into position. The barrel was set in motion (using water power at Tintern,[65] and no doubt at other places also) in a trough of running water, and it was rotated at about 30 rev/min for a period of 12 to 24 hours. The wire was removed wet, and stood until a coat had formed, which was preserved by dipping into lime, after which the wire was dried before a fire. The wire was then drawn through the first two holes, but in later stages of drawing it was sometimes cleaned with a mixture of vitriol and brewery grounds. Later stages of drawing were known as common-drawing or jigging.

There were ten scouring barrels at Tintern in 1798[66] and 16 in 1821,[67] disposed among four different sites, at three of which the barrels were driven by their own water wheel, while at the Tilting Mill site two barrels were driven from the same wheel as the hammer.

ANNEALING

Each time the metal is drawn through a die it hardens, and after each few drawings it is necessary to anneal it, ie. to heat it (usually to red heat) and to allow it to cool slowly, when its ductility is restored. This was a common and well-known process, in early days done in an open fire of some sort. The iron (or other metal) was thereby exposed (a) to the undesirable elements, such as sulphur, in the flames, and (b) to the oxygen in the air on cooling, thus causing scaling. No doubt this simple process was what was used at Tintern at least up to the end of the 17th century.

Improved annealing furnaces came into use elsewhere in the 18th century. Those used in the Bristol brass industry,[68] for example, were tall towers (around 30 ft high, or 10m) tapering from a base about 10 ft (3m) square. Inside the base was a smaller oven of refractory material, with a fireclay door which could be raised by means of a lever and counterweight. The metal to be annealed was put in this. The fire was outside it, and the flames and hot gases were caused to circulate in the gap between the oven and the tower itself. Thus the metal was protected from both the flames and the air. More efficient arrangements used in France are described by Abraham Rees[69] whereby the container or oven (made of iron) could be removed after heating in order to allow another to be put into the furnace while it was still hot.

No information is available as to what kind of annealing furnaces were used at Tintern up to about 1800. However, there are still a few remains extant of the new tongs and annealing mill at Pont-y-Saeson, built in 1803, and these indicate that the annealing furnace then provided had a square base very similar to those used in the Bristol brass works, and it is a nòt unreasonable assumption that the whole furnace was of the same general design.

PRODUCTIVITY

The object of introducing technical change must be either to improve the quality of the product or to increase productivity per unit cost. It is clear from the 1747 Agreement, whether it resulted in technical change or not, that it was the latter consideration which applied at Tintern. It is therefore worthwhile to determine what the productivity was at various periods. Unfortunately the account books which have so far been discovered[70] cover only the period from 1672 to 1700 – ie. the 'Ray' period. We record some conclusions from them in the hope that the data can eventually be used for comparison.

Analysis of the accounts shows an overall productivity of finished wire of about 1.8 tons per year per man employed at the wireworks, or about 4.5 tons per year per upperhouse wire-drawer. 62 tons of Osmond iron, purchased at £18 per ton, was dealt with by the hammermen at the wireworks in 1699 to produce 42½ tons of wire selling at an average of about £40 per ton, plus some miscellaneous iron selling at about £200.

CONCLUSIONS

It will have been seen how difficult it is to be certain about the processes used at Tintern. There are a few certainties, however:–

1 Water power was used from the beginning in 1566–8, and this was the first time it was so used in Britain, although an established practice on the Continent.

2 A detailed description of a water-powered mechanism for the Ripper's stage of wire-drawing was given by John Ray in 1674. The tongs had to be applied to the wire by the operator, or ripper, at each pull.

3 Finer stages of wire-drawing were also water-powered by 1674, according to Ray, being done in a 3-storey building powered by one water wheel driving shafting on each floor.

4 The accounts for 1699 show that bar iron was 'drawn' at the forge (not part of the wireworks, but associated with them) at the rate of 160 tons/year and that 62 tons of iron were dealt with by 'hammermen' at the wireworks. So the preliminary preparation of rod was done by hammering.

5 Radical changes in technique were proposed in 1747, the new rates of payment per cwt showing an increase for rippers but decreased payment to all other wire-drawers.

6 A rolling mill was provided around 1800, and by then the number of men required had been drastically reduced.

Apart from these facts, we have had to speculate; some of our suggestions are:–

i. Wire-drawing at Tintern had started using men in swing seats, moved to and fro by the water wheel, as described from tradition by Charles Heath around 1800. The men fastened tongs onto the wire each time they moved backwards and so drew the wire through the die. This is more or less the system described by Biringuccio in 1540.

ii. The radical changes of technique implied by the 1747 Agreement were never made.

iii. The rolling mill of c.1800 had grooved rolls, and was used for the preliminary forming of bar into rods, and thus reduced the work required from the rippers.

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APPENDIX 1

WIRE–DRAWING AT TINTERN, c.1600, ACCORDING TO CHARLES HEATH
(reference 34)

"The assistance of the mechanic powers to the operations of labour, appear to have been in a very infantile state at that period, if an opinion may be formed from the process of their work, of which tradition has preserved a feint recollection. A large beam was erected across the building where they carried on their trade, to which were affixed as many seats (in the form of large wood scales), as there were men employed, who were fastened in them by means of a girdle, that went round their bodies. The men were placed opposite each other, while between them stood a piece of iron, filled with holes of different bores, for reducing the wire to the various sizes. When the iron to be worked was heated, the beam was put in motion by means of a water wheel, that moved it, with the workmen in their seats, regularly backwards and forwards, who, with a large pair of tongs, passed and repassed the iron through the holes, till by force they reduced it to the sizes required. The motion was as regular as the pendulum of a clock; and if any one of the men missed seizing the iron with his tongs, he suffered a considerable shock in the return of the beam."

APPENDIX 2

WIRE–DRAWING AT TINTERN, c.1674, ACCORDING TO JOHN RAY
(reference 43)

"They take little square Bars, made like Bars of Steel, which they call **Osborn–Iron**, wrought on purpose for this manufacture; and strain ie. draw them at a Furnace with a Hammer moved by water (like those at the Iron Forges, but lesser) into square Rods of about the bigness of ones little Finger, or less, and bow them round. When that is done they put them into a Furnace, and neal them with a pretty strong Fire for about twelve hours: after they are nealed they lay them in water for a month or two (the longer the better) then the Rippers take them and draw them into Wire through two or three holes.

Then they neal them again for six hours or more, and water them the second time about a Week, then they are carried to the Rippers who draw them to a two-bond Wire, as big as a great Packthread.

Then again they are nealed the third time, and watered about a Week as before, and delivered to the small Wire Drawers, whom there they call Overhouse-men, I suppose only because they work in an upper Room.

In the **Mill**, where the **Rippers** work, the Wheel moves several Engins like little Barrels, which they also call Barrels, hooped with Iron. The Barrel hath two Hooks on the upper side, upon each whereof hang two Links standing a-cross, and fastened to the two ends of the Tongs, which catch hold of the Wire and draw it through the hole. The Axis on which the Barrel moves, runs not through the Center, but is placed towards one side, viz that on which the Hooks are. Underneath is fastened to the Barrel a Spoke of Wood, which they call a Swingle, which is drawn back a good way by the Calms or Cogs in the Axis of the Wheel, and draws back the Barrel, which falls to again by its own weight. The Tongs, hanging on the hooks of the Barrel, are by the Workmen fastened on the Wire, and by the force of the Wheel the Hooks being drawn back, draw the Wire through the holes.

They anoint the Wire with Train-Oil, to make it run the easier. The Plate, wherein the holes are, is on the outside Iron, on the inside Steel.

The holes are bigger on the Iron side, because the Wire finds more resistance from the Steel, and is streightened by degrees.

There is another Mill where the small Wire is drawn, which with one Wheel moves three Axes that run the length of the House on three Floors one above another.

The Description whereof would be tedious and difficult to understand without a Scheme, and therefore I shall omit it."

APPENDIX 3

PUBLISHED ILLUSTRATIONS OF EARLY WIRE–DRAWING EQUIPMENT

Date		Equipment illustrated and source
1540	1	Brake, hand-operated, horizontal table
	2	Vertical-shaft capstan
	3	Drums, hand-operated
	4	Water-powered hand-held tongs (Biringuccio, our reference 10)
1768		Brake, power-operated, horizontal table, with spring-beam return. For brass wire. (D. Diderot, **Encyclopédie**, Vol. 6)
1786	1	Brake, water-powered, sloping table, spring-beam return
	2	Brake, hand-operated, sloping table, leaf-spring return
	3	Drum-brake; wire wound through die by a drum, rotated by hand; sloping table
	4	Drums, hand-operated (Diderot & d'Alembert, **Encycl. Methodique**, Vol. 3 of plates)
c.1800		Brake, hand-operated, horizontal table (reproduced by Schubert, our reference 9, from D H Döhner, **Geschichte der Eisendrahtenindustrie**, Springer, Berlin, 1925)
1819	1	Brake, hand-operated, windlass, sloping table
	2	Ditto, geared, horizontal table
	3	Brake, water-powered, sloping table, spring beam

	4	Multiple drums, power-driven
	5	Drums, hand-operated
	6	Ditto, geared (Abraham Rees, our reference 41)
1839	1	Brake, power-operated, sloping table, lazy tongs
	2	Single drum, hand-operated
	3	Drums, power-operated (John Holland, our reference 44)
1853, 1869, 1873		Drum method, power-driven (C. Tomlinson, Encyclopedia . . .; W Crookes & E Röhrig, Pract. Treat. on Mety., Vol. 2; G H Makins, Manual of Mety.)

APPENDIX 4

WIRE SIZES, RATES OF PAY, AND TRADES AT TINTERN AT VARIOUS TIMES

Note: No source examined so far enables the actual wire size to be determined for any of the traditional names listed here. Most sources, including John Ray (see Appendix 2) agree that when the osmund iron left the tilt hammers, it was about the thickness of one's little finger and square in section. When a wire size or trade is mentioned in a particular year, it is named below. The payment for drawing one stone (14 lb or 6.35 kg) is given in pence (d) where recorded.

1574 (ref. 2)	1672/3 (ref. 48)	1698/9 (ref. 49)	1739 (ref. 71)	1747 (ref. 34)
	Boltack	Boltack	Bolttack	
	Buckle	Buckle		
	Two band	Two band		
	Round wire	Round wire	Round wire	
Riving 2d	Reeven 3d	Reevin 3d	Revin	Kleven 2d
Clavant 4d	Clavant 4d	Clavant 4d	Clavant	Clavant 3d
Northern 4½d	Northern 5d			
Bastard 6d	Bastard 7d	Bastard 7d	Bastard	Bastard 4d
	Course fine 10d	Coarse fine 10d	Corse fine	Coarse fine 5d
Fine 10d				
Fine fine 12d	Fine fine 12d	Fine fine 12d	Fine fine	Fine fine 6d
	Super fine 18d	Super fine 18d	Super fine	Super fine 9d
				Big Nogg 14d
				Small Nogg 16½d
Straining	Handmen (for drawing out Osmund, iron)	Hammermen		
Ripping	Rippers (for round wire)	Rippers		Ripping
Slipping	Slippers (for two band wire)	Slippers		Slipping
Scouring(of slip wire, of round wire)	Scourers (for round wire, for two band wire)	Scourers		Scouring of two-band
	Scallers (for round wire)	Scalers		Scaling of ripp wire
	Swager	Swager		
	Smiths	Smiths		
	Nealers	Nealers		
	Carpenter	Carpenter		
	Sawyer			
				Breaking of round wire
Rounding				Rounding

Benjamin Huntsman, 1704–1776

An abridged version of the commemorative lecture given by K C Barraclough at the Cutlers' Hall, Sheffield on Monday, 21st June, 1976 on the occasion of the 200th anniversary of the death of Benjamin Huntsman, inventor of 'Cast steel'

Benjamin Huntsman was the third son born to Quaker parents at Epworth in Lincolnshire on June 4th 1704. His father was probably a farmer; by tradition, the Huntsmans were originally Dutch, having come over with Cornelius Vermuyden in about 1626 to assist in the drainage of the Isle of Axholme and Hatfield Chase.

Little is known of the early years of Benjamin Huntsman until at the age of fourteen he was apprenticed to an Epworth clockmaker for a premium of £4. Seven years later he was established as a clockmaker in his own right, taking on his own apprentice at a premium of five times that amount![1] He was appointed to look after the town clock at Butcher Cross in Doncaster, to which he had moved, in 1727.[2] Two years later he married and the story is a little confusing. In the first place, the ceremony was by license of the Church of England, which must have caused problems with the Quaker community: it is probable that he was disowned by them.[3] In the second place both he and his bride, Elizabeth Haigh, were from Doncaster, but are described as of Mansfield, the ceremony taking place at Retford. The sojourn at Mansfield seems to have been to provide a residence qualification only, since both were back in Doncaster within the year.

There were two children by the marriage: Elizabeth, born in 1730 and William, born in 1733. There is a story that his wife secretly took their son to be baptised in an Anglican church, either at Penistone or somewhere in Derbyshire, whereupon Huntsman was so enraged that he vowed to have nothing more to do with his wife and she is then understood to have left him, taking the daughter with her. On the other hand, there is a record of the baptism having taken place in the Doncaster parish church on 2nd October 1733.[4] Nothing more is heard of his wife other than her death on 3rd November November 1760: she is the first name on the memorial slab on the grave in Attercliffe Chapel Yard (now Hill Top Cemetery). On the face of things, the estrangement between husband and wife cannot have been complete, since Benjamin Huntsman is recorded as having been laid to rest in the same grave sixteen years later, his daughter in law and two of her infant sons having been buried there in the interval; on the other hand, a thorough search through the Attercliffe parish registers has failed to reveal any record of the burial of either Benjamin or his wife Elizabeth, although the other three occupants of the grave are so recorded and it would seem more appropriate to refer to the Huntsman Monument rather than the Huntsman grave.[5]

Whatever his family troubles may have been, Benjamin Huntsman prospered in his business; he was appointed to look after the new town clock erected in Doncaster after the dismantling of the Butcher Cross in 1734.[2] In 1739 he rented a house in High Street, Doncaster; two years later he purchased the freehold for £210.[6] In addition to his clock-making he had developed a reputation for making and mending such things as locks and roasting jacks and other pieces of domestic engineering and people trusted him sufficiently to seek his advice when they had troubles with their eyes or pains in their bodies – although he was careful not to take payment for such services.[7] He took to making the tools and the instruments he required and found that the steel which was available for these and for his clockmaking requirements – springs and pendulums – left a lot to be desired. The metal which he found unsatisfactory was 'German Steel'. Here there is further confusion: it could well have been imported material or it could have been the type of material which was currently being produced by Wilhelm Bertram at Blackhall Mill on the Derwent, a tributary of the Tyne.[8] This was later to become known as 'shear steel' and, indeed, the introduction of the manufacture of shear steel into the Sheffield area was by Thomas Eltringham, a forger from Blackhall Mill, in 1767.[9] This material was essentially layers of high carbon and low carbon steel intimately welded together – a very satisfactory material for the manufacture of knife blades and swords since on hardening and tempering there were hard bands, to give cutting edges, backed by softer material giving flexibility and resistance to fracture. For fine tools or springs, however, it can be appreciated that there could be shortcomings. Imported 'German Steel', if this had been involved, would have been essentially similar, since it too had alternating bands of high and low carbon material.

Benjamin Huntsman, being of a practical turn of mind considered that, if he could melt down the steel in a crucible, as did the brassfounders, he could produce a more uniform material. Blister steel, or the shear steel made from it, had derived its carbon from a diffusion process in the solid state; never before had liquid steel been cast into ingots for forging. Huntsman faced considerable problems; the temperature needed for the fusion of steel was much higher than that for brass and not only required a suitable furnace design but a crucible which would withstand both the temperature and the possible attack of the steel on it. In a way, of course, he was born at the right time. Only thirty years earlier had Abraham Darby demonstrated that coke could be used as a metallurgical fuel in his blast furnace at Coalbrookdale. Using a deep bed of incandescent coke and a suitable draught it was now possible to maintain a high temperature for a much longer time than had been possible with charcoal, the previous fuel. And about the same time the value of Stourbridge clay as a refractory material had been demonstrated in glassmaking; it is significant that there was a glassworks at Catcliffe, with pots made from the not dissimilar Bolsterstone clay, operating at the time of Huntsman's earliest experiments, which are believed to have been late in the 1730's whilst he was still at Doncaster.

He sold his residence in Doncaster only about a year after purchasing the freehold[10] and moved to a cottage at Handsworth, then a village near Sheffield, in 1742.[6] These premises were demolished in 1933 but an old photograph and a watercolour exist; it has been reported that flue marks could be traced in the small building attached to the end of the house[11] and it must be presumed that it was here that the experimental work was carried out in deep secrecy. Meanwhile he continued his work as a clockmaker, setting on another apprentice in 1743, still appearing as 'of Doncaster'; this fact has made some doubt as to the date of his move to Handsworth but it seems that it was usual for the craftsman to be styled as of the place where he was first recognised in his craft. By 1751, however, he had mastered his new craft sufficiently to give up clockmaking and set himself up as a steelmaker.

He moved to premises he designed himself, said to be in the Worksop Road in Attercliffe. The firm run by his descendents, B Huntsman Limited always carried 'Established 1751' on its stationery. The whereabouts of these first premises is not definitely known, but there is a plan in one of the Fairbanks sketch books, dated 11th August 1763 showing property adjoining Attercliffe Green (which could arguably be considered as being on the Worksop Road) indicating buildings erected by Benjamin Huntsman, and containing a steel furnace; a note added in 1781 shows the furnace to have then been in the hands of Thos. Gunning.[12] It seems also that the same property was held by Charles Hancock in 1819.[13]

Huntsman was to move once more. It is generally suggested that this was in 1770[14] and that the building with the date 1772 in (allegedly) steel figures on the gable end, now the Britannia Inn in Worksop Road, was his residence for his last few years.[15] Not far away, on the same side of Worksop Road, but on the opposite side from the earlier location, the 1819 survey shows a house, a pleasure garden, ten houses, a steel furnace and a warehouse, together with other property occupied by Francis Huntsman, grandson of Benjamin;[16] the Ordnance Survey maps of 1854 and 1893 both show the same property, relatively unchanged, except for the ornamental shapes in the garden! These premises were occupied until 1899, when the firm moved to its final quarters on Tinsley Park Road and a new housing estate was built on the old site; Huntsman's Row, as the old houses had been termed, disappeared and only Huntsman's Garden School, built nearby in 1884, perpetuates his name in the area today.

It seems that Huntsman's steelmaking prospered; nevertheless, having perfected his invention he was not of a disposition to take the greatest commercial advantage of it, caring little for mere money making. The excellence of his steel brought his reputation and business and what came in this way, almost unsought, he attended to with care 'but he never condescended to push business by any of those arts which are now so common.'[17]

One of Huntsman's customers was Matthew Boulton, to whom he supplied steel rolls, hammers and 'dyes' as well as bar and sheet.[18] It seems that Huntsman was attempting to obtain the whole of the Boulton steel orders late in 1775 as was his son William only a year later, after the death of his father. Boulton sometimes remarked about the more favourable prices he could obtain 'from other people in your neighbourhood'; nevertheless 'for our very fine steel buttons we shall buy your steel, be the price what it will'. The connection with button making is of interest since William Huntsman was a partner of one Asline in Sheffield as button makers in 1774[19]. Huntsman and Asline appear in the ledgers of Thos. Patten and Company in Cheadle in 1761 as suppliers of steel; the same two names are coupled as steelmakers in 1787.[20]

Huntsman did not patent his process – such a move would probably have worked to his disadvantage in any case – but he was dependent on others for his crucible materials, his ingot moulds, his supplies of blister steel and for the forging of his ingots. That he would have inquisitive neighbours would be obvious; the fact that he was working in premises attached to his residence at Handsworth during his experimental work should have increased his security, however. The story of the beggar approaching the warmth of the furnace room on a cold winter night and seeking shelter from the elements is well known; having been permitted to enter, he feigned sleep but observed the whole process through half-closed eyes and then departed with all the secrets next morning.[21] It is a plausible and colourful story; considering the difficulties experienced by Huntsman with his crucible material, the provision of the correct temperature and the importance of the raw material selection, the beggar would have to have been extremely skilled in the art and extremely observant even to have been able to put in hand any meaningful experimental work, let alone copy the process. The industrial spy concerned in this deception is generally identified as Samuel Walker, who was involved in the iron trade. He had a steel furnace at Basbrough in 1748 – presumably a cementation furnace for making blister steel – but is reported to have built 'a house and a furnace for refining steel at Grennoside' in 1750.[22] It could be that this was his attempt to copy Huntsman; in this case, however, the espionage must have taken place at Handsworth and it seems unlikely at that time that there would be a group of workmen at night or that Huntsman himself, just next door, would not have been personally involved. The Walkers left Grenoside shortly afterwards and their next recorded steelmaking activity was in 1771 at Masbrough. The picture is confused, however, in that their premises at Grenoside were taken over by Benjamin Tingle, who had been in partnership with Samule Walker. Local tradition maintains that the secret was stolen by a joint effort between Walker and Tingle 'three years after it was found out' but that the two of them subsequently had a 'terrible flair up' and Walker left Tingle in charge of both the premises and the secret; there certainly was a continuing record of steel melting at Grenoside until at least 1863.[23]

Other attempts were made to copy the process. The Cutlers' Company ran trials, possibly with Huntsman's connivance, between 1764 and 1768 but these were unsuccessful.[24] Further afield there is a report of a failure near Newcastle about 1765,[25] although a furnace operating in Birmingham, possibly worked by Matthew Boulton himself, is described in 1770.[26] In Sheffield itself, John Love and Thomas Manson set up a business 'for the running and casting of steel' near West Bar in 1760, Manson being replaced by Spear in 1769, to be followed eventually by Spear and Jackson.[27] John Marshall, the progenitor of the Vickers organisation, was casting steel at Millsands in Sheffield by 1774 and his name became almost as famous as Huntsman's on the continent in the early years of the nineteenth century, one French report classifying a local product as being almost as fine as 'Huntzmann' or 'Marschall' steel.[28] In 1776 the Sandersons, later to become Sanderson Brothers and Newbould, set up crucible steelmaking at Wadsley Bridge[27] whilst Richard Swallow, having taken over the Attercliffe Forge in the same year, started similar operations at Oakes Green nearby.[29]

There is a tradition which detracts from Huntsman, making him the thief, the inventor being one Waller. This first appeared in print in 1773[30] and raised its head a number of times, finally as an anonymous letter to the Times on 21st December 1864. According to these accounts, Waller a goldsmith, attempted to produce steel rolls for use in his trade and, having discovered a satisfactory steel melting process, tried to sell it, first in Birmingham and then in Sheffield. In the latter town, the secret was wormed out of him by those skilled in the art and he was sent back to London with a mere pittance There was a firm rebuttal by Benjamin Huntsman, great grandson of the inventor, in the Times of 2nd January, 1865 and this was supported by such authorities as Professor le Play, Dr John Percy and Robert Hadfield during the nineteenth century, all of whom were convinced that Huntsman was the rightful inventor. The confusion may have arisen from an invitation given to Huntsman by the Royal Society to put evidence of his process before them with a view to being granted a fellowship; it seems that he had discussions with a committee headed by Lord Macclesfield but, in true Quaker fashion, declined the personal honour offered. One of Lord Macclesfield's friends who was present is supposed to have passed the information to his friend Waller and thus it came back full circle to Sheffield.[31] It, indeed, those more skilled in the art who cajoled the secrets out of Waller in Sheffield, happened to have been Walker and his partner, Tingle, this would explain matters and obviate the need for the picturesque legend of the shivering beggar.

By and large, however, Huntsman's invention caused more excitement abroad than it did in his local town. The Sheffield cutlers, finding the material more difficult to work than the blister steel to which they were accustomed, refused to use it. Huntsman therefore sought a market elsewhere, particularly in France. The French manufacturers soon realised they could produce superior edge tools and cutlery from cast steel and these found a ready market, not only in France but also in Britain, whereupon the Sheffield manufacturers, realising the threat to their own market, lobbied Sir George Savile to use his influence with the government to prohibit the export of cast steel to France; when Sir George, however, discovered that they were themselves unwilling to use the material he refused to have anything to do with their plea and they had to take up its use.[32] It was about this time that Huntsman was invited to set up his own works in Birmingham. It seems that he actually went there, but on learning that part of the agreement would be to teach six others his process, he indignantly refused and returned to Sheffield.[33] What a difference an alternative decision could have had on the whole future of the steel industry!

Foreign visitors undertook long journeys to call on Huntsman and from their reports we can learn something more of his activities. In July, 1761 the Swedish engineer, Ludwig Robsahm, saw the whole of the Huntsman premises but was refused any information on the production of crucibles.[34] Robsahm concluded that they were probably made from ground up plumbago crucibles which were imported from Holland with an admixture of Stourbridge clay; they were about 18" high and seem to have held about 15 lb. of metal, which was cast into a cast-iron octagonal mould about two inches across. Gabriel Jars, the Frenchman, came in 1765; whilst he does not specifically mention Huntsman in his report he describes the process quite closely.[35] Bengt Qvist Anderson, another Swede, is known to have visited Huntsman in 1767; his report does not mention the fact and does not even mention crucible steel. On his return to Sweden, however, he set up a crucible steelworks at Ersta and a drawing of this has survived, which is obviously of interest in showing what a contemporary Sheffield works could have been.[36] The final report of interest to us is from Eric Geisler who came in 1772. Again, whilst not specifically mentioning Huntsman, he left a drawing which could quite conceivably be the new Huntsman premises in 'Huntsman's Yard' near 'Huntsman's Row'.[37]

As far as the market for the steel was concerned, both Boulton and Jars make it clear that it was only used for special purposes. When account books become available to throw more light, Benjamin Huntsman had been dead for over ten years and his son was carrying on his father's business. It is clear that considerable quantities were still going to the Continent, to France and Switzerland in particular. Home customers included tool makers and cutlers in Sheffield. Peter Stubs of Warrington bought supplies for his filemaking, steel wire went to a number of firms particularly to Millwards of Redditch; Thos. Patten was still a customer. The trade in steel, however, is clearly a two way business; we find sales to other Sheffield steelmakers as well as purchases of steel from them from time to time. The method of payment is interesting as well: it may be in services rendered, such as rolling or slitting; it may be in finished goods, such as planes, scythes or saws; it may be in scrap or raw material supplies; or in items classed as 'goods', or even cloth or rum or lottery tickets! And the 'goods' – silver spoons, coffee pots and the various tools – were sold to customers along with the steel. In 1798 Boulton required steel for dies for the Soho Mint and William Huntsman was quite happy to receive in return £100 in penny pieces, all newly minted from his own dies! The reputation which Huntsman's steel was gaining can be assessed by reference to an unsolicited testimonial issued by Fourness and Ashworth, Engineers to the Prince of Wales, in 1792.[38] Significantly this was published simultaneously in English and French and the French themselves supported such sentiments, Professor le Play referring to 'well deserved homage to all the material and moral qualities of which the true Huntsman mark has been a guarantee for a century'.[39] This was written in 1846 by which time crucible steel was being produced in France, Germany, Switzerland and across the Atlantic in America. For another ten years, however, this process was the only method of producing ingots of steel.

Bulk steelmaking came in the wake of the inventions of Bessemer and Siemens, but crucible steel produced the major tonnage until about 1868 and its output still grew up to at least 1873, when the 100,000 tons per year level was topped in the Sheffield area. Then came the 'great depression'; output in Sheffield fluctuated over the next fortyfive years but never again reaching the previous maximum; the peak world output came somewhere between 1913 and 1917, probably being about a quarter of a million tons in the best year.[40] Such totals could only be achieved by increasing the unit weight to the maximum a man could be expected to handle – 60 lb. of metal plus 25 lb. of crucible plus 20 lb. of tongs – – and by increasing the number of holes and the number of crucibles per hole.

This, then, was the full flowering of a process perfected many years before by Benjamin Huntsman. It is now a thing of the past. Newer, much less labour-intesive processes have taken its place in the Sheffield steelworks, but the legacy survives. Huntsman not only invented a new process; he established a reputation for quality which became the hallmark of Sheffield and which has outlived his process. Incidentally, he also introduced a much wider principle – that of the casting of ingots in steel. From his first puny ingots of a few pounds in weight, his own process eventually produced ingots of up to 25 tons, by casting the contents of as many as 672 crucibles into one and the same mould over a period of something approaching an hour;[41] since then, other processes have made ingots of as much as 400 tons for special purposes.

The homage of Sheffield to Benjamin Huntsman was well expressed in the obituary notice of his grandson, Francis Huntsman[42]: 'Mr Huntsman was a member of a family of whom Sheffield has just cause to be proud, for it is to the invention of cast steel by Mr Huntsman's grandfather, Benjamin Huntsman, that the town owes its present position'. These sentiments echo around the whole industrial world in the statement made by that anonymous American quoted by Sir Robert Hadfield in 1894:[43] 'Huntsman's patient efforts, at last rewarded with success, entitle him to an elevated niche among the heroes of industry. The invention of cast steel was second in importance to no previous event in the world's history, unless it may have been the invention of printing.'

The full text of the lecture, complete with illustrations and appendices, containing much fuller references to the foreign journals, has been published by the Sheffield City Libraries as an Information Bulletin and copies may be purchased at 50p each, post free, by application to the Local History Section, The City Libraries, Surrey Street, Sheffield.

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1 E Wyndham Hulme: **The Pedigree and Career of Benjamin Huntsman,** *Transactions Newcomen Society,* vol. xxiv, pp 37–45. Much of the biographical detail here is derived from this source.

2 Receipts for these services are preserved in the Disbursement Registers in the Doncaster Archive Office as follows:

28.3.1727 (for looking after ye clock at Butcher Cross) one year at £1. 10. 0.

Similar entries occur 1.5.1728, 2.10.1730, 10.5.1731 and 10.6.1732

There follows a gap with a final receipt dated 16.2.1735: For looking after ye clock to 1st May 1736 £1.18.6 (one year and a quarter at £1.10.0 and a clock string at 1s. 0d.)

It is believed that the Butcher clock was dismantled some time around 1734 and that the last receipt covers a new clock erected in the Town Hall.

It should be noted that there is no record of a payment for 1729, the year of his marriage.

3 In the Index to the Quaker Records (Sheffield City Library Archives 66634/1), p. 20, there is an entry for 1729: 'Huntsman, Benjamin, married out, dis.' Unfortunately the volume of minutes to which this index refers was lost during the last war due to enemy action. Since there is no further entry, either in the index, or in the subsequent volume of minutes, which covers the period of his married life, the entry 'dis' is taken to imply 'disowned' rather than 'Disciplined', although it seems clear that he still followed Quaker principles, refusing to have his portrait painted and refusing the honour from the Royal Society.

4 The ceremony was performed by the Rev. Hollis Pigot. See C W Hatfield: **Historical Notices of Doncaster,** 1866, p. 436.

5 Communication from Miss R Meredith, Archivist, Sheffield City Libraries.

6 The date 1739 is given by Wyndham Hulme (loc. cit.) There is a lease of property in High Street, Doncaster to Benjamin Huntsman by Richard Burden on 26.9.1971 (West Yorkshire Record Office, Book 00, p.737, No. 1048), this being registered on 5.2.1742 (copy in Sheffield City Libraries, Reference Ph.C.445 a). The same property was let to William Haigh on 24.3.1742 (Book QQ, p.583, No. 763), the lease being registered on 15.7.1742 (Ph.C.445 b). The registration document is of interest in appearing to carry Benjamin Huntsman's signature. Further evidence comes from Alderman Sheardown writing in the Doncaster Gazette of 27.11.1863, where he reports that the house in High Street, occupied by Benjamin Huntsman up to 1742, had been demolished in 1830.

7 S Smiles: **Industrial Biography: Iron Workers and Tool Makers,** London, 1863, p. 103.

8 R R Angerstein: Resa genom England, 1753–55, vol.2, filios 233–5. The manuscript in the Jernkontorets Bibliotek, Stockholm. The translation of this extract and all other Swedish documents to which reference is made in this paper has been kindly provided by Torsten Berg, Esq.

9 J S Jeans: **Steel: Its History, Manufacture, Properties and Uses,** London, 1880, p.14.

10 According to Wyndham Hulme (loc. cit.) he made a loss of £10 on the transaction, selling for £200. According to C W Hatfield (loc. cit.) however, he received £250.

11 W S Patrickson: in discussion as reported in *Trans. Newcomen Soc.,* vol. xxiv, p. 46.

12 Fairbank Collection, Field Book 25, p. 38, 11.8.1763 (Sheffield City Libraries). There are amendments, in different ink, on this sketch and these appear to date from 1781. The plan numbered SheD 71S (1783) is based on these amendments and Huntsman's name does not appear on this particular plan. It thus seems that he had moved in the interim, the furnace being held by Thos. Gunning at this latter date.

13 Fairbank Survey of Attercliffe, 1819 (Sheffield City Libraries, reference CA13–1). Plan X.

14 Anon: **L'Invention de l'Acier Fondu par Benjamin Huntsman,** published privately in Paris about 1890 by Marchand, Bignon, Ammer et Cie., p. 13.

15 G R Vine: **The Story of Old Attercliffe,** 1936, p. 295. In the Fairbank Survey of 1819 this property was owned by Ann Hancock, part held by C. Hancock. It consisted of two houses, a warehouse, shops and yard; it should be observed that it was not owned by Francis Huntsman at this date, although he held considerable property nearby.

16 Fairbank Survey of Attercliffe, 1819 (Sheffield City Libraries, reference CA13–1). Plan XII

17 Anon: **The Useful Metals and Their Alloys,** London, 1857, p.347.

18 The original correspondence is preserved in the Birmingham Assay Office.

19 Sketchley's Directory of Sheffield, 1774, p. 37. The list of 'Sundry Manufacturers of Steel' on p. 20 only gives Thos. Boulsover, Benjamin Huntsman and John Marshall as makers of cast steel; on the other hand, John Love is indicated as 'Draper, Cast Steel Refiner and Factor' in the alphabetical section on p. 37.

20 Gales and Martin's Directory of Sheffield, 1787, p.38. The list of 'refiners' (cast steel makers) as against 'converters' (blister steel makers) includes Hague and Parkin; Wm. Houlden; Love and Spear; John Marshall; Townrow, Burdekin and Tingle; John Walker; Huntsman and Asline. In addition, not specifically indicated as cast steel makers, it is arguable that the following should also be included: John Harrison; Richard Swallow; Walker, Booth and Crawshaw; Younge, Sharrow and Whitelock.

21 Anon: **The Useful Metals and Their Alloys,** London, 1857, pp. 348–9.

22 A H John (ed.): **The Walker Family: Extracts from the Minute Books,** *Council for the Preservation of Business Archives,* 1951, p. 3.

23 J Beevor, Esq: Private Communication.

24 K C Barraclough: **An Eighteenth Century Steelmaking Enterprise: The Company of Cutlers in Hallamshire, 1759–1772,** *Bull. Hist. Met. Group,* Vol. 6, Part 2, 1973, pp. 26–8.

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26 Letter from Robert Erskine to R Atkinson, 11.10.1770. Original in the Library of the New Jersey Historical Society, Newark, NJ, USA.

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29 G B Callan: 400 Years of Iron and Steel, *Sanderson Kayser Magazine,* Vol. 2, No. 4, 1969–70, p. 7.

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31 A H John: loc. cit., Foreword, p. iii; R A Mott: The Sheffield Crucible Steel Industry and its Founder: Benjamin Huntsman, *JISI,* March 1965, p. 236.

32 S Smiles: loc. cit., pp. 106–7.

33 C W Hatfield, loc. cit., p. 438.

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37 T Althin: Erik Geisler och hans Utlandska Resa, 1772-1773, *Med Hammare och Fackla, XXVI,* 1971, pp. 32–3.

38 Fourness and Ashworth: A Report on Huntsman's Cast Steel, 28.3.1792. Printed privately. Reprinted in *British Steelmaker,* March 1942. There is a copy of the French version in the Sheffield City Library.

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Zinc production at Tindale Fell, Cumbria

J K Almond ©

Synopsis

Zinc metal, or spelter, was produced from 1845 to 1895 at a remote site in eastern Cumbria, Tindale Fell (NGR: NY 618592). Between 1930 and 1938 attempts were made at the site to recover zinc and cadmium by fuming. In this paper the establishment of the spelter works by J H Attwood is described, together with aspects of the smelting operations continued under the proprietorship of J C Swan. During the 19th-century working some 40,000 tons of zinc were produced. Occasional interest in the waste dumps after closure of the works in 1895 is outlined: details are given of the fuming operations conducted for a year in 1930–1 and again for three months in 1937–8.

(In this paper, all references to tons are to long tons of 2240 lb. One long ton is equivalent to 1.016 metric tons).

Introduction

The hamlet of Tindale is situated in eastern Cumbria roughly half way between Brampton and Alston. At an altitude of 210m (700 ft), it is on the northern flank of the high moorland of the Alston Block. At least from the 18th century, ownership of the land lay with the Earls of Carlisle, and successive earls encouraged exploitation of the thin coal seams found in the locality. Wagonways were built to transport the coal from outlying workings and it is said that the superiority of malleable-iron rails to cast-iron ones was first proved on the system, where such bars were laid between 1808 and 1812.[1]

The extensive lead mines of Alston Moor were situated 25 km to the southeast. The zinc minerals occurring with those of lead were commonly regarded as valueless: first commercial use of the zinc took place in 1794, when calamine (zinc carbonate) was sent away to the brass industry.[2] There is evidence that for a few years around 1820 attempts were made to produce metallic zinc at the Greenwich Hospital's Langley lead smelter in Northumberland. Demand for zinc, first isolated in Europe a century earlier, began to increase markedly in the 1830s. With the improved price, in Wales the Vivians started to produce the metal in 1835. Soon afterwards, steps were taken to establish a works for zinc at Tindale Fell; this was to remain at work until 1895.

J H Attwood and Tindale Fell Spelter Works, 1845–1868

Several members of the Attwood family played important parts in the nineteenth-century industrialism of northern England, although the family had no long-standing connexions with the region. James Henry Attwood (1785–1865), who founded the spelter works, was 4th of the seven sons of Matthias Attwood MP, who lived near Birmingham and had made a fortune from the iron trade.[3] The three elder sons took up banking or politics; the 5th son, Edward, became noted as a glassmaker in Sunderland, while the 6th was Charles (1791–1875), later a well-known maker of iron and steel, and founder of the Weardale Iron Company.

J H Attwood evidently spent some years abroad, in 1820 marrying a widow, Margaret Williams, in Vienna.[4] In 1845, however, he had an address at 13 Upper Seymour Street, Middlesex, from which he negotiated the 50-year lease of a site from the Earl of Carlisle in order to put up a works for spelter – and also for 'brass copper German silver and nickel'[5] The site selected lay at Rigg Foot, near to Tindale Tarn and in the lee of Tindale Fell. Rent was agreed at £20 a year. The lease stipulated that coal, coke and lime requirements were to be purchased from the local workings. The Earl of Carlisle's colliery railway, linking the coal pits with staithes near to Brampton, passed along the side of the spelter-work's site: for a few years around 1840 the celebrated locomotive 'Rocket' worked on this line. (Figure 1).

Besides these advantages, and the proximity of mines able to produce zinc minerals, there was available, in the nearby Tindale Tarn, a potential supply of water for driving crushing machinery. Moreover, the topography of the area was favourable, with an incised valley or ravine that could provide room for extensive dumping of waste materials. It is not known whether suitable clays were to be had in the neighbourhood for making the large quantities of refractory retorts and condensers demanded by the zinc-smelting process, but the lease gave power to get stone, sand and clay; perhaps fireclays associated with the coal seams were used.[6] Whether J H Attwood gave any consideration to the emission of sulphurous fume is also not known, but certainly the fume generated by the smelting operations became an important factor in the continued working of the plant, and hardened attitudes against renewing the site lease when eventually it expired. It might well be that, for pouring out uncontrolled noxious fumes, a sparsely-populated, remote country region would appear to offer greater freedom than an urban area.

In view of the subsequent closure of the Tindale Fell works when the 50-years' lease expired in 1895 it is pertinent to note that originally a lease for 63 years was hoped for; had this been granted, it would have allowed the continuation of zinc-making to 1908, by which date zinc prices had risen appreciably from the trough of the 1890s (Figure 2). It is possible that, in the northern Pennines, there might then have ensued the continued presence of a reasonably-large, locally-based mining and smelting company.

One at least of Attwood's relatives, Melville Attwood (1812–1898), had an active interest in the works,[7] but in 1852 he was obliged to emigrate to California for his wife's health. At the time the spelter works was started, Melville Attwood was working the Ecton mine in Derbyshire.[8]

It is not known at what date the first spelter from Tindale Fell was cast into bars, but in 1863 production amounted to 750–800 tons.[9] Shortly before that time, the equipment was described as consisting of a number of reverberatory furnaces for calcining the zinc ores, 12 subliming furnaces and 'a refinery'.[10] The same source stated:

> 'These works attract considerable attention as being the only zinc works in the north of England, also as the process used is a patented one, and supposed to be superior to any other in the country'[11]

It was not long before the noxious character of the smoke emitted from the furnaces began to be noticed by those roundabout. For example, in 1857, Lord Carlisle's Agent

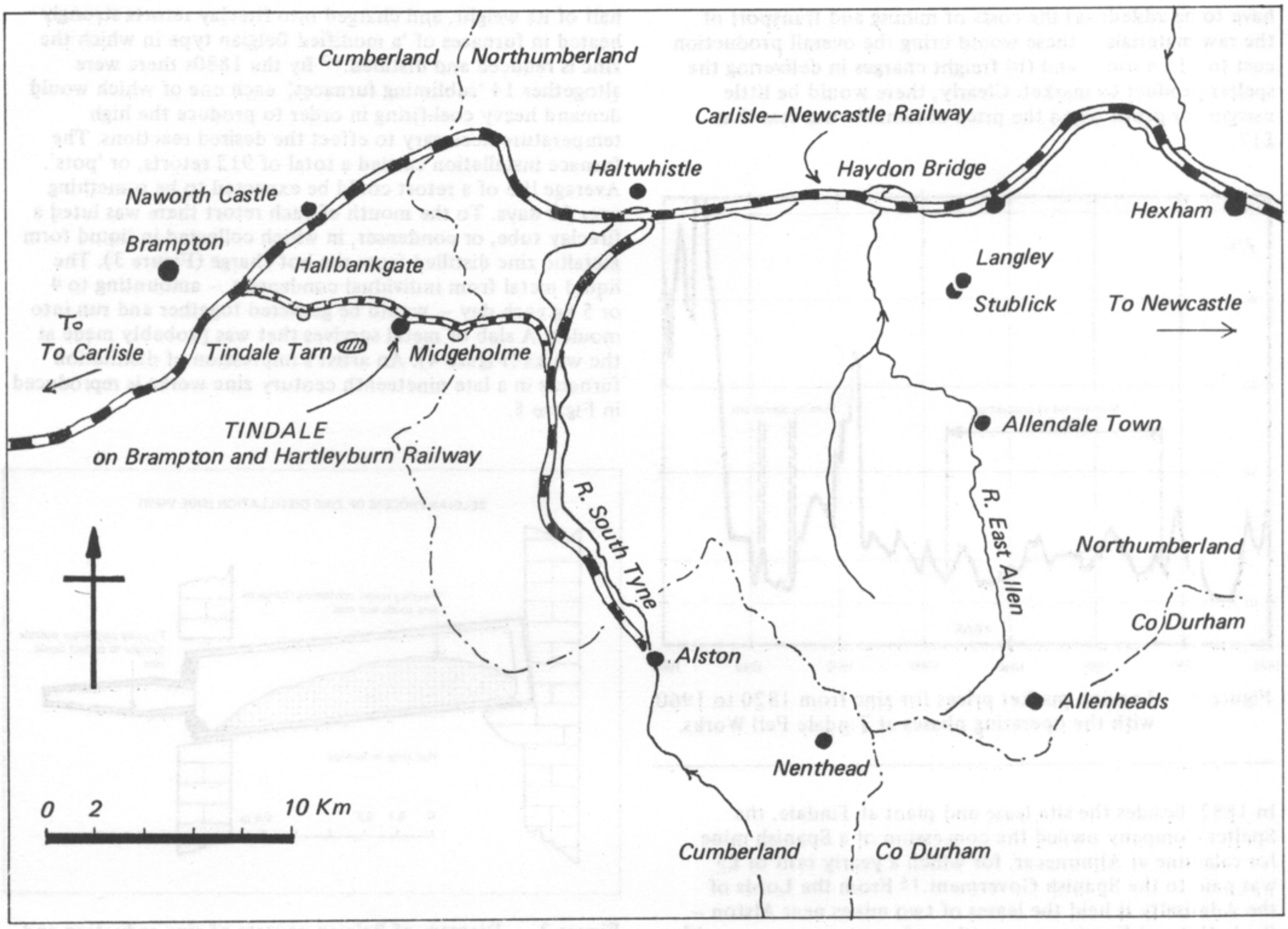

Figure 1 Locality sketch map, showing railways. The main east-west line between Newcastle and Carlisle was opened fully in 1838; the South Tyne branch from Haltwhistle to Alston was opened in January 1852; and the Brampton and Hartleyburn line through Tindale opened throughout its length in July 1852 as an extension of a part of the Earl of Carlisle's colliery system.

wrote to J H Attwood to draw his attention to complaints received. The effects of the smoke were 'worse each year and . . . they were much injured by it.'[12] The Agent went on to remind Mr Attwood that

'a clause in your lease . . . provides for a case of this kind and I should prefer if you would make some enquiry as to the extent of the injury of which they complain and likewise how far and in what way it can be obviated.'

Twenty-five years later, the proprietors of the Spelter Works were paying £65 each year, as compensation for damage to vegetation and adverse effects on farm stock.

Besides the zinc-bearing materials reaching the works from the local mines, an account prepared in 1863 stated that ores of zinc were 'imported from the Isle of Man and Ireland, through the ports on the west coast, and from the Rhine and Sweden to the Tyne.'[9] According to what is known of extraction efficiencies at the time, an annual yield of 800 tons of spelter would require something like 4000 tons of zinc concentrate or high-grade ore — as well as a similar weight of coal. As the mines in the locality contributed only some 600 tons of zinc-bearing material, it follows that imports must have amounted to 3000 tons.

Involvement of the Swan Family

In 1865 J H Attwood died, leaving his executors with instructions to sell his works within three years.[13] From 31 July 1868, the zinc-smelting operations were controlled by Tindale Spelter Company. In this the leading part was taken by John Cameron Swan (1827–1916), a mineral trader of Newcastle upon Tyne, with his relatives as other proprietors.[14] Output of spelter increased from 626 tons in the year ended 31 July 1869, to 1410 tons in the year ended 31 July 1869, to 1410 tons in the year ended 31 July 1882.[15] (Yearly output figures are given in the Appendix). As British zinc production in the 1880s was some 29,000 tons a year, the contribution from Tindale Fell amounted to 5 per cent of the total.

In the early 1870s, the high prices prevailing for zinc encouraged developments, so that considerable sums were expended on stores and improvements to the works, notably: enlarging the output of the furnaces without commensurate increase in labour cost; constructing a rail siding to enable coals to be let down into the company's own wagons; and removing the 'metal house' to the vicinity of the railway.

Around 1880 profit was said to average £1.25 a ton of spelter.[16] However, the steady slide in zinc prices that occurred in the years immediately before 1882 seems to have turned profits into operating losses. The average cost of making spelter at the works in the years 1880 to 1882 was given as £8.15 a ton of metal. But to this figure would have to be added: (a) the costs of mining and transport of the raw materials – these would bring the overall production cost to £15 a ton – and (b) freight charges in delivering the spelter product to market. Clearly, there would be little margin for profit when the price obtainable was less than £17.

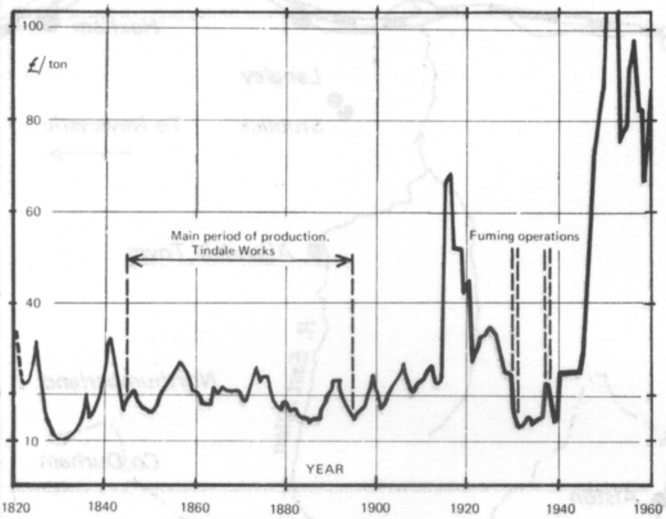

Figure 2 London market prices for zinc from 1820 to 1960, with the operating phases at Tindale Fell Works.

In 1882, besides the site lease and plant at Tindale, the Spelter Company owned the concession of a Spanish mine for calamine at Almunecar, for which a yearly rent of £5 was paid to the Spanish Goverment.[15] From the Lords of the Admiralty it held the leases of two mines near Alston – Bayle Hill and Farnberry – neither of much consequence.[17] In addition, the company worked the dressing floors at Wellgill, near to Nenthead, paying rental of £10 a year to the Admiralty.[15]

When written up on 31 July 1880 the Private Ledger of Tindale Works showed:[16]

	£	s.	d.
'Works (at £230 less than first cost	7000	0	0
spelter	597	8	4
stores and materials (including ore)	2550	1	6
trade ledger (debtors after deducting creditors)	2985	16	10
co-operative share	20	0	0
	13 153	6	8
Contra – bank advance	645	4	6
capital and undrawn profits	12508	2	2
	13 153	6	8

The Zinc-Smelting Process

Incoming zinc ores were first of all reduced to small size by passage through water-powered crushing and grinding mills. The finely-divided material was then roasted to oxide in one of 8 reverberatory furnaces.[18] During this process sulphur was expelled as sulphur-dioxide gas, and the weight of the solid diminished by about 20 per cent. The calcining step was responsible for generating most of the large amounts of sulphurous fumes which had adverse effects upon the surrounding vegetation. The resultant zinc oxide was mixed with non-bituminous coal fines to the extent of about one-half of its weight, and charged into fireclay retorts strongly heated in furnaces of 'a modified Belgian type in which the zinc is reduced and distilled.[19] By the 1880s there were altogether 14 'subliming furnaces', each one of which would demand heavy coal-firing in order to produce the high temperature necessary to effect the desired reactions. The furnace installation carried a total of 912 retorts, or 'pots'. Average life of a retort could be expected to be something over 20 days. To the mouth of each retort there was luted a fireclay tube, or condenser, in which collected in liquid form metallic zinc distilled from the hot charge (Figure 3). The liquid metal from individual condensers – amounting to 4 or 5 kg each day – would be gathered together and run into moulds. A slab of metal survives that was probably made at the works (Figure 4). An artist's impression of distillation furnaces in a late nineteenth century zinc works is reproduced in Figure 5.

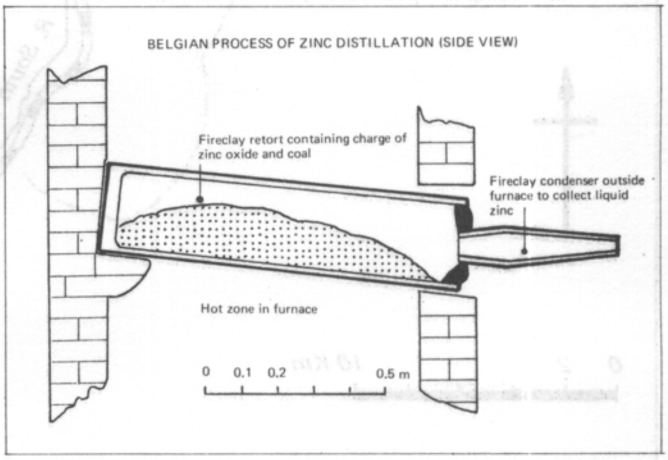

Figure 3 Diagram of Belgian process of zinc reduction and distillation.

Figure 4 A slab of metal, probably of Tindale Fell zinc, made before closure of the works in 1895, and in the keeping of the Department of Geology, University of Durham.

In common practice the retorting cycle would take one day, including charging. After this the spent residues would be raked from the retorts and fresh charge introduced, while at the same time any damaged retorts would be replaced by new ones. Besides the intensive labour needed for a period of a few hours each day to charge the retorts in the furnaces, some men would be required to fire the distillation furnaces throughout the 24 hours, as well as to rabble the zinc-bearing material in the roasting furnaces, and to make new fireclay retorts and condensers.

The Nenthead and Tynedale Lead and Zinc Company Ltd, 1882–1896

After being held for more than a hundred years, in 1882 the remaining leases in the northern Pennines of the London

Figure 5 Inside a nineteenth-century Belgian zinc works, showing distillation furnaces, with condensers protruding.
(From W C Roberts-Austen: **Introduction to metallurgy** London: Griffin, 1902)

Lead Company were to be surrendered. John Cameron Swan and his associates took the opportunity to consolidate mining and smelting activities in the region by acquiring from the London Lead Company the leases of mining properties together with the lead-smelting works at Nenthead. To accomplish this, a new organisation was formed, the Nenthead and Tynedale Lead and Zinc Company Ltd; this assumed responsibility for the operations from 1 October 1882. The new arrangement made it advantageous to extract ores of both lead and zinc at the same time from the various mine workings, the lead ore to be smelted to metal (with extraction of contained silver) at Nenthead smelting mill, and the zinc ore to be smelted to zinc at Tindale Fell works. In this way it was hoped each commodity would support the other in the face of falling prices (especially for lead), as British demand for metals came to be met increasingly by imports from large-scale operations on the Continent of Europe and in America. Under the terms proposed, the new company was to pay some £18,000 for the assets of the Tindale Spelter Company.

The Nenthead and Tynedale Company was, however, operating in adverse economic conditions and when, in 1895, the 50-year lease of the spelter-works' site expired, the works closed. Both the Earl of Carlisle and the Countess, the lessors, were ardent social reformers and temperance campaigners, and laid down as conditions for renewal of the lease stringent requirements for improvements that J C Swan did not feel able to meet. The fact was that the Carlisle family did not want the sulphurous industry on the estate.[20]

Fuming Operations at Tindale Fell, 1930 to 1938

In the years following closure, the estate office received several enquiries concerning the large dumps of zinciferous materials that were left at Tindale but, until the 1920s, none came to anything. It appears the residues from the retorting process completely filled the triangular-shaped area of ground that lay immediately to the north of the works and was bounded by the tracks of the railway. One enquiry that deserves comment was made around 1910, by Thomas Huntingdon (of Huntingdon and Heberlein). He proposed to recover zinc from the dumps as oxide using 'blast roasting', but the scheme foundered because Huntingdon would not guarantee that no sulphurous fumes would be generated.

In the 1920s came fresh negotiations to treat the Tindale dumps, and in due course these led to the formation of a private company – Tindale Zinc Extraction Ltd – registered in August 1928 with a nominal capital of £47,250 'to exploit refuse heaps and carry on metallurgical operations'.[21] Amongst the six directors were Sir Richard Pease, Bart, MSc, and Charles H Roberts, son-in-law of the 9th Earl of Carlisle, Before long the National Smelting Company, which was at that time in process of becoming the leading British producer of zinc, had up to £7500 invested in the Tindale Company.

Fuming was proposed, to extract zinc from the dumps as oxide – a considerably cheaper operation than the production of zinc as metal. Where this differed from Huntingdon's earlier scheme was in the use of a rotary kiln for effecting the volatilisation of zinc from the charge. This technique was developed in Germany by Krupp Grusenwerk at Magdeburg, and publicised from 1925. By the mid-thirties 21 rotary-kiln plants were in existence in various countries, that at Tindale being the only one in Britain.[22]

The new plant was started-up in March 1930, but alas, because of continuing difficulties in making a zinc-oxide product of acceptable pigment grade, closure occurred after operations had persisted for just over a year (ie until April or May 1931). The chief trouble was said to have been caused by contamination of the white zinc oxide by carbon, carried over from the kiln. A second contaminant may have been lead.[23] At all events, the product could not be sold for paint-making as intended, and was suitable only as feed for a conventional zinc-reduction plant. It was taken by the Avonmouth smelter of National Smelting Company, an income of £1450 being obtained. Another barrier to satisfactory working of the plant was the poor suction draught it was possible to achieve with the equipment.

The heart of the zinc-extraction process was the rotary kiln, where the mixed feed of zinc-bearing materials and carbonaceous matter was exposed to high temperature under suitable conditions.[24] The single kiln supplied by Krupps' was 30m long and 2.5m in diameter inside the steel shell, which was lined with refractory bricks. It was heated by oil burners placed at the discharge end. Rated daily capacity was 100 tons of Tindale residues plus 20 tons of coke breeze. The gases drawn from the kiln by the 65-hp fan were at a temperature of some 700°C; they were cooled by passage through zig-zag metal flues until at 100° they became safe for blowing into the woollen-bag filters where the bulk of solid product was caught. A diagram of the installation is given in Figure 6.

By the end of 1930, £25,000 had been spent on equipment and a further £10,000 on buildings: by March 1931 £9,900 had been obtained by debentures.[21] In November 1931 a receiver was appointed, and from the next month a major item of expense at the Tindale site was £6.47 (£6.9s.6d) monthly in watchman's wages.

The plant stood idle until, in 1933, ownership passed to the National Smelting Company, followed by dissolution of Tindale Zinc Extraction Ltd in 1935. The next brief chapter in the chequered history of the German plant is curious: it was used experimentally to treat cadmium-rich residues

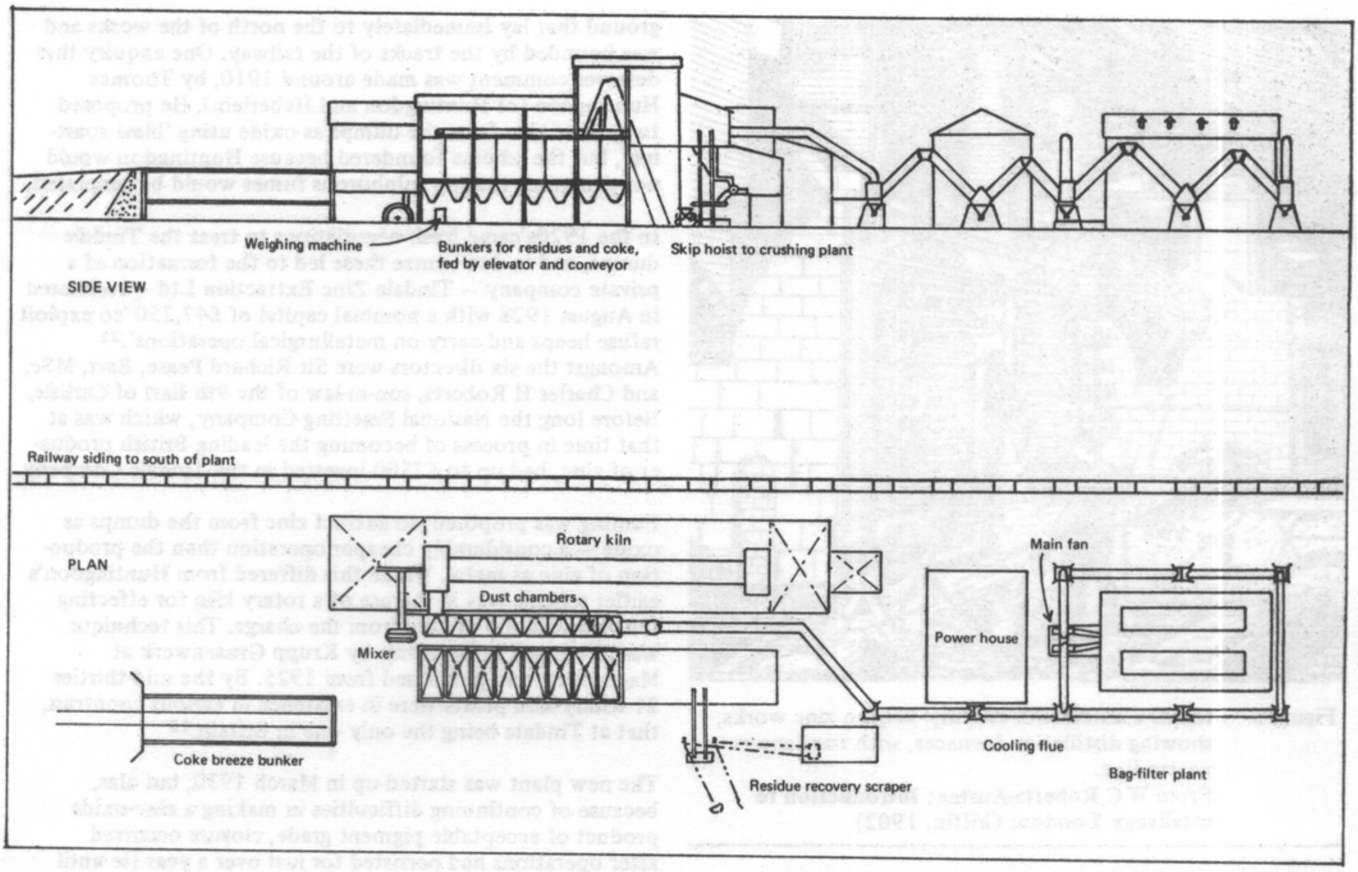

Figure 6 Rotary-kiln installation for fuming zinc from Tindale residues and recovering it as zinc oxide. The plant stood at site from 1930 to 1939.

arising in the zinc works at Avonmouth and Swansea Vale. Rehabilitation for the National Smelting Company Ltd began in June 1937, and £3000 was spent on recommissioning.

A major aim in re-opening the Tindale plant was to process a stock of 'sinter rappings' that had accumulated at the two zinc smelters in south-western England. These 'rappings' were cadmium-rich encrustations collected on the pallet bars of the down-draught sintering machines in use at the time. They contained 4 per cent of cadmium. The problem was to concentrate the cadmium to such a level that its extraction would become economic by wet-chemical means, and it was expected that such further processing would be handled by Orr's Zinc White Ltd., of Widnes. After transport to Tindale, the cadmium-rich residues were mixed with suitable proportions of local dump material to act as carrier, and coke breeze, and fed into the kiln.

In the event, the experimental fuming operation lasted for only 87 days[25] before catastrophic mechanical failure of the brick lining of the kiln, and severe accretions, brought it to a final standstill. During this short period of re-activity, some 40 to 50 men found employment. In the campaign, besides the cadmium-bearing materials, 3400 tons of Tindale residues were processed, assaying 5.7 per cent zinc and 1.7 per cent lead. Forty-six gallons of fuel oil for firing the kiln were consumed for each ton of fume product collected, and during the more-efficient parts of the campaign operating costs were about £630 a week. A total weight of 46 tons of cadmium was obtained in the fume product; this represented a recovery of better than 95 per cent. At the time of the abrupt end to the working, it was considered that technologically some of the chief troubles had been identified if not rectified, and fresh supplies of bricks had been obtained in readiness to renew and modify the kiln lining. Economically, however, the markets for both zinc and cadmium were weak, and it was these factors that led to the abandonment of the project, and the end of metallurgical operations at the Tindale site, nearly a century after they had first begun.

Demolition and Subsequent Use of Parts of the Fuming Plant

Following the cessation of the fuming experiments on cadmium-rich materials the plant and buildings at Tindale were sold for scrap, mainly to T W Ward in April 1939.[26] In 1938 the market price of zinc stood at £14 a ton; two years later, after the outbreak of war, it had risen to £25¾. By 1948 it was £80. As G E Flack observed in his 1957 report.[26]

'Had one been able to predict that a world war would break out five months after the sale of the plant for scrap, to be followed by a period of very high zinc prices, then the story of the Tindale Waelz plant . . . (might) have been vastly different.'

In fact, the bag-filter plant and some other items of equipment were transferred to Avonmouth where they were involved in further experimental work intermittently until 1948, when the filter was sold to the Wolverhampton Metal Company. The kiln itself was bought by the Ministry of Supply, ca.1940, for use (after extension to a length of 54.8,) in the Ocean Salts factory at Barry Moor, South Wales, where its function was to calcine dolomite as one of the steps in the extraction of magnesia from seawater. At the end of hostilities the kiln found itself once again in the hands of T W Ward, but this was not its end, for in 1951 it was re-purchased (for £14,000) by the National Smelting Company. Re-erected at Avonmouth, it formed the calcining (ie oxidising) stage of a Waelz fuming plant dismantled in 1961.

Remains at the Tindale Spelter-Works Site Today

From the Tindale works' site, a large proportion of the derelict dumps was reputedly removed for use as land fill at the Government's Spadeadam rocket-testing area, situated some 15km northwards. Judging by earlier accounts of the extent of the dumps, many thousands of tons must have been taken for, although bands and heaps of residues still remain, the steeply-sided valley can be clearly seen as such. In several places the stream bed itself is exposed at the bottom, together with the stone-arched culvert built a century ago to enable refuse from the works to be safely dumped over the Tarn Beck. (Figure 7).

On the flat shelf of ground immediately south of the stream valley remain the concrete foundations of the rotary-kiln installation of 1930–38, with the track of the railway siding to the south again, and rough moorland rising beyond. Immediately to the west of these relics may be identified the concrete floors and the roots of brick walls of the terrace of workmen's cottages, Spelter Works Row. As the 20th-century fuming plant was built directly over the site of the 19th-century spelter works, few remains of the latter are to be found, although traces of its operations are plentiful in the debris lying on the valley sides.

The debris is of several different kinds: waste residues remain both from the main period of zinc-smelting, 1845–95, and from the short-lived kilning activities of 1930–38. Material dating from the main phase of working is easily identified by the presence of a high proportion of fragments of fireclay retorts and condensers. A photograph of these smelter residues on a part of the site is given in Figure 8. The fragments of retorts include some that suggest an original elliptical internal section, with an external section partly polygonal; these would correspond with retorts of 'Rhenish' pattern, having flat faces for standing upon the shelves of the furnace chambers.[27] Many retort fragments have adhering to them remains of the charge they contained – lumps of coal or coke in a matrix of small-sized carbonaceous matter and powdered zinc calcine. The fragments show extensive glazing and fritting that result from their exposure to intense heating while charged with reactive materials.

Two shapes of fireclay condensing tube have been noted: while one is a straightforward conical tube of circular section, the other is a tube of generally-similar dimensions, but oval in section. The significance of the variation at Tindale is not at present understood. (Figure 9) Most of the fragments of condenser carry encrustations of white zinc oxide on their inside surfaces, and some are choked by other residual material. It is reasonable to suggest that originally each of the fireclay tubes would be about 0.5m long.

The heaps also contain firebricks of various ages: some marked 'Glenboig' and 'Tyne' have been noted, which pre-

Figure 7 View looking westwards across the site of Tindale Fell Spelter Works, 1975, showing residues remaining on the steep banks of the Tarn Beck.
The works itself (and the subsequent fuming plant) was situated on the shelf of flat ground near the top of the bank on the left of the picture. In front of the white cottage stood the terrace of dwellings for workmen. The large, dark-coloured boulders strewn in the bottom of the ravine are agglomerates left from the kilning operations.

sumably date from the 19th century, while specimens of 'Pict A' would be associated with the rotary kiln of the 1930s. Towards the eastern corner of the site, bordering the railway embankment, occur banded deposits of brick-red burnt shale – these bands may be ash residues from the coal used as fuel in firing the furnaces for smelting and roasting.

On the steeply-sloping southern bank of the stream valley material of a different character abounds. This is chocolate-brown clinker that probably arose in the rotary-kiln fuming process. Although most of the individual pellets of clinker occur in sizes less than 10 or 12 mm, these individual nodules are fritted into agglomerates, some notable masses approaching a metre in dimension. A rotary kiln carrying such ponderous, intractable boulders would be in trouble indeed!

These relics at Tindale, now with considerable vegetation growing around them and suffering 'contamination' from dumped derelict motorcars and domestic equipment, are the tangible remains of a significant metallurgical enterprise that was at the height of its activity a century ago.

Acknowledgement

Both Mr E J Deas of Gosforth and Mr G E Flack of Avonmouth have made available important unpublished material that is incorporated in the paper, and have provided encouragement which it is a pleasure to acknowledge. The Cumbrian County Archivist, Mr B C Jones, has also readily supplied information and drawn attention to useful sources. The staff of the Department of Palaeography and Diplomatic in the University of Durham have made it pleasant to obtain material from the Howard of Naworth estate papers in their keeping.

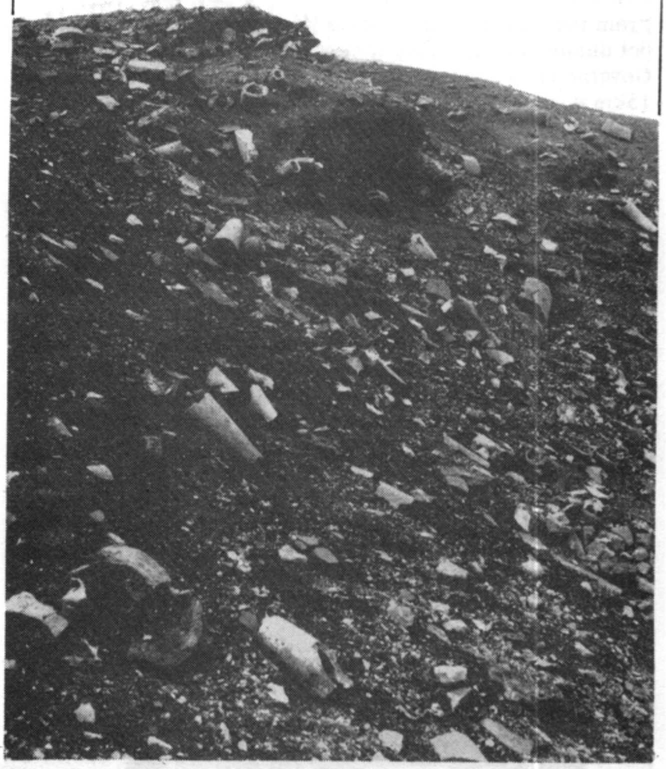

Figure 8 Zinc-smelting residues remaining on a part of the Tindale site, 1975. Fragments of conical condensing tubes can be easily distinguished, together with pieces of the larger fireclay retorts.

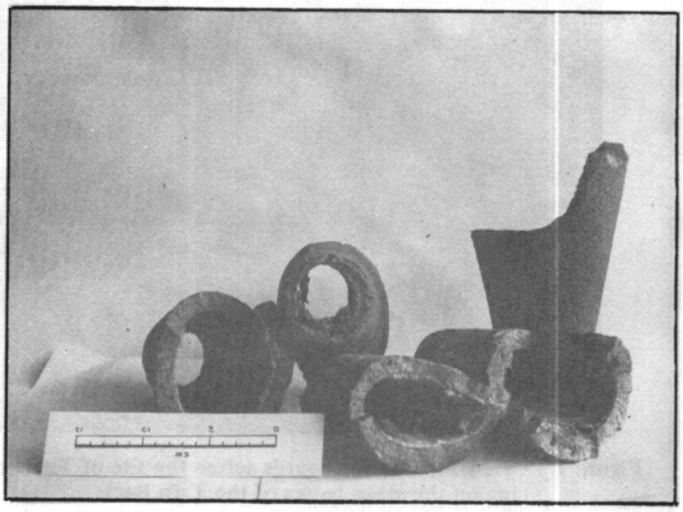

Figure 9 Some of the fragments of clay condensers are oval in section, as shown here, while others are circular. Note the encrustation of zinc oxide (and metallic zinc) on the inside surfaces of some of the tubes.

Notes and References

1 **Tomlinson's North Eastern Railway, its rise and development.** (new edition with introduction by K Hoole) (Newton Abbot: David and Charles, 1967), 15.

2 Wallace, William: **Alston Moor: its pastoral people . . .** (Newcastle upon Tyne, 1890), 160.

3 Ashton, T S: **Iron and steel in the industrial revolution.** (Manchester Univ. Press, 1968), 230. (First publ. 1924).

4 Robinson, John: **The Attwood family with historic notes and pedigrees.** (Sunderland: printed for private circulation by Hills & Company, 1903).

5 HN C 134. 'Counterpart lease of spelter works . . . 8 July 1845'. Howard of Naworth estate papers in the keeping of the University of Durham. Subsequent references to this collection are marked 'HN'

6 Can it be coincidence that a bed of fireclay was 'discovered' on Tarn House Farm, 0.8km from the site of the works, in 1896, the year after the lease expired? – HN C 607/3. 21 September 1896.

7 HN C 590/IV. No.126.

8 Melville Attwood returned to England in 1839 from the gold and diamond fields of Brazil. He then 'leased and worked the celebrated Old Ecton Copper Mine in Derbyshire, and was engaged in mining and metallurgical works in the North of England and Staffordshire, and in 1843 he gave zinc a commercial value by successfully rolling the first English spelter'. (**Geol. Mg.**, decade IV, vol.5 (July 1898), 335–6).

9 **Rpt. of 23rd meeting of the British Association . . .** (London: John Murray, 1864), 725.
The same year the local material was re-published as **The industrial resources of . . . Tyne, Wear, and Tees . . .** (Eds) Sir William G Armstrong, I Lowthian Bell, and others. (Newcastle upon Tyne, 1864).

10 Whellan, William: **The history and topography of the counties of Cumberland and Westmorland.** (Pontefract: W Whellan & Co., 1860), 675–6.
I am grateful to Dr Alan Harris of Hull for drawing this source to my attention, 1976.

11 Besides the Tindale works, J H Attwood had interest in a spelter works at Ripley, Derbyshire, of which the original proprietor was John Cleaver. In 1843, Cleaver was granted a patent (no.9903) for 'An improved furnace for subliming or reducing . . . zinc', so it seems possible the first furnaces at Tindale were built to this pattern, in which each furnace contained 10 relatively-large retorts to which were fitted cylindrical condensing tubes. The complicated shape of the retorts (resembling that of a 'tin' bread loaf), coupled with their inaccessibility in the furnace structure, may well have made the system impracticable. Relics found at the Tindale site point to retorts and condensers of more common shape.

Ripley Spelter Works seems to have been managed by Edward Anthony Attwood (a son of J H Attwood) in the 1850s, and to have been in the hands of his widow in the 1860s. The works appears to have been abandoned soon after 1870. (I am grateful to Mr Roger Findall, of Long Eaton, for elucidating some of these details, in 1976).

12 HN C 565/IV, No.75. 'John Ramshay to J H Attwood, 18 May 1857 (copy)'.

13 Will of James Henry Attwood of Moss Hill in the parish of Farlam, proved at Carlisle, 21 August 1865.

14 J C Swan's younger brother was Sir Joseph Wilson Swan, FRS, famed for his part in the successful development of filament electric lamps and for improvements in photographic materials.

15 **Nenthead & Tynedale Lead & Zinc Company Ltd. prospectus** (Newcastle upon Tyne, 1882). Copy of information is contained in Public Record Office, BT31/14717.

16 Information on activities of the Tindale Spelter Company, 1868–1882, is derived from a manuscript 'Nenthead & Tynedale Lead & Zinc Co., Memorandum as to purchase of property, etc, 27 October 1882' in possession of Mr E J Deas of Gosforth, and kindly lent by him to me in 1975. Authorship of the report is unknown.

17 Dunham, K C: **Geology of northern Pennine orefield,** vol.1. (HMSO, 1949), 148.

18 **Bulmer's directory of east Cumberland, (1884).** Midgeholme parish, 470–1. I am grateful to Mr B C Jones, Cumbrian County Archivist, for supplying me with this information, 1973.

19 Pattinson, John L: in **Official local guide industrial section.** Visit of Brit. Assocn. to Newcastle upon Tyne 1889. (Ed.) W Richardson. (Newcastle upon Tyne: Andrew Reid, Sons & Co., 1889). 131.
The author of the report on Tindale Fell Works, John Pattinson of Newcastle, was a director of the Nenthead & Tynedale Company, and brother-in-law of John Cameron Swan.

20 It is hoped a fuller account of the factors involved in closure will be published elsewhere.

21 Public Record Office, file BT31/32971.

22 Harris, W E: The Waelz process. In **Metallurgy of lead and zinc. Trans. Am. Inst. Min. Metall. Engrs.** (1936) Vol. 121, 719.

The use of a rotary kiln for fuming and similar metallurgical treatments became known as the Waelz process because of the rolling action. (German; Wälzen=roll).

A similar plant to that at Tindale, based on testwork carried out by Krupps' in 1934, was installed in Ireland at Silvermines, Co. Tipperary, and operated for some time early in the 1950s. (See S V Griffith: Silvermines operation, Co. Tipperary, Eire. **Mining Mag.**, vol. 92 (March and April 1955), 137–50; 206–10).

23 Personal comment by the late Mr C L Wainwright, 1974. At the time of the operations described, Mr Wainwright was in charge of the Sulphide Corporation's Seaton Carew Zinc Works on the east Durham coast, and he had knowledge of the work done at Tindale.

24 Much of the information presented here is obtained from an unpublished report prepared in 1957 by Mr G E Flack of Imperial Smelting Corporation Ltd., and kindly made available by him to be in 1975.

25 Duing the period 12 October 1937 to 27 January 1938.

26 All the information in this section is derived from the unpublished report of Mr G E Flack (1957), reference 24.

27 In the case of the angular retort fragments, the flat bottoms are about 90 mm wide, and the internal width of the retorts would appear to be 160 mm, with height somewhat greater because of the oval internal profile.

One cylindrical retort end that has been examined shows an internal diameter of 160mm, and a wall thickness of 40–45 mm, giving an outside diameter of 250 mm.

Additional note

Amongst the descriptions of specimens that appear in the printed catalogue to the collection of Dr John Percy MD, FRS, first Lecturer on Metallurgy at the Government School of Mines in London, are two items emanating from Tindale Fell:–

"1271. 'Grey oxide of zinc'. Collected from the neck of the retorts at Alston Works. Communicated by G Attwood.

1272. Zinc fume. From the Alston Works. Contains 49.92 of zinc. Communicated by G Attwood'.

(Quoted from **Catalogue of the collections . . . formed by the late John Percy** . . . by Professor J F Blake. (London: HMSO, 1892), 157). Miss S Cackett, of the Science Museum, kindly drew my attention to this reference, 1874–5.

'G Attwood' may have been George Attwood (1845–1912), son of Melville Attwood, who was born in Carlisle and later became a consulting civil and mining engineer with an office in London.

Appendix: Published Zinc Production Figures for Tindale Fell Works.

YEAR	TONS PRODUCED	
1863	750 to 800	(1)
1869 (ended 31 July)	626	(2)
1870 ditto	690	
1871 ditto	809	
1872 ditto	1028	
1873 ditto	1170	
1874 ditto	1156	
1875 ditto	1153	
1876 ditto	1293	
1877 ditto	1193	
1878 ditto	1118	
1879 ditto	1210	
1880 ditto	1383	
1881 ditto	1340	
1882 ditto	1410	
1883 (calendar year?)	1556	(3)
1884 ditto	1384	
1885 ditto	1380	
1886 ditto	1193	
1887 ditto	1317	
1888 ditto	1516	
1889 ditto	1507	
1890 ditto	1530	
1891 ditto	1440	
1892	?	
1893	?	
1894	?	
1895	?	

(1) 1863 **Rpt. 23rd meeting of British Association (London: John Murray, 1864), 725.**

(2) 1869 to 1882. **Nenthead & Tyndale Lead and Zinc Company Ltd Prospectus. (Newcastle upon Tyne, 1882). Public Record Office, BT31/14717.**

(3) 1883 to 1891 **The mineral industry . . . vol. 1, 469. (1892), (New York, 1893).**

Wanlockhead: an introduction

Peter Swinbank ©

Preface

Leadhills and Wanlockhead are the two highest villages in Scotland, situated on either side of the Lanarkshire-Dumfriesshire boundary at NS 886150 and NS 875130, and form the twin centres of one of the most historically interesting lead mining areas in the whole of the United Kingdom. At an earlier period the district was known as "God's Treasure House in Scotland" in reference to the richness not of the lead only but also of the gold and the other minerals.

For many years the landowners have been the Hope family on the Lanarkshire or Leadhills side and the Buccleugh family on the Dumfriesshire or Wanlockhead side. As a result of this separate ownership the mining histories have diverged considerably from time to time, and there has frequently been a good deal of rivalry between the inhabitants of the villages. This introductory article is concerned primarily with the Wanlockhead side of the boundary. (Figure 1).

The history of the area has been described in a wide range of publications, few of which can be regarded as perfect even within their own terms but of which the most generally useful and reliable are J Moir Porteous: 'God's Treasure House in Scotland' of 1876,[1] John Mitchell: 'The Wanlockhead Lead Mines' of 1919,[2] and T C Smout: 'Lead Mining in Scotland, 1650–1850' of 1967.[3] The geological features are discussed in volume XVII of the 'Special Reports on the Mineral Resources of Great Britain' of the Geological Survey, 1921,[4] and R A Mackay: 'The Leadhills Wanlockhead Mining District' of 1959.[5]

It seems that the earliest unarguable references to gold in this part of the Southern Uplands date from the early years of the 16th century, for it is then that payments are recorded to the miners. Later, over a few years at the end of the 16th and early in the 17th centuries, there was exploration under the direction of Sir Bevis Bulmer, who was mainly concerned with the Leadhills side, and of George Bowes on the Wanlockhead side. Examination of the documents printed by Cochran-Patrick and of his commentary[6] gives the impression of a good deal of expenditure and activity, a fair degree of quarrelsomeness but not much

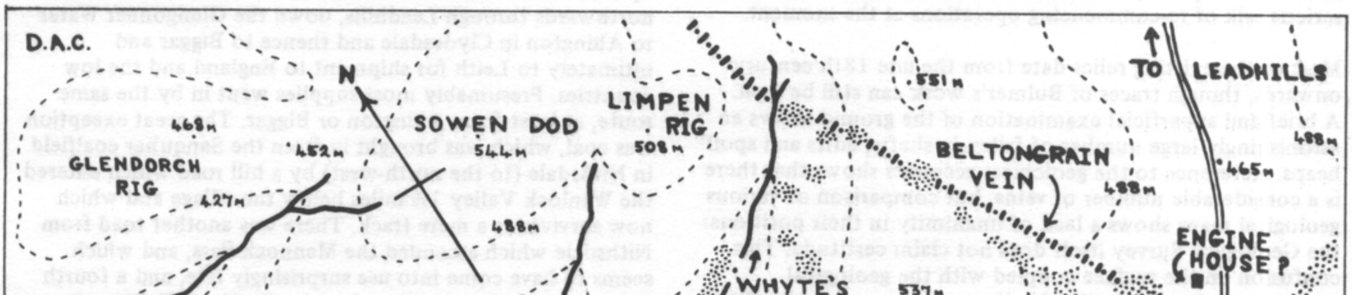

Fig.1 The valley of the Wanlock Water

success! A lot of earth was moved, but no tortunes were made from the gold. The whole history of Southern Uplands gold abounds in legend and fiction. Some of the early stories were probably elaborated to give a good impression, and more recently there may even have been some deception. Gold can still be found in the area: some is washed almost every summer. However, most of the wealth has been in lead.

From about 1550 onwards the lead was regarded as important, but it was not until Sir James Stansfield and his associates started work in earnest on the Wanlockhead side in 1675 that the period of serious development began. In 1710 a company for smelting lead with coal, which probably came to be known as the London Lead Company, started work. In 1721 the Friendly, or Quaker, Company joined in. The relationship between the London and Quaker Companies is not very clear: for a while they seem to have worked together and it is said by some authorities that they were but one company. After a period of confusion, in 1755 the whole of the Wanlockhead enterprise was taken over by a company led by Crawford and Meason. This company seems to have remained in charge until 1842 when the Duke of Buccleugh took the mines into his own hands, working them until 1906 when the Wanlockhead Lead Mining Company took over. In the post-war years the business did not prosper, and the mines closed in 1934. There was an abortive attempt to re-open them in the 1950s, but operations ceased in 1959. Local gossip insists that 'there is as much lead in the ground as ever came out', and it seems that the mining companies have not completely lost interest in the area, but there is no serious talk of re-commencing operations at the moment.

Most of the existing relics date from the late 18th century onwards, though traces of Bulmer's work can still be seen. A brief and superficial examination of the ground shows an astonishingly large number of fallen-in shafts, adits and spoil heaps. Reference to the geological accounts shows that there is a considerable number of veins, but comparison of various geological maps shows a lack of unanimity in their positions: the Geological Survey itself does not claim certitude. This confusion on the surface coupled with the geological uncertainty, together with the disappearance of much of the written record of the mines, makes a detailed mining history impossible to achieve. Help in understanding the overall pattern of exploitation is, however, provided by a simple consideration of economic factors. Towards the end of the 18th century the price of lead was high, the mines were developed, and it was sensible to import coal to Wanlockhead to fuel pumping engines and winding gear. When the price of lead fell after the establishment of free trade in 1832 importing fuel was no longer economic, for it had to come some 10 miles horizontally and 1,000 feet vertically, and there was a great development of water power, in terms both of waterwheels and other low-head devices and of water pressure engines. Later in the last century, after the Duke took over the mines himself, capital became more freely available and steam power was re-introduced, the network of communications was improved, a railway joining the main Glasgow-Carlisle line was opened, new ore-dressing and smelting plant was installed and the mines took on a prosperous appearance. It seems likely, indeed, that the workings were at this period over-lavishly equipped for the possible output, and it could well be that this lavishness was a factor leading to their decline.

Since the decline of the mines and the closure of the railway in the 1930s the villages of Wanlockhead and Leadhills have both shrunk in population and assumed the dreary aspect of run-down industry. There are still a few of the old miners about, and, as might be expected, a good deal of folklore concerning the mines can be heard. In the last few years there has been a growth of systematic study, led by Mr G Downs-Rose and Mr W S Harvey, who have been examining several aspects of the industry and the human geography of the area, and in four successive years the Department of Extra-Mural and Adult Education of the University of Glasgow held a Summer School in Industrial Archaeology at Wanlockhead. An important feature of these recent studies has been a conscious attempt to examine both documentary evidence and physical remains in detail and in depth. Almost as soon as the first pick is driven in at a given site the inadequacies of existing knowledge show themselves. There is much to be done in order to obtain a coherent outline of the pattern of mines and history.

This is not the place to treat the social history of the village, but it should be noted in passing that the economy was centred on the lead industry but that working hours were for the most part fairly short so that the workmen had time to cultivate the land. There was a Library and a Miners' Institute: the Library has been preserved and is being actively restored, the Institute has been destroyed and the only active social institution is now the Miners' Club! Even the village school is now closed.

Visible Remains

The traces of the communication system provide the best framework for an examination of the visible remains.

Until the very end of the last century all communication was by road. The main route out for lead from Wanlockhead was northwards through Leadhills, down the Glengonnar Water to Abington in Clydesdale and thence to Biggar and ultimately to Leith for shipment to England and the low countries. Presumably most supplies went in by the same route, at least from Abington or Biggar. The great exception was coal, which was brought in from the Sanquhar coalfield in Nithsdale (to the north-west) by a hill road which entered the Wanlock Valley 1½ miles below the village and which now survives as a mere track. There was another road from Nithsdale which ascended the Mennock Pass, and which seems to have come into use surprisingly late, and a fourth linking Leadhills with Elvanfoot in the Clyde Valley a few miles south of Abington. In 1898 a Light Railway Order was granted to the Caledonian Railway authorising a line from Elvanfoot, on the main line from Glasgow to Carlisle, to Leadhills and on to Wanlockhead. This line was completed in the first years of the century, and provided the principal access until about 1930, when goods traffic was discontinued, and 1938 when the last passengers were carried. From the Elvanfoot to Leadhills road the line of the railway is still clearly visible for most of its length. Soon after leaving Elvanfoot village a neat bridge over the river can be seen to the left, and higher up the valley there is a handsome brick-faced viaduct crossing the side valley known as Risping Cleuch. This viaduct is an excellent piece of railway architecture, carrying the line on a gentle curve high above the valley floor. The mineral field extends to Risping Cleuch: at one time gold was extensively worked here. The railway continues to ascend all the way to Leadhills, where traces of the station and mineral depot can be seen, and is then almost level through cutting and over embankment to Wanlockhead. It was the highest working railway in the United Kingdom, and though single-track all the way there were fairly complex arrangements at both villages for handling coal and minerals. Details at the Wanlockhead end can best be traced with the aid of the 1921 edition of the 6" geological map. The line crosses the Wanlock Valley from east to west very near its head, and terminates just short of the Mennock Pass. The line overlooks the whole mining area, and at first it appears peculiar to have the mineral depot so high above the workings. However, simple consideration of the topography shows that this was the only possible place.

The valley floor shows traces of a considerable network of 20" gauge mineral lines. Analysis by the University of Glasgow Summer School has enabled the history of adaptation and modification of these tramways to the changing pattern of the industry to be worked out in some detail. Before the coming of the railway the flow of ore was down the valley – northwards – to the ore-preparation plant and smelter, obviously making use of gravity to provide motive power. The ore-dressing plant latterly in use was about a mile below the village and the smelter half-a-mile further on – the sites both being clearly chosen in part for convenience of mineral access. When the railway was built the main flow was reversed, with ore coming up the valley towards the mineral depot, the last part of the journey being up a steep rope-hauled incline at right-angles to the main line. The remains of the incline can be clearly seen. It was driven by a compressed air motor which derived its air from the New Glencrieff mine about a mile away.

In some ways comparable to the railway and tramway system is the array of water-lades, which can be seen contouring the hillsides in all directions, bringing the water from adits and reservoirs to operate waterwheels, water-pressure engines, washing plant and so on. The availability of water-power was a second factor in determining the positions of the fixed installations. As noted above, there were changes in the use of water-power resulting from the introduction of steam and shifts in the economic balance. It has been found possible to work out in part the relationship between the traces of lades still existing and the phases of the mineral exploitation, but more work is needed on this topic.

It is interesting to note that the village of Wanlockhead is towards the head of the valley while the principal smelter is well down. It would probably be a mistake to think that this was to free the inhabitants from the noxious fumes: it is known that the very earliest smelter was in the village itself, the second just below it and only the third in a remote setting. It was power and transport, not health, which were important in choosing the sites.

It is not possible to detail or even list all the surface remains which are still visible: at various times a great many shafts have been opened and adits driven, and not all of them can be readily identified. Indeed, some of the shafts have a distressing tendency to move about on the Ordnance Survey maps. Certain structures which have been investigated recently can, however, sensibly be discussed.

Engine House at Beltongrain

Running approximately parallel to the Wanlock Valley and cutting the railway and road to Leadhills about half-way between the valley floor and the top of the pass is the Beltongrain vein. This was exploited extensively, and the mine records give a certain amount of its history. In 1803 a Boulton and Watt beam pumping engine was installed at a newly-excavated shaft to drain the mine. The original Boulton and Watt drawings and accounts for engine and engine house, together with a few relevant letters, are preserved in the Boulton and Watt Collection in Birmginham Public Library.[8] From the mine records and the maps it was deduced that a ruinous structure close to a fallen-in mine-shaft at NS 878131 had been the Boulton and Watt engine house. Since such engine houses are rate and also since some of the constructional details are of possible relevance to a much more important site at Wanlockhead it was decided to excavate this ruin. Excavation revealed a lot of wall, a certain amount of building refuse, a large stoneware jar, traces of habitation, including a ruinous pair of trousers, and a number of puzzles. The remains exposed correspond in width to the Boulton and Watt drawings, but are too short to have accommodated the engine. Furthermore, the front, or lever, wall should be 6½ ft thick at the bottom, with a drain in the centre facing towards the shaft, and built of properly-squared masonry. In excavation it was found to be only a little over 2 ft thick, with no drain and of a low standard of construction. It almost certainly could not have supported the weight of lever and pump rods. Furthermore, though the building excavated is close to the edge of the shaft it is not as close as would be expected bearing in mind that the engine beam had to project over the shaft. It could be, of course, that the shaft has fallen in in a very asymmetrical way, so that the centre of the shaft is nowhere near the centre of the crater, but even so the dimensions do not fit at all well. Perhaps the original engine house was very thoroughly demolished and the site cleared, and a cottage built instead. But if the walls were too flimsy to be a Boulton and Watt engine house they seem to be too massive for a cottage! Finally, the Boulton and Watt records clearly show the location of the boilers, which is specified in unusual detail, but no trace of them or even of substantial quantities of ash were uncovered when excavating. Thus, the Beltongrain site, impressive though the remains are, does not really throw any light on the mining history. It rather demonstrates the difficulties of industrial excavation, for clearly either the excavation was not at the site of the Boulton and Watt engine house or the changes have been almost inconceivably large. The written records, interpreted in a straightforward way, are inadequate!

The Straitsteps Beam Engine

The most famous of the Wanlockhead relics is the beam engine on the Straitsteps vein at NS 871131. Nearby is the clearly-visible site of a horse gin, and the concrete capping shields a shaft which is still laddered at least in part. The engine has been described and discussed by G Downs-Rose and W S Harvey,[9] who conclude that it was probably a very simple water-bucket engine, with water admitted to a self-emptying bucket suspended from one end of the beam, and an underground pump operated by a spear rod (part of which is still in place) from the other. Perhaps the most surprising feature of this engine is that it can only have been a minor pumping device, built in the second half of the last century, but nevertheless with fine masonry work on the pillar and with elaborate decoration on some of the timber. Something much more utilitarian in design and rough and ready in construction might have been expected. The remains have recently been given the attentions of the Department of the Environment and should now be safe from further decay. The horse gin and other nearby traces are being actively examined.

The Pate's Knowes Smelter

A short distance down the valley from the beam engine are the remains of a lead smelter. A certain amount of information about it can be found in the mine records, from which it appears to have been built in the 18th century and to have continued in work until the 1840s. Clearing the site has been one of the major tasks of the University of Glasgow Summer School, and is now being continued by others. The building, or group of buildings, was quite extensive, and the perimeter of the site may not yet have been reached. There seems to have been a waterwheel in the middle of the complex, for traces of a lade, a wheel-pit and a tail race can readily enough be seen. Further comment cannot be made on the site itself until excavation is further advanced, but the most exciting finds of the summer school work were made here in 1975. A mechanical excavator, used for clearing the top cover, turned up a number of cast iron components of smelting furnaces. These were no longer in their original working positions, and may have simply been gathered together for the convenience of the scrap merchant! They correspond astonishingly closely to the Scotch Hearth as described by Percy, pages 278–281.[10] A hearth-bottom, several workstones and three bearers have been identified, with dimensions matching those shown by Percy. Other pieces of iron have also turned up which do not fit Percy's principal description so clearly, but could conceivably be fragments of shallower hearth-bottoms of an alternative pattern which he describes in pages 285–286. Earlier, in 1974, two other massive pieces of cast iron were turned up not far away, and they, also, could be interpreted as furnace components. Unfortunately, the masonry at this site is so far decayed that the furnace arches have disappeared completely, and there is no visible trace of the flue.

The Bay Mine, Whyte's Cleuch (Figure 2)

Opening to the east from the main valley and just beyond Pate's Knowes is the side valley of Whyte's Cleuch. The name Whyte first appears in the search for gold early in the 17th century when there are references to 'the old gold washer Whyte' and it seems reasonable to believe that this valley takes its name from the gold washer. There are here numerous traces, including adits, lades, fallen-in shafts, remains of tramways, etc. The most noticeable include a large waterwheel pit of undetermined age and undetermined function at the lower end of the valley and the surface working of the Bay, or Charles, Mine, NS 868137. This mine had two shafts, one now fallen-in and one concrete-capped. It is known from the records that maining operations started here in the late 18th century and that the first engine built to Symington's design was erected here. The 25" Ordnance Survey map shows the outline of mine buildings as they were at the turn of the century: but since then they have been partly overlaid by

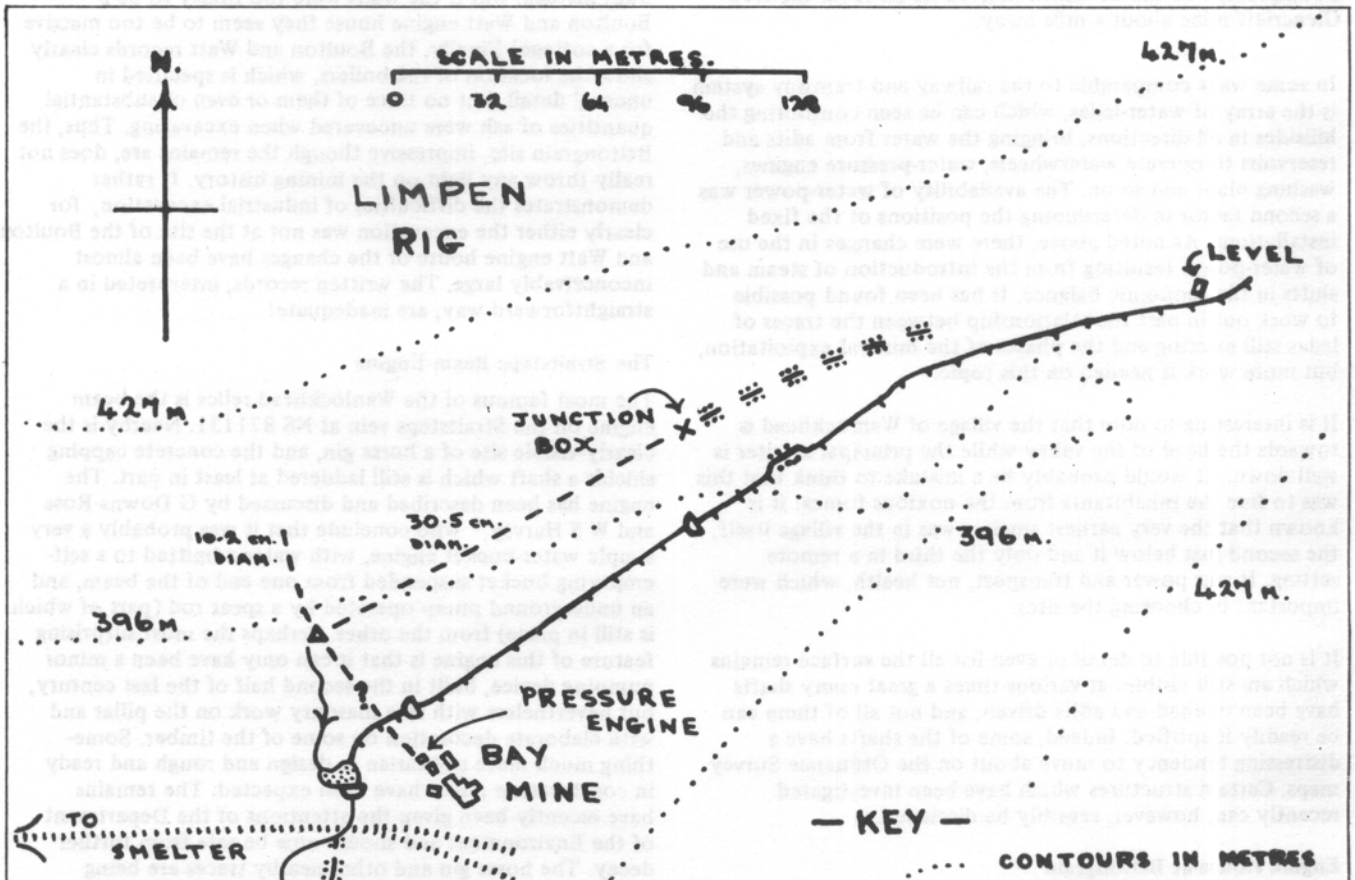

Fig.2 Some lades in Whyte's Cleuch

foundations put in when an attempt was made to de-water the mine in the 1950s. For several years the University of Glasgow Summer School concentrated on this site, and has succeeded in revealing most of the structures shown on the map. It has been found possible to analyse the function of various parts of the head-workings, though not all the details of the hypotheses are thoroughly convincing. Slightly deeper excavation has revealed a group of sandstone blocks which could well be the foundations of the Symington Engine. One of the principal motives for the Beltongrain excavation was the hope that corresponding foundations might be found there, for that engine followed the Symington by some six years. However, no such traces were found at Beltongrain. It can be shown that the sandstone blocks fit conveniently with a conjectural reconstruction of the Symington Engine: they form simultaneously one of the most exciting and most frustrating finds of the summer schools. The history of this mine has been discussed at some length in a recent pamphlet by W Harvey and G Downs-Rose,[11] which incorporates results from the University excavation.

The New Glencrieff Mine

The largest mine in the district is situated across the Wanlock Burn from the foot of Whyte's Cleuch. Plans and sections of this mine are preserved by the Wanlockhead Museum Trust, but no attempt has so far been made to examine the remains in detail because the spoil heap is itself being exploited for road metal.

The Meadowfoot Smelter

In the main valley below Meadowfoot Cemetery (which contains the graves of a number of lead workers and their families), the lines of water lades and tramways leading to the ore preparation plant and to the nearby smelter at NS 855144 can readily be traced. There is hardly anything left at the ore preparation plant, presumably because the machinery there could be used elsewhere. The equipment in place towards the end of its life was described by Mitchell[12] and that of an earlier time by Porteous.[13] One feature which is still clear is the system of gravity feeding, by which minerals came down the valley by their own weight, fell through the preparation plant and proceeded by a low-level tramway downhill to the smelter.

The remains of the Meadowfoot smelter are simultaneously the largest and most disappointing in the district! The smelter was started in the 1840s, re-equipped in the 1870s and again in the first decade of this century. Unfortunately it was used for artillery practice during the last war, and the efforts of the gunners, coupled with the effects of lead fume, have reduced the buildings to a crumbling and very dangerous heap of rubble.

From 1845 the smelting furnaces were in the position of the present main building with a gas washer immediately behind them. They were the very latest thing in lead smelting plant, and the washer was described in the Catalogue of the Great Exhibition of 1851[14] as one of the greatest of contributions to lead working. In 1873 new furnaces were installed and the surviving gas washers and flue system erected. This flue system is probably unique in that the framing is made of wood and in that it consists of two concentric loops with various subsidiary passages, rather than a set of linear flues. Porteous[15] states that the flues cost £3,000 and that the value of lead saved paid for them in the first year and a half. Wanlockhead was one of the few places in Britain in which the lead was de-silvered, Pattinson's process being used, and the plant housed in a building, now completely ruinous, on the north side of the smelting house. De-silverisation was discontinued in 1910. In the main smelter itself there were latterly two roasting furnaces, five Scotch Hearths and one slag hearth, according to Mitchell.[16] It is possible to pick out the pit for the waterwheel which, from the 1870s, drove a Rootes' blower providing air for the furnaces. One concrete furnace arch can still be seen, but the rate of decay is great and how much will be left in ten years' time it is impossible to say. It is already impossible to sort out the precise positions of the furnaces or the route by which the gases found their way to the flues or the way in which the flues were used. Between the present gas washers and the flues there is a large rectangular area which probably held gas control gear, but no documentary or other information about it has yet come to light. The flues had to be cleaned out from time to time, and to the south of the smelter building there are concrete settling ponds. Whether the flue dust was washed into them or swept into them is not now known: from their construction it would seem that they were intended to have the dust washed into them, but talk in the village seems to be of gangs of men sweeping the flues.

It is hoped that this short article will have drawn attention to the interest and complexity of this small area of Scotland: there is ample scope for study and exploration both on the ground and in the documents. Possibly it is unequalled as an area suitable for the intensive pursuit of mining history in Britain.

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Book reviews

THE BEWL VALLEY IRONWORKS. David Crossley
Published by The Royal Archaeological Institute, 1975.
97 pp + plates. £5.00

This is a well-documented, well-illustrated account of the sites of Chingley Forge and Chingley Furnace in the valley of the River Bewl on the Kent-Sussex border. The sites lay upon the area to be drowned by the construction of a new reservoir and so excavations were carried out to ascertain as much detail as possible before the final inundation.

Documentary evidence for a late medieval bloomery from c.1300 and for the forge and furnace up to the early eighteenth century is given; from this it seems that the furnace did not survive the early 1580s, while the forge apparently dates from the 1580s and continued with interruptions until c.1730.

The detailed excavation reports are models of clarity, and the whole is supported by reports upon many of the associated finds. It is a pleasure to see so much care expended upon an industrial site and Dr Crossley deserves our thanks both for the excavation and for this excellent publication.

Norman Mutton

HISTORIC INDUSTRIAL SCENES – THE MINES OF SHROPSHIRE, I J Brown. Historic Industrial Scenes – The Mines of Shropshire, Moorland Publishing Company 1976. 112pp. 160 photographs, £3.95.

As this book makes clear, there is much more to Shropshire's industrial history than its justly famous ironmaking activities. Coal, ironstone, limestone, clay, lead, copper and witherite are only some of the minerals that have been won from its earth and in this impressive collection of historical mining photographs, only a few of which are superfluous, our attention is directed both to these industries and to the importance of photographic evidence as primary source material.

The author, a mining engineer and geologist, has made good use of his expertise in providing valuable captions and notes, although the introduction should have included a brief statement on the relative importance of Shropshire's mining industries within a regional and national context. There is little of direct relevance to the Historical Metallurgist but the photographs give a valuable insight into the nature of the mining industries of this important metallurgical area. Some of the photographs are familiar and appear in recent books by the same publishers; many, however, are new and some are gems. A postcard entitled 'Modern Coal Pit' shows striking miners using an upturned bicycle as a winding engine. A photograph of 1934 shows new, Bedford trucks collecting coal from a pit worked by a hand windlass. Other pits have impressive arrays of steam power and thus the photographs demonstrate yet again and in a way that is perhaps unrivalled, the varying degrees of technological sophistication that might be found in any industry at a particular moment in time.

Most of the photographs show surface features and regrettably, there are few significant underground scenes. It is to be hoped that the publication of this book might flush a few out. It might also encourage those involved in photographic recording work today to be more catholic in their approach. Finally, in a publication where the quality of photographic reproduction is all important the publishers are to be commended on their use of high quality paper and their reasonable selling price.

Stafford M Linsley

THE LEAD INDUSTRY OF WENSLEYDALE AND SWALEDALE: VOL. II, THE SMELTING MILLS.
Arthur Raistrick, 1975. Moorland Publishing Co. Hartington, Derbys. A5 format 120 pages including 41 illustrations and 7 maps. Hardback £2.95.

In this volume Dr Raistrick has concentrated on describing the remains and detailed histories of some 43 smelting mills in the two Dales, complementing and extending the architectural survey made by Clough some 15 years ago. Whilst his first volume, The Mines, which in fact included several pieces on smelting, was clearly intended as an introductory description and guide for a wider market, this will be of particular interest to the specialist also. If anything the introductory material, though not slight, is too slender, only an outline being given of the process and equipment, and though Raistrick specifically guides readers to the main contemporary accounts, he has unfortunately been too modest to footnote his own significant contributions. For the general reader without access to library facilities and specialist works, this will be a disadvantage which could easily have been overcome, and is notably out of balance with the first volume.

On the other hand the individual site descriptions contain a wealth of detail, and as Raistrick intends will certainly act as a source and a stimulant to further research. Of particular interest are descriptions of ingot weights and markings which otherwise are practically unknown for the area, but which are the main means to identification of the ingots now being discovered worldwide. An appendix, made whilst the book was in proof deals with a Jenkins Patent Reverberatory Furnace of the 1850s, one of the several smelting innovations of that period, and with the result of further examination of Old Gang, emphasise the potential of further detailed investigation into the industry.

The first Volume unfortunately contained several of the imperfections which Mutton in this Journal had already commented on for an earlier Moorland publication. Happily this now seems to have been corrected, whilst the selection of photographs and line diagrams deserve commendation. It remains a pity though that these two slim volumes could not have been brought out in a single back, which might have allowed a slightly lower price in aggregate.

Lynn Willies

A POCKET BOOK FOR INDUSTRIAL ARCHAEOLOGISTS
Kenneth Hudson. pp. vii + 134, 207mm x 113mm. Published by John Baker Ltd. September 1976. £2.25.

The author, as well as the reviewer, of a book such as this faces considerable problems. As he states here, most interested parties will confine their interests to an area within 20 miles of their residence; it should probably be added that they also tend to confine their activities within a rather narrow field within the overall technology and thus become a collection of local specialists. Both author and reviewer are likely to, and it would seem in this case do, have this sort of background.

It would be unjust not to state forthwith that the author has surmounted many of his self-imposed obstacles eminently successfully. His general introduction, the outlining of the main tasks for the next ten years and his instructions on recording findings should be given serious consideration. The section on Industrial Archaeology and the Law is most valuable. The list of Museums, Libraries and so on is also quite helpful.

The two final sections, however, must call forth some adverse comment. Amongst 'Organisations and Institutions likely to be helpful' our own Society receives no mention, a surprising omission in view of the author's expressed admiration for our publications elsewhere in his writings. It also must be pointed out that the reader seeking information on ferrous metals will not really find any assistance from the Iron and Steel Institute: it left the address quoted over four years ago and passed out of existence two years ago. It might also be remarked, in passing, that, despite his eulogy on the Abbeydale Hamlet, he does not mention the Sheffield Trades Historical Society, which was mainly responsible for its preservation and which still thrives, numbering Wortley Top Forge restoration among its activities.

The final section on Key Inventions is not helpful to the metallurgically minded. A list of dates of the laboratory discovery of the various metals has of itself very little relevance to the Industrial Archaeologist. Chromium may have been first isolated in 1797 but it was first used in steelmaking about 1870 and its advent into everyday life in the form of untarnishable finishes (plating or stainless steel) was a 20th century development. One would have thought that Boulsover's 'Sheffield Plate' invention of 1742 and Elkington's electroplating process of a century later were worthy of mention as is the pig-boiling process for wrought iron. Rather strangely, the two outstanding inventions in the steel-making field, those of Bessemer and Gilchrist-Thomas, are not included under Metals at all, although they most oddly occur under Furnaces elsewhere.

The book is well produced – it does indeed fit the pocket and the laminated cover renders it suitably robust. It could have been better checked at the proof stage, however: Huntman and Polheim do jar somewhat.

K C Barraclough

SHEFFIELD STEEL, K C Barraclough.
Moorland Publishing Co., Hartington, 1976, £3. 95.

Those who know Ken Barraclough and have witnessed his enthusiasm and thoroughness will not be disappointed in this albeit brief history of Sheffield Steel. The book is an early title in the promising series Historical Industrial Scenes, now emerging through the enterprise of the Moorland Publishing Company, which has for some years been a fertile source of literature dealing with specialised topics of interest to the local historian and industrial archaeologist: the present volume should command a far wider readership.

The book is essentially a series of carefully annotated pictures preceded by an outline history of steel in Sheffield. The latter traces the development of the industry in the area from the mediaeval period, with its early emphasis on cutlery manufacture, to that time during the eighteenth century when the town emerged as the pre-eminent steel producing centre of Great Britain. Cementation, crucible, Bessemer and open hearth steelmaking are accordingly covered, as is the subsequent role of basic steelmaking in shifting the centre of gravity of the bulk operation out of Sheffield and out of the United Kingdom. From the text, however, emerges the enduring role of the area in relation to the quality product, which still involves Sheffield in almost half the sales value of British steel output.

Forging and rolling receive appropriate attention and a section of the book is devoted to the lighter steel products which have always flavoured the local industry with the craft atmosphere; other salient points to emerge very clearly are the long Swedish connection and the labour intensive character of early manufacturing operations. Apart from first rate photographs, good use is made of early paintings and prints to give a detailed appreciation not only of plant design and construction but of the style and location of the works themselves and the importance of the local geography. The book touches on the preservation, at the eleventh hour, of the relatively few surviving examples of plant and buildings, which owes much to the band of local enthusiasts of whom the author of this obvious labour of love is one. A bibliography and index are included.

Commensurate with a quality-based industry, the binding, paper and production of this important book are of a high standard, so that it represents excellent value for money in all respects.

P R Beeley

THE OLDEST SHEFFIELD PLATER, John and Julia Hadfield, Published by the Advertiser Press Limited, Huddersfield, 1974 pp. 189 plus insert fold (maps), £3.25.

Two men were largely responsible for the development of the metallurgical arts in Sheffield in the middle of the eighteenth century: Benjamin Huntsman, renowned for his invention of Crucible Steel and the production of steel ingots, and Thomas Boulsover, the inventor of Sheffield Plate. Both these discoveries are traditionally dated to the same year, 1742. The men themselves had other things in common: they were both strong non-conformists and both appear to have been of a somewhat retiring nature. As a result, very little is generally known of them; there are certainly no extant 'lives' of either which can be relied on to distinguish between fact and myth.

For this reason, the present offering by this man and wife team is most valuable in that it brings out newly discovered facts about the Boulsover family and puts them quite clearly in the context of local history as well as in the better known national scene. They have established that Thomas Boulsover was born in the parish of Ecclesfield and was baptised in its fine church, still locally known as 'The Minster of the Moors', on 18th October, 1705; they have also proved that he spelt his name with a 'u' included, despite the fact the road subsequently named after him omits it.

It is interesting to follow the interplay between the various trades in Sheffield at this time. Boulsover's invention arose from his repairs to cutlery and he first put it to use in the making of buttons; Huntsman's invention came from his dissatisfaction with the steel available for his clockmaking needs; his product was taken up by the French cutlers and the Birmingham buttonmakers and his son became a buttonmaker in Sheffield; Boulsover considered Huntsman's steel would produce good saws and applied his rolling process to this end, eventually setting up as a Crucible Steel manufacturer in competition with Huntsman.

The metallurgist will not find any detailed technical description of Boulsover's process here; sufficient information is given, however, to guide the general reader as to what was involved in the manufacture of the raw material. The methods by which it was fabricated into innumerable articles, both of utilitarian and decorative value, in the century which followed upon the discovery, form the subject of a well illustrated chapter. Perhaps the most interesting technological feature, however, which the authors bring to light is the reintroduction of the fused plate a century after Boulsover's material became obsolescent following upon the production of electropate in 1840. It seems that a fused silver-copper plate was the only suitable material for an intercooler on the Merlin and Griffon engines and that some 500 tons of such a material was produced during the War years, a specification, DTD 631, eventually being issued to cover this application; it is fascinating to recall also that at this period a number of the disused Crucible furnaces in the Sheffield area, including those now preserved at the Abbeydale Hamlet, were brought back into service to produce further quantities of the much needed high speed steel for which they were so eminently suited.

This little book has obviously a particular interest to the Sheffielder, but it should be read by all who have an interest in the history of the common people of the seventeenth and eighteenth centuries, of the interplay of agriculture and technology, of the appallingly high infant mortality rate and the short expectancy of life even in better class surroundings and of the profound effect that individuals could have on the future of their own district and of the country as a whole. It is worthy of a good reception.

K C Barraclough,

COPPER MINING IN MIDDLETON TYAS, T R Hornshaw. North Yorks. County Record Office Publications No. 6. 1975. £4.00. (A4 format; 150 pages).

This book was written to provide an account of the copper mining industry in and around Middleton Tyas of the later 18th century, and its temporary revival in the later 19th century. Much of the evidence is based on contemporary records, (company accounts, correspondence, etc) which means that the account is essentially an historical one. However an attempt is made to relate this information to archaeological evidence on the ground, and to include technical information of some of the processes involved.

The first chapter presents a rather involved account of the various individuals concerned with the beginning of the exploitation in the mid-18th century. The second chapter proceeds, after a brief but readily understood account of the general geology of the area, to describe in detail the copper mineralization. The unusual presence of a horizontal 'float' of ore (as well as the more normal, vertical 'pipes') would have been attractive to the early exploiters due to the relative ease with which it could have been worked. The minerals present included 'oxide' ores such as malachite and some 'sulphide' minerals such as chalcocite. The purity was impressive with figures of 45 – 66% copper being quoted. The third chapter attempts to identify the original workings of the first exploiters, as described in contemporary accounts, with evidence on the ground. Here the author is drawing on evidence (mostly incomplete) of widely differing nature and on the whole succeeds in producing a well argued account. The next chapter gives a more detailed survey of the early history of one group of mines using evidence from a surviving set of very full accounts. These are most useful for the years 1741 to 1754 when the mines were worked directly by the owners. Information is given on the nature of the expenditure that was necessary, but in addition, some of the methods of exploitation and the problems met with are revealed. However the author of the book does use other evidence to aid his account and it is not always clear which he is using. In the following chapter the same accounts, along with other evidence for the later periods, are used to give information on the terms of employment of labour and how these varied with time. The cost of materials is also discussed, these inevitably rising with time, and the effect of the mining on the population of the village as well, this being increaed by the arrival of immigrant labour. The attempts to solve the ever present drainage problems are discussed in the next chapter. This involved the employment of horse-engines, but one of the exploiters tried, and eventually succeeded to a degree, to employ a steam engine of the Newcomen type. As the author points out, this is particularly interesting in an isolated industry employing many, very primitive methods, for at this time in the north-east, such engines were practically only used in coal mines. Here, the evidence is used to present well argued, clear and detailed reconstructions of the machinery involved. The next chapter presents an account of the methods used for ore-concentration, and extraction. Here the author relies heavily on Gabriel Jars who visited the site in about 1765. But he does not seem to have understood the technical aspects of Jars' observations. The ores used were partially oxidized sulphides and these were smelted in a reverberatory furnace to give raw copper, matte and slag. The matte was returned to the furnace where it was in time oxidized to the metal, and the raw copper went forward to a refining process either in Derby (in the early days) or at Middleton later, where it underwent a loss of 10%, due probably to the elimination of iron and other impurities. Unfortunately the author sometimes confuses matte with impure copper. This account would require a little more information for the non-metallurgist. Also, it is a great pity that the production technique used in the book does not reproduce Angerstein's contemporary sketch of buddles (for ore-concentration) at all well. A line drawing made from the sketch would have been better.

The generally unsuccessful attempts of the late 18th century to mine copper to the west, as the mines at Middleton Tyas itself declined, (due to the patchy ore running out, and the original exploiters passing on) are discussed next. The final chapter is concerned with the rather short, turbulent history of the later 19th century 'Merrybent' companies, formed to exploit the ore veins to the north, and build a railway to carry the ore away (neither venture being really successful). The evidence is taken from contemporary newspaper accounts and provides information on little more than the company politics involved.

There are some criticisms which apply to the book as a whole. For example the reference system is rather inadequate and at times this is irritating. One feels that if this was improved, the confusion that arises over some of the sources used, could easily be avoided. The absence of a glossary is rather unfortunate. There are times when technical terms are used which would hinder the understanding of many not well acquainted with mining or metallurgy. Also, it would be useful to collect together the dialect or antiquated, technical terms referred to in the text in such a glossary. The method of reproduction used (type reproduced by offset litho) is obviously chosen for cheapness. However, any pictures other than line drawings will not reproduce successfully by this method. Thus the two attempts to reproduce sketches from Angerstein's contemporary account, are not of the standard to be expected in a published work.

Roger Hetherington

FIRST RADIO–CARBON DATES FROM CHINA Noel Barnard Monographs on Far Eastern History, No.8. ANU, Canberra. Second revised and enlarged edition, 1975. $A 5.95.

As its title implies this is not of great interest to historians of metallurgy. But it so happens that some of the dates relate to sites on which metal objects have been found and, in the course of discussion on their dating, considerable detail is given about the objects which is not easily obtainable elsewhere in English.

A ^{14}C date of 375 ± 85 BC has been obtained on a piece of bone from a tomb of the Chan-Kuo period. In this same burial were a number of slaves, and the iron collar from one of these has been examined. It is quite clear that the two pieces of the collar are of wrought iron. This is of great importance since most of the early iron in China is cast iron and there has been little evidence as to the production of wrought iron before the Han period. In Yunnan in the South of China, a site dated to 1348 ± 154 BC shows the appearance of metal finds in a basically Neolithic context. These comprise copper fish-hooks, awls, a curved knife blade and a bracelet which appear to have been shaped by forging. Moulds for socketed axes with splayed blades have also been found on this site. It is interesting to note that this splayed form is alien to the Chinese nuclear area far to the north.

Three bronze implements were found on a Late Neolithic site which is comparable in character with another Lung-Shan site with a ^{14}C date of 2809 ± 143 BC. These artifacts had been previously given a possible Chan-Kuo or Han date but Barnard thinks that they may be even earlier than the ^{14}C date suggests!

Another Neolithic site, this time in the north at Ch'ing-hai, has been given a date of 2177 ± 110 BC and has yielded bronze artifacts, a chariot wheel and casting dross. The bronzes are strongly reminiscent of Central Asian types; a socketed axe resembles those from the Turbino Culture. The knives are of typical Shang type and the socketed axe-heads resemble those of Late Shang times. These, therefore, seem out of context and could be intrusions in Chun-Kuo or Han times.

In his discussion on this, the third, group of ^{14}C dates to emanate from China, Barnard reviews the impact of these dates on the origin of metallurgy in China. He reiterates his general thesis that metallurgy in China had independent origins. He states that this view is supported by the application of the new ^{14}C dating technique to several Chalcolithic sites. It is quite clear that these dates show Chinese metallurgy to be much earlier than was hitherto thought since most of the artifacts found had been dated traditionally not earlier than the Shang period (ie. not before 1500 BC). But of course this does not preclude the influence of western ideas and techniques, as metallurgy was in full swing in Asia Minor in the third millennium BC, and there are indications of possible diffusion routes for this period.

R F Tylecote

Abstracts

GENERAL

P A Lins and W A Oddy: The origins of mercury gilding. *J. Arch. Science 1975, 2, 365–373.*

A survey of almost 50 gilded objects in the British Museum which shows that the process was used in the 3rd century BC (Chou period) in China, and in the later Roman and Sasanian empires of the 3rd-4th century AD. The process was identified by emission spectroscopy and microscopic examination. Earlier (and some later) processes involve fusion or solid phase welding. The criteria for distinguishing the processes used are given and discussed.

RFT

M Tenenbaum: Iron and Society: A Case Study in Constraints and Incentives. Met. Trans. A., March 1976, 7A, 335–350. Met. Trans. B., March 1976, 7B, 5–16.

An attempt is made to describe a pattern of recurrent constraints, incentives and innovations that have, over the centuries influenced the manner in which iron and steel have emerged as the world's leading structural materials. APG

BRITISH ISLES

Lynn Willies: The Barker family and the 18th century lead business. *Derbys. Arch. J., 1973, 93, 55–74.*

Historical; deals with partnerships, ore supply, smelters, disposal of the lead, and capital and profits. The firm had many smelters in and around the Derwent valley. First to use reverberatory furnaces.

RFT

J Wacher: The towns of Roman Britain. *London, 1974.*

Iron smelting activity is briefly mentioned in connection with Lincoln, Canterbury, Chichester and Silchester. Smithing was practiced at York, Silchester and Caerwent.

RFT

Anon: Holwell Works Centenary. *Steel Times, Feb. 1976, 96 204, (2).*

A brief editorial note about the centenary celebration, with an outline of the history of the Holwell Works near Melton Mowbray, Leicestershire. From its beginnings as an ironstone mine in the 1870s, it quickly turned to smelting, the first blast furnace dating from 1881. In 1904 large scale foundry-work upon the American pattern began, and there are notes of more recent changes.

NM

E Davey: A Vanished Foundry. *Foundry Trade Journal, 1976,* **141**,*(3089), 46.*

A plaque on a wall in King Street, King's Lynn (Illustrated) marks the site of John Aickman's 'Foundery' which operated between about 1822 and 1877 under various names. At first supplying general castings for domestic, agricultural, and shipping requirements, the foundry later supplied castings to the Frederick Savage company for use in constructing traction engines.'

APG

J C Wright: 120 years of quality casting development. *British Foundryman, July 1976,* **69** *(7), 161–179.*

The first ten pages of this long article are devoted to an account of steel casting in the UK from c.1855, with critical comments upon historical concepts of quality as illustrated by government specifications and reports.

The second half deals with modern aspects of quality control in steel castings.

NM

H A Green. Fireproof Cast-Iron-Framed Building. *Foundry Trade Journal, 24th June 1976,* **140**, *(3088), 891–895.*

An early iron-framed building, part of Beynon and Bage's Canal Terminus Flax Mill at Shrewsbury, built between 1806 and 1809, has now been recognised and listed as a building of historic interest. Conversion of the mill into a terrace of four houses between 1856 and 1861 has made little difference to the basic structure. The history of the mill and its uses is covered in fair detail in the article.

APG

R F Tylecote. Weardale Iron and Steel Making 1876–95. *The Metallurgist, 1976,* 8 *(5), 269–271.*

The discovery of two books of analysis of the Weardale Iron Company for the periods December 13, 1876 – J January 24th, 1878 and from November 13th 1893 to July, 6th 1895, gives a great deal of information about the compositions of ores, pig irons, wrought iron, Bessemer steel, open hearth steel, limestone and fluorspar, as well as indicating sources of supply of raw materials. They They also indicate that commercially successful production of steel by the Bessemer process at the Tudhow works began on September 12th, 1877, rather than 1861, as suggested by Carr and Taplin (History of the British Iron and Steel Industry).

In an appendix **Kenneth Barraclough**. comments on the very high standard of control of carbon and manganese contents in the open-hearth furnaces. A table shows the number of heats produced week by week, in seven open-hearth furnaces during a period of 100 days in 1895.

APG

G Hammersley. The Charcoal Iron Industry and its Fuel. 1540–1750. *Economic History Review, 1973,* **26**, *593–613.*

This detailed paper sets out to demolish the generally held view that the location and development of the charcoal iron industry in Great Britain were determined by the state of fuel supplies and their tendency to local exhaustion. Careful examination of the evidence shows that the number of occupied blast furnace sites in England and Wales reached a maximum of 89 early in the 17th century, but continued at over 68 until a second peak of 82 was reached during the decade 1710–1719. The Wealden iron industry grew rapidly until the 1580's, but then declined to a low level of activity during the next hundred years, but this decline is attributed to the spread of the new technology to other areas with more reliable sources of water power and better iron ores for making pig iron for the forge. Evidence shows that exhaustion of the woodlands around the furnaces was not a significant cause of the decline. For example, of the furnaces in England and Wales, twelve were active for more than two hundred years, and forty-six for over one hundred years. Twenty seven Wealdon furnaces stood on sites which were active for more than one hundred years.

Estimates of iron output are difficult to make. Improved handling of the operating furnace, increased output while the furnace was in blast, and improved materials and methods of furnace construction increased the proportion of time that the furnace could be kept in blast, so the annual output of Wealdon furnaces increased from about 100 tons to 200 tons p.a. during the sixteenth century. Elsewhere during the seventeenth century further improvements together with increases in furnace size raised the production from some furnaces to as much as 950 tons p.a. But it seems that peak production in England and Wales was probably below 35,000 tons p.a. of pig iron. Further estimates of the charcoal consumption in the blast furnace and the forge indicate that the maximum consumption of wood was 60 million cubic feet p.a. 22,000 acres of illkempt coppice would have been needed to supply this amount of wood, a small fraction of the total area under woodland during this period. More significantly, taking the rate of growth of wood as about 100 cubic feet per acre per year. 650,000 acres under wood-land – less than 2% of the land surface of England and Wales, could provide fuel indefinitely for the industry working at its maximum output. Or one large furnace would require the annual production of wood from 7,000 acres – a forge converting most of the product to bar iron would need 6,000 acres. A five mile radius covers approximately 50,000 acres, so even if only one third of the area were woodland, charcoal need be carried no further than five miles to supply a large blast furnace and associated forge indefinitely.

Comparable figures for the costs of coke and charcoal are not available, but it is suggested that early work on the use of coal or coke in the blast furnace seems to have been more in the nature of technical experimentation in the hope that the change would eventually lead to a cheaper iron, rather than a search for a way out of a desparate situation arising out of the high cost and increasing scarcity of charcoal in the country as a whole. Only in a very few cases did the charcoal requirements of the industry exceed the production capacity of the country round about, leading to a decline in the iron production from that area.

APG

David Brinn: BSC's Port Talbot Works. *Steel Times, July 1976,* **204**, *(Pt7), 511–552.*

An article of great interest about the iron and steel working of the Magam and Port Talbot works up to the present. Starting briefly with medieval references, there is a continuous account of 19th and early 20th century developments in in the first 6 or 7 pages. The bulk of the article deals with the more recent history, with much detail, usefully gathered in tabular form or as appendices, but with a good narrative content. There is an excellent and extensive bibliography in Appendix 9.

NM

EUROPE

J R Maréchal: The process of iron smelting with semi-sunk furnaces giving slag blocks and its distribution in Europe during the first few centuries AD. *Rev. Mét. 1975,* **72,** *849–855 (In French and English).*

Draws attention to the fact that slag blocks of this type occur in France as well as in other north European countries. They occur in Sarthe near Segre dated to 680 ± 100 AD and weigh 20 kg, and in other sites from the 3rd century AD to Merovingian times. These include Allones near Le Mans, La Ferrière-aux-Étangs, Bellou en Houlme and La Coulon where good ore containing up to 65% Fe can be found. It now appears that this type stretches from N. Germany through Belgium to N. France and from Sweden to East Anglia. This paper also has some observations on spindle-shaped bars, peat charcoal, the nitrogen content of iron, and on pattern welding.

RFT

A Anteins: Black metal of Lithuania (in Lithuanian with Russian summary). *Riga, 1976.*

This is a complete history of iron technology in Lithuania from its beginning up to the 1950's. Chapter 1 deals with early iron-working and smelting. The first iron objects appeared in Lithuania about 500 BC. The process developed quickly and in the 5–10th centuries AD the level of smithing techniques equalled that of ancient Russia. This is based upon metallographic research embracing 600 specimens including many blooms. Describes iron smelting sites with furnaces at Spietyni (500 AD), Asote (10th century AD), and Daumgale etc. The abundant pattern-welded swords and lances are discussed.

R Pleiner.

K Roesch and H H Kuhn: Reconstruction of bloomery iron smelting and working. *(In German). Arch. Eisenhuttenwesen. 1976,* **47** *(1), 5–8.*

German experiments were made in order to verify processes observed in Saharan Africa. Use was made of Indian ores low in P and German ores rich in this element. Carburisation was only possible with the Indian ore which also welded easily. Welding processes were hindered by iron phosphates.

RP

A Lazlo: The beginning of iron metallurgy in Romania *(In Romanian). Studii si cercetari de istorie veche siaarheologie, 1975,* **26** *(1). 17–39.*

A new list of early iron objects found in Romania. Includes bars and slag.

RP

V V Kropotkin and V E Kapetian: A new centre of the iron industry of the 3rd to 4th century AD in the basin of the Middle Bug *(In Russian). Sov. Ark. 1976 (2), 317–324.*

Describes an iron smelting bloomery shaft furnace of the slag-pit type. Finds include tuyeres which are slagged at one end for a distance of 5–10 cm which suggests that they protruded into the furnace.

RFT

D. Colls, C. Domergue, F. Laubenheimer and B. Liou: Tin ingots from the wreck 'Port Vendres II'. *(In French) Gallia. 1975,* **33,** *61–94.*

The finding of these 14 tin ingots was referred to in JHMS, 10 (1). In this paper, photos, drawings and stamped inscriptions are given and discussed together with AAS analyses for Cu and Pb in 10 of them. The Cu content varies from 0 to 276 and the Pb from 0-174 ppm. They date from 20–50 AD and the authors believe that they come from Iberian sources and were on their way to inland France via Narbonne.

RFT

A E Leontiev: The classification of knives from the site of the town of Sarskoy *(In Russian). Sov. Ark. 1976 (2), 33–45.*

The site lies near the town of Rostov-the-Great NE of Moscow and dates to the 8th–11th century AD. The classification is based on the position of the tang relative to the back of the blade. This gives three groups:– 1 consists of blades with the tang in line with the back; 2 has the tang central with the blade joining it either with a notch (a) or a sudden change of section (b); 3 is similar to 2(b) but there is no notch and a very gradual change in section from the blade to the tang. The knives are examined metallographically and we see the usual methods of joining iron and steel, with a sandwich of iron with steel inside, externally carburised iron, and welded-on edges. In the case of type 1, the blades are entirely of iron while types 2 and 3 consist of 3 layers. Type 1 represents the product of the local Finnish tribe of Merias. The others have resulted from contact with other tribes. Type 2(a) belongs to the 8–9th centuries. The rest belong to the 10–11th centuries and are related to the appearance of the Slavs and the eastern Finns.

RFT

V D Gopak: Smithing technique of the Eastern Slavs in the second half of the first millennium AD in the region between the Dniepr and the Dniestr *(In Russian). Sov. Ark. 1976 (2), 46–56.*

This paper gives the results of metallographic work on knives, scissors and other edge tools. The techniques used were of a high order and show evidence of welding and well-carried out heat treatments. They are believed to be Russian in style. The usual blade-making techniques are used as mentioned in the previous abstract. Full details of the structure and hardness are given; the latter reached 946 HV in one case.

RFT

A Kola and G Wilke: The production of cross-bow bolts in the Middle Ages in the light of recent work. *Acta Universitatis Nocolai Copernici–Archaeologia (Torun), 1975, 5, 161–181 (In Polish).*

784 bolts came from a town destroyed in 1414. Production times for hot forging using swages etc was studied. 185 secs were required for a simple tanged type.

RP

R Pleiner: Shaft furnaces in European ferrous metallurgy *(In Czech). Z dejin hutnictvi (Prague), 1975, 2, 77–84.*

Underlines importance of shaft versus bowl hearth and discusses the temperature regime and gas conditions.

RFT

R Pleiner: Iron smithing in the early middle ages in central Europe. *Fruhmittelalterliche Studien (Munster), 1975,* **9,** *79–92. (In German).*

A survey dealing with recent work on European blacksmithing from the fall of the Roman Empire to 8th century AD. Historical and metallographical.

RFT

K Bielenin: Continuation of researches on the sites of early iron furnaces in the region of the Holy Cross Mountains *(In Polish). Materialy Arch. (Krakow), 1976,* **16,** *43–52.*

New excavations of bloomeries, reheating hearths and charcoal burning sites. Charcoal analyses and 14C dating.
RP

Arsrapport 1975. Helgoundersokningen samt Foskningsprojekt. *State Historical Museum, Stockholm.*

This issue contains contributions on the early history of iron relating to the Migration period site at Helgo by J-E Tomtland, M Lagerquist and S Modin, and R Pleiner.

J Emmerling: Metallurgical reseraches on La Tène swords and knives *(In German). Alt–Thuringen, 1975,* **13,** *205–220.*

Includes the metallographic examination of 2 swords and 4 knives originating in Yugoslavia and Hungary. Deals with iron-steel welding and heat treatment.
RP

ASIA

N Barnard: Some remarks upon the origin and the nature of the art of Ch'u. *Proc. 1st N.Z. Int. Conf. on Chinese Studies Part III. Ed. D. Bing, Univ. of Waikato, Hamilton, N.Z., 1974, 47 pp. A4.*

The state of Ch'u belongs to the Warring States period, 575–400 BC. Various artifacts have been considered including bronzes. There is no reliable evidence for the penetration of metallurgy into the Ch'u region from the north in Sung and West Chou times. The independent Ch'u style dates from the E. Chou period and became more common in Chan-kuo times. Three inscribed cast bronze swords with mythical zoomorphic creatures were cast in clay piece moulds. There is evidence of a form of pseudo-granulation in which granulation designs are copied by piece-mould means. This shows the influence of outside (China) where granulation was practiced and gold globules were attached to the ground by colloid copper soldering (the 'gold-glue' process). Gold was rare in China in this period. Apparently gold-plated low-tin bronze was used later in the Chou period. Silver was also introduced in inlay form in this period. New designs in bronze, mirrors, seals, etc. Lost wax techniques were not used. The pattern was etched onto swords blades etc. The cross-bow was invented in this, the Ch'u, period.
RFT

N Barnard: The Che'en Ni Fu-Tray; Problems of identification in the study of forgery. *Mon. Serica. 1972–3,* **30,** *439–497.*

The trays examined were thought to belong to the Chou period (1120–770 BC), X-ray and microscopic evidence on one of them shows that the walls have been made from separate castings rather than from one casting as would be expected from a genuine article. Pb–Sn (± Sb) soft solder has been used to join the parts which in some places cover the inscription. It would seem that the walls have been cast by the lost wax process using a genuine vessel as the pattern. The analyses show the presence of up to 5% Zn and 1% Sb and 1–4% Sn while attested examples show straight leaded tin-bronzes. The patina is also quite different. The attested objects give crystalline malachite and cuprite while the green 'patina' of the others is featureless. This consists of an amorphous clay with a blue-green pigment and fibrous material. Detailed AAS and emission results are given for trace elements. The decoration itself is not typical; the motifs are parodied and the distribution is incorrect while the combination of motifs is anachonistic. Analyses of cores (clay) and metal from comparable and attested artifacts are also given from which we see that Zn is not detected.

J Piaskowski: The production technique of the Malay ***Kris.*** *(In Polish). Kwartalnik historii nauki i techniki, 1975,* **20,** *515–531.*

From the Polish Army Museum in Warsaw. It has been made by welding two piled bars of ordinary bloomery iron to another central one of lower phosphorus iron which had been carburised at the tip. Each bar of metal has been made from several strongly carburised layers of iron which gave dark lines in the surface of the blade. Except for a central layer 0.5 mm thick in the middle of the central bar, the other carburised layers were very thin (0.02–0.05 mm). The Ni content in these carburised layers was as high as 3.9% while in the ferrite and in the slag inclusions there was only a trace. The structure of the steel layers was that of acicular troostite with a micro-hardness in the range 319–408 HV. The mean hardness was 187 HV. It appears that the bars had been carburised with a mixture containing Ni. The three bars had all been made by piling and they had been welded together to give in all about 10 laminations.
RFT

AFRICA

H M Freide and R H Steel: Notes on Iron Age copper smelting technology in the Transvaal. *J. South African Inst. Min. Met. 1975, Nov., 221–231.*

Gives analyses of furnace linings, tuyere ends, and crucible slag from prehistoric sites. Experiments were based on smelting evidence found on S. African sites. The furnaces were smaller versions of the bowl-type iron bloomery furnace. The ore was a dressed malachite from Palabora (17.5% Cu). Reduction smelting without a flux gave a poor yield but the use of sand as a flux increased this to 16.4%. By mixing the malachite with an equal part of azurite (40% Cu) from Nchanga the yield was increased to 24.2%. The blowing rate was 120 1/min and the metal contained 4.4% Fe, 0.02% Ni, 0.008% Zn and less than 0.001% of As, Sn, Pb, Sb and Bi.
RFT

R H Steel: Ingot casting and wire drawing in Iron Age Southern Africa. *J. South African Inst. Min. Met. 1975, Nov., 232–237.*

Results of experiments on reproducing known types of copper ingots and drawing them down to wire. The metal used was that made in the smelting experiments of the last abstract. The copper was heated in a ceramic crucible in a charcoal hearth blown with skin bellows. The Cu was poured into sand moulds made by wood in a bed of moulding sand d. The wire was drawn through a draw-plate with the aid of a primitive vice looking rather like a tuning fork with a ring pushed over it.
RFT

AMERICA

E T Clarke. Radiographing the Liberty Bell. *Foundry Trades Journal 1976.* **141** *(3091) 223–228.*

Gives a brief outline of the history of the Liberty Bell, Philadelphia, USA, and quotes the conclusions of the metallurigcal tests performed in 1962 by Committee for the Preservation of the Liberty Bell. " . . . , the inevitable ageing of the bell may be expected to bring on volume changes with attendant internal localized stresses. These will, in turn, act to produce new cracks or extend those that already exist". In the light of these conclusions, it was decided to radiograph the bell before moving it to a new location. The article tells how this was done and discusses the findings. APG

TECHNIQUES

C J Evans: Recreating an ancient bronze casting method. *Tin and its uses. 1976 (10), 14–15.*

Describes the experiment made by R Savage and his colleagues of the Gloucester College of Art and Design. This was televised by the BBC. Bronze was melted in a hemispherical clay crucible with a pouring hole in the side which was heated at the bottom of a charcoal hearth blown with 4 pot bellows. After 1 hour the contents were poured with the aid of iron tongs into a clay mould immersed in the hot charcoal of the same hearth. About 5 kg of charcoal were needed to melt 0.5 kg of bronze.

W D Kingery: A technological characterisation of two Cypriot ceramics. In *Recent Advances in Sci. and Tech. of materials (Ed. A Bishay). Vol 3, 1975, 169–186.*

A tüyere from Enkomi and a piece of Cypriot pottery have been examined by a number of analytical techniques. The tuyere was found to have been fired at 750–800°C and worked up to 1200°C in a copper furnace. It is quite different from the pottery but very appropriate for its purpose. A very useful example of the application of the standard refractory techniques to archaeological work.

D Ankner: Research on the metals of prehistory *(In German).* **In** *Ausgrabungen in Deutschland. Mainz, 1975, Vol. 3, 145–155.*

This includes a paragraph devoted to iron (pp 154–155) as a part of a general survey devoted to analytical methods. The use of spark-erosion is included.

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