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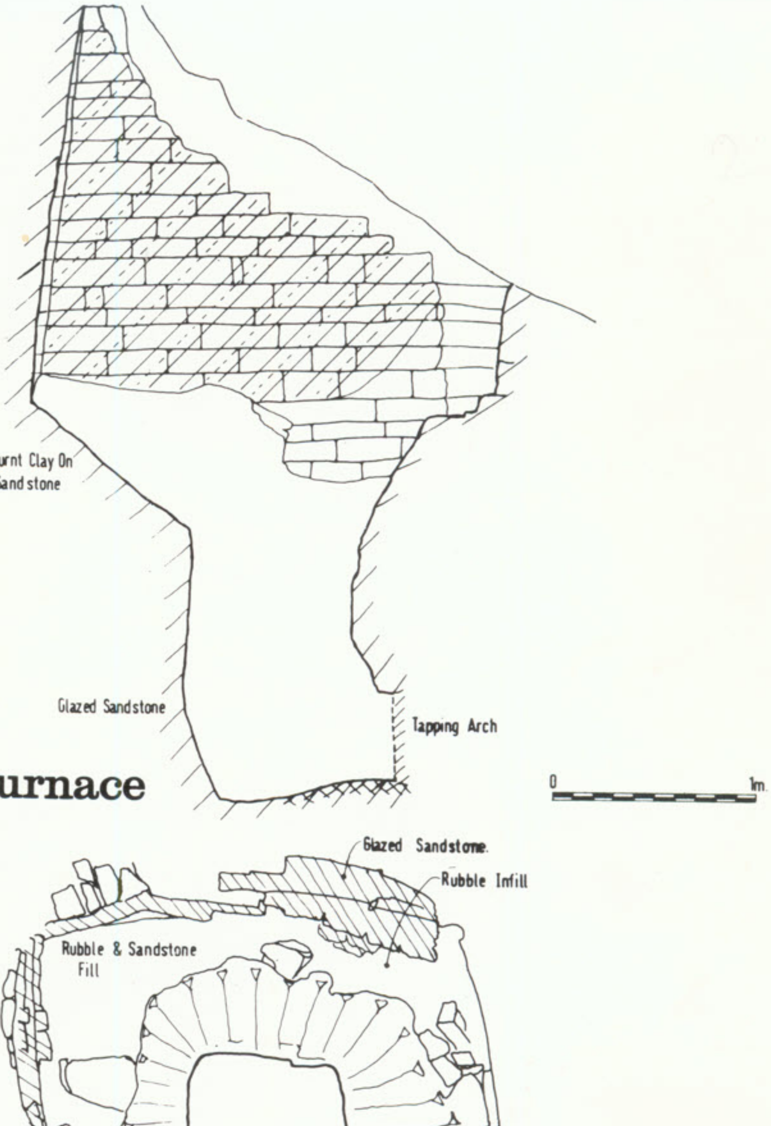

Allensford Furnace

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A Seventeenth Century Blast Furnace at Allensford, Northumberland

Stafford Linsley and Roger Hetherington

Introduction

In a book of poems by Joshua Lax, published in 1884[1], a footnote to a poem about Shotley Bridge in Durham reads as follows . . . .

'. . . near Allensford, are the remains of an old furnace, which[1] probably had been used by the Bertrams. The effect of the extreme heat can yet be traced on the glazed stones. A few yards from this pile, up a steep acclivity to the west, are three ruinous kilns, where the ironstone appears to have been put through its first process – roasting. The shape of the furnace had been hexagonal, narrowing towards the top; that of the kiln round, narrowing towards the bottom.'

The Bertrams were one of a group of German families who settled in the Derwent Valley around Shotley Bridge in 1688 or 1689, having been induced to establish sword making by 'The Hollow Sword Blade Company'. In 1863 Isaac Lothian Bell referred to the remains of a small high-blast furnace '. . . five or six feet in the boshes . . .' erected at Shotley Bridge sometime after the arrival of the sword makers.[2]. The Victoria County History for Durham repeats the above information[3] and in an article concerning the sword makers written in the 1930's[4] Rhys Jenkins tentatively suggested that the German Swordmakers may have erected the furnace at Allensford and obtained their steel from the cast iron which it produced. In the discussion to Jenkins' paper, Dr J A Smythe reported that the analysis of slag picked up near the furnace site suggested a furnace working at low temperature with a charge of fuel, clayband ironstone and a relatively small amount of dolomitic flux, although the nature of the fluxing agent was questioned by another commentator.[4] The questions concerning the furnace were such that it is surprising that it received no further detailed investigation until the present excavation commenced. Indeed the furnace was not included in the lists of 17th and 18th century blast furnaces published by the Historical Metallurgy Society. However, the recent interest in industrial archaeology in the North East of England led to a greater interest in what was thought to be the remains of the region's only charcoal fired blast furnace.

Iron and Steel Working in the Derwent Valley

Ironworking has been practised in the North East since the 13th century; the ready availability of local raw materials and markets encouraged such developments. Nevertheless, only two or three blast furnaces are believed to have operated before 1750, although the Derwent Valley had emerged as the country's major centre of cementation steel making. This activity was, however, based on imported bar iron, the Derwent Valley being convenient for access to continental supplies of iron via the navigable Tyne. Additional attractions were the local supplies of charcoal and coal and of course the river itself, a reliable source of water power. At Allensford, an '. . . Iron-forge for the making and working of iron. . . ' was the subject of a conveyance dated 1670 and by 1692 Dennis Hayford and Partners had taken a lease on Allensford blast furnace and forge, the lease previously being held by someone named Davison[5]. In 1713 '. . . the Allensford Forge with all utensils, Iron, Ironplates, Bellis and other materials and things whatsoever to this said forge usefull and belonging and now there being . . .' were conveyed to Nicholas Fenwick of Newcastle[6]. He was also given liberty to win and use freestone, quarried at Allensford, for repairing the forge and its dam, as well as stone, clay and sand whenever it was needed at the forge[6]. Allensford does not appear in a list of forges dated 1717[7] but by 1728 it was being leased by the Crowleys who had massive iron and steel interests further down the Derwent[8]. In a list of forges dated 1736, Allensford was said to be out of production but to have a capacity of 130 tons per annum.[7]

The Crowley firm was first established near the junction of the Rivers Derwent and Tyne in 1691 at the village of Winlaton; the enterprise then developed works at Winlaton Mill 1699, Swalwell 1707, and Teams 1735 all of which activities have been well documented[9]. Developments further upriver saw the establishment of Derwentcote Forge c 1719 by Alderman Reed[10] and Blackhall Mill c 1719 by William Bertram for Dan Hayford[8]. All of these sites except Winlaton had cementation furnaces from soon after their founding and there is clear evidence that by 1719 Blackhall Mill was supplying cementation steel to the Swordmakers of Shotley Bridge[8] although previously, Dan Heyford had apparently supplied it from Roamley Forge near Pontefract[11].

Whilst these 18th century developments gave the Derwent Valley an international reputation for iron and steel working, only at Allensford (and at the Consett Iron Company in the 19th Century) was Pig Iron manufactured. It is clear that Allensford predates all of the above developments including sword making at Shotley Bridge and it is tempting to see it as an isolated development. However earlier sites are known for Weardale a mere 10 miles away, and there is a tentatively identified bloomery site on the Hisehope Burn less than two miles from Allensford. As Raistrick pointed out[4] clayband ironstones outcrop on the banks of the Derwent and a mine adit still remains only about 100 metres from the Allensford furnace site, being driven in shale under a sandstone outcrop. The adit may lead to the series known as the German Bands Coal but it has not yet been de-watered sufficiently to allow exploration. It was the availability of these coalmeasure iron stones that later led to the establishment of the iron works at Consett in 1842, at which time about 0.4 m of ironstone were worked from a section about 2.1 m in height. At a depth of about 8 m below this and lying above 0.5 m of coal, a 1m bed of shale contained a further 0.15 m of ironstone[2]. This latter ironstone band may well be that displayed in 1971 by opencast coal workings at Whittonstall which revealed an area of ironstone bell pits. They were about 5 m deep and 4 m across at the base with up to three ironstone nodule bands in the shale at the base of each pit. Near the surface and below the base were narrow seams of excellent coking coal which, however, was clearly not worked by the bell pit miners. The ironstone had therefore been intended for charcoal smelting and although Whittonstall is nearly four miles north of Allensford, it is possible that Whittonstall ironstone was packhorsed there.

The Evidence for Allensford

That a forge existed at Allensford in 1670 for the making and working of iron is clear from documentary evidence. That it existed until c 1730 seems equally clear although its furnace may not have been in blast beyond c 1715. It was undoubtedly using local ironstone, possibly from outcrops along the banks

of the Derwent, or from shallow mines at sites like Whittonstall. Although there is a tradition that the forge may have supplied steel to the Swordmakers at Shotley Bridge, the immediately local coalmeasure ironstone would not appear to be suitable for this purpose. Weardale ores associated with the metalliferous veins of the limestone strata may have been more suited to cementation steel-making in that they reputedly gave good bar iron in the 19th century[2]. However, since none of the 18th century Swedish and other Continental visitors to the Derwent Valley even mention Allensford, it seems unlikely that steel was manufactured at the forge. Immediately prior to excavation the presumed furnace site showed two short, slightly curving walls meeting at right angles and projecting out of a mound of presumed debris. The masonry of the walls was glazed and well burnt. The mound with slag heaps nearby was adjacent to a steep bank, at the head of which was a debris-filled masonry-lined bowl, thought to be an ore-roasting kiln. There was no obvious bridge between this kiln and the presumed furnace top. About 10 metres upriver of the furnace as a visible wall and beyond this, non-continuous linear depressions running alongside the river seemed to indicate a water race. This led back in the direction of the nearby Allensford corn mill whose head-race can be traced back to a substantial dam across the Derwent. The Middleton family owned a corn mill at Allensford in the 16th Century although the present building seems to date from the 18th or 19th Centuries during which time it remained active as a corn mill. It remains possible that the mill and the forge used the same dam and race.

Thus the documentary and field evidence pointed clearly to an iron making site at the location of the excavation. The field evidence for a water powered charcoal fired blast furnace was fairly clear but there was no obvious evidence for a forge; it seems possible that the forge may have been located nearer Shotley Bridge rather than immediately adjacent to the furnace. It was hoped that an excavation would clarify some of these possibilities.

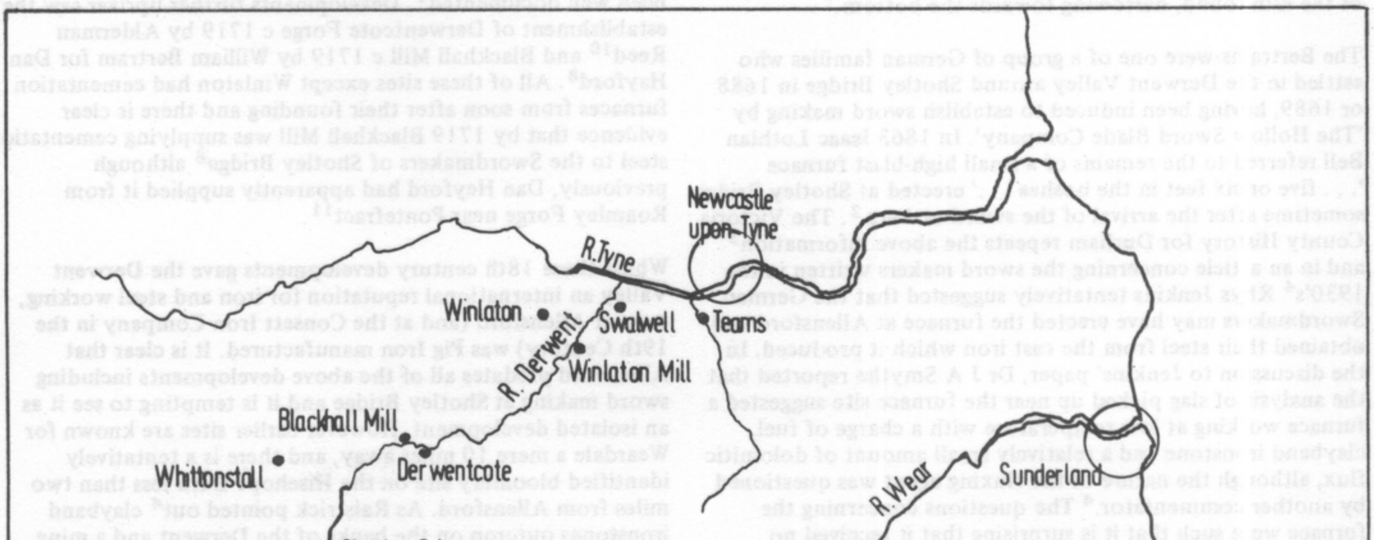

Fig. 1 Early iron and steel making sites associated with the Derwent Valley

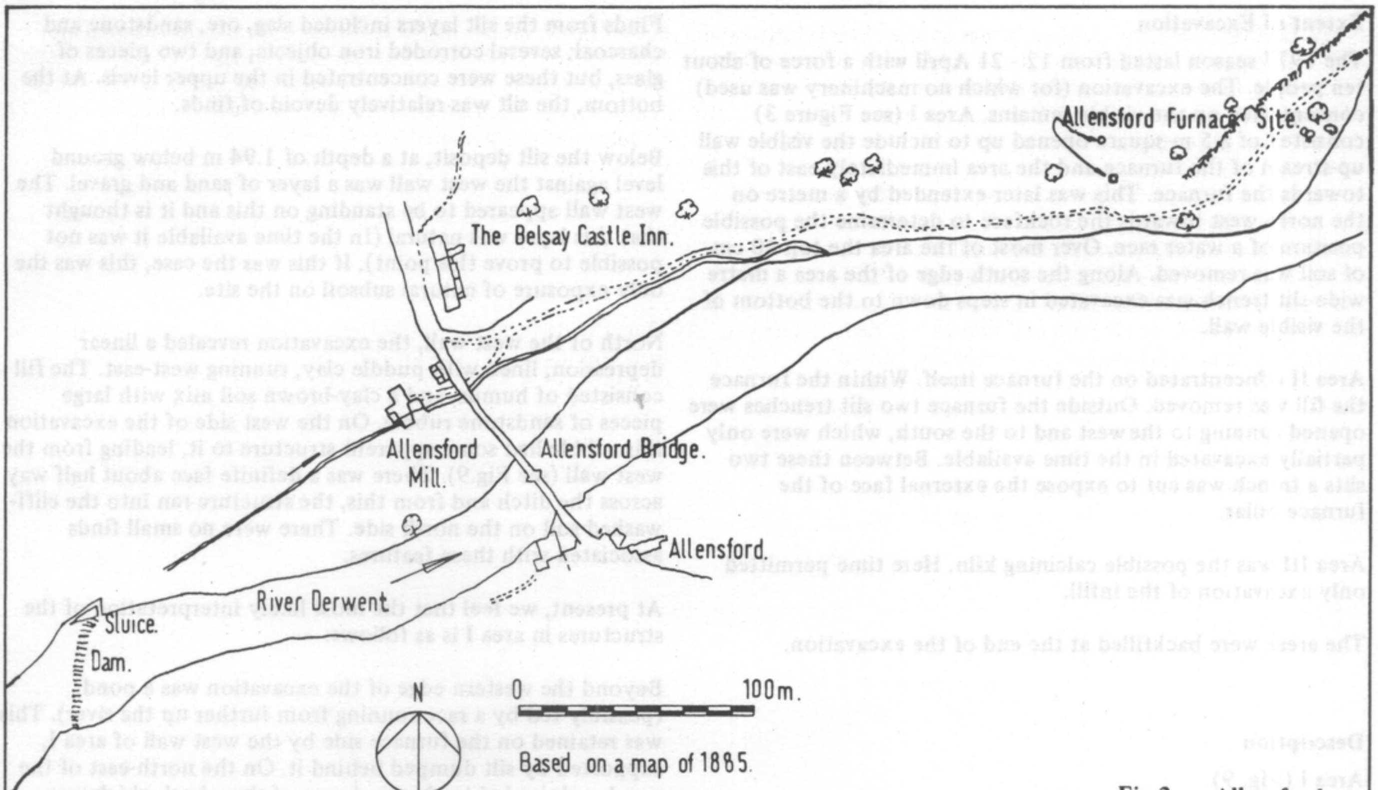

Fig 2 Allensford

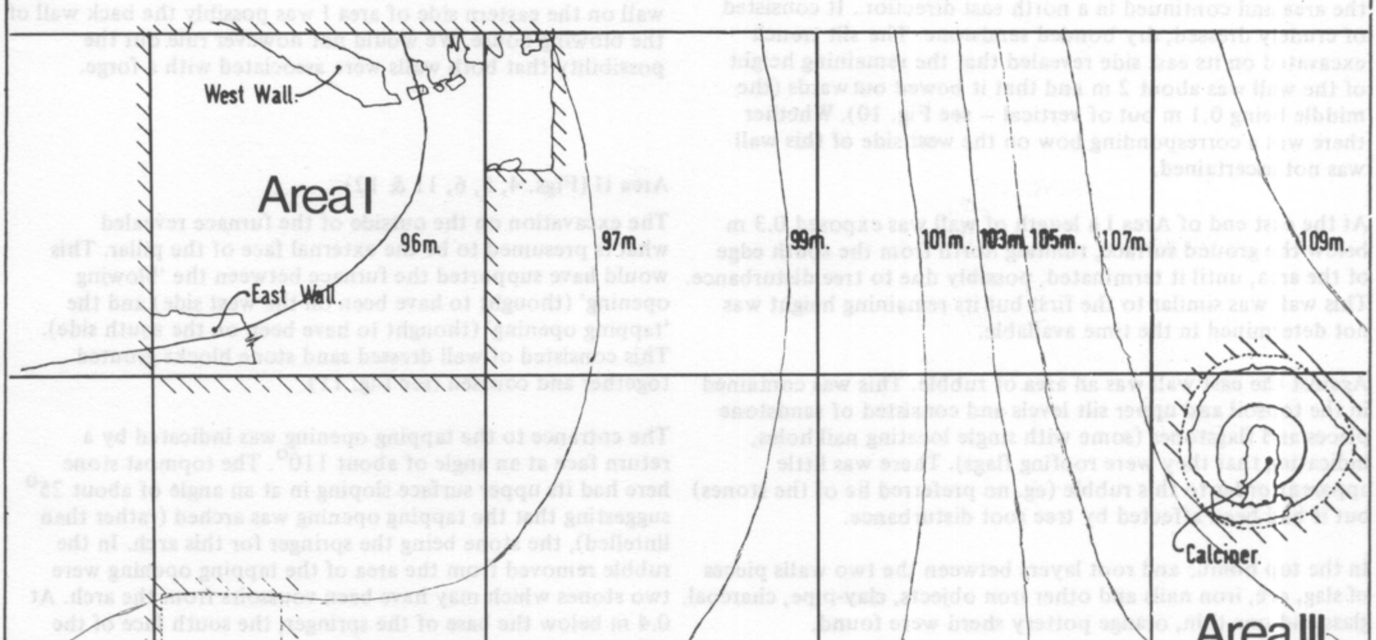

Fig 3 Plan of excavated areas

Extent of Excavation

The 1977 season lasted from 12 - 21 April with a force of about ten people. The excavation (for which no machinery was used) concentrated on the visible remains. Area I (see Figure 3) consisted of a 5 m square opened up to include the visible wall up-stream of the furnace and the area immediately east of this towards the furnace. This was later extended by a metre on the north west towards the rockface to determine the possible position of a water race. Over most of the area the top 10 cm of soil was removed. Along the south edge of the area a metre wide slit trench was excavated in steps down to the bottom of the visible wall.

Area II concentrated on the furnace itself. Within the furnace the fill was removed. Outside the furnace two slit trenches were opened running to the west and to the south, which were only partially excavated in the time available. Between these two slits a trench was cut to expose the external face of the furnace pillar.

Area III was the possible calcining kiln. Here time permitted only excavation of the infill.

The areas were backfilled at the end of the excavation.

Description

Area I (Fig. 9)

The wall seen on the surface intersected the western edge of the area and continued in a north east direction. It consisted of crudely dressed, dry bonded sandstone. The slit trench excavated on its east side revealed that the remaining height of the wall was about 2 m and that it bowed outwards (the middle being 0.1 m out of vertical – see Fig. 10). Whether there was a corresponding bow on the west side of this wall was not ascertained.

At the east end of Area I a length of wall was exposed 0.3 m below the ground surface, running north from the south edge of the area, until it terminated, possibly due to tree disturbance. This wall was similar to the first but its remaining height was not determined in the time available.

Against the east wall was an area of rubble. This was contained in the topsoil and upper silt levels and consisted of sandstone pieces and flagstones (some with single locating nail holes, indicating that they were roofing flags). There was little apparent order to this rubble (eg. no preferred lie of the stones) but it had been affected by tree root disturbance.

In the top humus and root layers between the two walls pieces of slag, ore, iron nails and other iron objects, clay-pipe, charcoal, glass and one thin, orange pottery sherd were found.

Below the top humus and root layers was a large deposit of silt. This was mainly grey in colour but the section along the south edge of area I revealed several deposit levels. Against the west wall this silt deposit had a thickness of 1.55 m below the top soil, but it was not possible to determine its thickness against the east wall. There was no trace of any construction trench cut into this silt for the west wall (and neither for the east wall, though this needs further investigation), and thus it would appear that the silt was deposited after the west wall was built. The section along the south edge of the area was rather difficult to interpret. There were no signs of current bedding in the silt (which would have indicated natural deposition), but there were possible tip lines sloping towards the east. This would suggest that the silt was artificially built up against the west wall.

Finds from the silt layers included slag, ore, sandstone and charcoal; several corroded iron objects; and two pieces of glass, but these were concentrated in the upper levels. At the bottom, the silt was relatively devoid of finds.

Below the silt deposit, at a depth of 1.94 m below ground level against the west wall was a layer of sand and gravel. The west wall appeared to be standing on this and it is thought that this layer was natural (in the time available it was not possible to prove this point). If this was the case, this was the only exposure of natural subsoil on the site.

North of the west wall, the excavation revealed a linear depression, lined with puddle clay, running west-east. The fill consisted of humus, and a clay-brown soil mix with large pieces of sandstone rubble. On the west side of the excavation this rubble had some apparent structure to it, leading from the west wall (see Fig.9). There was a definite face about half way across the ditch and from this, the structure ran into the cliff-washed soil on the north side. There were no small finds associated with these features.

At present, we feel that the most likely interpretation of the structures in area I is as follows: –

Beyond the western edge of the excavation was a pond, (possibly fed by a race running from further up the river). This was retained on the furnace side by the west wall of area I, supported by silt dumped behind it. On the north-east of the pond, a sluice led to the head race of the wheel which was possibly just beyond the 1977 north-east limit of area I. The wall on the eastern side of area I was possibly the back wall of the blowing house. We would not however rule out the possibility that both walls were associated with a forge.

Area II (Figs. 4, 5, 6, 11 & 12)

The excavation on the outside of the furnace revealed what is presumed to be the external face of the pillar. This would have supported the furnace between the 'blowing opening' (thought to have been on the west side) and the 'tapping opening' (thought to have been on the south side). This consisted of well dressed sand stone blocks grouted together and coursed (see Fig. 11).

The entrance to the tapping opening was indicated by a return face at an angle of about 110°. The topmost stone here had its upper surface sloping in at an angle of about 25° suggesting that the tapping opening was arched (rather than lintelled), the stone being the springer for this arch. In the rubble removed from the area of the tapping opening were two stones which may have been voussoirs from the arch. At 0.4 m below the base of the springer, the south face of the pillar was stepped out about 0.1 m.

The entrance to the 'blowing arch' was indicated by a return face at about 100°. Here the masonry did not remain as high as on the south side and there was no apparent springer in-situ. However, in the rubble infill of the blowing opening there were more possible voussoirs and so it is probable that this also was arched over. There was no step in the west face of the pillar corresponding to that on the south face.

Towards the south-west corner of the pillar the facing stones had disappeared (possibly robbed for building stone) and behind the facing stones the pillar appeared to consist of a loose rubble infill. Outside the face and in the blowing and tapping openings the material removed consisted of tumbled masonry in a red, sandy soil which was possibly either

decayed sandstone, mortar, or furnace lining. In this were occasional horizontal charcoal spreads, suggesting several periods of collapse. Also, there were occasional yellow patches (mortar from the masonry?) and blue clay. Finds from these destruction layers included slag, ore, charcoal, clay pipe fragments, small iron objects and nails, and material from the interior of the furnace.

Altogether, the appearance of the faces of the pillar indicated a considerable degree of competence in stone dressing and laying by the builders.

On the inside of the furnace the structure could be considered as two parts; the superstructure or stack, and the hearth. The stack consisted of well coursed and dressed sandstone blocks with a green glaze on their internal face (caused no doubt by the smelting operations). The north and east faces still stood and they narrowed towards the top at an angle of about 10^{o} to the vertical, their faces being slightly curved (Figs. 4,5 & 6). The south and west faces of the stack were discovered lying at a reversed angle below from where they had fallen, and were in a damaged state. By matching up the coursing of the stones, it was estimated that these two faces had fallen about 1.5 m. (The cause of collapse was probably failure of the supporting pillar as external facing stones were robbed). The positions where the south and west faces had met the standing north and east faces were clearly marked by the glaze on the north and east faces stopping at the north-west and south-east corners. Also, at the north-west corner, the return of the west face was indicated by two stones keyed into the north face.

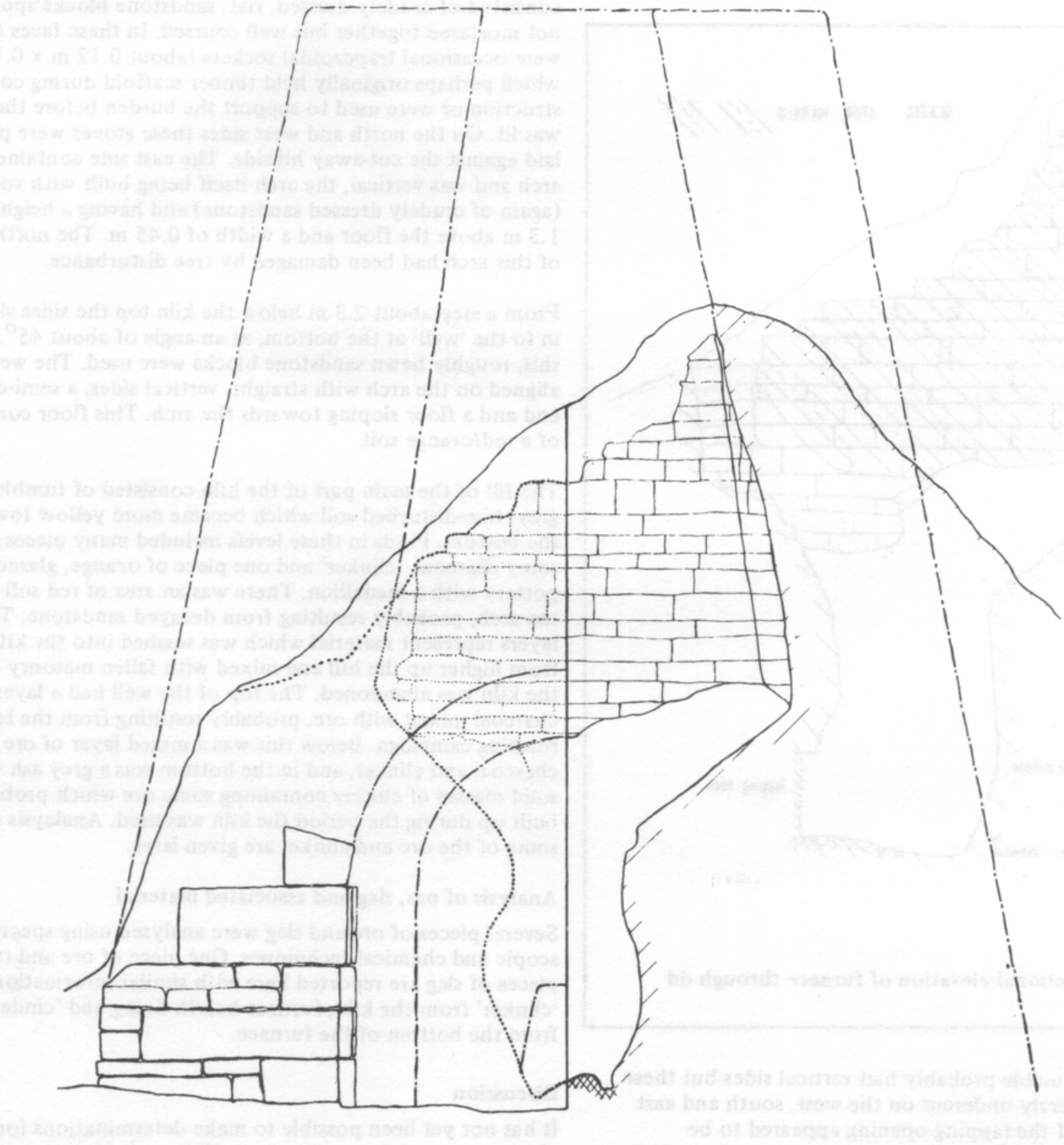

Fig 4 Half sectional elevation of furnace on jj with conjectural outline of tap arch and stack

From the stack the bosh sloped into a rectangular crucible at an angle of about 40° to the horizontal on the west, north and east faces, and 60° on the south face (see Figs. 4 & 5). It consisted of sandstone blocks, lined on the west, north and east faces with refractory clay which had a burnt surface (see analysis). There was apparently little such lining on the south face of the bosh. The north-east corner of the bosh was intact right to where it met the stack. However, the collapse of the west and south faces of the stack had destroyed the top of the bosh on these sides and dragged some of it away. This revealed that the glazing on the stack face stopped where the bosh met it, yet the stack continued down below the bosh at a similar angle as before (possibly to the bottom of the furnace) and between the stack and the bosh, there was apparently a rubble infill. At the junction of the bosh and stack a ledge approximatley 0.03 m wide was built into the out-curving faces to support the bosh. The bosh had been brought up higher in the corners of the furnace.

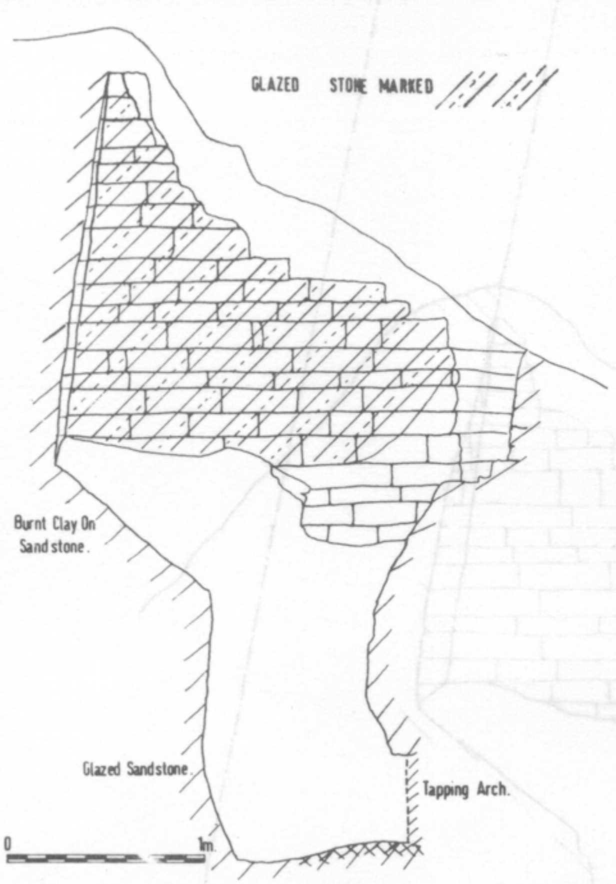

Fig 5 **Sectional elevation of furnace through dd**

Originally the crucible probably had vertical sides but these had become severely undercut on the west, south and east faces. The top of the tapping opening appeared to be lintelled over on the inside. Its sloping sides gave it a width of about 0.5 m at the bottom of the crucible. Apart from the severe undercutting of the west wide of the crucible, there was no indication of the position of a tuyere. This however had probably been slagged over, for the sides of the crucible consisted of sandstone blocks with heavy slagging on their faces.

The fill of the furnace appeared to consist mainly of rubble in an orange/red, gritty soil which was probably decomposed hearth lining. Finds in this rubble included many pieces of slag (some of which appeared to have been only partially smelted) and some ore. Towards the bottom several bent, iron nails were recovered, possibly originating from a timber superstructure to the furnace. At the bottom of the crucible was a layer of cinder some of which had fused into a solid mass. Similar material was recovered from the corners of the bosh and an analysis of this is given later. Below the cinder was a layer of charcoal with cinder.

Area III (Figs. 7, 8 & 13)

The presumed calcining kiln had an inverted conical profile with a sunken 'well' and a 'draw arch'. The internal faces consisted of crudely dressed, flat, sandstone blocks apparently not mortared together but well coursed. In these faces there were occasional trapezoidal sockets (about 0.12 m x 0.1 m) which perhaps originally held timber scaffold during construction or were used to support the burden before the fire was lit. On the north and west sides these stones were probably laid against the cut-away hillside. The east side contained the arch and was vertical, the arch itself being built with voussoirs (again of crudely dressed sandstone) and having a height of 1.3 m above the floor and a width of 0.45 m. The north side of this arch had been damaged by tree disturbance.

From a step about 2.3 m below the kiln top the sides sloped in to the 'well' at the bottom, at an angle of about 45°. For this, roughly hewn sandstone blocks were used. The well was aligned on the arch with straight, vertical sides, a semi-circular end and a floor sloping towards the arch. This floor consisted of a red/orange soil.

The fill of the main part of the kiln consisted of tumble in grey, tree-disturbed soil which became more yellow towards the bottom. Finds in these levels included many pieces of ore, some charcoal, 'clinker' and one piece of orange, glazed pottery with a medallion. There was an area of red soil near the arch, probably resulting from decayed sandstone. These layers represent material which was washed into the kiln from higher up the hill and mixed with fallen masonry after the kiln was abandoned. The top of the well had a layer of charcoal mixed with ore, probably resulting from the last roasting campaign. Below this was a mixed layer of ore, charcoal and clinker, and in the bottom was a grey ash with solid masses of clinker containing some ore which probably built up during the period the kiln was used. Analysis of some of the ore and clinker are given later.

Analysis of ore, slag and associated material

Several pieces of ore and slag were analysed using spectroscopic and chemical techniques. One piece of ore and two pieces of slag are reported here with similar information on 'clinker' from the kiln, furnace hearth lining and 'cinder' from the bottom of the furnace.

Discussion

It has not yet been possible to make determinations for phosphorus, sulphur and carbon. This probably accounts for the low total for the ore (specimen 1). because the iron recorded as 'Fe0' was probably present as $FeCO_3$. In roasting this would be coverted to Fe_20_3 and specimen 2 would represent an intermediate stage in smelting where Fe_20_3 was being reduced to Fe0 and thence to iron metal. Specimen 3 is very similar in composition to the slag that Smythe analysed[4].

TABLE I – The Specimens

Specimen	Type	Provenance	Description
1	Ore	Calciner – 'well'	Red with quartz veins
2	Slag	Furnace fill	Dark with some rust colour, magnetic
3	Slag	Furnace fill	Dark green, glassy
4	'Clinker'	Calciner – 'well'	Dark, semi-fused, with charcoal
5	Hearth lining	Furnace bosh	Orange red, friable with burnt surface
6	'Cinder'	Furnace bottom	Dark, semi-fused but dense, some rust colour, magnetic

Assuming that specimen 1 is typical of the ore used, the figures give no evidence to support Smythe's suggestion that fluxing with dolomitised limestone was carried out. However, there does appear to have been a significant addition of silica (about one part to ten parts of ore). The $FeO - Al_2O_3 - SiO_2$ and $CaO - Al_2O_3 - SiO_2$ phase diagrams[12] show that such an addition would lower the melting point of the slag and so it may well be that this addition was intentional. This information, and taking into account the effect of the alkali oxides, suggests that the running temperature of the furnace was very roughly in the region of 1300°C.

The analysis of the 'clinker' from the calciner (specimen 4) indicates that it was a semi-vitrified fuel ash. The remaining 52.4% unaccounted for was probably made up of residual carbon, present as charcoal.

The hearth lining (specimen 5) was probably applied as a clay, heavily grogged with sand to give it refractory properties. Its appearance suggests that it had not endured much smelting and thus, it would seem likely that the bosh was re-lined frequently, possibly prior to each campaign.

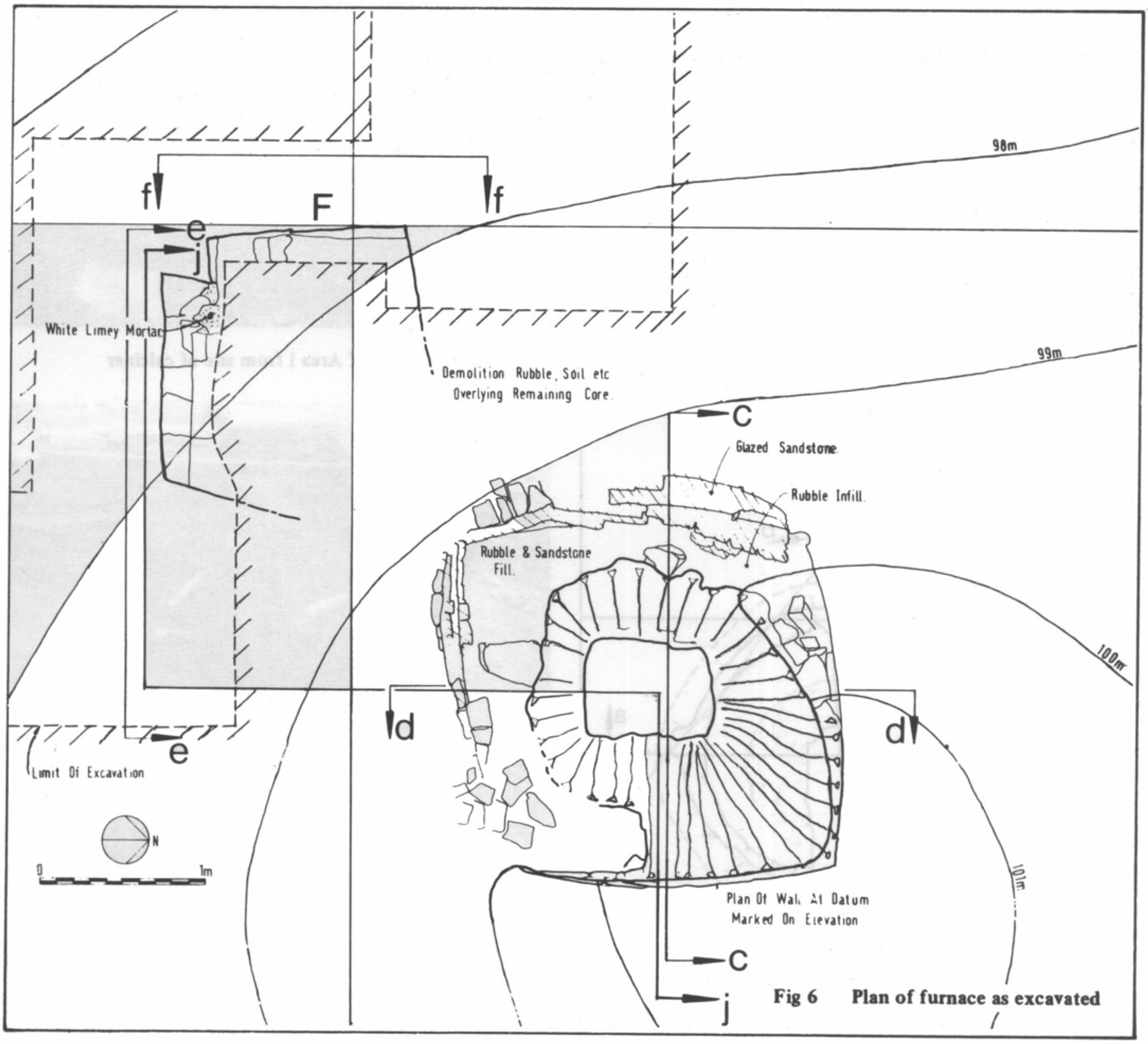

Fig 6 Plan of furnace as excavated

TABLE II – Analysis (wt %)

Specimen	$Si0_2$	$A1_20_3$	$Ti0_2$	Fe	Fe0	Fe_20_3	Mn0	Mg0	Ca0	Na_20	K_20	Total
1	8.51	8.73	–	n.d	35.74	14.44	0.85	0.99	4.74	2.29	1.00	77.29
2	19.47	9.81	–	1.80	25.07	36.52	1.54	1.64	4.51	2.94	1.23	104.53
3	48.25	20.33	0.77	0.62	9.71	0.71	1.38	2.65	6.81	1.79	3.09	96.11
4	35.00	6.16	0.15	n.d	1.27	2.19	0.08	0.03	1.37	1.08	0.27	47.6
5	82.13	7.99	0.16	n.d	0.10	4.16	0.13	0.33	0.08	1.10	1.16	97.34
6	11.11	7.26	0.38	3.39	12.58	43.68	1.41	2.75	4.98	1.52	2.16	91.22

The 'cinder' from the furnace bottom (specimen 6) would appear to have been charge which had fallen through the furnace prior to addition of silica flux and remained in the bottom in a semi-fused state.

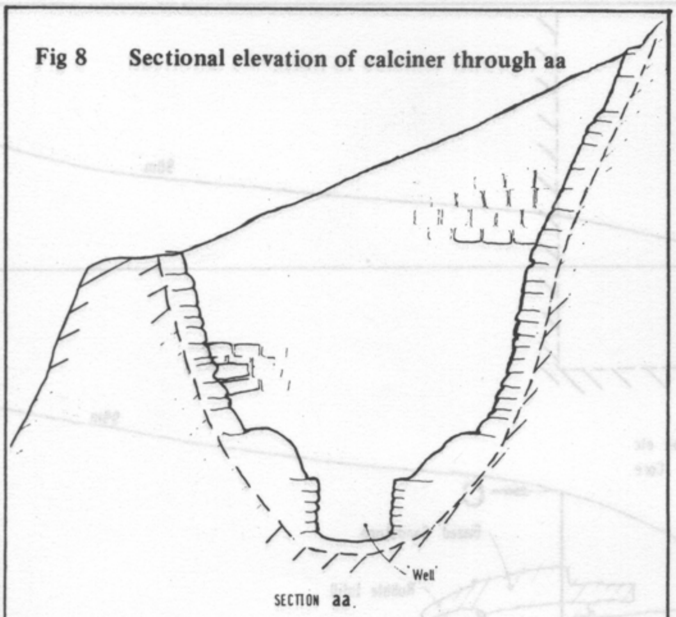
Fig 8 Sectional elevation of calciner through aa

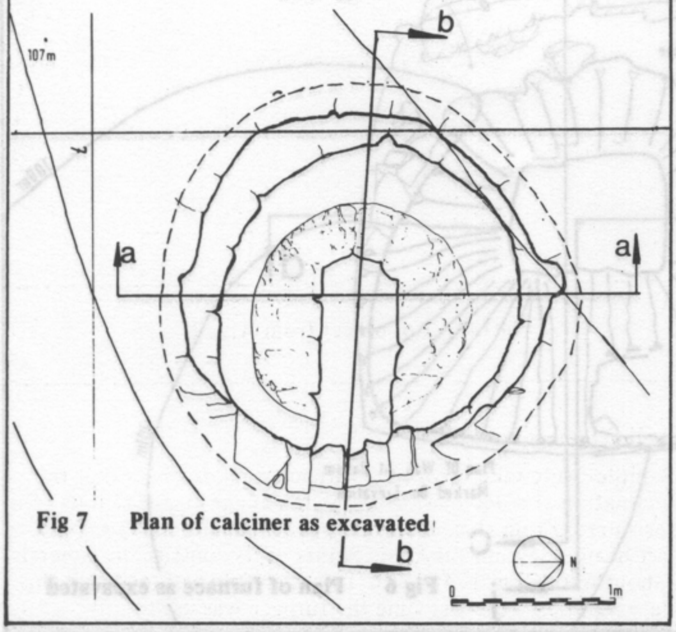
Fig 7 Plan of calciner as excavated


Fig 9 View of Area I from site of calciner


Fig 10 Area I, east side of west wall

Finds

Clay Pipe

Two parts of decorated bowl were recovered and several stem fragments. The bowl decoration was a floral design and from the work of Parsons[13] it would appear that this type is rather later than the period in which the furnace is thought to have been in use. All the pipe fragments were found in unstratified or destruction levels and so it is reasonable to presume that they were left by visitors to the site subsequent to its abandonment.

Pottery

Only two sherds of pottery were found on the entire site. A fragment of a thin, unglazed, orange ware came from a root disturbed level in Area I, and a piece of thicker, orange glazed ware with a medallion came from the upper levels of the calciner fill. As both of these sherds were in essentially unstratified contexts there is little point in discussing them further at this stage.

Fig 11 Furnace pillar and springer of tapping arch viewed from south west

Iron

In the furnace rubble, several nails were recovered; all were square in section and most had been bent. Their original length would have been about 40 mm. Their context would suggest that they fell into the furnace as a timber structure above it rotted and collapsed. This may well be evidence for a charging platform at the top of the furnace.

In area I more iron nails were located in the silt levels along with various, badly corroded pieces, of apparently irregular shape. More work remains to be done on these pieces but perhaps they were stray lumps of pig iron from the tapping floor in front of the furnace. There was one piece, from the rubble at the east end of area I, which had a more definite shape (Fig.14). It was a bent bar, with a fixed pin at one end. On the opposite side to the pin were fragments of wood replaced by corrosion product. It would certainly seem possible that this piece was associated with blowing machinery.

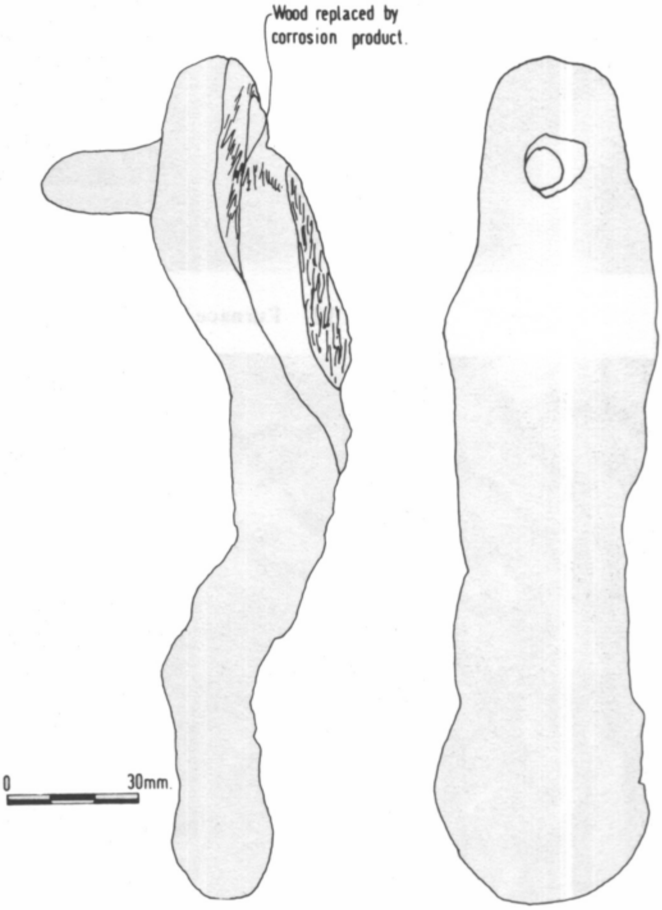

Fig 14 Iron object from Area I

Archaeo-magnetic dating

Samples were taken from the furnace stack in order that the inclination and declination of the remanent magnetism be measured. From this, it would appear that the structure was last heated beyond the Curie Points of its constituent minerals (about $670^{\circ}C$) in 1740 ± 10. It is therefore assumed that this date represents the last time the furnace was used.

Fig 12 Furnace hearth viewed from standing north face of stack

Fig 13 Calciner, looking into well and inner face of draw arch

General discussion and conclusion

The excavation proved the site and remains of a blast furnace at Allensford, which was almost certainly charcoal fired and with water powered blowing. Whilst there is literary evidence for a bank of calciners, only one survived, its internal form being similar to lime kilns of the late 17th/early 18th centuries. As this is the only iron ore calciner known to survive from that period, it has not been possible to compare it with its contemporaries. The presence of the calciner on the site suggests that locally extracted ores were smelted Whilst there was evidence for a water race and collecting pond wall on the excavated site, it was not possible in the time available, to trace the watercourse back to the River Derwent, nor was it possible to determine a wheelpit or tail race. Nevertheless it would appear appear that water powered blowing was employed and that the surviving dam on the river above the cornmill site may be the original water take off point. Likewise although there was strong evidence for the blowing and tapping arches, the blowing house and tapping floor were not proven. Although manuscript sources indicate the presence of a forge in connection with the furnace, no direct field evidence was detected; neither was there any evidence to substantiate the idea that the Allensford works were involved with steelmaking or the activities of the Shotley Bridge Swordmakers. Whilst manuscript sources indicate the presence of an 'Iron forge for the working and making of iron' by at least 1683, the only dating evidence obtained was the archaeo-magnetic date of 1740 ± 10 for the final campaign. However it seems most unlikely that the furnace had been in regular use until then.

The furnace remains were sufficient to clearly indicate that it is of the shallow bosh, narrow crucible type but the survival of its bosh and hearth make the site of particular importance in that nothing comparable is known to survive at other sites in Great Britain. The furnace is contemporary with and similar in style to that inferred for Gunns Mill, comparison with which suggests a total height of about 6.0 m for the height of the Allensford furnace[14]. This would bring the top of the furnace within one or two metres of the base of the calciner. The furnace is also contemporary with others of a more advanced design (eg. Coed Ithel[15]) and seems therefore to represent a primitive form constructed during a period of considerable experimentation in furnace design. This may reflect the fact that North East England was not at that time, one of the important iron smelting areas. Nevertheless the curved faces of the freestanding stack do suggest a response to the trend towards circularisation of the internal designs of blast furnaces.

The findings of this exploratory excavation are of sufficient importance to warrant further excavaton particularly in the areas of the presumed blowing house, tapping floor, wheelpit, tailrace, and calciner draw arch. Further consideration also needs to be given to the whereabouts of the forge.

Acknowledgements

We are particularly grateful to our excavation, survey and drawing team which comprised R de Quidt, G Douglas, H Fleming, K Leahy, J Field, T Purdie and R Lea, assisted from time to time by several others. Mr E Atkinson, the site owner, and Major Husband who allowed us access and kindly provided a storage hut, are also deserving of special thanks.

We are grateful to the Excavation Committee of the University of Newcastle upon Tyne, to the Historical Metallurgy Society and to the Department of the Environment for funding the excavation and to the Department of Adult Education at the University of Newcastle upon Tyne for the provision of equipment. Mr J Gall drew our attention to the poetry of Joshua Lax and we are grateful to Dr M Noel for the magnetic dating and to Mr G Douglas who prepared the drawings for publication.

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Medieval Iron Artefacts from the Newbury area of Berkshire: Metallurgical examinations

H H Coghlan and R F Tylecote

Considering the large amount of medieval ironwork now available to the archaeologist it is surprising that so little has been examined by the metallurgist. It is normal to have a typological examination in most reports covering medieval ironwork but up to the present it has not been the general practice to include a complete metallurgical examination. However, this matter is being rectified in the case of the Winchester Excavations where a full report on the metallurgical aspects will be forthcoming. Meanwhile we have a number of special reports on groups of artefacts from narrow areas such as the present paper or special groups such as weapons[1], or armour[2].

The present examination covers ten iron artefacts from Berkshire, now in the Newbury Museum. Their dates range from the 11th century (Viking) to Late Medieval. Five are arrowheads, a rather neglected artefact judging from the record, two are spearheads and two appear to be knives. The last is a stake-like implement.

A Arrowheads

S.466(1) A barbed and socketed arrowhead in which the socket is continuous with the blade (Fig 1). The blade has a midrib although this feature is not very pronounced. The arrow is in poor condition and the socket has broken off just below the barbs. At least in the remaining portion, the socket tube is thin, not exceeding 1 or 2 mm in thickness. The carburized hardened barbs broke off during sectioning, they had apparently been welded on, but the weld was poor and therefore severely attacked by corrosion. The socket will have been formed by building up a tapered tubular shape by forging round a mandrel. As a whole, skilled forging would have been required. As received, the total remaining length is 54 mm; maximum width of the blade is 17 mm, and maximum thickness of the solid part of the blade is about 5 mm.

Three sections were taken from metallographic examination:

Section A	A longitudinal section extending back from the point of the arrow.
Section B	A transverse section through the blade remote from the point (Fig 2).
Section C	A transverse section through the hollow socket tube.

Examination of the material in the unetched state showed considerable corrosion attack, particularly in sections B and C. Slag inclusions typical of a wrought iron, and elongated in the direction of forging, are seen. In section B, the corrosion products suggest the use of piled material, while in section C, in places, the corrosion products show contorted layering again suggesting a piled structure in the original metal.

Upon etching with 2% nital, in section A, a martensitic structure showed that the point of the arrow had been carburized, but the centre of the section remains ferritic with variable grain size (Fig 2). In section C, taken through the socket tube, is a ferritic structure again of variable grain size. This arrow has been made from a low carbon piled wrought iron, the point being carburized and quenched, while the cutting edges of the blade have been carburized.

The hardness of the ferritic core is 123 HV but the hardness of the martensitic barbs is only 240 HV which suggests a rather low carbon content for such a well-developed martensitic structure. Clearly the carburized material was folded around the ferrite core and badly welded to it. The whole was quenched from about 1000°C and tempered.

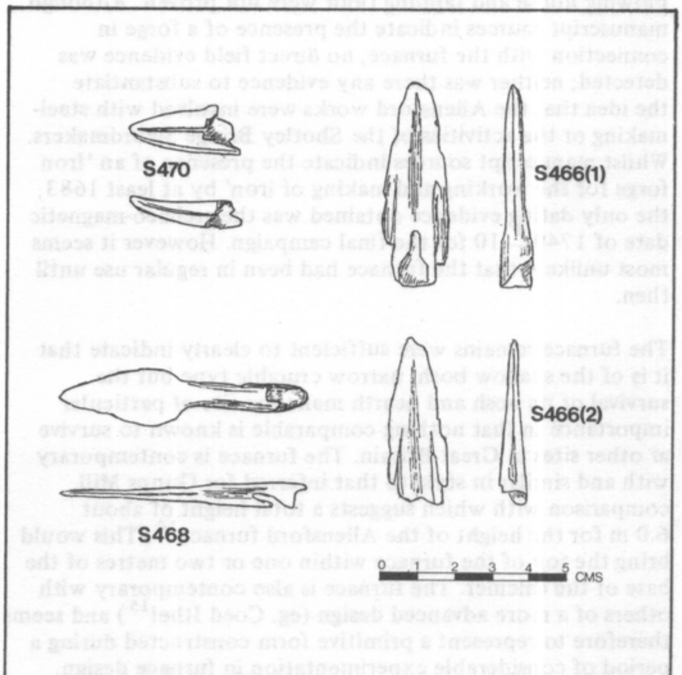

Fig 1 Arrowheads

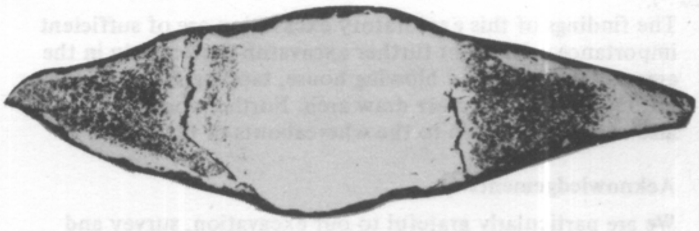

Fig 2 Arrowhead, S 466(1). Section B; showing ferritic core and carburized and hardened barbs. x 8.

S.466(2) This barbed and socketed arrowhead comes from the same place as arrowhead number S.466(1), and is a smaller example of that arrowhead, the same remarks as to its condition apply (Fig 1). As received, the total remaining length is 43 mm. The maximum width over the blades is 13.5 mm, and the maximum thickness of the solid part of the blade is 4 mm. Three sections were removed for examination.

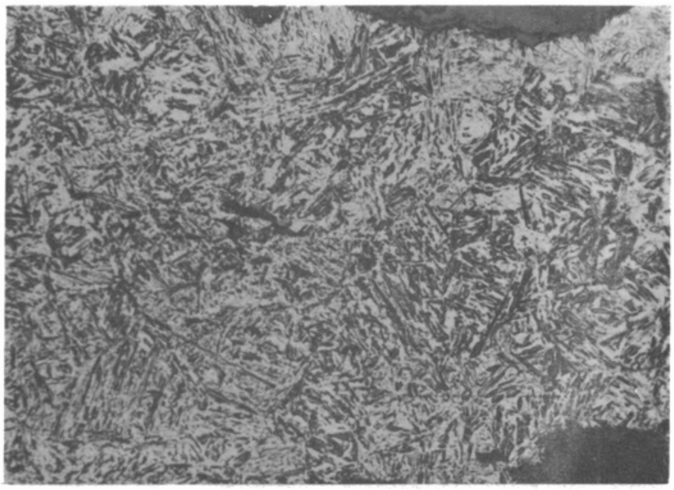

Fig 3 **Arrowhead, S 466(1); martensitic structure of barbs. x 200.**

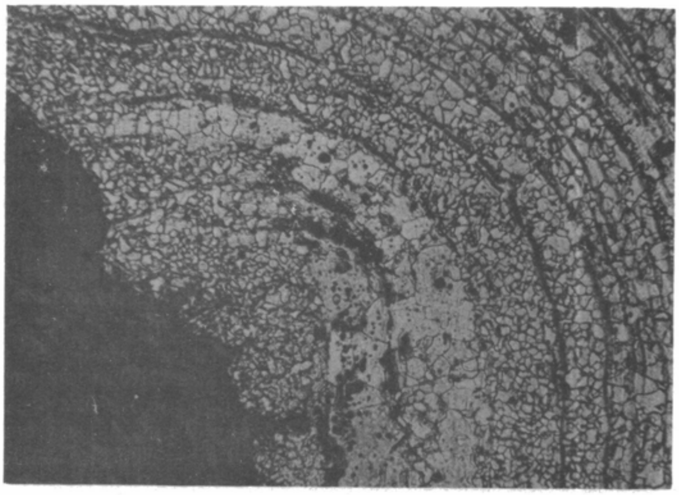

Fig 4 **Socket of arrowhead, S 468. Showing laminated and piled nature of mainly ferritic iron. x 50.**

Section A	was a longitudinal section extending from the point.
Section B	was a transverse section taken through the blades, and
Section C	was a transverse section through the end of the socket.

The socket was so badly corroded that it disintegrated during sectioning. However, section C did show the method used to form the socket with a scarfed lap-joint.

Examination in the unetched state showed that section A had suffered severe corrosion attack; the remaining sound metal was fairly free from slag but there were a number of slag inclusions elongated by forging. In section C, adjacent to the longitudinal lap-joint the metal had been completely corroded away. Slag inclusions were bent round following the forging of the socket. Upon etching section A, the ferritic structure of a low carbon wrought iron was seen, apparently in the as-forged state. In the corrosion products layering can be seen suggesting that the arrow has been piled from a number of thin laminations of iron. Similar structures were observed in sections B and C.

S.468(3) A small iron socketed arrowhead with a somewhat leaf shaped blade (Fig 1). In cross section the blade is almost flat and there is no midrib. The socket was in very poor condition, much corroded and broken at the open end. The socket tube is approximately circular and is very thin, only about 1.5 mm in thickness. Even with the aid of a taper mandrel the fabrication of such a small socket will have required delicate forging. As received, the total length of the arrowhead was 65 mm length of blade 30 mm and maximum width of blade is 15.5 mm. Although difficult to estimate, the open end of the socket appears to have been only 7 or 8 mm in external diameter. For metallographic examination three sections were taken.

Section A	being a longitudinal section extending back from the point
Section B	was taken transversely through the blade at its widest point
Section C	was transverse through the hollow socket (Fig 4).

Examination of the unetched metal of the three sections confirmed that corrosion attack had been severe. In section C, the joint of the socket tube is now merely a mass of corrosion products so that it is not possible to tell what was the nature of the joint. Upon etching, most of Section A showed the ferritic structure of low carbon iron of small grain size, but a band of higher carbon material ran along the length of the specimen. Section B showed a similar ferritic structure, but in places the grain size was much increased. In places, in the various sections, layering in the corrosion products would suggest that the arrow has been piled from a number of thin iron laminations (Fig 4). The hardness of the ferritic structure was 110 HV.

S.470(4) This specimen consists of the point of a barbed and socketed arrowhead. It was in a very poor and corroded state. The arrow has broken away at the end of the socket (Fig 1) of which only a very small portion of some 12 to 13 mm remains. The blade has a very pronounced mid-rib, the point of the arrowhead has been slightly bent by mechanical damage. Judging from the remaining portion, the socket tube was very thin, probably not exceeding 1.5 to 2 mm in thickness. The socket is continuous with the blade, not doubt forged round a taper mandrel. From its rather complex shape the arrowhead was clearly the product of a skilled smith. As received, the total length was 30 mm, maximum width of the blade 11.5 mm, and maximum thickness over the mid-rib 7 mm. Owing to its poor condition it was only possible to take a longitudinal section from the point.

In the unetched state considerable corrosion attack was seen, especially at the point; apart from the corroded areas the metal did not show any gross defects. Numerous slag inclusions are substantially elongated in the direction of forging. Upon etching a coarse-grained ferritic structure appeared. In places, Neumann bands in the ferrite grains show that the blade has been subjected to some cold hammering (Fig 5).

The hardness of the ferrite was about 165 HV; while the hardness of that showing Neumann bands rose to 178 HV1.

1924–20a(5) This barbed and socketed arrowhead was in a very poor condition and much corroded (Figs 1 and 6). One barb, and the open end of the socket had been broken off and was missing. The blades had a marked mid-rib, and both blades and bars were thin, about 1.5 to 2 mm in thickness. Not enough of the arrow remained from which one could obtain accurate dimensions. From the broken end of the of the socket to the point of the arrow was about 61 mm and the probable maximum width over the barbs would have been about 60 mm. For metallographic examination a

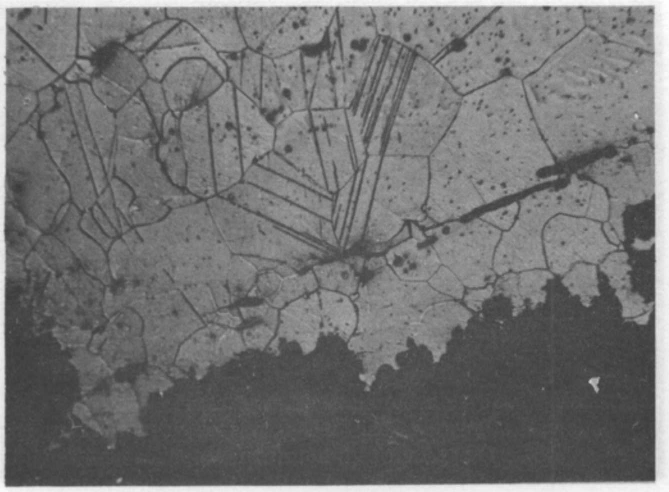

Fig 5 **Section of arrowhead S 470 showing Neumann lamellae. x 50.**

section was taken through one of the blades, and included the cutting edge.

Examination of the unetched specimen showed that upon the exterior of the metal corrosion attack had been severe, but the mass of the metal is relatively sound. Some slag inclusions of duplex structure are drawn out by a forging operation. Upon etching, only the ferritic structure of a very low carbon wrought iron is seen. The cutting edge of the blade has not been carburized. The structure was ferritic with a hardness of 185 HV.

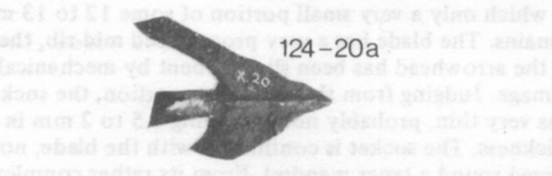

Fig 6 **Typical medieval arrowhead (1924–20(a) and spearhead (1924–18a) Scale cms.**

B Spearheads

(1) 1924-18(a) This is a small socketed spearhead with a thin shaft and, in cross section, a flat blade without a mid-rib. (Fig 6). The socket was formed by forging over a tongue of metal but by visual inspection it is not possible to say if the socket-fold was welded. The total length of the spearhead is 16.6 cm; maximum width over the blade 22.5 mm, maximum thickness of the blade 16 mm. For examination, a section was taken through the cutting-edge of the blade (Fig 7).

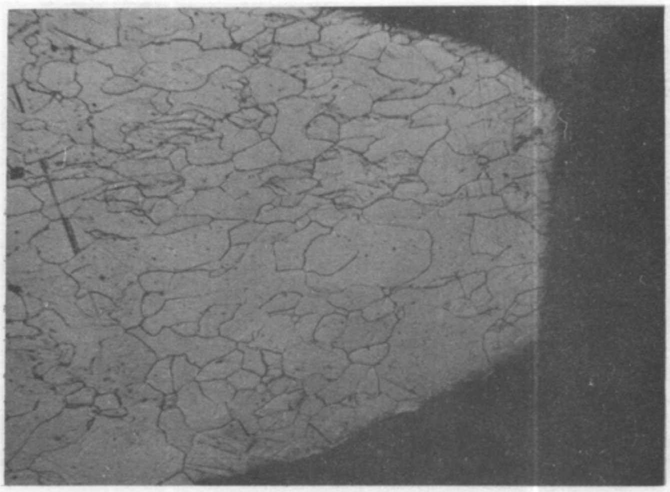

Fig 7 **Microstructure of tip of spearhead 1924–18a.**

In the unetched state corrosion attack was seen to be but slight and the metal sound, clean, and with few slag inclusions. Viewed after etching, the structure was substantially that of a low-carbon wrought iron, but at one place remote from the cutting-edge there is an area of higher carbon material. The ferrite grain size is very variable; the hardness near the tip was 165 HV1.

(2) Large Viking spearhead; 1927-2 As is often the case, this spearhead (Fig 8) was very heavily corroded at the socket and the thin edges of the blades. The socket metal is very thin towards the bell or mouth where some metal has completely corroded away. At the open end of the socket are two large peg holes of approximately 7 mm diameter. The socket has apparently been made by folding over and the joint welded. There are very strong central ribs extending from the socket to the point of the blades. Apart from the socket, the spearhead is a very substantial piece of work. The total length is 30 cm. Maximum width over the blades 45 mm, and maximum thickness over the central ribs 24 mm; approximate internal diameter at the mouth of the socket 27 mm. The thickness of the socket tube is about 2 mm.

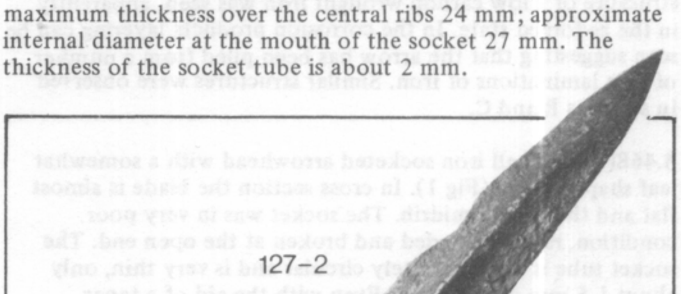

Fig 8 **Viking-type spearhead (1927–2). Same scale as fig.6.**

For examination, a section was taken from the cutting-edge of the blade. Along one edge of the specimen corrosion had been severe, otherwise the metal is in sound condition. Numerous slag inclusions are elongated in the direction of forging. The blade has been piled from a number of laminations of wrought iron, and the cutting edge has been carburized, showing ferrite and fine pearlite. In places there has been some carburization on the edges of the blade where large grains of ferrite are seen. The hardness of the ferrite and pearlite regions was 160 HV, and that of the decarburized area, 133 HV.

C Knives

(1) OA 190(B) This is clearly a knife used for some special purpose since the blade has been intentionally bent round following the arc of a circle (Fig 9). Surface corrosion, except upon the tang, has not been severe and the cutting edge remains quite sharp. Compared with the overall length of 127 mm the blade is a deep one, 27 mm wide. The length of the tank is 63 mm. For examination, a section was taken through the cutting-edge of the blade.

Upon viewing the unetched metal hardly any corrosion attack was seen; the metal is clean and sound and slag inclusions were not observed. Upon etching it was found that the whole of the section had been carburized, ferrite and pearlite being seen throughout. The composition is probably around that of a 0.7% carbon steel. The blade has not been quenched and tempered. Hardness readings gave figures of 283-305 HV reflecting the different amounts of ferrite and pearlite. (Figs 10 and 11).

(2) OA 190C This is an indeterminate object of which the purpose is not known (Fig 9). It may have been some form of knife or other cutting tool. A bent tang remains, but most of the blade has been broken off, and is now missing. For examination, a section was taken from what would appear to have been a cutting-edge.

Upon viewing the unetched metal, numerous slag dots, typical of a wrought iron seen in cross section are present. There is also entrapped slag at the cutting edge, and a long lap or crack filled with corrosion products adjacent to the edge. Upon etching, the section mostly shows the ferritic structure of a low carbon wrought iron of variable grain size, and one piled from a number of laminations of iron. Adjacent to the cutting-edge (Fig 12) there is a small area of higher carbon material so that it is possible that the cutting-edge had been carburized, but partially decarburized during the course of some later working. There is little evidence for an intentional weld although the coarse pearlitic central area does contain some slag stringers. (Fig 13).

The hardness of the cutting edge was 283 HV, while that of the back was only 140 HV which seems to indicate that the knife was intentionally carburized to harden it.

D Stake-like Object

OA 190A It is difficult to define the purpose for which this tool was used. In appearance, it resembles a metal worker's stake anvil used for raising small vessels. (Fig 9). However, even for use by a gold or silver smith, the arms would appear to be much too weak for the purpose. On the other hand, it is possible that the tool is a light double-ended hammer used by a gold or silver smith for decorative work. A small boss gave the impression that the tang may have been socketed through the arms. Hence a section was taken through the top of the tang and the arm. Examination of this section, through the tang, showed that it had been socketed into the arm, and rivetted over at its upper surface; this was shown by different forging directions between the tang and arm.

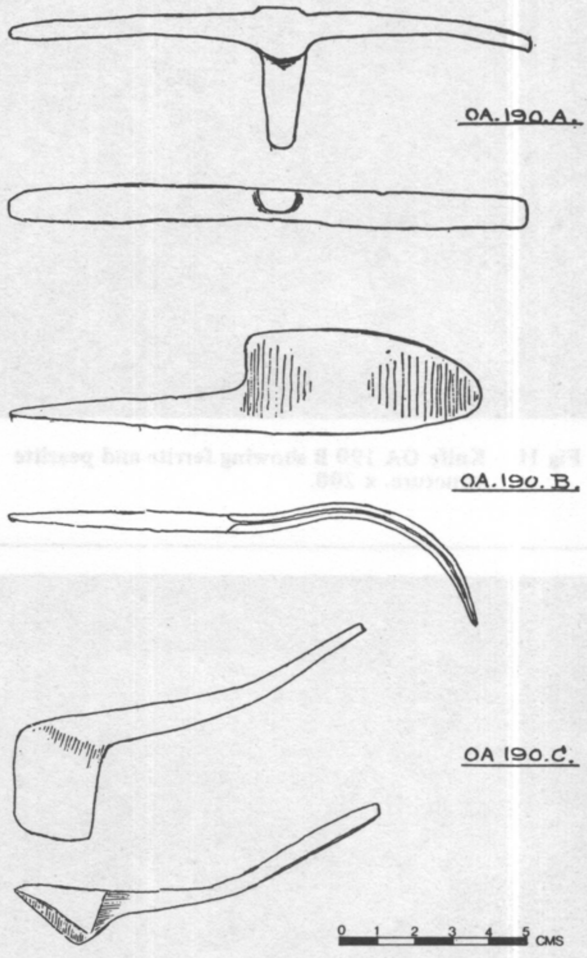

Fig 9 Knives and other objects

The object has been highly corroded all over, and is in poor condition. As received, the total length over the arms was 137 mm. The arms are too badly corroded to tell what the original dimensions were, but in one place the rectangular cross section now measures 9.5 x 4 mm.

For metallographic examination a longitudinal section was taken from the end of one of the arms. The unetched metal showed heavy corrosion upon the edges of the specimen; otherwise the metal was clean. Slag inclusions, elongated in the direction of forging only appeared upon the edges of the specimen. Upon etching, the structure was substantially ferritic, ie. that of a low carbon wrought iron. While there was a thin band of higher carbon material following one edge of the section, it appears that this tool has been left more or less in the as-forged state. The hardness of the ferrite was 142 HV.

CONCLUSIONS

To sum up, we examined five arrowheads; four of these date to the 13th century AD, and one to the 15th century. Of these, only one, number S.466 (1), dating to the 13th century was found to have been carburized and quenched. The others consist of wrought iron left substantially in the as-forged

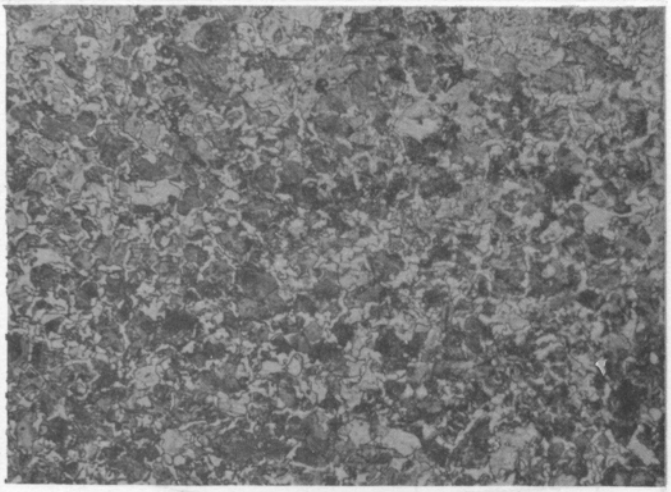

Fig 10 **Knife OA 190 B showing ferrite and pearlite structure. x 200.**

Fig 11 **Ferrite and pearlite of OA 190 B. x 400.**

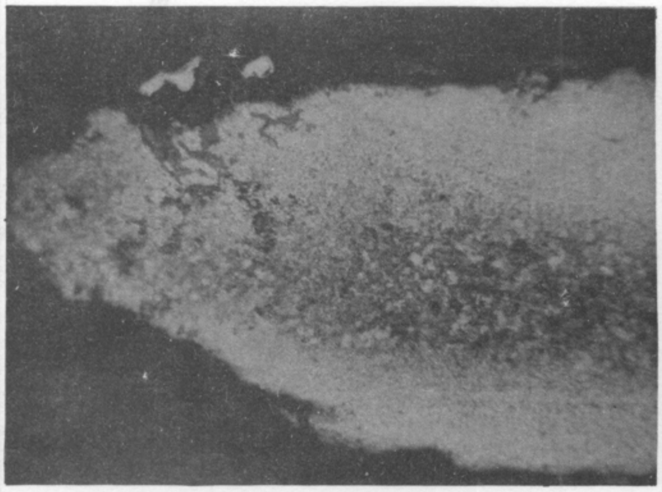

Fig 12 **Knife OA 190 C; cutting edge. x 20.**

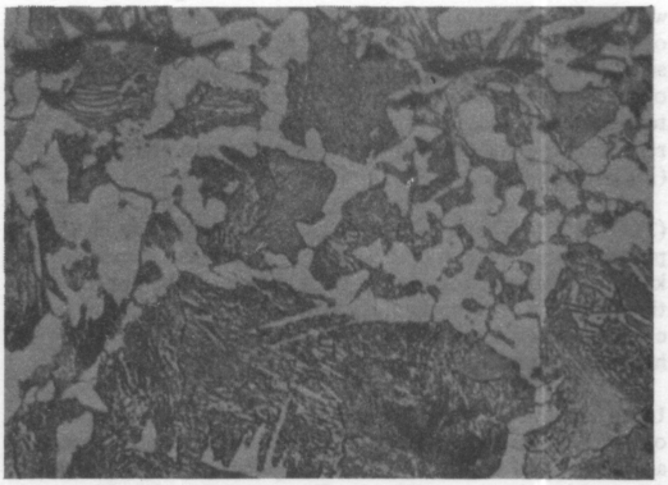

Fig 13 **Knife OA 190 C; showing ferrite and pearlite in the high carbon region of the cutting edge with slag stringers. x 400.**

condition with the exception of number S.470 which had been cold hammered with the object of hardening it. The medieval arrowhead, number 1924-20a, may be compared with a similar one from Woodeaton, Oxon, also of wrought iron in the as-forged state.[3] One the other hand, a medieval arrowhead, again of similar type from Essex, was found to be of dirty steel possibly containing 0.25 to 0.3% of carbon.[1]

The 13th Century spearhead, number 1924-18a, is made substantially of wrought iron, but may have been carburized; while the Viking spearhead had been carburized bringing it into the category of a low carbon steel. From the late medieval period we have three objects. A tanged knife, OA.190.B, a knife-like tool OA.190.C, and a stake-like tool OA.190.A. The stake was found to have been made of low carbon wrought iron. The tanged knife, OA.190.B is well carburized but not quenched or tempered, while the knife-like object is substantially of low carbon iron; but an attempt has been made to produce a high-carbon cutting edge. These few examinations suggest that medieval arrowheads, while skilfully forged, in general consisted of wrought iron. Spearheads and knives may well be in a higher metallurgical class.

The hardness of the ferritic objects suggests that they had quite a high phosphorus content. On the whole, the metallurgy of the cutting tools does not compare favourably with those from other medieval sites, which shows the danger of drawing conclusions from small numbers and the necessity of looking at the picture as a whole.

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3 H H Coghlan. Notes on Prehistoric and Early Iron. p. 192, Plate XVI (1-4) Pitt-Rivers Museum, Oxford, 1956.

1 & 2	S 466 (1) Arrowheads from the Barnes collection Found at Pore Farm, Lambourn, Berks. Dated to 13th century AD
3	S.468 Arrowhead. Found in the Lambourn Valley, Berks. Dated to the 15th century.
4	S.470 Arrowhead from the Barnes collection. Found during the building of the Lambourn Valley railway. Dated to the 13th century.
5	1924-20(a) Arrowhead from the bed of the River Lambourn at Donnington, Newbury, Berks. Dated to the 13th century.
6	1924-18(a) Spearhead from the bed of the River Lambourn at Donnington, Newbury, Berks. Dated to the 13th century.
7	1927-2 Large Viking spearhead found at Colthrop, Thatcham, nr Newbury, Berks.
8	OA 190.B Tanged knife blade found in Salcombe Road Road, Newbury, Berks. Dated to the Late Medieval period.
9	OA 190.C Knife-like object, also from Salcombe Road. Late Medieval.
10	OA 190.A Stake-like object, also from Salcombe Road. Believed to be Late Medieval.

TABLE 1
LIST OF OBJECTS EXAMINED WITH THEIR PROVENANCE

No.	Object	Part	Structure	Hardness HV1
S 466(1)	A/H	Centre	F	123
S 466 (1)	A/H	Tip	TM	240
S 468	A/H	–	F	110
S 470	A/H	–	F	165
S 470	A/H	–	F (N.L.)	178
1924-20(a)	A/H	Tip	F	185
1924-18(a)	S/H	Tip	F	165
1927-2	S/H	Tip	F and P	160
1927-2	S/H	Tip	Decarb.	133
OA 190 B	Knife	Edge	F and P	283
OA 190 B	Knife	Back	F and P	305
OA 190 C	Knife?	Edge	F and P	283
OA 190 C	Knife?	Back	F	140
OA 190 A	Stake		F	142

Notes: F = Ferrite; F and P = ferrite and pearlite; TM = tempered martensite; NL = Neumann lamellae.

TABLE 2
RESULTS OF HARDNESS TESTS

Early Iron working sites in North East Yorkshire

R H Hayes

INTRODUCTION

In 1884, Canon J C Atkinson published a paper on 'Cleveland Iron Working' in the Yorkshire Archaeological Journal in which he described several and listed about fifty sites.[1] Since then B Waites has published a list in 'Geography'.[2] There are references to this in 'Medieval Bloomeries in the North of England' by R F Tylecote in 'Vita Pro Ferro', 1965.[3]

None of the Waites' sites quoted in this list has a grid reference and I doubt if he ever located several of them. For instance he gives two furnaces in Rosedale, but none were located until the publication of 'Rosedale Mines and Railway', in 1968.[4] W Champion told the present author and J G Rutter of his Uncle Page seeing slag and cinders when the Lecture Hall and School were built on the site at Rosedale Abbey in 1875. The other one in this list was found by Douglas Smith in 1973. It is now under excavation opposite the Hartoft Beck site No.68. Waites' record must have been taken from Early Yorkshire Charters, or the North Riding Record Series – Honour of Pickering, where two sites are mentioned in Rosedale as working in the 13-14th century AD.

Another list of smelting sites and slag heaps was published in the History of Helmsley,[5] in 1963; – Appendix K gives a list of 17 sites in the area of the Duncombe Estates compiled by RHH, including six of Atkinson's sites.

The best account of the industry of medieval times in Upper Ryedale and Bilsdale (1150-1650 Ad) was written by J Gerald McDonnell in the Ryedale Historian No. 6 1972, in which he describes 17 sites. The present list brings to date 124 sites for the North Yorkshire Moors and Dales; no doubt many more remain to be discovered. About 8 of these sites have produced only a small quantity of slag; many others much larger quantities. Few have been excavated; many have been destroyed by forestry or farming. In the 17-19th centuries many were removed for road metal.

Most of these that have been examined thoroughly or excavated have proved to be medieval, though four are certainly of the late Iron-Age. The most important is the small domed furnace in the centre of a hut with many post-holes and concentric ditches (Levisham Moor No.115). This site is to be published in full by the Scarborough Society. The other Iron-Age sites are No. 38, Roxby Low Moor, where the base of a bowl type furnace and much slag were found in Hut 2. Excavations by the Teesside Archaeological Group, directed by D A Spratt and R Inman are proceeding. Others are:–

No. 37 The Hulleys, Cloughton – a well known Iron-Age site, where inside a stone circle or hut the remains of an early bowl furnace was found.[6,7,8]

No. 39, Burgate Farm, Harwooddale, Cinderhill, though mainly medieval, it was claimed by P Farmer to have a Iron-Age hearth and sherds.

No. 11, Crown End, though thought to be a Bronze-Age Settlement has produced iron slag and hints of a furnace.[9]

No certain Roman furnace has yet been found, there is a 'Cinderhill Field', 300 m W of Lease Rigg Roman Camp (or Fort), and another on Moss Brow – not much further west. Slag with Roman pottery was found in the enclosure during the 1976 excavations. No. 89, in Cockerdale Wood, sectioned by R S Close and RHH, though near a Roman pottery kiln, gave no evidence of date.

No Saxon or Viking bloomery has been found though they are described in the Sagas as 'great smelters of ore'. Smidersdale – E of Bilsdale was pre-Norman conquest, but we have no evidence from the slag heaps at Crosset or Smithy Ellers. Viking metal work was thought to have been made at Crayke – but that is out of our area.

Excavation has shown only six proven medieval furnaces – Nos. 12 and 13 at Baysdale, excavated by R S Close and F A Aberg in 1964–5 but not yet published. No. 22, Postgate Hill Glaisdale, excavated by the late George Harland, and reported by R F Tylecote. See G Harland's Queen of the Dales, 1970 – 2nd Edition 1973, p. 43-47, for his description of this and other sites; also for the excavation of bell-pits at Holey Intake. No. 46 (Ainthorpe), excavated by Danby WEA Group with C V Bellamy in 1963, is still unpublished. No. 68 Rosedale West is still under excavation. The pottery is 14–16th century and a coin of Edward I (1307-8) was also found.

No. 63 The small stone box-like furnace set up in Whitby Museum which is doubtfully correct was found by L G Rowland near the SW end of the village.[10] There is no evidence of its date.

Odd sherds have been found at Mitchell Hagg, Bransdale, Wheeldale Gill, and other sites but more evidence is needed. The more important sites are now being scheduled by the Department of the Environment.

The industry seems to have ceased almost entirely by the end of the 18th century. Marshall in his review of Rural Economy in 1790 says – 'There are many traces of early ironworkings in the dales north of Pickering but the only one now working is in Forge Valley'. The gap was probably caused by the edict of 1620, forbidding the use of timber for smelting and glassmaking, as the forests were depleted and there was a shortage of timber for ships. The great revival came in the mid 19th century with the demand for iron by the railways and shipbuilders, and many other industries. Modern blast furnaces replaced the forest forges and the water-powered furnaces such as that at Rievaulx and the recently discovered one at Hartoft. The end of the Cleveland 19th-20th century boom period began after the 1914-18 war. Rosedale East Mine closed down for good in 1926 during the strike. (see 'A Gazetter of Cleveland Ironstone Mines', S K Chapman 1967). The last of the Cleveland Mines was North Skelton which closed down in 1964. Incidently, this was the year we found the Iron-Age furnace at Levisham Moor, which was probably working 2,000 years earlier.

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6 R Knox. East Yorkshire. 1855, p 158-168.

7 F Elgee. Early Man, 1930, p. 215-16 and Fig. 65.

8 Scarborough Arch. Soc. Trans. 1958, 1 (1).

9 D A Spratt and N H Harbord, JHMS 1975, 9 (1), 32-33.

10 Elgee. op. cit. p. 188.

Note: In the following list the expansion of initials is as follows: –

RHH	R H Hayes
RHC	R H Close
RFT	R F Tylecote
JCA	J C Atkinson (Forty Years in a Moorland Parish)
HH	History of Helmsley
GH	George Harland
SDAS	Scarborough and District Arch. Soc.
NH	N Harbord
DAS	D A Spratt
YAJ	Yorkshire Archaeological Journal
J McD	J McDonnell
DS	D Smith
GWG	G W Goodall
WG	
JGR	J G Rutter
FWD	F W Dowson

IRON AGE OR MEDIEVAL IRON WORKS

Location	Remarks	Water Supply	Period	Publication
1 Botton	NZ 6960412? Atkinson's No.13. Not seen RHH. Iron Age Querns from Falcoln Farm. (Pub. RHH Ryedale Historian No. 7 (1974)	Falcoln Beck		JCA YAJ 1884 No.13
2 Honey Bee Nest	688034 2 Sites Atkinson. Not found. RHH. Now extensively farmed by Botton Estate.	Danby Beck		JCA 1884 Nos. 11 and 12
3 Dale Head?	Not found RHH. Old pits shown on 6″ OS one at Botton Cross has leading from it (695020) and others at 688–9022 probably coal. Old pits shown at 682026 on boundary and old road to Rosedale may be ironstone.			JCA 1884 No. 10 HH. 1963 p. 460
4 Westerdale Broadgate Broadgate Farm	NZ 673047 Near Cinder Hill Field on old Helmsley DP Estate map lead RHH to investigate and farmer dug up slag from ploughed down heaps at 650 ft OD ¼ m S of farm. Opposite is Swarthey Hill. Samples of slag kept.	On Tower Beck		Not given by JCA
5 New House Westerdale	NZ 650047. Not seen RHH	Stockdale Beck		JGA YPJ 1884 No. 4 HH 459
6 Stockdale House	NZ 643046 Late Medieval Long House. 32 m x 3 m 2 bays enlarged to 4 bays. Inhabited in 18th early 19th century. R Close dug under floor and found iron slag. No clue to date.	Stockdale Beck		
7 Westerdale Village Sub-Ref Holes	NZ 66410559 and 66410563 (Pits) (DS). 650 ft OD. Main seam of ironstone. In a narrow strip of enclosed rough pasture 200 yards SW of the church marked PITS on OS map. Slag heaps and at least 4 pits dia. about 5-7 ft traces of foundations in E side. (RHH 1961) Not excavated. 12C. 'Guy de Bovincourt. Granted to the nuns of Baysdale the meadow at the head of the hill of Westerdale south of the 'Sub-ref holes'.'	Bugdale spring very small supply		JCA YAJ 1884 No.3a '40 Years' p. 174. UCH 11 p.414. HH 1963, p. 459.
8 Westerdale Hall YH	NZ 663061. Furnace-shaft type? said to have been found by Youth Hostel Members before 1961 but kept quiet – no information (new warden) RHH.	R Esk		JCA 1884 No. 5 HH 1963. p439
8a Rye Garth Well	NZ 66420595 (DS). Bloomery in garden nearby			
9 Fir Tree Farm	NZ 661065 Slag heap SE of farm. (not visited RHH)	Spring only		JCA 1884 No. 3 HH 1963, p. 459
10 Wood End and Waites and Little Waite	NZ 650035 approx. (Wolfdale 1186) Slag heaps mentioned by Atkinson. Not found RHH. (Howthwaite 1185 AD)	R Esk		JCA 1884 No. 6, 7 8 HH 1963, p. 460
11 Crown End	NZ 669074 2 lots of slag found. Inside quadrangular stone walled enclosure with E Gate at 700 ft OD near Cairn group and ancient fields. Bronze Age; Elgee. Iron Age; Dr Spratt (see analyses of slag). Rutter thought much of this could be early medieval?			Note in Whitby Naturalist's Club Rep. No. 1940
12 Gin Garth Westerdale Moore	NZ 652071 Small bowl furnace, 0.5 m diameter tapering to 0.3 m. deep. Burnt, natural clay coated with slag and cinder. Small platform of stone to NW. A few medieval sherds of 15th century. Dug by RSC before 1957. Close to thatched building with malt kiln. Pottery 1720 or earlier. Now almost down to ground level.	Spring	15th C	Unpublished (pencil) sketch by RHH)
13 Baysdale Beck	NZ 644075 Just north of beck by stone wall. Excavated by RSC in 1945/6. One of 2 furnaces. One was 2.4 m x 60 cm wide and north of wall. No. 2 was S of wall. Excavated by F A Aberg in 1964/5. Foundation of hut on S bank of beck, and several bell-pits on Gt Hograh Moor, ¼ mile to south at NZ 64050704 (RHH).		13th-14thC	Unpublished
14 Hob Hole ¼ mile E of above?	Listed by JCA in YAJ, 1884, No. 2. This may be the same site as above.			

Location	Remarks	Water Supply	Period	Publications
15 Crag Bank Wood, Kildale	NZ 630099 Iron Age to Romano-British hut and field system dug by RSC in 1958 and DAS in 1973. Small amount of iron slag found by RSC.			YAJ, 1975, 47, 61-8.
16 Black Hag Beck, Baysdale Moor	NZ 62280350 RS Close noted a semi-circular hearth set in the side of a moor-coal pit heap. On it was iron ore and much coal. He concluded that it was an attempt to smelt iron with coal(!). Further examination in February 1977 by RHH showed that it was 2 m diameter with a stone back 0.55 m high set in mortar which was not medieval. Nearby were 4 miners' cottages and a smithy. 8 or more pits and some bell-pits were on the moor to the NE. The ore was not heavily burnt and no slag was found. Probably worked up in the smithy. Tradition places the industry in the late 18th to early 19th century. There is a stone trough at one end and a stream close by.			
17 Pale End, Bankside, Kildale	NZ 609104/6 Iron Age to R–B. Excavated by RSC in 1962-68. Small amount of iron slag found.			YAJ, 1966, 41, 687-700 by RHH
18 Percy Cross Rigg	NZ 61011155 Five round huts with stone foundations. Iron Age to R–B. Two or three pieces of slag.	Spring to NE		YAJ, 1972, 44, 23-31 by RSC
19 Gt. Ayton Moor	NZ 599113 Quadrangular enclosure with internal ditch and central hut. Excavated by W R Ross in 1953 and B Tinkler in 1961-3. (Unfinished). Iron slag found with a possible hearth. Analysis by DAS and NH in YAJ, 1977, 49.	No stream now. Spring to E		
20 Stanghow. Aysdale Gate. (Lower Site) 800 ft OD	NZ 650145 Slag heap in slack by small boggy runlet of water. Heap 10 m dia by 30 cm high. Mr Watson (farmer) has ploughed up pieces of red pottery(?); possibly furnace lining.			
21 Stanghow. (Lower Site 670-700 ft OD	NZ 650143 Circular or U-shaped bank of slag close to small spring. Heap 10-12 m wide; bank 1 m wide, 0.5 m high. Heap higher up the slope from which a sample of heavy slag was taken. Both sites visited by DAS and RHH in September 1974.			
22 Glaisdale Postgate Hill (Pussket 13C)	NZ 7590459 Oval stone-lined furnace in rock cut hollow. Exc. Geo. Harland 1951. Re-excavated during 1963. Pottery. 13th-14th Century	No Height 725-30ft OD	Med. 13-14th	YAJ. CLXII 1964 p. 167/8 Fig.2 RHH. R F Tylecote. Med. Bloomeries in N England. 1965.
(Pussket – Postgate 13 C)	NZ 758046 Ket-Chet-Coed 'Wood'. Atkinson 1884 at least 4 bloomeries under Priory of Guisboro.			Mr G Stainthorpe Ryedale. Historian No.2 (Plan RHH) 'Queen of the Dales' G Harland. 1970 p. 40-46
23 Glaisdale Red House. Nearby to W is Hart Leap Dykes	NZ 739034 Large slag heap 30 ft by 4 ft high. (Photo RHH). Pits centered on NZ 734054. NZ 733034/5 group of bell pits. Just south of dykes and N of Hardhill House gate to moor		Med?	Unexcavated. E Harland says he located 12 sites in Glaisdale.
24 Another	Group in moor to SW of Hardhill NZ 732030/1			Seen RHH
25 Hardhill Gill	NZ 73700298 A paved pannier way leads from Common to the ruin of a small house 44 ft x 18 ft divided into 2 cottages in 19 C with fireplaces and salt boxes. Close by large slag heap. No land with these – probably ironworks dwellings?	On N bank of Hardhill Beck		Seen RHH shown by Fred Hall previous of Hardhill. Notes Scar. & Dist. Trans. Vol. 2 No.15 1972 RHH
26 Caper Hill	NZ 735023/4 approx. 'Descending from Cockheads to Glaisdale by Caper Hill the Whitby Naturalist saw road men working on roadside bank exposing old iron smelting furnace;slag left from the ore clung to the stones of the kiln. The presence of iron stone was confirmed by water in gutter of the present road running bright red.			Brief note in Whitby Naturalist Rep. 1945/47 p.69 P B & A Smith Last rep. publ. by them. Not found RHH. But iron stone water at bend in road – 1974.
27 Dale Head	NZ 743014. Slag heap near spring. Report to RHH by Mrs Stainthorp. Not visited.			
28 Glaisdale Side	NZ 742027 near Yew Grange slag – not found RHH			J C Atkinson 1884 No. 32
29 Nab End	NZ 751025 approx. Ore outcrop, slag and bell pits. (G Harland). Now planted over by dense cover of larches by Forestry Commission.			Not visited (RHH) G Harland. 1970 p.45 JCA 1884 (38,39)
30 Wintergill	NZ 75801314 Slag heaps and old pits. (G Harland & A Smith) who had piece of med. pottery from this site. Visited JGR & RHH but could not find slag heaps. All forestry. 1970. Ruin of 19 C ironworkers house here.	Small beck		YAJ 1884 p.48 JCA 1884 (36, 37). Site found by D Smith 21.12.74.
	NZ 75420133 200 m WSW of ruin. Slag heap 10 m dia, up to 0.7 m high eroded by stream at ends. 4 wall-sherds of green-glazed ware found in slag.			S D A S Trans. 1975, 3 (18), 28.
31 Glaisdale Beck nr Ford	NZ 775042/3 Iron slag and workings. G Harland. Could not find any slag heap. May be jet workings. RHH (1969-70). At NZ 77530410. Prob. Med. bloomery.			
32 Snowdon Nab. nr Holey Intake	NZ 785045/6 Good group of 30-40 pits still visible. (photo RHH) Slag heap very large led away 1904/5 by G Harland's brothers. Information from GH who says Rev J Williams exc. one of these pits (in the 1920's). The pit was 8 ft dia. sides and ends were undercut about 2 ft 6 ins, the bottom was about 13 ft square. Iron stone 15 ins thick. He never found any at the bottom as it was all extracted by the miners. No pottery found. Plan given to GH who said he had redrawn it with plan of 150 or more pits adjoining. Given to Whitby Museum? Delves or diggings is name of farmhouse to E of pits. Smiths Lane leads to Hamer and Rosedale.	Spring only		

Location	Remarks	Water Supply	Period	Publication
33 To S in Egton Grange	NZ 787040 Scatter of iron slag seen by RHH	No		
34 Busco Beck	NZ 753059 Iron slag west bank of stream seen RHH	Yes, water; small beck		
'Birkscog'	13 Century iron working. Birch Wood in Guisborough Charter of 1223.			
35 Harwood Dale S of Burgate Farm	SE 970947 300 yds (approx) S of Burgate Farm – a very large mound marked Cinderhill (SE 971948) on 1848. 54 OS map Peter Farmer (Scar. Arch. Site) in letter to RHH 24.1.68 said 'We uncovered a major med. smelting site over 3½ acres, depth of slag 24 ins. Trial area 750 sq yds – we uncovered part of a domestic building (prob. foundation of 17-18 C farmhouse formerly on site RHH) and 1 furnace – not much left of it – pottery 1158 to 1400 AD. Also under med. material was part of hut circle and hearth. ¼ mile SW is Clocks or Pits Wood.	E Syme beck 50 m to W		Very brief note in Scar. Trans. 1958, 2, (11). Not visited by RHH
36 Harwood Dale Nr Castlebeck Farm	SE 953974 About 120 yards S of present Castlebeck Farm and only 50 yds. S of Old Farm in bend of Castle Beck on N bank near present bridge medium sized Cinderhill marked on 1848–54 OS map. (Not visited RHH) Third of a mile N in Dry Head Wood several pits shown. Another group follows 400 ft contour line near Jugger Howe Beck 1 mile N.	Yes – on N bank Castle Beck		No 1817. E Young 'Hide Whitby' 11–617 Elgee E Moorland of N E Yorks, 1912 p 26
37 Hulleys. Cloughton.	SE 003961 Iron Age. From Scarborough & District Soc. Trans. Vol.1, No.1, 1958 'SE section of site (1923/5) using the stone (or hut?) circle as backing the remains of an early iron bowl furnace were found. Approx. 3 ft dia. by 12 ins deep. Samples of slag and furnace lining submitted to Mr H S Baker of Scourton, Yorks. Mr Baker (in museum) makes the point that the presence of calcium components in the slag is a sure indication of the use of bellows and that the date of the furnace could not have been earlier than the 15th C? – no longer valid as there is now evidence that bellows were in use in Britain before Roman times . C J Taylor. R W Shepherd & F C Rimington.	Small stream fr from spring		No Elgee EM p.215-8. Knox, E Yorks. 1853 C J Taylor unpublished. Report in Scar. & Dist. Trans. Vol.1 No.1 1958. p.22-23. Rough plan of circle and site of furnace.
38 Roxby Low Moor	NZ 762138/9–141 & 764145. Group of 6 or more Iron Age round ditched huts-dia. 8-9 m. Teesside Arch. Group under Dr D A Spratt and R Inman, 1973/4. Iron slag inside Hut 2. Slag samples taken. DAS. Base of bowl hearth in hut 2 with IA pottery.			To be published. YAJ? Pottery in B. Arch. Reps. 20/1 2 Vols. Note in SDAS Trans. 1975, 3, (18), 37
39 Fryup Dale Stonebeck Gate	NZ 716053 Mentioned by J G Atkinson, P166/7; also in 'In Little Fryup not far from Chapel of Ease (near Stonebeck Gate) 7 or 8 slag heaps covering 120 acres.'	Little Fryup Beck		YAJ Vol. 8 1884 (p.30-48. 22, 24)
40 Crossley House Fryup	NZ 711053 Mine pit field (J C Atkinson, 40 years) Cinder Hills near Fairy Cross Plain. Now removed (1 piece of slag RHH)			JGA
41 Crossley Side	Not found. RHH			27.28 JCA. YAJ, 1884
42 Furnace Farm & Bridge	NZ 742069 Large slag heap between farm and bridge close to beck. JCA	Yes		YAJ Vol. 8 1884 No. 21
43 Fryup Gill	J C Atkinson 1884. 'A person remembers 50 years ago (1834?) the remains of a furnace near a slag heap in Fryup Gill. Conical interior – point downwards? depth 3–4 ft dia. at widest part of upper structure 3 ft or so.' (of Bell's engraving).			JCA 1884 (20)
44	NZ 723042 I was told of slag at junction of Slidney Beck and Fryup Beck (RHH). Not visited.	Yes		
45 Bainley Banks	NZ 737/8 040/5? Slag heaps here? Not yet found RHH. Guisboro' Chart. Iron, Banwithlith		13th C	
46 Ainthorpe Danby	Very large slag heap under 19th C cottages extending downhill to small stream – Toad Beck. Large not with scooped hollow on top – used for trough? 1963 Excavations here by Danby W E A Group under direction of Mr C V Bellamy c/o W E A 7 Woodhouse Square, Leeds. Bowl furnace remains in wet clay with drains or flues? 13–14 C pottery. RHH and R Close had one weekend there in 1963.	Toad Beck		Atkinson YAJ 1884. No.18 and also mentions No.19 Ainthorpe Unpublished report C V Bellamy. Sketch RHH.
47 Danby Lodge (Nat. Park Centre)	NZ 717084 Given by Atkinson 1884. Not seen. RHH slag found by D Smith and G W Goodall '20 slag heaps in Danby alone' JCA 1884.			JCA YAJ 1884 No.20
48 Danby Bridge	? Not visited RHH			JCA 1884 No.20
49 Castleton Howe End	NZ 694079 Large slag heap (JCA, 1884) Not seen by RHH			YAL 1884 No.17
50 Castleton Piper Bridge	NZ 690108 Under the tower of the church built in 1914 the builders found much charcoal and iron-slag-this cinder hill can be traced from here all the way to P1/24 Bridge. (J Ford – Reminiscences) 1944,(200 yrds approx). Now mainly used in road making. (RHH); found by Blacksmith here abbut 1939–40.			JCA 1884 (16) J Ford
51 Castleton Maddy House	NZ 672081. 'Cinder Hill' marked on 6" OS of Hagg Wood but could not be found by RHH or KC – slag found just N. of Farm House.	No stream		
52 Castleton Box Hall	NZ 676091 Slag heap W of Box Hall on E bank of Commondale Beck; possibly another site near railway.			JCA YAJ 1884 No.15 JCA YAJ No.14 RHH in SADS Trans.

Location	Remarks	Water Supply	Period	Publication
53 Commondale Moor	NZ 677093 On plateaux N of Howl Dyke a small earth-work possibly Iron Age – 2 pits 8 ft dia. 2 ft deep full of charcoal and rock burnt red – slag – 1 section RHH RC.			B Arch Rep 20/1. Elgee EM P149
54 Lealholm Park Head	NZ 752084 Confirmed slag heap site. (K Chapman)	Small stream		JCA YAJ 1884 No.40
55 Under Pyke? Under Park	NZ 772070 Mentioned by Atkinson. Unconfirmed?	River Esk		JCA YAJ 1884 No.41
56 Stonegate Lealholm	NZ 778090 Slag heap on top of hill west of mill house shown to RHH by G Harland. 50-60 ft above beck. cf. J Castillo's poem Stonegate Gill – he thought the slag was of Roman origin – (1820). Stonegate thought to be Roman by Elgee. (Romans in Cleveland) ‘By the rude heap of SCALLS that remain on the . . :, It was where they forged their weapons of war’Castillo 1820. Note: SCALLS = SCOWLES of the Forest of Dean.	Stonegate Beck		JCA 1884 (42)
57 Egton Church Cliff	NZ 799066 Iron slag picked up with Iron age or Romano-British on mole hills just E of old church site. 1971. RHH. HELL SLAR WOOD ¼ m. W seemed to have iron working? Not visited.	None		None
58 Egton Bridge	NZ 800051 Scally Hill – of Scalls (S of bridge on turn of road to Goathland) Site not examined. RHH			
59 Topstone Folly	NZ 832078 Romano-British IA site. Some slag found there.			Pub. SDAS Rep. No.4 p.79 (RHH & JGR)
60 Newbiggin Hall	NZ 836073 Romano-British hut site. Slag not kept. Excavated by group from Whitby Naturalists 1964.			Pub. YAJ 166 Vol. XLII 1968 p. 120-25. RHH. Article in Whitby Gazette only published by Whitby Naturalists WG. October 29 1965.
	GOATHLAND AREA			
61 New Wath	NZ 814001 Probable site of water-powered hammer and furnace. Water power and wind power? One field, adjoining site of smelting here, has been levelled, another is channelled in several places; whilst many charred and blackened stones can be seen in the boundary wall – two stages of levelling and tips which may have sited machinery. F W D (seen in 1948 RHH).	Wheeldale Beck		Goathl. in Hist. & Folklore FW Dowson. 1947. p. 46–4 JCA 1884/49.
62 Killing Pits	SE 820-1 998-9 About 24 shown in 1930 Edition of 6″ map but on Provisional Ed. 1950 only 12 shown by + site of – they are all there yet – RHH 1973: haphasard group as at Hardhill and Harland Moor and Holey intake. Very similar in size. Deep hollow way leads down hill towards Goathland and branches W to New Wath. F W D p.46 says EllerBeck seam – ‘Kiln pits’ old name – similar pits south of peat bogs and E of the above pits, which number 160 +. A further set may be seen on both sides of Hunt House Rd. SW of Cherry Tree cottage.			JCA 1884/47 FW Dowson. 1947, p. 46.
63 Nr Goathland Church	SE 823006 (approx). Found by Lewis G Rowland in 1909–10 (described as in small quarry above Goathland church: FWD p.47). Stone 12″ high and hearth 18″ square. 4″ slag and charcoal adhering and inside – minus the front. – No potsherds found. Pencil plan kept by Mr Sherratt, his daughter (shown to RHH 1950). On direct trackway to above pits. Earth and sand surrounding had been burnt red – Elgee. The front had fallen out, nothing to show any vent or flow of iron. No mention of pottery here. Stones now set up in Whitby Museum.			None. Apart from FWD p.47. Restored now in Whitby Mus. Elgee E M p.188 Whitby Lit. & Phil Soc. 1910. Whitby Nats. Club Rep. 4 p.4 RFT 1965 p.131
64 Hollins Hill NW of	NZ 81080104 Heap of iron slag, marked ‘Cinder Hill’ on 1915 Ed. 6″ OS: visible in 1949 by 1974 almost gone; several more said to have existed.		Roman	Rev G Young 1817 p.750 RHH, JGR. Wades Causeway, SDAS Rep. No.4, 1966, p.65.
65 Oakley Beck Egton Parish	NZ 81090227 Scanty remains of heap of iron slag SE side of Oakley Beck ‘Cinder Hill’ in OS 6″ 1853. Close to line of Wades Causeway – The Roman Road.	Small Beck		SDAS Rep. No.4, p.65. Whitby Nat. Club Rep. 1942 p.31.
66 Yaks (Oaks) Wood. Wheeldale Gill	SE 798991/2. Large slag heap S bank of Wheeldale Gill stream. Remains of leat (Mrs A Hollings) who thinks this was the site of Robert Short's Forge – NR Rep. Vol. 12–19. Robert Short (smith) in 1322 applied for a licence to work a forge? in Wheeldale (or Newtondale?) 5/– A place where he could make a charcoal factory and purchase dry wood; a licence to live in Wheeldale warrants for some officials of Pickering Forest on demand (nearby is small walled enclosure called Wetherhouse (sheep hosue) which may be on site of his dwelling. Mrs Hollings found a green-glazed medieval sherd in slag heap in 1957. Others found later by D Smith.	Wheeldale Gill Beck		Goathland-Alice Hollings p.15; but she only quotes NR Rec. Vol. 12, 19. Whitby Nats. Rep. 1940/41, p.45. quoting JCA 1884.
67 Lease Rigg Roman Camp	NZ 813042. Trial dig in rampart marked ‘Earthwork’ on 6″ OS map 1914. by RHH and party 1945 produced spongy cinder described as ‘scum from primitive iron working’ by local blacksmith. 1 piece of iron slag inside NW corner. 1976 excavations. (Esk Valley 19th C Iron working ¼ mile E).	Spring only		Roman Camp. Ex RHH, JGR and party. 1957 Scar. & Dist. A S Rep. No. 4 p67–75.
67a	NZ 80700374 Cinderhill field on Egton estate map 1636. Moss Brow. Lower slope 1 m S of Egton Bridge, ½ mile W of Lease Rigg Roman camp. Slag heap on hill side near hollow way. Examined by RHH, DS & GWG, Aug 1976.			

Location	Remarks	Water Supply	Period	Publication
67b	NZ 812041 Another Cinder Hill on above 1636 estate map. No slag found by DS etc in 1976.			
68 Rosedale West (Opposite Hartoft Bridge). Edge of Spaunton Moor	Furnaces and hearths and two other structures found by D Smith in 1973. U Bank slag heaps and charcoal platform under excavation. Dogger? 1974. D S – GWG – RHH. Pottery 14th-16th century. Coin of Edw. I 1307/8. Possible site of lease by St Mary's Abbey, York (Lord of Spaunton Manor) to John son of Richard' chief smytheman' 1339. SE 748925.	River Seven		To be publ. Ref. N R Rec. 4 NS IV? 1954 Rosedale;see Mines & Railway SDAS Rep. No. 9, 1974.
69 Rosedale West Hollins	SE 729945 Site of Kitching-Garbutt deposit – the nugget of magnetic ironstone 1856. Worked out by drifting.			see above p. 7–8.
70 Rosedale East. Lecture Hall & School	SE 723959 Information from Arthur Champion of Castleton whose father Wm. Champion worked the mines from 1875 to 1926 and lived to the age of 97. Iron slag and charcoal found in quantities when site was cleared prior to building 1873. 'Amoth Wath'.	Junction of River Seven and Northdale Beck	13th C	Early Yorks Charters. Clay YAS Record series IX 1952/12 b. 1327–8. Iron works of Eustace de Stuteville in place called Badgethwaite Meadow.
71 Rosedale Head	The Swineheved (Seven? Head) of the De Brus charter to Guisboro'. 'Old Workings' 6" OS NZ 687-8 003 could be for ironstone by Guisborough tenants. No slag heaps found yet. RHH.	River Seven		Surtees Soc. Edit. W. Brown Vol. 89, 190-1.
72 Hartoft Wood oppos. Spires Bank overflow marked 'Old Pit' on 6" OS	SE 752931-2 Site of large dam bank 6–8 ft high in places 15-18 ft wide – 50 paces long by 24 paces widest part. RHH. 1967. Large slag heaps to south and another inside S bank. Large 'blast' furnace to SW and standing 4–5 ft high with oak tree growing out of it. Fused stones of furnace and much red burnt material, clay etc and some dressed stone. Ore heaps on natural platform above. (Slag samples taken). Found by DS 1973.	Hartoft Beck unexcavated		VCH 11, p.453 (ironstone, moor coal and quarries here making 40/– yearly profit 1583). SDAS Trans. 1975, 3, (18), 30.
73 Hartoft, White House Ford	SE 757961. Small heap of iron slag on west bank of stream near ford. D Smith 1973. Some walling, associated slag could have been used for road repairs.	Hartoft Beck		SDAS Trans. 1975, 3, (18), 30.
74 Hartoft. Row Mikes	SE 753967 Spongy iron slag and cinders in walls near Beck. Search failed to find heap or furnace. Could be early workings.	Hartoft Beck		Found by DS 1973. SDAS. Trans. 1975, 3 (18), 30.
75 Hartoft High Hamer	SE 74189770 No iron slag is visible in the vicinity of Low Hamer but at High Hamer, between two existing buildings, several pieces were found by D Smith. Probing of the grassy area between Hamer Beck and the N of the two buildings would suggest a concentration of slag, although none is visible in the bed of the stream. (Very heavy cindery slag and run slag).	Hartoft Beck		Joseph Ford. Some reminiscences. Folklore of Danby, 1953, p.20. 'At Low Hamer, when digging foundations of sheep house or shooting box, it was found that a pre-existing building had stood upon a site where iron has been smelted'.
	HAWNBY AREA			
76 Thack Wath	SE 529921 Large iron slag heap 30-40 feet long by 4 ft 6 in high. A lot of slag has been removed. Sample taken by RHH.	River Rye		J G McDowell RH 6 1972; (No.8).
77 Cow Wath	SE 514950 U-shaped bank of slag on bank of river Rye; 30 ft to bank 2-3 ft high by 10-12 ft wide.	River Rye		JMcD/RH/6/1972 (No.10)
78 Black Intake Cinder Hill	SE 520932 Very large heap 40 paces long and 3 to 10 ft high approx. on steep slope. Traces of furnace red-burnt and clay to west top of mound. Heavy slag, sample taken and photos of slag heap made by RHH.	Near spring ½ mile to Rye		as above JGMcD No.10
79 Blow Gill	SE 528932 Large heap (1) close to beck. Small (2) at 528932 also close to beck.	River Rye		as above JGMcD No.9 as above MGMcD No.9A
80 Low Cote	SE 514949 Drift mines, adits and water channel. U-shaped bank and slag heap.	River Rye		JGMcD/RH/6/1972 JGMcD No. 11
81 Rye Farm	SE 503931. As above.	River Rye		as above
82 Daleside Drive	SE 541892 Only a few pieces of slag and possibly partly late. Not visited by RHH.	Pond?		JGMcD No.7
83 Hemsley Moor	SE 57-92 approx. Slag heap ½ mile from Hanging Stone on the old road from Rievaulx Abbey to Cleveland 'the Magna Via' Inf. from John McDonnell, 1962. Not located by RHH.	None		None
84 Cockerdale Wood. Oldstead	SE 527814 Iron slag heaps; several, some large and very overgrown in slack by small runnel of water NE of Cockerdale House. Hard glassy slag. One heap trenched by R Close and RHH in 1954. Charcoal identified by Prof. Dimbleby as ash (2 pieces), birch (3), hawthorn or apple (1), no potsherds were found but Roman pottery kiln 200 yards North. (RSC & RHH)'	Small stream or runnel close by		Hist. Helmsley 1963 p. 458, Appendix K
85 Scawling Gate and Farm. West of Oldstead	SE 526806 Place name indicates iron slag heaps			None
86 Hawnby Ladhill Gill	SE 55019378 A group of over 60 bell-pits, 17-18 ft dia x 6-7 ft deep, on a very good air photo taken by A Pacitto in 1974. Group examined by GWG and RHH, prob. of Ellerbeck ironstone but no slag-heaps or furnaces Foundations of small rect. hut 200 m SW. Miner's dwelling?	Howe Beck		SDAS Tr. 1975, 3 (18), 27.

Location	Remarks	Water Supply	Period	Publications
87 Bilsdale	SE 58-59 951. 1145 AD Smidhesdala. The 'Ironsmiths Dale', now Smiddales. Rievaulx charter 1180. Smith PNYNR 1928, p. 39. Very early med. site judging by name. RHH walked length of this little valley from Kirkhall and Low Mill where the stream Kyloe Cow Beck joins the river Seph. No sign of slag – grown over?' Jet workings on S slope at 650-75 ft OD worked by J Moore 1865.	Kyloecow Beck		Hist. Helmsley & Dist. 1963. p. 459. 72, 116, 123.
88 Low Crosset	SE 576945, SE 574942 Two sites. Large slagheap near tiny stream SW of Low Crosset House. Wm Ainsley to RHH. 1969. Visited RHH.			JGMcD. RH6, 1972, No.16
	2nd site on east bank of Seph close to road above steep bank of river prob. much carted away for road metal. To SE is small copse called Smithy Ellers (Smiths Alders).			No.15 JGMcD
89 Oak House, Laskill	SE 574912 On side of road from lane to Oak House. Slag only. Not visited RHH.			No.14 JGMcD
Woolhouse Croft Cinderhill field	SW of SE 562912 U-shaped mound. Bank 12 ft wide to 18 ft. Much slag removed 100 yards from fence an old farm road and 46 ft long to Bowbridge Beck. Repeated ploughing. Still visible 1971.	Small stream		No.13 JGMcD
90 Grange Bilsdale	SE 572961/2 In triangular field S–SE of house. RHH and party visited in 1969. J Ainsley just finishing haymaking gave them spade to dig there. Iron slag, tiles, red glazed and med. pottery in small hole. No further investigation.	River Seph 200 yards W		No.17 JGMcD
91 Fangdale Beck	SE 568947 Medieval and 19th Century working. John Wood (wheel ploughmaker). Stainton (lost Manor in this region). Iron mined and river diverted to serve it on Bilsdale W (Riev. Chart, 179).			Hist. Helmsley 73, 116
92 Timber Holme, Laskill	SE 566903 Leat and pond, see J G McDonnell in Ryedale Hist. 6/1972.			RHH/6/1972, p.31, JGMcD No.12
93 Birk Bank, Lower Ryedale	SE 359871, 561871 Slag heaps and banks of slag S bank of Caydale Beck Akimside house – to E 1598. Not visited.	Caydale Beck		JGMcD RH 6, 1972.
94 Rievaulx	SE 575830 or 576851 Blast furnace slag. Very large slag heaps. E Exceptionally glassy slag.		16th C 1650	Hist. Helmsley p.175-9. No. 5 Hammersmithy site doubtful.
95 Forge House	SE 576842 Large heaps of slag in slabs. Mossers; Finery/Chafery hearth sites.	River Rye	16th C	No.2 JGMcD
96 Rye House	SE 576847 Mossers near wall on N side of road to Rievaulx; of doubtful origin.			No.3 JGMcD
97 Stainton Bilsdale W side	Cf.91 Iron mined and river diverted to serve it. Ironworks in 1538 with license to dig ore. Riev. Chart. p.179, 311-315, PRO/E. 315/401.			
98 Hagg House Bilsdale E Side	SE 582973 Iron and ? glass slag trenched in Nov. 1975 by DS, JKH, GWG & RHH. Med. sherds.	Tripsdale Beck		None
99 Bilsdale East	SE 590977 Hagg and Ashnuiken. NE side of Tarn Hole Slag heap and 2 furnaces exc. by JKH and J Owen 1975-6 above and N of Tarn Hole Beck.			Prelim. rep. by JKH
100 Harland Moor W Eastmead	SE 676923 W Eastmead, Historia Rievallensis 1824 p.458. 'Near a place called Park Nook on the W side of Farndale are nodules of ironstone of a curious nature – some like flattened hemispheres, having on the horizontal side several cells like a lady's work box (Dogger?). In this place are a considerable number of pits which tradition says were made by extracting ironstone. On the R hand of the hill leading to Farndale is a mound – like a small howe – the end being removed it proved to contain cinders or slag, produced by smelting ironstone similar to that at Park Nook to the left of the road, not far from the slag heap is a quarry of sandstone, which contains iron pyrites, some in veins and others as kidney-shaped nodules, formed by several lamina, one on the other like an onion, with a yellow nucleus. (Dogger). (This is where I took a photo of the two bell pits in 1958). RHH. Two pits 8ft-10ft down into the dogger bed 5 ft wide at base 3–4ft at surface depression – only 2 ft apart here – entirely filled with loose rubble. It would have been much easier to quarry opencast as the roadmen were doing in the 1950s. Bell pits stretch for about ½ mile. Remains of slag heap found by GWG & DS at SE 67469320.	None		Eastmead 1825 'Nodules of richer ironstone some granulated with green specks which seems to indicate the presence of copper? HH App. K459 RFT 1965, p.131
101 West Gill Scarth Gill	Pit Hill Field. Site of former slag heap. Noted by Crosland 1920-30. Now ploughed out. Sample RHH. SE 661953	200 yds W Gill Beck Water		HH. 1963, K.459.
102 Breckon Banks W Sterinn	SE 686944 Old drift excavation here, worked in mid 19th Century. Farndale Old Works. Wm Feather(?) told RHH of slag heaps ¼ mile NE of this – search proved fruitless – undercliff had slipped in severe winters of 1947-63.	Small stream		
103 Oak Crag. 50 yds SE of house?	In field east of road and old thatched cruck house of 16th century or earlier D Leng (Mason) was making channel for run-off of sheep dip tank. Bowl shaped hollow is natural yellow clay, 9 ft by 3-4 ft full of slag. On NW a platform of large stone 7 ft wide length not ascertained stones burnt on top. Slag spread to part of stream – no pottery found. Site had to be filled in as channel was for use later. 9-12 ft below turf. On the Moor ¾ mile E are Stone Hagg ancient ironstone? quarries. SE SE 678962	100 yds to small stream		Note in YAJ. 166 Vol. XLII, 1968, p.110 RHH.

Location	Remarks	Water Supply	Period	Publications
104 Blakey Gill	SE 678978 Iron slag in tumble of loose stones on N bank of small spring? No sign of large heap – confirmed by farmer H A 1964.	Gill Beck ¼ mile		
105 Middle Heads	NZ 633007. Trevor Dodsworth of Pickering reports iron slag on bank of stream – not found RHH 1974. Ruin of large house- rebuilt 1683 to N of this and on very old medieval way.			
106 Green How Botton – Plane Hill. Cleveland Hills.	NZ 587033. Mound of slag 10-14 ft dia. on nat. hill (height irregular) (dogger?) Close to small stream and brushwood. Trial hole by farmer M Grimstone, R Close, Bill Cowley and RHH. 1962. Burnt stones appeared to form curved hearth – not fully excavated. 8 sherds. 5 green-glazed and 1 small piece of strap handle 13th-14th century. Rim of what may be crucible?			Note, YAJ. RHH.
107 Ingleby Greenhow Shepherd Close	NZ 594029 Slag heap reported by RS Close to RHH 1962. not visited. Just above is Blue Mells Trough, 19th Century ironstone drift mine.			
108 Bransdale. Mitchell Hagg. Cinder Hill	SE 632923 Very large heap of slag. 30 paces E–W by 25 N–S and 4 to 8 ft high. Broken 17th-18th century stone chimney on top. Foundation of dwelling to W. Trial hole produced green glaze 15th-16th century? In large walled enclosure.	Springs? Nearest stream ¼ mile away to N		None. Unexcavated. Mentioned in Survey 1637.
109 Mitchell Hagg Wath	SE 640918 Small slag heap revealed by woodmen hauling logs over ford in 1938. Some slag left 1974. RHH.	Hudge Beck		
110 Ousegill Beck. Ankness	SE 641923 Small slag heap on W bank of beck, now grassed over, Seen by RHH. 1965. Hollow way leads NE to Rudland slack	Ousegill Beck		None
111 Bransdale On E of Blowath Beck	SE 624988 Large piece of tap slag brought to RHH by J N Grayson of Helmsley making forestry road 1960. Site now planted. (Not visited RHH)	Small spring		None
112 Sleightholmedale Water Fall Bransdale	SE 649904/5 Semi-circular bank of iron slag and earth. Excav. RHH. J G McDonnell 1970. 2 trial trenches. Plan RHH. No furnace found, no pottery. Iron spike of hoe or rake only find. Slag and burnt earth in trial hole near stream. Charcoal platforms 1 mile SW under Aldergate bank.	Stream close by		Ryedale Hist. Vol. 6, 1972. p.33-35 JGMcD Plan 2 p.33-35
113 Pockley Moor Cinder Hill Wath	SE 612930 Small heap of iron slag 15 ft by 2 ft highest point on old track 100 yds of Bonfield Gill Beck? Several moor coal piles close by. To the west of stream are 3 moory intakes, central one was ploughed in 1970 and large black patch of charcoal and slag revealed at SE 609931.	Beck 100 yds Dist.		HH 1963 RFT 1968, p.171
114 Rudland Beck	SE 64859267 Slag heap found by DS and GWG in 1976.	Close to stream on W		None
114(A) Bransdale. Hodge Beck	SE 63879196 Small slag heap on E Bank of Hodge Beck alongside a trackway and near an old gatepost with inscrption 'CD' (Charles Duncombe) and '1804'. Site 200 m NE of No.109 above. Found by GWG and DS 1976.	Hodge Beck		None
115 Levisham Moor	SE 830922 Site of iron workers' hut. Late Iron Age pottery. Finger tip cup under rim. Hut outlined by postholes; 25-30 ft dia. porch to E surrounded by two concentric ditches, 30-40 ft dia. Outer dia. 3 ft 6 ins, inner 2-3 ft deep (30 ft dia). October 1964, D Smith, R Close & RHH did excavation in area. Instead of expected hearth, we found small domed clay furnace 3 ft 6 ins. dia base 13 in x 16 in inside dia. 16 in high. Bee skep shape of clay and stone on underside with dome vent lined with pieces of iron slag and remains of clay hearth beneath – all in area 8 x 10 ft. Only one small vent hole in dome(from RHH, 1964) Did not see final excavation – April 1965 by JCR. and party. Site scheduled 1966 to prevent Syndicate ploughing it out. Sold to Mrs J Shaw of Newton on Rawcliff 1973. Iron slag heap E of hut and slag found in ditches of 3 other earthworks to NE. (Now purchased and preserved by National Parks).	Pig Trough stream dries up most of year		Excav. Scar. & Dist. Arch. Soc. 1964/65. Ref. JGR forthcoming. RFT 1965, 122 Challis & Harding BAR 20/1. (pottery only)
116 Levisham Beck	SE 839918 Large slag heap, grass covered on W Bank of Beck several ft long, 2-3 ft high. Trenched Oct. 1957 by members of Scarboro' Arch. Soc., R S Close, H Frank and RHH. 25 x 6 ft wide. Only find part of 14th century medieval jug. No furnace found. First mention of iron working here 1210 AD 1314 rent of smelting works at Levisham? VCH. Vol. II, p. 348 says this is very low and suggests early origin of forge. Even as late as 1438-9 they seem to have been at work. NRR 33. Note: Duchy of Lancs record Vol. 1 p.101- 1661 a forge at Levisham let to Ino Peycey 2/6 p.a. Charcoal – identified by Prof. G W Dimbleby – large pieces of oak – incredibly slow grown.	Levisham Beck		NR Rec. Ser. p.42, 45 Close Rolls 3.1310. Smelt works of Bolbeck 1314 AD. P R Henry III. 1255 forge in Levisham Wood.
117 Newton Dale Pifelhead End	SE 84509511 Slag found by Mrs Hollings. Some in Beck. Not seen RHH. Slag found by DS, 1975 – covered by Forestry plantation.	Havern Beck Small beck below.		SDAS Tr. 1975 3 (18), 33.
118 Walker Pit	SE 823928 1859-66. James Walker from Leeds (Ironfounder) sunk pit which was complete failure; poor quality ore and inrush of water.			
119 Rhumbard Snout	SE 819912 Pit and spoilheap visible 1974; burnt stone, no slag.			
120 Grove House Levisham Station	SE 819911 Mr Holmes of Grove House (1974) told RHH and DS he found iron slag in his garden. Not visited. Pit 150 yds. to NE marked on OS map.	Small stream close by		SDAS Tr. 1975, 3 (18), 33.

Location	Remarks	Water Supply	Period	Publications
121 High Dalby (opp. Rose Cottage)	SE 832890 On east bank of beck, T Hoggart reported iron slag and seam of ore exposed in bank by erosion of stream. Slag probably medieval (K Green, Gamekeeper). 1 mile E of Stonehouse Rigg, a Roman coin, a jet bead and iron slag was found by TH.	Staindale Beck		Waites, 1964, RFT, 1965, App. 131.
122 Dalby	2 sites at Dalby mentioned in Waites but no references.			
123 Grosmont, Smithy Holm Wood	NZ 830050 G Young, Hist. Whitby Vol. 2, p. 762 (note) 1817. 'There has been a forge on the opposite side of the river (Mirk Esk) in a place called Smithy Holm. The road leading up from the river to the Alum Garth is paved with slag'. Old Workings shown on 6" OS map 1916 as 'Jet Working' (830051) Not visited RHH. Grosmont Bridge – site of iron working. Also mentioned by Young 1817.	River Mirk Esk		JCA 1884, p.48.
124 Grosmont Priory	NZ 828057 On N bank of river Esk R J M Rastall of Grosmont Priory showed RHH, in 1946 a 15" layer of slag, charcoal, bones, tiles and potsherds exposed by floods – only 3–4" above normal water level. Some potsherds and tiles were sent to the BM and Bruce Mitford said they were late medieval 15th-16th century and tiles could be later. None were Roman. Much disturbed area to SW of 19th century iron-workings.	River Esk		

A Cleveland Ironstone Pillar

J E Hemingway

The North-East Coast Exhibition, held in Newcastle upon Tyne from May to October 1929, was mainly devoted to an extensive demonstration of machinery and industrial products of many kinds, but with only few source materials such as coal, clays and ores. Among these latter, however, was an almost entire seam (Pillar) sample of Cleveland ironstone, mined from Skelton Park Mine (NZ 644180) in north-east Yorkshire. This impressive specimen, which has survived, is in the form of a single column 33 inches square at the base and tapering slightly through its height of 9 ft 4 ins. The provenance of the pillar 'Skelton Park Mine' is deeply cut into its west face and 'Skelton Park Mines' on its east: the final 's' was a late addition presumably in acknowledgment of the other adjacent mines in the area such as North Skelton, South Skelton and Skelton. These and nine others were all worked by Dorman, Long & Co. at the time of the exhibition, but the company's name has been lost from the column.

On the closure of the exhibition the column was moved to the University of Newcastle upon Tyne (then Armstrong College) where it was erected in an obscure and very confined quadrangle. By 1966, when few realised its significance or indeed its unique character, it was pulled down as a preliminary to its intended destruction and only after protracted vicissitudes was it re-erected in the grounds of Close House (NZ 125657), the recreational estate of the University of Newcastle upon Tyne. A descriptive plaque has now been added.

The column is an almost complete sample of the Main Seam of the Cleveland Ironstone Series of Middle Lias (Jurassic) age in its best development. It lacks only the so-called Sulphur Band, a pyrite-bearing oolite up to 6 inches thick, which normally caps this seam. Although this had at times been used in Middlesbrough and Newcastle upon Tyne as a source rock for the making of sulphuric acid, it was valueless – and indeed harmful – in iron-making and in consequence was normally left unmined in the roof.

The quarrying and mining of the Cleveland iron ores, on which the Teesside iron and steel industry was founded, started in north-east Yorkshire, after preliminary difficulties, in the 1850s. It continued until 1964 when the last mine, Skelton North, was closed. The mining property of Skelton Park, which was worked from 1872 to 1938, lay near the northern limit of occurrence of the Main Seam, where the ore is not only thickest, but also richest, averaging approximately 32% metallic iron. Its recorded thickness here was 9 ft 10 ins in comparison with a maximum of 11 feet in the nearby Eston property. To the south and south-east of this area the seam splits with the development of an intervening shale which itself thickens southwards: in addition the iron content is also reduced southwards. These factors, together with the importation of richer and cheaper ores from overseas, were largely responsible for the abandonment of the ore-field.

The ironstone pillar has suffered remarkably little from its exposure of nearly 40 years to a city atmosphere. The siderite ($FeCO_3$) which forms almost one-third of the rock is now reddish purple at surface, in contrast to the grey-green chamosite, a complex ferrous aluminium silicate (c 30% of the rock). Many of the chamosite ooliths are bleached but the few calcitic fossils are almost unaffected and stand out in mild relief. Now that the column is in what is essentially a country atmosphere its weathering pattern is being changed, with increased biological influence. Already it is greened over in parts.

CLEVELAND IRONSTONE

This pillar is a cross-section of the Main Seam of
Lower Jurassic Ironstone.
3 metres thick and containing 32 per cent of iron,
from Skelton Park Mine, Cleveland.
This ore was the foundation of the
N. Yorkshire iron industry,
and was worked for over 100 Years
1850 - 1964

The Skelton Park pillar sample was not the sole example of the Main Seam in the exhibition, though it is the only one that has survived in its original form. The base of a block of the Main Seam 47 x 15 inches and 21 inches thick, but of unknown original thickness, lies in the grounds of the Hancock Museum, Newcastle upon Tyne. The incised inscription is partly obliterated but reads:

Cleveland [Ironstone]
Pease Partners
Lingdale Mine.

The Lingdale property (NZ 676165), opened in in 1878, was one of four originally mined by Pease & Partners Ltd and lay in the southern and less rich part of the ore-field. The median bed of shale averaging one foot in thickness occurred throughout the mine and separated the lower block of ironstone (2 ft 6 ins) from the upper (3 ft 9 ins). Furthermore the iron content averaged only 26-28%, but despite these disadvantages the mine was one of the last to close (1962) on the abandonment of the field.

At the present time the Main Seam is only rarely exposed and that principally on the adjacent coast where it may be seen in its less rich and split form. Because of this, these two seam samples are of outstanding importance. The Skelton Park pillar in particular is unique and both merit their continued preservation as standards of reference.

The Iron Industry of East Denbighshire during the late Eighteenth Century

John T Turley

ABSTRACT
The iron industry of East Denbighshire during the second half of the 18th century was dominated by the Bersham Ironworks, which, under the control of the Wilkinson family, was transformed into a concern of national significance specialising in the manufacture of castings and precision engineering. The coincidental introduction of John Wilkinson's improved cannon and cylinder boring techniques at Bersham when such techniques were necessary for the successful manufacture of Watt's steam engines assured Bersham of a monopoly in the supply of cylinders for these engines that lasted until 1795. However, there were no special factors to retain a specialised ironworks in East Denbighshire other than the acumen of an entrepreneur and the skill of his work force, and once these were lost the demise of the Bersham Ironworks was inevitable.

The second half of the 18th century was a period of technological revolution and economic expansion in Britain's iron industry. Freed of the constraints on growth, which persisted while charcoal was the only satisfactory fuel, the ironworks with their coke-fired blast furnaces were now able to exploit the vast fuel resources of the coalfields, and the output of iron increased accordingly. In 1788 Britain's annual output of iron was 68,000 tons, and this rose to 125,000 tons in 1796 and 250,507 tons in 1805 (Figure 24). In 1788 only 26 of the 85 blast furnaces then in use in Britain continued to depend on charcoal, and three years later only 11.8% of the country's pig iron came from charcoal blast furnaces.[1]

To understand the reasons for this large increase in the output of pig iron, which the widespread use of coke made possible, it is necessary to turn in part to the political events of the second half of the 18th century. T S Ashton in his study of the British Iron and Steel Industry during the Industrial Revolution[2] has clearly demonstrated the effect of war as a factor fostering the growth of metallurgical and associated industries. In his words 'to the ironmaster the actual clash of arms sounded the advent of a new prosperity', and John Wilkinson as early as 1779 acknowledge war to be 'the sinews of business'.[3] The outbreak of hostilities meant an increased demand for iron in the form of cannon, gun carriages, shot and firearms, and large orders were placed by the Office of Ordnance and trading companies such as the East India Company with those ironworks that could supply such equipment. The amount of British iron that was exported was negligible and the restriction on trade occasioned by the outbreak of hostilities gave British ironmasters a firmer hold on their domestic market by protecting them from foreign competition. In each of the wars of the 18th century a trade boom was generated in Britain's metallurgical industires, but after each war came trade depressions during which the ironmasters painfully adapted their concerns to the products of peace; 'under the influence of the political storm the normal wave of the trade cycle became a billow on which the iron trade was carried high for a period, only to be dashed later on the rocks with a force proportional to the height from which it had been hurled'.[4] In 1756 the outbreak of the Seven Years War led to a steep rise in the price of iron, 'no bar iron was to be sold at Liverpool under £17 a ton'[5] and there was a rash of new furnace building which lifted Britain's iron industry out of the stagnant waters of the first half of the 18th century. Some 11 new blast furnaces were brought into operation between 1756 and 1763 and many ironworks, including Bersham in East Denbighshire became entirely involved in the supply of armaments and ammunition. In the following eleven years of peace only four new blast furnaces were built, but with the onset of the American War of Independence and its European consequences, a rash of new furnace building occurred, particularly in Yorkshire and Derbyshire and by 1780 the price of bar iron was twice its level of 1740.[6] By 1805 under the stimulus of the Napoleonic Wars, Britain's output of pig iron had risen to over 250,000 tons per year.

The large increase in the output of iron and the number of blast furnaces in Britain during the second half of the 18th century was not matched by a corresponding increase in iron production or in the number of blast furnaces operating within East Denbighshire. The three charcoal blast furnaces which had been adapted to use coke and which were functioning in 1750, at Bersham, Plasmadoc and Ruabon, had all been abandoned by 1788, and during that period only one new coke-fired blast furnace was built in the region at the Bersham Ironworks.[7] One more blast furnace was built in 1791 at Ruabon, and in 1796 the Brymbo furnace began to produce pig iron, but this was at the expense of the Bersham coke furnace that it was designed to replace. The outcome was stagnation in the iron output of East Denbighshire at a time when the national output of iron was increasing rapidly. In 1791 East Denbighshire's share of the national output of pig iron had fallen to approximately 0.9% compared to 4.7% in 1717, and even in 1796, when both the new Ruabon furnace (Ruabon II) and the Brymbo furnace were operating, the proportion remained below 2%. By the end of the century the iron industry of East Denbighshire had little significance in national terms as a producer of pig and bar iron, and the output that was achieved was almost entirely used to satisfy local demands.

The main reason for the relative decline in the importance of East Denbighshire as an iron producing area during this period was the continuing inadequacy of internal communications and the absence of effective transport links with other parts of the country, compared to other regions that had come to be better served in this respect. The growth of the canal system after 1760, had brought many advantages to those iron producing areas which, unlike East Denbighshire, were in contact with the evolving network. Birmingham's first canal, for example, which joined the city with the Staffordshire and Worcestershire Canal in 1772, was designed with the express purpose of 'uniting the numerous hearths and furnaces of industrial Birmingham with the prolific coalworks of the contiguous mining districts of South Staffordshire'.[8] The trunk lines of the canal network which linked together with rivers Trent, Mersey, Severn and Thames and their respective ports and which were completed by 1790 opened up an enormous potential for industrial development by creating 'interior lines of communication by water carriage across the heads of the river systems, breaking the economic watersheds which run down the spine of the country'.[9] The central pivot of the network lay between Birmingham, Coventry and Stafford, and there were eventually to be 160 miles of canals in the immediate vicinity of Birmingham, upon which the enormous industrial expansion of the Central Industrial Region during the late 18th and early 19th centuries was to be based.

The ironworks of East Denbighshire, unlike their competitors in the Midlands, South Wales and Lancashire, gained little from the canals which were completed before 1805. Their nearest access to the national network was at Preston Brook, an overland journey of 26 miles from Wrexham. The Chester Canal which was nearer had no link with the Grand Trunk Canal and was of no advantage to ironworks in East Denbighshire. Without easy access to the national network of cheap water transport provided by the canals, the iron industry of East Denbighshire could not compete effectively in the sale of pig iron and bar iron to national markets with more favoured areas, and there was no reason to establish new blast furnaces in the region over and above those that were sufficient to meet internal demands for iron.

However, despite the drawbacks outlined above, an iron industry continued to survive in East Denbighshire during the second half of the 18th century, but in so doing it became increasingly specialised and identified with one concern in particular, the Bersham Ironworks. Building on the foundations laid at Bersham during its long association with the Coalbrookdale Company, and introducing an expertise and pioneering inventiveness that few other ironmasters could equal, the Wilkinson family made the Bersham Ironworks the core of a company whose output, particularly of ordnance and vital components of steam engines, was technically so excellent that there was a nationwide demand for it. The activities of the remaining ironworks were overshadowed by the success of the Bersham Company, and they came under the control of Edward Lloyd Rowland who continued to produce bar iron and rod iron to satisfy the local demand, for which Bersham, with its more profitable markets elsewhere, did not cater. By the end of the epoch, however, his activities too were closely linked with those of the Bersham Company, and the new Ruabon furnace built in 1791 by Edward Lloyd Rowland provided much of the pig iron consumed by the Bersham Company.

It is clear, therefore, that the evolution of the iron industry of East Denbighshire during the second half of the 18th century hinged on the progress that was made at the Bersham Ironworks and that these developments and the factors responsible for them merit detailed consideration. Many of the events which occurred at Bersham have been the subject of published historical research, including that of A N Palmer,[10] and the enterprise of the Wilkinson family has been examined by several authors, but much hitherto unused evidence from contemporary sources included in the Boulton and Watt Collection, the Chirk Castle Manuscripts and the Plas Power Papers provides further insight into the operations at Bersham, and the contribution made by the Bersham Company to industrial developments within East Denbighshire and Britain as a whole. This evidence, together with published sources, has provided the basis for the following case study.

THE BERSHAM IRONWORKS 1753 TO 1796: A CASE STUDY

i) The origins of the involvement of the Wilkinson family in the iron industry of North-East Denbighshire

The involvement of the Wilkinson family in the iron industry of East Denbighshire began in 1753 when Isaac Wilkinson and his son John took the lease of the Bersham Ironworks for a period of seven years. Two years later, on 1st September 1755, a further lease of the ironworks was made to Isaac and John Wilkinson by William Lloyd who was then 'seized of the said ffurnace . . . subject to the estate for life of Catherine Roberts', and under the terms of this agreement the Wilkinson's leased the 'said ffurnace and premises for the term of 30 years at the yearly rent of £60'.[11]

Before moving to Bersham, Isaac Wilkinson had been involved in the iron industry of the Furness District of Lancashire, where he had specialised in foundry work, as furnace fireman at Cookson and Company's Brigfoot furnace and subsequently as chief caster or pot founder to the Backbarrow Iron Company.[12] At the Backbarrow Ironworks he perfected his skill, and was engaged in the production of a wide range of cast iron products, including pots, pans, boilers, skillets, cylinders, rollers, sad irons and box irons. His work was every very remunerative and in the year 1744 he was owed £770 by the Backbarrow Iron Company for foundry work.[13] In 1748 he left the Backbarrow Ironworks, and with the capital derived from his potfounding, took control of an iron furnace and forge at Wilson House near Grange-over-Sands.

The movement of the Wilkinson family to East Denbighshire in 1753 probably resulted from two main factors. In the first instance the Bersham Ironworks was in a better situation than the ironworks in Furness to cater for the market for cast iron goods in the North-West of England and North Wales which had become centred on Liverpool and to a lesser extend Chester. Isaac Wilkinson already had important business contacts in Liverpool and 'some Liverpool Gentlemen' were involved with him in his early activities at Bersham.[14] A second, but equally important reason, however, was the progress that had been made at the Bersham Ironworks in the production of cast iron goods during its long association with the Coalbrookdale Company. Coke had been used as a fuel in the blast furnace from as early as 1721 and the pig iron produced was far superior to that of charcoal blast furnaces for the manufacture of cast iron products. The ironworks in Furness, because they had no easy access to coal deposits, continued to depend on charcoal to meet their fuel requirements. An air furnace and moulding facilities had been added to the Bersham furnace in 1733, and by a process of experimentation and contact with Coalbrookdale the work force had become very skilled in the art of iron founding. Such a concern situated on a coalfield and relatively near to markets in the North-West of England was an ideal base from which the Wilkinson family, with their interest in foundry work, could operate.

ii) Functional operations at the Bersham Ironworks before 1775

During the period 1753 to 1775 the original Bersham Company and the New Bersham Company which subsequently replaced it were primarily engaged in the production of a wide range of cast iron products. The early years coincided with the Seven Years War, and this provided a major stimulus for the Bersham Company, as it did for most other companies engaged in the iron industry. At Bersham, the opportunity was taken to engage in the production of cannon and other ordnance, which in the period of Quaker control had not been produced. This required boring facilities, and a boring mill was added to the furnace and foundry at the Bersham Ironworks. Bored articles such as cannon and steam engine cylinders could command a much higher price than unbored products; later in the century cast iron goods were sold by the Bersham Company for 18 shillings per cwt whereas bored articles cost 30 shillings per cwt, the weight of the latter being determined before the articles were bored.[15] The production of cannon for the Office of Ordnance was noted by Palmer in his reference to the now lost first ledger of the Bersham

Company, under May 28th 1764 the Office of Ordnance is charged with 32 guns value £238.12.9d and there are many other items relating to charges for guns consigned to ships in the ports of Liverpool and London. The shells mentioned were 4$^{2}/_{5}$ inches in diameter'.[16] The same ledger also made reference to other cast iron articles made at Bersham, including box heaters, callendar rolls, malt mill rolls, sugar rolls and pipes, and in his patent of 1758 for a new method of moulding Isaac Wilkinson described its use in producing 'guns and cannon, fire engines, cylinders, pipes and sugar rolls'[17] all of which were presumably made at Bersham.

In order to improve the quality of the pig iron used at Bersham, and the standards of the articles produced for sale, various important innovations were made by Isaac and later John Wilkinson, which kept the Bersham Company in the forefront of technical progress. Between 1756 and 1758 a Newcomen steam engine was erected to raise water, after it had passed the water wheel, which drove the furnace bellows, and return it to the race so that it could be used again, and in March 1757 Isaac Wilkinson patented a new type of furnace bellows. These were cast iron bellows and formed part of a blowing engine which at Bersham conveyed the air to the furnace 'from a considerable distance' by underground pipes.[18] This machine was later perfected by John Wilkinson, and such blowing engines were produced and sold by the Bersham Company. A report in the Cumberland Pacquet of April 1st, 1777 recorded that 'a pair of bellows . . . at Neterhall furnace . . . were cast at Birsham, near Wrexham and weigh exclusive of the pistons 146 cwts'.[19] It seems clear also that the blast furnace in use in 1753 at Bersham was abandoned and replaced by a new furnace which was independent of water power.[20] The foundry was enlarged and equipped with four reverberatory furnaces, the existence of which in 1775 is confirmed in the report of the Marchant de la Houlière to the French Government.[21] This records that '80 cwts of cast iron were placed in four reverberatory furnaces . . . and a 32 pounder cannon run into the mould'. The charge was made up of pig iron and a significant proportion of scrap including 'a damaged forge hammer' and 'half a broken cannon'. Using these furnaces de la Houlière reported that 'cylinders . . . can be made 76 inches in diameter together with working barrels for pumps, water pipes, cannon balls, bombs, plain or toothed wheels, pinions, plates, grids, doors and porches – in general all sorts of cast iron work and even most of the things we make of wrought iron. These reverberatory furnaces are heated with raw coal . . . and are charged with crude or scrap iron, pieces of cannon, anvils, hammers, old scrap iron castings or bars of pig iron'.

iii) The Role of the Steam Engine in the Development of the Bersham Ironworks after 1775

The year 1775 marked the beginning of a new phase in the development of the Bersham Ironworks and a new period of prosperity that was to continue for two decades. The origins date to the year 1774 when John Wilkinson devised and patented a new method of boring cannon and cylinders.[22] This replaced the former method, using a rotating bar and cutter, with the cannon securely fixed to a moveable carriage, by a system that utilised a lathe on which the cannon or cylinder could rotate around a fixed boring bar along which the cutting tool could traverse. Using this method a bore could be produced that was accurate in both longitudinal and cross sections, unlike those produced by the earlier method, and its application at the Bersham Ironworks considerably enhanced the New Bersham Company's reputation for producing bored articles.

The introduction of this new boring technique at Bersham also occurred coincidentally at the time when James Watt was seeking to perfect a new type of steam engine, making use of a separate condenser and potentially far more economical in its use of fuel than earlier Newcomen engines. His experimental machine was set up at the Soho works of Mathew Boulton in 1773, but failed to perform satisfactorily as the cylinder which was manufactured from tin collapsed in use.[23] Shortly afterwards a new cast iron cylinder manufactured at Bersham and bored using John Wilkinson's patented system was obtained and this proved eminently suitable for the task as James Watt himself wrote in a letter to John Wilkinson 'the cylinder I had from you was rough at first but it is now got smooth and does pretty well, I may say very well'.[24] The success of the experimental engine led James Watt to order a 50 inch cylinder from Bersham for a steam engine to be erected at the Bloomfield Colliery, Tipton and this in his words was 'by much the best I ever saw of that diameter' it 'doth not err the thickness of an old shilling in no part'.[25] This engine did the work of the 72 inch Newcomen Engine that had originally been ordered for the Bloomfield Colliery with a considerable saving in fuel.

The success of Watt's steam engine at Bloomfield was followed by a spate of orders for the new machine and this had far-reaching consequences for the Bersham Company, which alone had the facilities to manufacture 'inside and outside cylinders, bottoms, pistons, lids and stuffing boxes and condensers'[26] with the accuracy that was now necessary. Writing to a customer in December, 1778, Mathew Boulton stated 'such parts as relate to the engine end of the beam must be had at Bersham in Wales as there is no other proper apparatus in Britain for producing the parts with that truth and exactness we require'.[27] For almost twenty years the Bersham Ironworks enjoyed a virtual monopoly in the supply of cylinders and other precision castings for Watt's steam engines, a fact confirmed by James Watt in a letter written in July 1795, 'It was only after many expensive experiments that Mr Wilkinson attained the degree of perfection in casting and boring which could satisfy us. We in consequence constantly recommended his castings, and in the course of 20 years have not erected more than three or four engines the cylinders of which were not of his manufacture'.[28]

The expansion of work connected with steam engines at Bersham after 1775 also coincided with a growing demand for ordnance as a result of the American War of Independence and the outbreak of hostilities between France, Spain and Holland and Britain in 1778. The new boring techniques introduced at Bersham were originally intended for use in the manufacture of cannon and other ordnance and in this field they were equally successful. Writing to Boulton and Watt in 1779, John Wilkinson reported that 'the demand for guns and ordnance' was 'great and pressing at the Office and India Co.,'[29] and the heavy demand for both ordnance and steam engines placed a serious strain on the Bersham Ironworks, which alone could cater for the need. The problem, however, was not resolved at the expense of steam engine work as Wilkinson himself confirms: 'I shall continue to sacrifice (ordnance manufacture) to the Engine Bench as I have done, considering it is a more lasting trade than the other which the present war alone occasioned'.[30] In the same letter he remarked that 10 tons of ordnance could be produced in the time and with the labour necessary for 'engine work', and the temptation to sacrifice the steam engine for lucrative ordnance work must have been considerable.

With its unrivalled excellence in the field of specialised iron founding and precision boring, the Bersham Ironworks expanded rapidly after 1775 into 'a concern of great magnitude . . . displaying such a profusion and tumultuous melody of machinery as to leave the mind not a little astonished at the sight of it'.[31] Detailed records which would provide a complete picture of the scale of operations at Bersham and the profitability of the concern are unfortunately unavailable, but certain contemporary data, including extracts from the original Bersham ledgers transcribed by a Mr Fawcett in 1795, do provide some information. Between 21st May, 1788, and 5th October, 1793, for example, the firm of Boulton and Watt purchased articles from Bersham to the total of £8,688, and these included 36 cylinders, 4 wrought iron boilers, and other cast iron articles including 'sun wheels and planet wheels'.[32] A 24 inch cylinder and its accessories was said to weigh 21 cwts 1 qt. and at a cost of 30 shillings per cwt its purchase price was £31.19.4d. Orders for ordnance also expanded, and in 1786, when writing to his foreman at Bersham, John Wilkinson gave instructions for 160 four pounder cannon 4 feet long and a number of three pounder cannon, 3¾ feet long, to be made for the Office of Ordnance.[33]

In addition to the orders for cylinders, boilers and other components received by way of Boulton and Watt, the New Bersham Company also received orders directly from customers for complete steam engines, and these were manufactured and assembled for testing at the Bersham Ironworks. Certain of these engines were the subject of a dispute between John Wilkinson and Boulton and Watt, and a list compiled by William Wilkinson indicates who purchased these engines and where they were erected.[34] It appears that 50 steam engines at least were manufactured between 1776 and 1795 for use by lead mining, coal mining, tin mining, iron and canal companies. John Wilkinson also made extensive use of steam power in his own undertakings and by 1796 had 20 steam engines at work, 9 at Bradley, 2 at Snedshill, 1 at Willey, 1 at Wilson House, 4 at Llyn y pandau, 3 at Brymbo and 3 at Bersham.[35]

It is clear, therefore, that throughout the Bersham Epoch the demand for the specialised products of the Bersham Ironworks continued to expand, particularly after 1775, when new boring techniques were brought into use, and the output directed increasingly towards the needs of the steam engine. This happened despite the increasingly unfavourable geographical situation of the Bersham Ironworks compared to other concerns that had easier access to the evolving network of canals and the cheap transport that they could offer, and can only be explained by the fact that, of the many ironworks that existed Bersham alone had the facilities and the expertise to manufacture certain categories of goods. Customers of the New Bersham Company had little choice other than to pay the price demanded and to meet the transport costs involved, as there was no other comparable source of supply for the commodities they required.

iv) The Transport of manufactured goods from the Bersham Ironworks

Under the skilful management of the Wilkinson family the demand for the specialised output of the Bersham Ironworks increased, and it s marketing area was extended to embrace most parts of the British Isles and even the mainland of Europe. Much of the ordnance produced was delivered either to Liverpool or London by the Company and at that point its responsibility ceased, but in the case of steam engine work, the many cylinders, condensers, pumps, pistons and other components had to be delivered to the site where the engines would be used, and assembled there. The tin mines of Cornwall, where Watt's engine rapidly replaced the less economical Newcomen engines, were a major early market, but particularly after 1782, when the sun and planet gear made rotary action possible, steam engines of James Watt's design were set up in all the industrial regions of Britain.

The transport of cannon and other ordnance and the large cylinders and other steam engine components was a major problem for the New Bersham Company. The roads of the day were far from adequate to cope with the movement of heavy castings weighing several hundredweights, and the cost added considerably to the final selling price of the articles. Wherever possible, long overland journeys were avoided, but the landlocked position of the Bersham Ironworks and its relative remoteness from the network of canals meant that land transport had to be utilised. The Company maintained a labour force of carriers which used teams of horses to pull the heavy castings, and it appears from the limited data available that this added approximately 3.75p to each ton of cast iron articles every mile that they had to be transported. (To deliver one ton of castings from Bersham to Eastham for transhipment to Liverpool cost 17 shillings. The Bow Engine cylinder and its associated castings weighing 55 cwts could have been delivered overland to London at a cost of £25, and this would have added 30% to its original purchase price).[36]

In view of the high cost of land transport the usual procedure was to transport articles to Chester or Liverpool from where they could be despatched by sea to their destination, or, if the destination was inland, the goods would be taken to Preston Brook and loaded on to canal barges. Some difficulty in the use of sea transport occurred in the early years as boats were not always available when needed, and the Bersham Company purchased a brig the 'Bersham', replaced in 1779 by two others the 'Mary' and the 'Peter', to cater for the growing volume of trade.[37] When overseas destinations were involved the journey was often complicated and very expensive, as illustrated by the fact that when the 'Peter' sailed for Nantes with the steam engine manufactured for Mr Jarry, 100 guineas were necessary for 'all the port charges in England and France' and 'an indemnification of £300 for the return of the vessel from France'.[38]

The use of canals for the transport of cylinders is mentioned in a letter from James Watt to John Turner, the clerk at Bersham in 1778, 'we beg you to forward Mr Wright's engine goods by the cheapest conveyance to the nearest part of the long trunk navigation alias the Staffordshire Canal with orders for the boat owner to forward it'.[39] On occasions, however, the handling of cylinders by inexperienced crane operators employed by the canal companies led to damage being caused to the relatively brittle castings and for this reason long journeys using carts and teams of horses were often made, despite the higher cost involved. This is confirmed in a letter of 1791, 'the last cylinder which went to Ocker Hill (Tipton, Staffordshire) was taken there by our team . . . the same might be done with this', a decision occasioned by damage to a previous consignment by crane operators at Preston Brook.[40]

v) The Site and Morphology of the Bersham Ironworks

The form and extent of the Bersham Ironworks as it was during the third quarter of the 18th century can be reliably deduced from a plan of the works contained in a lease of a 'Quillet of land – part of Erw Furnace' drawn in in 1763. This shows that the ironworks consisted of a large building housing the foundry and furnaces, a smith's shop, a store room, a warehouse and a dwelling house, and most of the buildings were located on a small area of flat land between the River Clywedog and the steep northern valley side (see map). The blast furnace itself rested against the valley side and could be fed with coke, ironstone and limestone from the 'coaking banks' which were themselves the terminus of a wooden railroad used to transport raw materials to Bersham from Rhosllanerchrugog. Power for the ironworks came from an overshot water wheel which derived its water supply, by way of a race, from a weir on the Clywedog river, although it is possible that by 1763 a Newcomen steam

engine may also have been functioning at Bersham.

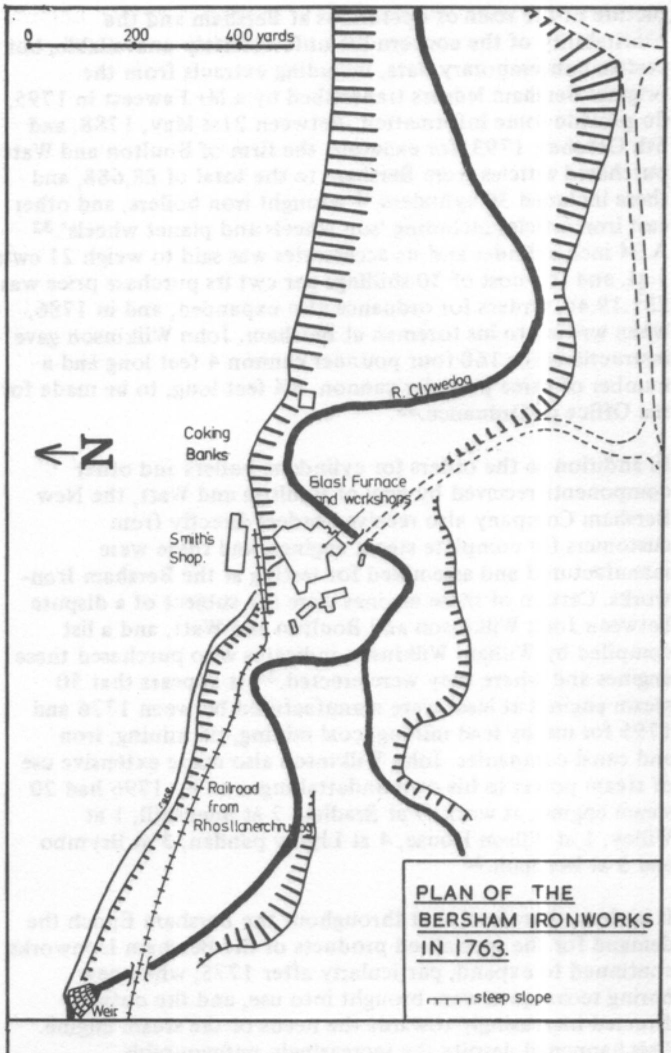
With the establishment of the New Bersham Company in 1763 and the increased demand for its products that soon followed, it was apparent that the ironworks could no longer function effectively within the limits of the original site and in buildings which had changed little since the 1730's. To overcome this problem a large area of unoccupied land between the River Clywedog and the southern valley wall was leased by the Bersham Company from the Myddleton family who owned the land and new buildings which included a cannon foundry and an engine house were erected on the site. The course of the Clywedog was also straightened to make the best possible use of the limited space available.[41] Several years later further land downstream from the original site was also leased by the New Bersham Company, and here a new boring mill was constructed in 1779. This was supplied with water power by a race fed from a new weir, and its main purpose, as John Wilkinson confirmed in a letter to James Watt, was to bore cylinders for steam engines – 'our cylinder pit is now at liberty to supply new demands. Can you give me any proper size to make on speculation for I wish to keep a set of hands employed entirely on that article'.[42] In 1785 a new lease was negotiated by the New Bersham Company with Richard Mydddleton, whereby the land on which the ironworks then stood, together with that occupied by workmen's houses, some 68 acres in all, was leased by the Company for 100 years at a rent of £100 per annum.[43]

The New Bersham Company also took control of the Abenbury forge which had been reconstructed in 1726, and which was capable of producing 80 tons of wrought iron per year. This was initially leased by the New Bersham Company to William Travers of Gresford, but after 1779 it became part of the Bersham complex. This is made clear in a letter of 1779 from John Wilkinson to James Watt,[44] in which he refers to the Abenbury forge then 'lying idle' which would make 'an excellent plating forge' and could be employed to advantage in 'Boylers and Heavy iron work'. In this letter he stated that the intention was to 'have the best metal sent from the north in such shapes or moldes as might be required' and these would supplement local 'coak piggs' mixed with 'charcoal piggs' from the Furness district to make wrought iron of the quality required for 'engine work'. Writing in 1795, William Wilkinson described the Abenbury forge as 'the place where we (the Bersham Company) make and turn large ironwork for engines'.[45] Having obtained a local supply of wrought iron, it was obviously advantageous for the New Bersham Company to have the facilities to produce wrought iron plates for boilers and in 1788 a rolling mill was constructed adjacent to the new boring mill in the eastern section of the Bersham Ironworks.

By this date the Bersham Ironworks had reached its maximum geographical extent occupying parts of the valley floor for a distance of some 500 yards at Bersham, with the Abenbury forge three miles away included in the complex. Three steam engines had been constructed for various purposes, but water power, which originally attracted iron making to the site, continued to be used to drive the boring machinery, and the original furnace water wheel was adapted in 1779 to drive 'one large lathe for wood patterns and another for bars and iron'.[46]

v) Sources of fuel and raw materials for the Bersham Iron Ironworks

Although the Bersham Ironworks was situated within the zone of outcropping Middle Coal Measures strata, thick deposits of superficial material concealed the underlying seams of coal and ironstone in the immediate vicinity of the works, and the Bersham Company obtained the bulk of its fuel and raw materials from neighbouring areas where coal and ironstone were more accessible.



Based on a plan contained in a lease of land from R Middleton to Isaac Wilkinson 1763, Chirk castle Ms 4007 NLW

The first of these was the Rhos-berse and Nant area situated approximately 1½ miles upstream from the ironworks in the Clywedog valley, where the coal measures outcrop along the valley sides. It is this source of coal and ironstone that is mentioned in the lease of 1755 to which reference has already been made.[47] Under the conditions of the lease Isaac and John Wilkinson were given permission to 'carry on the said coalworks in the closes of William Lloyd for 30 years' and royalties of 'one sixth part of all the coal, kennel and slack . . . and two shillings a dozen for every strike of ironstone' were to be paid. This source of supply, however, although conveniently situated, was inadequate for the needs of the furnace, and, as in the earlier period, the Bersham Ironworks relied on the rich drift free coal and ironstone deposits of Rhosllanerchrugog as its main source of fuel and raw materials. Isaac Wilkinson in partnership with John Philips leased the 'Ponkie' colliery in Rhosllanerchrugog from Richard Myddleton in 1756.[48]

The ironstone raised at the 'Ponkie', on average some 1285 tons per year, was sufficient to produce approximately 300 tons of pig iron and this suggests that the bulk of the Bersham Ironwork's ironstone requirements came from this one source. The coal output from the 'Ponkie', on average some 3,400 tons

per year, was probably not all suitable for coking, but despite this it would have met the greater part of Bersham's coal requirements.

In addition to this major source of raw materials, Bersham was also supplied from an area called Bronydd in Rhosllanerchrugog by an associate of Isaac Wilkinson, Samuel Payne, who leased the land from Richard Myddleton.[49] Further supplies came from pits operated by Thomas Meredith and his son of Pentre Bychan Hall, who also leased the land from Richard Myddleton and were required 'to keep at least two pitts constantly and effectively at work'. In addition they were allowed to 'turn the said coals . . . into charcoals on the bank'. Such coking near the pits was advantageous in that it reduced transport costs, and coke could command a higher price per ton than coal. The weekly output from Meredith's pits in 1756 was 35–40 courses which increased to over 100 courses in 1758.[50] The use made of reverberatory furnaces at Bersham, 'a most necessary operation' according to de la Houliere to produce a metal suitable for casting all but 'common objects' greatly increased the demand for raw coal with which they were fired, but they also made possible the use of scrap metal as a raw material on a much larger scale than hitherto and so reduced the demand for pig iron.

A major problem for the Bersham Company concerned the transport of coal and ironstone from Rhosllanerchrugog to the ironworks, which was hampered by inadequate roads and the comparatively small loads that could be carried. The problem was resolved, however, by the construction of a wooden railroad from the collieries to Bersham, which was completed in 1758 and which terminated at the 'coaking banks' overlooking the furnace. For part of its route the railroad crossed land belonging to Richard Myddleton and an indenture dated 1758[51] gave Issac and John Wilkinson and Edward Blakeway permission to construct the railroad across Cadwgan Fechan in order to 'carry coal, kennel, slack and ironstone from the coleworks of the said Issac and John Wilkinson and Edward Blakeway, and any other colework that they shall carry to and from, for the use of the Bersham Furnace'. The railroad ran for a distance of approximately 2 miles and, as was the practice in Shropshire,[52] the wagons conveying the coal and ironstone were pulled by horses.

Throughout the Bersham Epoch the Bersham Ironworks was dependent on leasehold sources of coal and ironstone and this added considerably to the costs of production in view of the heavy royalty payments that were usually demanded. An alternative was to purchase pig iron directly from other ironworks, and there is some evidence to suggest that this occurred particularly after 1790 when the Ruabon II blast furnace began to operate in Rhosllanerchrugog. In 1792, however, John Wilkinson purchased the Brymbo Estate and shortly afterwards he began to set up a blast furnace there which, using readily available coal and ironstone deposits, was intended to supply all the pig iron needed at the Bersham Ironworks. This scheme, however, was frustrated by the dramatic decline in the fortunes of the Bersham Ironworks after 1795, a decline which the purchase of the Brymbo Estate by John Wilkinson largely initiated.

vi Factors leading to the demise of the Bersham Ironworks after 1795

At the beginning of the year 1795 the Bersham Ironworks was undoubtably one of the leading industrial establishments in the British Isles and was engaged in the production of a wide range of metal products, in particular ordnance and the multivarious items required for the manufacture of steam engines. John Wilkinson's boring patent had expired in 1788, and other ironworks, notably the Coalbrookdale Company and Walkers of Rotherham, had established boring mills on the Bersham model,[53] but despite this Boulton and Watt continued to recommend cylinders manufactured by John Wilkinson, who in their view was the only person with the facilities and a skilled labour force capable of producing borings of the accuracy they required. However, despite the excellence of the Bersham Ironworks and the quality of its products, the seeds that were to lead to the rapid demise of the New Bersham Company had already been sown and during 1795 were to make their presence felt in a most dramatic fashion.

The main reason for the rapid change in fortune of the New Bersham Company was a bitter dispute that developed between John Wilkinson and his younger brother William. During the mid 1770's William Wilkinson had managed the Bersham Ironworks on behalf of his brother,[54] and shortly afterwards he became a partner in the concern. Later he spent considerable time in France handling the foreign business of the New Bersham Company and John Wilkinson's other enterprises, and played a significant part in the modernisation of the French iron industry. On his return to England in 1787, however, the relationship between the two brothers deteriorated rapidly. The exact point at issue is uncertain, but William conceived himself to be deprived of his fair share in the profits of the New Bersham Company.[55] The quarrel was intensified in 1792, when John Wilkinson purchased the Brymbo Estate and set up a blast furnace there. This purchase was motivated by a desire on the part of John Wilkinson to gain personal control of the raw materials consumed by the Bersham Ironworks, rather than to continue to depend on leasehold raw materials at Rhosllanerchrugog, the lease of which was due to expire in 1797. William Wilkinson was given no share in the Brymbo Estate and the outcome was a public rupture between the two brothers, which, in the early months of 1795, led to the temporary closure of the Bersham Ironworks and the cancelling of its orders. Arbitrators were appointed to settle the dispute and their decision was that the partnership of John and William Wilkinson should be dissolved and the Bersham Ironworks sold.[56] The sale took place in the autumn of 1795 and the ironworks were purchased by John Wilkinson, his brother William receiving £10,650 for his share of the partnership and its stock.[57]

This traumatic episode in itself need not have meant the end of the contact between Bersham and the lucrative steam engine contracts provided by Boulton and Watt, had it not finally convinced the latter that their heavy dependence on John Wilkinson was against their own interests. An offer by William Wilkinson that they should partner him in the purchase of the Bersham Ironworks in 1795 was rejected,[58] instead they set up their own foundry and boring mill on the banks of the canal at Smethwick.[59] In this enterprise they received valuable technical assistance from William Wilkinson, who from that time onwards worked actively to prevent the recovery of the Bersham undertaking. He encouraged the skilled workmen employed at Bersham to leave the works and establish themselves at Smethwick, where he negotiated the terms of their employment with Boulton and Watt. The workmen themselves were anxious to leave for a variety of reasons. There was a serious lack of orders at Bersham, and problems with the new blast furnace at Brymbo, 'the iron they have made is quite unfit for foundry and forge',[60] led to it going out of blast in August 1796. In April 1796 John Kendrick, the cylinder moulder, gave notice to John Wilkinson that he was leaving his employment the reason being that 'they had no iron fit for business and that it was useless for him to work and have blame. Out of 12 cylinders cast only 2 are fit to send and those very poor ones.[61] During 1795 and 1796 Abraham Storey, the foundry foreman, Edward Pugh, a moulder, Thomas Griffiths, a sand and loam moulder, Edward Edwards, a moulder, John Jones, an air furnace man, William Davies, a turner and many other workmen, including John Kendrick, left Bersham for the Soho Works of Boulton and Watt in Smethwick. Others, including Gilbert Gilpin, the manager at Bersham, left for ironworks in Manchester or Chesterfield.[62]

The departure of such highly skilled workmen from Bersham was a serious blow from which the Bersham Ironworks could not recover. In 1798 because John Wilkinson 'decided to fulfill no conditions of the lease which are numerous and expensive but what the law obliges him'[63] the landlord dismantled 'all the mills in the meadow' and two years earlier in 1796 the 'Bank (coking bank) which had groaned under the weight of coals, mine and other such cumbersome loads for fifty years' had been 'sown with turnips'.[64]

A new steam-driven boring mill was erected at Bersham during 1798, but it met with little success, despite the financial help John Wilkinson gave to his nephew, Thomas Jones Wilkinson, who operated the concern from 1797 onwards. The loss of the skilled labour force, the severing of the business link with Boulton and Watt and the increasingly irrational behaviour of John Wilkinson during the closing years of his life, were all contributory factors to a situation which in a very short space of time reduced the Bersham Ironworks from its prominent place in the British iron industry to a rather insignificant foundry.

CONCLUSION

The changes that occurred in the iron industry of East Denbighshire during the second half of the 18th century clearly reflect the emergence of new factors which mitigated against the development of the region as a major centre of primary iron production. Remote from the main centres of demand for iron, isolated from the new canal network and no longer able to attract ironmasters with an abundance of fuel resources that other areas did not possess, the iron industry of East Denbighshire could not function as it had done during the Charcoal-Iron Era, when it formed part of a national system involved in the manufacture and marketing of raw iron. All that remained was the local demand for pig and bar iron, and in itself this was insufficient to justify any major expansion of iron making capacity in East Denbighshire.

The history of the Bersham Ironworks during this period, however, indicates that the industry of the area was able in part to overcome its locational drawbacks and gain national significance in certain specialised branches of iron founding and engineering. This was achieved at Bersham through the initiative and enterprise of one family of entrepreneurs, and in particular one member of the family, John Wilkinson. In a geographical location far from ideal for the manufacture of heavy and bulky, if valuable, products, the success of the Bersham Ironworks rested entirely on the inventiveness and business acumen of the Wilkinson family and the skill of the highly trained labour force that they employed. However, once personal emnity had destroyed the stability of the concern and its highly personal relationship with the firm of Boulton and Watt, and once its highly skilled labour force had been lost, the rapid demise of the Bersham Ironworks was inevitable. There were then no longer any advantages peculiar to Bersham that would allow the monopolistic situation that existed until 1795 to continue, and within a few years the enterprise was a pale shadow of its former self.

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Eighteenth Century Blast Furnaces: A New Checklist

Philip Riden

Historians and statisticians have tried to measure the output of the iron industry, usually in terms of tons of pig smelted annually, since the early eighteenth century. The most recent effort in this direction is my own (Riden 1977), which includes a resumé of previous work and is particularly dependent on earlier papers by George Hammersley (1973) and Charles K Hyde (1971, Appendices A–K). My attempt to provide long-run estimates of the output of pig falls into three parts. For the period between 1530 and 1710 Hammersley's estimates of average annual output within each decade (Table 1) are unlikely to be challenged until local studies revise his figures for the number of furnaces in use, since they are based on this number multiplied by average output, which is effectively the only basis for such a calculation. This series I have accepted without modification. For the period between 1790 and 1854, when the official **Mineral Statistics** began to publish returns of pig iron production, there is enough contemporary material to produce an annual series of aggregate estimates (Table 3).

It is the period between the beginning of the eighteenth century and 1790, which saw the transformation of the industry from charcoal to coke fuel and from water to steam power for blowing, that present the greatest problem. At the start of the century output was probably about 80,000 tons (Table 2). Ideally one would like to compile a year-by-year series for each type of iron and then combine them to produce an aggregate series for the entire industry. For this, however, the necessary contemporary material is almost wholly lacking and one has to fall back on the expedient of counting the number of furnaces in use at a particular time and multiplying by an estimate of average furnace output. Since eighteenth-century furnaces are in general better documented than their sixteenth- and seventeenth-century predecessors it is possible to bring reasonable precision to the estimates by using separate multipliers for charcoal and coke furnaces and by counting furnaces in five-year rather than decennial groups. Average output can be determined with some confidence from contemporary statistics but the accuracy of estimates of the number of furnaces depends on the success with which dates of opening or closure, or conversion to coke-smelting, can be established. The most detailed attempt to compile a list of eighteenth-century furnaces and their dates of operation is Hyde's, based largely on Schubert (1957, Appendix V) and later local studies. The list in Table 4 is taken from Hyde's thesis (with some minor corrections made to place-names and obvious errors of dating) and has not been published before.

Table 4 probably represents the best available list of blast furnaces at work in eighteenth-century Britain and for this reason alone would be worth publishing. On the other hand, it is more than likely that readers of **Historical Metallurgy** with a detailed knowledge of particular districts will be able to suggest further amendments to the list, which is another reason for presenting it here. Although I feel it is improbable that any errors would be of such magnitude as to alter significantly the aggregate output estimates in Table 2, the appearance of the list may bring to light minor inaccuracies which it would be useful to correct. May I, therefore, invite anyone who notices such errors to send details either to me or to the editor, so that eventually a revised list may be published in this journal? I need hardly add that the source of any corrections would be fully acknowledged in a future paper.

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Date	Furnaces	Average output (tons)	Total output (000 tons)
1530–39	6	200	1.2
1540–9	22	200	4.4
1550–9	26	200	5.2
1560–9	44	200	8.8
1570–9	67	200	13.4
1580–9	76	200	15.2
1590–9	82	200	16.4
1600–9	89	200	17.8
1610–9	79	215	17.0
1620–9	82	230	19.0
1630–9	79	250	20.0
1640–9	82	260	21.0
1650–9	86	270	23.0
1660–9	81	270	22.0
1670–9	71	270	19.0
1680–9	68	300	21.0
1690–9	78	300	23.0
1700–9	76	315	24.0
1710–9	74	340	25.0

Table 1. Occupied blast furnace sites, average furnace output and total output, by decades, England Wales, 1530–1709.

		Charcoal Pig			**Coke Pig**		**Aggregate Output**
	Furnaces	**Average Output**	**Total**	**Furnaces**	**Average Output**	**Total**	
1720–4	77	350	27,000	–	–	–	27,000
1725–9	82	355	29,000	–	–	–	29,000
1730–4	77	360	28,000	–	–	–	28,000
1735–9	73	365	27,000	–	–	–	27,000
1740–4	71	370	26,000	–	–	–	26,000
1745–9	71	375	27,000	–	–	–	27,000
1750–4	68	380	26,000	4	525	2,000	28,000
1755–9	63	390	24,000	11	590	7,000	31,000
1760–4	57	395	22,000	18	650	12,000	34,000
1765–9	53	400	21,000	26	710	19,000	40,000
1770–4	42	405	17,000	30	775	23,000	40,000
1775–9	34	410	14,000	41	840	34,000	48,000
1780–4	23	420	12,000	56	900	50,000	62,000
1785–9	24	425	10,000	72	960	70,000	80,000

All figures are in tons

Table 2. Estimated output of pig iron in Great Britain, by quinquennia, 1720–1789

Tons (000)		**Tons (000)**		**Tons (000)**		**Tons (000)**	
1790	*90*	*1810*	*400*	*1830*	*680*	*1850*	*2250*
1791	100	1811	360	1831	600	1851	2500
1792	100	1812	360	1832	630	*1852*	*2700*
1793	110	1813	370	1833	780	1853	2900
1794	110	1814	400	1834	790	*1854*	*3070*
1795	120	1815	340	1835	930	*1855*	*3220*
1796	*120*	1816	270	1836	970	*1856*	*3590*
1797	140	1817	260	1837	1030	*1857*	*3660*
1798	160	1818	280	1838	1120	*1858*	*3460*
1799	170	1819	280	*1839*	*1250*	*1859*	*3710*
1800	180	1820	320	*1840*	*1400*	*1860*	*3830*
1801	200	1821	390	*1841*	*1330*	*1861*	*3710*
1802	220	1822	360	*1842*	*1080*	*1862*	*3940*
1803	230	*1823*	*450*	*1843*	*1220*	*1863*	*4510*
1804	240	1824	550	*1844*	*1560*	*1864*	*4770*
1805	*250*	*1825*	*580*	*1845*	*2200*	*1865*	*4800*
1806	270	1826	520	*1846*	*2210*	*1866*	*4520*
1807	290	*1827*	*690*	*1847*	*2000*	*1867*	*4760*
1808	300	*1828*	*700*	*1848*	*2090*	*1868*	*4970*
1809	350	1829	690	1849	2170	*1869*	*5450*
						1870	*5960*

Figures in italics are based directly on contemporary estimates; others are interpolated.

Table 3. Pig Iron Production in Great Britain, 1790–1870

Table 3. continued

Low Wood	Lancashire	1785
Heathfield	Hampshire	1787

c. Coke furnaces built before 1790

Coalbrookdale 1	Shropshire	c1709
Coalbrookdale 2	Shropshire	1715
Willey	Shropshire	1733
Maryport	Cumberland	1752
Bersham	Denbighshire	c1753
Horsehay 1	Shropshire	1755
Horsehay 2	Shropshire	1756
Ketley 1	Shrophsire	1756
Ketley 2	Shropshire	1756
Hirwain	Glamorgan	1756
Madeley Wood 1	Shropshire	1757
Madeley Wood 2	Shropshire	1757?
Lightmoor 1	Shropshire	1758
Lightmoor 2	Shropshire	1758?
Dowlais 1	Glamorgan	1760
Seaton (Workington)	Cumberland	1760
Carron 1	Stirlingshire	1760
Carron 2	Stirlingshire	1761
Clifton	Cumberland	c1764
Masborough (Rotherham)	Yorkshire	1765
Neath (Melincourt)	Glamorgan	1765
Clydach	Monmouth	1765
Cyfarthfa 1	Glamorgan	1766
Bradley (Hallfields) 1	Staffordshire	1766
Carron 3	Stirlingshire	1766
Carron 4	Stirlingshire	1766
Plymouth	Glamorgan	1769
Bradley 2	Staffordshire	1770
Carron 5	Stirlinghsire	1771
Benthall 1	Shropshire	1775
Benthall 2	Shropshire	1775?
Willey 2	Shropshire	1775
Calcott	Shropshire	1775
Dukinfield	Cheshire	1775
Madeley Wood 3	Shropshire	1776
Madaley Wood 4	Shropshire	1776
Chesterfield 1	Derbyshire	1777
Chesterfield 2	Derbyshire	1777?
Carron 6	Stirlingshire	1777
Chapeltown 1	Yorkshire	1778
Chapeltown 2	Yorkshire	1778
Sirhowy	Monmouth	1778
Snedshill 1	Shropshire	1778
Snedshill 2	Shropshire	1778?
Clee Hill	Shropshire	1778
Masborough 2	Yorkshire	1779
Beaufort	Monmouth	1780
Chesterfield Stonegravels 1	Derbyshire	1780
Chesterfield Stonegravels 2	Derbyshire	1780?
Birkenshaw	Yorkshire	1780
Seacroft	Yorkshire	1780
Wilsontown 1	Lanarkshire	1782
Tipton 1	Staffordshire	1782
Tipton 2	Staffordshire	1782
Morley Park	Derbyshire	1782
Wingerworth 1	Derbyshire	1782
Wingerworth 2	Derbyshire	1782
Dowlais 2	Glamorgan	1782
Wednesbury	Staffordshire	1785
Pennydarren	Glamorgan	1785
Clyde 1	Lanarkshire	1786
Clyde 2	Lanarkshire	1786
Wilsontown 2	Lanarkshire	1786
Staveley	Derbyshire	1786
Ketley 3	Shropshire	1786?
Conneyberry	Shropshire	1786
Donnington	Shropshire	1786
Park (Sheffield)	Yorkshire	1786
Cyfarthfa 2	Glamorgan	1787
Hollinswood 1	Shropshire	1787
Hollinswood 2	Shropshire	1787
Old Level	Staffordshire	1787
Cleland (Omoa) 1	Lanarkshire	1787
Cleland (Omoa) 2	Lanarkshire	1787
Deepfield	Staffordshire	1788
Ettingshall	Staffordshire	1788
Muirkirk	Ayrshire	1788
Haigh	Lancashire	1789
Apedale	Staffordshire	1789
Blaenavon 1	Monmouth	1790
Blaenavon 2	Monmouth	1790
Blaenavon 3	Monmouth	1790
Blaendare	Monmouth	1790
Cefn Cribbwr	Glamorgan	1790
Ebbw Vale	Monmouth	1790
Old Park 1	Shropshire	1790
Old Park 2	Shropshire	1790
Brierley	Staffordshire	1790
Graveyard	Staffordshire	1790
Dale Abbey	Derbyshire	1790
Springwood	Staffordshire	1790

Table 4. Blast Furnaces in Great Britain, 1720–90

a. Charcoal furnaces erected

Carr	Cheshire	1720s
Brecon	Breconshire	c1720
Bedlington	Northumberland	1723
Clifton	Cumberland	1723
Melbourne	Derbyshire	c1725
Glen Kinglass	Argyllshire	1725
Abernethy	Inverness-shire	1727
Invergarry	Inverness-shire	1727
Nether Wellwood	Ayrshire	c1729
Duddon	Lancashire	1736
Nibthwaite	Lancashire	1736
Masborough	Yorkshire	1740
Pentyrch	Glamorgan	1740
Whitehall (Chester Burn)	Durham	1745
Newlands	Lancashire	1747
Lindale	Lancashire	1748
Low Wood	Lancashire	1748
Pennybridge	Lancashire	1748
Bonawe (Lorn)	Argyllshire	1753
Goatfield (Argyll)	Argyllshire	1754
Dovey	Merioneth	1755
Halton	Lancashire	1756

b. Charcoal furnaces closed

Waldron	Sussex	1724
Ashdown Forest	Sussex	1730s?
Poole Bank	Warwickshire	1730s
Gun's Mill	Herefordshire	1731
St Weonards	Herefordshire	1731
Glen Kinglass	Argyllshire	1731
Willey	Shropshire	1733 to coke
Invergarry	Inverness-shire	1736
Netherwellwood	Ayrshire	1737
Abernethy	Inverness-shire	1738
Vale Royal	Cheshire	c1738
Holme Chapel	Lancashire	1738
Hawkhurst	Kent	1740s?
Pounsley	Kent	1740s?
Robertsbridge	Sussex	1740s?
Sowley	Hampshire	1740s?
Rockley	Yorkshire	1740s?
Seacroft	Yorkshire	1740s?
Rushall	Staffordshire	1740s
Conshuple (Combe)	Sussex	1740s
Renishaw	Derbyshire	1749
Kirkby	Nottinghamshire	1750s?
Elmbridge	Gloucestershire	1750s?
Newent	Gloucestershire	1750s?
Cunsey	Lancashire	1750
Lawton	Cheshire	c1750
Carr	Cheshire	c1750
Nibthwaite	Lancashire	1755
Lindale	Lancashire	1756
Whaley	Derbyshire	1757
Willey	Shropshire	1757 to coke
Bersham	Denbighshire	1760 to coke
Clifton	Cumberland	1760 to coke
Beech (Netherfield)	Sussex	1760s?
Kemberton	Shropshire	1760s
Leighton	Shropshire	1760s
Brecon	Breconshire	1760
Mearheath	Staffordshire	1762
Darvell	Sussex	1763
Mill Place	Sussex	1763
Lamberhurst	Kent	1765
Neath (Melincourt)	Glamorgan	c1765
Brede	Sussex	1766
Whitehill	Durham	1770s?
Bardon	Kent	1770s?
Gravetye	Sussex	1770s?
Warren	Sussex	1770s?
Plas Madoc	Denbighshire	1770s?
Grange	Staffordshire	1770s?
Chapel	Yorkshire	1770s?
Seacroft	Yorkshire	1770s?
Bedlington	Northumberland	1770s?
Doddington	Cheshire	1770s
Madeley	Staffordshire	1770s
Beckley (Conster) S	Sussex	1770
Charlcott	Shropshire	1772
Staveley	Derbyshire	1773
Bank (2)	Yorkshire	1774
Barnby	Yorkshire	1774
Fernhurst (Linchmere)	Sussex	1776
Halesowen	Shropshire	1777
Conway	Cheshire	1779
Titchfield	Hampshire	1780s?
Dolgyn	Merioneth	1780s?
Ruabon	Denbighshire	1780s?
Cradley	Worcestershire	1780s?
Pennybridge	Lancashire	1780
Melbourne	Derbyshire	1780
Aston	Warwickshire	1780
Wingerworth	Derbyshire	1784

A new kind of Copper Slag from Tawi Aarja, Oman

Gerd Weisgerber

The existence of copper smelting slags in Oman has been well known since 1928 when the nickel content of slag from an unidentified site entered into discussion about the position of Magan, believed to be the source of Sumerian copper.[1]

In 1969, Bibby[2] again called attention to this subject and, more recently, the Harvard Archaeological Survey found at some 3rd millennium BC sites (mainly Samad 5) traces of copper smelting.[3,4] Recent analyses show that these slags arise from matte smelting.[5] Further evidence on the historical aspects, based on some years of prospecting work on Omani copper mineral deposits, will be forthcoming.[6]

It is usually reckoned that there are three distinct periods of mining activity in Oman:– 3rd millennium BC, 9-10th century AD and 17th century working by the Portuguese But the possibility of activity during Sassanian rule should not not be forgotten.

During a short stay in Oman[7] in January 1977 it was possible to visit some of the main copper production centres near Wadi Jizzi:– Semdah, Aarja, Beyda, Assayab and Lasail.[8] In all these cases large slag heaps surround enormous reddish ferruginous gossans. The tapslags, today broken by weathering, were originally of a round plano-convex shape. Their weight of ca. 50-60 kg and their diameter of about 50 cm show that they belong to a developed smelting process probably of medieval times. At Semdah big tuyeres lay on the surface. Many holes in these slag heaps demonstrate that these round slags were covering an older slag, certainly reworked in more recent times. This older slag lying in unworked pieces sometimes around the holes was tap slag too, but of a more irregular, flat shape and considerably smaller and lighter. Remains of the furnaces of the large slags are situated one beside the other in a chain on the lower part of the slopes (Beyda, Semdah).

In all the above-mentioned sites except Beyda, a large number of anvils and crushing stones was found. Probably there were used in a very early period of copper production, but unfortunately we do not know their last period of use. The prehistoric burial cairns on the top of the surrounding hills at Semdah tend to confirm the early dating.

At Tawi Aarja in the plain between Aarja and Beyda there occurs another type of slag. Here, important prehistoric features such as a temple[9] and a hillfort have survived, and also a late palaeolithic settlement. A large slag field, but no heap, is formed by a type of slag not hitherto described. The form is round, 25-30 cm diameter at the top and tapering to 11-14 cm; the sides are curved and they weigh from about 13 to 16 kg. The upper side is blistered by gas bubbles (Fig 2),

Figure 1 **Mining and smelting area of Lasail (Oman). The gossan (centre) was recently levelled. The holes in the slag heap may form by reworking the slag.**

the sides are rough due to the contact with sand and the bottom flat. Both the upper and lower sides almost invariably have the rim broken away (Figs 3, 4). Fragments show that at the top was a 5-9 cm high rim of thin slag, some showing an impression of a bellows tube. At the lower side was a short rim, once surrounding the bun-shaped copper ingot (Fig 4), which because of the surface tension had a rounded, not a sharp edge. The interpretation of this slag type would indicate a bowl furnace. All we can surmise of the furnace at present is the part in the ground, which gave a bun-shaped copper ingot at the bottom of the bowl under the heavy slag-block described above (Fig 5). It seems that the bowl was lined because of the white fritted sand baked on the outside of the slag-block of the upper part of the bowl. We do not know how many bellows were used for each furnace, but we may suppose two. Without excavation we can know nothing about the upper part of the furnace.

Figure 2 ← **Tawi Aarja slag, gas blistered surface with broken rim.**

Figure 4 → **Lower side of the slag cake with broken rim, once surrounding the copper ingot.**

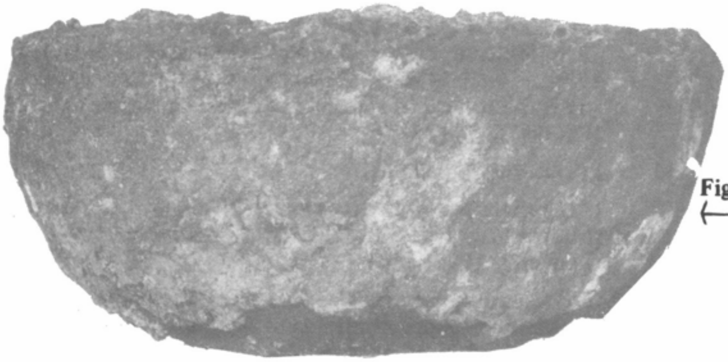
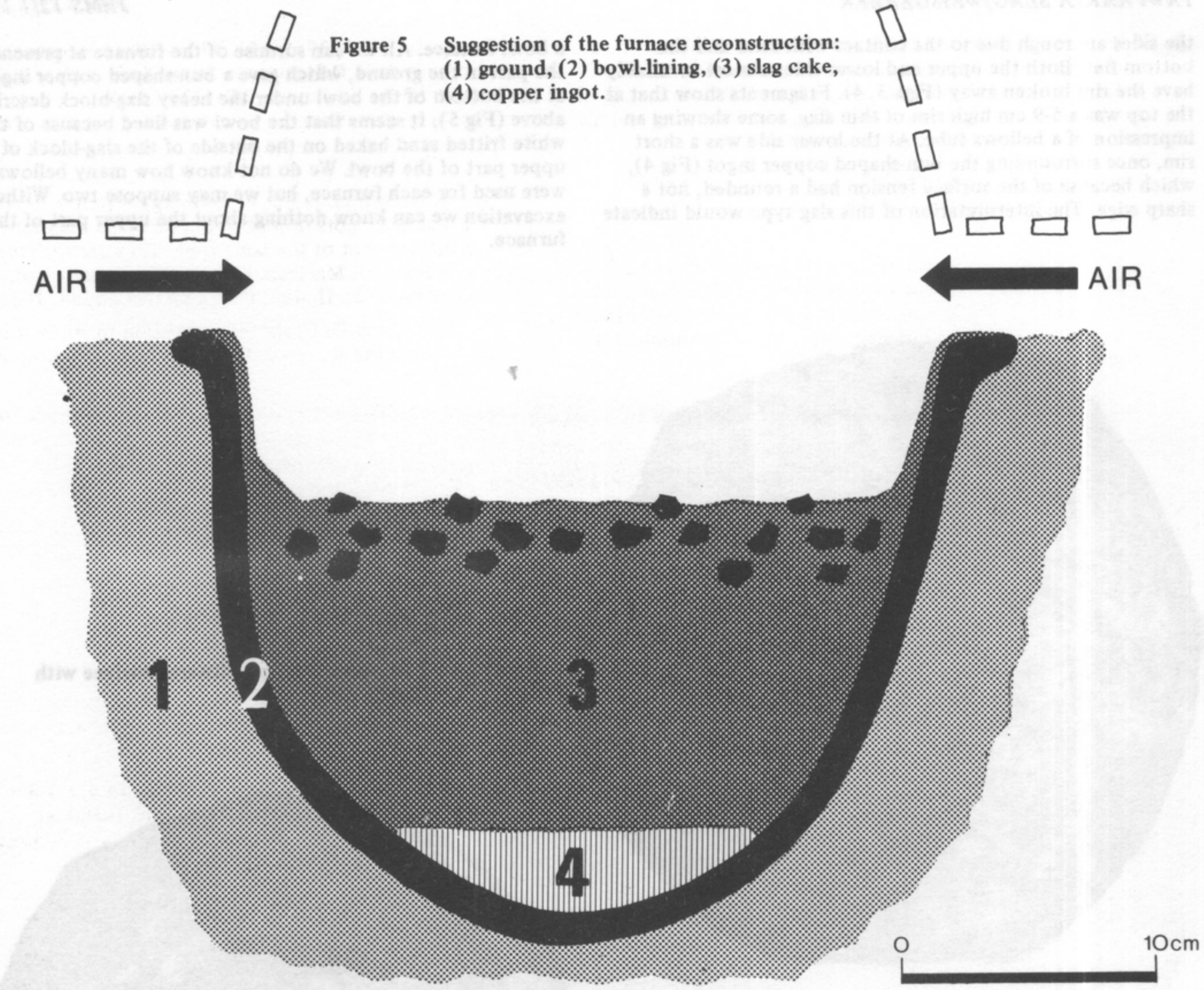


Figure 3 ← **Sandy rough side of the slag cake with broken upper and lower rims.**

Figure 5 Suggestion of the furnace reconstruction: (1) ground, (2) bowl-lining, (3) slag cake, (4) copper ingot.



This way of smelting gives a typical form to the smelting sites. To extract the copper from the furnace it was necessary to move the upper part of the furnace (if not to destroy it) and to lift the cake of slag to get the copper ingot below. So for each smelt, the lining of the bowl had to be renewed or a new bowl had to be dug. In consequence, the furnaces frequently moved, leaving behind a flat field of slag, but no real heaps, as seen at Tawi Aarja. Today these slag cakes are cracked and broken by weathering. Sometimes corrosion shows the green oxidised copper prills. This type of slag could belong to an old smelting process[10]; it resembles the early 3rd millennium smelting tradition of Iran, but on a much larger scale.[11] This Iranian method of copper production, improved at Shar-i-Sokhtar and Shahdad, finally gave a little copper button (About 150-200 gr) at the bottom of a small flat hole in the ground, and a small slag-cake of about 10-12 cm diameter and 2-3 cm in thickness with the typical rim at the bottom which surrounded the copper-ingot. The technical progress in the Omani process is seen in the enlargement of the charge made possible by better blowing. The result was a big plano-convex copper ingot of about 1.5 – 2.9 kg. It seems indeed that the smelting process used to produce the five ingots of Susa[12] and the one of Lothal (1.438Kg) was similar to that at Tawi Aarja.[13]

In January 1977, the same type of slag as found at Assayab in a small field. The Harvard Archaeological Survey collected among its 3rd millennium BC potsherds similar slag fragments at its newly discovered sites, Zahir 2 and 3, and Batin 1.[14] But the two C 14 dates which have now been obtained on these give dates of 850 ∓ 80 BP (HAM 865) which indicate that these sites were worked in medieval times.[15] Examination of a piece of the slag from Samad shows that it contains copper rather than matte and that it was probably smelted from oxidised ores (ie. either carbonates or oxides).

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7 The author wishes to thank the Ministry of Information and Culture of the Sultanate of Oman for their kind support and his friend, Dr Paolo Costa the Archaeological Adviser. Many thanks are due also to Mr A Russel and his staff from Prospection (Oman) Ltd.

8 Lasail with its 100,000 tons of slag is mentioned in: – JOS, 1975, 1, 126.

9 op. cit., ref. 3, JOS, 1975, 1, 13, Fig. 7 Pl. 5b-6b.

10 As shown by many remains of old irrigation systems, the plain of Tawi Aarja was once in intensive agricultural use. The remains of water canals ('falaj') crossing the slag fields and built with the aid of slag blocks gives a terminus ante quem for these metallurgical activities.

11 Indeed there is much evidence for cultural contact between eastern and southern Iran, and Oman.

12 Antiquity, 1963, 37, 99, Pl. XI b. – R de Mecquenem. Memoires de la Delegation au Perse XXV, 189, Fig. 21, No. 16 Musee du Louvre, SB 2723/65-69.
I am very grateful to Prof. P Amiet for the photographs.

13 S R Rao. A Persian Gulf Seal from Lothal. Antiquity, 1963, 37, 96-99, Pl. XIa – S R Rao. Lothal and the Indus Civilisation. p. 80 – (1.438 kg) – Here it must be said that the ingots of Mohenjo-daro often mentioned together, are not of the same type. They are the result of melting. – J. Marshall. Mohenjo-daro and the Indus Civilisation. Vol. II, 485, Pl. CXXXII. London, 1931.

14 I wish to thank Dr Costa for permission to study these materials in the stores of the Department of Antiquities at Mutrah.

15 Dates by: – Ordinariat fur Bodenkunde, University of Hamburg, Prof. Scharpenseel.

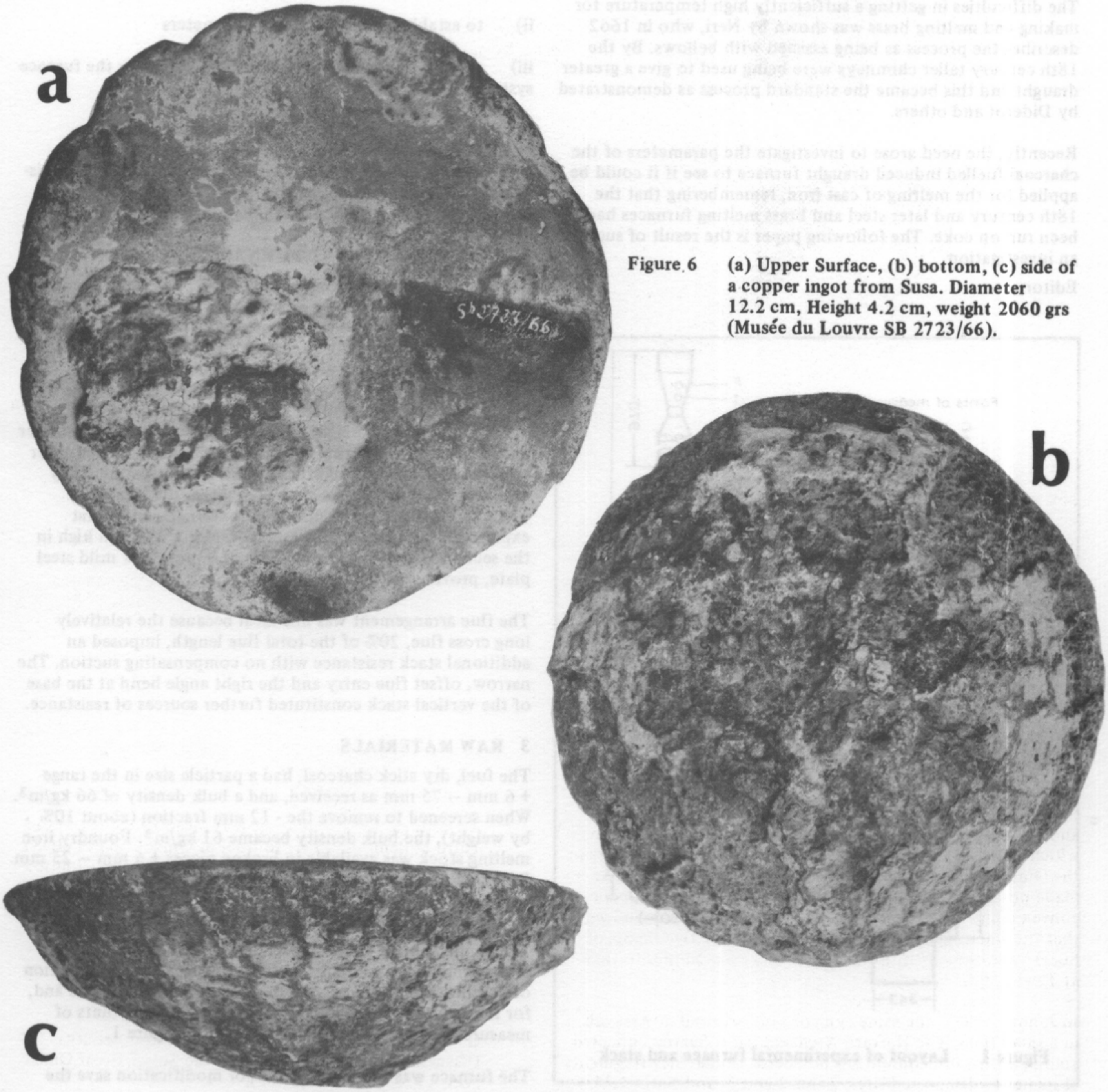

Figure 6 (a) Upper Surface, (b) bottom, (c) side of a copper ingot from Susa. Diameter 12.2 cm, Height 4.2 cm, weight 2060 grs (Musée du Louvre SB 2723/66).

The performance of an experimental Charcoal fired Crucible Furnace

A E Wraith

Introductory Note

The history of the induced draught shaft melting furnace is a long one. The type reached its zenith in the 18th century when Huntsman applied the type to the melting of steel to create a more homogeneous product. Previous to this the type was mainly used for the melting of non-ferrous metals for casting operations when maximum temperatures of the order of 1000°C were all that was required. Such a furnace is first mentioned by Theophilus in the 11th century.

The difficulties in getting a sufficiently high temperature for making and melting brass was shown by Neri, who in 1662 describes the process as being assisted with bellows. By the 18th century taller chimneys were being used to give a greater draught and this became the standard process as demonstrated by Diderot and others.

Recently, the need arose to investigate the parameters of the charcoal-fuelled induced draught furnace to see if it could be applied for the melting of cast iron, remembering that the 18th century and later steel and brass melting furnaces had been run on coke. The following paper is the result of such an investigation.

Editor

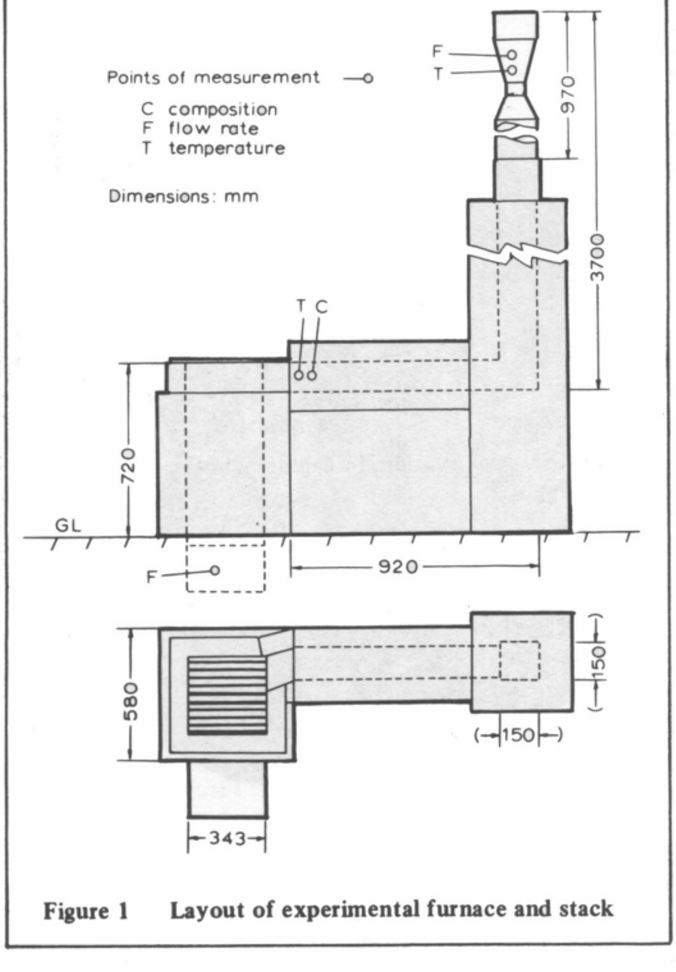

Figure 1 **Layout of experimental furnace and stack**

1 INTRODUCTION

This note reports experimental work done to provide data for the design of a natural-draught charcoal fired pot furnace suitable for melting foundry iron. There were three objectives:

i) to determine whether, and under what conditions, a high enough temperature and heat generation rate could be obtained to melt and superheat foundry iron in an embedded crucible.

ii) to establish physical design parameters

iii) to establish an effective modus operandi for the furnace system.

In addition to any current interest in setting up simple crucible furnaces for foundry work[1], the findings were thought relevant to the operating and production characteristics of early crucible and melting processes. The work could therefore provide useful archaeo-metallurgical insights.

2 THE EXPERIMENTAL FURNACE

An existing furnace, normally coke fired, was used. Furnace layout and dimensions are given in Figs 1 & 2. The main chamber and cross-flue were constructed from medium quality fire brick; the chimney was of building brick. Exact details of the vertical chimney section were not obtained – the bracketed dimensions if Fig 1 are estimates. The furnace was partly sunk into the ground, bringing the furnace top to a convenient working height. The firebars were 18mm diameter mild steel rods, excepting the centre pair which were thicker to support the weight of crucible and stool. Commercially available crucibles of two sizes were used, the smaller, 156 mm diameter x 184 mm high (external) in the first experiment, the larger, 171 mm diameter x 210 mm high in the second. The furnace cover was of 9 mm thick mild steel plate, provided with a lifting hook.

The flue arrangement was not ideal because the relatively long cross flue, 20% of the total flue length, imposed an additional stack resistance with no compensating suction. The narrow, offset flue entry and the right angle bend at the base of the vertical stack constituted further sources of resistance.

3 RAW MATERIALS

The fuel, dry stick charcoal, had a particle size in the range + 6 mm – 75 mm as received, and a bulk density of 66 kg/m^3. When screened to remove the - 12 mm fraction (about 10% by weight), the bulk density became 61 kg/m^3. Foundry iron melting stock was available in broken pieces + 6 mm – 25 mm. Broken glass provided the covering flux.

4 INSTRUMENTATION

The progress of each melting cycle was monitored by measurements of the temperature, flow rate and composition of combustion products, together with combustion rate and, for the forced draught experiment, air rate. The points of measurements are shown schematically in Figure 1.

The furnace was used without major modification save the

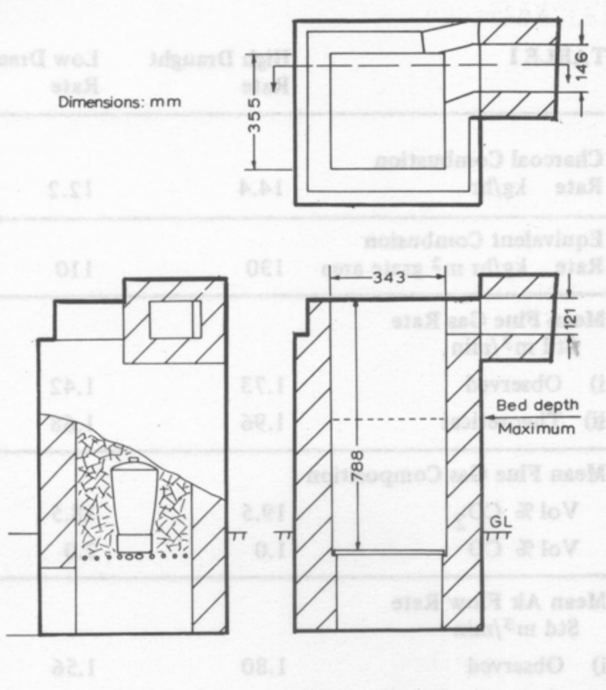

Figure 2 Detail of furnace chamber

addition of a venturi 0.95 m long, 150 mm bore at the chimney top. In the forced draught experiment, the furnace ash well was covered by a steel plate sealed to the floor, through which air was introduced from a hand driven blower. This air flow was measured by a Dall type venturi in the delivery line.

5 MELTING EXPERIMENTS

The first, natural draught, melting cycle provided a test of the inherent characteristics of the existing furnace structure as a combustion system. The second, forced draught, cycle allowed major changes in combustion conditions to be imposed on the system.

Start-up procedures were similar in each cycle. A fire was started with wood wool; when this was well alight, with evident chimney draught, charcoal was charged and allowed to burn through before further additions were made. The charcoal ignited without hesitation. Both cycles started from cold.

After start up, charcoal was charged in 2 or 4 kg lots as required to keep the crucible covered by the fire bed, a fuel bed depth of about 0.4 m maximum (Fig 2).

(i) Natural Draught Cycle

Charcoal was screened to + 12 mm. The barren furnace was preheated for an hour whilst measuring equipment was commissioned and an operating routine worked out. A 75 mm stool, together with crucible and lid, were then placed in position on the fire bars. After a further hour of pre-heating, 4 kg broken iron, with a little glass, was added to the crucible, whose temperature was now about 750°C.

After four hours continued heating it became clear that the furnace was unlikely to melt the iron, so the cycle was stopped.

The lower layers of iron, about 40 mm depth, had softened and slumped to form a partially sintered mass 25 mm thick in the crucible bottom. This softening indicated a temperature in the region of 1100°C. The glazed surface of the stool suggested that the cool entry region at the base of the fuel bed was only about 30 mm deep. Thus the crucible base had been positioned roughly 40 mm above the bottom of the hot zone in the fuel bed. This represented an equivalent loss in potential heating zone depth, that might be recovered by reducing the stool height.

During this first experiment it was realized that the frequent fuel handling necessary to maintain a relatively stable fire bed depth caused repreated interruption of the heating cycle, and severely hampered the smooth operation of the furnace. A major short-coming of charcoal firing had been confirmed, namely that smooth operation was undermined by the low bulk density of the fuel.

(ii) Forced Draught Cycle

Charcoal was screened to + 24 mm. A stool 50 mm high was used with a crucible approximately 25 mm deeper than before. In this way the hot zone could be better utilized without loss of overall fuel bed depth.

The crucible was placed in the furnace at start up, complete with a 2 kg charge of iron. Steady air flow was maintained between fuel charges by hand blowing, latterly at a higher rate, and in two hours the charge had melted, ultimately reaching an estimated temperature of 1280°C. The operating data are shown in figure 3, figure 4 and table 1.

The molten charge was poured, producing a satisfactory casting in a total time of 2½ hours after start up from cold.

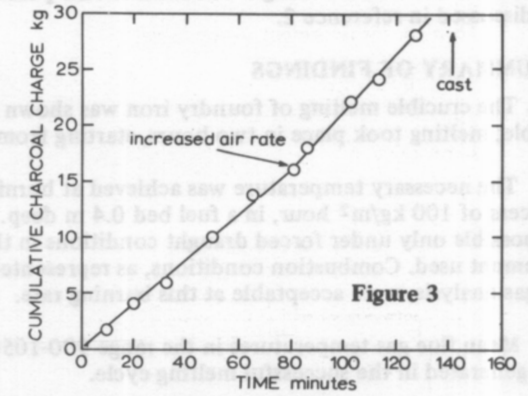

Figure 3

Charcoal consumption, forced draught experiment

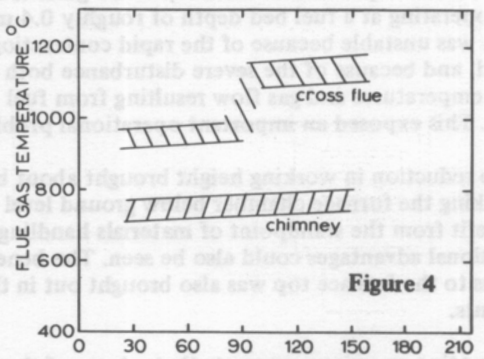

Figure 4

Flue gas temperatures, forced draught experiment

6 ANALYSIS OF DATA AND OBSERVATIONS

A comparison of observed and calculated stack gas flow rates indicated that the induced draught experiment was hampered by air in-leakage amounting to 25 to 30% of the total flow, which clearly reduced the stack efficiency. It was also evident that the stack was inadequate to handle the higher gas rates of the forced draught experiment where, despite higher stack temperatures, there was a 15% out-leakage. Leakages occurred mainly around the ill-fitting chamber cover, a factor that would require care in any furnace design.

The forced draught experiments suggest that fuel rates of 100 kg/m^2 hour or more would be required to secure iron melting temperatures under comparable heat loss conditions (Table 1). Assuming a charcoal bulk density of 60 kg/m^3, a fuel bed consuming 100 kg/m^2 hour would contract at 2.8 cm/minute, necessitating frequent small charges to maintain reasonably steady bed levels and flow conditions. In the experiments, brightly burning beds 0.3 to 0.4 m deep (that is, 5 to 10 times the charge particle size) were quickly established after charcoal additions, but the bed was extremely unsteady. Operation with a bed considerably deeper that the crucible height offers a way of preventing the bright fuel bed level from falling below the crucible lip when charging is intermittent.

The provision in this way of a fuel reservoir to stabilize the hot zone depth does, however, incur a penalty in fuel and stack efficiency. It is inevitable that deep fuel beds will produce flue gases high in carbon monoxide as a result of the carbon solution reaction. This was deomonstrated in recent work on the charcoal blast furnace[2]. It is also evident that fuel beds appreciably deeper than those used in the present work might require large particles size to minimize gas flow resistance under natural draught conditions. This point is also discussed in reference 2.

7 SUMMARY OF FINDINGS

(i) The crucible melting of foundry iron was shown to be feasible; melting took place in two hours, starting from cold.

(ii) The necessary temperature was achieved at burning rates in excess of 100 kg/m^2 hour, in a fuel bed 0.4 m deep. This was possible only under forced draught conditions in the equipment used. Combustion conditions, as represented by flue gas analysis, were acceptable at this burning rate.

(iii) Mean flue gas temperatures in the range 900-1050°C were generated in the successful melting cycle.

(iv) The low bulk density of charcoal fuel created charging problems. In the experimental furnace, with a grate area of 0.12m^2, operating at a fuel bed depth of roughly 0.4 m, operation was unstable because of the rapid contraction rate of the bed, and because of the severe disturbance both to fuel bed temperatures and gas flow resulting from fuel additions. This exposed an important operational problem.

(v) The reduction in working height brought about by partly sinking the furnace chamber below ground level was of great benefit from the standpoint of materials handling. Constructional advantages could also be seen. The benefit of free access to the furnace top was also brought out in the experiments.

(vi) Operating experience suggests that a team of three men is needed to work a furnace. One of the men would work intermittently, mainly on the casting side.

OPERATING DATA: FORCED DRAUGHT EXPERIMENT

TABLE I	High Draught Rate	Low Draught Rate
Charcoal Combustion		
Rate kg/hr	14.4	12.2
Equivalent Combusion		
Rate kg/hr m^2 grate area	130	110
Mean Flue Gas Rate Std m^3/min		
i) Observed	1.73	1.42
ii) Theoretical	1.96	1.68
Mean Flue Gas Composition		
Vol % CO_2	19.5	18.5
Vol % CO	1.0	2.0
Mean Air Flow Rate Std m^3/min		
i) Observed	1.80	1.56
ii) Calculated (to give observed gas composition)	1.81	1.56
Equivalent Air Flow Rate		
Std m^3/min m^2 grate area	16.2	14.1
Charcoal Particle Size		
mm	+6–75	+25–75

8 OUTLINE DESIGN FOR NATURAL DRAUGHT FURNACE

On the basis of the findings set out above, and using additional experimental data, vide[2,3], concerning fuel bed and stack gas flow resistance, a design was worked out for a simple furnace capable of melting tens of kilograms of foundry iron in a two-hour cycle. Fig 5 is a sketch of the design.

Sketch of natural draught furnace design

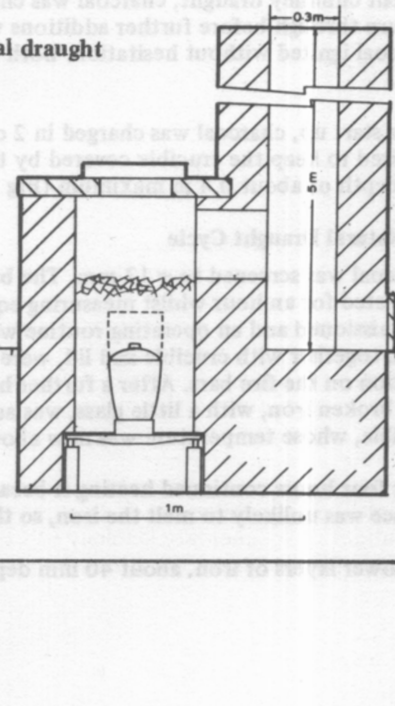

Figure 5

ACKNOWLEDGEMENTS

The author wishes to acknowledge the help of Mr K Smiles and Mr G E Stokoe with the experimental work, and to thank Intermediate Technology Group Ltd for financial support, and for permission to publish. Thanks are also due to Mr E Mobsby for the use of his furnace and for his unstinting assistance.

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Letter to the Editor

Dear Sir,

Charcoal ironmaking in the Department of Lot-et-Garonne, France.

I should like to refer briefly to my paper under this title which you published in volume 10/2 (1976). On page 68 I mentioned that I had been unable to visit Majoulassy, thought to have been an early Catalan forge site as it paid rent in iron even though it had been a paper mill for centuries.

In August 1977 I was able to visit the site, which is set in a particularly beautiful section of the valley of the river Lede. The whole site, 2 or 3 hectares, is covered with slags and other debris, not only under the roadway and in the dam structures, but throughout the grounds, the gardens of the mill house, and along the bed of the river. I collected samples of raw and calcined hematite ores, slags and fragments of furnace lining.

It seems to me that the quantities of slags etc., and their ubiquitous distribution confirm that the site had indeed been used for ironworking before the paper mill was built in the 17th century.

Yours faithfully,

Norman Mutton

Notes on contributors

R H Hayes MBE was a professional photographer until his retirement. He is joint Foundation Member of the Hutton-le-Hole Folk Museum a recognised authority on the local history and traditional life of the Cleveland area.

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Dr A E Wraith is Senior Lecturer in the Department of Metallurgy and Engineering Materials, University of Newcastle upon Tyne. He specialises in Process Metallurgy, currently with an emphasis on gas injection in liquid metals.

Mining History in South East Europe
The First Symposium, Bulgaria 1975

T A P Greeves

This symposium has probably escaped the notice of most Historical Metallurgy Society members, and it is the purpose of this note to summarise the topics covered by the symposium, especially those likely to be of most interest.

The symposium was held in November 1975 at Varna in Bulgaria. Over a period of 2½ days some forty papers were presented, covering the whole history of mining from prehistoric times to the nineteenth century. About one hundred delegates were present, mostly from east European countries.

The papers have been published in two volumes, amounting to almost 550 pages of text. The title of the volumes is as follows: **Pyrvi Simposium po Istoriya na Minnoto Delo v Yugoiztochna Evropa, Sbornik Dokladi, Tom I–II** (Sofia, 1975–6). Copies may be available from: A Vulchev, Director, National Polytechnical Museum, Rakovski 108, Sofia, Bulgaria.

The great majority of the papers are written in either Bulgarian or Russian. However, five are in French and four are in English.

The four papers written in English are all concerned with prehistoric topics which will be of general interest to 'historical metallurgists'. Three are in Volume I. The first (pp. 14-23) is by Hans Günter Conrad on ores, and techniques of prehistoric copper mining, at Timna, Israel. An illustrated paper, **Primary Mining in the Central Balkans** (pp.40–57) by B Jovanovic, is a useful summary, mostly concerned with the eneolithic site of Rudna Glava. **The Use of Copper in the Cucuteni-Tripolye Culture of South–East Europe** (pp 127–149) by T A P Greeves, is a summary, with tables, of Russian and Romanian work on an eneolithic culture. The tables include details of miscellaneous metallurgical and other evidence, details of metalworking techniques applied to objects in different periods, and a list of nine Carbon-14 dates. The fourth paper in English is in Volume II (pp. 119–121) and is entitled **Early Metallurgy on the Island of Kythnos, Greece,** by K Honea. It is mostly concerned with the evidence for Bronze Age metallurgy on the island.

The papers in French are the following:

1. **Histoire des travaux miniers dans l'île de Thasos,** by A E Karathanassis (Vol. I, pp 202–230), which is a summary of the exploitation of copper, lead, silver, zinc and iron ores from classical times onwards.

2. **Donnees Numismatiques pour L'Exploitation Minière de la Peninsule Balkanique,** by K Kolev (Vo. I, pp 243–263; also in Bulgarian in Vol. II, pp 70–78). This covers prehistoric to medieval times and includes a discussion of the evidence for the use of bronze sickles and axes, and copper ingots, as units of exchange.

3. **Les Ouvrages Miniers Prȇhistoriques et Antiques en Europe du Sud-Est dans la Litterature Scientifique Allemande,** by G Weisgerber (Vol. I, pp 264–274).

4. **L'exploitation et L'usinage des Métaux chez les Thraces Transylvains dans la Période Hallstatt A (1200–1000 BC)** by M Rusu (Vol. II, pp 26–36). Techniques of metal production are covered in some detail.

5. **Rapports Sociaux dans la Sidérurgie de la Région de Samokov au XIX^{e} Siècle,** by N Todorov (Vol. II, pp 64–70) also in Bulgarian pp 58–63).

All the other papers, in Bulgarian or Russian, are of interest, but I select only a few for comment here, giving their titles in English.

Two useful papers on prehistoric material in Bulgaria should be mentioned. One, by H Todorova, is entitled **The Earliest Evidence for the Use of Metals in Bulgaria** (Vol. I, pp 5–13), and the other, by I Panayotov and K Yordanov, is **On the Problem of Mining and Metallurgy in Thrace during the Bronze and Iron Age** (Vol. I, pp 24–39).

A paper on **Roman Mining in Eastern Macedonia** by A Keramidchiev (Vol I, pp 58–69) gives information on the analysis of slags.

There are several papers in Volume I on gold mining in Bulgaria and they contain much useful information on techniques of exploitation from prehistoric times onwards.

A Contribution to the History of Iron Production on Mt. Vitosha, by F R Wut (Vol I, pp 150–165) describes primitive and 'Vidni' type furnaces, methods of working, types of slag etc. The following paper, by D Kraev, **Finds in Old Workings at Rosen, Plakalnitsa, Rakovitsa and Spakhievo (Khaskovsko) Mines** (Vol I, pp 166–178), describes and illustrates tools and mine equipment, and also clay tuyeres found among iron slag near the Iskur Dam, Samokov district.

The smelting of copper and the production of cast and wrought iron is discussed in a paper by V Simic entitled **Iron and Copper Mining in Majdanpek (Serbia) from 1849 to 1858** (Vol I pp 188–201).

A summary of mining history in Poland is given by F Shvagzhik in his paper **The History of Mining in Poland from Earliest Times to the 19th Century** (Vol I, pp 293–313).

Mining in the Rila-Rhodopes Region in Ancient Times, by E Maximov (Vol II, pp 43–58) is a very interesting description of finds of tools and old workings.

The very rich evidence for Bronze Age metalworking in the Caucasus is discussed by E O Mindeli, V Ph Chanishvili, and T P Mudzhiri in their paper on **The History of the Technique of Processing Copper and Antimony Ores in Antiquity** (Vol II, pp 101–110.

A useful Bulgarian translation of mining laws dating from the fifteenth to the seventeenth centuries is given in a paper by G Konyarov on **Mining Laws in Medieval Serbia and Bulgaria** (Vol II, pp 137–229). Further notes on this are given in Vol II, pp 78–83 by M Gruncharova.

Other papers include a study of the history of coal mining in Bulgaria, and also more local studies of mining evidence. In general, this collection of papers is a comprehensive review of our state of knowledge of mining and metallurgical prehistory and history in south-east Europe.

Book reviews

A HISTORY OF METALLURGY R F Tylecote

The Metals Society, London, 1976. 182 pp £10 post free.

A good book – unlike a good meal – leaves you with the immediate wish for more; R F Tylecote's 'History of Metallurgy' is such a book. Anyone attempting to write a history of metallurgy in two-hundred pages is either an optimist or a real expert. Tylecote is an expert. This means that the book is permeated by a sense of reality that one finds so rarely in any treatise on 'The History of . . . .'.

The trust of this history is evidence, not hearsay, and much of this evidence would stand up on a court of Law. 'This I know experimentally' could be the motto of many of the book's chapters. Essentially the work traces the development of metal winning, shaping and processing on the basis of technical studies – frequently the author's own work. Tylecote's overall attitude to the subject is traditional, mildly evolutionary and diffusionist, assuming that people learn from each other but not assuming that learning is a one-way process.

The book uses the archaeologist's division of time into Stone- Copper- Bronze- and Iron ages without making a production of it and without attempting to correlate closely the 'technological stages' and an overall absolute chronology. This provides a self-consistent framework within which Tylecote presents his survey of the development of technical competence. The recent work on arsenical coppers is included and so are the studies on early iron in Africa, which have not been summarized before as part of the global evolution of metallurgy.

After treating with great care the evidence related to early copper, bronze and iron, Tylecote gives us some of his best expositions in a chapter on the Roman Iron Age. This is followed by chapters on medieval and post-medieval metallurgy. The author's long and direct involvement with British Metallurgy, both modern and historical, is well reflected in an authoritative treatment of metallurgy during and after the industrial revolution. (Chapters 9 and 10). The author's presentation of the evidence does not include a critical discussion of the methods by which this evidence was gathered. The problematique surrounding the revision of C^{14} data warrants only the briefest of statements (p.5); the uses and abuses of chemical analyses are not discussed at all. There is, in fact, not even an index entry for 'composition', 'trace elements', 'spectroscopic analysis' etc.

The book closes on a surprising note. A final chapter 'The contribution of the Scientist' is tucked in at the end. In it the work of those who contributed to our formal knowledge of the structure and properties of materials is touched upon, as is 'radioactivity', 'Magnetism' and the periodic table.' Maybe this chapter is intended to answer the archaeologist's question. But how do you know . . . ? Those not familiar with the field of historical metallurgy may benefit from reading this last chapter first, because, other than a short glossary of technical terms, there are few concessions to the non-metallurgist in this 'History of Metallurgy'.

The book is very concisely written, the style is clear and mercifully free of jargon and big words. The text is richly illustrated, with clear schematic drawings and black and white illustrations. A set of maps is included in the appendix. The Metals Society has published the work in a simple and unfussy edition, hopefully large enough to meet the demand the book will create.

Obviously, this is a good and timely contribution suitable for those who try to teach and those who try to learn; what more, then, can anyone want. I, for one, have further wishes. As far as the details of Tylecote's book are concerned, I would like to see a good index of references included, or even issued as a supplement. At present, the references are sequentially numbered within each chapter and listed in this order at the end of the chapters. This makes it quite difficult to trace a particular reference. For many, the book will become a basic handbook and such an index would be of real use.

But my main wish is much more general. Thinking about the book, I was suddenly struck by the complementarity of Tylecote's approach and that of Cryil S Smith. The centre of Tylecote's attention is the metallurgical process, Smith focusses on the artifact and its maker. This intrigued me more and more and I began to play point-counterpoint with the 'technical' and 'humanistic' view of metallurgy. Of course, Tylecote and Smith, as individuals, take both these components into account. But – like Yin and Yang – one or the other can dominate; for instance, there is no photograph of a 'beautiful' metal artifact in Tylecote's book.

And so I began to wish that the History of Metallurgy before me could be the first part of a larger opus, a trilogy on ancient metals. It would be followed, as Part II, by a comprehensive collection of the work of C S Smith, starting with 'Metallurgy as a human experience' and the 'Metallurgical footnotes to the History of Art.'

Part III, of the opus would be an Atlas of Microstructures of Ancient Materials. Many of the diagnostic features of ancient structures have no modern equivalents. A thoroughly documented and well printed compilation of structures seen now in old materials – taking into account what was there and what happened to it in time – is urgently needed. The recent surge in experimental studies of ancient materials begins to make such an endeavour possible. Is this a very unreasonable dream?

Certainly it would need money to commission, organize and print such an opus. But money is spent every day; often on things much less useful or interesting. One could dream, for instance, that NATO would forego the purchase of just one of all its new tanks, such as the Leopards, which Canada will contribute (130 are on order from Germany) at the cost of about $1.5 million each. A fraction of this would produce and distribute a superb 'Trilogy on Ancient Metals'. Wouldn't this be a nice way for the tanks to acknowledge their debt to metallurgy? Elementary, dear Watson; Dreams, Holmes, idle dreams.

Ursula Franklin

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YESTERDAY'S GOLCONDAS – NOTABLE BRITISH METAL MINES. R H Bird, Moorland £3.95

The author is an industrial photographer by profession and a mine enthusiast by predilection. This collection of annotated photographs is well produced and should succeed in its objectives of interesting people new to industrial archaeology and introducing the more knowledgeable to areas they have previously ignored.

Cornwall, Mid and North Pennines, and Wales each account for about a quarter of the 137 photographs, the remainder being devoted to Derbyshire, the Isle of Man and Shropshire. Most of the pictures, both above and below ground have been taken during the last few years and a series of dated photographs with map references could be extremely useful in checking future deterioration of non-ferrous mining sites. The notes accompanying each photograph vary in length from 50 to 500 words and contain as much information as one could expect in a book of this description. The glossary of terms could have been longer with advantage and the two page bibliography contains suggestions for future reading with with useful and pertinent comments.

Norman Swindells

CAST IRON DECORATION, A WORLD SURVEY by E G Robertson and Joan Robertson. Thames and Hudson. 336 pages 500 ills. £14.00.

Dr Graeme Robertson has written several books on Australian ironwork. This is a publication of absolutely superb photographs taken by his daughter Joan. Miss Robertson has achieved photographs which clearly show the design of the ironwork, yet never become prosaic. They are consistently well reproduced, and could take their place in any volume of photographic work in their own right, the fact that they so admirably illustrate Dr Robertson's survey of world ironwork is equally no mean achievement. By far the most beautiful record of cast iron yet produced.

By their very nature world surveys cannot be comprehensive, and as far as Great Britain is concerned, the present work adds little to previously published material. The Australian section, however, is strong, and even includes the fascinating history of an all iron house, in Geelong, Victoria, of which the cast sections were made in Edinburgh. The existence of so much decorative cast ironwork, not only in Australia, but also in America and Europe, from Paris to Moscow, will be a revelation to many in this country. In fact the whole panorama of world ironwork laid out before the reader is bound to greatly increase interest and appreciation in this form of art and industry.

Amina Chatwin

OFFICINA FERRARIA. Walenty Rozdzienski.

A Polish Poem of 1612 describing the noble craft of ironwork. Translated by Stefan Pluszczewski. Edited by Waclaw Rozanski and Cyril Stanley Smith. Published Jointly by the Society for the History of Technology and the MIT Press. Cambridge, Massachusetts and London. About 140 pp, no price stated.

This is a likeable little book, even if at first glance it looks an unlikely subject for study by historical metallurgists. It is well worth reading in its own right by all interested in the charcoal iron bloomery. Many other people of very varied backgrounds have found it fascinating too. The long introduction tells how a single copy, the only existing copy it seems, of the printed poem of 1612 was found in 1929 and of the massive interest and subsequent research it engendered. This interest was on many non-metallurgical grounds, yet as the author was a practical and practising forgemaster, those parts of the poem which relate to the management of the bloomery at the end of the 16th and beginning of the 17th centuries, just as it was about to be replaced in Poland by the blast furnace, are valuable.

The translation is into (American) English. The stanzas have been kept, but they have been translated into prose. The introduction helps to keep the poem in perspective; only about one third is concerned with iron mining and ores, and the bloomery; the rest is a compilation of classical references and ideas on the spread of smelting and some more miscellaneous matters. A ghost story or two, some comments upon ironworkers as a social class, comments on Reformation and Counter-Reformation and some pithy, commonsense sayings about being a forgemaster make this a book well worth reading.

Norman Mutton

TRANSPORT AND INDUSTRY IN SOUTH YORKSHIRE. P H Abell. Published by the author at 14 The Croft, Elsecar, Barnsley, South Yorkshire S74 8EB (84 pp: £1.50).

Mr P H Abell traces the economic development of the rich, southern lobe of Yorkshire from Roman times. It concentrates, as would be expected, on the vast development in the 18th and 19th centuries and shows them to be based on the well-founded initiatives of the two preceding centuries. In their turn these were dependent on the naturally occurring endowments of the region, the vast amounts of coal and the much less, though historically important ironstone, flanked by limestones and sandstones, all lying within a terrain which ranges from the hilly Pennines on the west to the low lying carrs and marshes of the Don and Trent to the east. These fundamental advantages were and are exploited to the full, as this work clearly shows.

This book is essentially an account of the evolution of the coal and iron industries, and their ancillaries such as brick and pottery-making, stoneworking in its several forms including sandstones for grinding and limestones for flux. As the influence of water-power from the Pennines and charcoal burning for ironstone smelting waned, coal was mined in ever increasing quantities to replace them. The rapidly evolving techniques in steel making as well as the discovery of the making of Sheffield plate further stamped their character on the region, though to differing degrees. Doubtless the developing indigenous skills were responsible for the attraction of cotton spinning, lead smelting and handloom weaving, though on a yet smaller scale.

Such booming progress was not possible without equally dramatic changes in transport. The pack-horse system, though itself well-organized, was totally inadequate and was steadily replaced following the building of metalled and turnpiked roads. What was initially even more important was the drainage, canal-cutting and canalization of some of the rivers in the eastern part of South Yorkshire, to which in some cases, horse-drawn waggon-ways were built. Weaker canal links were formed with south Lancashire. This, in pre-railway days, opened the products of the region to a far wider market than hitherto, not least cutlery exports to America and in 1827 steel to the Prussian market. A comprehensive chapter on railway development demonstrates clearly the next phase, uncomfortable though it was initially for passengers, until, for example, a considerate company drilled holes in the floor of the coaches for the drainage of rainwater.

In this booklet the many strands contributing to the industrial evolution of South Yorkshire are not only carefully and clearly brought together, but are also linked to the wider British scene. This is no generalized account, but a comprehensive synthesis supported by abundant data and informed interpretation. As such it is well worth its place on the shelves of those concerned with the fundamentals of industrial development' It is illustrated by clear maps drawn by Miss Harper and by photographs. It is well printed in a bold typeface with only few errors but an excess of capital letters. The inclusion in parenthesis of metric units for linear measurements is not always necessary and is at times in error (p.60).

The omission of four pages from the reviewers copy was not compensated for by the duplication of four others. The former may have carried some of the additional maps which in future editions should be added to some chapters to define the many smaller localities not familiar to the general reader.

J E Hemingway

PHOKAISCHES ELEKTRON–GELD VON 600–326 V. CHR. (PHOCAEAN ELECTRUM COINAGE OF THE PERIOD 600–326 BC), Friedrich Bodenstedt. Verlag Philipp von Zabern, Mainz. 120 DM. A4 170 pp, 22 plates.

Electrum is gold with a high percentage of silver. By the Mycenaean period copper was being added to gold. At the time of Croesus, cupellation and cementation was already in use in Lydia for refining as shown by the lead content of the gold and silver. Electrum could be produced artifically. Such an alloy (56% Au, 38% Ag and 6% Cu) was produced by the 6th century BC for coinage. The lower melting point made the metal more easily melted and increased the wear resistance.

Three different alloys can be distinguished:

Period I	600–522 BC 53.7–55.5% Au, 38.4–41.2% Ag and 5.1–6.1% Cu
Period II	521–478 BC 47.4–48% Au, 43.7–44.6% Ag and 8.0–8.3% Cu
Period III	477–326 BC 40.2–40.6% Au, 49.0–49.4% Ag and 10.4% Cu

The numismatic significance of these changes is discussed. They were mainly due to the necessity of the Phocaean state to align itself with neighbouring currencies.

The author discusses the alloy electrum and the minting techniques, the alloying of electrum in the three alloy periods, and the results of further physical and metallurgical researches. The book includes a number of appendixes giving the detailed results of the various organisations that contributed to the exercise. The Bundesanstalt fur Materialsprufung have done the neutron activation analysis and have determined the density, thickness and macroscopic cross section (cm^2/g). This section is entitled 'The non-destructive determination of the alloying components, Au, Ag and Cu of 162 ancient Greek gold coins'.

As a check, four coins were analysed by chemical methods by Degussa. The results when compared with NAA varied from 1.8% high (on 40%) on the gold values, through 0.28% low (on 50%) of the silver values to 1.89% low (on 10%) of the copper values. While the figures for gold and silver are reasonable, that for the copper is very high.

These figures were accepted and used to correct the NAA values. This discrepancy was found to be due to blisters or slag inclusions in the coins and was not revealed by X-radiography. The NAA had assumed that all coins were solid and had not been able to take account of such defects. While the chemical analyses would be more accurate, even here in one case it was only possible to account for 97.59% of the coin material; the rest was not determined and was probably due to impurities such as Bi and Sn, and slag. The iron content was 0.1% and the lead varied from 0.2 to 0.3%. It was therefore concluded by the author that it is a mistake to include specific gravity in calculations of metallic composition.

The metallographic examination shows the structure to be mainly as cast (ie. cored dendrites) and it is clear that little homogenisation had been done on the coin blanks which contained primary solid solution and eutectic. The blanks had been coined in the cold state and this was confirmed by hardness tests on the experimental blanks which Degussa made as standards. These alloys were melted under argon in an alumina crucible and cast into copper moulds. The blanks were annealed at $500^{\circ}C$ for 4 hours in carbon monoxide.

Full details of polishing and etching of the specimens are given. The hardness of the four sampled coins varied from 159-186 HB. The experimental discs were deformed by 60% and their hardnesses were measured in both the worked and annealed state.

From this it can be seen that all efforts were made to deal with the scientific aspects fully along the lines that are becoming more common in numismatic studies. The principle of printing facsimiles of the original laboratory reports avoids any criticism due to incorrect interpretation and is to be recommended.

One is impressed by the accuracy of control in the Phocaean mints at Phocaia, Mytilene and Kyzikos. It would seem that their standards of reproduction were every bit as good as our standards of analysis today. The depreciation in the value of the currency seems to follow a familiar pattern.

One must end by congratulating the author and the publishers on a competent piece of work well presented.

R F Tylecote

Abstracts

GENERAL

Hans Grothe: Beginnings of metallurgical engineering. *Erzmetall, 1975, 28(4), 165–172. (In German).*

A historical account is presented of methods used for the metallurgical processing of ores and minerals to yield copper bronze, tin, gold, silver, brass, lead, and zinc, covering the period from 6000 years ago to Roman times.

AATA

John Hatcher and T C Barker: A history of British pewter. *Book. London, Longman, 1974, 363, £7.50. Plates, Figs, refs. index.*

Part I of the survey treats pewter before AD 1700: its chronological development, the gilds, the techniques of manufacture, supply of raw materials, industrial structure and trade at home and overseas, Part 2 is on modern pewter.

CL(BAA)

E G V Newman: The gold metallurgy of Isaac Newton. *Gold Bulletin, 1975, 8 (3), 90–95.*

This paper deals with the work of Newton while he was employed at the Royal Mint and with his interest in metallurgy. His reorganization of the mint is mentioned and details of the ceremony of testing the fineness of the alloys are given. Some analyses are given of seventeenth century gold trial plates.

WAO

William D Horr: Ancient plated coins- an enigma. *Report of the Australian Numismatic Society, 1975, 39, 36, 40, 43–44 (March, April, May).*

A brief review is given of the occurrence, methods of manufacture and likely reasons for production of ancient plated coinage.

DJR

J S Forbes: Hallmarking of gold, silver, and platinum: *Metallurgist and Materials Technology, 1975, 7 (3), 141-143.*

The history of hallmarking of gold and silver is traced from 1300 AD, when the first hallmarking statute was passed in England, to the Hallmarking Act of 1973 which covered platinum as well as gold and silver. The legal standards and hallmarks are discussed and the assaying and marking procedures are described.

MG

R W Berg: About tin disease. *Meddelelser om Konservering, 1975, 2 (6), 189–192. (In Danish with English summary).*

The transformation of beta tin to alpha tin (and vice versa) is described. Treatment in an incubator for 24 hours at 70°C is recommended for the prevention of tin disease.

KR

I R Selimkhanov: Differentiation of human ancient history based on the chemical study of metals. *Tr. Mezhdunar. Hongr. Istor. Nauki. 13th., 1974, 7, 231–234. (In Russian).*

The use of metals through human history and various criteria for differentiation of human history into stages with respect to metals used are discussed. The discovery of tin seems to be the most relevant turning point in human history.

(AATA)

M J Cole: Gold. Its history and influence on mankind. *Met. Aust., 1975, 7, 189–190.*

A brief historical account of gold and its effect on mankind since antiquity, is presented.

(AATA)

Hanns–Ulrich Haedeke; trans. Vivienne Menkes. Metalwork, the social history of the decorative arts. *Book. Weidenfeld and Nicolson, London, England. 1970. 227. 264.*

This book contains descriptions of the mining, smelting, and working techniques used in the production of various metals and their alloys (copper, bronze, brass, iron, tin, pewter) from the Carolingian period to Art Nouveau.

LRA

L B Hunt: How electrolytic gilding began: a short account of the controversies surrounding the birth of a great industry. *Galvano Organo, 1974, 43 (444), 455–463. (In French).*

The history of electroplating is reviewed in detail from Volta's pile through the Wright-Elkington controversy, with reference to early examples of electroplating as for example the five domes of the now-destroyed Church of the Redeemer in Moscow, electro-gilded in 1839.

MG

L B Hunt: The oldest metallurgical handbook-recipes of a fourth century goldsmith. *Gold Bulletin, 1976, 9 (1), 24–31.*

An important reassessment made of the so-called Leyden Papyrus X which contains lists of recipes of workshop practices in Egypt in the fourth century AD. This paper deals with the history of the document and with dating and provenance. It then considers in detail the recipes concerning the technology of gold and its use.

WAO

BRITISH ISLES

Janet Lang and James Graham–Campbell: The scientific examination of a fragment of a silver-bossed brooch from Cuerdale, Lancashire, England. *Norweg Archaeol. Rev. 1976, 9, 127–8.*

Metallographic analysis showed this brooch was made by forging an ingot or cast blank of c.97.5% silver content into its final shape before chasing and pounding the decoration on to the surface. However, some other decorated metalwork of the period is known to have been made as unretouched castings.

CL(BAA)

R B K Stevenson: The Hunterston Brooch and its significance: *Medieval Archaeology, 1974,* **18**, *16–42.*

The archaeology, art history and technology of the 7th to 8th century decorated silver pseudo-penannular brooch from Hunterston in Scotland is discussed with technical details of the method of construction and details of the analysis of the brooch and fastening pin.

	Ag	Cu	Sn	Pb	Zn	Au	Bi %
Brooch	62	35	0.6	0.3	0.04	1.9	0.2
Pin	60	35	2.6	1.0	0.2	1.5	0.2

(Method of analysis not stated but probably atomic absorption spectrophotometry).

WAO

Barbara Clayton: Metal analyses: their limitation and application to the Early Bronze Age in Ireland. *Univ. London Inst. Archaeol. Bull., 1974,* **11**, *(1973), 75–129.*

The introduction discusses the variables affecting the final composition of a metal artifact (ores, smelting, alloying, casting, subsequent working, burial environment). Analyses from various sources are discussed under the headings unalloyed copper + arsenic, copper + arsenic + tin, copper + tin, and the objects were divided into axes, halberds and daggers, and miscellanea

CL(BAA)

M J Rowlands: The production and distribution of metalwork in the Middle Bronze Age in S Britain 1, discussion; 2, catalogue and plates. *Brit. Archaeol. Rep., 1976,* **31**, *446. Price £7.50 (paper) for 2 vols.*

Metalwork is an unreliable cultural and chronological indicator and is best considered in its own right as part of a regionally based economic framework. From the pattern of finds and hoards it appears that most early MBA metalwork was produced by local smiths, probably in fixed workshops, for local consumption only; there was little long-distance trade, peddling or exchange. North of the Thames this position held for some time, but to the south the increasing numbers of hoards in the later MBA suggest a move towards a more efficient organization: smiths worked seasonally to build up stock for peddling later. Certain specialisms became evident, eg. weapon-smiths. Innovations of newer metalworking centres had a partial influence on older workshops.

CL(BAA)

David Coombs: The Dover Harbour bronze finds: a Bronze Age wreck? *Archaeol. Atlantica, 1975,* **1** *(2), 193–5.*

Summary note on the 89 bronze objects found 30 ft underwater off Dover. They include Rosnoen sword fragments, median-winged axes, spearheads, Portrieux palstaves and a Taunton-Hademarschen socketed axe. All are of Continental origin, c1000–900 BC, and may be from a BA wreck.

CL(BAA)

J Gibson-Hill and B C Worssam: Analyses of Wealden iron ores and their archaeological significance. *Bull Inst. Arcaheol. Univ. London, 1976,* **13**, *247–63.*

Discusses the results of analyses of ores from the Crawley district of Sussex in the light of recent excavations at the Broadfields RB industrial settlement and of related studies. Technology, organization, mining, roasting and smelting are considered, and variations of operating methods at least partly attributed to differences in the consistency of raw materials.

CL(BAA)

Richard S Kelly: Metalworking in N Wales during the Roman period. *Bull. Board Celtic Stud., 1976,* **27**, *127–47.*

Metalwork studies should consider patterns of mineral exploitation, who was responsible, whether the patterns differ from metal to metal or from civil to military, and so on. This enquiry is confined to the area of the Chester command, where 20 ore-extraction sites and 35 metal-working sites are tabulated and discussed, together with a selection of finished metal objects.

CL(BAA)

C Cookson: For whom the bell tolls. *Welding and Metal Fabrication, 1975,* 43 *(4), 283–285.*

The welding of bells is something of an unknown quantity. In order to repair the 8 cwt bell at St John's Stanground, Eire, cast in 1617, a series of materials tests were made. The bell's composition is 21.6% tin, 1.0% nickel, 0.6% lead, 0.8% iron, and balance copper. Hot ductility and bend tests on a bar of the same composition suggested a preheat of 600–650°C. Welding was accomplished using the tungsten-arc inert gas process with a filler rod of the same composition but with the addition of elements to deoxidize the weld deposits. The only welding equipment required was a water-cooled 450 amp torch operated at a current of 220 amps dc negative and a supply of argon. The bell has been rehung and played for some time; the repair is considered a success.

MG

Henry Cleere: Some operating parameters for Roman ironworks. *Bull. Inst. Archaeol. Univ. London, 1976,* **13**, *233–46.*

Uses data from excavations and field survey of Roman ironmaking sites in the Weald of SE Britain to assess the effect on an ancient landscape of ore mining and deforestation to provide charcoal as fuel for smelting. It is calculated that operations on six of the largest sites would have resulted in the clearance in a little over one century of 300-500 km^2 of forest and ore exploitation over an equivalent area. Data from experiments in reconstructed Roman furnaces and from modern primitive ironmaking are used to assess the probable manning requirements of individual furnaces, settlements, and the entire military operation in this part of the Weald. Author.

CL(BAA)

George Boon: A Graeco-Roman anchor stock from North Wales. *Archaeol Atlantica, 1975,* 1*(2), 195–9.*

The first Mediterranean-pattern anchor stock from Britain was found off Porth Felen (Llyn Peninsula) by members of a sub-aqua club. One face is decorated with apotropaic 'knuckle-bone' lumps, and the anchor's weight suggests a vessel of about 25 tons.

CL(BAA)

David H Kennett: The products of an 18th century bell foundry at Wootton: a static distribution reviewed. *Bedfordshire Archaeol J, 1975,* **10**, *71–4.*

Briefly summarizes the evidence for work by Thomas Russell (fl 1715–43) and William Emerton (fl 1768–90) in Beds-Northants-Bucks-Herts-Hunts. The two working lives between them produced fewer than 100 bells and covered only a limited geographical area, which prompts some reflections on the reliability of distribution maps for identifying workshops in undocumented periods.

CL(BAA)

George C Boon: An early Tudor coiner's mould and the working of Borrowdale graphite. *Trans Cumberland Westmorland, Antiq Archaeol Soc, n ser, 1976,* **76**, *97–132.*

The mould found in Netherwasdale in 1865, which was used for counterfeiting Henry VII coins no later than 1500, is the earliest evidence for the exploitation of Borrowdale graphite. The coins to be copied were hammered into the graphite and the resulting impression was deepened by engraving; the resulting casts would have been difficult to pass off. The earlier phases of working of the two graphite mines on Seatoller Fell are described with the help of documents 1555–97. Mention is made of graphite from the medieval Passau (Bavaria) mines, used in ceramics etc. Marketing arrangements for the Seatoller mines are also described.

CL(BAA)

Ian Kinnes: The Standlow (Derbyshire) dagger. *Proc Prehist Soc, 1976,* **42**, *319–22.*

SK1653. The dagger acquired in 1873 and rediscovered after wartime storage is published for the first time. The blade is of unique shape, has three rivet holes and a rivet notch, and is of arsenical copper with a rivet of different alloy. Its whale ivory pommell (? earliest in Britain) has a tenon fixing. With the dagger was a battle-axe, Roe's Calais Wold, Stage 2; both items would fit a Migdale-Marnoch or developed Beaker context just pre-Wessex Culture.

CL(BAA)

P J Riden: The output of the British iron industry before 1870. *Economic History Review, 1977,* **30** *2nd ser. (3), 442–459.*

Although iron has been made in Britain since prehistoric times, no attempt can be made to measure the size of the industry before the sixteenth century. Since the number of furnaces in use at a given date can be established fairly precisely, as can their average output, one can multiply one by the other to make rough estimates of total output. This is done for each decade from 1530–9 to 1710–9 and for five-year periods to 1785–9, distinguishing (after 1750) between charcoal and coke smelted iron. Between 1790 and 1853 there are sufficient contemporary output estimates to construct an annual series; government statistics begin in 1854.

Author

Robin G Livens: A Don terret from Anglesey, with a discussion of the type. In *G C Boon and J M Lewis, (eds), Welsh Antiquity, Cardiff, 1976, 149–62.*

SH 373781. The terret found during rescue excavations at Y Werthyr is of Don or 'massive' type with heavy lips; the 22 previous finds are catalogued and theories about them reviewed. The type probably developed in NE Scotland in 1st–2nd centuries and was widely distributed and long-used. The exact function is puzzling; wear is on the top of the loops as if the 'terrets' were used upside down. Appended is a metallurgical report for two examples, one brass, one bronze.

CL(BAA)

C S Briggs: The indigenous minerals and metallurgy of the earliest Irish Bronze Age. *Ir Archaeol Forum, 1976,* **3** *(1), 9–15.*

The presence of gold, amber and faience in the graves of the Wessex Early Bronze Age need not be interpreted as evidence for control of an extensive trade network nor even indicative of any long-range trade at that period. All three materials could have derived from areas within Britain and the quantities involved are so small as to provide little support for the idea of substantial trade. Indeed, Ireland is more plausibly seen as the area with a concentration of EBA wealth. DVC

(BAA)

A G Down: Medieval Bell (casting) pits discovered in Chichester. *Foundry Trade Journal, 1977* **142**, *1246–1250.*

Traces of the craft of bell founding, including fragments of 24% tin content bronze, slag, clay mould materials, and the remains of a 0.86 m diameter bell casting pit, came to light in 1974 as a result of the excavation of a large area situated about 80 yards north of the cathedral.

Pottery remains suggest that the site was operated in the 14th century and consistent with the date of 1320 mentioned in records for the installation of the 'great bells'. A lost wax procedure was used for making the moulds, and the description by Theophilus of the casting methods used is quoted. Four illustrations.

APG

J K Almond: Production of Iron and Steel at Tudhoe Works, County Durham. *The Metallurgist, March 1977,* **9** *(3), 127–128.*

The article reviews the considerable but inconclusive evidence that Bessemer steel was produced at the works in commercial quantity before 1877. It seems that Bessemer had steel ingots from his own works in Sheffield rolled into ships' plates at Tudhoe ca. 1860. Shortly afterwards, the manager of Tudhoe Works went to Sheffield to observe the process, and he was followed by the proprietor, Charles Attwood, who took with him 20 tons of Weardale iron. A manufacturing licence was purchased and reports suggest that four 2½ ton convertors were being erected at Tudhoe in 1861. However, Attwood retired in 1865, and it seems that it was not until about 1872 that ingots which could be forged and rolled could be consistently produced. As late as 1880, 17,000 tons of puddled iron was produced at the works, but only 2,000 tons of Bessemer steel.

Other equipment at the works is described, including the new cogging mill erected in 1892. However, the works closed in 1901, and suitable items of equipment were removed in 1903 for installation at the then new works at Cargo Fleet, a couple of miles east of Middlesborough.

APG

A E Mullarkey: Light Alloy Founding. *Foundry Trade Journal, 1977,* **142**, *(3110), 1142 and 1164.*

A summary of a lecture given to the Midland Branch of the Die Casting Society, describing the evolution of the industry in Britain. The first metal was imported from France, but C R Gerhart began production by the Deville process – the reduction of aluminium salts by sodium metal – at Battersea in 1859. The Bell Brothers plant at Washington, County Durham, commenced operation in 1860. By 1862 the metal was being sold at £2 per pound. The Aluminium Crown Metal Company established at Hollywood, Birmingham by James Webster, in 1881–1882 was finally successful in ending the French domination of the British Market. The American Castner set up the UK based Aluminium Company Limited in 1887, and taking over Webster's business, established a new works at Oldbury which produced 250 lbs metal daily, selling at £1 per pound. However, electrolytic extraction methods soon took over from the earlier methods based on sodium reduction and the production of metal increased and the price fell.

The famous aluminium statue of Eros at Piccadily Circus dates from 1893, and at the first motor show in 1902, William Mills and Company displayed an astonishing range of castings including cylinder blocks and heads, crackcases, and other automobile components in aluminium – illustrated in the article.

APG

Anon: Gravity Die Casting in Tudor England. *Foundry Trade Journal, 1977,* **142,** *(3110), 1164.*

An illustration showing the cope die used for the production of cast iron cannon balls at Darwell Furnace in The Weald.

J Gould. **Charcoal Burning at Canwell and Drayton Bassett, Staffs.** Trans. S. Staffs. Arch. Hist. Soc. *1973–74,* **15,** *40-42.*

As account of finds at charcoal burning sites in the area between Sutton Coldfield and Lichfield. It includes details of a metallographic examination of an iron axe head, believed to be produced from bloomery iron.

MMH

S and S Wrathmell. **Excavations at the Moat Site, Walsall, Staffs. 1972–74.** Trans. S. Staffs Arch. Hist. Soc. *1974–75,* **16,** *19–53.*

On the site studied stood the Walsall Manor House from the 12th to the 15th centuries. There were two clear phases, before and after the construction of the moat and the use of the excavated clay to form a flat platform across the site in the second half of the 14th century. There are written records of production of iron in a bloomery. A good deal of slag was found, dating before and after the moat construction, also what may have been an ore roasting hearth. Appendices deal with visual examination of the slag and of the charcoal. The most interesting feature was the association of some slag with a layer of a white powder which appeared to be lime. Further examination is awaited. 70% of the charcoal was found to be hazel and 30% birch.

MMH

J H Denton and M J T Lewis: The River Tern Navigation. *J. Rly and Canal Hist. Soc., July, 1977,* **23** *(2), 56–64.*

No less than ten ironworks have been sited along the banks of the Shropshire River Tern. Of these, the two lowest, Tern and Upton Forges, were in their day of very considerable importance. The story of the Navigation is so intimately bound up with these two forges that a detailed history of the Tern Forge from its opening in 1710 to its closing in 1757, and an outline of the development of the Upton Forge, 1670-1790, are essential parts of the article. Pig iron for Tern came from Bersham, from Coalbrookdale, from Charlcotte furnace under Brown Clee Hill, and probably from the Forest of Dean, water transport playing an important part in every case. Similarly most of the bar iron, nails, wire and steel and brass produced probably went out by water. Upton Forge probably made less use of the navigation particularly after the opening of the Shrewsbury canal in 1796.

APG

EUROPE

Ch. J Marchal: Silver, copper and lead mines in the County of Rosemont. *Revue d'Histoire des mines et de la Métallurgie, 1971,*3 *(2), 113–147. (In French).*

An archive survey of unsigned documents dealing with the mining of ores containing silver, copper and lead in the County of Rosemont during the period 1327–1791.

Herbert Kueas: Technology and chronology of the 'Thomas' chandelier from Leipzig. *Arbeits-und Forschungsberichte zur sachsischen Bodendenkmalpflege, 1971,* **19,** *207–238. (In German. Illus.).*

During excavations in the Thomas church in Leipzig, a 17 cm high Roman altar-chandelier of cast bronze was found. It was analyzed by L Liebetrau who found 82.5% copper, 7.05% tin, 3.0% lead, 2.6% zinc and 3.0% iron. The restoration was done in Weimar by J Ersfield, W Stahl and G Blumenstein. The chandelier was cast by the lost wax process. In the upper part of the original, residues of a clay core were found and analysed by chemical and spectral analysis by R D Bleck and R Rautschke. Stylistic-critical comparisons are made with many other Roman chandeliers having three legs and animal and floral ornaments which are also illustrated. This chandelier is assumed to date from about 1200.

RDB
(Trans. WA)

A Herculano de Carvalho: Chemical analysis of lead tubes of the Roman era. *An. Quim, 1974,* **70,** *(12), 1184–1185. (In Spanish).*

The Sb, Bi, and Sn content of Pb pipes of Roman origin is studied, and the source of the ore is determined by comparing the Sb and Bi content. Some pipes show a high Sn content only in the seam region, indicating their manufacture by soldering. The assignments of origins coincide with those determined by isotopic composition work.

(AATA)

Keith Branigan: Aegean metalwork of the Early and Middle Bronze Age. *Book. Clarendon Press, Oxford University Press, England, 1974, 216, £18.44 illus.*

Included are 200 metal analyses, and some discussion of metalworking techniques. (From review in Times Literary Supplement, Jan 10, 1975).

FWF

Richard Pusch: Metallurgical investigations of ancient iron workings. *Stahl und Eisen, 1974,* **94** *(15), 682 (In German).*

A general review of research into the methods, products, and the way in which modern metallographic, metallurgical, and analytical techniques are used to examine the discoveries of articles and remains of ancient ironmaking plant is given.

MG

Helmut Otto: The evaluation of metal analyses in SAM 1–2. *Acta Prehistorica Archaeologia, 1975,* **4,** *1973. (In German).*

Through examples, the main groupings and conclusions of SAM 1 and 2 are explained and found to be not only reliable but a useful basis for further typological and technological studies which ought to go hand in hand. SAM divides the statistical analysis of the objects according to chemical content rather than shape of the objects, and creates 4 main groups, based largely on the relative amounts of arsenic and antimony, though occasionally also nickel (bismuth not important). One sample from each object sufficies for analysis. SAM's main groupings are sound and can be used to provide a technological succession: 1) raw copper (eg. E 00); 2) arsenical-copper alloys (eg. E 01 A, E 01, C3); 3) metals with greater quantities of silver, antimony and nickel (eg. E 10, FD); and 4) Fahlerz (which can be further subdivided). These various groupings are explained in metallurgical and partly also in archaeological terms.

(BAA)

P Grierson and W A Oddy: The standard of Sicilian Taris from the 11th century until 1278. *Revue Numismatique, 1974,* **16,** *6th series, 123–134. (In French).*

This paper deals with the gold contents of gold coins of Sicily after its capture from the Arabs by the Normans in 1059. The composition was found by the specific gravity method and was remarkably constant for 200 years, and only during the reign of Frederick II (1198–1250) was any falling off in fineness detected. Analyses of some late Fatimid coins are included for comparison.

WAO (AA)

J Piaskowski: Metallographic examination of the iron objects from the cemetery at Karczewiec, Wegrow District. *Wiadomości Archaeologiczne, 1974,* **39,** *(1), 80–89. (In Polish).*

The iron objects have been submitted to an extensive investigation. Data of quantitative and qualitative chemical analysis, metallographical observation of grain size and metal hardness tests are given. The high content of phosphorus in some iron finds is thought to be specific for this district as it has not yet been detected in excavated iron objects from the western Ukraine. A stylistic study of the objects with respect to the local culture is also presented.

TS

M Leoni: Considerations on antique bronze statuary. Fonderia Italiana, 1974, 23 (7/8), 233–235. *(In Italian).*

The chemical analysis of bronzes used in statuary, using non-destructive techniques such as x-ray fluorescence can be used to tell the age and origin of the pieces.

MG

Waclaw Rozanski and Irena Slomska: Suitability of charcoals in the ancient smelting of iron ore as established by investigation of their reactivity. *Kwart. Hist. Nauki. Tech., 1974,* **19** *(4), 729–736. (In Polish).*

Metallurgical processes occurring in primitive furnaces for iron-ore smelting in Swietokrzyskie mountains were discussed, and the results given of analysis of the ancient slags and remnants of charcoals found in the vicinity of the ancient ovens. The amount of CO released in the process of reduction depended on the reactivity of the fuel involved. Studies at 873–1273°C showed that in indirect reduction at lower temps., charcoal from pine wood was most suitable for smelting, followed by that of beech and fir woods.

(AATA)

Josef Riederer: Metal analysis of Roman sesterces. *Jahrbuch fur Numismatik und Geldgeschichte, 1974,* **24,** *73–98. (In German).*

131 roman sesterces were analyzed from the period of Augustus (27–14 BC) to Gordian II (238–244 AD) by means of atomic absorption spectrometry.

(AATA)

Jerzy Piaskowski: About damascene steel. *Book. Ossolineum, Wroclaw, 1974, 366. (In Polish with English summary).*

Part I General information on 'damascene' blades and how their pattern is produced, and other ornamental techniques.

Part II The development of damascene steel, examinations of 'Indian' steel, early examinations of damascene blades, and modern methods of physical metallurgy in research on damascene steel.

Part III Atempts to produce damascene swords in Europe: experiments in Western Europe; and the work of major-general Anossoff and his successors.

Part IV Damascene steel in historical written sources and accounts: ancient and medieval times, 16–18th century, 19–20th century.

HJ

Jerzy Piaskowski: Relation between the content of phosphorus in iron ore or slag and bloomery iron. *Stud. Mater. Dziejow Nauki Pol., 1973, Ser. D, 7, 39–69. (In Polish).*

The P content of ancient Fe objects was correlated to the P content of the ore from which they were produced, and to the P content of the slag. The information contained in old metallurgical records, data available in reports of analyses of old Fe objects and slag, and direct experimental investigation involving the smelting of bloomery Fe from various ores were considered.

(AATA)

Eugeniusz Olszewski: M Radwan's studies on the correlation between the phosphorus content in bloomery iron and slag. *Stud. Mater. Dziejow Nauki Pol., 1973, Ser. D,* **7,** *71–75. (In Polish).*

M Radwan's treatment of the phosphorus balance in his studies of the relation between the phosphorus contents of bloomery iron and slag was discussed.

(AATA)

Zoltan Szabo: On the refining of gold. *Muzeumi Mutargyvedelem, 1975, 2 (1), 105–119. (In Hung. with Germ. and Eng. summaries).*

The author analyzes the variations of two ancient methods of gold refining, cupellation and cementation, as well as later procedures introduced in the Middle Ages such as quartation and the application of sulfides. The role of gold in the history of mankind is described. Finally on the basis of the book entitled Aranyfinomito konyv (Book of Gold Refining) by Laszlo Debreczeni, he discusses the techniques of medieval gold refining and the social background of the refining of gold.

(AATA)

Zoltan Szabo: Archaeological and scientific examination of the Frank winged spears. *Dissertationes Archaeologicae, Ser. II, 1974, (3), 3–54 (In Hung., with Eng. and Germ. summaries).*

Frank winged spears are approached from an archaeological point of view, making use of scientific examinations as well. From the results of the spectrographic and metallographical analysis, the processing technique and provenance of the raw materials can be determined. The Frank winged spears found in Hungary with very few exceptions, could have been produced in the arms manufacturing works along the Rhine using a raw material from the mines of the county Pfalz, in Germany.

SZ

Robert Thomsen: Bog iron ore and country-type iron: *Glimt Metall. Udvikling Da., 1975, 151–163 (In Danish).*

Eidted by Buchwald, V Fabritius. Dansk Metall. Selsk. Copenhagen, Den. The history of iron production in Denmark since 300 AD was presented.

(AATA)

Claude and Daniel Mordan and J–Y Prampart: The bronze hoard from Villethierry (Yonne, France). *Paris, CNRS, 1976, 237 pp, (= 9 suppl Gallia Prêhistoire).*

Publication of the 867 ornaments found in a large pot and turned up by the plough. There are large pins with disc-heads of various kinds, crook-headed pins, single-spiral pins, fibulae and wheel pendants, all subjected to detailed technical study, micrography etc. They appear to represent a finished collection ready for sale, and thus provide a unique glimpse of LBA workshop practice.

CL(BAA)

Richard Harrison: Ireland and Spain in the Early Bronze Age; fresh evidence for Irish and British contacts with the proto-Atlantic Bronze Age in Spain in the second millennium BC. *J Roy Soc Antiq Ir, 1974,* **104,** *52–73.*

A find of two W European tanged daggers was associated in a cist at Atios (Pontevedra) with two sheet-gold ribbed dagger-mounts (?) best paralleled in Scotland and Ireland, and an Argaric silver ring. At Finca de Paloma (Toledo) two Carrapatas halberds with high arsenic content and related to Irish Carn and Clonard types were associated with four Palmela points, a tanged dagger, gold strip and two-edged saw. The later Beaker developments in Iberia can now be linked to EBA Atlantic Europe of c 1750–1500 BC.

CL(BAA)

Martin J Almagro Gorbea: The Bodonal de la Sierra (Spain) gold find. *Roy Soc Antiq. Ir, 1974,* **104,** *44–51.*

The treasure found in 1943, not previously fully published, consisted of portions of thick gold bar torcs with expanded recurved terminals and armlets, clearly Irish in origin. The gold belongs to Hartmann's Group M, common in the Bishopsland phase. Such torcs are often found in France but not previously in Iberia. Deposition c8th century BC is suggested, when the damaged pieces could have been 200 years old already.

CL(BAA)

Patric André: A copper ingot from Britanny. *Bull Board Celtic Stud, 1976,* **27,** *148–53.*

A bun-shaped ingot recovered while deep-ploughing at Bubry (Morbihan) is the first such discovery in Gaul; moreover the ingot is unlike Iberian examples but is closely paralleled in N Wales and Anglesey. The inscription reads AMIL.SVN.F and there is a countermark of an incised trident. The abundance of such ingots in Wales almost presupposes the trade which this example demonstrates.

CL(BAA)

Ida Bognar-Kutzian: On the origins of early copper-processing in Europe. In *Megaw, J V S (ed), To illustrate the monuments: essays on archaeology presented to Stuart Piggott, 1976, 69–76.*

Although the earliest (native) copper object appeared in Early Neolithic Transylvania, it took another half-millennium before true metallurgy, locally carried on, was under way. It is not yet possible to say whether the process was invented independently in the N Balkans and Carpathian Basin or borrowed from the Near East. Some Late Neolithic copper mines are now known in Yugoslavia.

CL(BAA)

Ole Schmidt: The Anholt-cannon. *Nationalmuseets arbejdsmark, 1974, 80-88. (In Danish).*

This article describes the manufacture and function of the early breech-loading cannon and chamber. The conservation process is discussed with examples of the information given by metallographic tests as to the quality of the metal before conservation and the details of manufacture.

HBM

G Riccio: A fragment of history: bells and cannon. *Fonderia Italiana, 1975,* **24** *(10), 309–315. (In Italian).*

The development of foundry technology for the manufacture of cannon and of bells is interrelated. The casting of some famous large bells in the 17th and 18th centuries is considered in the context of the development of ordnance manufacturing in the 16th and 17th centuries.

MG

Jean Puraye: Making damascus barrels, part I. *The American Rifleman, 1976,* **124** *(4), 25–28.*

The traditional 19th and early 20th century European methods of manufacture of firearm barrels with laminated iron and steel are described. A preference for charcoal smelted iron and the difficulty of obtaining it in the 1880's is mentioned. Factory owners and lessee, and gunmakers of the Leige (Vesdre Valley) region of Belgium of 1907 are listed.

GHG

Jean Puraye: Damascus barrels: they faked those, too (part II of Damascus barrel story). *The American Rifleman, 1976,* **124** *(5), 33–35.*

Methods of producing imitation Damascus gun barrels by acid etching or paper transfer, and resulting legal action in Belgium of the late 1880's are described. Inscriptions fabricated in the lamination of genuine Damascus barrels made in the Liege region are mentioned. Competition of steel barrels and other factors which led to the end of Damascus barrels are discussed.

GHG

G V Inanishvili; L G Orlov; F N Tavadze and L M Utevskii: Electron microscope study of the structure of archaeological iron. *Izvestia Akademii Nauk SSR, Metally*, Jan-Feb 1976, (1), 243–245. (In Russian).*

The structure of iron obtained from tools and monuments dated 1000 BC was studied under the electron microscope, and showed evidence of hot forging carried on above the critical temperature.

*A cover-to-cover translation of this journal is published in London as Russian Metallurgy (Metally).

MG

Jan Peder Lamm: A mirror from Helgö and new information about the mirror from Paviken. *Fornvannen, 1974, 198–201. (In Swedish).*

A hack-silver piece from Helgö, Uppland, is identified as part of a Roman hand-mirror, the second Roman mirror found in Sweden. Metallographic analyses are made on both mirrors.

HBM

B Jovanovic and B S Ottaway: Copper mining and metallurgy in the Vinca group. *Antiquity, 1976,* **50** *(198), 104–113.*

The authors discuss the finds of metal and evidence of metal working from the Vinca cultures. In particular, the Vinca copper mines of Rudna Glava, Yugoslavia. Analysis of the ores, malachite, etc are published.

PTC

Ragnar Engestrom: Medieval bronze-casting on Gotland-A newly discovered workshop at Block Priorn in Visby. *Gotlandski Arkiv, 1974, 51-66. (In Swedish).*

In a refuse layer from Medieval bronzecasting 5000 fragments of molds were found. The workshop, dated to 13th Century, mainly manufactured pots with three-pawed legs. The location at the Maria Church, Visby, may indicate that the caster was from Germany. The technology of bronzecasting is discussed, and an attempt at reconstruction is made. HBM

F N Tavadze; V I Sarrak and G V Inanisvili: Study of the mechanical properties and character of destruction of archaeological iron. *Soobsceniya Akademii Nauk Gruzinskoy SSR, 1975,* **80** *(2), 409–412.*

Ten specimens investigated from Georgian sites: from the 10th/19th centuries BC, 6th/4th centuries BC, 7th/5th BC, and 4th/1st BC. Mechanical tests show the quality of iron to have been lower than that of the more recent material used for archaeological purposes. This phenomenon is due to the considerable heterogeneity of carbon and to the quantity of slag inclusions. Deformation patterns appear in areas low in carbon. CPSA

B A Sramko: On the history of development of ancient iron smelting and iron working. *Voprosy istorii yestervoznaniya i techniki, Moskva 1976,* **4** *(53), 49-54.*

General remarks. Meteoritic iron artefact from Bickin Bulak (1750-1500 BC), cast iron cauldron from Nikolayevka (Hellenistic) and cementation furnace from the hillfort Lubotinskoye(ca. 500 BC) mentioned. In the author's opinion the present sources do not allow us to consider only one centre of the spread of iron technology. Detailed arguments might be useful to support this idea. CPSA

I A Baranov: A medieval mould for casting found at Stary Krym. *Sov. Ark. 1977, 2, 242-246. (In Russian).*

A stone mould for casting various small ornaments. ECJT

J Ilkjaer: A bundle of weapons from Vimose. *Kuml, 1975 117-162. (In Danish).*

The find represents presumably a sacrificial booty of weapons dating into the early Late Roman Period. It contains 29 lance heads and 8 barbed spear heads wrapped in a cloth. CPSA

J Ilkjaer and J Lonstrup: New excavations in Illerup Adad. *Kuml, 1975 (1976), 99–115 (In Danish)*

Two accumulations of iron weapons were discovered in this moor deposit by means of a proton magnetometer, about 6–7 m from the ancient shore: 20 swords (stamped and inscribed by Roman swordsmiths), spear and lance heads, shield bosses. One group dates from about 200 AD., the other from about 400 AD. CPSA

S V Kouzminykh: The metallurgy of the Volossova and Garino-Bor cultures. *Sov. Ark. 1977, (2), 20-34. (In Russian).*

Researches carried out on the middle Volga and in the Kama region have brought to light new facts about the metallurgy of the Volossova and Garino-Bor cultures. Only traces of a copper industry were found but no slag nor ore. Smelting was probably carried out in small hearths based on the cupriferous sandstone deposits of the region. The objects found consisted of simple knives, awls, chisel and socketed arrowheads made from copper sheet folded over to make a socket. Open stone moulds and crucibles were used for casting ingots. ECJT

V Maly: (Summary: Metallographic analysis of a hunting knife from Krasna Dolina near Rakovnik). *(In Czech). Studie a Zpravy Okresniho Muzea Praha-vychod 1973/6, 15-21.*

A large hunting knife, found in a 15th century AD wood-tar burning plant at Krasna Dolina, Rakovnik, central Bohemia (excavated by the Archaeological Institute Prague): blade was wrought iron only. CPSA

G Alfoldy: *Noricum. London-Boston 1974.*

History of the Regnum Noricum with valuable remarks on pre-Roman (Celtic) and Roman iron industry in the iron ore regions of the recent Carinthia and Styria (pp 28, 45–46; 99–100, 110, 175, 206). CPSA

H Amborn: The significance of the culture of the Nile valley as regards iron production in Subsaharan Africa *(In German) Studien zur Kulturkunde Nr. 39 Wiesbaden 1976.*

Detailed analyses of the ancient material cultures of Egypt and Sudan persuade us that not only iron but also tin bronze were used in the everyday life, but only exceptionally. The sudden increase of iron working came extremely late ie. after the Persian occupation. Ancient Egypt hindered the spread of iron to Africa via the Nile valley. Surprising is the scepticism of the author concerning the relatively late iron slag heaps of Meroe because he doubts they could represent bloomery waste at all (despite Dr Tylecote's recent reports and analyses). CPSA

H F Cleere: Some operating parameters for Roman ironworks. *Bulletin no. 13 of the Institute of Archaeology of the University of London, 1976, 233-243.*

An attempt at the economical and social evaluation of data known about the iron industry of Weald, operated by the Roman Navy (Classis Britannica). Calculations of possible productivity, output consumption of ore and timber influence on the ancient landscape. CPSA

S Pazda: Early medieval ironworking at Piotronowice, (Kreis Wolow.) *Studia Archeologiczne (Wroclaw), 1976, 9, 57–92.*

Two reheating hearths for iron blooms excavated at a site dating from the 11th century AD. They are kettle-shaped, lined; finds of clay tuyeres. CPSA

P L Pelet: Research on classifying early historical iron furnaces. *Archiv für das Eisenhuttenwesen, 1976, 47, 709-712.*

A new proposal on classifying numerous iron smelting furnaces brought to light by recent excavations in Europe. The author underlines the thermal insulation of shafts. The capacity of furnaces depend to a large extent on the height and diameter of the shaft. Primitive types of bloomery furnaces survived in regions where economic conditions did not allow the transition to some more productive installations, (shortage of means or needs). CPSA

Kh. Todorova, N V Ryndina and E N Tchernykh: Investigation of copper objects of the Eneolithic period from Goliamo Deltcheva (Bulgaria). *Sov. Ark. 1977, (1), 15–25. (In Russian).*

A spectrographic and metallographic examination of 18 copper objects (Awls, chisel, double spiral pin, shafthole axes, flat axes) from a tell near the village of Goliamo Deltchevo in north-east Bulgaria and dated to the 4th millennium BC. They belong to the Gumelnitsa – Kodjadermen – Karanova VI culture. Metallographic examination showed that double moulds were used in casting hammer axes and chisels. This is the first time we have evidence for such a type of mould being used in the Balkans in that period.

ECJT

B A Chramko; L D Fomine and L A Solntsev: The initial stage of iron working in east Europe. *Sov. Ark. 1977, (1), 57–74. (In Russian).*

The 20 iron objects examined belong to the pre-Scythian period of the 8th-7th centuries BC. Apart from meteoric iron little is known about the technology during the 2nd millennium BC. By about 1500 BC iron mining started but it was not until the 8th century that metallurgists had learned to produce a better quality iron, including carbon steel. However amongst the objects produced pure iron prevails. Later, objects had a higher carbon content. Cementation was known but still rare. Welding of iron and steel was successfully employed. The differences in technique make it possible to trace the oldest centres of iron mining and working to the north Caucasus, the basin of the Dniepr and its tributaries and the Volga–Kama basin. Already in the pre-Scythian period an important centre was established at Belskoie.

ECJT

V B Vinogradov and SlL Doudarev: Bronze objects found at the village of Sovietskoie (Tchetcheno-Ingouchetia). *Sov. Ark. 1977 (1), 276-279. (In Russian).*

Two splayed axes and a bucket with everted rim and handle were analysed. The bucket was made of pure copper sheet metal. The axes are of a unleaded bronze. Date 8th century BC.

ECJT

Ingegerd Sarlvik: Iron production at Ryd. *Vastergotlands fornminnesforenings tidskrift 1975-76. Skara, Sweden. pp 105-115, 9 figs. (In Swedish).*

An ironworking site was discovered in 1968 in Ryd, near the town of Skovde in central Vastergotland in the southwestern part of Sweden. The site was located in an area rich in prehistoric monuments. It came to light when a bulldozer removed the topsoil from a cultivated field. This operation left only the lowest levels of the prehistoric constructions. The archaeological excavation, that followed, revealed 227 slag pits, 144 hearth pits with charcoal and firecracked stones, eleven stone-paved floors of huts and three other, rather extensive, stone pavements.

The slag pits were concentrated in six major areas, where they were placed together. The hearths were more evenly distributed. The floors were located outside the slag pit area. The stone pavements were found in a damp depression in the field. The diameter of the slag pits varied from 0.5 m to 2.5 m, and their remaining depths from 0.1 to 0.85 m. The amount of slag in the pits could be as little as two or three pieces or as much as 32 kg. There was often more slag in small pits than in large ones. This could indicate that the small pits were the remains of smelting furnaces while the bigger pits were the remains of forging. Some of the hearths could have been used for charcoal burning.

Some slag pits turned out to have been lined with stones or clay. Sometimes so much burnt clay was found that it could indicate the use of a shaft furnace. Some slags showed impressions of straw. Because of these findings the author suggests that the furnaces in Ryd may have been of the same character as the furnaces found in Jutland.

Metallographic analyses of nine samples of slag have been made by Elon Hedstrom, Strassa, and he had also analysed water from streams near the site. Three radio-carbon analyses have been made, showing the following dates: 2160± 100, 1250± 100 and 1120± 145 BP (St. No. 3385, 3431 and 3432).

Author's abstract

Birgit Arrhenius: East Scandinavian Style I—A review. *Medieval Archaeology, 1974,* **17**, *24–42. (In English).*

In the article it is suggested that the frequent use in the Salin Style I of small ornamental fields bordered by high ridges was a technical feature to prevent the mold from cracking during casting, especially where high-tempered bronze was used. Mold fragility was evidently a real problem, except for smaller molds.

HBM

Richard Harrison and Carmen Priegu: Beaker metallurgy in Spain. *Antiquity, 1975,* **49** *(196), 273–278.*

This brief report on the excavations at El Ventorro, Spain provides an important archaeological link with the Beaker peoples and early Spanish metal working. Among other remains of copper smelting were unusual but distinctively decorated crucibles, allowing a firm cultural horizon to be assigned.

PTC

Krystyna Cygorijni and Stefan Knapik: Medieval wire drawing technology and equipment. *Wiad. Hutn., June 1973,* **31***(6), 228–230. (In Polish).*

Manual drawing of a forged rod of soft metal through a die appears to have been used until the 16th century when such mechanical aids as the water wheel, windlass, levers and small hand rolls came into use. The first reference in the Polish literature to the manufacture of sheets and wire occurs in a 1524 grant of manufacturing rights to a Cracow merchant.

MG

M Aklberg; R Akselsson; B Forkman and G Rausing: Gold traces on wedge-shaped artifact from the Late Neolithic of Southern Scandinavia analyzed by proton-induced x-ray emission spectroscopy. Part I. The wedge-shaped pendants of the Scandinavian Neolithic. *Archaeometry, 1976,* **18** *(1), 39-42.*

Wedge-shaped pendants made from black slate have been identified as touchstones for bronze and precious metal. The authors state that tests of modern bronze alloys on slate pendants allow one to distinguish alloys with a 2% difference in tin content.

JSO

M Aklberg; R Akselsson and B Forkman: Part II. Analysis of wedge-shaped pendants by proton-induced x-ray emission spectroscopy. *Archaeometry, 1976,* **18** *(1), 42-49.*

The irradiation and counting conditions and the equations for determining concentration are given for analysis by PIXE for multielement determinations. The results obtained are expressed as ng of Au and of Ag and % of Au in the total for nine locations on each of two late Neolithic wedge-shaped artifacts.

JSO

Willfried Epprecht and Alfred Mutz: Drawn Roman wire. *Draht, 1975, 26 (12), 645-9. (In German).*

Several specimens of ancient Roman wire were subjected to spectral and x-ray fine structure analysis to determine their method of manufacture.

(AATA)

ASIA

A Werner and M Cowell: Report on the compositional analysis of two groups of coins from the hoard. *Numismatic Chronicle, 1975,* **15**, *7th series, 123–124.*

This report is included in a paper entitled 'An early tenth century hoard from Isfahan' by N M Lowick. Altogether six silver dirhams of the Abbasid dynasty and another six of the Samanid dynasty were analyzed by atomic absorption spectrometry for silver, copper, lead, bismuth, and gold. The silver of the Abbasid coins was in the range of 91 to 96% and that of the Samanid ones in the range of 92-98%. Various other elements were detected at the trace level by emission spectroscopy, the most interesting being mercury which was present in three coins. WAO

B Rothenberg: More on dating the Mrashshash Slag Heap: *Israel Exploration Journal, 1975,* **25** *(1), 39-41. (In English).*

Slags found at Mrashshash (today in the area of the Port of Eilat in Israel) were dated to the Roman Period. It was concluded that the chemical composition of ancient smelting slags is not acceptable as a chronological indicator. Copper smelting slags from Palestine, Sinai, Iran, Turkey, Spain, Cyprus, etc had extreme variability of chemical composition. The variable composition was not, however, a function of their date. ZG

Tsuramatsu Dono: Discovery of metals and development of the culture. *Scientific Papers on Japanese Antiques and Art Crafts, Dec. 1975, (19), 9–14.*

A brief historical review on the discovery of various metals such as copper, bronze, and brass is based mostly on Chinese literature. KY

U Zwicker; H Rollig and E Grembler: Examination of copper slag samples from two early smelting sites at Timna (Negev) *Metall, Dec. 1975,* **29** *(12), 1193–1197. (In German. 14 refs).*

The results of x-ray fluorescence macro- and micro-analysis of the material which was in the form of ore and of slag and other products are presented. MG

Trevor Watkins: Two unfinished spearheads in the Ashmolean Museum, Oxford. *Levant, 1974,* **6**, *188–192.*

The two unfinished bronzes of EB2-3 date show evidence of casting technique. One, from Anatolia was cast in an open (lidded) mold and x-ray fluorescence analysis showed it to contain Sn 0.8%, As 0.4%, Pb less than 0.1% and Sb 0.5%. The other, from near Carchemish on the Euphrates was cast in a two-piece mold and XRF showed it to contain Sn 6.2%, As 0.5%, Pb 1.0% and Sb less than 0.1%. Two approaches to metal working are thus illustrated, the former relying much on forging to achieve the final shape (the forging evidence on the first bronze is very interesting. The smith worked roughly up one side, turned the casting over and worked on the opposing surface before the work ceased). The latter bronze appears to be a miscasting, with the bronze pouring stopped halfway, and evidence of an unmatched pair of molds being (accidentally) used. The article concludes with a discussion on the introduction of tin-bronzes. MJH

J Armstrong and F T Wheelwright: Tin smelting in Malaysia: *Pamphlet Paper No. 3.1. Fourth World Conference on Tin, Kuala Lumpur, Malaysia, Oct 3–Nov. 5, 1974, 20 pp (In English, 8 refs).*

The historical development of the tin industry in the Malay Peninsula is traced, with particular reference to smelting. Early smelting techniques and practices are described including the introduction of European smelting technology. The history of the two Malaysian smelters is followed by a review of subsequent developments in plant and process and a description is given of the current operations at the smelters of the Straits Trading and Eastern Smelting Co. MG

J E Curtis and K R Maxwell-Hyslop: The gold jewellery from Nimrud. *Iraq, 1971,* **33**, *101-112.*

The complete corpus of jewellery from Nimrud has been published in this article separately from the main reports. Two items are of interest regarding technique of manufacture: a granulated cylindrical bead and the 'Nimrud jewel' which is a chalcedony stamp seal set in gold and attached by a thin chain to a fibula. Details noted on the latter include soldering and repairs carried out in antiquity; both items show a high degree of technical skill. MJH

J Mishara and P Meyers: Technical examination of a Bronze Iranian beaker from Iran. *American Journal of Archaeology, 1974,* **78** *(3), 252–254.*

The authors examined the method of fabrication, the composition of the bronze, and the kind and extent of the corrosion. From the collected data, the metallographic observations, especially the manner of corrosion penetration into the bronze body (intergranular corrosion), it seems that the beaker is of ancient origin. The arguments and reasoning used to reach this conclusion are apt and convincing. TS

Robert Maddin: Early iron metallurgy in the Near East. *Trans. Iron Steel Inst. Jpn, 1975,* **15** *(2), 59-68.*

Iron meteorites found in the Near East were analysed, followed by conjecture of Fe etymology. The city of Metsamor, the probable iron-producing center of the ancient world located in present-day Armenia SSR, was described as well as a metallurgical plant of the city.

Mary A Littauer and Joost H Crouwell: Early metal models of wagons from the Levant: *Levant, 1973,* **5**, *102–126.*

This is a study of the four-wheeled model wagons from Syria and Anatolia which have been dated to late 3rd/early 2nd millenium BC. Details of the construction techniques are given, and the light this throws on early wheeled transport. There are detailed discussions of the axles, frame, wheels, etc, of the authenticity of the models and an appendix gives some semi-quantitative spectrographic analysis of the various parts of one cart from Anatolia. MJH

John P Rappolt: Analyses and thermoluminescent dating of a 'Chung'. *MASCA Newsletter, May 1975,* **11** *(1), no page numbers, article occupies one page.*

Analysis of the metal sampled from a Chinese chung (clapperless bell) by x-ray diffraction and x-ray fluorescence spectrometry showed it to be 99% copper. Earthen core material from the handle was dated by thermo-luminescence and gave 1500 ± 350 BC. Differential thermal analysis and thermogravimetric analysis of the same core material supported the belief that it had been heated to more than 400°C. JW

M L Nigam: Andhra Pradesh State Museum Series No. 13: A catalog of arms and armor in the State Museum, Hyderabad, (A.P.). *Book. Government of Andhra Pradesh, Hyderabad, India, 1975, 102 pp., 23 pls.*

Methods of fabrication, technology of steel manufacture, and pattern-welding or damascening are considered. In South India, iron is said to have been in use since the beginning of the first millenium BC.

The manufacture of steel from iron is discussed. Special treatment was given after fabrication by heating and hammering with dry bone powder to produce lustrous surfaces. The final operation of bringing out the grain or pattern-welding (damascening) was achieved by applying alum or salt peter. Another unidentified mineral was also applied after heating the objects. Various techniques such as inlaying, enamelling, chiselling, jewelling and other forms of decoration are described. BBL

C W Brewer: Metallographic examination of two bronze figures from Khmer. *ICOM Comm. for Cons., 4th Triennial Meeting, 1975, pp 75/25/2–1 to 75/25/2–6.*

The Department of Mining and Metallurgical Engineering of the University of Queensland is carrying out chemical analyses and metallographic examination of ancient bronze figures from Asia, which are held in the Australian National Gallery, Canberra. The object of this long-term project is to accumulate data regarding the chemical composition and metallurgical structure of the bronzes, and later to try to relate the compositions to the metallurgical ores found in the regions where the bronzes were made.

This short paper covers only the metallographic examination of two bronze figures from Khmer. A comprehesive joint paper with Noel Barnard et al has been written, covering all aspects of the examination, and is being published by the Australian National Gallery. AA

V I Sarianidi, N N Terekhova, E N Tchernykh: The beginning of metalworking in ancient Bactria. *Sov. Ark. 1977, (2), 35–42. (In Russian).*

12 analyses of copper arsenical objects dated to the end of the Bronze Age. A smelting hearth was discovered with traces of an unsuccessful smelt with remains of copper drops. Metallographic examination was carried out. ECJT

AMERICA

J E Hanafee: William Penn's Bolts Get Checkup. *Metal Progress, March 1976,* **109** *(3), 36–48.*

The Franklin Institute Research Laboratory was asked to inspect metallurgically the fasteners which hold together the 27 ton statue of William Penn installed in the top of Philadelphia's City Hall in 1895. The statue consists of about 45 bronze castings each with an internal flange ½ to ¾ in. thick and approximately 4 in. wide. Mating flanges are held together by approximately 1300 ¾ in. diameter 3 in. long bolts, and 86 1 in. diameter 5 in. long bolts connect the statue's stump to the base plate. A mixture of two types of bronze nuts and bolts, wrought iron, and medium carbon steel nuts and bolts with or without steel or bronze washers, was found. Although the microstructure of the bronze left much to be desired by the standards of today, little corrosion had taken place. Some of the wrought iron bolts were seriously corroded in the area where the flanges meet. The statue was caulked in 1895, but the caulking has long since deteriorated, allowing air and moisture to penetrate the gap, giving ideal conditions for corrosion by galvanic action.

The recommendation which was made and accepted was that all the fastners should be replaced by forged high-silicon bronze (copper alloy 655) fasteners, purchased as one lot to ensure that all were made in the same alloy with the same thermo mechanical treatment. APG

A.R Rosenfield: The Crack in the Liberty Bell. *Int. J. of Fracture, 1976,* **12** *(6), 791-797.*

After reviewing all the evidence, the author concludes that the failure had its origin in the necessity of using a brittle alloy as the material of construction. The problem was compounded by improper operation and maintenance. APG

CH Goedicke and J Riederer: Metal analysis of some copper objects. *In Eisleb, D: Altperuanische Kulturen, 1975, pp 71-73. (In German).*

All exposed Peruvian copper objects of the museum of ethnology in Berlin were analyzed by means of the energy-dispersive XRF Two groups of metals were found. The larger group consists of a very pure copper, a small group contains higher amounts of arsenic. JR (AA)

AFRICA

Philip J C Dark: Brass casting in West Africa. *African Arts, 1973, (4), 50-53, 94.*

Variations in the use of open-mold and lost-wax techniques among different peoples in West Africa are described. These include different combinations of materials for the mold, different methods of venting, etc. B Ap

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H M Friede: Composition of pre-European copper and copper-alloy artifacts from the Transvaal. *J S Afr. Inst. Min. Metall, 1975,* **75** *(5), 185-191.*

Cu artefacts (5 ingots and 2 ornaments) found at prehistoric sites in the Transvaal were analyzed. All the artefacts showed a high Cu content and a relatively low level of impurities. A little-known ingot type from the Limpopo Valley (nail ingot) was described, and its analysis given. The analysis of 2 Cu ornaments that come from sites dated to the 5th Century AD and the 11th Century AD showed the constancy of the composition of Cu articles over long periods. The well-known Blaauwberg Ingot was reanalyzed, and the results showed that this ingot could be regarded as a true bronze. Analysis values for the composition of 3 brass artefacts from Bambandyanalo (Mapungubwe), Northern Transvaal were given. Some aspects of pre-european bronze manufacture and brass smelting, and of early metal trade from the East Coast into the interior of South Africa, were discussed. (AATA)

H M Friede and R H Steel: Notes on Iron Age copper-smelting technology in the Transvaal. *J. S. Afr. Inst. Min. Metall., 1975,* **76** *(4), 221-31. (In English).*

Iron age copper metallurgy and copper-smelting techniques in Transvaal are described, and copper furnaces are classified. The analyses of furnace slags and sherds of glazed crucibles from archaeological sites of Transvaal and neighbouring Orange Free State provides evidence of copper smelting there in Iron Age Times. (AATA)

TECHNIQUES

C W Brewer and B J Heffernan: Metallographic examination and chemical analysis of ancient bronzes. *Proc. National Sem. Cons. Cult. Materials, Perth, Australia, 1976, 258-263.*

The paper describes the methods of metallographic examination of bronze and the chemical analysis of bronze by several methods. The information which can be obtained by the metallurgist from metallographic examination is outlined. The object is to accumulate data regarding the chemical composition and metallurgical structure of the bronzes, and later to try to relate the compositions to the metallurgical ores found in the regions where the bronzes were made. CP

Wolfgang Czerny and Gerhard Winkler: Nondestructive analysis of bronze coins by activation with 14 MeV neutrons. *Oesterr. Akad. Wiss. Math-Naturwiss. Kl., Sitzungsber., Abt. 2, 1974,* **183**, *(4–7), 271-284. (In German).*

A cast coin was analyzed to determine if it was genuine or a modern falsification. The principles of activation analysis, the actual analysis, data for activities of Cu and Sn, standards for comparison, and comparison of the results with those of x-ray fluorescence methods were described. (AATA)

E G Thomsen and H H Thomsen: Early wire drawing through dies. *Journal of Eng. for Ind. (Trans. Amer. Soc. of Mech. Eng., Series B), 1974,* **96** *(4), 1216–1221.*

The history of wire drawing through dies is reviewed and the description of the process by Theophilus, dating from about 1100 AD, is discussed. It can be assumed that the fact that this early metal worker did not mention a die angle was due to his lack of knowledge of its function. It is suggested that deburred holes, or holes in which boring operation inherently produced conical surfaces were sufficient to make the wire drawing process successful without the operator knowing the reasons for his success. The recent data presented by Okolo and Wistreich seem to confirm that wire drawing is possible over a wide range of operating conditions and die angles. (12 refs). MG

L H Cope: The chemical composition of a tetradrachm of Probus with a reverse type illustrating codex Theodosianus XII, vii, 1. *Numismatic Chronicle, 1975,* **15**, *7th series, 187–190.*

Gravimetric and neutron activation analysis of a tetradrachm of Probus minted in Alexandria in 277/278 AD was carried out. The results follow: Cu 92.65%, Sn 2.11, Ag 2.04, Pb 2.59, minor amounts of Fe, Ni, Co, Zn, As, Sb and Au. WAO

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