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The cover illustration is a photograph of a public house sign recently commissioned by Courage Western Limited and painted by David Fisher of Midsomer Norton for the Bell Inn, Pruett Street, Bristol. It reflects the growing interest being shown in industrial history in many spheres of leisure activity.

The old wireworks and ironworks of the Angidy Valley at Tintern, Gwent

by H W Paar and D G Tucker

Introduction

Tintern, a village on the tidal part of the River Wye, in Monmouthshire *(now the new county of Gwent)*, is famous for the ruins of its abbey, but the casual visitor does not know that Tintern was for nearly three and a half centuries an important industrial centre. Here, Britain's first water-powered wire-drawing works were set up in 1566 , and by the mid-eighteenth century there was a large complex of iron and wire works spreading from the banks of the River Wye up the valley of the small Angidy river for nearly two miles, entirely water-powered, and in 1821 using 20 waterwheels. There were eventually twelve dams *(or dammed ponds)*, and some extensive leats. The iron and wire works finally closed in 1901. Now there are very few remains except for the ponds which add to the charm and beauty of this steep-sided, well-wooded little valley.

The financial and managerial history of the Tintern works has been told before, (1,2,3,4,5,6) but the published accounts do not say much about the events of the 18th and 19th centuries, or about the geography of the works, and this paper particularly attempts to deal with these matters. The Angidy valley also sheltered several corn water-mills, reference to which is confined to the caption to Fig.1, except in cases where mills were incorporated into the iron industry.

The general layout of the Angidy river system and of the ponds, leats and mills is shown in Fig.1, the caption to which lists the thirteen mill sites *(there were many more than 13 individual mill buildings)* in terms of their 19th-century designations.

The early history of wire- and iron-making at Tintern

In centuries past, one of the largest, and probably the most important, of uses for wire was in the making of "cards" for the preparation of wool for spinning; others were for bird-cages, knitting needles, curtain rings, small chains, etc. In the mid-sixteenth century the British hand-drawn product was inferior to that of the Continent. It was, however, official Government policy to make Britain less dependent on imports. Thus William Humfrey, Assay Master of the Royal Mint in London, was able to get support for the establishment of a wire-making industry at Tintern using water power, in 1566. It was at first intended to make brass and brass wire at Tintern, and Humfrey went to Saxony to obtain the services of an expert, Christopher Schutz, who came to Tintern in 1566. However, only a small amount of brass was made, and he started to draw iron wire instead. At first this was not very successful, as much experimenting was necessary and it proved difficult to get suitable iron as exceptional ductility and tenacity were required. An iron known as Osmond iron was really necessary. Further foreign experts had to be obtained and all this caused about two and a half years of delay.

Eventually iron wire drawing proved lucrative, and much wire was sold.

In 1568 the works were taken over by the Company or Society of the Mineral and Battery Works, who held the lease until 1631.

It was said that by 1597 there were 5000 workers employed in different parts of the country making goods from Tintern wire. Such was the demand for wire that the Company built a second wireworks in 1606-7 at Whitebrook, a few miles to the north of Tintern. (7,8)

For a long time the Company had a legally-enforced complete monopoly of wire-making in Britain, although several attempts were made to break it. (1)

Iron-making at Tintern

We do not know when the furnace and forges at Tintern were first built. In the early days of the wireworks the Osmond iron was made at Monkswood, where for a time the forge belonged to the wireworks. The raw iron used was made by the bloomery process. When blast-furnace iron came to be used as the raw material is not clear. There were charcoal blast furnaces around Pontypool in the last two or three decades of the sixteenth century, but it is unlikely that their product was used for making Osmond iron.

It has been suggested that there were two different furnace sites (1,2) but we have been unable to find any **positive** evidence for more than one.

The early furnace was a large and efficient one, producing in 1672-3 no less than 1142 tons of pig iron in 62 working weeks, and in 1675-6, 1034 tons in 61 weeks, using a mixed charge of cinders and myne *(ie ore)* in the ratio of two to one (9). In the accounts (10) for the year 4 August 1694 to 31 July 1695, the amount of pig iron "made this Blast" was 943 tons, and it appears that about 2000 loads of charcoal were used for this, with 1374 dozen bushels of "Iron Oar". Stocks of ore were held at "Brockwear, Redbrook and Abby Back", and stocks of cinders at "Monmouth, Abby Back, Brockwear" and at the furnaces.

There were two *(and almost certainly three)* forges by 1690, for account books (11) refer to the Upper and Lower Forges and to Bont Seyson (sic) Forge. Indeed, the forge at Pont-y-Saeson must have been built by 1675, for it is shown in John Ogilby's map of that date (12). The accounts previously quoted (10) give some details of production at the Upper and Lower Forges. For example, in the year ending July 1695, the Upper Forge produced over 61 tons of Osmond iron, nearly all for the wireworks, and the Lower Forge produced over 81 tons of merchant and bar iron. That the Upper and Pont Saison Forges were separate is reasonably certain, as sites are known, from later records, for three forges.

Lessees and operators at Tintern

The land on which the Tintern works were built belonged to the Earls of Worcester, who later became the Dukes of Beaufort, throughout the existence of the works. The operators of the works were lessees except during the period up to 1631 when the Company of Mineral and Battery Works were the lessees and then the operators were sublessees *("farmers")* of the Company. For the sixteenth and seventeenth centuries, Rees gives details of the operators, and from his involved account Section A of Appendix 1 has been prepared. The present authors have found only one discordant piece of evidence, which is noted.

When it comes to the eighteenth and nineteenth centuries, however, there is no clear comprehensive account of the matter, and Section B of Appendix 1 has been put together from a large number of sources. Several contradictions are included, which cannot at present be resolved.

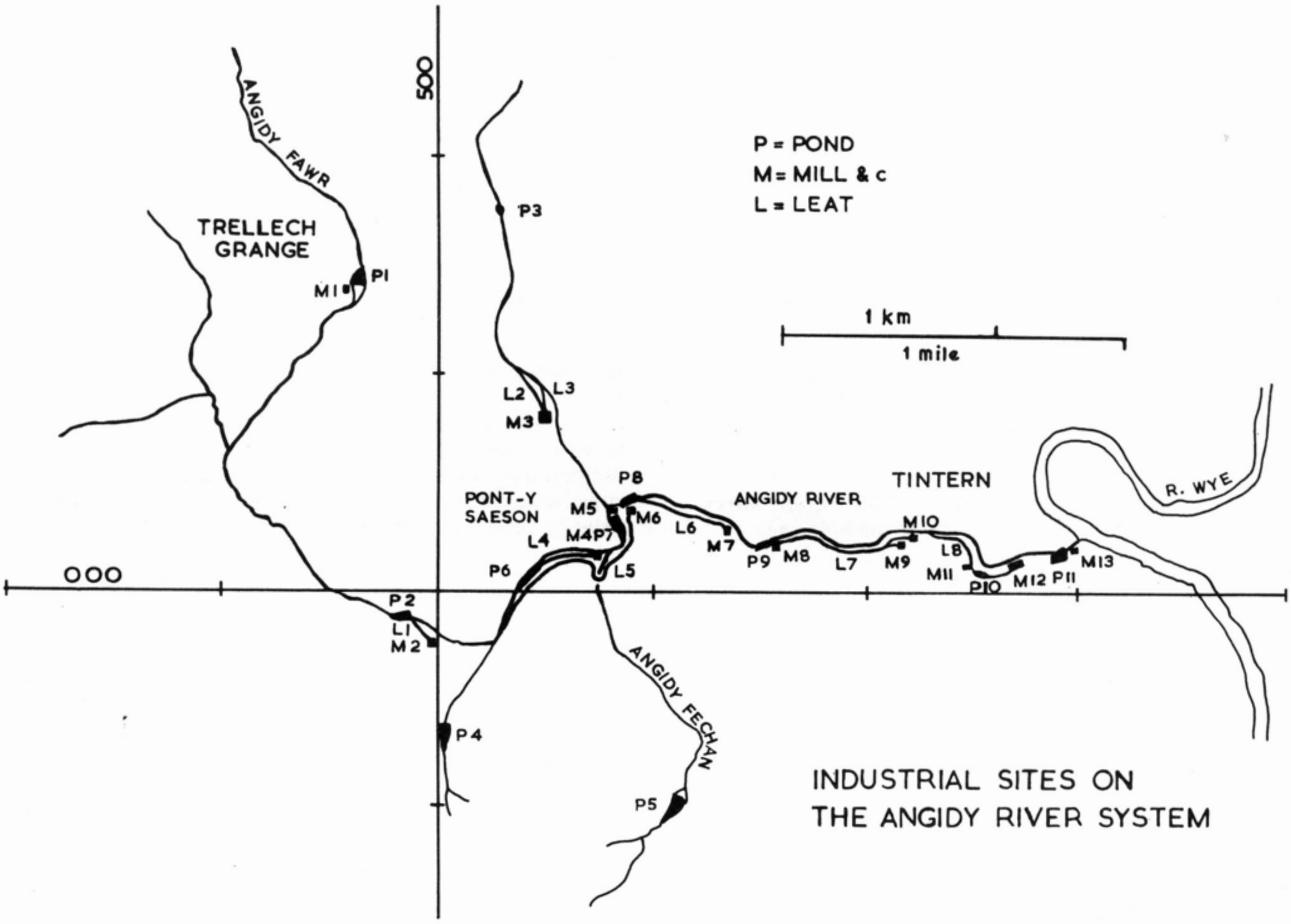


Fig 1

Map of the industrial sites on the Angidy river system at Tintern. P = pond, M = mill, works, etc., L = leat

M1	Trellech Grange Mill with pond P1 *(building used as house, ancient mill site)*
M2	Panta Mill with pond P2 *(demolished, probably early 19th century)*
M3	Unknown mill *(derelict, two leats at different levels)*
P3	Farm pond
P4	Fedw Pool *(fish pond/storage pond)*
P5	Fairoak Pond *(fish pond/storage pond)*
P6	Probably a fairly modern pond associated with extraction of water from river for augmenting public water supply
M4	Pontsaison Mill
M5	Pontsaison Forge with "Forge Pond" P7
M6	New Tongs Mill *(Upper Wireworks)* built about 1803
M7	Blast Furnace with "Furnace Pond" P8
M8	Tilting Mill
M9	Chapel Wire Mill *(formerly Oil Mill)*
M10	Middle Wire Mill
P9	Pond for M8, M9, M10
M11	Hammer House; Little Block Mill
M12	Lower Wireworks with Pond P10
M13	Abbey *(or Lower)* Forge and Corn Mill with "Forge Pond" P11

Corn-mills embodied in the industrial complex

There were undoubtedly mills on the Angidy river system in medieval times, and when the wireworks had been established over half-a-century, we find references to grist-mills within the workworks:- (13)

"In 1625 Lord Herbert, son of the Earl .... further pressed for the release of the ripping-house at Tintern in order to set up a grist-mill there, a request that was granted.

"In 1629 the position was complicated by the action of a tenant of the Earl, Gwenllian Welsh, whose mill, built when the works were idle, had become incorporated into the Tintern lease without any stipulation as to its legal position, and Welsh, after receiving a lease on the site from the Earl, imposed a rent of £7 on the use of the water-course, which she threatened to close."

It is not clear whether one, or two separate mills are involved here.

In 1742, Richard White's lease of the wireworks included a "Mill called Abby Orchard". It is a source of much confusion that there is an area and hamlet in the Angidy Valley about half-way between the Wye and Pont-y-Saeson which is called Abbey. This mill would almost certainly be at this place, and could just possibly be the same as "Abby'es mill" which was leased to Thomas and William Jordan in 1707 with the description "that ancient water Grist Mill commonly called Abby'es mill and now lately converted into an Oyle mill and other sorts of mills"(15). This mill was at the site marked M9 in Fig.1. It had evidently been converted for grinding linseed to extract the oil, and was still an oil mill in 1763 (16), belonging to "Mr Jorden", but became a wire-drawing mill before 1813, when it is included in a lease of the whole Tintern works to Robert Thompson as "Wire Mill formerly an Oil Mill" at a rent of £14 pa (17). In 1763 there was a reference (18) to "Pontsaison Mill" at the site marked M4 in Fig.1. John Aram's maps clearly show the leats marked L7 and L4 in Fig.1, leading to the Oil Mill and Pontsaison Mill respectively. These mills were located quite explicitly in his maps, at points which now have the OS grid references SO 521 003 and 508 001 (5) respectively. Pontsaison Mill was again referred to in a lease of 1813 (19).

In 1821 we find the Abbey Corn Mill close to the Lower or Abbey Forge at grid ref. SO 529 002 approximately (20). Its equipment is included in the schedules reproduced in Appendix 2, from which we see it had three pairs of stones.

THE DEVELOPMENT OF THE ANGIDY VALLEY SITES IN THE EIGHTEENTH AND NINETEENTH CENTURIES

There must have been some continuing development of the works along the Angidy river between the Wye and Pont-y-Saeson during the early part of the eighteenth century, but little definite information seems to be available until 1763.

In 1707 there is an interesting reference (21) to "a place called ye wirepool" which was higher up the valley than the oil mill. This was presumably one of the ponds in which wire was placed for the process known as "watering".

In 1739 we have an inventory of stock (22) at the "Abby Wyre Works & Pontysayson Forge". This unfortunately does not include a list of equipment, but the materials in stock were valued at £1514, and very little of this was finished wire awaiting sale; it was mostly the raw materials for wire making, suggesting a healthy business. Nevertheless, shortly afterwards Thomas Price, who had been running the works for a short while as executor of the lessee Francis Price who died in 1739, petitioned the Duke of Beaufort to take over the works (23).

The first definite information regarding the location and extent of the works sites appears in the very fine volume of maps (24) produced in the survey of the Duke of Beaufort's estates by John Aram in 1763. These maps, mostly on the scale of 1 inch to 4 chains *(or 1 : 3168)*, give considerable detail. Referring to our Fig.1, we find the following shown as in existence in 1763:-

"Pontsaison Mill" *(M4)* with a leat *(L4)* about 300 yards long, but no pond *(ie P6 not in existence)*. The Angidy Fechan *(or Killkerks Brook as it is marked)* is at least partially diverted westwards to augment the flow in the leat.

"The Forge Pound" *(P7)* with "The Forge *(M5)*

"The Furnace Pound" *(P8)* with a leat *(L6)* to "The Furnace" *(M7)*.

"The Pound belonging to the Wire Works" *(P9)* with "The Water Course to the Oyl Mill" *(L7)* and "The Oyl Mill" *(M9)*, together with a short branch leat which fed "The Upper Wire Works" *(M10)*,
"The Hammer Houses" and "The Block House" *(M11)*.

"The Lower Wire Works" *(M12)* with a leat *(L8)* but no pond *(ie P10 not in existence)*.

"The Forge Pound" *(P11)* and "The Forge" *(M13)*.

It will be clear from what follows that the Tintern industrial complex in the Angidy valley was, by the mid-eighteenth century, already well developed and, in terms of sites occupied, not very far from its ultimate development.

Later the sites were mapped in great detail, on the scale of 25 inches to 1 mile, in successive indentures of lease; that of 1821 (25) not only includes a fine map, but also gives a schedule of all the equipment in all the works and mills. This is so important in assessing the nature and size of the works that it is reproduced in full as Appendix 2.

Figs. 2, 3, 4 and 5 show the layout of the different parts of the Angidy complex approximately as given in the map. Everything shown in Fig.1 is now present except the pond P 10.

Appendix 2 will tell its own story to the industrial archaeologist. We may note here that the Oil Mill of 1763 is now the Chapel Wire Mill, the tongs mill has been changed from "Upper" to "Middle", and the Abbey Corn Mill is part of the wireworks organization. The New Tongs Mill or Upper Wireworks *(M6)* with its long leat had been built about 1803 (26). The "Tilting Mill" *(M8)* just below the dam of pond P9 was evidently also built between 1763 and 1821. A count of the waterwheels in the schedule gives a total of 20 for the works and mills between Pont-y-Saeson and the Wye. The "river" *(only a small stream)* was evidently fairly fully utilized.

The equipment schedules of Appendix 2 show that the wiredrawing plant comprised 12 pairs of tongs and 23 blocks. When Robert Thompson leased the works in 1799, there had been only 10 pairs of tongs and 10 blocks, (56) so he evidently expanded the wiredrawing capacity very considerably.

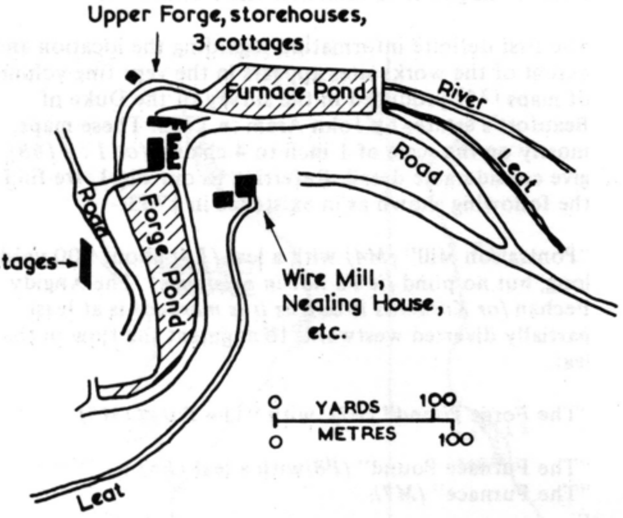


Fig 2 Map of works at Pont-y-Saeson, 1821

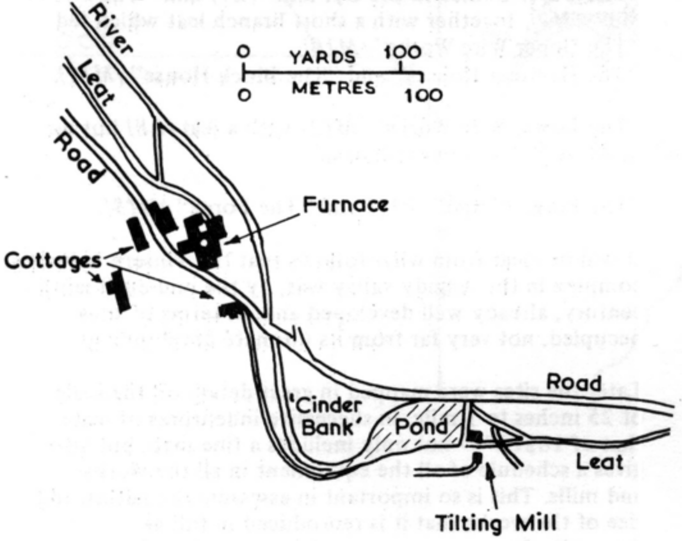


Fig 3 Map of works at Furnace and Pond P9, 1821

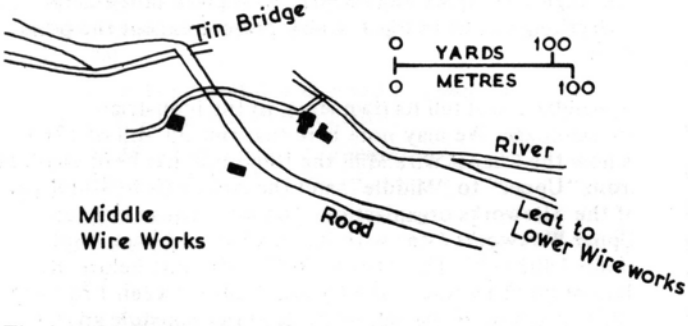


Fig 4 Map of works at the "middle" site *(M9 and M10)*, 1821

Unfortunately the 1821 map *(and also its successors in the leases of 1866 (27) and 1878 (28))* does not show the actual names or purposes of the individual buildings.

Little is known of the state of business in the middle half of the nineteenth century, but it is likely that it was not always good. In 1838 the Messrs Brown were trying to dispose of the lease of their works, and their advertisement(29) largely confirms the list of mills given in Appendix 2, and also shows that the wireworks complex included no fewer than 3 dwelling houses, 39 cottages, 3 farms, and miscellaneous gardens, etc. It mentions the "wet Dock and Wharfs" and then states:-

"A large sum has been expended by the present tenants in enlarging and improving these works, and every preparation has been made to put down a steam engine; but owing to the declining health of the senior partner, and the other partner being obliged to attend to their business in Yorkshire . . . . "

It appears that the works were running down. It is fairly certain that no steam engine was ever installed. It also seems from later documents that the Browns were unsuccessful in disposing of their lease. Nevertheless, the wireworks were reported as being "in prosperous operation" in 1863.(5)

The maps of 1866 and 1878 show how the works changed during the middle half of the century. From the 1866 map we learn that the small pond P10 had been inserted in the leat to the Lower Wire Works since 1821, and that the furnace was definitely disused, being marked only as "Site of Old Furnace". By 1878 the Upper Wire Works *(M6)* had gone out of use, being marked "Site of Wire Mill, etc"; this mill had thus existed for less than 75 years.

Although the wireworks were in decline in the 1870's, the Duke of Beaufort insisted on the Wye Valley Railway building a branch across the river to the Lower Wireworks *(M12)*, in order to secure the advantage of improved transport for the works. The branch was opened with the main line in 1876.(30)

However, there was a general slump in the British wire trade at that time (31) and the wireworks did not recover; so it was decided to embark on the manufacture of tinplate at the Lower Wireworks site. A new group of people leased the works in 1878 and started trading as J R Griffiths and Company (32) *(or as the Abbey Tintern Wire and Tinplate Company)* in February 1880, despatching their first waterborne cargo of tinplate on 14 April 1880:-

"The Abbey Tintern Wire and Tin-plate Company sent off their first cargo *(70 tons)* of tin down the Wye by the steamer ALBERT of Chepstow on Wednesday, Mr Josiah Richards and others interested in the manufacture being present. The company sent off several trucks of tin to Liverpool and Birkenhead last week."(33)

The plant had two rolling mills and "The Cold Rolls were worked by water power."(32)

It is probable that some wire-making continued for a time; Grey-Davies (34) says so, and the trade of "wiredrawer" continued to occur in the parish registers until 1888.(35) Brooke suggests that Griffiths and Co ceased trading in May 1895, when the works were taken over by the Abbey Tintern Tinplate Company. It is certain that the works were faring badly at this time, for on 1 June 1895 it was reported that (36)

"the Tintern Tin Works, which have been going most irregularly for some time past, closed up last Saturday, with no hope of an immediate restart. This is a serious blow for the neighbourhood, as the men, unless something is forthcoming soon, will have to remove, and the loss of about £100 a week in circulation must of necessity affect others beside the workpeople. On Wednesday the agents of the Duke of Beaufort placed Mr Coomber, bailiff of Chepstow, in possession for arrear of rent and unless an arrangement is come to a sale of all the loose plant and stock will be held on Monday."

Presumably some arrangement was made which prolonged activity for a while. However, the business had finally failed by 1900, and as it could not be sold as a going concern, it was put up for auction in small lots on 10 January 1901 "under instruction from the debenture holders." (37) Including not only the tinplate rolls and other plant but also the locomotive and trucks of the branch railway, it sold for about £1500.

The tinplate works site was used for industrial purposes for many years, first as a stone sawmill, later adapted to timber.

A local tradition for which no documentary evidence has so far been found has been told us by elderly local inhabitants and is worth recording as a tailpiece to this part of the paper. It is that some part of the first Atlantic telegraph cable was made in Tintern in 1857(38), and that the barge RINGDOVE was used for transporting it.

THE INDUSTRIAL ARCHAEOLOGY OF THE ANGIDY COMPLEX

Having outlined the history of the industrial activities that occupied the Angidy valley for so many centuries, it now remains to describe their present-day remnants and, where possible, to deduce something of the former arrangements. It is convenient to treat the subject geographically, working down the stream.

Pont-y-Saeson iron works

Forge Pond *(P7)* is still in good condition as far as the dam is concerned, but is rather silted up. There are few remains of the Upper Forge itself, once a considerable establishment as shown by the 1821 map *(Fig.2)* but now represented only by the few remains shown in the plan of Fig.7. It is probable that the water-wheel shown in Appendix 2 was immediately below the dam, in the large rectangular block shown in the 1821 map *(indeed, Aram shows two wheels there in 1763),* and that the fineries, with their chimneys, were in the comb-shaped block to the east.

Although the remains of the Upper Wireworks *(or New Tongs Mill)* are fragmentary, there are sufficient to enable some idea of the layout to be determined, as shown in the plan of Fig.8 which confirms the crude plan of 1821. The long leat *(L5)* which took water from high up the Angidy Fawr and crossed the Angidy Fechan by a stone structure that probably enabled water from the latter also to be taken, entered the wireworks at the eastern end and supplied a water-wheel which was probably of about 6m diameter and anything up to 2.5m wide. The wheel-pit is still quite distinct and adjoins the remains of the drawing-mill, a building about 12m x 7m which would probably have been of three stories, but now shows only small portions of the lower walls. To the west lie the remains of the annealing furnace; merely a small hearth and some pieces of wall remain. Possibly this furnace was of the tower type as used for the annealing of brass wire at Kelston, near Bristol, and illustrated elsewhere (39). The whole site was a very awkward one, on a steep slope high above the road, so that very extensive retaining walls were needed. The road approach to the site is from the east, by a lane from the valley road.

The blast furnace site

Furnace Pond *(P8)* is in very good condition, although the dam has probably been rebuilt in comparatively recent times to carry an enlarged road. The leat ran from the southern end of the dam; now, thanks to the good work of the Forestry Commission, who have cleared the whole route of the leat and the whole furnace site, the leat can be followed for the whole of its length. It comes to an end about 45m from the furnace itself, in a somewhat widened terminal basin, as shown in Fig.9, and at an elevation of about 10m above the river level.

The plan shows the layout of the site as it exists. It is not easy to interpret it. The remains of the furnace itself are clear enough. There is only a fraction of the furnace structure left, as can be seen from the photographs, but it is clear that it was about 3m diameter internally at the widest point, and its height could not have exceeded 6m. It was a broader furnace than the 17th century furnace at Coed Ithel(40), a few miles to the North; this had a maximum diameter of 2.3m. However, the Tintern furnace was in use until about 1826, and if it really had operated on this site since the 17th century, it would have been rebuilt once or twice, and it may well have started like Coed Ithel. David Mushet(41) stated that at the end of the 18th century Tintern furnace could produce pig iron at the rate of about 1500 tons per year, and was helped to do this by the introduction of blowing cylinders in place of the older bellows, being, he believed, the first charcoal furnace thus equipped in this country. It will be noted from Appendix 2 that all blowing at Tintern was done by cylinders, the three forges, like the furnace, each having two cylinders. Mushet stated that the Tintern furnace went out of blast around 1826 and was later used for experiments with Wootz ore.(42)

The blast furnace was built where the slope of the land made it easy to load the furnace on its north-west side, and to tap it on the south-east side. The low-level area at the south-east corner of the plan must have been the casting floor. Adjacent to the furnace on the north-east is a large pit, stone-lined, which must have contained the water-wheel and blowing cylinders. In spite of limited excavation to the level of the river water, no tail race arch has been found, nor is there anywhere any sign of a tail race. The water from the leat must have been brought to the wheel by an elevated wooden launder. According to the 1821 maps, *(see Fig.3)* the leat did indeed connect with this pit; moreover, Aram showed the wheel here in 1763.

It is probable that the areas around the furnace were covered by a roof; not only does the 1821 map suggest this, but Appendix 2 refers to the Bridgehouse and Castinghouse. There were also several offices and sheds, and a Mine Kiln *(ie an ore-roasting kiln).* The positions of these could be determined only by a very large-scale excavation.

A curious feature of the 1821 map is the 'Cinder Bank' between the road and the river to the south of the furnace site. The river does not now flow on the course indicated, nor did it when the 25 in.O.S maps were surveyed in 1879, but instead takes a course very close to the road. There is plenty of slag and cinder both in the river bed and between it and the other little stream indicated.

The middle works

If we define the middle works as those from Pond P9 down to Mill M10, then we have a group of works of which practically nothing remains except the pond and leat. The pond is in good condition *(the angling interests account for the present good state of so many of the ponds).* The leat, like all the others, is a wide one and can be followed throughout its length. It terminates abruptly on the hillside above where the middle wireworks were, at an elevation of about 12m above the Angidy. There appear to be two places where wooden launders might have taken the water down to a mill, and this is consistent with Aram's maps, which show two separate branches of the leat, as indicated in Fig.1. Below the first place there is an obviously artificially-constructed flat area about 6m above the river, and we may suppose that this was the site of the original corn-mill which became the oil-mill and finally the Chapel Wire mill; this would agree with the markings on Aram's map. The site is now used as a garden and there is no sign whatever of former buildings.

A Remains of blast furnace at Tintern, showing interior; white ruler is 1 ft in length.

B General view over blast furnace site, showing interior of furnace on left and wheel pit and blowing house in right foreground.

Aram's map appears to show the rest of the works, as existing at the middle site in 1763, located beside the river. There are some retaining walls here, obviously very old, which could have been the back walls of some of the buildings; there are also some a little further along, near where the leat commences that fed the Lower Wireworks. Since we have to account for the Middle Forge *(see Appendix 2)* as well as the Middle Tongs Mill, it is tempting to consider these areas as likely to have been at least associated with the works, but there is no evidence for this, and they were certainly not industrial sites on Aram's map of 1763. He shows the works as being where a pair of houses *(dated 1904)* now stands. There is a special feature connected with the easternmost house of this pair which lends support to this having been a works site. A public footpath descends from the upper road through the garden and right alongside the eastern wall of the house, and is in consequence rather embarrassing to use. But if this was the path into the forge and wiremill, what more natural place would one expect?

Another special feature which suggests the location of another works building is that a bungalow has been built on a platform spanning the Angidy river just where Aram shows part of the works. One must suppose that the platform was the original foundation of the works, merely utilised by the more modern building because it was already there. Smart (38) refers to this site and says there used to be a nail factory here.

Since the Chapel Wire Mill, the Middle Tongs Mill and the Middle Forge each had two water wheels, we have to account for six in all, and there is now no sign of where they could have been or how the water was got to them.

One other mill has to be accounted for in the middle group – the Tilting Mill *(M8).* The maps indicate the site of this as being immediately below the dam of Pond P9. From the schedules, it does not appear to have been a very large mill, and it is therefore just possible that some stonework in the present river bed could have been its foundations.

The lower wireworks

The leat supplying water power to the lower works left the Angidy at a small weir, the remains of which can still be seen, by means of a sluice-gate which still remains but has been blocked up. Parts of this leat are in very good condition, with the stone sides intact, but other parts have been filled in. This leat carried water for the turbine at what became the sawmill until the 1930s.

At the big bend shown at M11 in Fig.1 there were shown on Aram's map the Hammer Houses. In the schedules of 1821 no units of this description were included, nor were the buildings at this point identified on the 1821 map. On the other hand, the 1866 map quite specifically labels, these buildings as part of the Lower Wireworks, thus inferring that they were still in use. The only conclusion that we can thus draw is that these buildings were part of the rather large number of individual units included in the 1821 schedules from Gig Mill down to Lower Block Mill, and that they were most likely to be the Gig Mill (43) and Little Block Mill. If this is correct, there were two water wheels at the mills M11. At this point the leat comes to an end now at a level about 3m above that of the pond P10, which we have already shown to have been a mid-19th century addition. Presumably, therefore, the mills *(M11)* used a head of 3m. Nothing remains on the site except the rear retaining wall.

What seems to have been generally called the Lower Wireworks, ie M12 on Fig.1, was evidently an assembly of seven separate buildings, three of which *(a scouring mill, a rolling mill, and a wiredrawing or block mill)* used water wheels. In 1763 Aram showed three separate leats or launders to three water wheels, yet the 1821 map shows only two, these being the two eastermost of Aram's map.

How the water wheels were disposed is not known, but support for the small leat, which we have added in Fig.5 at the western end of the site comes from the fact that there remains to the present day a rectangular stone structure, suggestive of a wheel pit, at the north side of the road, in just the position indicated. Under the road at the eastern end of the present Forestry Commission buildings is a large arched opening, which may well be where the leats to the eastern end of the site crossed the road. Immediately to the east of this the large pipe, about 1m diameter which fed the later turbine, comes down at a steep slope from what must have been the line of the main leat across the road. This pipe is entirely underground. The turbine pit itself, which we think was constructed when the works were going over to tinplate making in 1880, is also entirely underground, about 6 m long by 3.5m wide and deep. At the end of the main pipe a Y-junction was fitted, with one branch blanked off obviously intended for a second turbine if business later necessitated it. The turbine fitted on the other branch is still in place, complete with governor of the "King's Patent" type. There is no maker's name detectable on the turbine which, as can be seen from the photograph, is a cylindrical type about 1.2m diameter. The pit wheel and shafting which coupled it to the machinery is still in good condition.

We have mentioned that a tramway or branch from the Wye Valley Railway came to this site. Nothing remains to indicate the position of its terminal, but the small embankment beside the Angidy River on which it approached the site can still be seen.

Apart from the features we have mentioned, there seems to be nothing else on this site which can be positively identified with the old wire or tinplate works.

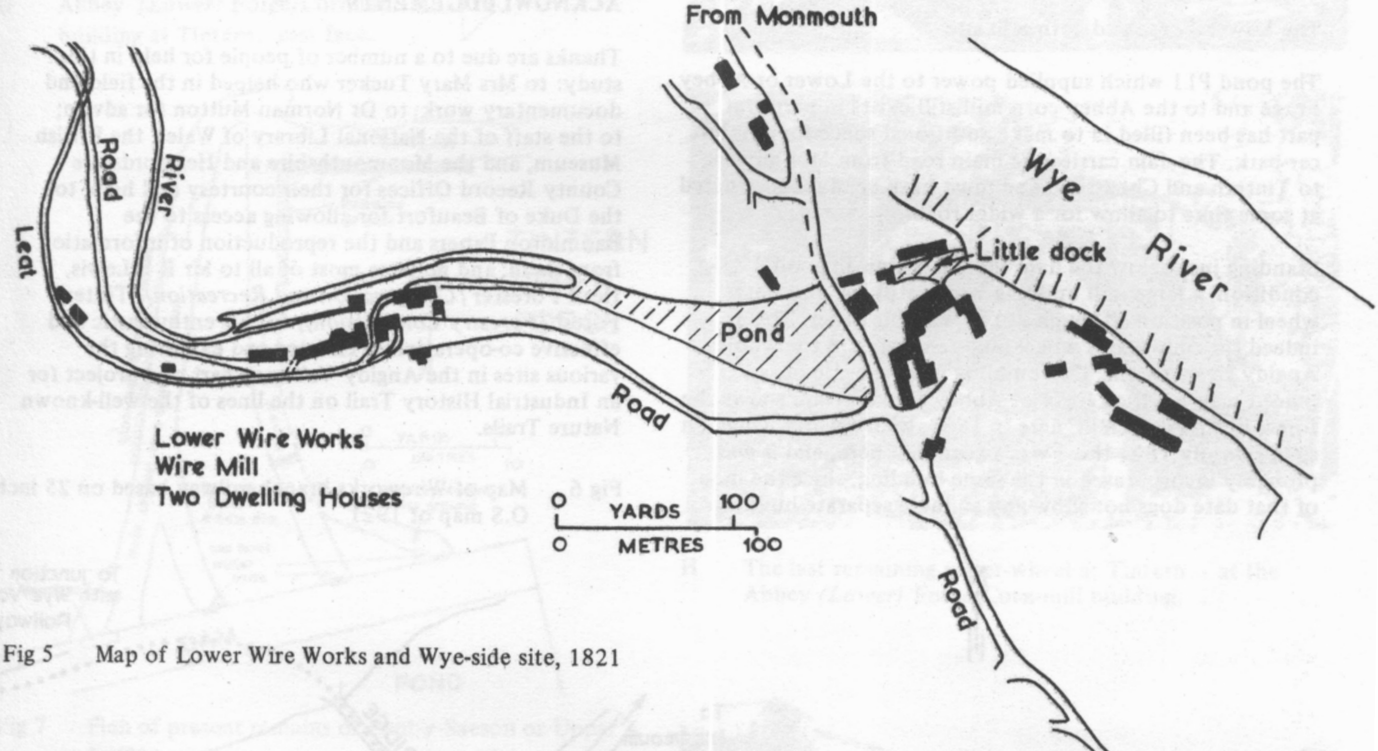
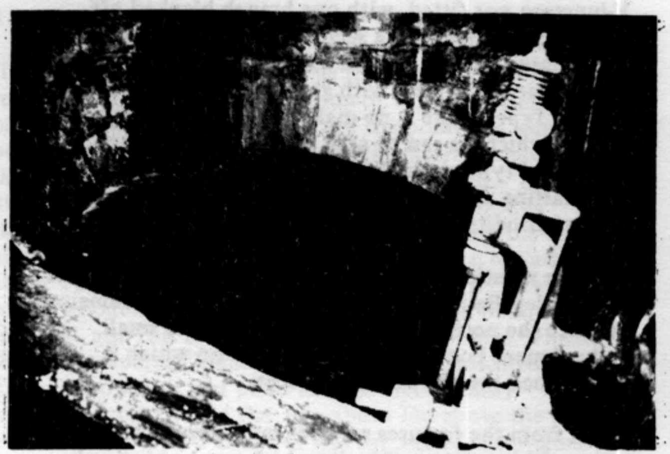


Fig 5 Map of Lower Wire Works and Wye-side site, 1821

C Turbine, probably dating from 1880, in turbine pit at Lower Wireworks site at Tintern. Diameter of turbine casing approximately 4 ft.

D Y-junction in turbine feed pipe at Lower Wireworks site; right-hand branch feeds turbine, left-hand branch blanked off.



E Tail-race arch in turbine pit at Lower Wireworks site, showing displaced governor of turbine.

The Lower Forge and corn mill site

The pond P11 which supplied power to the Lower or Abbey Forge and to the Abbey corn mill still exists in part, but part has been filled in to make additional space for a hotel car-park. The dam carries the main road from Monmouth to Tintern and Chepstow, and must have been reconstructed at some time to allow for a wider road.

Standing just below the dam there remains, in good condition, a large mill building which still has one water wheel in position although not in working order. This is indeed the only water wheel now remaining in the whole Angidy river system. This building is on the site of, and indeed may be, the Lower or Abbey Forge. Aram shows the forge, but no corn mill, here in 1763, with a water wheel on each side. By 1821 there was a corn mill here, and it was probably incorporated in the same building, since the map of that date does not show any suitable separate building. In that case, there were four water wheels here by that time.

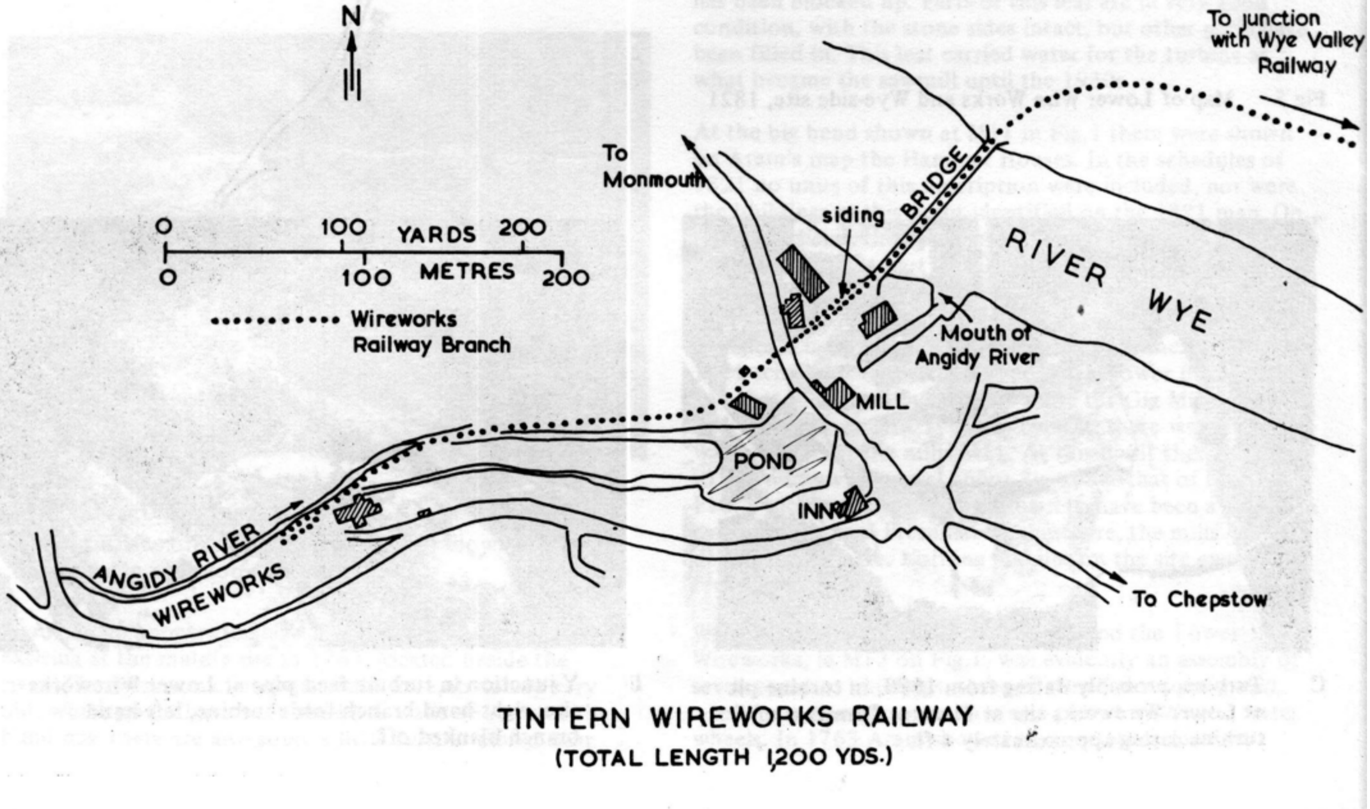
Aram shows other miscellaneous buildings associated with the works, and so does the 1st edition 25 inch O.S map of 1881; and of course, there were several wharfs which have now disappeared, together with the little harbour which at some probably later time, was fitted with tidal gates. This little floating harbour still exists, although its gates have gone, and in fact it forms the mouth of the Angidy. Its walls are sound, but it is understood that it is threatened by development.

Although the forge building remains, there is no sign of its former use for refining and shaping iron – it has had too many subsequent uses as wood turnery, wood sawmill, etc.

ACKNOWLEDGEMENTS

Thanks are due to a number of people for help in this study: to Mrs Mary Tucker who helped in the field and documentary work; to Dr Norman Mutton for advice; to the staff of the National Library of Wales, the British Museum, and the Monmouthshire and Herefordshire County Record Offices for their courtesy and help; to the Duke of Beaufort for allowing access to the Badminton Papers and the reproduction of information from them; and perhaps most of all to Mr R S Lewis, Head Forester *(Conservation and Recreation)*, Tintern Forest *(Forestry Commission)*, for his enthusiastic and effective co-operation in clearing and exploring the various sites in the Angidy Valley as part of a project for an Industrial History Trail on the lines of the well-known Nature Trails.

Fig 6 Map of Wireworks branch railway based on 25 inch O.S map of 1921



F Abbey *(Lower)* Forge/Corn-mill building at Tintern, west face.

G Abbey *(Lower)* Forge/Corn-mill building at Tintern, east face.

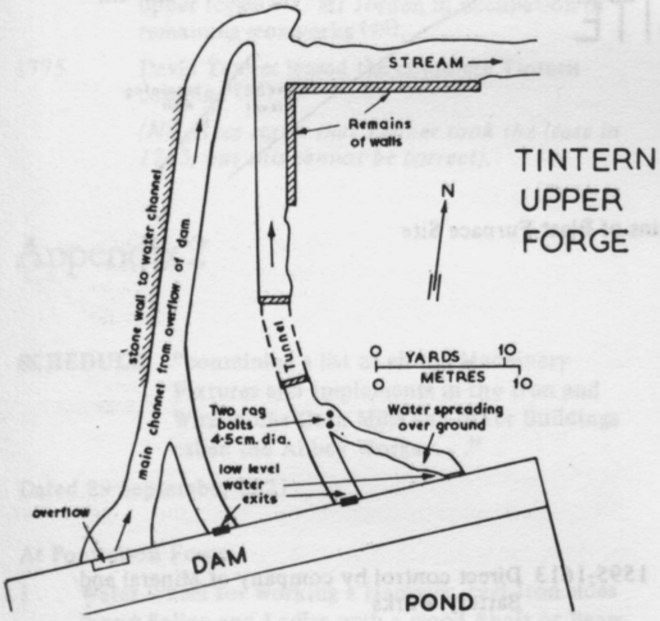
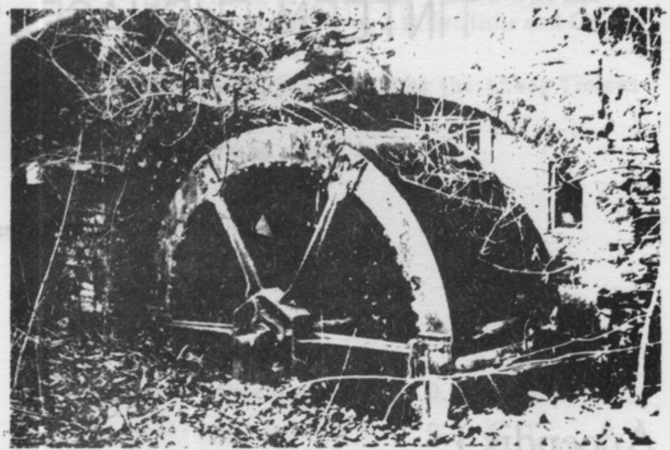


Fig 7 Plan of present remains of Pont-y-Saeson or Upper Forge



H The last remaining water-wheel at Tintern – at the Abbey *(Lower)* Forge/Corn-mill building.

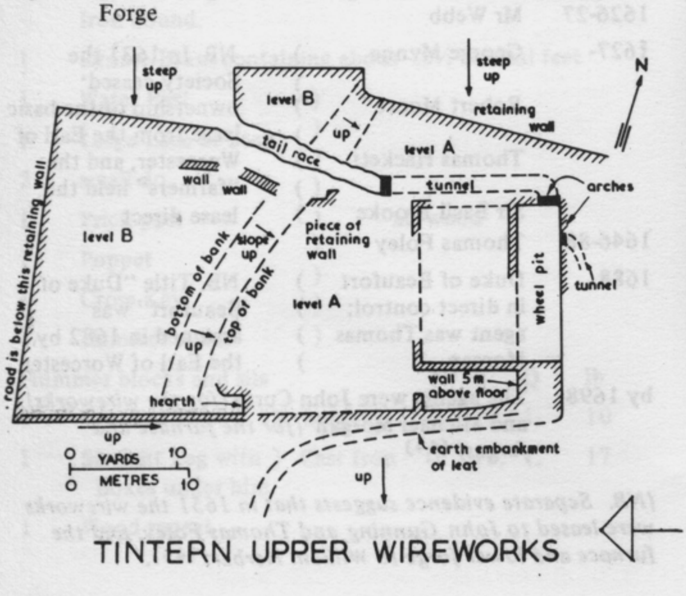
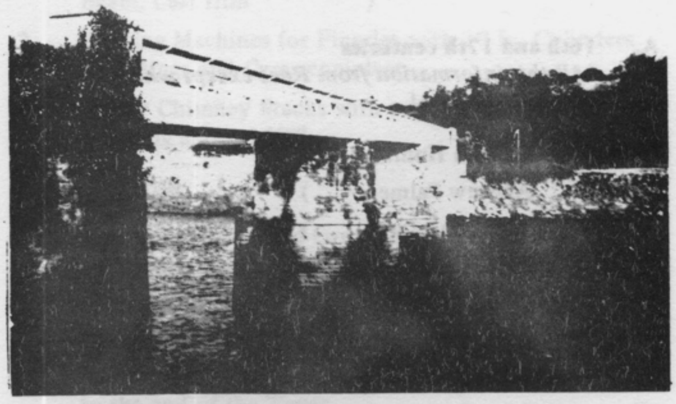


Fig 8 Plan of present remains of Upper Wireworks or New Tongs Mill



I Tramway bridge over River Wye at Tintern.

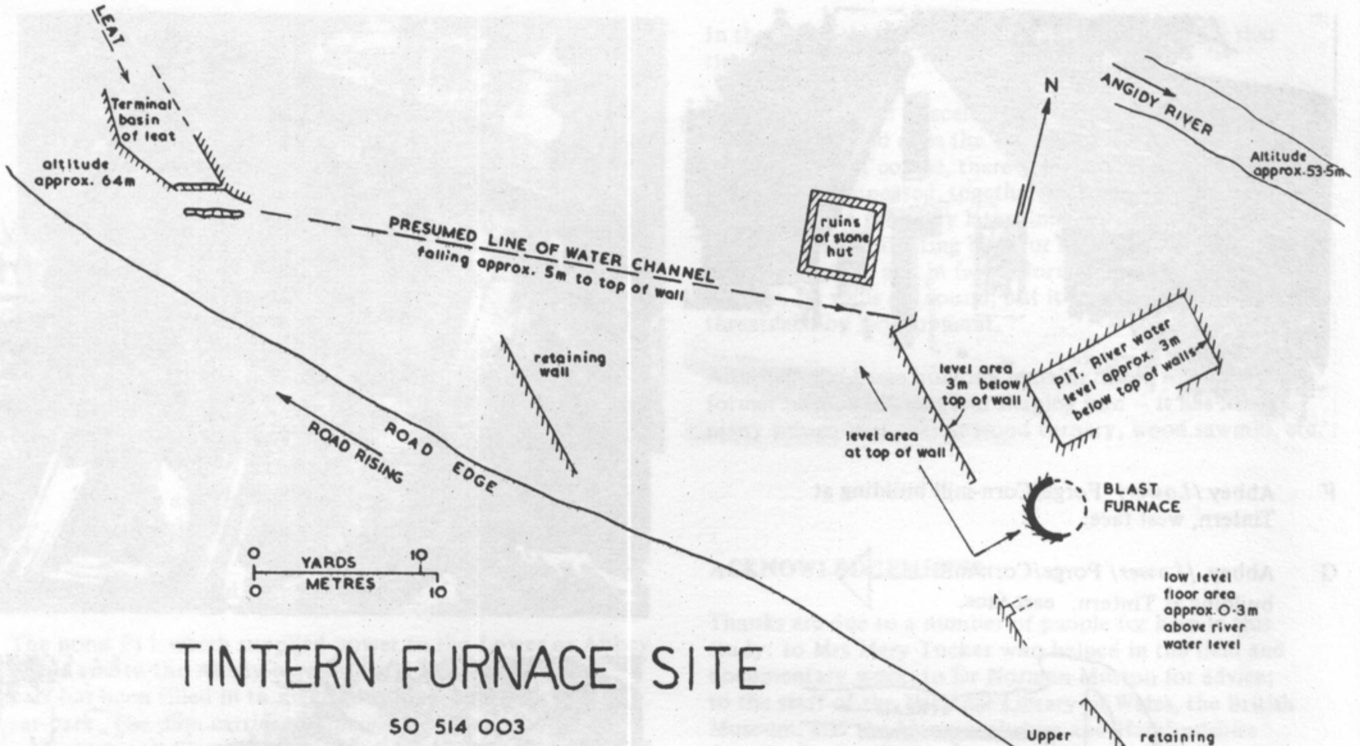


Fig 9 **Plan of present remains of Blast Furnace Site**

Appendix 1

LESSEES OF TINTERN WIRE AND IRON WORKS

A. 16th and 17th centuries

(All this information from Rees except where otherwise shown)

1566	William Humfrey	
1570-77	Andrew Palmer	
	John Wheeler	
	Richard Hanbury	as "farmers"
	Sir Richard Martin	Hanbury was the
	Alderman Gamage	chief manager
	Francis Eaton	
	John Eccleston	
1577-80	Martin and Hanbury	
1580-89	Martin	
1589-91	Martin and Hanbury	
1591-95	John Challenor. George and John Catchmay were also involved during this period.	
1595-1613	Direct control by company of Mineral and Battery Works	
1613-26	Mr Hackett	
1626-27	Mr Webb	
1627-	George Mynne	NB. In 1631 the Society ceased ownership of the basic lease from the Earl of Worcester, and the "farmers" held the lease direct
	Robert Moore	
	Thomas Hackett	
	Sir Basil Brooke	
1646-88	Thomas Foley	
1688	Duke of Beaufort in direct control; agent was Thomas Morgan	NB. Title "Duke of Beaufort" was assumed in 1682 by the Earl of Worcester
by 1698	The agents were John Curre *(for the wireworks)* and Michael Morgan *(for the furnace and forges)* (44)	

(NB. Separate evidence suggests that in 1651 the wireworks were leased to John Gunning and Thomas Foley, and the furnace and lower forge to William Herbert (45).

B. 18th and 19th centuries

1704	Thomas Dix leased wireworks and upper forge(46). Still there 1718 (47).
1706	George White junior leased furnace and lower forge (48).
1707-8	John Hanbury of Pontypool held furnace (49).
1739	Francis Price, to whom Abbey wireworks and Pont-y-Saeson forge had been leased, died(50).
1742	Richard White leased furnace, forge, etc(51). Still in occupation 1754(52).
1747	Rowland Pytt and Thomas Farmer leased wireworks(53). Ironworks leased by Hanbury of Pontypool, then George White, then Edward Jordan (53). *(NB. Schubert says ". . in the early eighteenth century the wireworks were in the hands of the Foley's." There is, however, no evidence to support this statement, which must be presumed to be erroneous).*
1763	Rowland Pitt in occupation of wireworks and upper forge(54). Mr Jorden in occupation of remaining ironworks (54).
1775	David Tanner leased the complete Tintern complex (55). *(NB. Rees states that Tanner took the lease in 1755, but this cannot be correct).*
1799	Robert Thompson leased the complete complex(55) which had been advertised for sale in 1798(56). Still in occupation 1813(57).
1821	William Mathews leased the complete complex(58). *(NB. Rees states that in 1822 Messrs Briggs and Rowbotham were in occupation, followed by Brown and Co.).*
1828	Lease assigned *(by Mathews)* to Copley Brown and Jeremiah Sharp Brown(59).
in 1848	the Wireworks in occupation of J.Brown, the Abbey Works in occupation of H. Hughes, the Middle Works in occupation of Wm.Crawshay(60). *(NB. Rees states that in 1850 the works were occupied by John Hughes, but this must be a slip, as a directory shows Henry Hughes as "wire manufacturer" in that year.* (61))
1866	Murrell and Stothert leased the whole complex(62). The works had been in the occupation of Henry Hughes, but were "now unoccupied".
1878	Josiah Richards, John Rowland Griffiths and David Williams leased the whole complex.(63) They traded as the Abbey Tintern Wire and Tinplate Co, and/or as J.R.Griffiths and Co, from 1880 to 1895.
1895?	Tinplate works operated by the Abbey Tintern Tinplate Co.
1901	Ironworking ceased for good.

Appendix 2

SCHEDULE "containing a list of all the Machinery Fixtures and Implements in the Iron and Wire Works Corn Mills and other Buildings called the Abbey Works. . . ."

Dated 29 September 1821

At Pontsaison Forge

			T	C	Q	lb
1	Water Wheel for working a Hammer, cast Iron sides Wood Soling and Ladles with a wood Shaft or Beam, cast Iron ring thereon weight 16^{C} 1^{Q} and wrought Iron bound.					
1	Drome Beam containing about 70½ cubical feet					
1	Water Post	all wood				
1	Large Lace or Stay					
2	small do.					
1	Prick post					
1	Poppet					
1	Cross Key					
4	Hammer Arms					
Plummer blocks and sils			T	C	Q	lb
1	Crooked Leg	weight	0.	10.	1.	10
1	Straight Leg with Boxes under him	Cast Iron	0.	10.	1.	17
1	Wood repeat					
1	Wood Hammer Helve					
1	Hurst on d^{o}. Cast Iron		0.	3.	0.	0
1	Hammer Do. Do.		0.	5.	1.	0
1	Anvill Do. double faced		0.	6.	0.	0
1	Anvill block d^{o}. new		2.	10.	0.	0
1	Standard under the inner Gudgeon of the Hammer Beam, Cast Iron		0.	4.	0.	0
2	Blowing Machines for Fineries with 30 In. Cylinders, Iron Rings and Cams compleat					
3	Finery Chimney Stacks with a Cast Iron to each weighing about 10^{cwt}					

New Tongs Mill

1	Annealing House and Oven, the casting in the annealing oven included with the oven.
1	Water Wheel with Cast Iron centre pieces without a fly.
11	pair of Tongs for drawing wire the machinery compleat to the end of the Tongs.

Blast Furnace

Upper Coal house on southside the Road and Mine Kiln adjoining Coal house on the North side with a slope or Shead at the Upper End.

— Stampers —

1 Water Wheel and Shaft

2 Rings on D^{O} Cast Iron

12 Cams – D^{O} D^{O}

2 Gudgeons in D^{O} D^{O}

2 Cast Iron uprights for Stamper helves to work in about 12^{cwt}

An Office for the Furnace Stocktaker

A Charcoal Shed near the Office

Blast Furnace Stack Bridgehouse and Castinghouse the Furnace without a Hearth

Blast Furnace machinery consists of 1 water wheel:

2 Cylinders 1 regulator and blast pipes as far as the bag.

Middle Forge

1 Water Wheel for working the hammer, cast Iron sides wood soling and ladles, Wood Shaft or hammerbeam with Cast Iron ring *(weight 16^{C} 1^{Q})* and bound with wrought iron hoops and 2 iron gudgeons

1 Drome Beam

1 Water Post

1 Large Lace or Stay)

2 Small do^{s})

1 Prick Post) Wood

1 Poppet)

1 Cross Key)

4 Hammer Arms)

	Plummer Blocks & Sils)		T	C	Q	lb
1	Crooked Leg)	Cast Iron	0.	10.	1.	10
1	Straight Leg with) boxes under them		0.	10.	1.	17
1	Wood repeat					
1	Wood Hammer Helve					
1	Hurst on hammer Helve Cast Iron		0.	3.	0.	0
1	Hammer D^{O}	D^{O}	0.	5.	1.	0
1	Anvill	D^{O}	0.	9.	0.	0
1	Anvill Block	D^{O}	1.	10.	0.	0
1	Standard under the inner Gudgeon of the Hammer Beam Cast Iron		0.	4.	0.	00

1 Water Wheel for blowing Machine for the Finery with 2 cylinders 3^{ft} 6^{in} diameter 2 Rings and 4 Cams in each Ring

1 Finery Stack and Cast Iron Lintel

Chapel Wire Mill formerly an Old Mill [*should be* Oil]

1 Water Wheel

1 Cog Wheel

1 Upright Shaft with nut working 6 Blocks compleat with Vices Springs, hand Staffs, Tongs, 6 Reels and pointing Anvills.

1 Water Wheel for Scouring Barrells working 6 Barrells Compleat with Lids *(Linings excepted being the Tenants)*

1 Drying Shed with four horses

Middle Tongs Mill

1 Water Wheel and Shaft with 2 Cast Iron Centre pieces Wood [. . . *illegible* . . .] 2 Cast Iron Gudgeons working a pair of Tongs compleat to the end of the Tongs.

1 Water Wheel working 4 Barrells for scouring Wire complete [*except Linings.*].

An Oven for annealing Wire, with Cast Iron plates belonging thereto.

Tilting Mill

1 Water Wheel and Shaft Iron bound and 2 Cast Iron Gudgeons, Tilting Hammer, Helve Anvill and Anvill Block Compleat and 2 scouring Barrells attached to the same wheel.

Gig Mill

1 Water Wheel, Shaft, 1 cog Wheel, 1 nut & upright shaft working 3 Blocks in lower loft and 5 Blocks in the upper loft compleat as before

Little Block Mill

1 Water Wheel Cast Iron centre pieces 1 Shaft Cog Wheel and Spur with an upright spindle working 3 blocks compleat.

Lower Wire Works

1 Water Wheel working 4 scouring Barrells compleat as before.

New Ware House with a Carpenters Shop underneath

Old Smith Shop adjoining the New Warehouse

An Oven for annealing Wire with castings in the Oven.

Rolling Mill

1 Water Wheel

1 Cog Wheel

1 nut

1 Counter shaft with fly all cast and wrought iron and the cross Plank oak.

Cleaning House

Lower Block Mill

1 Water Wheel with Shaft

1 upright Shaft with a Spur wheel to work 6 blocks as before.

Abbey Forge

1 Water Wheel for working a Hammer, cast iron sides wood soling and ladles with wood shaft or beam, cast iron ring thereon weight 16^{C} 1^{Q} and wrought Iron band with Cast Iron Gudgeons.

1 Drome Beam) Wood

1	Water Post	)				
1	Large Lace or Stay	)				
1	Poppet	)				
1	Cross Key	) Wood				
4	Hammer Arms	)				
1	Prick Post	)				
1	Lace to d^{o}	)				
Plimmer Blocks and Sils		)	T	C	Q	lb
1	Crooked Leg	) Cast	0	10	1	10
1	Strait Leg with boxes under them	) Iron	0	10	1	17
1	Standard under the inner Gudgeon of the Hammer Beam, Cast Iron		0	4	0	0
1	Wood repeat					
1	Wood Hammer Helve					
1	Hurst on d^{o}. Cast Iron		0	3	0	0
1	Hammer d^{o} d^{o}		0	5	1	0
1	Anvill d^{o} double faced		0	6	0	0
1	Anvill Block, d^{o}		1	10	0	0
2	Finery Chimney Stacks with 2 Cast Iron Lintels					
2	Water Wheels for blowing Machines with 2 cylinders to each of 30 Inches diameter each					

Coal house and Foundry Walls and Roof with the Pit for Moulding in.

Abbey Corn Mill

1 Water Wheel

1 Cog Wheel

1 nut on the Counter shaft

1 upright shaft and cog wheel working three nuts for 3 pair of stones

3 Wooden Flour Bins, Dressing Machines, Storehouse adjoining the Mill and the Machinery of the Corn Mill to the end of the Spindle.

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Erratum

We regret the error that appeared in the last issue of the JHMS (Vol.8, Part 2, 1974) in Dr Varoufakis' paper on page 95, in the heading of which the date was given as AD. This should, of course, have been BC. This mistake was carried over into the contents list on the inside front cover.

A brass tripod from Cyprus in the Newbury Museum

by H H Coghlan and George Parker

In the museum records this tripod is ascribed to the Roman period in Cyprus. Museum number 1947-6. As some doubt had been expressed as to the authenticity of the tripod, a limited metallurgical examination of the object was undertaken.

The tripod stands 15 cm in height (Fig. 1) and the outside diameter of the bowl at its rim is 7.2 cm. It has been made from the following separate components:–

(a) A substantial base plate

(b) Three 'stork's-head' columns which support the bowl.

(c) A thin sheet metal bowl.

As received, the patination covering the metal is of a greenish colour with, in places, some dark blue staining. Visual inspection alone showed both the stork's-head columns and the base plate to be castings. The stork's-head columns could have been cast by the lost-wax process or, since they are of relatively simple design, it is possible that they were cast in a conventional bi-valve mould; this is suggested since on one of the columns there are signs of a casting flash which had not been quite cleaned off. In places, what look like file markings are seen on the columns, but these may, in fact, be due to the use of a coarse gritted stone or hone used in the course of the finishing operations. Similar markings have been observed upon some prehistoric objects such as axes. Circular dimples were noticed underneath the base plate casting below the feet of the columns. Upon visual inspection it was thought that the feet of the columns had been provided with pegs to secure them in the base plate. However, upon sectioning through the foot of one of the columns, and through the dimple on the base plate, it was found that no peg existed and that the column had merely been attached to the base by means of soft solder. Hence the dimples have no functional purpose, they are but slight, and no reason can be advanced to explain their presence. The use of soft solder is not unexpected since the technique of soft soldering was well-known to the Romans. These findings were in line with those obtained from radiographs kindly made for us by Dr T Ll Richards.

The bowl of the tripod has been fabricated from very thin sheet metal, and this could have been done by raising, sinking, or spinning. Measurement with a micrometer showed the metal to be very thin and uniform; it only varied in thickness between 0.6 and 0.7 mm. The thickness of the bottom, and of the rim, is 0.7 mm. The external and internal surfaces of the bowl are very smooth and no marked irregularities or hammer marks could be detected, nor could any circumferential lines, as if from a spinning process, be seen. However, such markings could, of course, have been obliterated in the course of a finishing process by grinding and polishing. The connection between the rim of the bowl and the supporting columns has again been made with soft solder *(Fig 2)*. In general, the condition of the tripod is very good, and no serious corrosion attack could be seen. The workmanship of the bowl is excellent, while that of the stork's-head columns and the base plate, while satisfactory, cannot be described as of high quality.

Fig 1 Brass tripod from Cyprus. 3rd century BC. Newbury Museum 1947-6.

For the purpose of metallurgical examination the following sections were taken:

(A) Mount 65. A section through the side and bottom of the bowl.

(B) Mount 66. A section through the rim of the bowl, including a small part of the stork's-head column, and the soldered joint.

(C) Mount 67. This is a large section through the base plate, and one of the supporting columns which is soft-soldered to the base plate.

The composition of the metal, by courtesy of the British Non-Ferrous Metals Technology Centre, expressed in percentage figures, is:

Base Plate Material

As	Sb	Ag	Sn	Pb	Ni	Zn
0.03	0.05	∿.005	0.3	∿2	0.1	>10

Bi	Fe	Mn	Au	P	Al	Si
.005	0.5	∿.005	nd	∿.02	∿.01	<0.01

Bowl Material

As	Sb	Ag	Sn	Pb	Ni	Zn
∿.002	∿.002	∿.005	0.02	0.2	0.07	>10

Bi	Fe	Mn	Au	P	Al	Si
.001	0.1	nd<.005 if any	nd	nd<.01 if any	<.01 if any	<.01

It will be noticed that the material in both cases is an alpha brass, and that the metals of the base plate, and the bowl, are not necessarily the same. Note the difference in the iron as well as the lead contents. Too much importance need not be attached to the very low contents of both arsenic and antimony in the bowl material. Recent experimental research by McKerrell and Tylecote[1] has shown that there can be high loss of arsenic and antimony when copper is worked under oxidizing conditions. Hence, the original bowl metal may have contained much more arsenic and antimony than is recorded.

We are indebted to Mr R F Hills, AERE, Harwell, for micro hardness determination of the bowl material, the following positions being selected:—

> Positions 1 and 2 are from the curved side of the bowl.
>
> Position 3 is at the centre of the curvature where the flat base turns upwards to meet the side of the bowl.
>
> Positions 4 and 5 are from the small flat base of the bowl.

		100 gms.		**300 gms.**
	Outer	**Centre**	**Inner**	**Centre**
Position 1	118	110	108	109
Position 2	130	122	113	115
Position 3	97.1	83.9	89.6	93.6
Position 4	93.2	85.8	91.6	104
Position 5	126	116	122	132

All figures quoted are Vickers hardness numbers.

From the above figures it will be noticed that there is a general tendency for the hardness of the metal to decrease from the outside of the bowl towards the inside. This would suggest that the bowl was fabricated by spinning over a former. Since the hardness of an annealed 70/30 brass is approximately 65 HV, the figures show that, while the material is not highly worked, some work has been applied to the bowl after the final anneal.

Mr Hector S Campbell, BSc, FIM, FRIC (Head: BNF Metals Users' Consultancy Service) kindly examined the tripod and his conclusions are given in the Appendix. Mr Campbell's report clearly shows the patination upon the tripod is in the nature of an organic pigment which has been painted on. Hence the applied patination is a fake, and without doubt of recent origin. However, further close study of the artefact leads the authors to entertain certain reservations as to the whole tripod being a fake or modern copy.

EXAMINATION OF THE SECTIONS

Section A. Mount 65. Through the side and bottom of the bowl.

Section B. Mount 66. Through the rim of the bowl and its soldered joint.

In both sections, examination showed the metal to be reasonably clean, but quite extensive dezincification has occurred. Upon etching, the structure observed is of equiaxed twinned crystals tending to be of small grain size. Deformation, or slip banding, of the crystals was not observed *(Fig 3)*.

In both mounts, the dezincification appears largely to have originated on the outer surface of the bowl. There is a zone in each mount where the dezincification attack is sparse. In mount 65 this is where the metal is most curved, ie most worked. In mount 66 it is within and around the soldered joint. In either case one should not put appreciable weight on what might be pure chance, but the following is an interesting speculation. In mount 66 dezincification can be seen at each side of the joint where the solder ends in a meniscus, and then for a distance of a few millimetres there is very slight dezincification.

(a) Had the triple interface, solder/alpha brass/environment produced slightly increased dezincification corrosion effect with a small sacrificially protected zone around it?

(b) Did the absence of dezincification within the soldered joint imply that dezincification occurred in the fully assembled artefact?

Whilst H S Campbell is strongly of the view that the bowl, if ancient, would have failed through season cracking (Appendix), we respectfully point out that cold worked brass is not inevitably prone to such failure. So much depends upon the degree of tensile stress and its distribution. If, for example, the cold work were introduced in such a manner as to result in compressive stress of the surface, season cracking would not occur, whatever the age of the object. Thus if the spinning operation were performed so that in the last stages of the spinning the brass were fully supported, this could result in compressive stress at the surface and a "safe" result[2]. In the case of our bowl, spinning would no doubt have been carried out over a wooden former, giving rise to some compressive stress in the last stage of the spinning. The hardness figures recorded from the bowl would support this view.

Another possibility we envisage is that the heat supplied during the multiple soldering operation was sufficient to stress-relieve the bowl, and thus remove any proclivity to season cracking. Such a low temperature anneal does not reduce hardness.

Section C. Mount 67. Base plate and foot of column.

Except for a network of micro-porosity, the metal of this section appears to be clean, although possibly showing rather more non-metallic inclusions than would be expected in a modern brass. Penetrative corrosion was not observed. However, where the environment has been favourable such absence, or near absence of corrosion attack, while not common, has been noticed in the case of some prehistoric objects previously examined. As expected, the metal was found to be substantially in the 'as cast' state, and no mechanical work had been applied to the casting *(Fig 4)*. In the soldered joint between the base plate and column there are signs of good spreading of the solder, but none of its penetrating into the brass, nor of brittle intermetallic layers formed at the interface.

The evidence derived from examination of the cast metal in the legs and base was quite unhelpful in that it gave no clear indication of whether the object was ancient or modern. However, a possibility which we considered at an early stage was that the original bowl had disintegrated from some such cause as season cracking and the modern restoration entailed making and fitting the present spun bowl to ancient legs and base. However, such factors as the occurrence and distribution of the dezincification on the bowl inclined us to the view that it is the original.

CONCLUSIONS

The important piece of evidence appears to be the extent of the dezincification. If the tripod is assumed to be a fake, then it is difficult to imagine it being exposed to an environment, probably containing chloride, severe enough to cause such dezincification. Again, such an environment could induce season-cracking though this type of failure is not often actually found conjointly with dezincification[2]. The one exception we can envisage is a fake being buried for a time in such conditions as to produce a 'natural' patina, but this is contradicted by the clear B.N.F. evidence of what is virtually a painted artificial 'patina'. This consideration moves our opinion in the direction of the tripod, including its bowl, being ancient. The absence of dezincification of the bowl metal within the soldered joint very slightly adds to the possibility of the tripod having been found in one piece.

The balance of probability is in favour of the tripod being ancient, and not a fake or copy, but that it has undergone some repair or renovation. It is well to remember that even before World War II, there was a trade carried on by dealers and tomb robbers in the sale of antiques to well-to-do travellers. It is believed that the tripod was acquired in Cyprus by Lady Mary Holt shortly before the war, and was subsequently donated to the Newbury Museum. Although it must remain a supposition, it is possible that one or more of the original Roman soft soldered joints may have come apart in the course of time, or have been broken as a result of rough treatment during excavation. Hence some repair would have been called for. Cleaning-off the antique patina to produce a bare metal surface would be a pre-requisite for soldering. For the purpose of selling it, the dealer may have chemically cleaned the whole tripod and then resoldered the defective joints (that would explain the 'recent' appearance, e.g. absence of serious easily visible attack such as might have resulted in the breaking of the joints in the worse cases). Having restored the tripod, he painted on the fake patination, and sold the artefact as untouched.

In the last analysis, in certain cases, the only way to be sure that an object is truly ancient is to have cast-iron evidence that it was uncovered in the right stratum from a properly conducted excavation. The present examination has shown that, even by the application of metallurgical work, it is by no means always easy to distinguish between a fake and a genuine antique.

References

1 H McKerrell and R F Tylecote. The working of copper-arsenic alloys in the Early Bronze Age. Proc. Prehistoric Soc. 1972, 38, 209-218.

2 J B Cotton. Private communication.

Appendix

Report by Hector S Campbell, BSc, FIM, FRIC.
Head: Metals Users' Consultancy Service.
BNF Metals Technology Centre.

We have now completed our examination of the 'bronze' tripod from Cyprus that you left with me and which I suspected to be a modern copy. You will recall that you brought along some microsections, one through the cast base and one through the spun sheet metal bowl. You were interested in the fact that the bowl showed some dezincification, whereas the base showed none. I think that the this is not surprising in view of the difference in composition of the two materials as shown in the analyses that we carried out for you and which were reported in Mr Boxall's letter of 19th March. The general analysis of both materials and the structures shown by your micro-sections indicate that both were essentially 70/30 brasses. The cast material contained about 2% lead but the important differences from the point of view of dezincification are that it contained also 0.03% arsenic, 0.05% antimony and a trace of phosphorus whereas the bowl contained only traces (approximately 0.002%) of arsenic and of antimony with no detectable phosphorus. Alpha brasses are susceptible to dezincification unless they contain at least 0.03% of either arsenic, antimony or phosphorus. Since the cast material contained both arsenic and antimony in sufficient quantity to inhibit dezincification, it is not surprising that the material did not exhibit this type of attack. The bowl, on the other hand, containing neither arsenic, antimony or phosphorus in significant quantities, would be susceptible.

My belief that the tripod is a modern copy was based primarily on the appearance of the green and blue patina on it. This did not look genuine to me; it appeared to have been painted on. The blue material had been applied on top of the green and neither the blue nor the green had any apparent crystalline form, nor was there any sign of the corrosion products that one normally expects to constitute a patina on an old brass or bronze object. I would expect to find cuprous oxide, basic copper carbonate (malachite), possibly basic copper sulphate and a basic copper chloride (paratacamite). My visual examination of the tripod suggested that none of these materials was present. It also showed that the legs had been attached to the base by soft soldering, the soft solder having spread out for quite a distance round the foot of the leg. Curiously, however, there was green 'patina' on top of the solder apparently identical with that on the brass. This seems to me to be very strong evidence that the 'patina' was painted on.

We have now made an X-ray diffraction examination of the green and blue material forming the patina on one of the legs of the tripod. The green material gave no pattern identifiable as any inorganic compound. We did obtain a pattern from it, but it appeared to be an organic compound for which we have only limited X-ray diffraction information and for which much of the diffraction spectrum would be beyond the range of our instruments. It is quite clear that the green material is not any of the copper compounds that one would expect to find on an old patinated brass or bronze object, but is an organic pigment.

The blue material could not be identified exactly but the pattern that we obtained showed some similarity to the structure of aurichalcite $(ZnCu)_5\ (CO_3)_2OH_6$. This is not a material that we have previously found on antique objects, and I have never come across any reference to this being formed as a constituent of a natural patina. I think that it was simply applied as an inorganic pigment.

Apart from the nature of the patina on this tripod and the fact that it is found equally on the brass and on the soft solder surfaces, there is another reason for believing the tripod to be a modern copy. The bowl is a spinning which has been left in quite a hard condition.

It would, therefore, have a high degree of internal stress in it and, had the tripod been knocking around for any long time in an environment where there was ammonia or ammoniacal compound present, it would undoubtedly have suffered season cracking. It is most unlikely that a piece such as this could have survived hundreds of years without coming in contact with sufficient ammonia, or ammoniacal compounds of one sort or another, to produce season cracking.

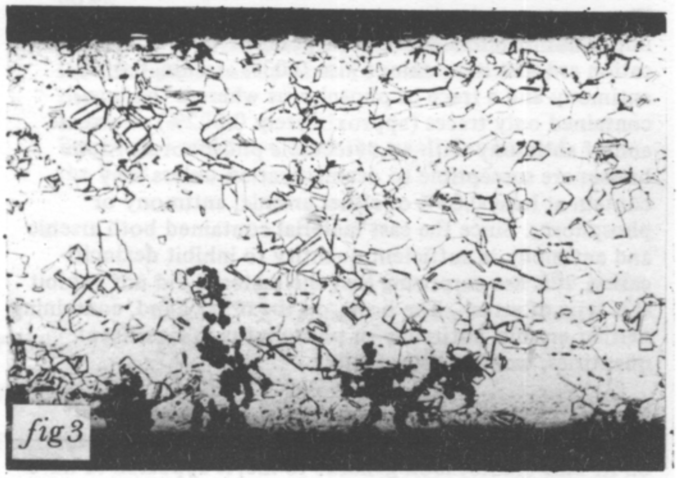


Fig 2

The soldered joint between the bowl and the leg. Mount 66.

Unetched x 50.

Fig 3

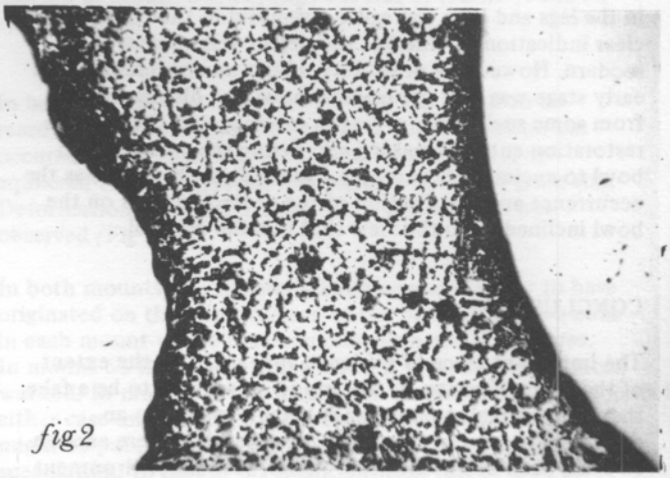
Section through side of bowl. Mount 65.

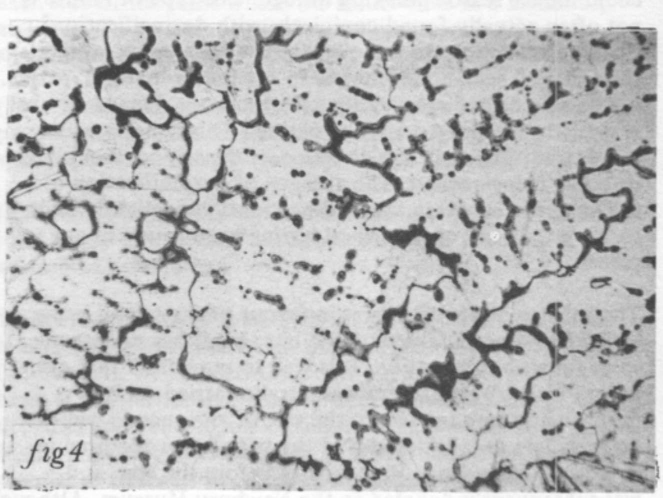
Etched x 100.

Fig 4

Section through the base plate showing substantially 'as cast' condition. Mount 67.

Etched x 50.





Examination of bearing from Saxon water mill

*By E M Trent**

The bearing was found during excavation of a Saxon water mill at Tamworth and was submitted by Mr P A Rahtz of the Department of Medieval History at the University of Birmingham. The archaeological evidence from this and other mills indicated that this one was of a type in which the rotor activated by the water was mounted on a vertical shaft which, at its upper end, was fixed to the upper millstone. There was thus no gearing, but the rotor with its paddles, the shaft itself and the upper millstone had to be supported by a bearing, the total load on which would have been of the order of 100 kg. The shaft was not found, but was almost certainly of iron or steel. Carbon 14 dating of the wood used in the structure of the mill shows that the date was 8th century, which agrees with the archaeological evidence.

The bearing was embedded in an oak beam approximately 2.5 m long by 165 mm wide and 50 mm thick which was found upside down on the floor of the mill embedded in mud at a depth of approximately 1½ m below the present ground surface. Figures 1 and 2 show the bearing embedded in the wooden plank. Conditions had been good for preservation of both wood and metal. The oak wood after drying had cracked and shrunk and was darkened. The bearing remained tightly embedded.

The bearing itself was approximately 75 mm square by 33 mm thick. The precise original size and shape were obscured by the thick layer of corrosive products which coated it on all surfaces. In the centre of the exposed face there was a roughly conical hole which had been the bearing surface. This was approximately 22 mm in diameter at the surface and 15 mm deep. There were quite deep circumferential ridges and grooves on the conical surface; the bottom of the hole was rounded and lumpy. The top surface of the iron bearing was approximately 7 mm above the surface of the dried wood. To extract the bearing a saw cut was made through the wood across the beam at the centre of the bearing and the beam was bent to break it cleanly away. The bearing had apparently been hammered into a recess cut in the wood and held in position by an interference fit. When exposed, the bottom surface of the bearing also was found to be heavily corroded, some wood fibres were attached to the rust and there was some fine silt more or less loosely attached to this corrosion product; Figure 3.

Metallurgical examination

The bearing was sectioned along the line A-A, Figure 1. In the first attempt a band saw was used but after a few millimetres penetration the teeth were worn off the saw as it cut into clean metal beneath the corrosion product. The sectioning was completed using an abrasive slitting wheel operated with a flood of coolant to prevent overheating. The surface nearest to the centre line of the bearing hole was metallographically polished.

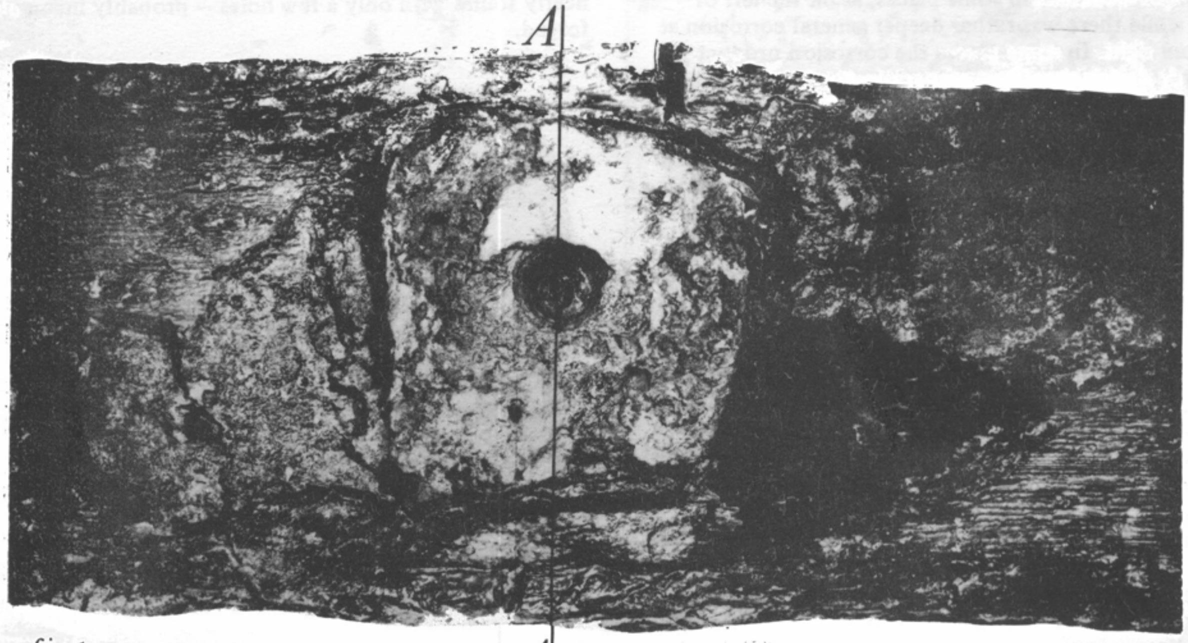


fig 1

Bearing embedded in wooden plank x 2/3 approx

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*Dr Trent is with the Department of Industrial Metallurgy, University of Birmingham

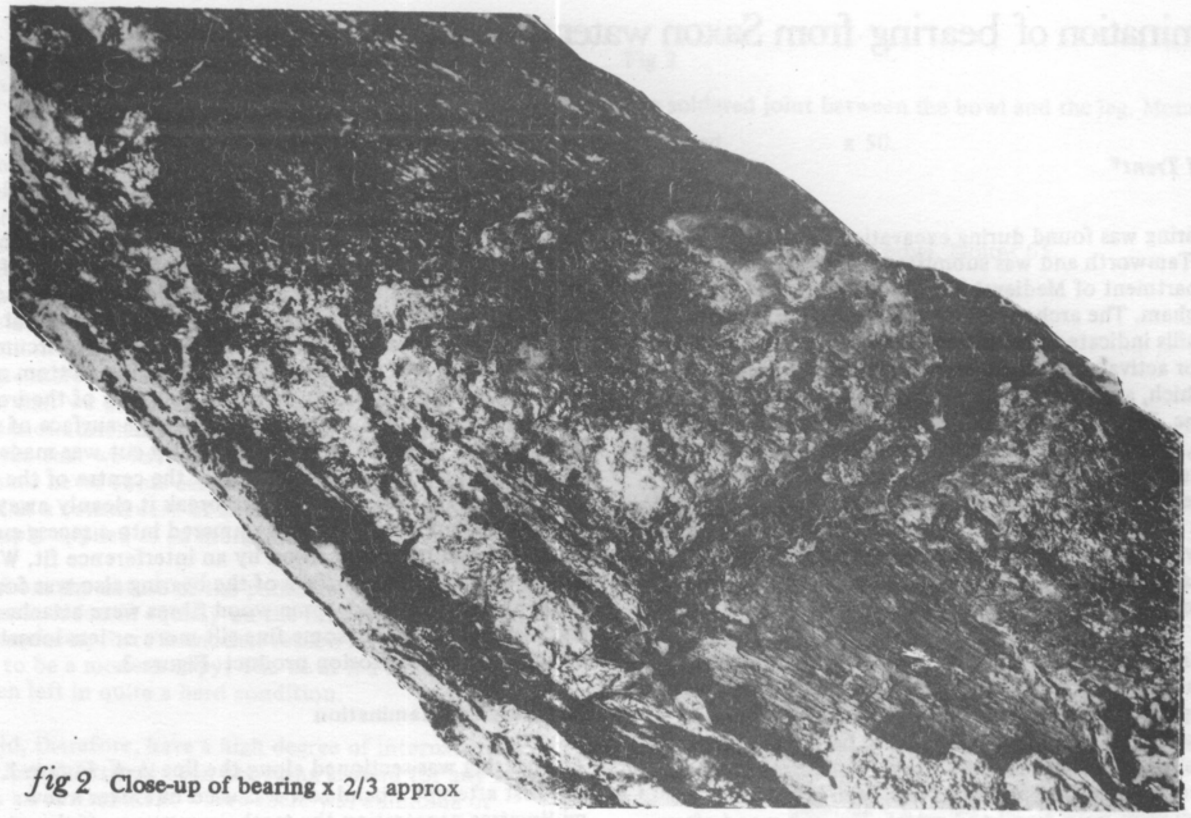


fig 2 **Close-up of bearing x 2/3 approx**

Unetched section

A low power photomicrograph *(Figure 4)* reveals a number of interesting features. Although there was a thick layer of corrosion product, the bulk of the metal was not corroded. Corrosion had eaten unevenly into the surface, penetrating along lines of weakness in some places, as on the left of Figure 4 while there was rather deeper general corrosion at the bottom right. In some places the corrosion product broke away during specimen preparation but it was mostly fairly strongly adherent. It could usually be distinguished by colour and texture from the slag and inclusions originally incorporated within the metal. The conical bearing surface is covered by an irregular layer of corrosion product, leaving the metal surface very uneven. There is no exact correspondence between the "hills and valleys" of the present metal surface and those of the visible external surface; *(Figure 1)*.

The quality of the metal was very variable through the section. Parts were sound and contained remarkably few non-metallic inclusions – for example in the upper right and just to the left of the centre line in Figure 4. In other areas, however, there were strings of non-metallic inclusions, pockets of slag *(Figure 5)* or voids where consolidation of the iron fragments was incomplete – at the left in Figure 4. There were also some extensive cracks as at the bottom left in Figure 4. The regions around the bearing surface were mostly sound except for some stringers of slag inclusions.

The most remarkable feature of the section, no indication of which was observed by surface inspection, was the second conical form immediately opposite the bearing hole on the bottom face. In this section the feature was approximately the same size and shape as the bearing hole and there was a layer of metal just over 1 mm thick separating the bottoms of these two features. The material filling this hole is of a different character from that of the rest of the bearing. It consists of an evenly distributed mixture of iron and of oxides (slag) – Figures 6 and 7. The oxide areas contain two phases which appear to be wustite ($FeO_{(1-x)}$) in a darker matrix of fayalite ($2FeO\ SiO_2$). This mixture is nearly sound with only a few holes – probably incompletely forged.

fig 3

Bottom of bearing, full size

This feature appears to be a second conical hole immediately opposite the bearing hole, which was filled in, as a secondary operation, with a mixture of iron and a siliceous slag. The infilled material is welded, but incompletely, to the base material as can be seen in Figure 8. The line of separation is more or less sharply defined at different positions along the interface and there has been some penetration of corrosion along this line of weakness. At the top of this hole *(Figure 4)* the large grey area is probably mostly corrosion product and may have been a hole. There are some fairly large slag areas at the boundary *(Figure 9)*. The evidence suggests that this material was hot forged into the hole, the slag at the interface perhaps being associated with the attempt to weld the two bodies together.

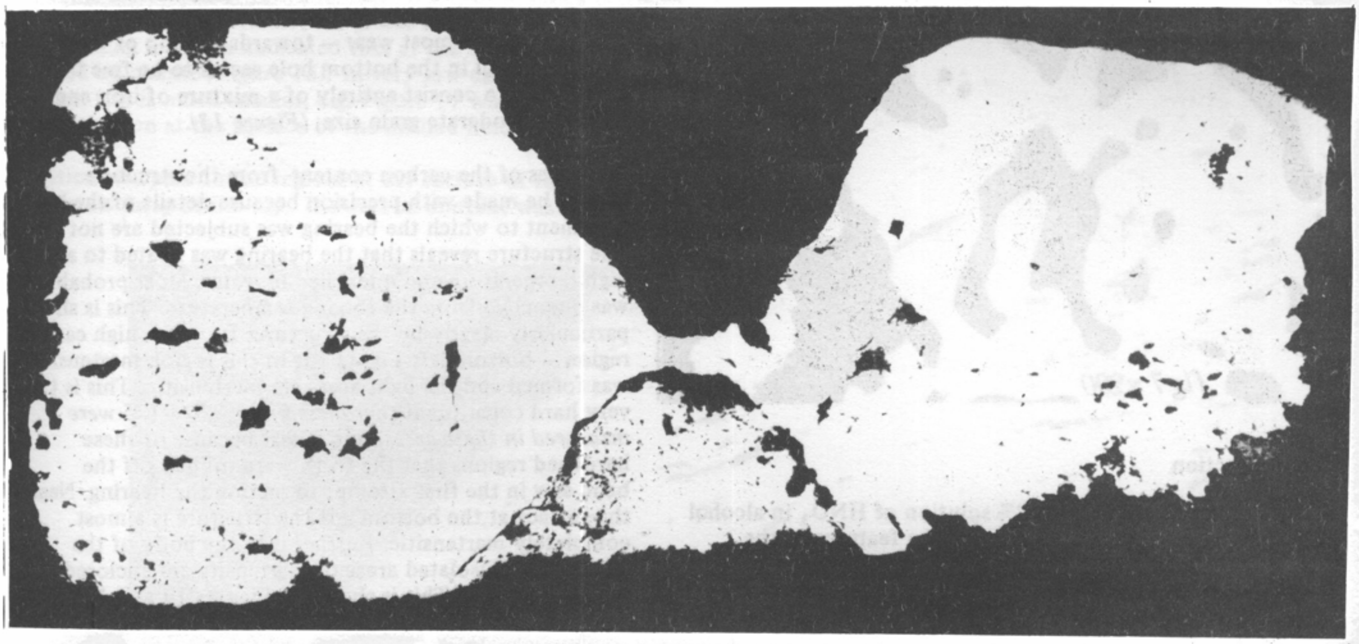


fig 4 Section through bearing x 3

fig 5 x25

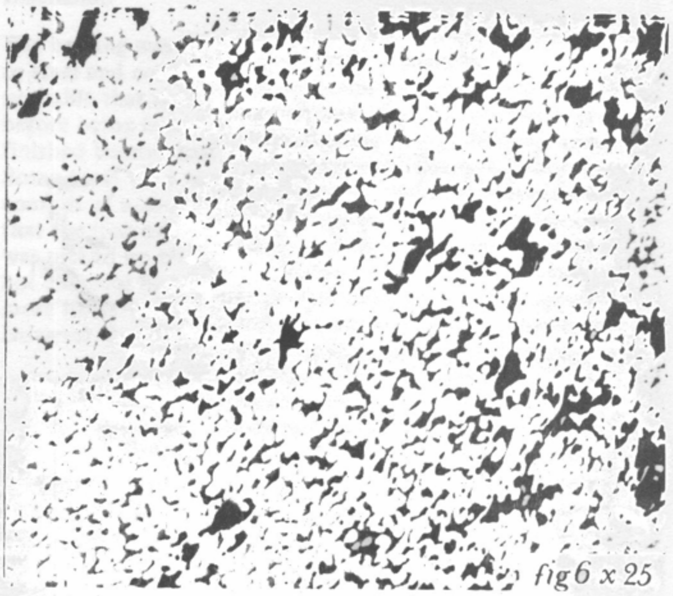


fig 6 x 25

The bearing hole shows evidence of having been hot forged. Near the top right, for example, *(Figure 4)* the lines of inclusions flow into the hole as would have happened during hot forging *(Figure 10)*. Further down the hole – position 11 in Figure 16 – lines of slag inclusions are incorporated in the corrosion product at the surface *(Figure 11)*. These lines of inclusions are elongated parallel to the bearing surface. They are of interest in showing not only that the hole was forged in, but also that the original bearing surface incorporated quite large areas of slag particles which may have played a part in the bearing performance.

The whole bearing appears to have been made by forging together fragments of ferrous metal. In some places the boundaries between the original fragments are visible as lines of slag inclusions with larger pockets where three particles were joined *(Figure 5)*.

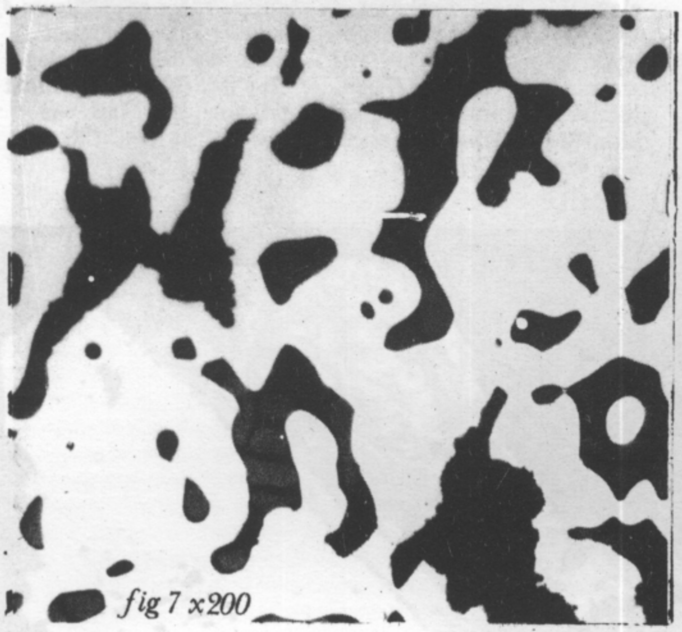


fig 7 ×200

Etched section

The section was etched in a 2% solution of HNO_3 in alcohol This etching reagent reveals most of the features of the structure – particularly the grain size and shape and the carbon distribution *(Figure 12).* A very heterogeneous structure is revealed, the most significant features of which will be described.

The carbon content is very variable across the section. In general the lighter areas *(Figure 12)* are low in carbon and the darker areas high in carbon (the sharply defined light areas at the bottom left, however, are high in carbon – this will be discussed later). There does not appear to be any systematic intentional distribution of the carbon to suit the purposes for which the bearing was made. The carbon content is fairly high at the bottom of the bearing hole and in the bottom right region, but the highest carbon content is at the bottom left. The carbon was very low over most of the bearing surface, particularly in the region probably subjected to the most wear – towards the top of the hole. The infill in the bottom hole seems to be free from carbon and to consist entirely of a mixture of iron and oxides of moderate grain size; *(Figure 13).*

Estimates of the carbon content from the structure cannot be made with precision because details of the heat treatment to which the bearing was subjected are not known. The structure reveals that the bearing was heated to a very high temperature and quenched in water. Most probably it was quenched from the forging temperature. This is shown particularly clearly by the structures from the high carbon region – bottom left Figure 12. In this region martensite was formed and the light areas are martensitic. This is the very hard constituent *(hardness up to 870 HV 5 were measured in these areas)* and it was because of these hardened regions that the teeth were rubbed off the band saw in the first attempt to section the bearing. Near the surface at the bottom left the structure is almost completely martensitic. Further into the body of the bearing small isolated areas of martensite are enclosed in softer bainite. This is shown in Figures 14 and 15.

That the bearing was quenched in water is shown by the presence of martensite. With an iron-carbon alloy only water quenching would produce this structure. That the quenching temperature was high is demonstrated by the

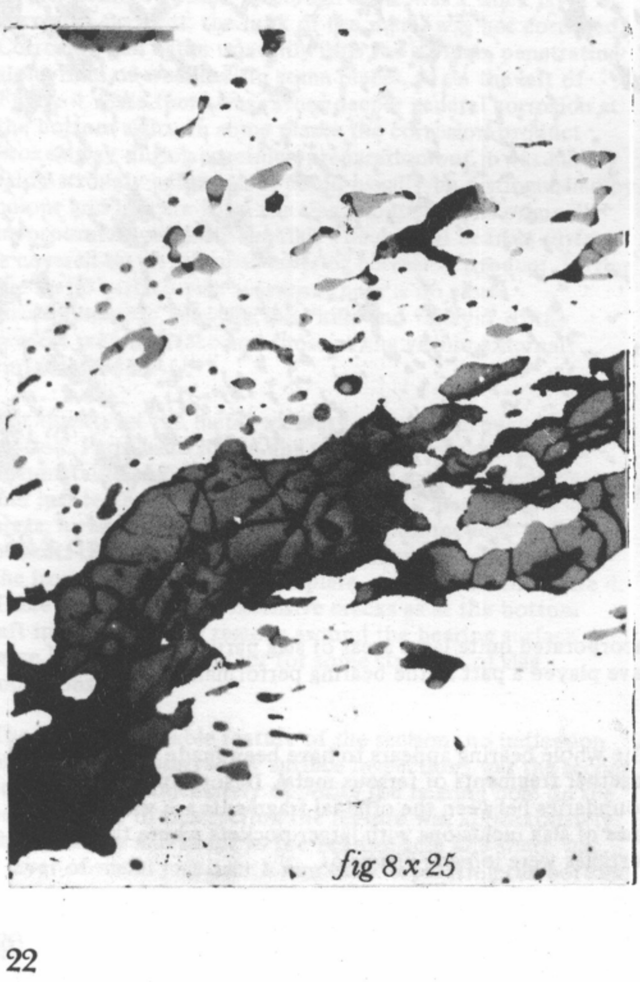


fig 8 x 25

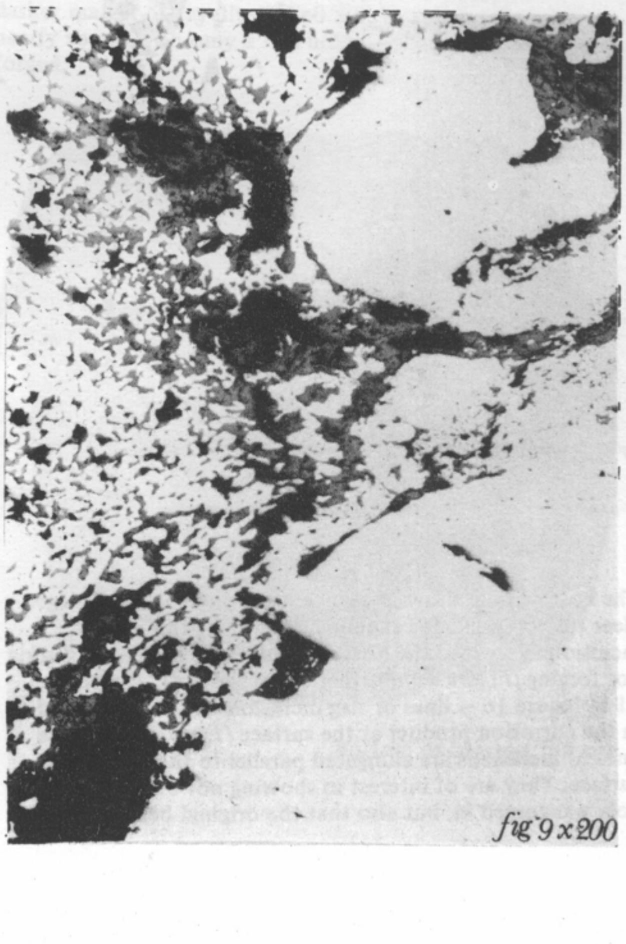


fig 9 x 200

very large grain size of the steel, particularly in the high carbon regions. The grains *(e.g. Figure 14)* are of the order of 1mm diameter. In the high carbon areas the grains are outlined by bainite nucleated at the grain boundaries *(Figure 15)* but before the bainite had grown across the grains, the temperature had dropped below the martensite temperature (MS) and the centres of the grains are, therefore, martensitic. In the areas where the carbon content is lower, but still appreciable, the grains are very large and on quenching ferrite is nucleated first at the boundaries, followed by bainite *(Figure 16)*. In very low carbon areas the grain size is much smaller, e.g. Figure 17 which shows decarburisation at the surface of the infilled hole.

Attention was paid to the regions at the surface of the bearing hole, particularly at the top. The carbon content was low or very low and here as elsewhere there were no signs of cold working. One of the objectives posed by the archaeologists was to determine the direction of rotation of the spindle by studying the flow in the surface layers of the bearing. Any metal deformed by action of the spindle must have been removed by corrosion and there was no indication of the direction of rotation of the spindle in the bearing.

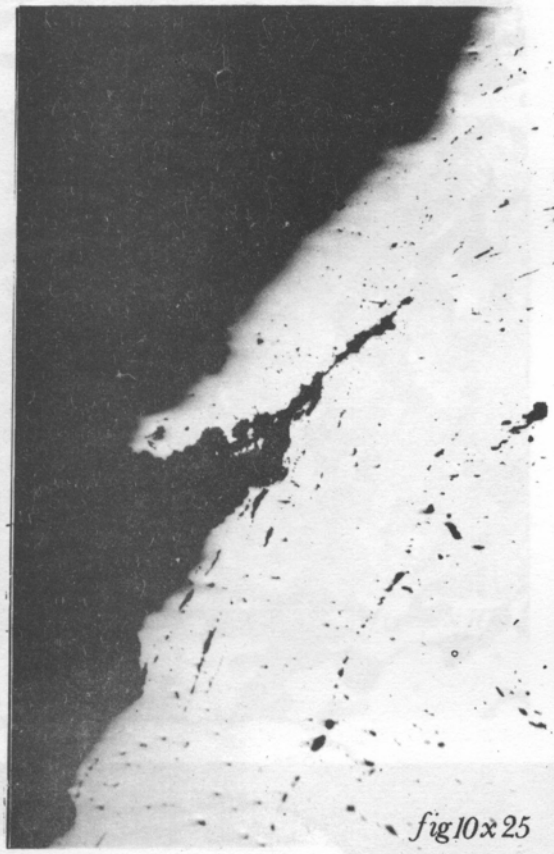


fig10x25

Hardness tests were carried out at various positions on the polished surface. The results are shown on the sketch map in Figure 18 *(which also shows the position of the detailed photomicrographs)*. In the martensitic areas hardness values of 753, 874 and 817 HV5 were recorded. Bainite areas were much softer – between 220 and 315 HV5 – while the low carbon areas with much ferrite varied in hardness from 150-185 HV. Areas near the bearing surface were mostly below 200 HV in hardness.

Discussion

The bearing was hot-forged from fragments or lumps of iron or steel and consolidated into the rectangular shape. It is probable that the fragments were of varying carbon content before being formed into the bearing, rather than that the finished bearing had been carburised by heating in charcoal. Some areas were very well consolidated and the very low content of non-metallic inclusions in these regions suggests that the iron ore used was pure. It is possible that carbon was picked up by accident by lumps of iron staying in the hot charcoal bed for long periods of time, but it seems more likely that the iron was deliberately heated in charcoal. However the control over this process was very inadequate.

The bearing holes were almost certainly hot-forged in to the required shape. The filled-in hole is interesting but the objectives of the fabricators are not clear. Several reasons for making this hole and filling it in have been suggested. The filled-in hole may have been the original bearing and this may have been unsatisfactory or may have been used and worn until it no longer worked well as a bearing. The original hole may then have been filled in before punching a new one on the other side – though it would not seem necessary to fill it in. It is interesting that the two holes are immediately opposite to one another – this would not have been very easy to achieve.

It has also been suggested that the two holes could have been forged simultaneously to achieve a high level of consolidation of the material around the bearing. Another possibility is that the first hole was used until the end of the shaft seized solid in the hole. The shaft could then have been broken off and the material in the hole could be the broken end of the shaft reheated when the new hole was forged.

The original hole may have been unsatisfactory because of low hardness due to low carbon content. If this was so, the second hole would not have been much better. Certainly a high carbon content giving martensitic areas at the hole surface would make a better bearing which would wear more slowly but the smith does not seem to have achieved this condition.

The bearing was certainly quenched in water from a very high temperature – probably after forging the hole. The temperature must have been 1000°C and possibly 1100°C or even higher. The quenching may have been accidental in the sense that it may have been done to cool the piece rapidly for convenience of handling. However, this seems unlikely. It is more probable that the smiths knew that the quality of the iron was improved for tools and weapons if quenched after soaking in charcoal – in fact that they were making steel and heat treating it. Control over this process for making conventional objects such as sword blades may have been fairly good but objects of unusual shape and size such as this bearing would present difficulties for the smith in the absence of any basic knowledge of what the processes were that he was trying to control.

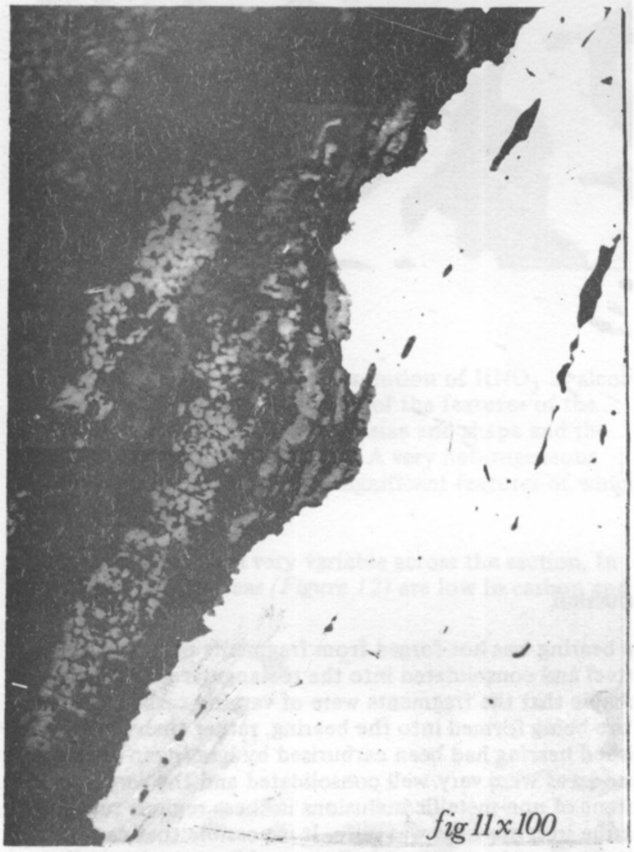


fig 11 x 100

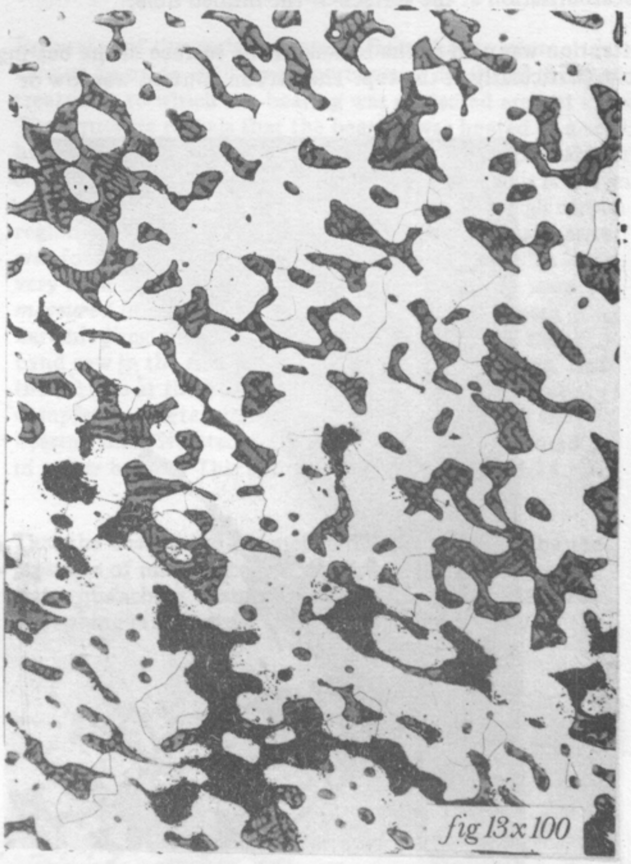
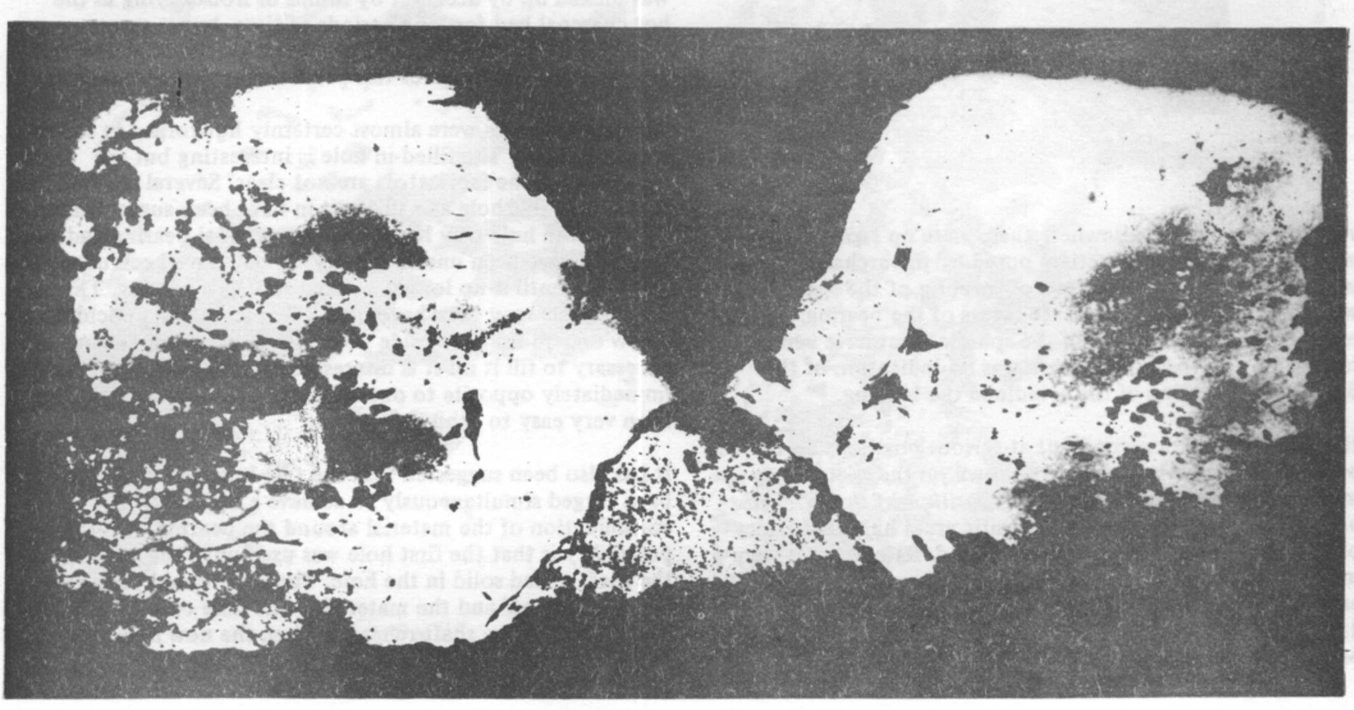


fig 13 x 100



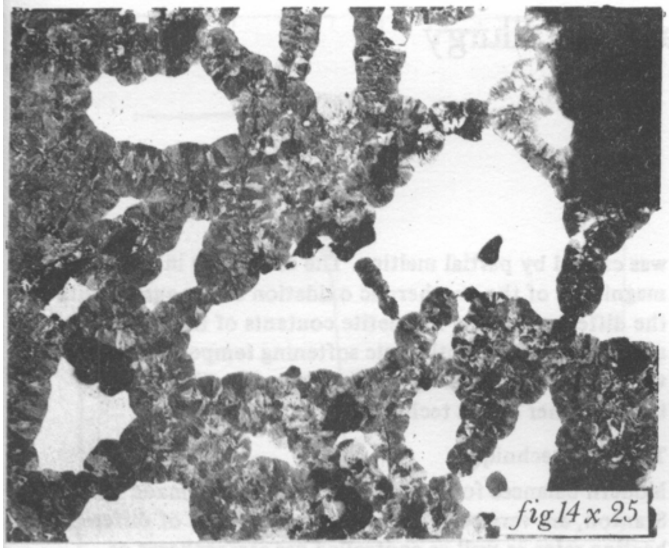


fig 14 x 25

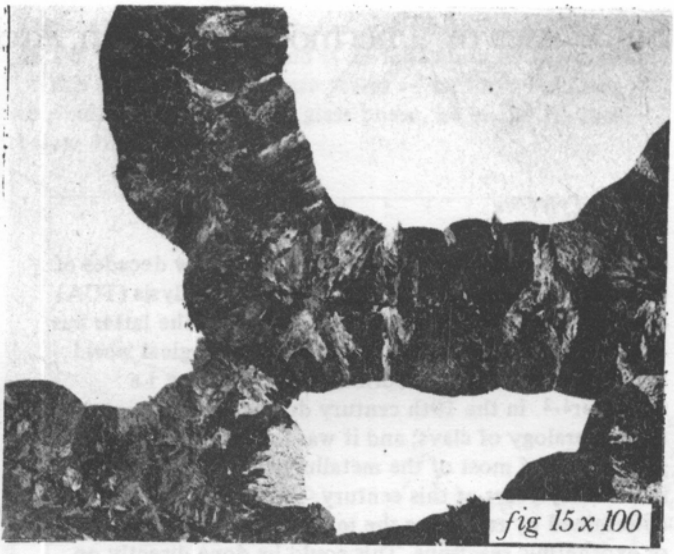


fig 15 x 100

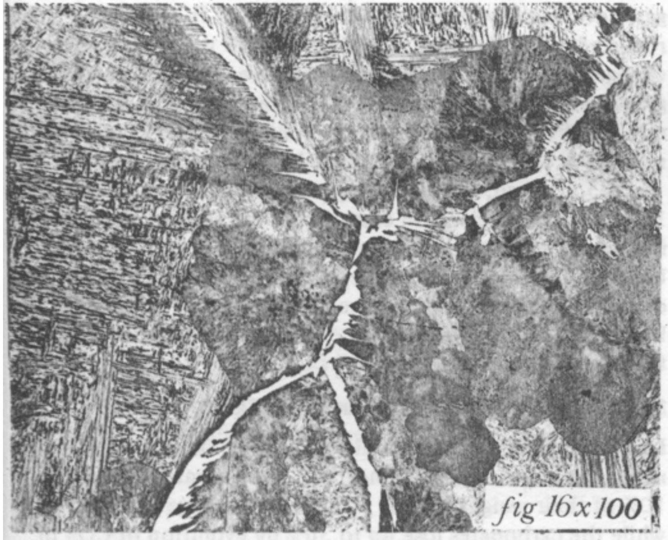


fig 16 x 100

fig 17 x 100

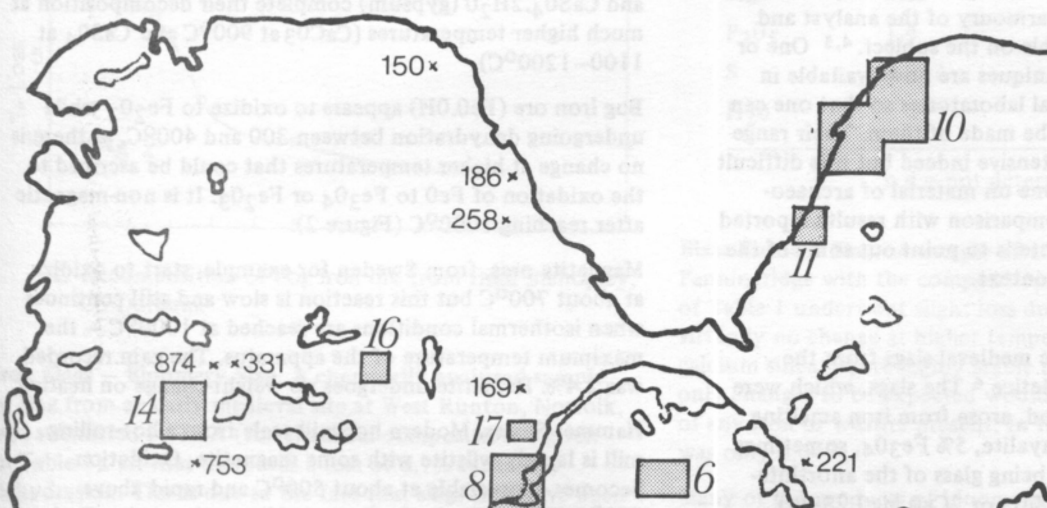


fig 18 Hardness measurements (HVS)

Some uses of Thermo-Analysis in Archæo-Metallurgy

by R F Tylecote

Increasing use has been made over the last few decades of two techniques:– 1) Thermo-gravimetric analysis (TGA) and 2) Differential thermal analysis (DTA). The latter has been in use in the mineralogical and metallurgical world for a lot longer than the former. It was used by Le Chatelier[1,2] in the 19th century during investigations on the mineralogy of clays; and it was responsible for the production of most of the metallurgical phase diagrams in the early years of this century. Phase changes were determined by recording the temperature of endothermic or exothermic reactions. This could be done directly on a temperature-time curve when the specimens were slowly heated or cooled, or more accurately by measuring the temperature difference between an inert specimen and that undergoing a change. It is the latter technique that is the basis of DTA today.

TGA has mostly been used for oxidation and reduction experiments, and the autographic recording of weight changes due to this process was pioneered by Chevenard and others.[3] Here, the basic piece of apparatus was the automatic recording balance recording the change of weight of a specimen, under isothermal conditions or controlled linear heating. A great deal of work on the oxidation of metals was done, and still is done, in this way.

However, in the 1940's there was an increasing awareness of the value of this technique and its equipment which had been primarily designed for oxidation. Those showing most interest at that time were concerned with decomposition reactions such as the calcining of aluminium sulphate to give alumina. These two techniques gradually became just another weapon in the armoury of the analyst and many books are now available on the subject.[4,5] One or other, or both of these techniques are now available in many research and analytical laboratories so that one can expect an increasing use to be made of them. Their range of use is, of course, very extensive indeed but it is difficult to find evidence of work done on material of archaeo-metallurgical interest for comparison with results reported here. The purpose of this note is to point out some of the possibilities in this special context.

Previous work

DTA has been used on some medieval slags from the Czechoslovakian site of Radetice.[6] The slags, which were not very typical of the period, arose from iron smelting and contained about 75% fayalite, 5% Fe_3O_4, sometimes 5–10% FeO, the remainder being glass of the anorthite-melilite type ($CaO.Al_2O_3.2SiO_2$ or $2CaO.MgO.2SiO_2$). Heating the finely crushed slag produced DTA peaks in the range 850–1000°C due to the exothermic oxidation of FeO or Fe_3O_4 to higher oxides or compounds. There were also some weak, low temperature effects, between 450° and 550°C which are said to be due to transformations in the glass phase. The glass phase was also responsible for an endothermic plastic stage in the range 1000–1250°C which was caused by partial melting. The difference in the magnitude of the exothermic oxidation effect agreed with the difference in the magnetite contents of the two specimens. The endothermic softening temperature agreed with that determined by other means. No other application of either of the techniques has been noted.

The TGA technique

Modern balances for TGA work, such as that made by Stanton, are very sensitive and permit the use of different heating rates as well as controlled gas atmospheres or vacuum. It is also possible to determine the analysis of the gases evolved (Evolved Gas Analysis, EGA) In the work reported here a Stanton recording balance was used and the changes of weight in normal room air were plotted autographically. The temperature was increased at a near linear rate (400°C/hr) by a programme control device. The mineral or slag specimens consisted of powder ground to < 0.05 mm and, for most purposes, a sample weight of 100 mg was sufficient. In cases where the change in weight is likely to be less than 10% a larger sample size may have to be used. The sensitivity of the balance was 10 mg per 10 cm of chart. The resulting record consisted of two traces side-by-side; change of weight, and change of temperature with time.

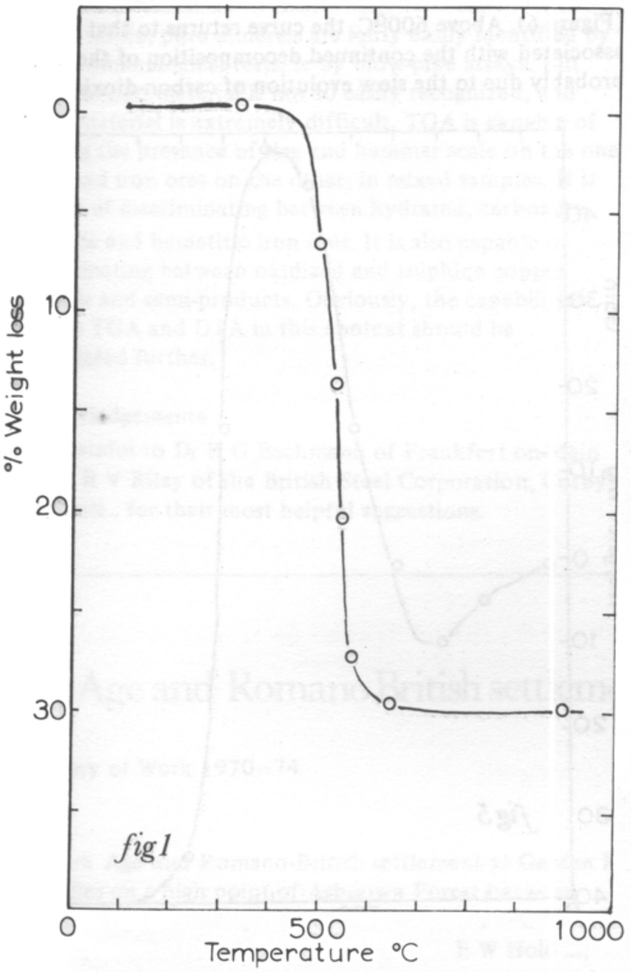
Some Examples of the Application of TGA

Iron Ores. Iron ores are mainly hydrated oxides or carbonates. Both decompose on heating. The hydrates lose about 10% of their weight by this process in the range 300-400°C, while the carbonates lose up to 30% by evolution of CO_2 in the range 500-550°C (Figure 1). Impurities such as $CaCO_3$ and $CaSO_4.2H_2O$ (gypsum) complete their decomposition at much higher temperatures ($CaCO_3$ at 900°C and $CaSO_4$ at 1100–1200°C).

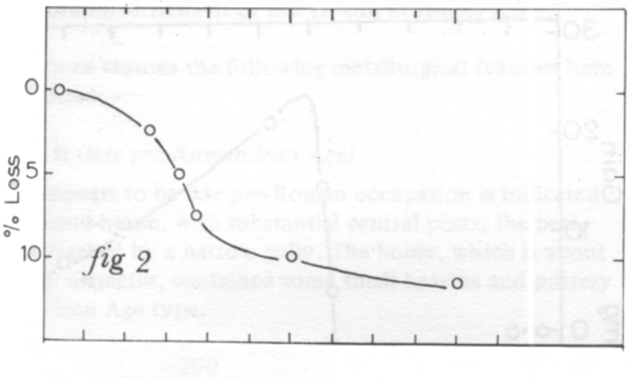
Bog iron ore (FeO.OH) appears to oxidize to Fe_2O_3 while undergoing dehydration between 300 and 400°C, as there is no change at higher temperatures that could be ascribed to the oxidation of FeO to Fe_3O_4 or Fe_2O_3. It is non-magnetic after reaching 1000°C (Figure 2).

Magnetite ores, from Sweden for example, start to oxidize at about 700°C but this reaction is slow and still continues when isothermal conditions are reached at 1000°C – the maximum temperature of the apparatus. The gain recorded was 2.4%. Hematite undergoes no weight-change on heating.

Hammer Scales. Modern hot-mill scale from a hot-rolling mill is largely wüstite with some magnetite. Oxidation becomes appreciable at about 500°C and rapid above 700°C (Figure 3). Both phases oxidize to hematite. Early hammer scales seem to be higher in magnetite, probably due to their lower temperature of formation, and often contain absorbed or combined water. Some medieval hammer scales from Waltham Abbey lost about 7% due to dehydration below 700°C and gained 2.7% due to oxidation of magnetite to hematite between 700 and 1000°C (Figure 3).



1. Decomposition of siderite from the Coal Measures at Whittonstall, Northumberland.

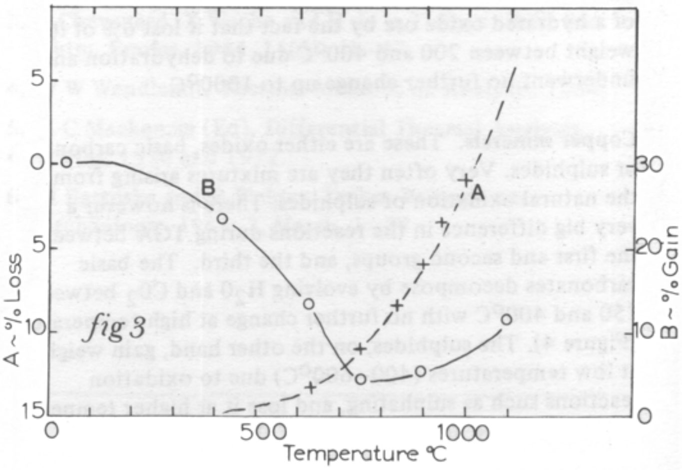


2. Decomposition of bog iron ore from High Bishopley, Co Durham.

Iron Slags – Bloomery Slag. A chemically analysed sample of slag from an early medieval site at West Runton, Norfolk, was submitted to TGA (the chemical composition is given in Table 1). At first there was a loss of 0.7% caused by dehydration. This is due to the fact that slags that have been in the ground for some time form hydrates and other oxides by the "rusting" of less stable constituents such as wustite. Above 500°C there was a gain in weight of 5% due to the reaction,

$$2FeO + \tfrac{1}{2}O_2 \longrightarrow Fe_2O_3$$

The temperature and degree of this weight-gain depends on the wüstite content and is an indication of the amount of this phase present. There seems to be little tendency to oxidize the iron in the glass phase, or in the fayalite, below 1000°C.



3. Decomposition and oxidation of scale from a modern hot-rolling mill (A), and hammer scale from Waltham Abbey (B).

TABLE I
Chemical Analyses of Slags

%	A Bloomery Slag (West Runton)	B Blast Furnace Slag (Panningridge)
FeO	56.8	0.04
SiO_2	27.1	45.5
CaO	1.4	20.6
Al_2O_3	10.2	19.2
MgO	0.8	9.6
P_2O_5	1.4	tr
S	0.022	0.115
H_2O	n d	nil

n d = not determined

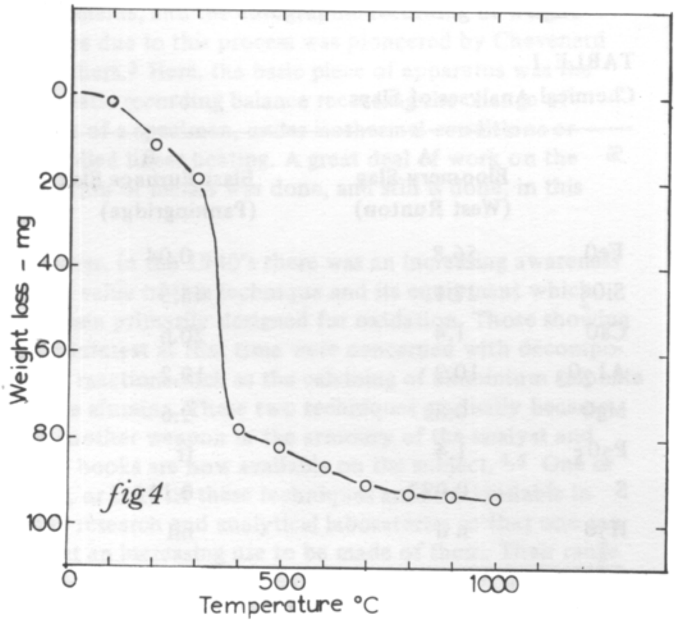
Blast Furnace Slag. A sample of a blast furnace slag from Panningridge with the composition shown in Column B of Table 1 underwent slight loss due to dehydration, and virtually no change at higher temperatures; such slags, being calcium silicates, are highly stable up to 1000°C and the only changes to be expected would be due to the oxidation of any iron or wüstite present. In this case the FeO content was only 0.04%.

Many of the products of bloomeries or forges are mixed and therefore complex. Some are waste material from hearths or floors; others are probably iron-containing material returned to the smelting furnaces for reworking. An example of such material from Netherne, Surrey, was shown by microscopic examination to consist of hammer scale and droplets of bloomery slag. This lost about 3%

of its weight at temperatures up to 400°C due to dehydration. It gained some 3% between 500 and 1000°C due to the oxidation of wüstite and magnetite in the scale and wüstite in the slag.

On the other hand, an unknown but finely powdered sample from Waltham Abbey was identified as the fines of a hydrated oxide ore by the fact that it lost 6% of its weight between 200 and 400°C due to dehydration and underwent no further change up to 1000°C.

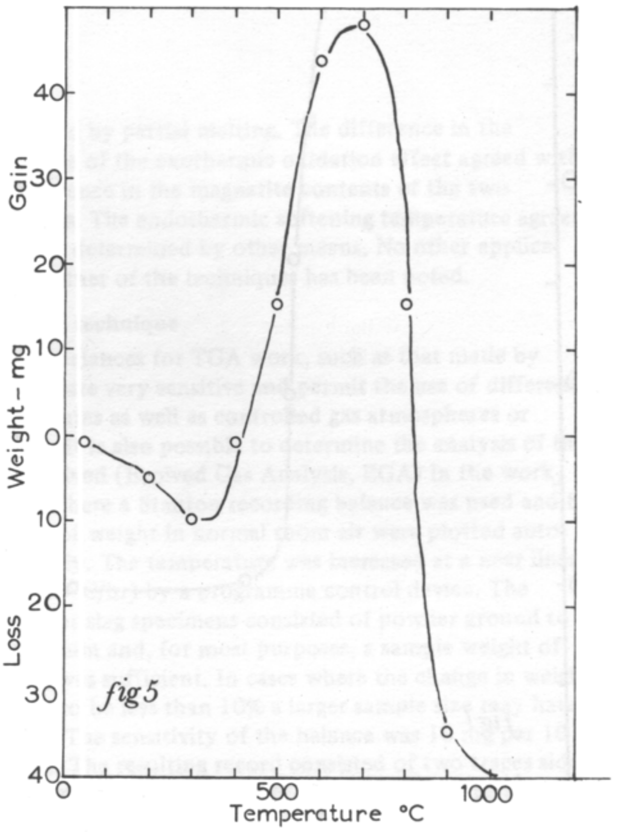
Copper minerals. These are either oxides, basic carbonates, or sulphides. Very often they are mixtures arising from the natural oxidation of sulphides. There is however a very big difference in the reactions during TGA between the first and second groups, and the third. The basic carbonates decompose by evolving H_20 and $C0_2$ between 150 and 400°C with no further change at high temperature (Figure 4). The sulphides, on the other hand, gain weight at low temperatures (400–600°C) due to oxidation reactions such as sulphating, and lose it at higher temperatures due to the decomposition of the sulphate (Figure 5). While there is no observable difference between azurite and malachite, there is an enormous difference between these basic carbonates and the sulphides and mattes.



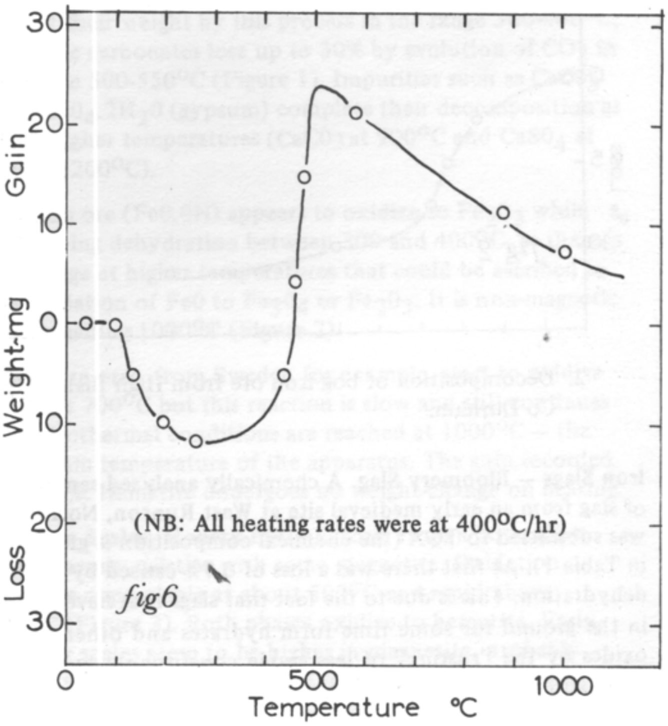
4. Decomposition of azurite from Cyprus (MCY 11).

Of course such differences are often immediately obvious from the difference in colour between the blue and green of the azurite and malachite, and the black or golden colour of the sulphides. But, in certain finely granulated material, this is not so obvious and TGA will immediately show the difference.

In the case of almost entirely corroded metal, where there is some doubt whether the material is corroded metal or natural azurite or malachite, TGA may show up the difference. As shown above (Figure 4), azurite decomposes at 150–400°C without much further change. On the other hand a mixture of copper and azurite, after losing some weight at low temperatures, will go on to gain weight in the range 400–500°C until all the residual metal is oxidized (Figure 6). Above 600°C, the curve returns to that associated with the continued decomposition of the azurite probably due to the slow evolution of carbon-dioxide.



5. Decomposition and oxidation of a copper sulphide concentrate from Avoca, Co Wicklow, Ireland.



(NB: All heating rates were at 400°C/hr)

6. Decomposition and oxidation of a mixture of Cyprus azurite and copper powder.

Conclusions

On the whole, pure minerals are fairly easily identified by normal mineralogical tests, ie by blow-pipe assays. But finely divided material is not so easily recognized, and mixed material is extremely difficult. TGA is capable of showing the presence of slag and hammer scale on the one hand, and iron ores on the other, in mixed samples. It is capable of discriminating between hydrated, carbonate, magnetic and hematitic iron ores. It is also capable of discriminating between oxidized and sulphide copper minerals and semi-products. Obviously, the capabilities of both TGA and DTA in this context should be investigated further.

Acknowledgements

I am grateful to Dr H G Bachmann of Frankfort-on-Main and Dr R V Riley of the British Steel Corporation, Corby, Northants., for their most helpful suggestions.

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Iron Age and Romano British settlement at Garden Hill, Hartfield, Sussex (TQ 444319)

Summary of Work 1970–74

The Iron Age and Romano-British settlement at Garden Hill, which lies on a high point of Ashdown Forest between Colemans Hatch and Wych Cross, was discovered in 1968 by Mr C F Tebbutt, FSA, and surveyed by Mr E W Holden, FSA. It covers an oblong area of about 6.8 acres (2.7 hectares) enclosed by a single bank and ditch of the late Iron Age; at the eastern end of this fortified enclosure is a Roman-British iron-working settlement of the 1st-3rd centuries AD.

After three seasons the following metallurgical features have been found:–

Period II *(late pre-Roman Iron Age)*

What appears to be late pre-Roman occupation is indicated by a round-house, with substantial central posts, the perimeter marked by a narrow gully. The house, which is about 11 m in diameter, contained some small hearths and pottery of late Iron Age type.

Period IV *(c. 120–200 AD)*

A small but complete bath-building (9 m long overall) was built immediately to the east of the remains of the rectangular building. The bath had a long stoke-hole (with position for boiler), a hot room (with bath annexe), tepid room, cold room and cold plunge. The two latter were floored with slabs of local sandstone and drained by lead pipes into gullies, one of which led into a sump near the bath, and the other ran down-hill towards the Iron Age entrance which, even if still used for traffic, can no longer have been part of a defensive system. What were left of the *pilae* of the hot room were made of the usual hypocaust tiles. In the debris of the hot room the remains of 18 'spacers' were found, one still threaded on its iron hold-fast, for use in the vertical hot-air flues. In the tepid room some of the *pilae* were of stone.

Period V *(post–2nd century)*

50 m to the SE a smithy working area and what may be the base of an anvil, probably belonging to this period were partially excavated in 1974.

THE SIGNIFICANCE OF GARDEN HILL

Enough is now known about Garden Hill to be reasonably certain that a settlement existed there in the late pre-Roman Iron Age; that it was fortified against an external threat, possibly the Roman invasion of AD 43; and that thereafter, under Roman influence, it became a centre for managing local iron-working, such as the 1st century AD smelting furnace in Pippingford Park, excavated by Mr Tebbutt. Whether or not industrial activities were conducted at Garden Hill throughout its life is not yet clear, but they were certainly a major feature of its existence after the abandonment of the bath building in the 2nd century AD.

Further work will include the systematic excavation of both the Romano-British area at the east end of the enclosure as well as other parts which the appearance of being unoccupied in the Roman period presents a unique opportunity of throwing light on the character of Wealden life in the late Iron Age and Roman periods; discovering whether or not the iron-working industry was carried on there before the Roman occupation; and of adding to our growing knowledge of the organisation and technique of iron-working during the Roman period. A great merit of the site is that it has not been disturbed by later occupation and will be available indefinitely for archaeological work.

J H Money, FSA

Aspects of early copper smelting

*B.S. Ottaway, M.A.**

The ancient copper mine of Rudna Glava in Yugoslavia *(22 km east of Madjanpek, south of Vinca and of Starcevo)* has been dated by the excavator *(Jovanović, 1971)* to the end of the early Vinca culture *(Vinca-Tordos)*. A series of vertical shafts produced evidence of early exploitation in the shape of typical early Vinca sherds, one sacrificial vessel *(Jovanović, 1971, Pl.III, 1-4)* and, more recently, primitive mining implements of stone and bone *(Jovanović, pers. comm.)*. It is not until the succeeding Vinca-Plocnik phase that a variety of ornaments and later heavy implements were made of copper. However, even allowing for the possibility that the evidence for any appreciable local copper production may not belong to periods prior to the transition from Vinca-Tordos to Vinca-Plocnik, the dates are still remarkably early, as can be seen from Fig.1.

One would expect European copper technology belonging to the first half of the 5th millennium BC to use the most simple and primitive smelting methods. However, as will be seen this does not seem to be the case: A sample of the ore from Rudna Glava[1] has been analysed[2] with the following results: *(Total 100%)*

Cu	Fe	As	Sb	Ag	Pb	Sn	H_2O + CO_2
32%	26%	0.003%	0.005%	<0.002%	<0.01%	<0.002%	Rest

The major minerals have been identified [3] as malachite and goethite, thus it appears likely that it is in the oxidation zone of an underlying vein of chalcopyrite *($CuFeS_2$)*.

Although this is nominally an oxide *(carbonate)* ore of copper, it cannot be smelted by a simple reduction process because of the presence of the hydrated ferrous oxide, goethite. To remove the latter it would be necessary to add a fairly carefully calculated quantity of quartz *(SiO_2)*, to the furnace, so that the iron would be sequestered in the slag.

This is clearly not a primitive smelting technique. The fact that a series of fairly deep shafts were driven into the ore body *(the early Vinca sherds were found at 6.5m depth of shaft 7; the sacrificial vessel at 12 m depth of another shaft)* shows that the associated smelters appreciated the problem and were able to solve it, even at this early date. These facts are in agreement with the evidence recently reviewed by Wertime *(1973)*; for example, the somewhat later Chalcolithic site of Timna in Israel *(Tylecote, Lupu & Rothenberg, 1967)*, archaeologically dated to the 4th millennium BC used another complex slagging procedure *(R. Tylecote, pers. comm.)*.
The evidence outlined above of the sophistication shown at Rudna Glave strongly indicates an even earlier primitive phase of copper smelting elsewhere.

Notes

1. Dr. Jovanović very kindly sent a sample of the ore from the access platform of shaft 7.1 to the author in 1971.
2. The author is grateful to Dr. McKerrell for the analysis.
3. The identification of the mineral was made by the British Museum laboratories.

Thanks are due to Dr. R. Tylecote for helpful discussions about the problem of smelting this ore.

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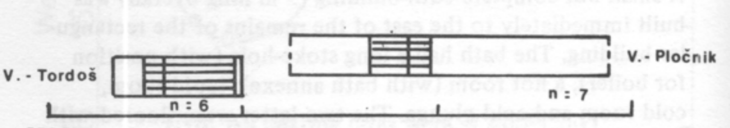

Fig.1 Interquartile ranges of ^{14}C dates corrected by the MASCA calibration curve (Ralph et, al, 1973) to sidereal years BC for the Vinca-Tordos and the Vinca-Plocnik cultures. For individual ^{14}C dates see Appendix.

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*Research Assistant, Department of Archaeology, University of Edinburgh

Appendix

^{14}C dates for:

Vinca-Tordos

Predionica , Bln 435 (Q & K,1969,237) 4330± 80 bc

Vinca , GrN 1546 (Rc V (1963) 184) 4240± 60 bc

Oszentiván (VIII series), No 2, Bln 479 (Q & K, 1969, 244) 4510± 80 bc

" No 3, Bln 480 (Q & K 1969, 245) 4100± 100 bc

" No.4, Bln 477 (Q & K, 245) 4320± 80 bc

" No.5, Bln 478 (Q & K, 1969, 245) 4120 ± 100 bc

Vinca-Plocnik

Valac , Bln 436 (Q & K, 1969, 232) 3945 ± 80 bc

Vinca , GrN 1537 (Rc V (1963) 184) 3895 ± 160 bc

Bapska 1 , Bln 348 (Q & K, 1969, 232) 3870 ± 80 bc

Banjica , GrN 1542 (Rc V (1963) 185) 3760 ± 90 bc

Gornja Tuzla, Bln 349 (Q & K, 1969, 232) 3760 ± 90 bc

" " , GrN 1974 (Q & K, 1969, 233) 3630 ± 60 bc

Divostin , BM 574 (unpubl) 3297 ± 144 bc

Abbreviations in Appendix

Q & K = Quitta & Kohl, 2969

Rc = **Radiocarbon**

Note

A NEW METHOD FOR THE REMOVAL OF METALLOGRAPHIC SPECIMENS FROM METAL ARTIFACTS

While the chemical and physical analysts of ancient metal artifacts are happy with a gram or less of drillings, often made with the aid of a dental-type drill, this is not the case with the metallographer who wants a piece of the order of 2-4 mm in all three dimensions. This can often be done by cutting away a piece from a broken edge or from an unseen part of the artifact. But where this is not possible, it is often best to trepan a small "core" from a reasonably good surface to the full thickness of the artifact. This is done in a manner rather like the core-drilling of rock specimens for mineralogical investigation but, of course, the piece is much smaller in size. Unfortunately, ultrasonic drilling of cores is impossibly slow on metals although it is suitable for many brittle non-metals. In "A report upon analytical methods" published by the Ancient Mining and Metallurgy Committee of the Royal Anthropological Institute in 1962, and printed in their Journal, Vol.92, Part I, pages 125-140, I sketched a design for a trepanning tool made of carbon steel *(p 132)*. Although this works reasonably well, it is very prone to breakage unless very carefully used. It is capable of giving a core about 2.5 mm dia.

However, for the machining of reasonably good conducting materials like metals we can use the process of spark-erosion. Recent work has given very good results. A 4 mm core has been trepanned from 7 mm thick pieces of leaded gunmetal (Cu-Sn-Zn-Pb alloy) or tin bronze in 10 minutes using as electrode a piece of copper tubing of 8 mm outside diameter. The setting-up time of the machine is about 30 minutes but once the right conditions have been established, pieces may be trepanned from a wide range of archaeological bronzes at the rate of one per 10 minutes. Most machines have a length restriction; for the machine used in these experiments, this was 50 cm. But, if a slightly oblique hole is acceptable, a piece longer than this can be immersed in the dielectric tank at an angle with one end sticking out, and a piece trepanned up to 20 cm from the immersed end. The core is reasonably parallel and no metallurgical damage appeared to have been caused to the specimen removed. Machines made for this purpose by the firm of Sparcatron cost about £4000 and therefore, to be economic, such a facility would have to be centralised. This would be inconvenient for many laboratories but quite often they would find facilities available in local industries and other laboratories reasonably close.

In most cases the more traditional methods would suffice and spark-machining would only be needed in a few cases. After trepanning, the hole may be filled in with a piece of metal rod of the same colour.

13th December, 1974 *R F Tylecote*

Work in progress

EXAMINATION OF CINDER FROM EARLY IRON WORKING AT CROWN END, NORTH YORKSHIRE MOORS

by N H Harbord, D A Spratt

The North Yorkshire Moors contain a number of prehistoric sites characterised by considerable stone remains such as cairnfields, standing stones, round barrows, ring cairns, field walls and lines of vertical stones. These were described in detail in 1930 by Dr Frank Elgee [1] who ascribed them to the Bronze Age because of their occasional association with the collared urns of this period, and no convincing alternative dating has been advanced since that time. Crown End, near Westerdale, *(Grid Reference NZ 668074)* is one of the most extensive and well-known of these sites. However, later archaeologists have thought that occupation continued here into the Iron Age or even later periods because it also has a stone-walled enclosure of similar shape and area to a dated Iron Age enclosure on Great Ayton Moor (9 kms north-west of Crown End), a rectangular Celtic field and pronounced lynchets indicating developed cultivation methods. Recently we found five pieces of iron cinder in the stone wall of the enclosure, and it seemed worth examining these in some detail to see if they provided information on a later period of settlement. Accordingly we studied the cinders visually, by microscopic and x-ray techniques and by chemical analysis, together with samples of Iron Age cinder from the dated furnace at Levisham Moor *(21 kms south-east of Crown End)*, and slag from the Sixteenth Century bloomery at Rosedale *(17 kms south south-east of Crown End).*

EXPERIMENTAL

Thin and polished sections were made of the cinders as found. Since a number of the cinders contained adventitious material, particularly sandstone, the x-ray examination and chemical analyses were carried out on slag material separated by hand from the crushed samples. The results are given in the table. The apparent difficulties in correlation of the data from the different techniques arise from the pronounced heterogeneity of most of the cinders.

DISCUSSION

In visual appearance, the irregular sponge-like cinders from Crown End resemble closely those from the Iron Age furnace at Levisham Moor, and are quite distinct from the rounded appearance of the solidified molten slag from the medieval bloomery at Rosedale. Samples B, C and E from Crown End are similar to 'furnace bottoms' as described by Tylecote [2] . Sample A is of furnace bottoms with attached cinder from the higher part of the furnace and Sample D is of cinder attached to the natural rock which comprised the furnace wall. Their appearance shows clearly that they are the waste products of smelting in a bowl furnace, and moreover their size suggests a small furnace, about 30 cm diameter, such as was used in the Iron Age, rather than the large bowl furnaces which were in use in the medieval period [3]

Technical examination of the Crown End and Levisham Moor cinders reveals a rather primitive state of technology shown partly by the heterogeneity of the cinders. Sample C for example is very heterogeneous, containing unreacted silica and iron oxide. Reduction is often incomplete, shown for example by the wüstite present in Samples A, E and G.

Even where there is little iron oxide, the presence of free silica *(Samples B and D)* indicates that much of the iron oxide would have been combined as fayalite rather than reduced to metallic iron. Sample B has an abnormally high silica content and low iron oxide, and seems to be a piece of melted furnace lining, similar to that reported from Camerton [4] Iron Age site. Microscopically the silica shows up as inclusions of sandstone, indicating a poor expertise.

It appears that the Iron Age metallurgists were using insufficient charcoal to give the strongly reducing conditions needed to reduce all the oxide to metal and extraction efficiency would have been low. Operating temperature was also evidently low, but above the liquidus of the fayalite-wüstite system ie in practice about 1150°C. The medieval slag H on the other hand had been virtually fully reduced and the iron extracted, at a temperature considerably in excess of 1150°C.

Our conclusion is therefore that the cinders from Crown End are the products of a simple metallurgical process in a small bowl furnace of the size found in Iron Age contexts. This, coupled with certain archaeological features – the enclosure, the celtic field and the lynchets, points to the conclusion that the settlement continued to be occupied after the Bronze Age, into the Iron Age. Recent excavations by Teesside Archaeological Society in a late Iron Age hut at Roxby, near Staithes *(11 kms north east of Crown End)* have revealed similar slags in a hut containing the remains of a small *(40 cm diameter)* bowl furnace. One piece was very similar to Sample A and included charcoal imprints and two others almost identical to furnace bottom Sample E. These finds in an undoubtedly Iron Age context tend to confirm our conclusions about the Crown End slag. We cannot entirely dismiss on the evidence the hypothesis that the Crown End slags may have originated from the maloperation of a later process, but it is unlikely. The hypothesis of Iron Age occupation and smelting is the most likely in the present state of knowledge.

We thank Mr R H Hayes for samples of Levisham Moor cinder and Rosedale slags.

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QUALITATIVE EXAMINATION OF CINDERS

SLAG EXTRACTED FROM CINDERS

% by Weight

Sample	Visual appearance	Thin Section Microscopy	Polished Section Microscopy	Al_2O_3	SiO_2	CaO	TiO_2	MnO_2	Acid Sol. Fe	Acid Sol Fe++	Acid Insol Fe	X - Ray Data			Comments
												Major	Minor	Traces	
A Crown End	Porous irregular cinder lump with convex curved base contains sandstone fragments. Imprints of charcoal. Base 8x9cm, height 12 cm	Porous 2FeO. SiO_2 slag with opaque FeO	Porous 2FeO.SiO_2 – FeO slag Trace of α Fe	1.9	18.7	0.2	0.1	0.5	56.5	45.6	0.9	Wustite Fayalite	Quartz	Cristobalite	Sandstone fragments are probably from the furnace walls. Reduction of wustite evidently inefficient.
B Crown End	Porous irregular cinder lump with convex curved base 10x9cm, height 4cm	Glassy slag with quartz grains	Rounded quartz (tridymite) grains in glassy slag with Fe_2O_3 and Fe_3O_4 crystallised from the slag	5.8	65.9	0.3	0.5	0.7	12.4	8.8	3.4	Quartz Cristobalite	Fayalite Magnetite	Tridymite	Crystalline Fe_2O_3 probably indicates slag solidfying in the presence of air. Much excess SiO_2 present (furnace wall?)
C Crown End	Porous cinder lump with convex curved base and flat top. Base 9x3cm, height 4.5cm	Low porosity 2FeO.SiO_2 slag with small amount Fe_3O_4. Some quartz	2FeO.SiO_2 with pockets of quartz Some Fe_3O_4 and Fe_2O_3. H_2O	3.6	35.4	1.6	0.3	0.5	39.7	35.1	1.2	Fayalite	Quartz	Cristobalite Wustite Magnetite	This slag has apparently cooled slowly and there appears to be good extraction. Much excess silica (furnace wall?)
D Crown End	Porous cinder solidified to the flat surface of a piece of sandstone each piece 11x7x7cm	Low porosity 2 FeO.SiO_2 slag with little opaque material	Coarse crystalline 2FeO.SiO_2 with traces of α Fe. A little surface Fe_2O_3. H_2O	6.6	32.1	0.2	0.3	0.7	37.8	26.5	2.9	Fayalite	–	Quartz	This is a well extracted slag
E Crown End	Porous cinder with convex curved base and flat top 9x10cm x3cm. Imprint of charcoal	Very porous 2FeO.SiO_2 slag with much FeO	Porous 2FeO.SiO_2 with much FeO and α Fe	1.7	9.7	0.5	0.1	2.1	60.1	41.0	<0.1	Wustite	Fayalite	Goethite Lepidocrocite Magnetite Tridymite	Probably a molten mass of ore which has partially reduced to iron
F Levisham Moor Iron Age Furnace	Irregular porous slabs of cinder 11x9x2 cm	Dense 2FeO. SiO_2 slag. a little FeO.	Two phase 2FeO.SiO_2 and glass	2.6	23.7	1.5	0.2	0.5	51.7	44.5	0.2	Fayalite Wustite	–	Quartz	A heterogeneous cinder
G Levisham Moor Iron Age Furnace	Small lump of cinder 6x4x3 cm	Very porous 2FeO.SiO_2 with much FeO	Porous 2FeO.SiO_2 glass with FeO. αFe close to surface. and fair amount $Fe_2O_3.H_2O$	1.7	14.6	1.4	0.1	7.6	54.0	42.3	0.2	Wustite	Fayalite	–	Probably a high concentration of iron before weathering.
H Rosedale C16th Bloomery	Irregular lump of slag 10x6x3 cm The slag had been fluid and solidified with smooth rounded surface	Porous 2FeO. SiO_2 slag with interstitial black glass	Highly crystalline 2FeO.SiO_2 slag with small amount Fe_3O_4	5.9	29.2	0.6	0.4	3.4	43.1	39.9	1.5	Fayalite	–	–	Product of an efficient metallurgical process conducted at higher temperature than A,E or G

(MgO. all <0.5%)

RESEARCH PROJECT ON THE GROWTH OF INDUSTRY BEFORE THE INDUSTRIAL REVOLUTION

A progress Report

In sixteenth and seventeenth-century England the growth of population led to an unprecedented prosperity in the agricultural sector of the economy. Wealth was relatively widely diffused, not being restricted to large estates, but enabling many farmers to improve their standards of equipment, housing and possessions. Many market towns benefited, with merchants and craftsmen sharing in new standards of comfort.

While in no way rivalling the great growth of demand during the Industrial Revolution, these increasing markets for durable goods in this earlier period provided incentives for the adoption of innovation in industry.

Many of the responses of industry are already known in general terms. It is, for instance, well established that in the iron industry the blast furnace superseded the bloomery during the sixteenth and seventeenth centuries, but the full picture of when and where this and comparable innovations took place in industries such as glass, lead, copper and ceramics is still the subject of a good deal of unsupported generalisation.

In the seasons 1966–71 a good deal of work had been possible on the sixteenth-century glass industry, and on the iron industry between 1500 and 1750.

Excavations at the glass furnaces at Bagots Park, Staffordshire, and Rosedale and Hutton, North Yorkshire, had made clear the great improvements in methods and quality in English glass production over the sixteenth century. Excavations on iron-working sites, the Forge and Furnace at Chingley, Kent, and the Furnace at Panningridge, Sussex, had clarified the methods and scale of working.

This work has continued:–

Iron: the gun-casting furnace at Pippingford, Sussex, was excavated over the seasons 1972–4. This site has added much to our knowledge of how cast-iron guns were made, for there was the remnant of a boring-mill, as well as a gun-casting pit in virtually perfect conditions. It is hoped that work here will continue.

More widely-spread work has taken place in the Sussex Weald, locating hitherto unknown sites, re-interpreting others, and, by visits to Record Offices, fitting them into their documentary background. Certain notable recent accessions to the Kent Archives office at Maidstone have been of great value.

A newly-discovered iron furnace in North Yorkshire will be the next site to be surveyed.

Glass: After the completion of work at Hutton, there has been a lull in the threats to glass-furnace sites. However, because of the great gaps in knowlege, in particular of the seventeenth-century industry, it has been important to watch all the possible sites, to ensure that none are lost by failure to excavate before destruction during land development. Thus the known areas of production in Sussex, Staffordshire and Yorkshire have been kept under observation. A major priority remains the excavation of one of the early coal-fired furnaces built early in the seventeenth century after the award of Mansell's patent to monopolise the manufacture of glass using mineral rather than wood fuel.

Lead smelting: The change from the natural or hand blown bole to the larger-scale ore-hearth took place in Derbyshire from the late sixteenth century, and in other lead-producing areas somewhat later, as far as can be told at this stage.

In 1973 the Nuffield Foundation awarded funds for a Research Assistant to work from this department to search for documentary references to lead smelting in Derbyshire in the period, and to visit all sites to which these could relate. This was done over the year 1973–4, and produced many references to individuals and sites not previously known to have been involved in the growth of the industry. By the use of a geochemical survey print-out kindly provided by Imperial College, London, it was possible to work from anomalous concentrations of lead and zinc in stream sediments to locate further smelting sites. It became clear that more micro-surveys of the sediments of certain streams would be necessary, and it is hoped to arrange these when time and funds permit.

The combination of documentary and archaeological research has proved an effective one. Frequently the position and date of archaeological material has provided a new focus for research in scattered archives, and, conversely, written evidence has led to previously unsuspected sites.

The book incorporating the results will, however, take some years to produce, as the material is ncessarily slow to gather. In particular, actual excavation is now very difficult to carry out, for the expense of modern methods means that full investigation can be done virtually only with the funds provided by the Department of the Environment for threatened sites. It is not possible to select what appear to be the most relevant sites and excavate on a non-rescue basis with research funds, and the availability of threatened sites is necessarily random. This is illustrated by the appearance of three valuable glass sites between 1966 and 1971, and none in the succeeding seasons.

D W Crossley
Dept of Economic History, University of Sheffield.

December 1974.

Letter to the Editor

From R C Tribbick

In the Volume 8 Number 1 issue of our Journal, there is a statement which could possibly bear closer examination. It appears in the Work in Progress section – Report on Bloomeries at Eccleshall. (p 61). Slag samples – Conclusions–

"The slags are definitely bloomery and not forge slags. The latter almost invariably contain large amounts of free wüstite and also some particles or droplets of metallic iron"

I realize that condensation of Mrs Wingrove's original report may have distorted the meaning but one is left with the inference that metallic iron particles are the means by which an undated slag can be identified, as free wüstite can be shown by forge-slags or primitive bloomery slags.

As one newly engaged in looking at industrial residues, I am still at the tentative stage when deciding between the two possible sources. I had, however reached a conclusion which seems to be in direct opposition to the above. The very nature of the bloomery process relies on the production of discrete metallic iron particles of which the majority coalesce into the raw bloom. At the end of a blow or indeed at any time during the process, these particles are migrating through the slag, not yet part of the working bloom.

It seems reasonable to suppose that both the tapped slag and the cinder residue will display metallic iron particles. Conversely, the slag formed in forging results from the combination of iron-oxide with either the lining or with sand deliberately used to flux surfaces prior to welding.

In the reducing-zone of the forge the oxide phase of slag already formed is unlikely to reduce to metal and nowhere is iron likely to leave the parent mass as metal and combine as such with the slag.

I raise these points because I feel too little has been published on the subject. Too often it seems that attribution depends on the presence of ore or the reverse that no ore is known in the area, or the finding of coal on the site which favours smithing rather than smelting.

We have the valuable practical experiments with smelting to give examples of bloomery slags. Mr Cleere's "Iron-making in a Roman Furnace" Britannia Vol II 1971, p 215 makes mention of metallic iron in the furnace residue and in the tap-slag. This seems to confirm the presence of metal under some smelting conditions.

In the smithing operations it would seem reasonable to argue that slags would build up gradually in layers over many heats and it is difficult to visualise how a cake for example one inch thick which shows by fracture a section which has all frozen at one time could have been formed in a forge. This may, of course be related to the scale of the smithing operation.

I for one would appreciate further information, particularly from Mrs Wingrove, which would enable us to be more positive in attributing a source for the slags presented to us.

R C Tribbick
75 Byron Road, Wembley, Middx.

Book reviews

W J Thompson. Industrial Archaeology of North Staffordshire. Moorland Publishing Company, Hartington, Buxton. 168pp. 79 photographs. Numerous maps and diagrams. Price £2.40 (soft covers).

This is a welcome book, even if the welcome has to be tinged with regrets. It is a sensibly-priced guide to the surviving industrial features of the landscape of North Staffordshire, which means far more than just 'The Potteries'. Indeed one of its virtues is that it does draw attention to so wide a range of industries and activities. Most of the book consists of short chapters, each on the outline history of a major activity, with a gazeteer of sites. There are also twelve suggested itineries for those who would like guided tours; these seem to be particularly valuable, as they are accompanied by straightforward sketch maps and give considerable detail about what may be seen.

The 79 photographs occupy 40 pages *(pp 49-88)* and cover a wide range of subjects and dates. Unfortunately the average standard of reproduction leaves something to be desired. The small size available, about 10 cms x 8 cms on average, in insufficient to do justice to many of the subjects. The choice is not always felicitous.

Obviously any book on North Staffordshire industries must mention coal mining, metal mining, the iron and steel industries and some other metal industries, notably lead and copper. This book does so, but in a way which to a specialist is irritating, and to a non-specialist may be misleading. Not only are there errors of fact, but the mode of expression is often imprecise, so that the effect upon the reader is not that which the author (presumably) intended. For instance, to refer to 'some nearby charcoal furnace' rather than to a bloomery when writing of the thirteenth century may or may not be anachronistic but it is certainly likely to confuse.

It is legitimate when writing of coal mining to remind the reader that it is dangerous work. It seems to me quite out of place in a book of this nature to devote two long paragraphs, plus a list which is itself longer than the mining gazeteer, solely to pit disasters. References to copper and lead mining are very brief, but accurate.

The chapter on iron and steel is patchy; the good part being on the iron industry of the late 18th and 19th centuries. Earlier ironworking is dealt with so perfunctorily that is a caricature, eg a bloomery is described as 'either a hole dug in suitable ground, or a small pile of stones' ! The author implicitly assumes induced draught. On p 40 it is quite wrong to say that pig iron was not melted in the finery; obviously it was melted down as the first stage in the oxidisation process. The author clearly thinks that a finery needed no power supply for either blowing or hammering as he specifically states that furnace and chafery 'both being water-powered would be near a stream'.
I thought that recent research showed little foundation for the view, given on p 41, that the iron industry declined in the later 17th century. On the same page there is the unfortunate implication that the iron made in the finery and chafery, and indeed in the bloomery, was not wrought iron. But full marks for pointing out that 'puddling' takes its name from the stirring of the iron – I have seen other explanations given!

Finally one must deplore the lack of thorough editing. Much of the English lacks precision; there are 'sentences' without verbs, spelling mistakes (some of them, like 'seperate', notorious in themselves), misuse of 'it's' for 'its', and malapropisms like 'testament' for 'testimony' on p 31. These things obscure meaning, they spoil the pleasure of reading what is a worth-while venture, and they spoil the anticipation of looking at other works from the same publisher. Yet they are so easily avoidable. It is to be hoped that any subsequent volume will be properly edited, and will have the technical detail checked for both accuracy and clarity, before it is published.

Norman Mutton

John Vaizey. The History of British Steel. Weidenfield & Nicolson, 1974, 205 pp, £4.25.

This publishing project was suggested by a merchant banker, the late Lord Melchett, and the jacket provides the necessary key to its tendentious title. The work skilfully covers the financial, political and social history of bulk steelmaking from 1918 as carried out by the constituent firms who in 1967 became the British Steel Corporation. It tells the inside story, based on the hoard of newly available archives, of decisions taken to keep the industry internationally competitive.

The author as Professor of Economics at Brunel University (London) has been placed like Howard Carter on looking into the tomb of Tutankhamen, but whereas Carter sub-let some of the metallurgical work Vaizey has taken it in his stride. In the result there is not much metallurgy but enough metallurgical slips: eg in the introductory pp 4-7; an illustration near p 38 stating that the Siemens OH furnace was "heated from below"; that arc steelmaking was a revolutionary development of the 1960s (p 176) – and incidentally the Kaldo Process indexed as p 189 actually occurs on p 159 and just as a name. The Preface disarms us by expressing regret for understandable errors and one hopes that our foreign members will appreciate the position.

The work is a painstaking summary of fifty years of reorganisation, with nationalisation weaving in and out and in, and it makes easy reading of a depressing story. Academic metallurgists could benefit from knowing these facts of life about a nation whose lifeblood is largely a supply of steel, and when blood was being shed during the War the leviathan performed at its best. We learn about the social background, upstairs and downstairs; that the financial wizards were not uniformly wise; and that strong personalities abounded. An early one was John Brown *(indexed as p7 – and not the Brown, John indexed as on p 83)* and this reviewer remembers an electrical engineer who as a youth had fitted out the Brown chateau with a prodigious system of burglar alarms as protection against a feared rival. We gather that man develops local loyalties and is greedy and fallible; interestingly enough in Victorian times the Derby Railway Works had one of the mess rooms kept quiet for Bible reading and the "railway church" was just up the road.

In a book with this title one might expect more about technical thinking and planning and execution, for integrated steelworks do not blossom overnight. It might teach a lesson that when an American continuous strip mill was the crux of renewal at Ebbw Vale in 1938 that the first Morgan continuous mill worked at Pontypridd in 1861. Continuous casting and oxygen-blowing were covered by Bessemer's 1857 patents and when electro-tinning was later bought from USA for Ebbw Vale we should remember that the first electro-copper refinery was installed by Elkington at Pembrey in 1869 and his idea could have been extended. Research and BISRA are not listed in the index and surely the technologists (Sir Andrew McCance FRS is mentioned) deserve some of the glow if not the limelight. The author realises *(p 183)* that today the questions that arise relate to technical progress and its connection with industrial organisation. The industry now has a British-type nationalisation, market - orientated, and with a sectionalised product basis, plus some private ownership, plus membership of the EEC; and one must wish it all good fortune.

Hugh O'Neill

Arthur H Stokes. Lead and Lead Mining in Derbyshire. Peak District Mines Historical Society. Special Publication No 2, 1973.

This new reprint of a work which has long been a classic will receive a welcome from all who are interested in the history of lead mining. The original papers were published in 1881-83 in several parts of the Transactions of the Chesterfield and Derbyshire Institute of Mining, Civil and Mechanical Engineers, and though well known by a few workers they have never been easy of access. They were collected into one volume by the P.D.M.H.S. in 1964, and their immediate success has warranted this improved reprint. Included with the papers there is a reprint of Manlove's Customs of the Mines of 1653, along with a glossary of words and a chronological history of the mines.

The work describes the extent of the mining field and the many kinds of veins along with the organisation and customs of the area. The many stages of work in actual mining the ore are detailed and this is followed by a practical discussion of the ever present problem of unwatering the workings. Adits and soughs are described and then detail of the hydraulic pumping engines is accompanied by excellent engineers' drawings of the engines at Alport mines. Dressing of the ore is fully described with some excellent drawings of apparatus. Sections follow on assaying and then on smelting the ores.

The author in his conclusions says that he has endeavoured to make his paper as complete as possible in as little compass as possible and there can be no doubt that these objects have been achieved in a masterly fashion. No consideration of lead mining in Derbyshire either in its historical aspects nor at the time of its greatest activity can afford to neglect this descriptive account. The very full discussions of the original papers are reprinted. The reprint is in excellent form, uniform with the proceedings of the society and the officers who have produced it are to be congratulated on every feature of its production. It includes at the end a most useful list of all the liberties with their owners and customs, and a folding map of the whole area.

A Raistrick

David E Bick. The Old Metal Mines of Mid-Wales: Part 1, Cardiganshire – South of Devil's Bridge. The Pound House, Newent, Glos. 21 x 15 cm, 52 pp incl. 10 photographs and 11 maps or diagrams. £0.75 (paperback).

Anyone interested in metalliferous mining history will welcome this first pamphlet of a five part series, which aims to outline the history and present day remains of over a hundred mine sites. Each pamphlet deals with a small area – 20 square miles in Part 1 – with each mine treated separately, and in addition there is a chapter – water power in this part – which deals with some aspect of mining technology. The mine descriptions are interesting and useful, and it is pleasing that selected references are given. Historians of other areas will find the attention paid to John Taylor and the Francis family, amongst others, particularly useful, though Bick accepts Taylor's failures a shade uncritically.

The logical basis behind the arrangement of the series is not clear: the chapter on water power is isolated and has the appearance of being padding. It would perhaps have been better to have devoted such sections to a separate pamphlet, together with a general geological and historical introduction.

There are a number of irritations. No index. No delineation of the mining areas on the map of Wales. Devil's Bridge is not shown and some other place names used in the text are not on the map. Maps on page 8 and 9 are poorly related, and might usefully be combined. Grid references are however given in the text. Other diagrams are better, but omissions of north points *(p 21)* or compass directions *(p 31)* should not occur.

The price of 75 pence is not cheap for a 20,000 word pamphlet, but presumably inflation accounts for this, and it is crammed with a wealth of information. It will be a much used handbook to the area.

Lynn Willies

P Knauth The Metalsmiths. A volume in the Time-Life series "The Emergence of Man" 1974. Price £3.50.

This book is a real delight. It covers the development of metal working in a very readable but yet technologically acceptable manner, dealing with copper, the bronzes, gold, silver and iron, from the Near East to the Far East, from Central Europe to the Americas. The old traditional techniques, the smelting of copper, the production of bronze and its open casting, forging, metal chasing, the raising of sheet metal, embossing, lost-wax casting, granulation technique, forge-fagotting of iron, gilding and sintering – all are not only described but are illustrated with drawings, diagrams and photographs. Most of the illustrations are in colour, all very naturally reproduced, of the metal ores, the raw metals produced from them and their appearance under the microscope, but the real delight comes in the colour reproduction of numerous fascinating works of art, for they are no less: the bull from the cemetery at Ur, the Austrian goddess chariot, the scenes depected on the Vace situla, the remarkable Chinese castings and gold and silver from Peru, Mexico and Columbia. It is always a matter of wonder as to how the so-called primitive metalsmith managed to produce such craftsmanship; with all the facilities now available the standard seems far lower. Possibly we now have neither the time or the love for the job. Perhaps we should repeat the verdict given at Schubert's funeral: Ja, er konnte etwas! Yes, this presentation may be a little expensive, but it is definitely worth reading and very nice to keep looking at every so often.

K C Barraclough

Abstracts

GENERAL

Maurice Schofield. The debut of Alloy Steels. British Steel, Autumn, 1974. p 30.

A brief exercise which acts merely as a reminder of some of the pioneers of such metals as platinum, titanium and tungsten and of their uses in alloying.

BRITISH ISLES

P W J McBride The Mary, Charles II's yacht: (2) Her history importance and ordnance. *The International Journal of Nautical Archaeology and Underwater Exploration. 1973,* 2 *(1), 61–70.*

K Priestman. (3) Conservation of finds. *pp 70–73.*

These two reports give details of the guns, shot and conservation treatment for the finds which date to 1675.

W A Forster and K B Higgs. The Kennemerland, 1971. An interim report. *Int. J Naut. Arch. 1973,* 2 *(2), 291–300.*

The wreck of an outward bound Dutch East Indiaman bound for Batavia on the Shetlands in 1664. The cargo manifest included two chests of quicksilver. Cannon, a bell, and over 18 kg of mercury were found in flagons. It is believed that this mercury was shipped to colonies for assaying or the extraction of gold and silver. A further report on this wreck is to be found in IJNA, 1974, 3 (2), 257–268, where a cast-iron shot mould is shown.

Margaret H Rule. The Mary Rose; a second Interim Report, 1972. *Int. J Naut. Arch., 1973* 2 *(2), 385–388.*

The Mary Rose sank in 1545. This report describes two pairs of stone shot moulds and some pewter ware.

R Larn, P McBride and R Davis. The mid-17th century merchant ship found near Mullion Cove, Cornwall. Second interim report. *Int. J Naut. Arch., 1974* 3 *(1), 67–79.*

The finds include iron nails (part of the cargo), boat-shaped lead ingots (exceeding 290 lbs each) fragments of copper "cakes", brass pins, guns (both bronze and iron), and many other miscellaneous non-ferrous artifacts (for further details see Cornish Archaeology, 1971, **10**, 75–78).

T A Morrison. A Brief History of the Merioneth Manganese Industry. *Industrial Archaeology, Feb 1974,* **11** *(1), 29–32.*

Production commenced in 1886, but the annual output of ore which typically contained about 30% manganese, fell below 5000 tons in 1894 and never exceeded 2,000 tons until all work ceased in the 1920's. The ore was sent by rail to Mostyn ironworks.

N Mutton. An Early Blastfurnace Site. *Industrial Archaeology, Nov 1973.* **10** *(4), 438.*

Quotes the Shropshire Newsletter, Dec. 1972, No 43, report that the site of the 1564 Shifnal Blast Furnace has been located in the valley of the Wesley Brook, just south of Shifnal village.

M Schofield. John Wilkinson's Master Invention. *Foundry Trade Journal 1974,* **136**, *(2983), p 158.*

Wilkinson patented a boring mill which was able to machine with sufficient accuracy the large cylinders required for the Boulton and Watt steam engines. The first mill was installed at Bersham, near Wrexham. Other features of Wilkinson's remarkable career are briefly outlined.

A G Baker. The Forged and Rolled Ring: a product with Both a Past and a Future. *Steel Times Annual Review, October 1974, pp 103–112.*

Brief, illustrated account of an ancient product, and its uses and development in the nineteenth century, followed by a much longer description of modern methods. The historical introduction is in pp 103–104 only.

Anon. The Durrans Group of Companies. *Foundry Trade Journal, 1974* **137** *(3019), 517–528.*

A brief commercial history of James Durrans and Sons Ltd, suppliers to the foundry industry, and associated companies, from the date of establishment at Penistone in 1863.

P McBride et al. A Prussian cannon recovered from a site in Plymouth Sound. *Int. J Naut. Arch. 1974,* 3 *(1), 160–164.*

This was of bronze dated to 1750–80.

A Bax and C J M Martin. De Liefde. A Dutch East Indiaman lost on the Out Skerries, Shetland, in 1711. *Int. J Naut. Arch., 1974* 3 *(1), 81–90.*

Four bronze breech-blocks, a bell, buckles, etc. pewter dishes and spoons and a set of three triangular, flat-bottomed crucibles (clay-graphite) a lead weight and a silver sword-hilt were included amongst the finds.

R Sténuit. Early relics of the VOC trade from Shetland; the wreck of the flute Lastdrager lost off Yell, 1653. *Int. J Naut. Arch., 1974,* 3 *(2), 213–256.*

The finds include silver-copper and pewter spoons, guns, ammunition (linked shot), navigational instruments, cooking vessels, a boat-shaped lead ingot and mercury. The uses and sources of the mercury are discussed in detail.

Lynn Willies. The Lord's Cupola, Middle Dale, *Peak Dist. Mines Historical Soc. 1974, April, 5 (5), 288–301.*

Alias Middleton Dale. This was the Duke of Devonshire's custom smelter and is known from 1740 when it had an ore hearth. By 1772 it had been converted to a reverberatory with a slag hearth (this latter was probably on the site of the earlier ore hearth). The site is now garages and the Dale works, but the author has done his best to determine the layout of the original plant. He has also found part of a lime kiln that may have been responsible for the flux. A plan of the plant's New Furnace – a reverberatory – built by Thomas Botham and Co. in 1809 is included. This is supported by the contents of two account books.

EUROPE

A N Roumiantsev. Questions regarding the development of spearheads from the coastal areas of the Black Sea in the Bronze Age (In Russian). *Sov. Arkh., 1974 (1), 12–23.*

Mainly typological. The appearance of lozenge-shaped socketed spearheads and stone moulds for making them is connected with the migrations of the Timber Grave culture in the 15th to 14th century BC. These spearheads are contemporary with those of the Borodino hoard and the Andronovo culture. They can be divided into 3 groups. The oldest, the Pokrovsk type, has forged tips while the latest is contemporary with the Borodino culture which owes its ornamental style to diffusion from the Mycenean civilisation through Macedonia, along the Danube and along the Black Sea coast.

B A Raev. A bronze cauldron from Tumulus III of Sokolovski. (in Russian). *Sov. Arkh., 1974 (3), 181–189.*

From a Sarmatian tumulus near Novocherkassk which contained imported Roman artifacts analogous to those from Pompeii. Various parts of the cauldron were analysed showing that they were tin-bronzes (15.7–20%Sn) with 0.2–9% Pb and little, if any, zinc.

V S Titov and B I Markevitch. New finds on the western boundaries of the final Tripolye culture. (in Russian). *Sov. Arkh., 1974 (3), 150–164.*

Includes some copper flat axes or chisels found in north Moldavia similar to those of the Bodrogkeresztur culture.

P L Pelet. Une industrie bimillénaire: la Sidérurgie du Jura vaudois, in Annales, Economies, Sociétés, Civilisations, *1974, 789–812.*

It gives a fine overview of the technological development of the iron industry in the Jura, setting it into an historical and ecological framework, while dealing with archaeological and documentary sources to elucidate the changes that the iron technology underwent over two thousand years.

H G Bachmann and A Jochenhövel. Bar ingots from the Rhine near Mainz (in German). *Archäolog. Korrespondenzblatt, 1974, (4), 139–144.*

Gives the composition of some of the 57 Cu-base alloy bars found in 1891. Some others, previously found in the same area, were included in the examination. The bars weigh from 162 to 314 g; the majority are in the range 210–240g. They appear to have been cast in open moulds of stone or clay, and one appears to have been stamped. They are about 25cm long x 1.5cm wide and 1cm thick. They can be placed in 3 groups:–

1. alloys with 5% Sn and 10% Zn (all the 1891 find falls into this category);
2. alloys with about 18% Sn and low zinc;
3. impure coppers with less than 1% Zn and Sn.

Group (1) are probably of Roman date; the impure coppers could be of the same period while the high tin-bronze is thought to belong to the Urnfield (LBA) period.

T B Bartseva. Non-ferrous alloys used in the Early Iron Age in the North Caucasus. (in Russian). *Sov. Arkh., 1974 (1), 24–37.*

Spectrographic analyses of Cu-base alloys from EIA sites in the North Caucasus. These relate to three periods:–

1. the LBA to EIA transition period, 8th–7th century BC;
2. the Scythian period, 6th–4th centure BC and
3. the Sarmatian period, 3rd century BC to AD 300.

Eleven groups of Cu-base alloys can be distinguished, and these are related to the periods involved. The alloys used cover the usual range of European Cu-base alloys from impure copper through Cu-As, Cu-As-Sn, Cu-Sn, Cu-Sn-Pb, Cu-Sn-Pb-Zn etc. Each analysis is placed in one of the above groups and the number of each type is assessed for the particular period of culture. The 8th–7th century examples are mainly Cu-As while the rest are mainly Cu-Sn-Pb alloys.

T N Nikolskaia. Small (stone) moulds for casting trinkets and other artifacts from the Russian Medieval town of Serensk (in Russian). *Sov. Arkh., 1974 (1), 237–240.*

B A Shramko et al. On the fabrication techniques of Sarmatian swords and daggers. (in Russian). *Sov. Arkh. 1974 (1), 181–190.*

The earliest, dated to the 7th–5th centure BC, was made of piled steel and iron laminations giving fine grain and a hardness of 140–190 HV. The structure was ferrite and pearlite. The dagger was more homogeneous than the above and consisted of a carbon steel in the range 0.4–0.5% C. The hardness was 150–180 HV. Grooves or "fullers" had been ground in. This blade dates from the 3rd to the 2nd century BC. Two swords with annular pommels were dated to between the 2nd century BC and the 2nd century AD. These were made from blades in which a layer of steel had been welded to a layer of iron in such a way that the steel layer formed the cutting edge, or where the steel was sandwiched between two layers of "iron". The hardness was in the range 120 to 250 HV in the 2-layer case, and 250 in the central layer of the 3-layer sandwich. The carbon content rose to 0.8 – 1.0%. Details are given of the methods of making the hilt-guards and pommels. (Translation available from BLL, Boston Spa, RTS 9207).

H G Bachmann. Investigations on Prehistoric copper working slags in Cyprus. (in German). *Leitz Mitt. F. Wissenschaft u. Technik. 1974, 1 (5), Suppl. 177–180.*

Slags from Kalopsidha and Hala Sultan Tekke. The first is Middle Cypriote, 1775–1575 BC and the latter dates from the 15th to the 14th century BC. Stereoscan photos showed that the first contained a crust of iron oxides with grey secondary copper minerals. Under this there was some cuprous oxide and copper. A fresh fracture showed metallic copper inclusions; it clearly had high Cu content. XRF showed the presence of Fe, Cu, Co and Mn; the slag minerals were FeO and fayalite. Another specimen from the same site gave a crust containing paratacamite and the spinel phase, $CuFe_2O_4$; no silicate was present.

The slag from Hala Sultan Tekke contained some ceramic (? crucible) and charcoal. The fracture revealed matte, and XRF examination gave the same metals as the first. Also detected in this sample was carphosiderite, $Fe_3(SO_4)_2(OH)_5.2H_2O$, Fe_2O_3 and FeO; while $CuFe_2O_4$ was found in the crust. It is concluded that the slag from Hala Sultan Tekke is made from sulphide ores while the ore source of the Kalopsidha slag is less certain.

The report gives some good stereoscan photos of Fe_3O_4, gypsum, and iron sulphate.

S N Korenevski. Metal axes of the Maikop civilisation (in Russian). *Sov. Arkh., 1974 (3), 14–32.*

Can be divided into three groups, the earliest dated to 2500–2300 BC. The similarities between these shaft-hole axes and those from Susa and Iraq show that they belong to the same tradition and it is clear that the earliest period of Maikop was familiar with metal usage. The axes of the other two groups can be dated to 2300–2000 BC – the Novosvobodaia period of the Maikop culture. 24 of the 26 axes have been analysed and the results are given in detail. All are made from arsenical copper containing from 0.2 to 6.0% As. A few of these have high (greater than 1%) Ni, and one group of axes came from a metallurgical workshop of the Pit-Grave civilisation.

The Maikop axes were made in 2 part moulds open in the middle with the shaft-hole vertical. This fashion spread along the Volga and the coastal area of the Black Sea. The diffusion of another technique in the second millennium introduced 2 part moulds which were cast from the back of the axe with the shaft-hole horizontal.

A P Jouvavlev. The earliest workshop for the manufacture of copper in Karelia. (in Russian). *Sov. Arkh., 1973 (3), 242–246.*

C–14 dates cover the 3rd millennium BC. Finds include a square stone hearth with interior measurements 22 x 14 x 4 cm deep. No slag is mentioned but the other finds include two round hammer stones, a quern stone and some small copper drops.

V D Blavatsky and B G Peters. A wreck of the late 4th or early 3rd century BC near Donuzlav. (Black Sea). *Int. J. Naut. Arch., 1973,* **2** *(1), 25–31.*

The finds include bronze nails, lead sheathing and the imprint of an iron shipwright's axe in concretion.

V Cosma. Anchors from Tomis (Romania). *Int. J. Naut. Arch., 1973,* **2** *(2), 235–242.*

The finds include the parts of lead anchors from the Black Sea of the Graeco-Roman period.

C O Cederlund and C Ingelman–Sundberg. The excavation of the Jutholmen wreck, 1970–71. *Int. J. Naut. Arch., 1973,* **2** *(2), 301–327.*

A 17th to 18th century wreck near Stockholm. It yielded guns, cannon-balls and bar-shot.

A J Parker. Lead ingots from a Roman ship at Ses Salines, Majorca. *Int. J. Naut. Arch., 1974,* **3** *(1), 147–150.*

Seventeen typically Roman, inscribed, incised and stamped lead ingots from the Vespasian period. The weight varied from 30–35 kg.

F Carraze. Note on two decorated lead anchor stocks. *Int. J. Naut. Arch., 1974,* **3** *(1), 153–157.*
Also contains comparative list.

G Toncheva. Cape Kaliakra, Balchik, Bulgaria. *Int. J. Naut. Arch., 1974,* **3** *(2), 322–323.*

Ox-hide shaped gold copper-alloy ingot weighing 1.46 kg. Not dated. Similar in shape to those of the 14th century BC. The composition is 32% Au, 18% Ag, 45% Cu including Ni and S. They were found with a stone anchor.

M Bukowski. Industrial Buildings in Upper Silesia. *Industrial Archaeology, Nov 1973,* **10** *(4), 357–366.*

Iron smelting technology appears to have been introduced to Silesia from Czechoslovakia. In the first half of the seventeenth century, Italian craftsmen were brought in, but "Italian" or "half-high" furnaces never seem to have become popular. The first blast furnaces were built in 1751, but these were smaller than those elsewhere in Europe owing perhaps to the limited supplies of water power. In the early 19th century, numerous civil servants from the Prussian Office of Mining and Metallurgy, masquerading as workers or landscape artists, toured Britain and other West European countries, bringing back information on developments in technology, which were subsequently applied in Silesia. There are 5 pages of illustrations of old ironworks, and one of a zinc works designed in 1825.

ASIA

A Raban. The Mercury carrier from the Red Sea. *Int. J. Naut. Arch., 1973,* **2** *(1), 179–183.*

The wreck of a 17th century ship near Sharm-El Sheikh in southern Sinai was found to have contained leaded bronze bowls with low As content; these appear to have contained metallic mercury. Large glazed jars were also found. The ship is belived to have been on its way to the gold mines in Arabia or Africa. The principal mercury sources of the period were at Teima (in North Hijaz) and Cyprus.

T V Gousseva. Artisan's workshops in the eastern (oriental) suburbs of New Sarai. (in Russian). *Sov. Arkh., 1974 (3), 125–141.*

A group of workshops dated to the 14th century AD. They practised working on bone, jewellery manufacture and ceramics. Discusses the types of pot kilns and the social position of the artisans. The crucibles shown include circular and triangular types. There are few details about the metal work but the hearths and furnaces are of great value. The town was the capital of the Golden Horde.

N N Terekhova. Technology and fabrication of the first metal tools amongst the primitive agriculturists of Central Turkmenia. (in Russian). *Sov. Arkh., 1974 (1), 213–217.*

Mainly awls consisting of Cu-Cu_2O eutectic heavily worked and twinned. Hardness, 80–118 HV.

Ya I Sunchugashev. A Bronze Age Copper-smelting furnace. (in Russian). *Sovetskaya Arkheologiya, 1973, (4), 244–247.*

This is one of very few copper smelting furnaces found in Siberia by the Khakassian Research Institute for Language, Literature and History. The site is situated on the upper slopes of the Kyug ravine near the Mongol village of Upper Askiz.

The slag heap was 5m in diameter and ¼m deep. The lumps of smelting slag were up to 0.35m long and 0.13m thick and contained some small prills of copper. The bowl-shaped furnace was 0.45–0.55m diameter made of stone slabs bonded with clay with a sand-lining 5cm thick. Larch charcoal and one tuyere as well as fragments of clay moulds were found withthe slag. Dated to last period of Karasuk culture (8th century BC).

K R Maxwell-Hyslop. Assyrian sources of iron. *Iraq, 1974,* **36** *(1–2), 139–154.*

A preliminary survey of the historical and geographical evidence. In the early part of the period (13th century BC) iron was rare and precious, and copper axes were still used. Discusses the trade between Assyria, the Hittites and Mitanni, and the Kaska and the supply-routes involved. The latter lived on the southern border of the Black Sea between Trabzon and Samsun where there are large deposits of magnetite sands but as yet little evidence to connect them with iron working.

The paper ends with a plea for more fieldwork to discover furnaces etc and for chemical and metallographic analysis of those objects already found. There is a final suggestion that some iron workers were itinerant and working seasonal.

T N Troitskaia. Armament of the inhabitants of the Ob basin in the region of Novosibirsk at the end of the 1st millennium BC (in Russian). *Sov. Arkh., 1974 (3), 45–55.*

In this period the Bolchevetchie culture was supplanted by new people. The abundant arms include west Siberian socketed bronze axes, iron axes, iron swords and daggers, and bronze arrowheads (tri-and bilobate). Found in tombs. Their deposition allow one to distinguish the traits of the northern forest civilisation which penetrated the Koulai culture in this region and was responsible for its local variety. This is mainly typological and non-metallurgical, but it can be seen that some arrowheads are cored castings while others are wrought.

N N Terekhova. Technology of Mongol iron founding in the Middle Ages (in Russian). *Sov. Arkh., 1974 (1), 69–78.*

At Kara-Koroum, the capital of the Mongol state in the first half of the 13th century AD. The objects considered were wheel hubs and cauldrons. The metal cast was white cast iron with 1.86–2.8% C, 0.42–1.42% Si, and 0.5–1.27% S and 0.21–0.55% P. The sulphur content leaves little doubt that the fuel was coal. It is believed that the ore was reduced in crucibles using mineral coal as fuel along the lines of more recent Indian and Chinese reports. The metal was remelted in crucibles and the objects cast in multi-part moulds in the usual way. The cauldrons were probably 40 cm dia and 20-30 cm high but only a part of a triangular leg was found.

(Transl. available from BLL Boston Spa, No RTS 9206).

AUSTRALASIA

G T Bloomfield. The Kawau Copper Mine, New Zealand. *Industrial Archaeology. Feb. 1974,* **11**, *(1), 1–5.*

Mining activity on Kawau Island, 30 miles north of Auckland, lasted from about 1843 to 1851 when sea broke in and flooded the workings. Transporting the ore to South Wales became difficult when it was found that it became dangerously hot in transit and in consequence smelters from Swansea were engaged in 1848 to establish a local smelting plant.

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