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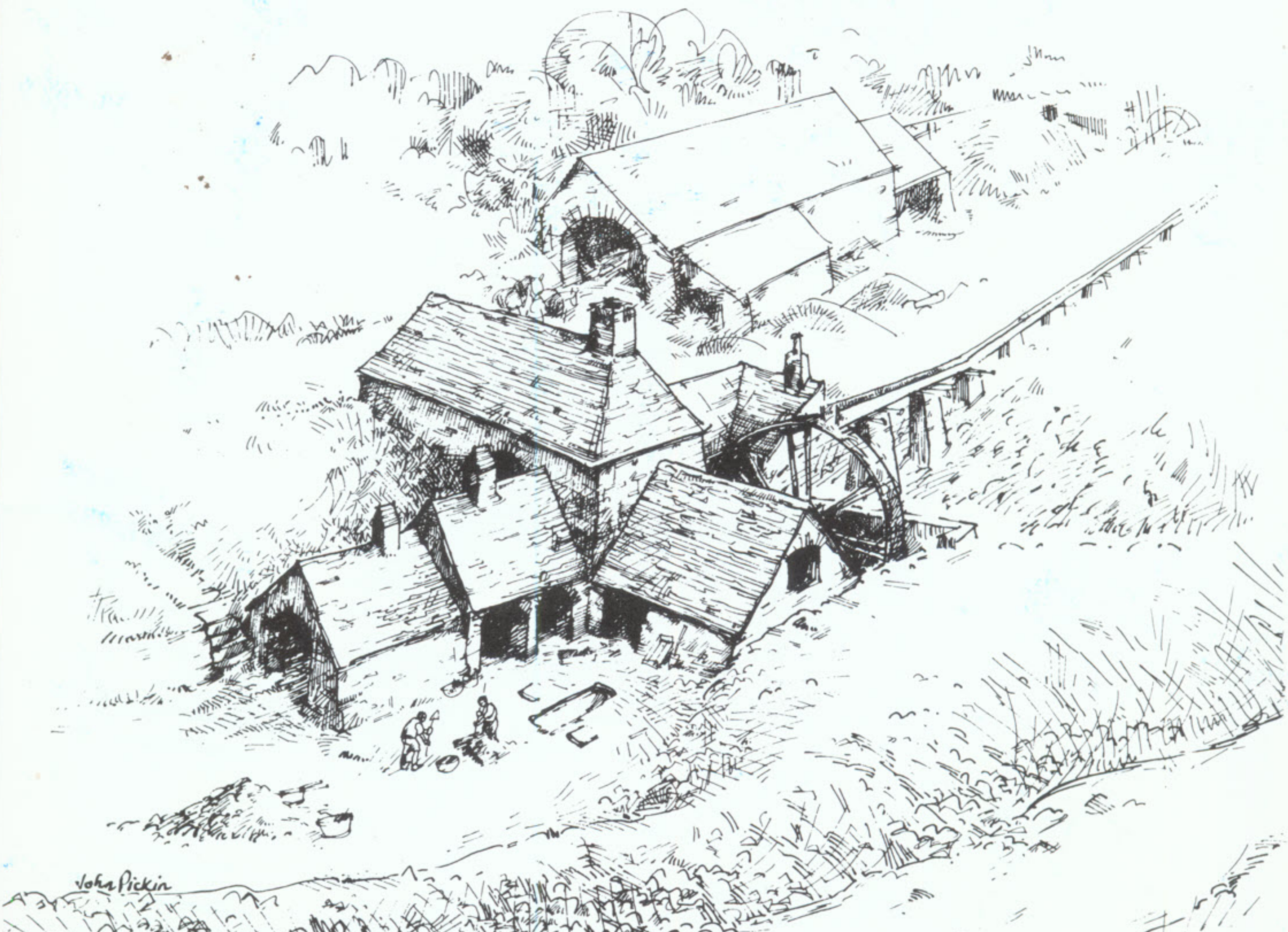

Abbey Tintern Furnace

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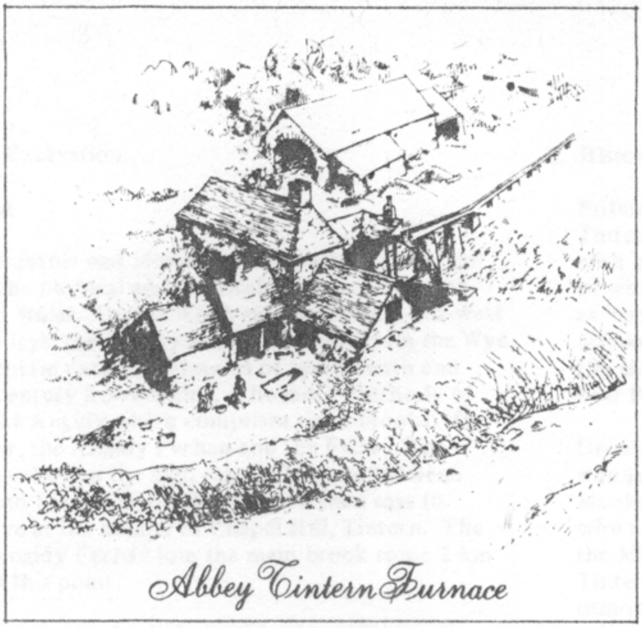

Abbey Tintern Furnace (SO 513002) has been extensively excavated through the combined efforts of the Gwent County Council, the Manpower Services Commission, the Welsh Development Agency and the Forestry Commission. The excavation was directed by John Pickin (who produced this conjectural drawing) and substantial remains were found of the furnace and associated wheelpit together with foundation evidence of the cast, blowing, bridge and charcoal houses. A leat system serving the furnace wheel and a set of stamps was also discovered and corroboration of three distinct phases of industrial activity on the site, which was in production between 1669 and the 1820s.

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Excavations at Abbey Tintern Furnace

John Pickin

* **Part I. The Excavation.**

1. **Introduction**

Between Chepstow and Monmouth the valley of the river Wye forms the physical and political boundary between England and Wales. On the Welsh side two major east-west tributary valleys, the Angidy and Whitebrook, join the Wye, and both contain extensive remains of seventeenth and eighteenth century ironworking. The more southerly of the two is the Angidy which comprises three brooks: the Angidy Fawr, the Angidy Fechan and the Fedw. The Angidy Fawr rises on the high ridge of ground between Devauden and Llanishen and flows south then east to enter the Wye at the hamlet of Chapel Hill, Tintern. The Fedw and Angidy Fechan join the main brook some 2 km upstream of this point.

Evidence for industrial activity within the valley survives in the form of eight embanked ponds (Fig 1, C). In the western section of the valley the ponds seem to have been connected with corn mills, some of which may be medieval in date, but from the junction of the Angidy Fechan with the Angidy Fawr, and downstream to the Wye, the ponds are associated with an iron and wire working complex dating from the late sixteenth century.

The Abbey Tintern furnace was built on the southern bank of the Angidy Fawr (SO 513002) some 1.6 km from its confluence with the Wye and it would have formed an integral part of the total industrial complex (Fig 2). Its location was dictated by that of the pre-existing valley industries and not by geological or geographical considerations. Even so it was within 15 km of the rich limonite deposits at Bream and Clearwell in the Forest of Dean, bloomery slag could be collected 5 km away at Trellech, and the wooded slopes of the surrounding area could be cut and coppiced for charcoal. In common with the other industries in the valley the furnace could use the waters of the brook as a power source and the Wye, which was still tidal at Tintern, allowed easy access to the ports of Bristol and Chepstow and, via the Severn, the market places of the Southern Midlands.

Much of the area is now planted with conifer woodland, although small stands of mixed oak remain with patches of birch, hazel and alder along the bottom slopes of the valley. One effect of recent afforestation has been a drastic change in the mean water table so that much of the present furnace area is prone to periodic flooding over much of the year.

When excavation began in 1979 the site area was in use as a small poplar plantation and the majority of the above-ground features were obscured by brambles. A visit by the Newcomen Society in 1947 failed to find the site[1] and it was not until the early 1970s that any systematic work was undertaken. The furnace was surveyed and initial excavation took place on the leat and wheelpit and, at the same time, some excavation was carried out by the National Museum of Wales in the area of the furnace hearth, and a slag sample was taken.

2. **History** *with Mark Taylor*

Britain's first water powered wireworks was established at Tintern in 1556 and its subsequent history has been dealt with by Rees[3], and Paar and Tucker[2]. A basic requirement of wire making was the specially forged, ductile iron known as 'osmond' and this was produced for the wireworks at Monkswood, 20 km west of Tintern, using pig iron from the Monkswood furnace and a second furnace at Pontymoile near Pontypool.

Growing difficulty in obtaining osmond iron of the required standard, especially after 1591 when John Hanbury held the Monkswood works, led to a decrease in the quality of wire and a consequent drop in demand. As early as 1577 the Mineral and Battery Company, which controlled the Tintern concern, had considered the possibility of a local osmond forge[4] and certainly by the end of the century, as a direct result of Monkswood's inability to supply high quality osmond, the need was seen for an independent source and, perhaps, a centralisation of furnace, forge and wire-works.

In 1629 the lease held by the Mineral and Battery Company expired and John Gwynne was appointed as caretaker-manager of the works for the Countess of Worcester. Bradney[5] refers to Gwynne's 'forge accounts' and 'furnace account' for the half year ending 27th March 1630; this is the first reference to forge(s) and furnace at Tintern but it is unfortunate that Bradney does not give a source for his information. Rees[6] is sceptical of this reference; he claims that it is not borne out by contemporary evidence, as the Tintern works up to that time, and later, were drawing their supplies of wire iron from other quarters. In fact, the evidence seems to suggest the opposite: the lack of reference to a supply of osmond from Monkswood or elsewhere, implies a local source, which could be Gwynne's forge. If a policy of centralisation led to the establishment of a local osmond forge then it is plausible that a furnace would be erected to supply the iron it required.

A 'Survey of the Manor of Portgasseg' in 1651 lists:

'All that Mansion House, one iron forge house, one large coal house built with timber, one way house, one stoare house and one coal yard containing half an acre, one furnace to melt iron myne with the steames and ponds and coalhouse to the same and other outhouses to the same app'teyninge Abbuttinge upon the river wey to the North' (NLW Bad No 1631, p 12).

It has been suggested[7] that this refers to the Coed Ithel furnace north of Brockweir, but as the survey was made for the Marquis of Worcester and Coed Ithel lies in a different manor to Worcester's, this is unlikely. Harris[8] believes that it refers to Tintern, but interprets the description 'abbuttinge upon the river wey to the North' as meaning that the furnace stood at the mouth of the Angidy brook, and regards it as evidence for two furnaces at Tintern, the second and later furnace being the one situated west of Tintern in the Angidy Valley. This view is also held by Schubert[9] but the 1651 survey is the only evidence there is to support it and it is doubtful how strong a claim can be made for its geographical accuracy. There has been no

* Part II on the Finds, Interpretation and Conclusions will follow in Volume 17, Part 1, in 1983.

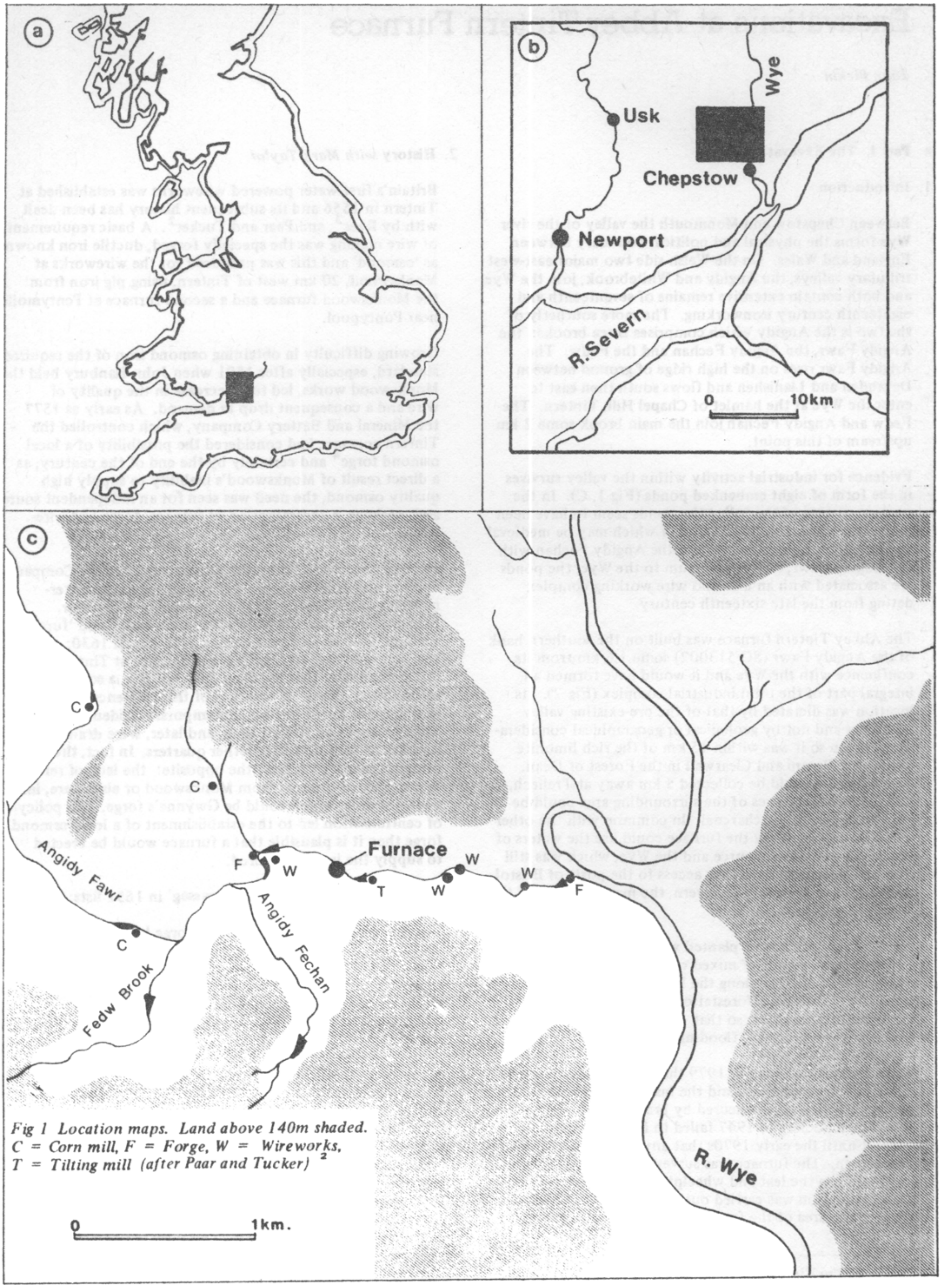

Fig 1 Location maps. Land above 140m shaded. C = Corn mill, F = Forge, W = Wireworks, T = Tilting mill (after Paar and Tucker) [2]

archaeological evidence to suggest a second furnace at Tintern or in the Angidy Valley[10].

A furnace was certainly in existence in 1665 when Marmaduke Rowland of York viewed the works and saw:

'the fire of the furnaces where they melt the iron – so great that looking into the hole where the nosell of the bellows are it looks like the sun on a hot day at Noon'.

In 1647 Thomas Foley of Stourbridge took control of the Tintern works[11]. The surviving Foley accounts for the furnace run from June 1672 to January 1676 and October 1682 to June 1685, each one being numbered to correspond to the period during which the account was reckoned. The period 1672 – 73 is given the number 4, 1673 - 75 the number 5, up to number 13 for the eighteen month period ending June 1685. The accounts cover periods of twelve or eighteen months and so the earliest date that can be given for the first account book is 1668 – 69 and two isolated memoranda (H R O F - Vi - DBf - 5220 and 5322) show that sow iron was being produced in 1669.

This is the earliest verifiable date for the Tintern furnace, but it cannot be ascertained if it refers to the same furnace, perhaps reconditioned, as recorded in 1630, 1651 and 1665, or whether it is the date when a new furnace, perhaps on the site of the former, was blown in. In 1669 767 tons of pig iron were cast, 861 tons in 1670 and 1004 tons in 1671; this steady increase in the level of production might suggest a new furnace was being tried. A 62-week campaign in 1672 - 73 produced 1142 tons, and 1034 tons were produced in a 61 week campaign in 1675 – 76[12]. indicating that a stable level of output had been obtained by this time, unless the earlier production figures are seen as reflecting a shorter campaign.

Weekly output is recorded for the 42-week campaign of 1698 - 99[13]. In the first week 11 tons were cast which increased to 15, 18 and 21 tons over the following three weeks until a steady 22 - 24 tons was being achieved at the end of the campaign.

The Foley interest in Tintern furnace continued until at least 1685 and during this time it was linked directly to both the Upper and Lower Forges in the Angidy Valley, with sow iron sent to the former for conversion into osmond iron for the wireworks, and to the latter for conversion into merchant bar iron. The Lower Forge also received sow iron from the Redbrook Furnace, 10 km north of Tintern, which, similarly, was part of the Foley Partnership[14]. The accounts for 1672 - 73 (H R O F - VI - AF - 2) shows the Lower Forge receiving 91 tons from Redbrook compared to 24 tons from Tintern; this disparity could indicate lower production at the Tintern furnace but it is as likely that much of the Tintern output was used in the Upper Forge for osmond iron.

In 1673 'cinders' or bloomery slag, were brought to the furnace from Trellech, the Abbey of the Marquis of Worcester (Tintern Abbey ?), Monmouth, St Briavels and Brockweir, and mine or iron ore from the Forest of Dean and Prassect (H R O F - VI - AF - 3). 'Prassect' refers to the

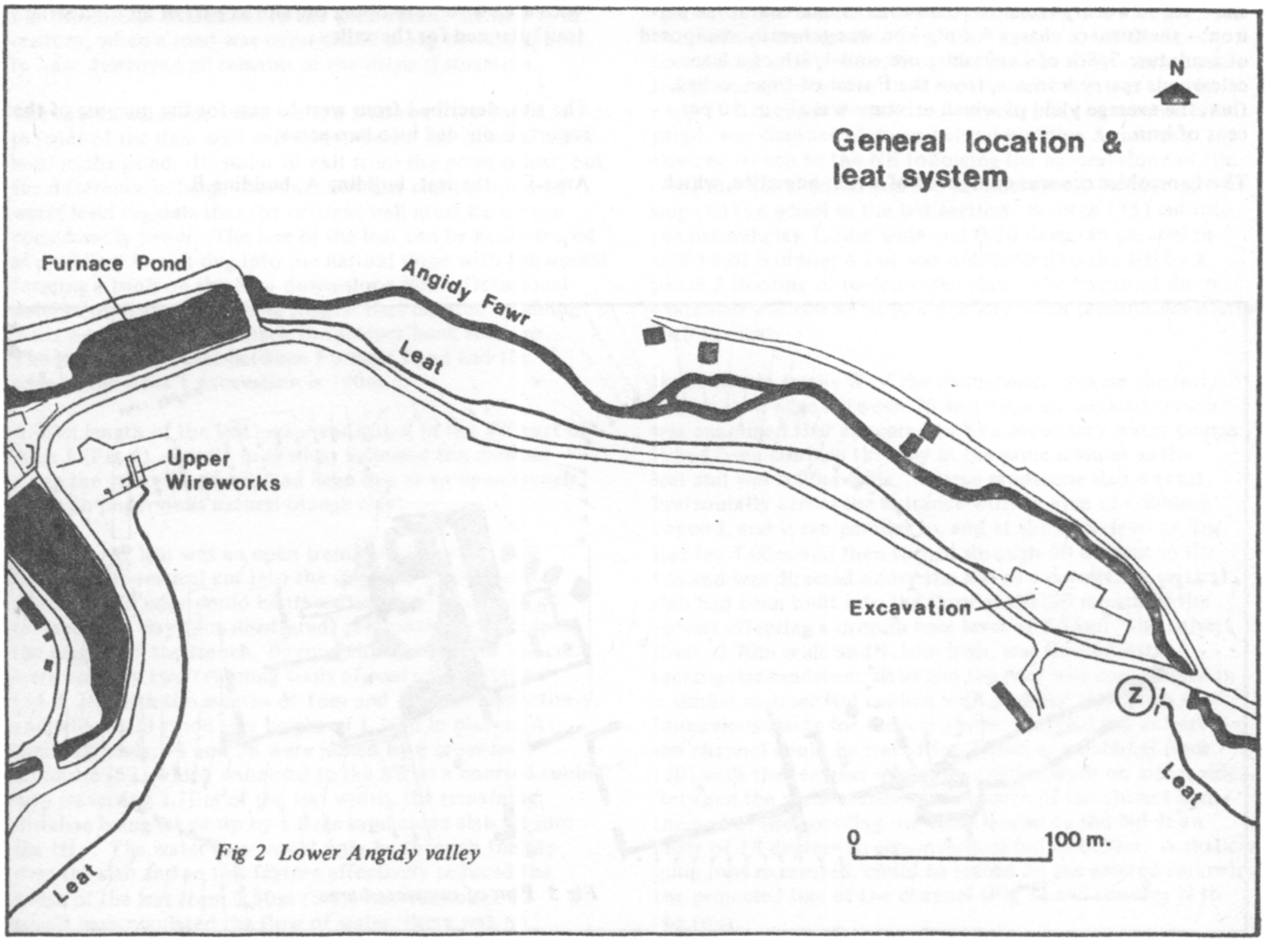

Fig 2 Lower Angidy valley

small, scowles-like workings at Mine Pit Wood, Porthcasseq, 3 km south of the site. The only other ore source in east Gwent that is mentioned is Purscuitt or Portskewett, 6 km South west of Chepstow, and in 1672 - 73 payment was made to Major Henry Rumsey for ore received from this place (H R O F - VI - AF 1 2 fol 6). The mine at Portskewett was leased to Rumsey by Thomas Lewis in 1662 (G R O Misc Mss D 501 1332).

After 1685 the Tintern works reverted to the direct ownership of the Duke of Beaufort who leased them to John Hanbury the ironmaster at Pontypool and Clydach, in 1699 (GRO Misc Mss 1156). Little is known about the furnace during the eighteenth century although a list has been produced of the ownership of the various concerns during this period[15].

It appears that during the first half of the century there was individual ownership of the various units but that, after 1775, with the leasing of the whole complex to David Tanner, the interrelationship of furnace, forge and wireworks which had existed during the period of Foley control was recreated. Both Tanner and his successor, Robert Thompson, had extensive interests in the iron industry of the Forest of Dean and in the Redbrook Copper Works[14] and naturally this must have had a direct influence on the economics of the Tintern furnace in terms of management and market. Tintern pig at this time was being sent to the New Weir Forge at Ross and the Blackpool Forge in Pembrokeshire[16].

Mushet[17] (1840 : 314) recorded the production of the furnace during the early years of the nineteenth century:

'When in blast, Tintern Abbey charcoal furnace, in Monmouthshire, made weekly from 28 to 30 tons of charcoal forge pig iron – the furnace charge for pig iron was generally composed of a mixture 7/8th of Lancashire ore, and 1/8th of a lean, calcareous sparry iron ore, from the Forest of Dean, called flux, the average yield of which mixture was about 50 per cent of iron.'

The Lancashire ore was composed of a rich hematite, which could not be worked alone from its great richness (from 60 to 63 per cent) and another ore of a more clayey nature, and easily carbonised, and which was then known by the name of white-riggs.

When the proprietor wished to make smooth-faced or No 1 pig iron, a portion of the iron was withdrawn from the furnace, which had the effect of raising the quantity of charcoal to 20 sacks per ton of iron.

The furnace went out of blast in 1828 and during its last campaign was used by Mushet for experiments with wootz iron ore[18]. Twenty tons of wootz were sent to him from India with 'a view to having it smelted and the resulting pig iron worked with charcoal to make steel iron'. Tintern furnace was chosen for these experiments, the success of which, it was hoped, would allow iron suitable for steel making to be made commercially in India for export to Britain, and thereby end the dependence of the British steel industry on high cost Swedish and Russian iron[19].

3.1 Excavation

The site was excavated between April 1979 and April 1980 by a team of ten employed under the Special Temporary Employment Programme of the Manpower Services Commission and organised through the Planning Department of Gwent County Council.

There was no direct threat to the site other than that posed by continued activity from the Forestry Commission and the excavation was undertaken, in the first instance, to establish the state of preservation of any remaining structures with a view to developing the site as part of an 'industrial trail' planned for the valley.

The site, described from west to east for the purpose of the report, is divided into two areas:

Area 1 : the leat, building A, building B

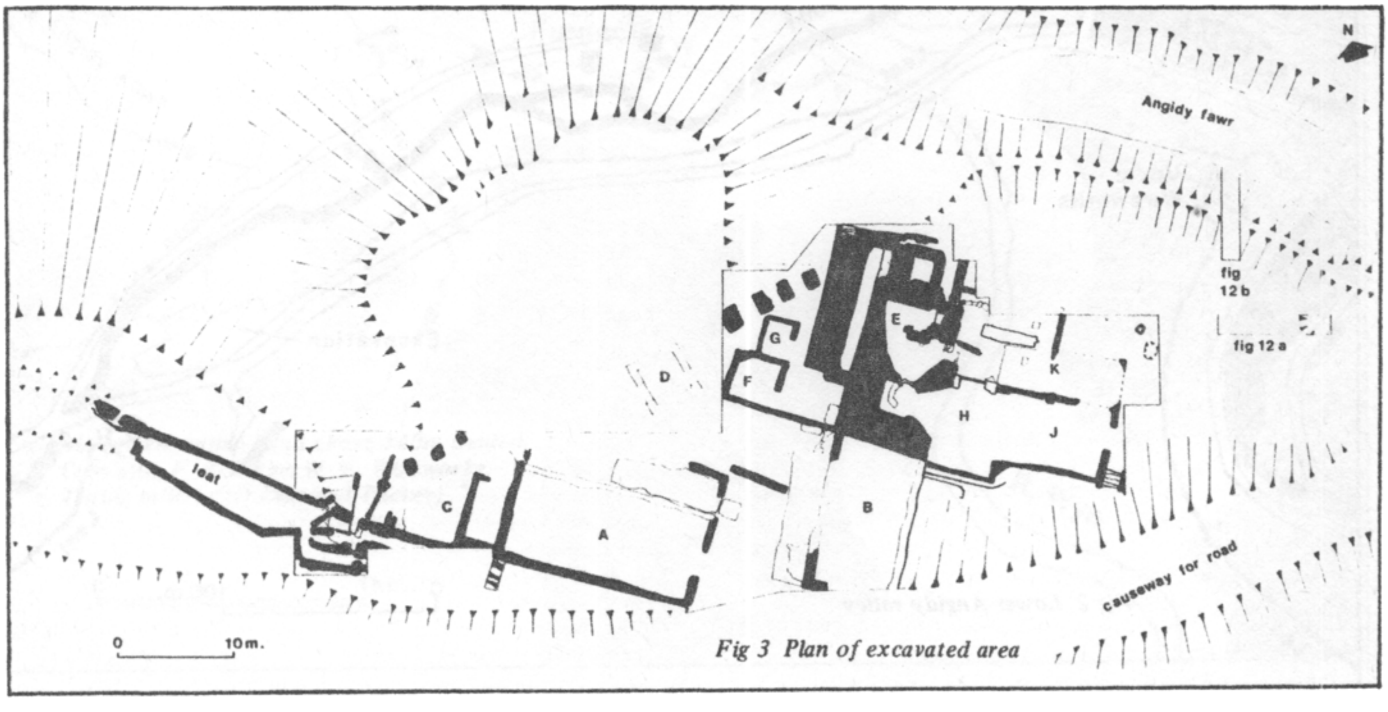

Fig 3 Plan of excavated area

Area 2 : the furnace, the wheelpit, buildings E, F, G, H, J, K

A plan of the excavation, divided into the two areas to be discussed, is shown in Fig 3.

As it was intended to preserve as many of the surviving structures as possible, total excavation of the site could not be undertaken, with the result that there was a problem of relating the stratigraphy in different parts of the site. The excavation is described in the three phases, two industrial and one post-industrial, which could be defined across the site, but which contain isolated sub-phases confined to certain sections alone.

3.2 **Area 1**

Area 1 was a level terrace of ground (48 m x 40 m) which followed the 60m contour. The valley slope rose steeply to the S into Buckle Wood, 230 m OD, and fell sharply to the N and E to the Angidy Fawr, some 6m below (Fig 3). The only feature apparent before excavation was a shallow trench, assumed to be the line of the leat, and so an area 80m x 10m was opened up, its southern edge controlled by the line of the modern Tintern-Raglan Road, to examine the ground to the E of the leat.

3.3 **Area 1, Phase 1**

The Leat

Furnace Pond (SO 509006 and Fig 2) was built as the water source for the furnace and so must belong to the first phase of industrial activity on the site. The pond still holds water but substantial alterations to the dam wall in the mid-19th century, when a road was constructed along its top, appear to have destroyed all remains of the original structure.

The first trace of the leat is on the S bank of the brook, 15 m in front of the dam wall and 1.80m below the present water level in the pond. Its point of exit from the pond is lost, but the difference in height between the leat and the modern water level suggests that the original wall must have been considerably lower. The line of the leat can be easily traced as a shallow trench dug into the natural slope with the upcast forming a bank on the N or down-slope side. Occasional patches of dry-stone walling suggest that isolated retaining walls were built to hold back the steeper bank sections. The length of the leat between Furnace Pond and the W edge of the Area 1 excavation is 390m.

A 30m length of the leat was investigated in the SW part of Area 1 (Fig 4). For 25 m the leat followed the contour along the valley slope and had been dug as an open trench on to an impervious natural orange clay.

Initially, the leat was an open trench with the SW face being a near-vertical cut into the clay bed 1.20m deep, while the NE edge could be traced as a low bank (53) of re-deposited clay (not illustrated) presumably upcast from the digging of the trench. Beyond this the sides of the cut were lined by two retaining walls of coursed sandstone (34 & 28) with the lengths of 16m and 12.50m respectively, and which still stood to a height of 1.10m in places. At their NW ends, 34 and 38 were joined by a cross-leat structure (52) which remained to the SW as a coursed rubble wall traversing 1.10m of the leat width, the remaining distance being taken up by a large sand-stone slab set into the clay. The water flow could only be through the gap over the slab and so this feature effectively reduced the width of the leat from 2.50m to 0.60m. Although 52 would have regulated the flow of water, there was no evidence to suggest the existence of a sluice at this point.

From wall 52 the leat widened out again to a maximum width of 3.90m at the SE end of 38, only to be reduced to 1.30m as a result of a directional change to the W in the line of 38 in its continuation as walls 36 and 35.

The changes in leat width in this section are shown below, the distance being measured along the line of the NE side of the leat commencing at the W edge of the excavations:

distance along leat –	0m	5m	8m	9m	15m	20m	25m
width across leat –	2.90	2.00	0.60	2.50	2.80	3.10	1.30

The W ends of 34 and 35 had been disturbed by subsequent alterations (see 3:4) which had also destroyed a 2m length of the leat. Further investigation of the leat beyond this point was hampered by the line of the modern road but a section excavated behind building A (Fig 3) showed it to continue in the original direction and to have been constructed against the back retaining wall of that building. The floor of the leat was composed of a green-yellow puddled lias clay suggesting that the natural clay must have sloped away to the N and E in the area of the disturbance mentioned above, and that this portion of the leat rested on an artificial backfill behind buildings A and B designed to maintain the level of the leat.

No trace of the leat could be found to the E of Building A and it is to be assumed that it was destroyed by later activity. If the leat fed the furnace wheel then it must have turned sharply to the NE at the corner of building A. The level of the leat in the E section behind building A was 7.65m above the assumed hub-level of the wheel (see 3:6) which would seem too great a vertical drop for the leat to be carried as a launder to the wheel, unless the launder itself was steeply angled. It is possible that the leat, beyond the area investigated, was channelled down behind building A, ran as a covered trench to the NE following the natural slope of the clay, and was then carried as a launder from the edge of the slope to the wheel in the last section. A ditch (75) cut into the natural clay 1.20m wide and 0.20 deep ran parallel to wall 14 of building A but was obliterated to the NE by a phase 2 flooring of re-deposited clay. The length of ditch examined was too short to allow any but a tenuous association with the leat.

Immediately to the W of the disturbance area on the leat, and on its S edge between 35 and 36, a stone-lined trench was examined that appeared to be a secondary water course. It had been cut into the clay in the same manner as the leat and was 0.90m wide. A large sandstone slab was set horizontally across the entrance with an area of cobbling beyond, and it ran parallel to, and at the same level as, the leat for 4.00m and then turned through 90 degrees to the NE and was directed under the leat as a culvert. A vertical slab had been built into the floor at the SE mouth of the culvert effecting a drop in base level of 0.55m. The culvert itself, 0.70m wide and 1.10m high, was floored with rectangular sandstone slabs and the roof was constructed in a similar manner and capped with puddled clay as an impervious lining for the leat above. Beyond the culvert the channel could be traced for 2.70m as a cobbled floor (20) with the remains of stone retaining walls on either side. Between the vertical slab at the mouth of the culvert and the end of the cobbling the floor sloped to the NE at an angle of 18 degrees to give a vertical fall of 0.30m. A shallow gully, not excavated, could be traced on the ground following the projected line of the channel (Fig 3) and running N to the river.

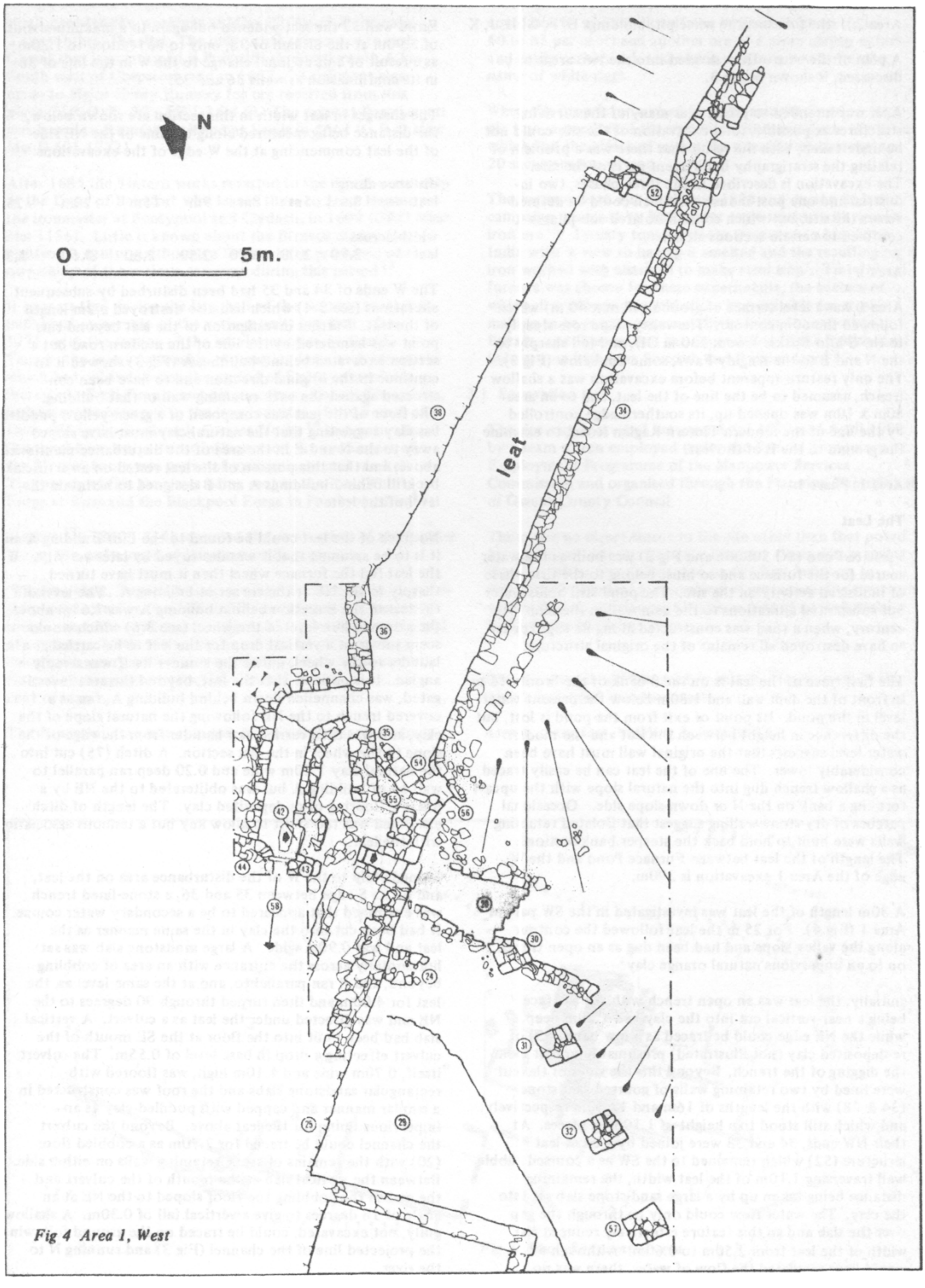

Fig 4 Area 1, West

From the outlet of the culvert the natural clay sloped to the NE before dropping steeply to the river, and its S line was marked by retaining walls 25 and 27 which, as shown above, also acted as a control on the line of the leat. The remains of a stub wall (24) were excavated 1.80m to the E of the culvert outlet. It was poorly built out of randomly coursed sandstone side-blocks set on to an orange clay and mortar matrix, and was built directly on top of the natural clay and appeared to form the W limit of an extensive cobbled area (29) which ran E in front of 25 for 7.40m and had a maximum width of 7.80m. This flooring had not only been set on to the clay but followed the natural slope of the bank which gave it an angle of 20 degrees. The cobbling took the form of rectangular end-pitched sandstone laid in a complex manner with a SE - NW runner of large stone acting as a central rib with the cobbling on either side curving in towards it. As no mortar had been used the patterning must represent a deliberate pitching designed to create a natural interlocking of the stone necessitated by, and making use of, the clay slope. With the exception of wall 24 there was no evidence to suggest that this area was ever enclosed.

Building A (Fig 5)

Immediately to the SE of 29, and on the same axis as 25, was a large building 18m x 8m. It was demarcated by the walls 14, 15, 16, 27 and 28. The walls were of dressed and coursed sandstone with a rubble mortar infill and had an average width of 0.75m. All were set into a foundation trench dug into the natural clay to a depth of 0.30m with the exception of wall 27 which was built on a foundation course of large boulders of conglomerate sandstone resting on the clay. The level of the natural clay within the building did not conform to the angle of slope observed beneath 29, and so it must be assumed that a rectangular area was excavated into the clay bank to accommodate the structure; for this reason walls 27 and 28 act not just as structural support walls for the building but also as retaining walls for the clay bank. The only entrance to the building was in the E end between walls 14 and 15 and had a width of 2.25m. No features were observed within the building with the exception of a small area of paving in the SW corner and three sub-circular pits in the NE corner (17, 18, 19).

Pit 17 (0.28 m wide; 0.30m deep) was directly in front of, and slightly undercut, the corner wall footings of 15 and 16. It was filled with charcoal and grey ash and may pre-date the construction of 15/16.

Pits 18 and 19 (0.35m wide, 0.20m deep and 0.25m wide, 0.25m deep respectively) were connected by a shallow scoop and had a similar fill of charcoal and ash as 17 although it was not possible to establish any relationship between the three.

A trench 2m wide was excavated NE of the mid-point of wall 16 of building A to establish the angle of the natural clay slope (Fig 6). It was found to be 0.90m below the level observed within building A and, running SE - NW across the clay. Set into it, in a shallow foundation trench, was the remains of a neatly coursed sandstone wall (74) standing to a height of 0.18m. Given the small width of the excavated section it was impossible to interpret the wall in a functional sense, but as it ran parallel to wall 16 it is possible that it was a retaining wall built on to the top of the slope to hold a path or trackway alongside building A. This wall was covered over by phase 2 dumping and then robbed to its present height prior to the construction of the cobbled area 62 (see below 3:4).

Building B (Fig 5)

A second rectangular building 14m x 8m was examined in the E portion of Area 1. The N wall of the structure lay under the modern road and so was not excavated, but the layout of the building could be obtained from the two side walls (68 and 69). Wall 68 had been built in a foundation trench dug into the natural clay and was of a coursed sandstone construction similar to that observed in building A. The clay sloped to the E at an angle of 15 degrees and wall 69, although set against the clay, also acted as a retaining wall, suggesting that the natural surface fell sharply at this point (Fig.7). The inner base of 69 was 0.25m below that of 68 which is accounted for by the natural slope, but the outer face of 69 was examined in section to a point 0.85m below this and appeared to continue further down still with a stepped profile. The front of the building abutted directly on to the back wall of the furnace and it was apparent that the two formed a structural whole (see 3:7). To compensate for the natural slope within the building alternating layers of charcoal and clay were dumped to build up a level floor surface.

3.4 **Phase 2**

The second phase of industrial activity was represented by a massive dumping of waste to effect a substantial extension of the working area. This took place between the W end of the cobbled surface 29 and the NW wall of Building B, and to the N of wall 16 of Building A. The natural valley slope seems to have fallen sharply from this point towards the river and by dumping in this area an extension of up to 2.5m was obtained which could have involved some 2400m^3 of material. A section excavated NE of the centre of wall 16 (Fig 6) indicated a mixed fill of clay, mortar, dressed building stone and slag in observable tip lines; this sequence was duplicated elsewhere but with an increase of slag towards the E. A number of new features and alteration of pre-existing ones relate to this phase.

The Leat (Fig 4)

One of the major changes that was observed was a re-alignment of the leat. To the E of the opening of the secondary water course an E - W wall of coursed sandstone (54) was built on to the clay floor of the leat. This effectively blocked the phase 1 leat to the SE, and red clay and mortar (55) was piled behind 54, perhaps to make the wall impervious. The NE retaining wall of the leat (34) was partially demolished at this point, the coursing altered to give it a curving aspect on the internal face, and a sluice gate (56) set up between 54 and 34, its footings surviving as a beam slot with remnant mortar and timber. Directly E and down slope from this break in the wall of the leat a set of four stone pillars (30, 31, 32, 57) had been built into the top of the dump layer. They had an average size of 2m x 2m but only the foundation courses remained, so it was impossible to estimate their respective heights. The continuation of this line of pillars was excavated in Area 2 (see 3:8) on the dump slope to the W of the wheel pit, and they are interpreted as a series of supports for a launder feeding the furnace wheel. The width of the leat at the assumed 'take-off' point represented by sluice 56 was 0.50m and this would not be unreasonable for a timber launder.

The secondary water course can be placed in Phase 1, for it respected the line of the leat in its culverted section. But, as the phase 2 dump layer extends as far W as the secondary leat, but does not cover it, it seems that it continued in use after the original leat had become obsolete, although some structural alterations took place. Wall 44/43 (Fig 4) to the immediate S of the opening for the

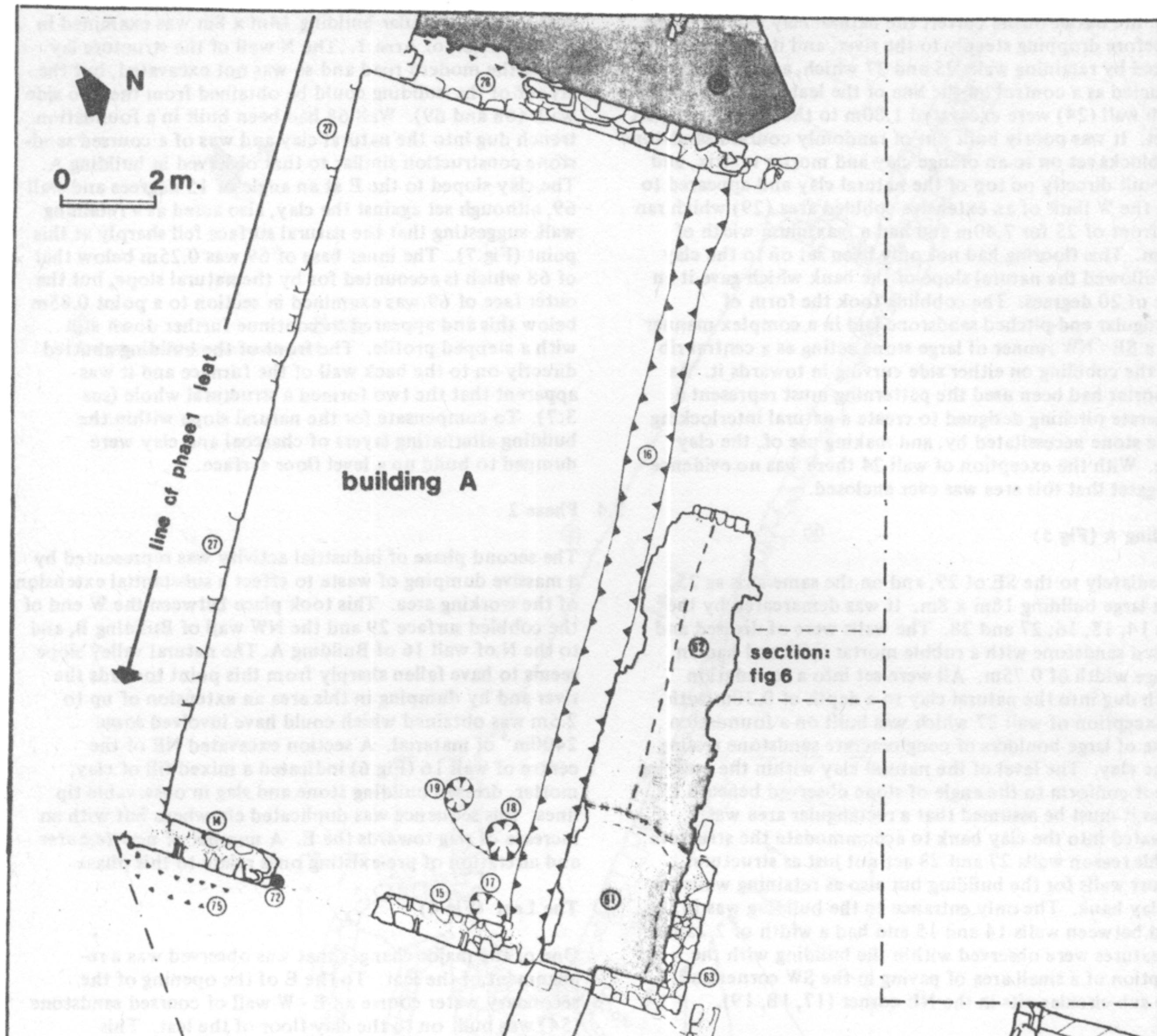

Fig 5 Area 1, East

culvert, was broken through to accommodate a cut-and-cover channel (58) which was dug parallel to, but to the S of, the phase 1 leat. This was observed in section at the corner of walls 26 and 27 (Fig 3) and had coursed sandstone walls with a slabbed roof; it was almost completely filled by a homogenous grey silt. It dropped in level by 0.30m over a distance of 10m from its mouth, while the leat dropped by only 0.08m over the same length. A second section,excavated S of the mid point of retaining wall 27 (not illustrated) produced evidence for the original leat but not for channel 58, suggesting that it must have run away to the SE which would have taken it from the main working area. A beam slot, identified as a probable sluice base, was found at the mouth of 58 and set into the bottom coursing of walls 43 and 44. A second sluice (42) was positioned immediately to the W, which crossed the secondary water course at the mouth of the culverted section. The presence of two sluice gates, perhaps working on connection with the sluice to the launder on the main leat suggests a complex system of water control in which channel 58 may have acted as an overflow for the secondary water course. This is discussed below (5:2).

The large cobbled area 29 was described as part of phase 1 because it was built directly on to the clay and abutted neatly onto retaining wall 25 and the W wall of building A. Its NW edge runs parallel to the line of support pillars for the launder which would indicate that it was truncated by the re-orientation of the main water course in phase 2. Such activity would also explain the short length of wall 24 as it is conceivable that in phase 1 area 29 was rectangular, with the W edge demarcated by a much longer 24, and that the NW corner was destroyed by the construction of the launder.

Buildings A and B and their surroundings (Fig 5)

Building A remained unaltered in this phase although a side structure was added to the NE and built against wall 16. It was excavated as a rectangular cobbled area (61, 62) 10.20m long x 3 m wide, with an entrance to the SE fronted by a square, cobbled forecourt or porch (72). A coursed sandstone wall (63), butt-jointed on to the NE corner of building A, enclosed the SE edge of the cobbled area but could only be traced for 3.50m along the NE edge. The end of this wall corresponded to a change in the patterning of the cobbling. This might indicate that the easterly section (62) was a later addition, as 61 was laid out with square sandstone cobbles, exhibiting a number of colours and set in parallel rows SW - NE. A shallow drain ran parallel with the inner face of 63 along the SW edge, while 62 was constructed out of larger sandstone blocks, laid only in approximate rows. The presence of mortar on many of the cobbles suggests that they might have been re-used building material.

The NE margin of the ground build up in Area 1 was delineated by a massive retaining wall (4). This stood 3.90m high, with a slight batter observable on the outer face, and ran from the NW corner of Building B for 10.50m. It was not possible to examine the footings of this wall, but it seems probable that its construction was contemporary with the dumping phase. It was built on to the slope of the natural clay and the area to the S was in-filled to the height of the wall, which corresponded approximately to the height of the clay within building A, so forming a level surface.

Built against the outer face of wall 68 of Building B was a rectangular area of cobbling (67) 11.50m x 2.50m, which was set on to the dump layer in the same manner as 61/62. The stone had been laid in a regular SE - NW pattern with vertical sandstone slabs forming the W edge; no trace of mortar binding was found, nor was there any evidence for an enclosure around this area. At the NE end of 67 a stone-sided drain (71) was found, that ran from the edge of the cobbling, along the outer face of 68, and was then carried through the stonework of 4 at ground level in a short culvert, 0.40m high and 0.50m wide. This short drain could have collected water from the roof of building B. A small linear depression in the cobbling to the SW of

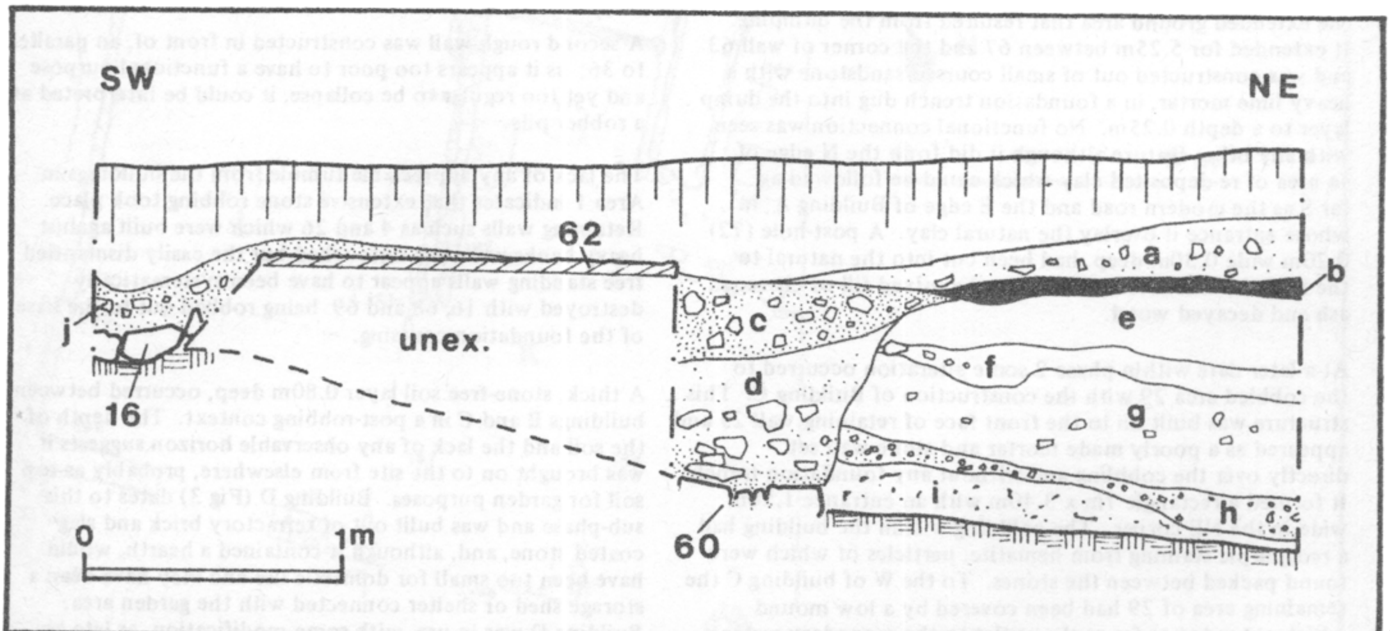

Fig 6 *a = mortar and stone, b = charcoal, c = mortar, d = mortar and stone, e = clay, f = sand and clay g = clay, h = small slag, i = clay and charcoal, j = mortar*

drain 71, and which appeared to join with it, could have been a secondary drain although it had no functional association unless seen as the only evidence for a roof over the cobbled area 67. The proximity of the furnace would have meant that a great deal of care was necessary in regard to drainage.

The interior of building B underwent little change in this phase although the floor level may have been raised by 0.20 - 0.30m by the dumping of slag on to the original clay and charcoal floor, and the covering of the whole with a compact orange clay (Fig.7). Occasional patches of small hematite were observed over this clay floor, with a heavy concentration towards the S part of the building.

Phase 3

All observable activity that took place in Area 1 in a post-industrial context is described as phase 3. A grey-stone-free silt layer built up to a depth of 0.40m in the leat and in the gully to the N of the cobbled section, 20, of the secondary water course. Into this silt, and following the line of 54, had been cut a road drain (5), stone built and of cut-and-cover construction, and which was later modified to carry a flanged, salt-glaze drain pipe, 0.20m in diameter, and laid in interlocking sections 1.30m in length. This drain emptied into the gully referred to above and built up a second layer of silt to a depth of 2.00m. Contemporary with this a poor dry-stone wall (3) was built across the leat

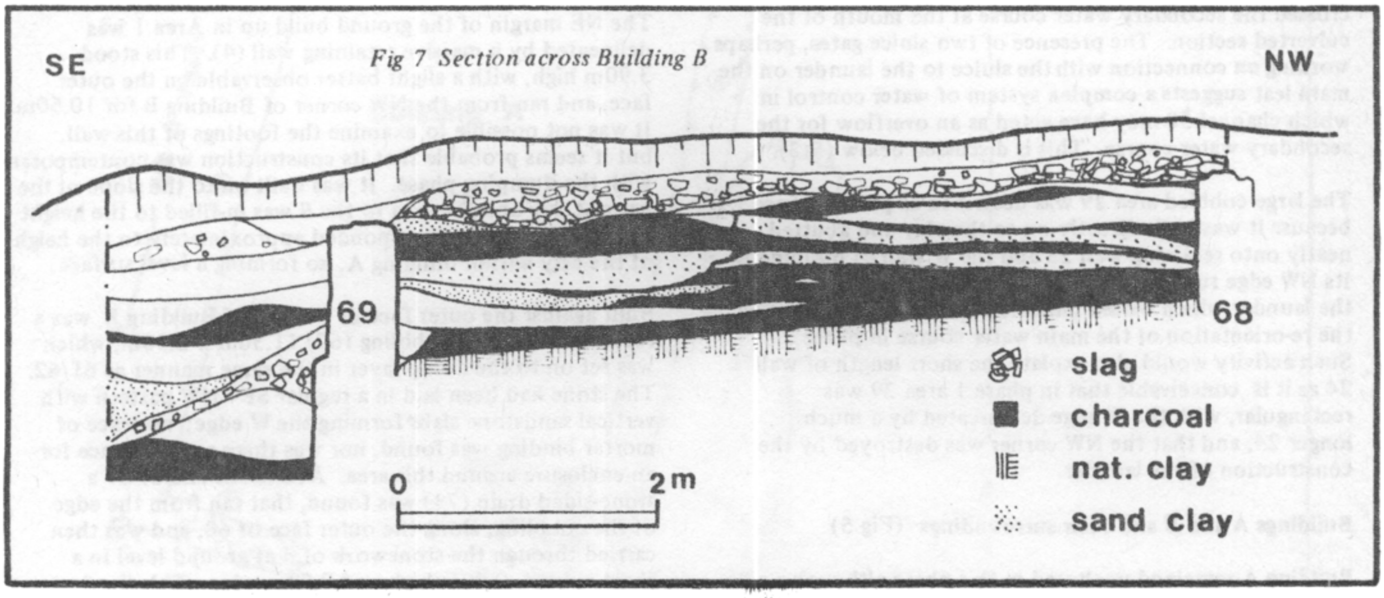

Fig 7 Section across Building B

With the exception of the side structures added to buildings A and B and the launder pillars, only wall 64 made use of the extended ground area that resulted from the dumping. It extended for 5.25m between 67 and the corner of wall 63 and was constructed out of small coursed sandstone with a heavy lime mortar, in a foundation trench dug into the dump layer to a depth 0.25m. No functional connection was seen with any other feature although it did form the N edge of an area of re-deposited clay which could be followed as far S as the modern road and the E edge of Building A, in whose entrance it overlay the natural clay. A post-hole (72) 0.20m wide 0.30m deep, had been cut into the natural to the S of the entrance and contained a mixed fill of charcoal, ash and decayed wood.

At a later date within phase 2 some alteration occurred to the cobbled area 29 with the construction of **Building C**. This structure was built on to the front face of retaining wall 25 and appeared as a poorly made mortar and stone wall set directly over the cobbling and without any foundation trench. It formed a rectangle 7m x 3.40m with an entrance 1.50m wide in the NE corner. The cobbling within the building had a red/purple staining from hematite, particles of which were found packed between the stones. To the W of building C the remaining area of 29 had been covered by a low mound which extended as far as the outlet to the secondary water course culvert and ran on to the dump layer immediately to the S of the line of launder pillars. A section through this mound showed it to be made up of layers of clay, dressed stone and forge slag presumably dumped from the S, or road side, over 29 but respecting building C and the secondary water course.

and set into the silt, perhaps as an outer retaining wall for drain 5.

A second rough wall was constructed in front of, an parallel to 36; as it appears too poor to have a functional purpose and yet too regular to be collapse, it could be interpreted as a robber pile.

The lack of any appreciable tumble from the buildings in Area 1 indicates that extensive stone robbing took place. Retaining walls such as 4 and 26 which were built against heavy banks were left untouched but the easily dismantled free standing walls appear to have been systematically destroyed with 16, 68 and 69 being robbed out to the base of the foundation coursing.

A thick, stone-free soil layer 0.80m deep, occurred between buildings B and C in a post-robbing context. The depth of the soil and the lack of any observable horizon suggests it was brought on to the site from elsewhere, probably as top soil for garden purposes. Building D (Fig 3) dates to this sub-phase and was built out of refractory brick and slag coated stone, and, although it contained a hearth, would have been too small for domestic use and may have been a storage shed or shelter connected with the garden area. Building D was in use, with some modification, as late as 1950 by Mr J Pickering of Furnace Farm who used it as a cow-shed.

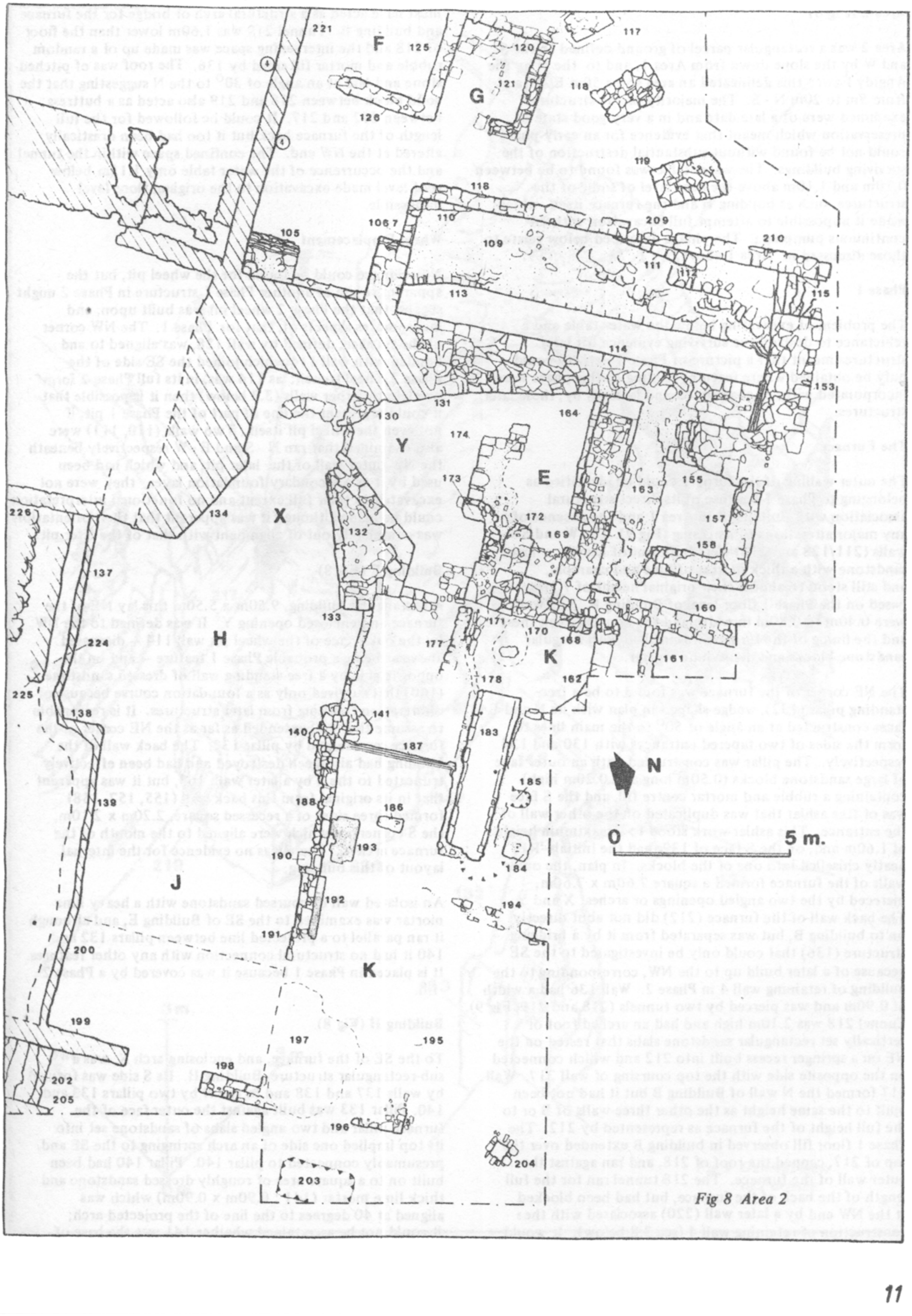
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Fig 8 Area 2

Area 2 (Fig 8)

3.6 Area 2 was a rectangular parcel of ground defined to the S and W by the slope down from Area 1, and to the N by the Angidy Fawr; this delineated an area some 50m E - W and from 5m to 20m N - S. The majority of the structures examined were of a late date and in a very good state of preservation which meant that evidence for an early phase could not be found without substantial destruction of the surviving buildings. The water table was found to be between 0.70m and 1.10m above the base level of some of the structures, such as building H and the furnace itself, which made it impossible to attempt full excavation without continuous pumping.;. The phases described below relate to those discussed in Area 1 above.

3.7 **Phase 1**

The problem of excavating below the water table and a reluctance to destroy the surviving evidence for later structures meant that a picture of Phase 1 activity could only be obtained where features relating to this phase were incorporated with, or abandoned and isolated by, these later structures.

The Furnace

The outer walling of the furnace could be identified as belonging to Phase 1 because of its direct structural association with Building B in Area 1 and the absence of any major alterations to its casing (Fig 9). The W and SW walls (211/128 and 212) were built out of heavily coursed sandstone with a thick mortar of lime and charcoal, and still stood to almost their original height of 7.10m. based on the Phase 1 floor level of Building B. The walls were 0.40m to 0.50m in width and the area between these and the lining of the furnace was infilled with irregular sandstone blocks and dense lime mortar.

The NE corner of the furnace was found to be a free-standing pillar (132), wedge-shaped in plan with its N and E faces constructed at an angle of 50^{o} to the main lines to form the sides of two tapered entrances with 130 and 134 respectively. The pillar was constructed with an outer face of large sandstone blocks (0.50m long and 0.20m high) containing a rubble and mortar centre fill, and the S face was of fine ashlar that was duplicated on the other wall of the entrance. This ashlar work stood to a maximum height of 1.60m and, on the S face of 132, had the initials 'RF' neatly chiselled into one of the blocks. In plan, the outer walls of the furnace formed a square 7.60m x 7.60m, pierced by the two angled openings or arches, X and Y The back wall of the furnace (212) did not abut directly on to building B, but was separated from it by a bridging structure (136) that could only be investigated to the SE because of a later build up to the NW, corresponding to the building of retaining wall 4 in Phase 2. Wall 136 had a width of 0.90m and was pierced by two tunnels (218 and 219, Fig 9). Tunnel 218 was 2.10m high and had an arched roof of vertically set rectangular sandstone slabs that rested on the NE on a springer recess built into 212 and which connected on the opposite side with the top coursing of wall 217. Wall 217 formed the N wall of Building B but it had not been built to the same height as the other three walls of B or to the full height of the furnace as represented by 212. The Phase 1 floor fill observed in building B extended over the top of 217, capped the roof of 218, and ran against the outer wall of the furnace. The 218 tunnel ran for the full length of the back of the furnace, but had been blocked at the NW end by a later wall (220) associated with the construction of retaining wall 4 (see 3.8 below). It would seem that in Phase 1 218 was an open-ended tunnel that must have acted as a structural arch or bridge for the furnace and building B. Tunnel 219 was 1.60m lower than the floor of 218 and the intervening space was made up of a random rubble and mortar fill sided by 136. The roof was of pitched stone and laid at an angle of 30^{o} to the N suggesting that the solid block between 218 and 219 also acted as a buttress between 212 and 217. It could be followed for the full length of the furnace back but it too had been drastically altered at the NW end. The confined space within the tunnel and the occurrence of the water table only 1.15m below roof level made excavation to the original floor level impossible.

Wheel Emplacement

No evidence could be found for the wheel pit, but the apparent re-use of another Phase 1 structure in Phase 2 might suggest that the Phase 2 wheel pit was built upon, and incorporates aspects of, that for Phase 1. The NW corner of the furnace, defined by wall 128, was aligned to and bonded with wall 114 which joined the SE side of the Phase 2 wheel trench; as 114 was, in its full Phase 2 form overlain by other walls (3.8 below) then it is possible that it could represent the line of part of the Phase 1 pit, if not even the wheel pit itself. Two walls (110, 111) were also examined that ran N - S and E - W respectively beneath the NW outer wall of the later pit, and which had been used by it as a secondary foundation layer; they were not excavated to their full extent and no functional interpretation could be made although it was apparent that their orientation was completely out of alignment with that of the later pit.

Building E (Fig 8)

A rectangular building, 9.50m x 5.50m this lay NE of the furnace and enclosed opening Y. It was defined to the NW by the outer face of the wheel pit wall 114 – discussed above as being a probable Phase 1 feature – and on the opposite side by a free-standing wall of dressed sandstone (160) that survived only as a foundation course because of obliteration resulting from later structures. It is reasonable to assume that 160 extended as far as the NE corner of the furnace represented by pillar 132. The back wall of the building had also been destroyed and had been effectively truncated to the S by a later wall, 163, but it was apparent that in its original form this back wall (155, 157, 158) formed three sides of a recessed square, 2.20m x 2.10m, the S corners of which were aligned to the mouth of the furnace arch Y. There was no evidence for the internal layout of this building.

An isolated wall of coursed sandstone with a heavy lime mortar was examined to the SE of Building E, and although it ran parallel to a projected line between pillars 132 and 140 it had no structural connection with any other features. It is placed in Phase 1 because it was covered by a Phase 2 fill.

Building H (Fig 8)

To the SE of the furnace, and enclosing arch X, was a sub-rectangular structure, Building H. Its S side was formed by walls 137 and 138 and to the N by two pillars 133 and 140. Pillar 133 was built against the outer face of the furnace pillar and two angled slabs of sandstone set into its top implied one side of an arch springing to the SE and presumably connected to pillar 140. Pillar 140 had been built on to a square area of roughly dressed sandstone and thick lime mortar (141 : 0.90m x 0.90m) which was aligned at 40 degrees to the line of the projected arch; it could not be ascertained whether 141 was the base of a pillar earlier than 140, or simply the foundation

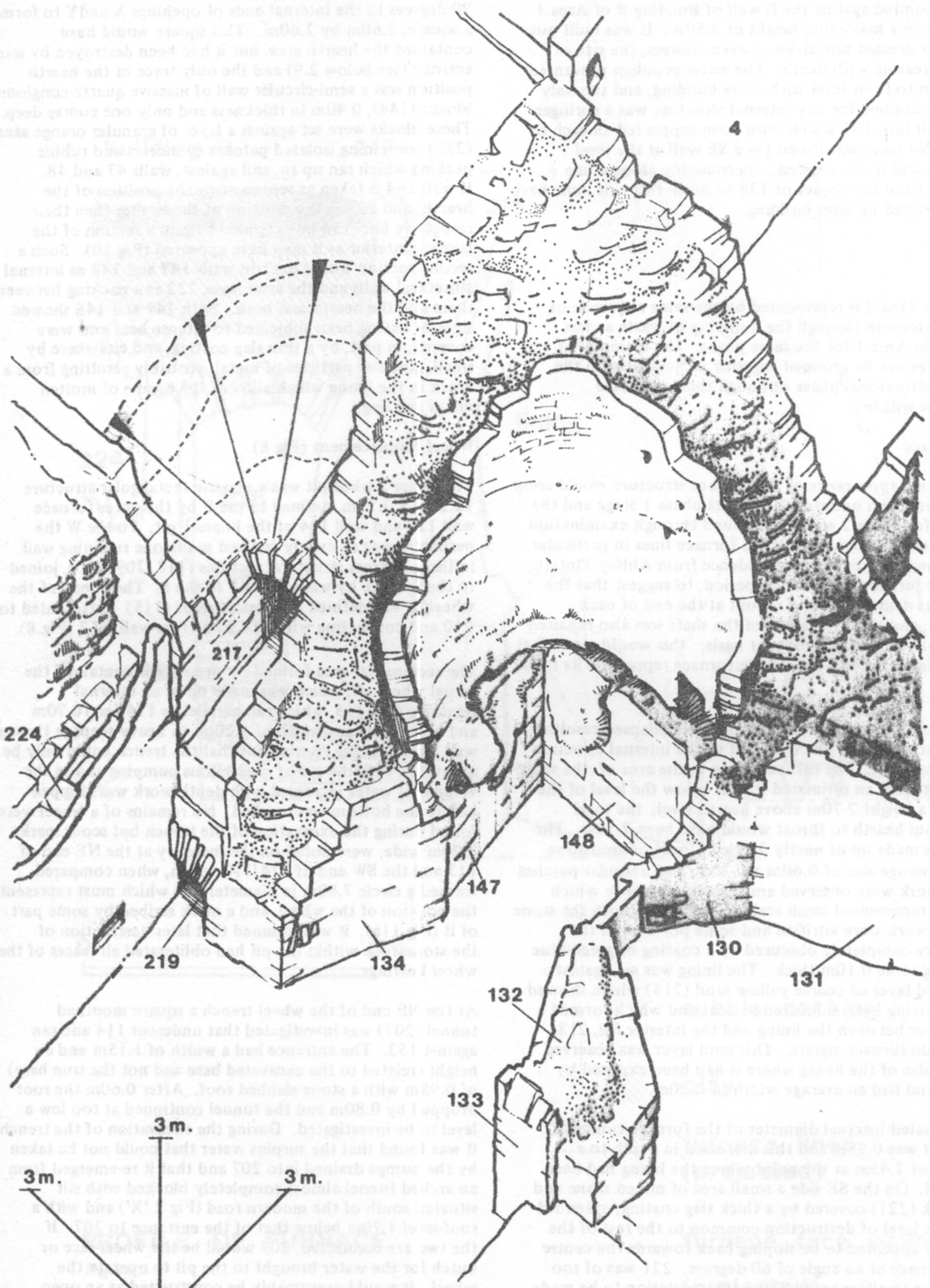


Fig 9 General view of Furnace

for 140. The wall forming the S line of the building (137) was butt-jointed against the E wall of Building B of Area 1 and stood to a maximum height of 3.50m. It was built out of roughly dressed sandstone in even courses, the size of stone decreasing with depth. The water problem prevented excavation to floor level within the building, and the only evidence obtained for any internal structure was a springer recess built into 137 which must have supported an arch to the NE. No trace was found for a SE wall at the level excavated and if one existed – presumably along a line projected from the corner of 138 to pillar 140 – it must have been destroyed by later building.

3.8 **Phase 2**

Phase 2 in Area 2 is represented by the same sequence of ground extension through the dumping of waste as was observed in Area 1 for the same phase. The majority of the features can be grouped together as belonging to the same constructional phase although there are some alterations within it.

The Furnace

The external appearance of the furnace structure would seem to have remained unchanged from its phase 1 stage and the evidence for phase 2 was to be found through examination of the internal structure, and the furnace lines in particular. There is ample documentary evidence from Abbey Tintern, and other furnaces of a similar period, to suggest that the hearth was demolished and rebuilt at the end of each campaign, and that the facing of the shaft was also repaired and re-built on a fairly frequent basis: this would mean that the remaining internal line of the furnace represents its final form.

The NE and SE faces of the furnace had collapsed resulting in the destruction of just over half of the internal structure (Figs 10 and 14). The furnace lining in the area of the shaft was intact from an estimated 0.35m below the level of the throat to a height 2.70m above hearth level; the total height from hearth to throat would have been 7.10m. The lining was made up of neatly dressed blocks of sandstone with an average size of 0.60m x 0.30m, and irregular patches of brickwork were observed amongst the masonry which probably represented small scale repair work. Both the stone and brickwork were vitrified and some portions of the lining were completely obscured by a coating of green-blue glassy slag some 0.10m thick. The lining was set against a compacted layer of coarse yellow sand (215) which showed signs of having been subjected to heat and which formed a buffer layer between the lining and the interior fill, 213, of the main furnace square. This sand layer was observed at both sides of the lining where it had been exposed by collapse and had an average width of 0.20m.

The estimated internal diameter of the furnace tunnel at the throat was 0.95m and this increased in depth to a diameter of 2.45m at the point where the lining had been destroyed. On the SE side a small area of mixed stone and brickwork (221) covered by a thick slag coating, extended below the level of destruction common to the rest of the lining and appeared to be sloping back towards the centre of the furnace at an angle of 60 degrees. 221 was of too small a size to allow any definite interpretation to be made but it is possible that it represents an isolated segment of the bosh, although it may be no more than a lump of 'scaffolding' which had accumulated on the lining and was never cleared.

Below the destruction level of the lining were two walls (47, 48) built out of large sandstone blocks and set at 90 degrees to the internal ends of openings X and Y to form a square, 2.60m by 2.60m. This square would have contained the hearth area, but it had been destroyed by later activity (see below 2.9) and the only trace of the hearth position was a semi-circular wall of massive quartz-conglomerate blocks (144), 0.40m in thickness and only one course deep. These blocks were set against a layer of granular orange sand (222) containing isolated patches of mortar and rubble packing which ran up to, and against, walls 47 and 48. If wall 144 is taken as representing the position of the hearth, and 221 as the position of the boshes then their respective lines can be extended to gain a section of the furnace interior as it may have appeared (Fig 10). Such a reconstruction would explain walls 147 and 148 as internal structural walls and the sand layer 222 as a packing between them and the hearth and bosh. Both 147 and 148 showed signs of having been subjected to intense heat and were covered, in part, by a thin slag coating, and elsewhere by small, globular particles of metal, probably resulting from a break in the lining which allowed the escape of molten metal and slag.

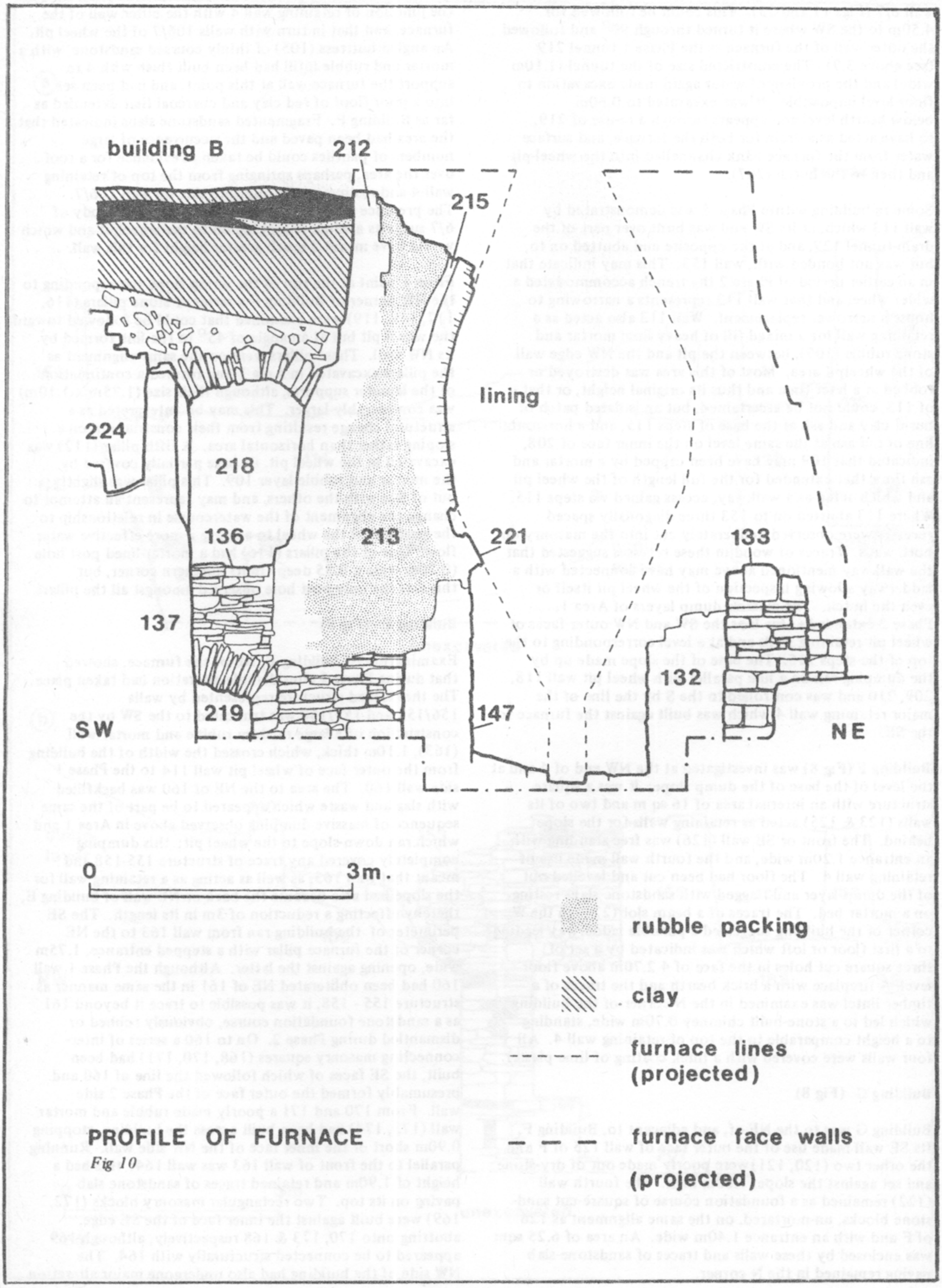
Wheel Emplacement (Fig 8)

The Phase 2 wheelpit was a massive rectangular structure 12.20m x 3.75m, defined to the E by the outer furnace wall 128 and wall 114 of the Phase 1 pit. To the W the perimeter was an evenly coursed sandstone retaining wall in three distinct structural sections (118, 209, 210), joined to the furnace by walls 6 and 7 to the S. The N end of the wheelpit was defined by a set of steps (115) butt-jointed to 210 and connecting with 114 by a cross-wall, 153 (Fig.8).

The rectangular area formed by these walls contained the actual wheel pit, which was made up of an internal retaining wall 113, which ran parallel to 114 for 10.70m and had a constant width of 1.20m. A heavy seepage through wall 153 from the river meant that the trench could only be excavated with the aid of continuous pumping and as the volume of water increased with depth work was stopped before the bottom was reached. No remains of a wheel were found during the excavation of the trench but scour marks 0.20m wide, were noted on the masonry at the NE end of 113 and the SW end of 114/112 which, when compared, formed a circle 7.80m in diameter and which must represent the position of the wheel, and a mark scribed by some part of it (Fig 11a); it was assumed that later destruction of the stonework within the pit had obliterated all traces of the wheel bearings.

At the NE end of the wheel trench a square mouthed tunnel (207) was investigated that undercut 114 and ran against 153. The entrance had a width of 1.15m and a height (related to the excavated base and not the true base) of 0.95m with a stone slabbed roof. After 0.60m the roof dropped by 0.80m and the tunnel continued at too low a level to be investigated. During the excavation of the trench it was found that the surplus water that could not be taken by the pumps drained into 207 and that it re-emerged from an arched tunnel almost completely blocked with silt situated south of the modern road (Fig 2 'X') and with a roof-level 1.70m below that of the entrance to 207. If the two are connected, 207 would be the wheel-race or hutch for the water brought to the pit to operate the wheel. It would presumably be constructed as an open trench, capped with stone to form a cut-and-cover drain, pre-dating most, if not all, of the buildings N and E of the furnace and thus a potential Phase 1 feature.

At the opposite end of the wheel trench a second tunnel



PROFILE OF FURNACE

Fig 10

(129) with a neatly constructed arched roof, ran under wall 6/7 (Figs 11 and 15). This could be followed for 4.50m to the SW where it turned through 90^{o} and followed the outer wall of the furnace as the Phase 1 tunnel 219 (see above 3.7). The constricted size of the tunnel (1.10m wide) and the problem of water again made excavation to floor level impossible. It was excavated to 0.60m below hearth level and appears through a re-use of 219, to have acted as a drain for both the furnace, and surface water from the furnace bank channelled into the wheel-pit and then to the hutch (207).

Some re-building within Phase 2 was demonstrated by wall 113 which, at its SW end was built over part of the drain-tunnel 129, and at the opposite end abutted on to, but was not bonded with, wall 153. This may indicate that in an earlier period of Phase 2 the trench accommodated a wider wheel and that wall 113 represents a narrowing to house a narrower replacement. Wall 113 also acted as a retaining wall for a mixed fill of heavy lime mortar and stone rubble (109), between the pit and the NW edge wall of the wheelpit area. Most of this area was destroyed or robbed at a later time and thus its original height, or that of 113, could not be ascertained, but an isolated patch of burnt clay and ash at the base of steps 115, and a horizontal line of red ash at the same level on the inner face of 208, indicated that 109 may have been capped by a mortar and ash floor that extended for the full length of the wheel pit and which acted as a walkway, access gained via steps 115. Where 113 abutted on to 153 three diagonally spaced recesses were observed deliberately cut into the masonry on both walls. Traces of wood in these recesses suggested that the walkway mentioned above may have connected with a ladderway allowing inspection of the wheel pit itself or even the hutch. The massive dump layers of Area 1, Phase 2 extended as far E as the SW and NW outer faces of wheel pit retaining walls and at a level corresponding to the top of the steps 115. The base of the slope made up by the dumping ran on a line parallel with wheel pit wall 118, 209, 210 and was controlled to the S by the line of the major retaining wall 4 which was built against the furnace to the SE.

Building F (Fig 8) was investigated at the NW end of 4 and at the level of the base of the dump slope; it was a square structure with an internal area of 16 sq m and two of its walls (123 & 125) acted as retaining walls for the slope behind. The front or SE wall (126) was free standing with an entrance 1.20m wide, and the fourth wall made use of retaining wall 4. The floor had been cut and levelled out of the dump layer and flagged with sandstone slabs resting on a mortar bed. The traces of a beam slot (221) in the W corner of the building suggested a possible ladderway leading to a first floor or loft which was indicated by a set of three square cut holes in the face of 4 2.70m above floor level. A fireplace with a brick hearth and the traces of a timber lintel was examined in the N corner of the building which led to a stone-built chimney 0.70m wide, standing to a height comparable to the top of retaining wall 4. All four walls were covered with a thick coating of lime plaster.

Building G (Fig 8)

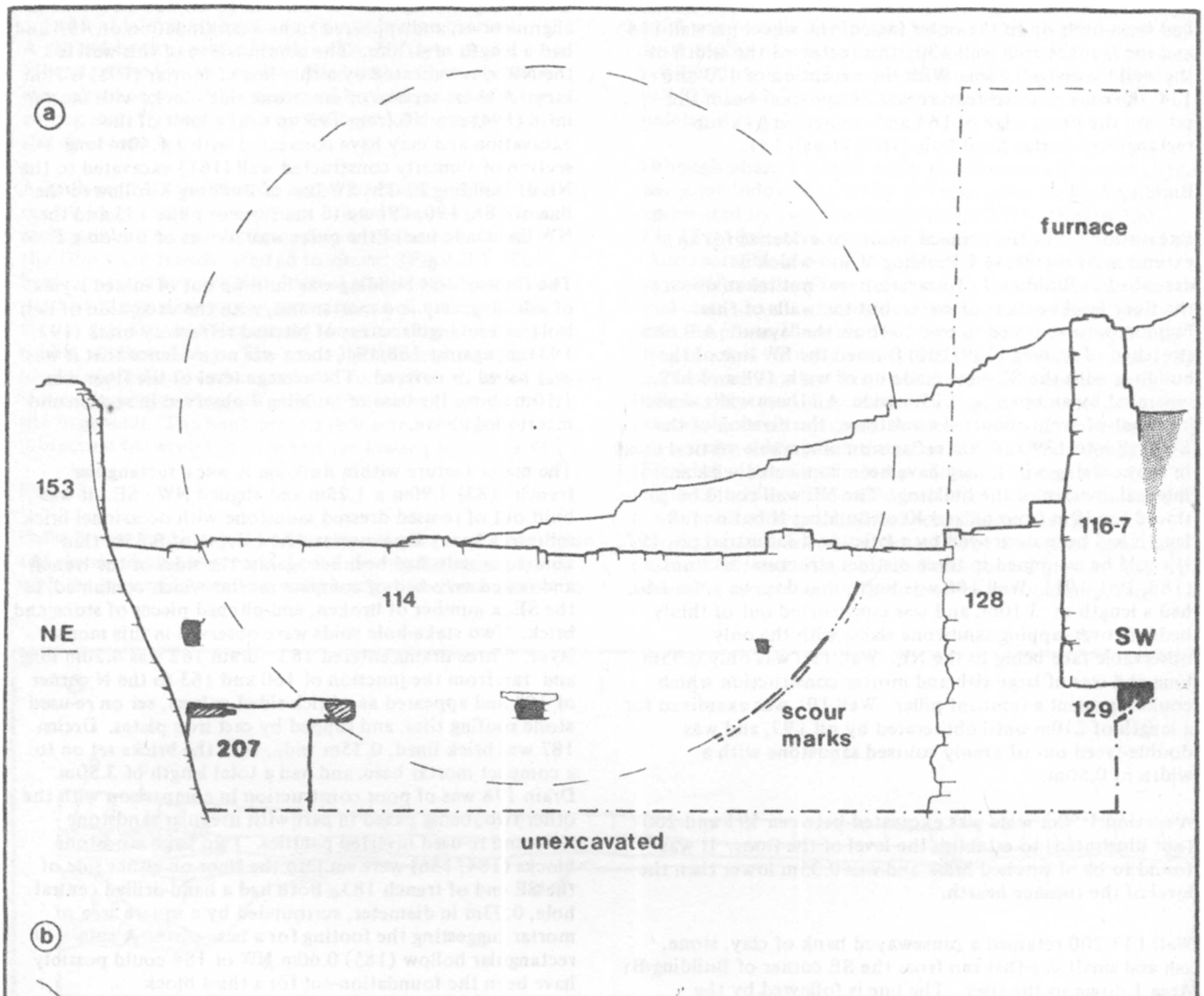
Building G was to the NE of, and adjacent to, Building F. Its SE wall made use of the outer face of wall 125 of F and the other two (120, 121) were poorly made out of dry-stone and set against the slope, 1.20m high. The fourth wall (122) remained as a foundation course of square-cut sandstone blocks, un-mortared, on the same alignment as 126 of F and with an entrance 1.40m wide. An area of 6.25 sqm was enclosed by these walls and traces of sandstone-slab paving remained in the N corner.

To the SE of Building F a rectangular area was enclosed by the junction of retaining wall 4 with the outer wall of the furnace, and that in turn with walls 106/7 of the wheel pit. An angled buttress (105) of thinly coursed sandstone with a mortar and rubble infill had been built flush with 4 to support the furnace wall at this point, and had been set into a poor floor of red clay and charcoal that extended as far as Building F. Fragmented sandstone slabs indicated that the area had been paved and the occurrence of large numbers of pantiles could be taken as evidence for a roof over the area, perhaps springing from the top of retaining wall 4 and resting on the opposite side on wall 106/7. The presence of a square cut 0.90m wide in the body of 6/7 suggests a window looking on to the wheelpit and which would have meant a much greater height for this wall.

From a point at the top of the dump slope corresponding to the NW corner of Building F a series of stone pillars (116, 117, 118, 119) were examined that could be followed towards the wheel pit but at an angle of 45^{o} to the line formed by its NW wall. These pillars were on the same alignment as the pillars excavated in Area 1 and formed a continuation of the launder supports, although their size (1.75m x 1.10m) was considerably larger. This may be interpreted as a structural change resulting from their construction on a sloping rather than horizontal area. A fifth pillar (112) was excavated in the wheel pit, its base partially covered by the mortar and rubble layer 109. This pillar was slightly out of line with the others, and may represent an attempt to change the alignment of the watercourse in relationship to the position of the wheel to achieve a more effective water flow. One of the pillars (116) had a mortar-lined post hole (0.20m wide x 0.35 deep) in its northern corner, but this was the only post hole observed amongst all the pillars.

Building E (Fig 8)

Examination of Building E, NE of the furnace, showed that during Phase 2 considerable alteration had taken place. The three sided structure represented by walls 156/155 and 157/158 was truncated to the SW by the construction of a large random rubble and mortar wall (163), 1.10m thick, which crossed the width of the building from the outer face of wheel pit wall 114 to the Phase 1 side wall 160. The area to the NE of 160 was backfilled with slag and waste which appeared to be part of the same sequence of massive dumping observed above in Area 1 and which ran down-slope to the wheel pit; this dumping completely covered any trace of structure 155-158 and meant that wall 163, as well as acting as a retaining wall for the slope had also become the back or NE wall of building E, thereby effecting a reduction of 3m in its length. The SE perimeter of the building ran from wall 163 to the NE corner of the furnace pillar with a stepped entrance, 1.75m wide, opening against the latter. Although the Phase 1 wall 160 had been obliterated NE of 161 in the same manner as structure 155 - 158, it was possible to trace it beyond 161 as a sandstone foundation course, obviously robbed or dismantled during Phase 2. On to 160 a series of interconnecting masonry squares (168, 170, 171) had been built, the SE faces of which followed the line of 160 and presumably formed the outer face of the Phase 2 side wall. From 170 and 171 a poorly made rubble and mortar wall (173, 174) had been built across the building, stopping 0.90m short of the inner face of the NW side wall. Running parallel to the front of wall 163 was wall 164; this had a height of 1.90m and retained traces of sandstone slab paving on its top. Two rectangular masonry blocks (172, 169) were built against the inner face of the SE edge, abutting onto 170, 173 & 168 respectively, although 169 appeared to be connected structurally with 164. The NW side of the building had also undergone major alteration



a
furnace
153
116-7
114
128
NE
SW
129
scour
marks
207
unexcavated
b
210
dump
layer
153
155
157
158
109
NW
163
SE
207
0
3m.
unexcavated

Fig 11

since the Phase 1 stage as was evidenced by wall 131 which had been built on to the outer face of the wheel pit wall 114 and the furnace arch wall 130; this increased the width of the wall by up to 0.80m. With the exception of 173 and 174, the only internal feature was an apparent beam slot set into the outer edge of 164 and connected to a sub-rectangular, mortar lined hole (165) in wall 131.

Building J

Excavation SE of the furnace produced evidence for an extension to the Phase 1 Building H and which is described as Building J. Excavation was not taken down to the floor level because of water, but the walls of this building were exposed in part to show the layout. A 9.60m stretched of walling (139/200) formed the SW line of the building, with the SE edge made up of walls 198 and 199, separated by an opening 2.15m wide. All these walls were built out of evenly coursed sandstone; the division of the SW wall into 139 and 200 reflects an observable vertical break in the coursing which may have been connected with an internal division of the building. The NE wall could be traced for 10m from pillar 140 of Building H but its full length had been destroyed by a later. post-industrial pit, 197. It could be examined in three distinct structural sections (188, 190, 191). Wall 188 was butt-jointed on to pillar 140, had a length of 3.10m, and was constructed out of thinly bedded, over-lapping sandstone slabs, with the only observable face being to the NE. Wall 190 was only 0.95m long and was of large slab and mortar construction which could represent a remnant pillar. Wall 191 was examined for a length of 210m until obliterated by pit 197, and was double-faced out of evenly coursed sandstone with a width of 0.50m.

A section 1.50m wide was excavated between 191 and 200 (not illustrated) to establish the level of the floor. It was found to be of pitched brick and was 0.35m lower than the level of the furnace hearth.

Wall 139/200 retained a causewayed bank of clay, stone, ash and small slag that ran from the SE corner of Building B, Area 1 down to the river. The line is followed by the modern road. This dumping also ran against the Phase 1 wall 137, so that in Phase 2 it became a retaining wall as opposed to a free-standing support wall; as the construction of this causeway is a Phase 2 activity it is probable that it was contemporary with the dump sequence observed elsewhere on the site although there is no direct stratigraphic connection.

Where the causewayed bank ran against the SE walls of Buildings H and J a drain (224) of neatly pitched stone had been laid, with a small retaining wall (225) built on the slope side. The drain was butt-jointed on to the outer wall of Building B, 3.90m below floor level and ran for the full length of Buildings H and J with a slope of 12^{o} to the SE. Horizontally, it had no functional connection with any other feature and so it is likely that it had a dual purpose and took water from the SE side of the roof of Building B and also acted as a gutter drain for H and J.

Built against wall 199 was the bottom of a flight of stone steps (202). These had been laid on to the dump layer and preumably gave access to the causeway. A section of retaining wall (205), of much poorer construction than 139/201 continued SE of the steps but only 0.50m was excavated. It had no apparent functional value other than to act as a retainer for the causeway.

Building K was adjacent to Building J to the N, and had an L-shaped ground plan. The SE wall (196) was on the same alignment as, and appeared to be a continuation of, 198 and had a length of 4.20m. The continuation of this wall to the NW was indicated by a thin line of mortar (195) 6.70m long. A short section of sandstone side blocks with mortar infill (194) ran NE from 195 up to the limit of the excavation and may have connected with a 1.40m long section of similarly constructed wall (161) excavated to the NE of Building E. Ths SW line of Building K followed the line of 188, 190, 191 up to the furnace pillar 133 and the NW line made use of the outer wall blocks of Building E.

The floor of this building was built up out of mixed layers of ash, slag, clay and mortar and, with the exception of two isolated rectangular areas of pitched refractory brick (192, 193) set against 188/191, there was no evidence that it was ever paved or covered. The average level of the floor was 1.10m above the base of building J observed in section and mentioned above.

The major feature within Building K was a rectangular trench (183) 4.90m x 1.25m and aligned NW - SE. It was built out of re-used dressed sandstone with occasional brick set into a heavy lime mortar. At a depth of 0.35m thin sandstone slabs had been set against the sides of the trench and rested on a bed of compact mortar which contained, to the SE, a number of broken, end-pitched pieces of stone and brick. Two stake-hole voids were observed in this mortar layer. Three drains entered 183: drain 162 was 4.20m long and ran from the junction of 160 and 163 to the N corner of 183 and appeared as a brick-sided culvert, set on re-used stone roofing tiles, and capped by cast iron plates. Drainn 187 was brick lined, 0.35m wide, with the bricks set on to a compact mortar base, and had a total length of 3.50m. Drain 178 was of poor construction in comparison with the other two, being paved in part with irregular sandstone slabs and re-used inverted pantiles. Two large sandstone blocks (184, 186) were set into the floor on either side of the SE end of trench 183. Both had a hand-drilled central hole, 0.03m in diameter, surrounded by a square area of mortar suggesting the footing for a base-plate. A sub-rectangular hollow (185) 0.60m NW of 184 could possibly have been the foundation-cut for a third block.

Although three drains were observed to enter 183 there was no evidence for a drain out of the trench although it is mostly likely that any water in 183 would have been channelled into the hutch from the wheel pit which ran beneath.

In the SW corner of Building K a poor sandstone wall (142) only one course thick was built between pillars 133 and 140. The area behind this wall was backfilled with slag to the same height as the floor level elsewhere within the building; this backfilling covered the isolated Phase 1 wall 177 and the pillar base 141.

To the NE of Building K and at the extremity of the excavated area two isolated features (203, 204) were excavated: feature 203 was a rectangular pit excavated into a hematite-stained earth layer and was 2.10m x 1.20m and contained a Phase 3 fill. Feature 204 was a stone-lined pit 0.45m x 0.50m which appeared to run as a slabbed drain to the SW, but this could not be verified due to water.

Other Features

A 10m x 2m trench was opened E of the Area 2 excavation (Fig3) to establish whether any further structures lay in this area (Fig 12a). Removal of top soil revealed a mixed deposit of clay, mortar and building rubble (a - e) which overlay a layer of furnace slag (h) This slag layer was excavated to a depth of 0.95m without any change being observed. A pit had been excavated within this slag layer at the SE end of the trench and was filled with a layer of orange clay which contained a number of broken pieces of vitrified casting sand (f) overlying a mixed layer of mortar, small slag and stone (g).

A bank ran between the NE corner of building E and the road bridge, and separated Area 2 from the river. This was sectioned at a point corresponding with the NW corner of the 10m x 2m trench referred to above. (Fig 12b). The bank appeared to have two distinct phases of construction: the first phase (layers g - l) was composed mainly of slag, mortar and clay and the second (layers a - f) of building rubble, earth and clay. The second phase increased the height of the bank and extended it to the SW. It is not known if the two phases observed relate to those noticed across the site in general. The bank presumably acted as flood protection between the river and the lower part of the site.

1.9 Phase 3

Phase 3 was characterised by the same sequence of demolition and stone robbing as seen in Area 1 during the same period, with the major freestanding walls being robbed out almost to foundation level. The causewayed road built S of Buildings H and J was increased in height by up to 2m in places through the dumping of a stone-free top soil. This bank was revetted S of Building H by the construction of a dry-stone slag wall (226) which abutted on to the outer face of wall 69 of building B (Fig 8).

Although phase 3 is essentially post-furnace, it would appear that some industrial activity did take place on the site, represented by two hearths (230 and 231). Hearth 230 (Fig 13a) replaced that of the furnace itself. It consisted of a horizontal floor of refractory brick set into a layer of grey, un-fired clay (? ganister) which abutted against the semi-circular wall of conglomerate sandstone associated with the phase 2 hearth. The tuyere end of opening Y had been blocked off by a poorly built random rubble wall (232) and between this and the brick floor was a shallow brick-built hearth containing residual iron slag. No continuation of this hearth structure could be found to the E. Hearth 231 was constructed against the outer face (170) of building E (Fig 13b). It was 0.40m deep with a maximum SW - NE length of 1.25m. Excavated into the floor fill of Building K, it was lined with red clay and contained a base layer of mixed slag and charcoal (e) covered by a layer of sand (d), charcoal (c), burnt sand (b) and compacted grey ash (a). It cannot be ascertained if these hearths are contemporary,

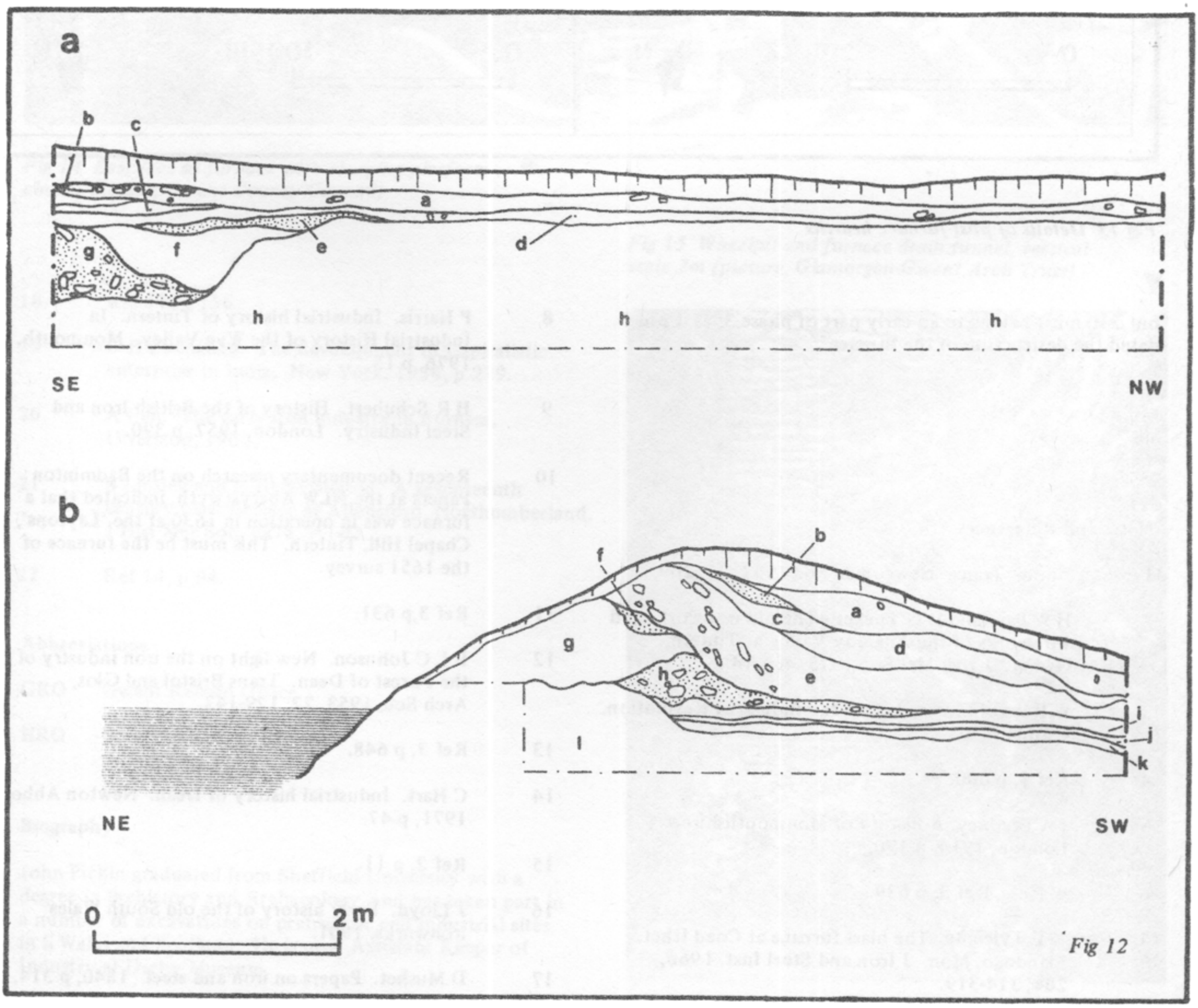


Fig 12

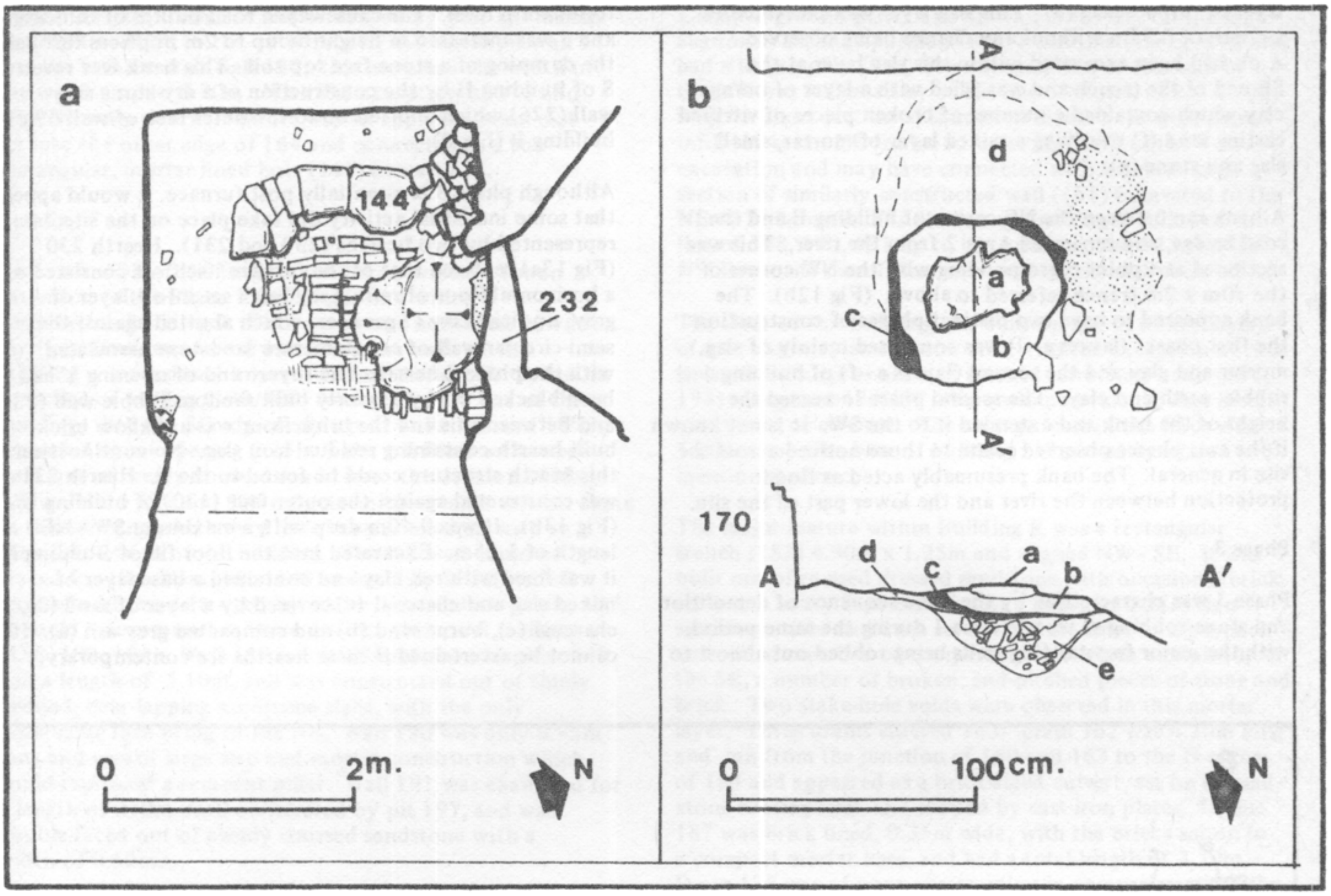


Fig 13 Details of post-furnace hearths

but 230 must belong to an early part of phase 3, as it predated the destruction of the furnace.

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Fig 14 East face of furnace with charging platform above (picture, Gwent County Council) ▲

Fig 15 Wheelpit and furnace drain tunnel, vertical scale 2m (picture, Glamorgan-Gwent Arch Trust) ▼

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Abbreviations

GRO Gwent Record Office

HRO Hereford Record Office:

Biography

John Pickin graduated from Sheffield University with a degree in Prehistory and Archaeology, and has taken part in a number of excavations on prehistoric and industrial sites in S Wales and Scotland. He is now Assistant Keeper of Industry at Derby Museum.

A non-ferrous industrial complex at Tintern Abbey

Paul Courtney

Tintern Abbey was the first Cistercian monastery to be founded in Wales in 1131. It lies on the west bank of the River Wye in the Welsh border county of Gwent (Nat Grid Ref SO 532001). Since 1977 excavations for the Ancient Monuments Board of Wales have been uncovering the outbuildings of the abbey's outer precinct.[1] This walled precinct would have housed guesthouses, stables and economic activities such as brewing and baking[2]. Excavation in 1980 revealed a deposit of medieval forge slag and charcoal apparently deposited in situ within a room off the west end of a courtyard complex. This deposit still awaits removal; however, the open courtyard itself has already revealed extensive remains of later non-ferrous metalworking (Fig 1).

This 'non-ferrous' complex is the subject of this short interim report. It occurs late in a long sequence of medieval building and levelling on the site. A lack of datable finds made it difficult to date the industrial activities by conventional archaeological means. However, the results of archaeomagnetic sampling now suggest a date within the fifteenth century.[3] Much work has yet to be done though on analysing both the archaeological and scientific data.

Around the edge of the open courtyard lay the remains of lean-to structures. That along the east side of the courtyard was represented by a series of postholes (P7-11); while a low wall (W1) lay along the N side of the court, probably representing a sleeper wall for a timber superstructure. Walls in the SW corner of the courtyard (W2 and W3) probably represent a further structure of low quality.

In the courtyard also lay a series of square stone structures (H1 - 6). They have been interpreted as the bases of waist-level hearths on the evidence of parallels from other sites. Differences in construction suggest not all were constructed contemporaneously; while H6 overlies the earlier H5 and yet a further base was found underneath this. The symmetrical layout, however, suggests alterations to a basically static plan. In the centre of the courtyard lay an open hearth (H10) composed of two reused millstones with signs of intense burning affecting the area around. A series of postholes (P1-6) may have formed some sort of screen around it.

Two pits (1 and 2) lay at the south end of the courtyard. These were both originally rectangular pits about 65 and 80cm deep respectively. Their sharp edges showed them to have been lined with brick, stone or less likely of timber. They were apparently robbed of their linings and their rubble fills contained eighteenth century material.

In the south-east corner of the courtyard a small kiln or oven was found. This included a firing pit with shelved edges probably to support kiln bars. Charcoal was found packed in the base suggesting the secondary sloping pit was for a bellows rather than for use as a fuel pit. At some stage the bottom of the firing pit was packed with clay and a pot was found resting on two stones, representing a secondary useage. This vessel has apparently misfired and was a lipped pot of about 22cm internal diameter. The lip and two grooves around its outer body, presumably to facilitate lifting, suggested it was a crucible. Unfortunately the pot had been badly damaged by a later posthole but was unlikely to be more than about 5cm deep internally. A parallel for a large crucible of similar date comes from Kirkstall Abbey.[4] This has the much greater internal measurements of 26cm diameter at the base and 35cm depth. Professor Tylecote has pointed to the high density of molten copper at about 9 g/cc and suggests these vessels might be furnace linings rather than portable crucibles.[5]

A series of bowl furnaces (bf1-6) were found clustered in the northern part of the courtyard. One exception (bf7) in the centre of the court was characterised by its relatively small size and a sloping tail-like appendage, presumably for a tuyere. X-ray fluorescence showed traces of copper, silica, lead and iron in slag adhering to the fragments of furnace lining which filled the bowl. Scrap copper fragments and a small prill of tin-bronze were also extracted.[6] The contents of the other bowl furnaces await analysis but visual examination suggests cupriferous use. Beneath bf1 and 2, a sequence of at least three earlier bowls awaits excavation. In addition a further bowl furnace was found within the west range but was apparently in the open during its period of use (not illustrated)

The range immediately north of the courtyard produced three stone structures. Two (H7 and 8) were rectangular in design and possibly the bases of hearths or forges although positive evidence is lacking. The third (H9) produced more convincing evidence of its function. It had been inserted into a wall and its chimney stack base still survived. In front of the chimney stack was a low stone platform with a bowl shaped hearth. Gases were presumably taken away by a projecting cowl whose position is probably reflected in the stonework of the chimney front. Such cowls, often in wattle and daub, are well known from domestic chimney hearths. A post-hole (P12) immediately in front of the hearth's bowl may have been for a bellows mount. A low wall (W4) with a post-setting (P13) may also have been associated with the structure. Unfortunately the hearth was isolated from the archaeological levels by earlier unrecorded excavations, but apparently not recognised as an industrial feature for the contents of the bowl were untouched. The bowl of H9 produced lumps of lead oxide intermixed with an ashy-clay lining. An ingot of lead or lead oxide was also found underneath the lining of one of the bowl furnaces (bf3). Both occurrences of lead appear to precede the later use of their respective hearths and are unexplained.

Archaeomagnetic samples from the bowl furnaces and the kiln suggest approximately contemporaneous useage in the fifteenth century. It is not possible archaeologically, however, to show that the other industrial features are of the same date. However, the co-ordinated layout of the area suggests they are mainly or all part of the same system. There is some evidence for a relative chronology with several bowl furnaces and hearth bases being replaced from time to time. Both the kiln and several of the bowl furnaces predate lean-to structures.

The lead and copper working on the site may have been contemporary or successive. Certainly no clear evidence has yet emerged for what was being produced. The large scale and duplication of features suggest a factory rather than a maintenance workshop, although conceivably the latter could be a secondary function. The fifteenth century date, a period of contraction in the abbey's economy, also militates against it being workshop for the abbey's own needs. If the site was a manufactory, a ready outlet was certainly available via the River Wye to Bristol with which the abbey had strong trade links due to its wool production[7].

Notes and References

1 Due to cutbacks no excavations took place in 1981 but it is hoped to complete the site in 1982.

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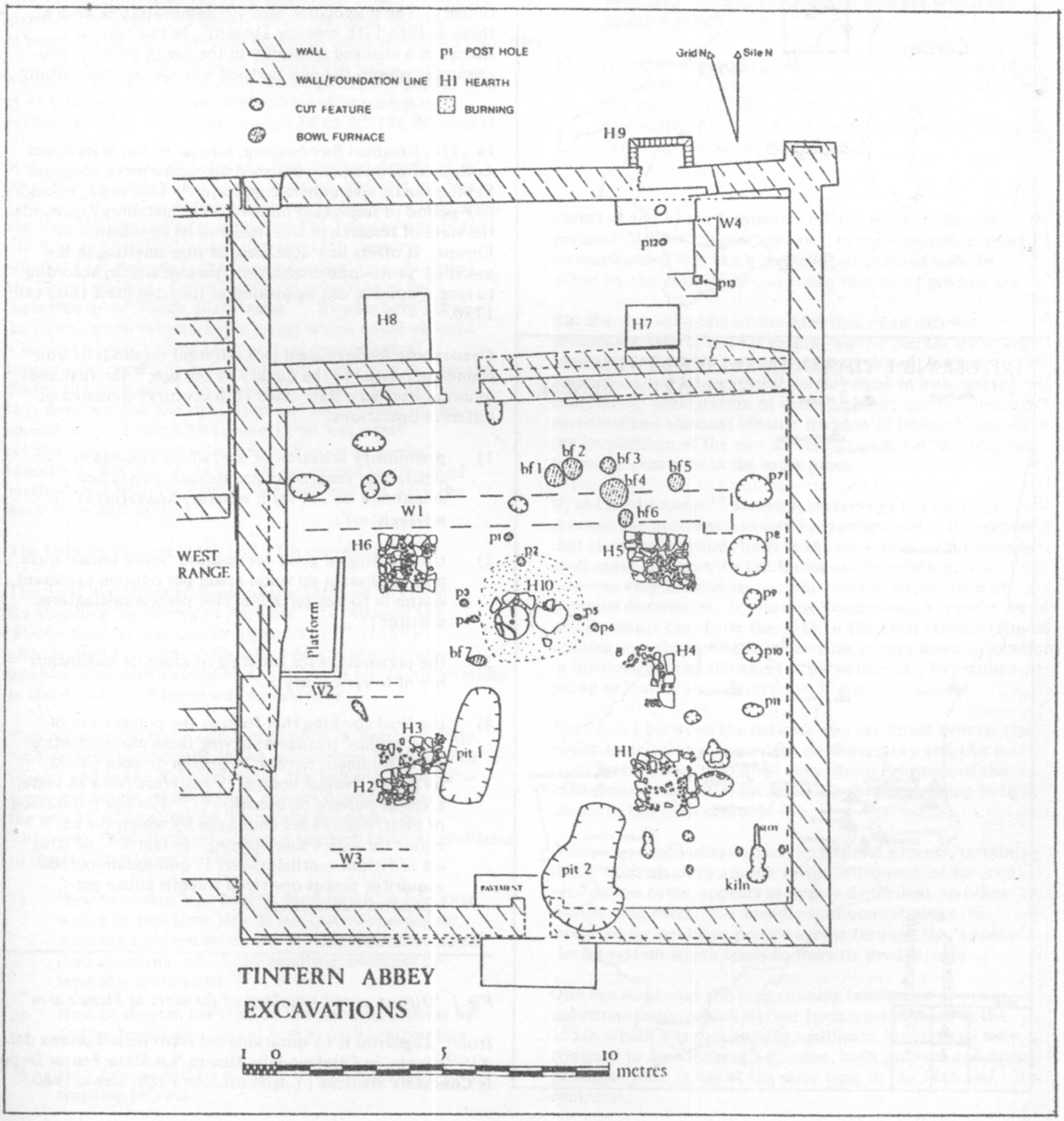
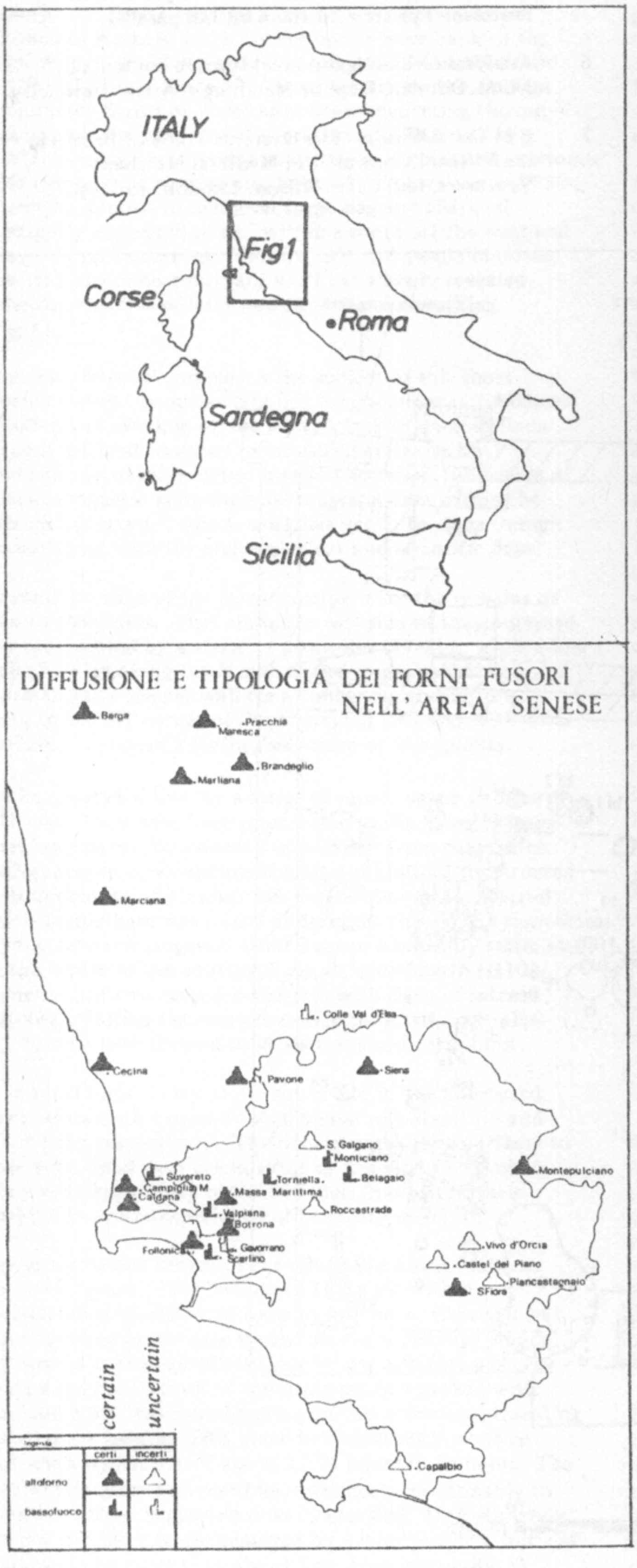


TINTERN ABBEY EXCAVATIONS

Swedenborg and ironfounding in Italy

Roberta Morelli



Abstract

The indirect method of iron founding was one of the most revolutionary discoveries in technology in Pre-industrial times. First adopted in Germany and then in Italy it changed radically the way of reducing refractory ironstone and obtaining cast iron. But the application of the new method mostly depended on economic rather than technological factors (such as the quality of ore) as E Swedenborg affirmed at the beginning of the 18th century. The microcosm used for demonstrating such a thesis is 16th-17th century Tuscany. In this region, thanks to a changed mentality in the use of political and economic power, the new method was applied successfully.

In 1734, Emanuel Swedenborg, scholar of the Metallicum Collegium in Sweden, published his masterpiece 'Regnum Subterraneum sive minerale de ferro'.[1] This work, belonging to a period of important discoveries in metallurgy, presents the state of research in this field and its application in Europe. It offers us a synthesis of iron smelting in the so-called 'proto-industrialization' period, which, according to recent opinion can be located in Italy between 1500 and 1750.[2]

Swedenborg distinguished two different methods of iron founding, related to the quality of the ore;[3] the first one, in use in Northern Italy since 16th century, consisted of different operations:

1) preliminary selection of ore, which consists in separating 'vena(m) bonae indolis, qua(e) non sulphurata est . . . from vena(m) Rozza(m) et selvaggia(m)';

2) the smelting of good ore because 'venae bonae, quae non sulphurata est quod etiam per odorem explorant, statim in focum ferrarium sine praevia calcinatione mittitur';

3) the preparation for smelting of sands or 'calcinanda' ore of lower quality;

4) the final smelting that follows the preparation of 'cannecchio' (furnaces) having these characteristics: 'ad altitudinem circiter 24 pedum ex saxo scilissi, tel gsteen Svevice vocatur . . . mixtura facta ex creta, arena et pulvere carbonario . . .'[4] For the production of blast, bellows are employed by which the air enters through a side opening. In fact '. . . ad latus est orificium ventilatorium . . . quibusdam in locis acquiritur ventus ope rivuli fluentis aquae per siphonem aut canalem . . .'[5]

Fig 1 'Diffusion and typology of furnaces in Siena's area'

from: **Tognarini I, La questione del ferro nella Toscana del XVI° secolo, in Catalogodella Mostra 'Lo Stato Senese Dopo le Conquiste Medicee', Luglio-ottobre 1980, Siena, 1980.**

The most important stage of this kind of iron founding is, of course, the final one wholly entrusted to the experience of a master **Fonditore** who 'per orificium ventilatorium inspiciens animadvertit liquefactam bene esse venam et scoriis undique contectam . . .'[6] The product of this smelting is cast iron (**ferraccio**) employed for ammunition, accoutrements and other weapons and, if refined, for civil purposes.

The second process is the method of iron smelting illustrated by Swedenborg, and ascribed to blast furnaces in Tuscany or in the territory close to Rome – 'alias quum a Roma Florentiam peragitur iter' – consisted of a single operation. The ore 'illius indolis est, ut non calcinata statim mittatur in focum, scilicet cum prius ope malleorum pulverisata sit; illico, ut in focum delata est funditur',[7] (ie the ore is introduced into the high furnace without previous calcination). The first smelting cycle, according to Swedenborg (ore to cast iron) does not take more than 4 hours 'qualibet quarta hora massa ferri liquati parata est, quae vocatur et ponderis est 1 et ½ centum pondii (a centum = 33.333 pounds) . . .' but the refining phase, to obtain pure iron '. . . ut eo melius in fluiditatem quandam reduci possit et liquefiat vena et ex ferro eo melius separetur scoriae et impuritates' is accomplished in 'spatio septimanae 36 ad 40' (36-40 weeks).[8]

It is easy to understand that the first method described by Swedenborg corresponds to the so-called 'indirect process' (ore → cast iron → pure iron), in use in Northern Italy since the Renaissance and later introduced in Tuscany and in the other areas of Italy starting from the 16th century; while the second one is the 'direct process' (ore < iron), the oldest method of iron founding, otherwise called 'bassofuoco' or 'fuoco allacatalana'.[9] Swedenborg's text, however, contains remarkable errors which could obscure a correct understanding of important technological innovations occurring in Central Italy, especially in Tuscany, during the 16th and 17th centuries. In fact, Swedenborg's text does not give the right degree of importance to the second method (the high furnace) that was a real revolutionary method of iron founding up to Darby's invention. But this is not all. He connects the choice of method only with the kind of ore used and not with the basic economic factors.

The Indirect Process (16th and 17th centuries)

The most important treatises of the 16th century, 'De Re Metallica' by Georgius Agricola[10] (1540) and the 'Pirotechnia' by Vannuccio Biringuccio [11] (1558) give the first technical explanation of a new method of smelting iron which could be applied with satisfactory results in the direction of increased productivity.

Conceived in Germany and first applied in Northern Italy (in Lombardia, especially in the area around Bergamo and Brescia and in the Val Camonica), the indirect 'process' – more commonly referred to in ancient documents as the process of smelting by 'forno alla bresciana' or 'altoforno' (high furnace) – gives a solution to some problems of pre-industrial iron working:

1) How to obtain high quality production, ie iron that would be free from slag 'le sue cattive compagnie, quali col fondersi insieme si fan con esso inseparabili' (bad company, which, by smelting, becomes inseparable from iron).[12]

2) How to shorten the time of the smelting process by casting large quantities of iron at high temperature.

3) How to save fuel by giving a certain continuity to the smelting process.

The furnace required for the first stage of the indirect process is provided, following Biringuccio, with 'un gran paio di mantici a guisa d'un gran paio d'ale che, per altezza, sono dalle 6 alle 8 braccia' (a big pair of blowers in the shape of a pair of wings 6 to 8 yards long)[13], usually moved by water but sometimes helped, as those illustrated by Leonardo da Vinci in 'Codice Atlantico' a century before, by mechanical instruments ('palo bilacato') or by pneumo-hydraulic pumps.[14]

The employment of this kind of furnace requires two lots of preconditions:

a) from the technical point of view – as Swedenborg well indicated – it is possible to smelt by the 'forno ala bresciana' method that kind of iron ore which can assure a good return;

b) from the economic point of view, the setting up of a new type of furnace needs a large investment absorbed not only by the cost of the furnace itself but, essentially, by the cost of the skilled labour employed in the construction.

Points a) and b) are frequently related in the Italian experience (16th-17th century) and, in the long run, it must be emphasised that the high initial costs could only be offset by the constantly increasing volume of production.

But the consequences of the adoption of an indirect process are several and far ranging on the market structure (demand and supply, price trends and so on); on the organization of labour (total employment in iron making complexes; immigration of skilled labour; employment of part-time and seasonal labour; division of labour); and on the localisation of the new structures and their holding out for many centuries in the same place.

If, as David Landes[15] assumes, metallurgy is a chemical process, the problem is mineral reduction and if it is proved that the turning point, both in the economic and technological sense, occurs with the Industrial Revolution, it is however very misleading to minimize the importance of previous discoveries. By reading Swedenborg's treatise we could assume that from the 15th to the 18th century, almost nothing was changed in iron smelting except some innovations in instruments and blowers (introduction of a hydraulic pump in 'bassofuoco') since the 1740s.[16]

The choice between the indirect and the direct process also appears exclusively dependent on ore quality and this is, from Swedenborg's point of view, the main cause of the existence of two different methods of iron smelting both in use since the 18th century.

Otherwise the application of the indirect process, certainly the first satisfactory answer to the bottleneck of the iron production cycle, appears as largely dependent on other factors, and often on a specific economic strategy, introduced by public or private agents through the 'appalto' (lease) system which tends to increase productivity.

One can single out the long running tendencies of proto-industrialization which started from a microcosm in the 1550s which was particularly significant in Italy and where, contrary to Swedenborg's opinion, both indirect and direct processes were in use at the same time in the 16th and 17th centuries.

Iron Founding in Tuscany in the 16th-17th Century

Tuscany is considered by 16th century authors to be one of the most important productive areas for cast iron, wrought iron and steel. An anonymous 17th century observer [17], notes that Tuscany, in spite of the vast destruction of wooded areas that occurred through the centuries, was an ideal place for location of iron founding works. In particular Follonica and the Maremma's district was '. . . in buona posizione, proprio in fronte alle miniere di Rio, circondata da gran foreste, dotata di una ricca e copiosa caduta d'acqua' (in good position, close to Rio's iron mines, surrounded by big forests, provided with a rich waterfall).

Biringuccio emphasised the quantity and quality of Tuscan ores. From the quantity point of view he declared: [18] '. . . e opinion di molti che fra certo tempo in quel terreno che gia si cavo di nuovo vi si regeneri, che veramente se fosse vero sarebbe gran cosa vi si mostrerebbe una gran disposition di natura o un gran potere de' cieli' (it is common opinion that some Tuscan mines are so rich that once exploited, new iron ores grow in the course of time, due either to Nature's goodwill, or to Heaven's disposition).

From the quality point of view, he stressed: [19] 'questa minera (e) di tal natura che per istraerne il ferro e ridurlo a purita non e soggetta sala potenza di violenti fuochi o de' molti ingengni o di straordinarie fatiche' (this ore is so good in quality that neither strong fire, nor high skill, nor extraordinary efforts are needed for smelting).

This was due to the natural environment. But Biringuccio's description makes no mention of the substantial political and economic changes occurring at the time. The documents contained in the **Magona** series (now collected in the Archivio di Stato di Firenze) indicate that, since Cosimo I's time, a new economic policy was adopted, giving more attention to the control and exploitation of internal resources both in mining and in the treatment of minerals.

Cosimo's ultimate aim was total control of the market, especially that of iron and other minerals. '17 marzo 1542. Il Magnifico Messer Giovanni Antonio Alato da Arcoli, dottore di legge, secretario e procuratore et come procuratore et in procuratorio nome delle Ill.mo Signor Jacopo Quinto di Aragona e di Appiano Signore di Piombino . . . ha venduto et per titulo di venditione consegnare promesse allo Ill.mo et Excell.mo Signore Duca Cosimo de' Medici, Duca di Fiorenza . . . tutta quella quantita di vena di ferro della Insula dell'Elba del prefato Signor di Piombino . . . per consumo di tutte le Maone dove si possa lavorare et fabricare ferro . . .' (on March 17, 1542, Sir Giovanni Angonio Alat . . ., secretary and in his capacity as representative of the distinguished Gentleman, Jacopo Salviati, Prince of Aragona and Appiano, Prince of Piombino, sold and promised to deliver to Cosimo de Medici, Duke of Florence . . . all the quantity of iron ore produced on Elba Island, belonging to the Prince of Piombino, to be used by Magone, where such operations could be made).[20]

Cosimo's new projects based either on the re-utilization of old structures or in the building up of new workshops were directed from Florence in all the parts of Tuscany, such as in the mountains near Pistoia where in 1550 the iron ore, coming from Elba, reached the Port of Signa, 'durante le invernate quando l'aqua d'Arno e navigabile' (during the winter, when the Arno is navigable)[21]; or Pietrasanta where a new high furnace was built at that time.[22]

The spreading of different techniques of iron founding from Florence into several areas of Tuscany, from 1550 to 1650 is characterized by the simultaneous existence of two different methods of production. As we can see in the map (Fig 1) in Maremma the same area in Southern Tuscany, we find four 'bassofuochi' and nine 'altofuochi'.

The coexistence of two different methods of iron founding – the traditional one (bassofuoco) and the innovative one (altofuoco) – is not caused by accidental or locational factors.

First of all, it does not depend exclusively on the quality of the ore: the iron ores used in 'bassofuochi' or 'altofuochi' in Tuscany all come from Elba Island which until the beginning of mature industrialization in the 19th century was the most important centre of production of ore in Italy.[23]

But it does not depend either on environmental factors. If it is of fundamental importance for iron works 'before Darby' to be located near energy resources, the system of water and fire (rivers, waterfalls and forests) holds for both systems.

Finally, it was not due to the need for a high degree of dependency on imported technology, either at the initial or at the subsequent stages of the productive process. The 'altofuoco' system was well-known in Tuscany thanks to a substantial migratory flow of skilled labour from Northern Italy. This was, of course, the traditional vehicle of diffusion of technology in a pre-industrial world.[24] Technicians and 'maestri' who reached Tuscany and Central Italy were often provided with a specific work contract. This is the case of: 'Maestro Giovanni, figlio di Maestro Faustino de' Tombonari, da Gardone di Saretto da Brescia' charged with the building up of a new furnace 'alla bresciana' for iron founding and for converting cast iron into steel in works located 'nella Montagna di Pistoia, in localita Pracchia, vicino al fiume Reno . . . (un forno) simile a quello construito per il Duca di Fyrrara in Garfagnana' (in the mountains of Pistoia, in the place called Pracchia near the Reno river . . . a furnace similar to the one built in Garfagnana for the Duke of Ferrara).[25] Should further problems arise, a solution could easily be found In June 1637, the Ambassador Ser Finaldi thus writes to the Granduca of Tuscany: 'Si e scoperto in questa montagna una miniera di ferro et S.E. ha mandato a pigliar certi bresciani della professione per far riconoscere et l'hanno trovata buonissima sono stati da me a dirmi che sentendo che il Serenissimo Padrone ne ha una che non resiste al maglio, cosi si offeriscono a farla diventare buonissima e con questa mando la memoria che ne hanno dato. Desiderano Angonio Rambaldino et Pietro Joannis da Bresca che V.E. Ill.mo ma scriva a Fiorenza quanto appresso per il discorso che sue fatto . . . per conto del negozio del ferro . . onde detti bresciani si offeriscono con lor virtu di dare lumi e ordini bastanti per far detto ferro venga ad essere perfezionato . . .' (We found an iron mine in this mountain and His Excellency sent some experienced people coming from Brescia to test it and they found it of best quality. They told me that as His Excellency has some ore which is not rich enough to be worked by the helve . . . they offer their help to improve it . . . and with this letter I send His Majesty this memorandum: 'Antonio Rambaldino and Pietro Giovanni da Brescia offer to enlighten and instruct so as to make this ore as perfect as possible').[26]

Again, this shows that the mobility of skilled labour makes for a flexible supply of technology.

Constant and Variable Capital

We can synthesize the development of iron working in Tuscany during the 16th and 17th centuries adopting a **Bipolar Pattern** below:

Bassofuoco	Altofuoco
Low degree of productivity	High degree of productivity
Low degree of investment	High degree of investment
Small scale production	Large scale production
Location of production changing with the availability of resources	Fixed location

Obviously the above scheme should not be interpreted as an order of priority between the two methods – as Swedenborg seems to imply when he tries to establish a comparison in a rather ambiguous fashion.

It is widely accepted that the new method – the high furnace – represents a decisive step, a real turning point in technology. But it should be explained why the introduction of such a radical innovation was not extended in the long run to all other geographical areas and iron works. In Liguria, for instance, two centuries later – at the beginning of the English Industrial Revolution – the two methods still coexisted.[26]

What Swedenborg considered as a 'natural' development, totally dependent on technical factors is, on the contrary, the effect of a pre-meditated choice adopted by some economic operators.

It would also appear as highly misleading to contrast a feudal, static, traditional approach tied to techniques inherited from the past to an innovative, dynamic, schumpeterian entrepreneurship such as that offered by the Medici family in this period.

It was, above all, the changed relationship between constant and variable capital that allowed the simultaneous presence of the two different methods of production each tied to a different market structure.[27]

The amount of constant capital needed for the 'bassofuoco' was extremely limited, given the low degree of technology, while the building of an 'altofuoco' implied from the start a much more sizeable investment.

The terms of the problems are presented by an anonymous writer in this letter to the Granduca: 'Occorreci per conto della Magona ridurre e memoria a VS.Ecc.a . . . che bisognava tenere il corpo fermo in detta Magona circa 12.000 scudi Anchora si disse che havendosi a fare nuovi edifizii bisogneria che V.Ecc.Ill.ma provvedessi el danaio atteso non essere mobile a sufficientia di far muraglie . . . Questo anno si fa la forno di Campiglia per V.Ecc.Ill. 350 in 400.000 palle imprteranno 3500 in 4000 scudi et la muraglia de forni et ferrier di Pietrasanta importera qualche 2000 scudi in 2500 in modo che queste due partite importeranno scudi 6000 che cavandola dalla magona non e possibile si possa far camminare detto negozio perche rimarra come in secca' (I must remind you that it is necessary to keep available money capital of about 12,000 scudi . . . and as we must build up new works, we need a proper amount of liquid resources for the walls. This year at the Campiglia's furnace 350,000 to 400,000 cannon balls will be produced at a cost of 3500 to 4000 scudi . . . and the walls of the high furnace and iron works of Pietrasanta will need an additional expense of about 2000 to 2500 scudi. These two items of the balance sheet . . . will amount to 6000 scudi and if we take the money out of current account, it will be impossible to run it as it will be left totally dry).[28]

Giving up the implementation of the high furnace was thus probably less the effect of a free choice originated by a blind conservatism, than a result of scarcity of finance.

Small, isolated operators are the first victims of this process of adaptation to the new technology. This happened in the case, for instance, of Giovanni di Lionardo dell'Antella, who, in 1549, closed his iron works 'nei pressi di Firenze perche non ne fece guadagnio alcuno . . . il fuoco e le acque consumorno tutto . . . chiuse tal impresa . . . essendo ancora debitore di 364 scudi' (located close to Florence . . . because he did not earn any profit . . . fuel and water consumed all (his) money and (he) gave up such an enterprise . . . still being debtor of 364 scudi).[29] If these were the differences in the technical and financial characteristics of the two methods the effects they have on market structure and on the overall economy also differ greatly.

The 'bassofuoco' system is not run on a continuous cycle of production. It was demand and its changes in the short run that determined the rhythm of production. This is apparent in war time when the demand of ammunitions causes an increase in quantity produced.[30]

In contrast, the 'altofuoco' system, to be economically viable, needs a continuous production cycle, so as to compensate for the high initial investment and the sizeable costs of running the works due to the large quantities of iron ore and charcoal needed for each production cycle.

Supply, rather than demand, becomes paramount here. The degree of market penetration is much higher than in the 'bassofuoco'. This is accompanied, in 17th century Tuscany, by a process of concentration of big firms producing for the whole market – Follonica in Maremma being the largest one. The Follonica cast iron production-- calculated approximately as 1/20 of total English production in the same period as estimated by Charles Wilson[31] – was largely destined for the iron works in Northern (Liguria), Central (Stato Pontificio) and Southern Italy (Calabria).[32]

Swedenborg and the other 18th century writers on iron metallurgy, such as Giovanni Arduino or Ermenegildo Pini offer to the reader a systematic approach to the iron working area in Europe up to the Industrial Revolution.[33] At that time, the future leader of economic development was in certain areas rapidly changing in a revolutionary way, while in other countries it was visibly characterized by stagnation or crisis. According to Swedenborg's opinion, Europe appears to be divided into two parts and the boundary between underdevelopment and development goes through Northern Italy. England, Germany, Sweden and Lombardia have accomplished the preconditions of development and the iron industry is organized on a factory system; in contrast, Central and Southern Italy and other Mediterranean regions are going on using the old methods of production.

The difference between the two areas is tied to the application of the high furnace, and Swedenborg affirms that the real cause of development in iron founding must be attributed to the new technology.

But technology itself could not be responsible for a long-running economic trend; technology – particularly the invention of the high furnace – is only responding to the most important problems of iron founding (lack of increase of production – continuity of productive cycle). The application depends upon financial strategies and the capital and is from available documents the only discriminating factor, in terms of quantity of investment needed and in terms of uncertain return, that marked the first experiments done in England, in Italy or in Germany from 16th to 18th century. Dudley summarizes a long series of doubts and discoveries in these terms: '. . . (the problem is) not only how to make a greater quantity of iron but also how to extract more iron . . .'[34]

From this point of view, the real boundary between the developed and underdeveloped areas is – contrary to Swedenborg's idea – internal to single sections of a nation.

Documentary proofs and remains scattered in the territory of Tuscany testify to the presence of two methods of production, that is to say of two economic policies of iron working, of different structures of market (self-consumption and the export market).

In this microcosm, particularly significant for iron working in the pre-industrial world, two ways of working and producing, both depending upon different employment of capital, occur at the same time. The contradictions of microcosmic Tuscany are witness to a long, discontinuous and disconnected *iter* in industrial development.

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For Biography of Roberta Morelli, see page 38.

The production of wrought iron in Finery Hearths
Part 2: Survey of remains

Alex den Ouden

Several sites exist in Europe, where remains of the hearth fining methods described previously can still be seen and studied. Of course, the remains are of varying importance, ranging from integrated, fully restored forges to exhibits of equipment. In this survey only the most important sites in the author's view are included; so omissions are to be expected!

Waterhammers and their technology form a trade in themselves, closely related to mill-wrighting. The development of the several types of waterhammers is closely bound to the evolution of the forges, but no tie exists between the type of forge, eg Walloon, German, etc and the specific type of hammer used in that forge[1]. Information on remaining waterhammers is condensed into a separate paragraph, which offers just some examples of the various types that have been used in forges producing wrought iron and steel.

The German forge

In Sweden several sites with important remains of German forges exist.

The old forge at *Havla*[2] was modernized in 1799 and in 1809. It then comprised a German hearth, two belly helve hammers and a Widholm blowing engine[3]. In the 1850s the forge was adapted to the Franche-Comté method by altering the hearth and a new – Bagge – blowing engine was installed. In 1883 two Lancashire hearths were added and the Franche-Comté (formerly German) hearth was modified again to become a chafery hearth. (Lancashire forge type 3). The exterior of the forge was at that time changed radically by the addition of a mechanical workshop and a new sparkchamber and chimney for the Lancashire hearths. Still later, the Lancashire hearths were fitted with Lagerwall rabbling devices, driven by the blowing engine waterwheel. The forge was blown down in 1924. It has been restored and now contains one Lancashire hearth with Lagerwall device; two hammers; one hearth reconstructed as a German hearth; the Bagge blowing engine and all fittings from the last period of operation.

At Riddarhyttan, at the site of an old copper smelting works, an 1820 Widholm blowing engine remains.

The forge at *Angelsberg* was built in 1840 as a German forge with two hearths, two belly helve hammers and a Bagge blowing engine[4]. In 1856 in this forge too, the Franche-Comté process was adopted by changing the hearths. In the 1880s two Lancashire hearths were built to replace these. The rest of the equipment of the forge was not changed. No chafery was built (Lancashire forge type 2). The original chimney was altered by addition of a sparkchamber at its foot. The forge was blown down early in the 20th century; it has been restored to its last working condition. Its lay-out and exterior are very typical of a Swedish German forge – where one imagines the Lancashire hearths were replaced by German hearths.

So, although no integral Swedish German forge remains, one can construct a creditable picture of a typical Swedish German forge from the period 1800 and 1850 from these sites.

In Germany, the situation is less clear-cut. The puddling process caused a fundamental change in the factors determining the suitability of a site for a forge[5]. Most of the old localities would no longer do for production of wrought iron. The German forge in Germany always was rather strongly diversified, not only producing iron, but also working it into tools for customers in the neighbourhood. So, in the 1830s, many of the old German forges specialized in forging work, buying their iron from puddling forges. This, coupled with the need for efficiency, resulted in changes in the forge, obliterating the typical iron production function.

In Western-Germany, at *Lendringsen*, a forge remains with one German type hearth, two general forging hearths and one belly helve hammer with its waterwheel. No bellows nor blowing engine remain.

In Eastern-Germany, near *Annaberg-Buchholz*, the Frohnauer hammer stands fully restored. It has one hearth with a set of bellows and a tilt of three tail helve hammers.

It is difficult to determine in how far the hearth construction is typical for a German forge of this type dated to around 1800 and 1750, respectively.

In Austria, no integrated German forge remain. In the technical museum at *Wien* an interior of a forge dating back to the 'Stuckofen'-era[6], ie to before 1750, is reconstructed from original equipment. The forge has a German hearth with tools; no bellows nor blowing engine[7]; but a single tail helve hammer with its waterwheel missing. The set-up is typical of a German forge fining and faggotting steel and wrought iron from 'Massl' and 'Kraglach'[6].

In the 'Eisenmuseum' at *Steyr* the interior of a scythe-smithy of the same period is reconstructed from original equipment. In such a smithy at least one German hearth was present, used mainly for faggotting of steel, but occasionally also for fining[8]. The smithy at Steyr contains one German hearth with two sets of single bellows. The bellows-drive mechanism is present – its waterwheel is missing. There is a tail helve hammer used for faggotting also without its waterwheel. The smithy also contains several hearths, a second waterhammer, and various other pieces of equipment related to scythe-making.

In the period shortly after 1750 the 'Stuckofen' were replaced by blast furnaces. At first 'Deutschhammer' were built. These combined a blast furnace with two German hearths[9] under one roof.

At *Kendlbruck*, some remains of such a works can be seen. The forge was started in 1756 and was finally laid down in 1830 – although some rebuilding took place in 1838[10]. The remains comprise the blast furnace body complete with stack lining and a large chimney on top of the blast furnace; several walls from which a general lay-out can be reconstructed and the common chimney of two 'side-to-side' German hearths. No hammer or watercourses remain, however. The hearths are just empty shells without any detail.

From about 1775, blast furnaces and fineries were generally built separate, due to the scarcity of charcoal [11] No example of a separate finery which is usually larger, remains in Austria.

The Walloon forge

Relatively few remains of the Walloon process can now be studied on site.

In Belgium, at *Saint Hubert*, a small 'affinerie' or forge can be seen. It is part of a small-scale charcoal blast furnace complex, built 1768 and in use up to 1830 with many interruptions. The forge building is restored, but no interior remains.

At *Liège*, original equipment from Walloon forges is shown in the 'Musée du Fer et du Charbon' Exhibited are: a finery hearth and a chafery hearth, both with two sets of bellows. The driving arrangements for the bellows as well as the pig iron supply are missing. The hearths date from the last quarter of the 18th century. Also a 17th century belly helve shingling hammer and a 19th century belly helve drawing hammer are shown. From these two sites a creditable picture of a typical Walloon forge can be composed.

At *Osterby*, Sweden, the famous 'Double Bullet' Walloon forge has been fully restored. The Walloon method was introduced at Osterby in 1627[12]. The forge underwent a major modernization in 1794 and was finally blown out in 1906[13]. It has been restored to the situation existing after 1837, when a new Bagge blowing engine was installed, and now comprises a complete finery hearth with pig iron supply; a chafery hearth; a belly helve hammer and the Bagge blowing engine both with their waterwheels; the 'labbit' or smiths' dwelling and the charcoal storage shed.

The Swedish Lancashire forges

In Sweden quite a number of Lancashire forges remain. Those at *Angelsberg* and *Havla*, mentioned in the paragraph on German forges, are representative of the types 2 and 3, respectively. But of the large scale forges several fully restored examples can also be studied.

At *Korsa*, some remains of a type 4 forge are exhibited on site. These comprise a Lancashire hearth; a gas producer and condenser of a Lundin regenerative reheating furnace (ca 1860)[14] The remains are isolated exhibits from several periods in the life of the forge (1860 - 1930). It takes some imagination to form a general picture from these; too much is missing. Unique however is the extensive collection of tools.

A similar forge, in this case completely restored, can be seen at *Stromsberg*. Three Lancashire hearths with waterdriven Lagerwall rabbling devices; a nose helve shingling hammer and an Ekman *charcoal* reheating furnace are combined with one belly helve waterhammer; one large and two small steam hammers for bar drawing and finishing. Steam is generated by waste gas boilers fed with combustion gases from the Lancashire hearths. This forge represents the transition from type 4 to 5. In this form the forge operated from 1902 to 1920.

A type 5 Lancashire forge is sited at *Karlholm*. This has six Lancashire hearths with two waste gas boilers and steam engine driven Lagerwall rabbling devices; a nose helve shingling hammer; a two-stand two-high rolling mill (roughing and rough bar; with waterturbine); a *charcoal* fired Ekman reheating furnace; two belly helve waterhammers and two steam hammers for bar drawing and finishing. No blowing engine remains. The forge was newly built 1880[15]. and blown out in 1931. It has been restored to its last working condition.

No type 6 *Lancashire* forge is to be found in Sweden. Equipment of the type 6 *puddling* forge however is collected in the museum at *Surahammar* – although not in situ. It has a complete collection with a wood fired puddling furnace with waste heat boiler; a nose helve shingling hammer; a *wood* fired Ekman reheating furnace; a three-stand two-high rolling mill (for roughing and railway wheeltyres); two three-high medium mills; a four-stand small section mill; tools and a Bagge blowing engine. The exhibits are not shown in their original lay-out. They generally date from the period 1860 - 1880.

Apart from the puddling forge equipment a Lancashire hearth with Lagerwall rabbling device has also been re-erected at *Surahammar*. At *Munkfors*, in the fully restored open hearth shop there, a further two Lancashire hearths are shown as isolated exhibits.

Hammers

Waterhammers are divided according to their mode of operation into tail, belly and nose helve types. A battery of several tail helve hammers driven from one waterwheel via one shaft is called a 'tilt'. Belly helve and nose helve hammers only existed in single types, ie each hammer had its own waterwheel.

	site	number	waterwheel	appr date
Tail Helves				
single	Steyr, A	2	no	1750
	Wien, A	1	no	1750
	Hasloch, W-G	2	yes	1800
tilt with 2 hammers	Rotz, W-G	1	yes	?
tilt with 3 hammers	Annaberg-Buchholz, E-G	1	yes	1750
	Theuern, W-G	1	yes	1850
Belly Helves				
specifically shingling	Liège, B	1	no	17th c
	Havla, S	1	yes	1830
	Angelsberg, S	1	yes	1840
specifically drawing	Karlholm, S	1	yes	1750
	Stromsberg, S	1	yes	1750?
	Havla, S	1	yes	1799
	Karlholm, S	1	yes	1800?
	Angelsberg, S	1	yes	1840
	Korsa, S	3	yes	1860
	Liège, B	1	yes	19th c
	Gimo, S	1	yes	?

general purpose	Lendringsen, W-G	1	yes	18th c
	Osterby, S	1	yes	1794
Nose Helves				
specifically shingling	Surahammar, S	1	yes	1845
	Karlholm, S	1	yes	1850
	Korsa, S	1	yes	1860
	Munkfors, S	1	no	1874
	Stromsberg, S	1	yes	1875?
	Ullfors, S	1	no	1875?
	Soderfors, S	1	no	1875?
specifically drawing	Korsa, S	1	yes	1860
Steam Hammers				
	Osterby, S	1		1880
	Karlholm, S	2		1880
	Stromsberg, S	3		1900
	Vikmanshytte, S	1		1900?

Notes and References

NB Sources: Roman numbers refer to items in the bibliography: arabic numbers to pages.

1 The factors determining the choice of hammer are:

a. existing water conditions (flow and drop);

b. power demand, ie scale of operations;

c. type of production, eg exclusively bars for export; mixed production of bars and tools etc.

2 All sites mentioned are shown on the maps included

3 A Widholm blowing engine consists of a vertical wooden frame with 2 or 3 sets of single wooden bellows on top and an iron crankshaft in bearings at the bottom. The engine is powered by a waterwheel.

4 The Bagge blowing engine has a wooden frame. This presumably derives from an older (Widholm?) blowing engine.

5 The main requirements of the old German forge were access to charcoal and waterpower – those of the puddling forge access to coal and transport.

6 In a 'Stuckofen', a loup of steel consistency – with carbon varying throughout the loup – and some liquid pig iron are produced. The former is called 'Massl' or 'Stuck', the latter 'Kraglach' or 'Graglach'. The 'Stuckofen' is charged at the top with alternate layers of charcoal and ore. There is just one tuyere, which from time to time during a melt is reset at a higher level to accommodate the growing loup at the furnace bottom. The loup was dragged out after removal of the tuyere wall. A total cycle took about 20 hrs, of which the effective blowing time was 15 hrs. The maximum weight of the loup was about 1000 kg.

7 Just a blast tube – this leads to the speculation that perhaps the forge was equipped with a Wackler blowing engine. This type of blowing engine is water-wheel driven. It consists of a vertical wooden frame holding an iron crankshaft (2 x 180^{o}) and – on top – 2 square sectioned wooden boxes, the cylinders containing wooden pistons. The cylinders hang in bearings and rock with the lateral movement of the connecting rods. They are double-acting. No windchamber is used.

8 Especially in times of interrupted sales of scythes, etc.

9 Occasionally one. Such works were called 'halbe Hammer'.

10 The site was bought in 1836 to obtain its charcoal rights. Transfer of these was only allowed after bringing back the Kendlbruck plant to working order. The rebuilt Kendlbruck furnace never did actually work.

11 Strict regulation of charcoal production and allocation was necessary and forges and mines and blast furnaces had to be separated by rather long distances: VIII, 148.

12 XXIV, 90.

13 IX, 84.

14 Two nose helve hammers with pitch-back wheels for shingling and drawing; one belly helve hammer with a pitch-back wheel for rough drawing; two belly helve hammers with overshot wheels for drawing and finishing.

15 The Lagerwall rabbling devices were installed at a later date.

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The Author

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Reference maps

1 Korsa
2 Karlholm
3 Stromsberg
4 Soderfors
5 Ullfors
6 Osterby
7 Gimo
8 Vikmanshytte
9 Angelsberg
10 Riddarhyttan
11 Surahammar
12 Munkfors
13 Havla

1 Liège
2 St Hubert

1 Lendringsen
2 Hasloch
3 Theuern
4 Rotz
5 Annaberg-Buchholz

1 Wien
2 Steyr
3 Kendlbruck

Conferences and Reports

Symposium on Early Metallurgy in Cyprus 4000 - 500 BC

The symposium was held at Larnaca in Cyprus during the first week of June. It was sponsored by the Pierides Foundation who have done so much to encourage the arts and sciences in their home town of Larnaca, in collaboration with the Department of Antiquities, Republic of Cyprus.

Its aim was to bring together scholars working actively in the field of early metallurgy of Cyprus and to discuss progress and to integrate the work so as to make its impact upon the archaeometallurgical problems more effective.

The sessions were formally opened in the Municipal Buildings of Larnaca and the opening address was given by Mr George Hadjicostas, Minister of Communications and Works who is responsible for archaeology, followed by welcoming speeches from Mr D Z Pierides, Professor J D Muhly of the University of Pennsylvania Centre for Ancient Metallurgy and by Dr Vassos Karageorghis, Director of Antiquities of Cyprus.

The working sessions started with an introduction to the geology of the mining region by Dr G Constantinou, Director of the Geological Survey Department of Cyprus. This was followed by Dr Weisgerber of the Bochum Mining Museum on early mining methods in Cyprus and the Near East..

Professor George Rapp of the University of Minnesota (Duluth) followed with an account of his latest work on native copper and its characteristics. Professor U Zwicker of Erlangen gave us new results on BA arsenical copper crucible deposits. The two other papers which completed the day's proceedings were more archaeological. The first was by Dr E Peltenburg of the University of Edinburgh and referred to his excavation at Lemba in western Cyprus where some small copper objects were found, dated to the Chalcolithic period and which might have been made of native copper. The second was by Dr Stewart Swiny who is now Director of the Cyprus American Archaeological Research Institute in Nicosia. He talked about his excavation at Phaneromeni near Episkopi which has yielded a large number of copper base artifacts dated from the Chalcolithic period to the LBA and which have been both chemically and metallographically analysed (by two of our members, P Craddock and R F Tylecote) These analyses now provide the largest single group from any Cypriot site.

On the second day R F Tylecote opened a discussion on the state of LBA metallurgy in Cyprus with particular reference to the cities of Enkomi and Kition. As an introduction he gave flow sheets for the smelting of oxidised and sulphuric ores by conventional processes which may have been carried on at the two sites, with comments on the furnaces, fuels and the slags and metals produced. Tamara Stech of the Centre for Ancient Metallurgy, University of Pennsylvania, gave a paper on 'Urban Metallurgy in LBA Cyprus' and discussed the problems of Athienou and Kition. Although much had been said about the possible use of bone ash at the latter site, there was no phosphate in the slags.

Professor Frank Koucky of the College of Wooster, Ohio, put forward his slag classification based on physical appearance. There appeared to be no steady change with time although the use of high manganese fluxes seemed to be Byzantine or medieval in date. These slags had a bluish sheen typical of pyrolusite (MnO_2). The next paper was given by Professor H G Bachmann of Frankfurt who discussed the slags from the LBA site at Hala Sultan Tekke. In view of the pressure on time it was decided to interpose some highly technical sessions in the middle of the afternoon. At one of these Professor Koucky put forward his theory that a great deal of the Cyprus copper production stemmed from the smelting of mixed sulphates (Fe + Cu + Mg) rather than matte smelting of the sulphide. The main objection to this theory seemed to be the 4 million tons of slag. But if the sulphates are sufficiently impure even this quantity of slag might be obtained from sulphates. His main support is, of course, the historical record that often refers to vitriols rather than smelting.

Professor B Rothenberg of the Institute of Mining and Metals in the Biblical World started the evening session with a description of his work in Timna, Israel and Rio Tinto, Spain, pointing out the similarities and differences. He drew attention to the recent finding of tin and copper ingots off the coast near Haifa dated to the 7th century BC and thought that the plano-convex copper ingots might have come from Cyprus and the tin from Spain.

The long-standing French work at Enkomi is now in the hands of Jacques-Claude Courtois of the Mission Archéologique Francaise d'Alasia (Chypre), Centre Nationale de la Recherche Scientifique, who discussed the conclusions from his latest volume on the French excavations. The sessions of the day ended with Professor Paul Astrom of Goteborg University giving us a summary of his excavations at Hala Sultan Tekke on which slag has been found.

On Wednesday we were treated to a conducted tour of two mining sites. The first near Mitsero and the second at Skouriotissa guided by George Constantinou and Frank Koucky followed by a most enjoyable lunch at a restaurant on the north flanks of the Troodos mountains. After a siesta (for some) at the American Institute we were dined by Dr Vassos Karageorghis and Dr Swiny in Nicosia.

Next morning work proceeded as usual with attention now being paid to the metals trade. Dr H Matthaus of the Archäologisches Seminar der Philips-Universitat talked about the evidence of Mycenaean contacts shown by Auniello daggers and cauldrons. In fact all the Aegean bronze working techniques had appeared in Cyprus by the 16th century BC. This was amplified by Professor Spyros Iakovidis of the University of Pennsylvania who mainly discussed weapons and tools.

Dr R S Merrillees, Government of Australia, Foreign Affairs, then talked about Cypriot type LBA metal vases. Professor J D Muhly of the Centre for Ancient Metallurgy, University of Pennsylvania gave a paper on the role of the LBA metals trade in the East Mediterranean. Naturally this was mainly based on the Cap Gelidonya ship wreck and it was pointed out that there must have been many such ships travelling the Mediterranean from the Levant coast to Sardinia. He considered the question of early references to Cyprus and accepted the conclusion that Alasia could be equated with Cyprus.

Dr Fulvia Lo Schiavo of Sassari, Sardinia, opened the evening session with a description of the 10 ox-hide ingots found in Sardinia of which 6 were from Nuraghi. She referred to the large numbers of stone moulds and the mining hammers and chisels. Now that more Myceanaean pottery is recognised on Sardinian sites, trade is clear although not likely to preclude the production of ox-hide ingots in Sardinia itself. She then spoke about the site at Sa Sedda where plano-convex ingots and a casting installation were found.

After, the first speaker on iron, Professor A M Snodgrass of Cambridge University, talked about the beginnings of iron technology in the east Mediterranean. Since Cyprus has plentiful supplies of good iron ores in the gossans, umbers and ochres that overly the pyritic ores it could have been the main supplier of iron to the Levant He emphasised three stages; prestige, use for practical purposes is less than bronze and finally use is greater than bronze. Stage 3 began in the 11th century BC. The speed of development in the various countries was very different with Cyprus having one of the fastest rates of development. The stimulus for this development came from Greece which had fewer ore deposits. This was questioned by Varoufakis.

Dr Vassos Karageorghis, Director of the Department of Antiquities, Cyprus talked about his excavations at Palaeopaphos-Skales and Amathus where tombs yielded large numbers of bronze vessels and bronze bowls of 30 cm dia dated to the 11th century as well as iron swords, daggers and knives. We get bronze swords with riveted iron handles (Snodgrass, Stage 1) and iron knives with ivory handles riveted with silver plated bronze rivets. All this indicates a period of prosperity in the 11th century BC.

On Friday we saw mining and smelting sites in the Kalavassos region and archaeological sites at Lemba and Paphos. To sustain us we visited a winery at Limassol and were royally entertained by the Cyprus Tourist Organisation at Paphos and Limassol.

On Saturday we returned to our seats at the conference tables where the discussion on iron continued. Professor R Maddin of the Centre for Ancient Metallurgy, University of Pennsylvania, opened with his paper on iron metallurgy in Cyprus. Since so much of the iron is totally rusted it is fortunate to find residual metal and much work has gone into developing structures in the rust. The main problem is to decide whether the residual steel is intentional carburization or the normal degree of carburization that we get in the bloomery process. Naturally, evidence of heat treatment will lie in the outer layers which are the first to corrode. But we do have evidence of martensite in some of the Cypriot steel as early as the 10th century BC giving hardnesses as high as 385 HV. The pick-axe from Israel dated to the 10-11th century had less than a 2mm thick corrosion layer and the surface consisted of tempered martensite with a hardness of 550 HV. He cited many other examples from Idalion, Lapithos and Kition all of which had been carburized and some had been quenched.

The next speaker was Dr G Varoufakis of the Athens Steel Works, well known to many of our members, who spoke about the early introduction of iron in Greece (17th-14th century BC) for finger rings. Analysis has shown that many of these contain 2-10% Ni, sometimes with 2% Co. They are now almost totally rusted, but like the Scandinavian and Polish nickeliferous iron it is not thought that these were made from meteoric iron. Since Greece has a deposit of nickeliferous laterite he smelted some of this and produced a small amount of iron with a similar nickel content. By the 12th century the nickel disappears from the artifacts so other ores were used, possibly from Cyprus or Crete, as phosphorus is now present in considerable quantities.

We heard more on the archaeology of bi-metallic objects from Dr Jane Waldbaum of the University of Wisconsin (Milwaukee) who referred to parallels in other areas of the Near East and recommended caution in accepting Cyprus as a source of the bi-metallic knives.

The day ended with Professor Constantin Conophagos, the author of the latest book on 'Le Laurium Antique' soon to be reviewed in these pages, who talked about his excavations at Laurion on lead dressing and smelting. He had also found iron-bearing 'furnace bottoms' of slag which were either by-products of lead smelting or the product of iron smelting. The lead ores of Laurion contain some gossans which could have been the source of the iron.

The symposium ended with short reports summarizing some of the important conclusions and the lines along which further work should be taken. One is under no doubt that Cyprus was the main supplier of copper in the East Mediterranean world from the LBA to the Byzantine period, but how this was made is still an open question.

The full account of this most interesting symposium will be published by the Department of Antiquities of Cyprus in the summer of 1982.

R F Tylecote

Book reviews

The Coming of the Age of Iron. Edited by Theodore A Wertime and James D Muhly. *Yale University Press. New Haven and London, 1980. 555 pages. Various illustrations and tables. Price $ 27.50.*

This substantial volume of over 500 pages has been written by fourteen authors expert in their various fields, it is packed with both technological and archaeological information. Within space limitations a review is not so easy, but some idea may be given of the major contents.

Chapter 1. The Pyrotechnologic Background. By Theodore A Wertime. In this first chapter Dr Wertime presents his views of the coming of the Iron Age. His discussion is wide ranging and considerable use is made of classical references. Wertime remarks that iron first became known to man in very low carbon form, accidently discovered in the guise of furnace slags or bears, occasionally produced in copper or lead. But, in view of the thousands of years of pre-iron copper smelting perhaps the discovery owed more to experiment than to accident. Chapter 2. The Bronze Age Setting. By James D Muhly, is a valuable and clearly written chapter with the advantage that it can be read with equal ease by archaeologists and metallurgists. Muhly discusses the high development in metallurgical technology during the 3rd millennium BC, and points out that in spite of much recent literature to the contrary there is still a good case to be made for the primacy of the Ancient Near East. Concerning the diffusion, or otherwise of metallurgy in the 3rd millennium BC, archaeologists could well ponder the statement, page 30, that much present-day antidiffusionist scholarship seems to imply that nobody ever went anywhere during the Bronze Age! The author also deals with the enigma of the tin trade, and the transition from Bronze to Iron.

In Chapter 3, Jane C Waldbaum writes on the First Archaeological Appearance of Iron and the Transition to the Iron Age. As a guide to the known finds she gives a number of helpful tables. Table 3.1 lists meteoric and smelted iron before c 3000 BC from the Near East and Eastern Mediterranean, a total of some 14 objects. For the Early Bronze Age table 3.2 shows some 22 objects, while for the Middle Bronze Age the total drops to only 8 (table 3.3). As we should expect, by the Late Bronze Age, c 1600-1200 BC, the number of finds much increases to a total of 74.

These figures are interesting, but of course depend upon excavations recorded up to the present time. Future excavation will certainly cause modification of the totals for the various periods. Of the general drop to only 8 finds for the Middle Bronze Age, Waldbaum comments 'Whether the general dearth is due to the arbitrary nature of excavation or whether it reflects a genuine temporary decline in iron usage remains to be seen'.

In chapter 4, Wheeler and Maddin survey the subject of 'Metallurgy and Ancient Man'. This chapter will be very useful to archaeologists because it is very clearly written without too much technical detail. With the published micrographs it should enable the layman to understand a little about the various production processes, and what the metallurgist sees in his microscope. In connection with the treatment of iron it is interesting to note the author's opinion that it is apparent that smiths were carburising intentionally on a fairly large scale by at least 1000 BC, in the Eastern Mediterranean area.

Chapter 5 'Ocher in Prehistory : 300,000 Years of the Use of Iron Ores as Pigments' By Denise Schmandt-Besserat. This chapter is entirely devoted to the use of pigments from the first evidences of the use of ochre to its use from the Chalcolithic to the present time.

In chapter 6, 'The Coming of Copper and Copper-Base Alloys and Iron : A Metallurgical Sequence', J A Charles surveys a wide field concerning the metallurgical sequence which led up to the coming of iron. The author devotes considerable space to native copper and its geological origins, properties, and working. He also treats in considerable detail, copper-arsenic and copper-antimony alloys and their properties, the advent of tin-bronze. Metallurgists will find matters of interest, and food for thought, in this chapter.

R F Tylecote, 'Furnaces, Crucibles and Slags'. Chapter 7. In this very important chapter one can say that Prof Tylecote brings what is known of the complex matter of furnaces, crucibles, and slags, up to date. The problems are surveyed and discussed from the early metallurgical furnaces and the smelting of copper through the various periods and stages right up to the production of iron in the Migration and Medieval periods. The importance of finds from various countries, Near East and Europe, Africa, India and China, are given due consideration. The author sheds welcome new light upon some old problems.

Chapter 8. By Dennis Heskel and Carl Clifford Lamberg-Karlovsky. 'An Alternative Sequence for the Development of Metallurgy : Tepe Yahya. Iran'. This chapter is of particular interest concerning the question of the copper-arsenic alloys in Iran at Tepe Yahya. The possible use of domeykite and algodonite to provide the arsenic in the early alloys is mentioned. 4th millennium copper artifacts are illustrated and discussed with the advantage of metallurgical examinations.

In Chapter 9, 'The Central Andes. Metallurgy without Iron', Heather Lechtman gives a very comprehensive and readable account of the history and evolution of gold and copper-Andean Metallurgy. To all interested in this field Lechtman's work is essential reading.

In chapter 10, Anthony M Snodgrass, 'Iron and Early Metallurgy in the Mediterranean' Professor Snodgrass presents the archaeology of iron in the Mediterranean region. He would see three stages for what he terms 'working Iron'. In stage 1, iron may be employed with some frequency for ornaments. In stage 2, iron is used less than bronze for practical implemental purposes, while in stage 3 iron predominates over bronze. The archaeological background is fully discussed.

Chapter 11. Radomir Pleiner. 'Early Iron Metallurgy in Europe'. In opening this chapter Dr Pleiner says that Europe must be considered a zone of secondary development in the spread of iron working technology, lagging behind Southwest Asia by about a millennium. The technology based on iron, however, eventually became a major factor in European civilisation.

Of particular interest are the five techniques in the preparation of forging tools (page 358). Also, table 11.1, giving technological schemes of Late Hallstatt and Early La Téne iron artifacts in Central Europe. The archaeological background and the rise and spread of the Iron Industry in Europe are well discussed. In the section on the Celtic metallurgy of iron, furnaces are considered including those somewhat peculiar Slag-pit shaft furnaces which are partly above and partly below the ground level. Finally, Pleiner treats of the fully fledged iron civilisation in Europe, various La Téne tools, etc and the more advanced fabrication of cutting tools and weapons.

Chapter 12. V C Pigott, 'The Iron Age in Western Iran'. In this chapter of archaeological importance Pigott studies the whole question of iron in Western Iran. He finds that in Western Iran large quantities of iron artifacts do appear between 1000 and 800 BC. Also, that the iron is widespread throughout the region. According to the author this widespread appearance of iron would not appear to coincide with any major cultural change except in the area of Luristan.

Chapter 13. N J Merwe, 'The Advent of Iron in Africa'. This is a most interesting chapter in which the author makes an extensive survey of the complex problems of Iron in Africa. In Van der Merwe's view every conceivable method of iron production seems to have been employed in Africa. And remarkably (page 486) 'African iron smelting cannot be described in terms of either the direct or indirect process, because its primary product is neither wrought iron nor cast iron. Instead, a bloom of high carbon steel was produced directly from the smelting furnace and subsequently decarburised in the forge.'

Chapter 14. Joseph Needham, 'The Evolution of Iron and Steel Technology in East and Southeast Asia'. In this concluding chapter of the book Professor Needham discusses the development of iron and steel technology in Southeast Asia and China, giving full consideration to the well-known but remarkable early production and use of cast iron in China. Also dealt with are the Chinese crucible processes and blast furnaces, steel making and hardening, damascening and Wootz steel in China.

Conclusion

Finally, this combined volume can certainly be highly recommended. Linking the results of the two disciplines, archaeology and metallurgy, so that each side understands the other is always a matter of difficulty. However, here the result can be said to be in the main satisfactory. For the more advanced students of this complex subject the work will surely become essential reading. The book is well produced in hard-back, and the printing good and clear to read.

H H Coghlan

Scientific Studies in Early Mining and Extractive Metallurgy
Ed P T Craddock. British Museum Occasional Paper No 20, 1980. pp173, illus. Price £6.00 post free.

This volume comprises eight papers presented in a separate session of the proceedings of the 19th International Symposium on Archaeometry and Archaeological Prospection held in London 1979.

Of the eight papers, three specifically relate to copper mining in Ireland, Spain and Yugoslavia. Four more are concerned with the smelting of copper, and the relationship between the ore and the final product. The remaining paper studies the role of Siphnos, in the Aegean, and its EBA lead-silver mines.

As the introduction points out, most previous research on copper metallurgy has concentrated on analysis of the end product. As a result there is a growing body of analytical data whose significance is poorly understood. This volume is an attempt to redress the balance by concentrating on the extraction of the ores and production of the metal.

It is difficult to generalise from the three papers on early copper mining as each has a very different theoretical bias. However, from the plans of the mines, and the discussion of techniques, some common ground seems to exist: there was no well defined system of galleries and shafts such as we see in the Roman period. The extraction method was determined by the nature of the deposit, eg drift or vein which when located was followed as far as was possible with the technology available.

Tools urilised were of stone, antler and wood. Jovanovic notes that the stone mauls were specialised to a degree, there being several types evident. Some were used for breaking the ore out of the deposit while others crushed it, separating it from the gangue. Antler material was used for picking and scraping the deposit, while wood was probably used as baulk material.

In his discussion of the Rudna Glava excavations (Yugoslavia) Jovanovic has two main theoretical interests. In a rather complicated discussion of mine stratigraphy he presents two main conclusions.

1) That on the basis of evidence from Rudna Glava and Aibunar (Bulgaria) the development of the mines is an independent and local phenomenon and that it is not possible to speak of a single or central source of metal in Europe.

2) In a rather confused sociological interpretation of the data he suggests that the stratigraphy in the mines reflects seasonal work and that ownership of the mines was very local, seeing a division of the ore bodies lying somewhere between family or tribal property rather than common ownership by one village or several villages.

Jackson, while presenting a valuable catalogue of sites of EBA mining in SW Ireland with excellent maps and plans, presents a simple argument concerned with scale of copper production represented by these mines in the EBA. The results suggest that copper production, or copper available and worked from the mines, far exceeds the quantity of copper represented by artefacts by a ratio of 5:1 and concludes from this that Ireland in this period was a nett exporter of copper. This conclusion relies on the SW mines only being exploited during the EBA which has some evidence to support it, and also on the calculation of the number of artefacts from Copper and EBA ages. Many of the artefacts produced during this period would undoubtedly have ended up as scrap, being re-melted during later periods and not necessarily exported from Ireland. The difference in magnitude is not that great and the conclusion must remain tentative on the basis of the present evidence.

Rothenberg et al, presents the results of recent work at the mines at Chinflon, SW Spain. He claims that Chinflon represents the earliest phase of mining and extractive metallurgy of copper-found to date. This claim is made on the basis of extremely tenuous evidence such as the proximity of the mining sites to megalithic tombs (dolmens), which are Chalcolithic in date, and the presence of rough hand made pottery which has been found in association with sites ranging from Neolithic through to LBA. All the dates obtained from the site except one point to a Late Bronze Age occupation; the other suggests earlier working though not Chalcolithic.

Moving away from copper metallurgy, Wagner and his colleagues present some interesting evidence from the island of Siphnos which leads them to suggest that the Aegean must have played a more important role in lead-silver metallurgy in the EBA than hitherto suspected. This is based on excavation of several mines from Siphnos with C^{14} and thermoluminescence dates presented. Lead isotope analyses are given for both the ore sources, and several lead objects from the Early Cycladic and Archaic periods. There is also evidence of cupellation.

XRF and isotope analyses of ores and slags are given along with maps and graphical presentation of the isotope data on lead and galena. The latter clearly indicates that the Siphnian field is quite distinct from any of the Cycladic islands sampled so far, and also from all important mainland ancient mining regions around the Mediterranean. This amounts to the first proof of lead and silver mining and cupellation during the EBA in the Cyclades.

The remaining papers all deal with copper production, the technology involved and its relationship to ore, slag and metal. Bachmann, using early copper smelting slags from the Sinai and Timna, presents a working model of slag analyses which permit the reconstruction and a better understanding of the basic principles of copper smelting technology practised in these areas from the fourth millennium to Roman times.

This is a very useful paper proposing a system of slag analysis from the field to the laboratory with a full breakdown of analytical techniques and a computer package to deal with the XRF results.

Mineral types expected in the ores and the slags are related to the probable furnace technology involved, eg furnace types, operating temperatures, etc . The author recognises the need for experimental work to support such assumptions.

Zwicker investigates several aspects of Sardinian copper metallurgy and specifically the oxhide ingots found on Sardinia, to check if production could have been local. Copper ore from Fontana Raminosa, slag from Nurallo and seven of the copper ingots were investigated using XRF, microprobe and spectrographic analyses. Most of the analytical results are qualitative; of the others only incomplete quantitative results are presented and the mineralogical analyses of the slags are confusing. They are not assigned mineralogical labels such as pyroxenes or olivines but as silicate mixtures, eg Cu-Ca-Fe-Mn-K silicate. Without quantitative analyses or an idea of the mineral phases present it is very difficult to assess the significance of such analyses and it is unlikely that the Cu is present in the above as a silicate.

These results were compared with laboratory experiments in which the ore was reduced by charcoal and the products were investigated by the same analytical techniques.

Seven ingots were examined, five had copper matte inclusions while the other two had oxide inclusions. This difference is explained by a change in the smelting conditions, the latter being held in a more oxidising atmosphere for a longer period of time. However, it would seem possible that these may have resulted from the smelting of non-sulphidic ores.

Laboratory experiments indicate the ease with which the local ores could have been smelted to produce copper and hence local production of the ingots but the author also notes the similarity in composition between the Sardinian and Cypriot slag and ore.

The remaining papers are on the analysis of ingot and finished artefacts from or near the production site of Timna, by Craddock, and on transformations which occur from ore-slag-metal, by Berthoud et al. These tend to confirm the general impression of doubt one gets from reading this volume and in fact many papers on compositional analysis of metals. It highlights the vast quantity of experimental work needed in this field, ie smelting and melting experiments, before the significance of a considerable quantity of artefact (Bronze) analyses can be understood.

In spite of the variable quality of the papers and also the poor reproduction of photographs, this is still a reasonably priced volume and an essential contribution to the study of early metallurgy.

R E Clough

Antike Numismatik – Teil 1 and 2. *Maria R Alfoldi. Kulturgeschichte Der Antiken Welt, Band 3, Verlag Philipp Von Zabern, Mainz am Rhein. Price: Volume 1 66DM, Volume 2 46 DM*

The name of Alfoldi is well known to all numismatists and it is a pleasure to welcome a new publication from Professor Maria Alfoldi. Her two volumes, 'Antike Numismatik', fill a gap not really covered by any parallel conspectus of the coinages of Greece and Rome. Whereas, for example, Jenkins' book on 'Greek Coins' emphasises the historical background and aesthetics of Hellenic issues, particularly by providing a series of fine, enlarged colour illustrations, Alfoldi underplays these aspects in order to deal at greater length with more technical matters. (Incidentally, Jenkins' initials are G K not K G as rendered in Alfoldi's text, a possible source of confusion with a relatively common surname).

In fact, the black and white illustrations, chosen for their relevance to the technical discussions rather than for the purpose of identifying a random specimen, are very good, the base metal issues, which nearly always fare badly, being unusually clear and legible. It is, therefore, unfortunate that the author has relied so heavily on the resources of the University Cabinet in Frankfurt; the worst consequence is that photographic skill has been expended on inferior coins, where plaster casts of better examples would have provided more visual information. One has only to compare the two decadrachms of Akragas and Syracuse to appreciate the difference – the former (No 133) is from a cast, the latter (No 134) is from a corroded original. Of course, such a criticism does not apply where other factors must be considered, as with the corroded but plated tetradrachms of Seleucus III (No 162) a good representation of this misapplied ingenuity of the ancient metallurgists. A final general point – the size of type employed is very small and would present, for most people, when reading an extended passage, an optically tiring experience.

The first volume contains chapters detailing the limits of numismatics as a discipline; a short history from its beginning in the Ancient world to the present day; methods of collecting and cataloguing; numismatic research in general (we shall discuss this below since it covers many scientific areas); finally, there are specific considerations of the Greek, Celtic, Roman Republican, Roman Principate, early Byzantine and 'Volkerwanderung' issues, as well as a few pages on coin-like pieces such as medallions. The illustrations are interspersed throughout in approximately the positions appropriate to the text.

When faced with an accumulation of coins to set in order, the well-established use of specially compartmented trays is correctly emphasised, although it is perhaps unnecessary to deprecate the Renaissance practice of actually punching into the separate specimens an inventory number or dynastic symbol (as did the house of Este) – tickets, in spite of their tendency to get lost, are adequate enough. The state of preservation is of greater interest to the collector than the scientist, but the latter naturally investigates the degree of wear when attempting to estimate the original weight; Alfoldi makes the point not merely of the wear resistant properties of different metals, but also of the varying speeds of circulation of bronze, used for market place transactions, as compared with silver, more suitable for bullion transfer. One might, I think, question her implication that copper was added to silver to harden it rather than for financial gain – although the alloy would indeed exhibit less weight loss than the pure metal, such a loss was regarded by issuing authority as hard luck on the part of the user. Her discussion of the various aspects of weight and fineness, supplemented by judicious quotation from ancient sources, will occupy the economist rather than the technologist; however, the latter should note her observation that, after an issue had been in circulation for some years, it would, in spite of wear, be overvalued in relation to more recent strikings; thus, the older coin would be melted down to supply the mint with fresh metal; hence, unless we know of large new sources, such as the Laurion mines, it becomes very chancy indeed to attempt to employ trace element analysis to postulate ore sources.

The production techniques are next referred to. She describes a number of different methods of obtaining the blanks, deducible from the coins as we now have them. Although the inaccuracy was normally high, with some issues, such as gold or the Athenian tetradrachms of the 5th century BC the weight variations were very small and Alfoldi thinks we should, in such instances, regard the mint as employing the modern 'al pezzo' theory as opposed to the older 'al marco'. She also subscribes to the theory that the little multiple moulds, so common on Iron Age sites in Europe, were used to get coin blanks, although their actual globular shape and low weight would make them unsuitable for striking. Experiments have convinced me, too, that pouring into water, unless from heights in excess of 20 m is quite unsatisfactory for blank production.

Die manufacture and the problems of inserting the design on the die faces are not dealt with in the detail accompanying other aspects. However, she does go into the possible use of hubs in antiquity, even suggesting that worn dies could be resuscitated by a fresh hubbing; if, as seems likely, even new dies were never wholly hubbed, but required further tooling, subsequent hubbing would tend to obliterate such engraved features. The breakdown of dies may not be catastrophic, in the scientific sense, and a series of illustrations of a Syracusan tetradrachm (Nos 10, 11, 12) show clearly the spread of a crack across a die face and indicate how the sequence of accompanying reverse dies can be put in correct chronological sequence as a result. In fig K, which attempts to explain how a die pairing series may be elucidated, reverse die 3 can, in fact, occur after 4, a point overlooked.

The difficulties of estimating die production are mentioned, although perhaps it is somewhat naive to insist on the obvious factor of chance preservation of smaller or greater volumes of material in determining the reliability of calculations.

The last section in the chapter on research methods deals with the importance of properly recorded hoards, and the types of numismatic information that can be gained from them. Without expouding upon them at any length, the author also mentions here the usefulness of metrology, physical and chemical analysis and statistics.

The second volume is an all-embracing bibliography of the various aspects of ancient numismatics dealt with in its predecessor. This is particularly valuable, since Professor Alfoldi often adds a few comments as to the scope or even the reliability of the works listed. As far as I can tell, very little seems to have been omitted – perhaps Plenderleith should have been accorded a place in the section on conservation and cleaning.

All in all, Professor Alfoldi's books will be welcomed, both for the excellence of her exposition of the problems faced by students of the coinages of Greece and Rome and for her assiduous assemblage of the relevant monographs for more detailed reference.

David Sellwood

Biography: see page 28.

Roberta Morelli graduated from the Political Science Faculty in Florence in June 1973. Her thesis on Economic History was about the Silk Industry in Tuscany during the Renaissance period. With the aid of a scholarship from the same University she published a book – 'La seta fiorentina nel Cinquecento' – and some articles on the Economic History of the 16th-17th century.

Letters to the Editor

Dear Sir,

In the paper by Tucker and Wakelin (*JHMS, 1981,* **15** *(2),* 94-100),it is stated that the term Block Tin is not understood. In fact it is the term used to denote fire refined tin. After the furnace oxidation treatment, the tin is allowed to stand just above the melting point in order to encourage the heavy impurities to settle. The top layers, being the purest, are ladled off and sold as refined tin, while the average middle layers are sold as block tin (presumably because they are cast in blocks) and the less pure lower layers are returned for further treatment. See, for example, *W Gowland, The Metallurgy of the Non-Ferrous Metals, London, 1921, p 528.* Block tin is the commercial grade of appropriate purity for tinning steel sheet.

On the other hand 'Some Account of Making Block Tin at Melin Griffith' is obviously wrong. Melingriffith were using block tin not making it and the authors' suggestion of an error in the original transcription seems probable.

M M Hallett

Abstracts

GENERAL

J A Charles: The development of tin and tin-bronze: some problems. In book *The search for ancient tin, edited by A D Franklin, J S Olin and T A Wertime, pp 25-32.*

An archaeological study is given on the usage on tin and tin-bronze in ancient times. **AATA**

J A Donaldson: The use of gold in dentistry: an historical overview; part 1. *Gold Bulletin, 13,Number 3, pp 117-124 (July 1980).*

Reviews the uses of gold in dentistry from the first millenium BC onwards. The use of gold wire for binding teeth by the Greeks and Romans is described. Apart from a brief reference to the origins of gold filling during the Renaissance period, the rest of the review deals with advances since the nineteenth century, especially in the field of dimensionally accurate lost wax casting. **AATA**

A D Franklin, J S Olin and T A Wertime; Editors: The search for ancient tin. *Book, GPO Washington, DC 1979.*

A seminar organised by Theodore A Wertime and held at the Smithsonian Institution and the National Bureau of Standards, Washington DC on March 14/15 1977.

AATA

E Foltz: Guss in verlorener Form mit Bleimodellen? (Lost-material casting with lead patterns]. *Archaol Korrespondenzbl, 1980,* **10**, *345-9.*

The theory that lead patterns (sometimes found in excavations) could be used in a manner similar to that of lost-wax casting has been examined experimentally and rejected. They are more likely to have been used for making two-part moulds. BAA

L B Hunt: The Long History of Lost Wax Casting. *Gold Bulletin, 1980,*13*, (2), 63-79.*

The origins of lost wax or investment casting, often known as cire perdue, and still the most accurate and reliable means of reproducing complex shapes in gold or other metals with all the fine detail of an original pattern, go back to the very first civilisations in the Near East and to a combination of primitive art, religion and metallurgy. The historical development of the process and its several variations are reviewed here as well as its transmission to other parts of the world. Author

R Maddin, T Stech Wheeler and J D Muhly: Distinguishing Artifacts Made of Native Copper. *Journal of Archaeological Science, 1980, 7, 211-225.*

Various features considered to be diagnostic in the identification of native copper in artifact form are examined. Through analytical studies of unworked native copper, native copper artifacts and objects made of worked, smelted copper, it is determined that no adequate criteria exist for distinguishing artifacts of native copper from those of worked and recrystallized smelted copper of high purity. Authors

N D Meeks and M S Tite: The Analysis of Platinum-group Element Inclusions in Gold Antiquities. *Journal of Archaeological Science, 1980, 7, 267-275.*

The results of the analysis, using the energy-dispersive X-ray fluorescence spectrometer attached to the scanning electron microscope, of platinum-group element inclusions in a range of gold jewellery and coins from the Near East and eastern Mediterranean spanning the period from 3200 BC to AD 300 are presented. The fairly frequent occurrence of PGE inclusions in the jewellery and coins examined confirms that gold from placer deposits was extensively used in antiquity. All the inclusions analysed are of the iridium-osmium-ruthenium alloy type and no platiniridium inclusions were detected. The inclusions found within a single object frequently exhibit a wide range of compositions and therefore the composition of the inclusions does not normally provide a basis for characterizing the source of the gold. In particular the hypothesis that the Pactolus valley was an important source of gold which was used throughout the Near East cannot be confirmed. Author

R Brownsword and E E H Pitt: Medieval 'bell-metal' mortars – a misnomer, *Metallurgist and Materials Technologist, 1981* **13** *(4) 184-185.*

Metallic mortars have been made from cast iron, brass and 'bell-metal', a term generally used when the alloy is not obviously brass. 33 examples of mortars have been analysed, mainly from the 17th and 18th centuries, together with 13 examples of standard capacity measures and woolweights which appeared to be of similar material. Lead contents were in the range 4-18%, tin 1-5% and zinc less than 2% except for 5 samples, and in no case is the alloy the composition of bell metal. Significant amounts of antimony, arsenic and metal were present, probably derived from copper ore or possibly introduced with the lead used for alloying. APG

R H Nutall: The First Microscope of Henry Clifton Sorby. *Technology and Culture, April 1981, 22 (2), 275-280.*

The author concludes that though Sorby's successful researches sprang from his own individual genius, they were greatly facilitated by the instrument he was able to work with. APG

BRITISH ISLES

Anon: Ancient Waterwheel on view at Cornish Foundry. *Foundry Trade Journal, March 26, 1981,* **150**, *(3209) 564.*

In the yard of Charlestown Engineering (ECC) Ltd, St Austell is preserved a large waterwheel which once supplied power to the foundry. Water is conducted from a high level pond by a rising cast-iron flume to the wheel, which is of composite wrought iron and cast iron construction. APG

Anon: A Brass Foundry Preserved. Foundry Trade Journal, *April, 9 1981,* **150** *(3210) 685-688.*

The complete stock-in-trade, machinery and records of the modest engineering works and mineral water manufactory of JB Bowler & Son Ltd are displayed at Camden Works, Bath. Illustrations show parts of the pattern stores, brass foundry and brass finishing room in the old Corn Street works, and as now exhibited at Camden Works. APG

Anon: Cast-iron Splendour on View in Leicester. *Foundry Trade Journal, September 1981,* **151** *(3221), 414-415.*

Four independent rotative-type compound condensing beam engines built in 1890-91 form the centre-piece of the recently established Abbey Pumping Station museum. Although many components are made of cast iron, the beams are made of rolled steel, indicative of the progress which had been made in rolling heavy steel plate. APG

O Bedwin: The Excavation of a late 16th Century Blast Furnace at Batsford, Herstmonceux, E Sussex, 1978. *Post-Medieval Archaeol, 1980, 14, 89-112.*

The blast furnace had two phases: a small square structure 5.5m across was followed by a larger one poorly built in near-rubble masonry. The wooden wheelpit, tail race, and a waterwheel fragment were well preserved. An ancillary hearth was perhaps for drying gun-moulds, and a gun-casting pit had been robbed out. Author (abridged) BAA

W R Childs: England's Iron Trade in the 15th Century. *Econ Hist Rev, 1981, 33, 25-47.*

Since taxed iron imports are a better guide to consumption than estimates of bloomery production, information was sought from customs accounts. These showed that 15th century imports were much larger than thought, and heavily dependent upon Spain (3000+ tons/yr). The traffic was already heavy before the second half of the century and greatly increased in late 15th, presumably owing to peacetime needs of building, ships, agriculture, and consumer goods. The trade is attributed to a reluctance to invest in phosphorus ore processing when good iron was easily imported. BAA

P T Craddock and M S Tite: Late Bronze Age Artefacts from Hertford Heath. *Hertfordshire Archaeology, 1979,* **7,** *6-9.*

Reports the composition of 5 late Bronze Age artefacts and 20 ingot fragments. Author

M Daniel: A Note in the Anglo-Saxon Lead Industry of the Peak. *Bulletin of the Peak District Mines Historical Society, 1980, 7 (6), 339-341.*

After reviewing the evidence the author suggests that 'bole' replaced 'cost' as the description of the place where ore was smelted during the 13th and 14th centuries. It is uncertain whether this change was accompanied by a parallel change in the mode of smelting or lead production, but it could possibly be associated with the declining silver content of the ores produced as the mines became deeper. A list of place names incorporating the element 'cost' is presented. APG

L N W Flanagan: Industrial Resources, Production and Distribution in Earlier Bronze Age Ireland. *Proceedings of Fifth Atlantic Colloquium. M Ryan (ed) Dublin 1979 145-463.*

The author compares the shapes of early bronze age axe heads found in Ireland in order to try to determine how many came from a given matrix (mould cavity). Herbison's work (The Axes of the Early Bronze Age in Ireland, Munich 1969) in which1950 axe heads are grouped into six 'types' is used as a basis. The results indicate, for example, that 180 matrices of the L Ravel type produced 503 axes. Three of these matrices each produced more than 20 extant products, but many produced only one known product. By plotting where axe heads from a given matrix were found, it is shown that there is generally a very wide distribution of the products of one matrix. Surprisingly, the immediate environs of the places where the moulds have been found are most lacking in the products.

Estimating the total production of axe-heads on the basis that each postulated matrix produced a number of axe-heads equal to the maximum number observed for any matrix, the total copper consumption would be 4,390kg over a period of 350 years, and 70kg of tin over a period of 250 years – hardly enough to justify suggestions that large-scale exploitation of ores took place. APG

T A P Greeves: An Outline Archaeological and Historical Survey of Tin Mining in Devon, 1500-1920. *ICOHTEC Internationales Symposium zur Geschichte des Bergbaus und Huttenwesens, Vortrage. band I, 73-89. Wachtler, E and Engewald, G, eds. 1980, 73-89 (In English).*

There is documentary evidence of tinworking in Devon concentrated on and around the granite mass of Dartmoor from the 12th to the 20th century. The earliest workings were opencast, but there is evidence to suggest that shaft mining began in the 15th century. After crushing in water-powered stamping mills and concentrating, the ore was smelted in a blast furnace with peat-charcoal, and cast into ingots in granite mouldstones. The extent of the documentary evidence and the field remains of the industry is indicated. APG

C J Harrison: 'The Cannock Chase Ironworks' Report – an Assessment', *North Staffs Journal of Field Studies,* **19** *(1979), 22-9.*

In July 1590 an unidentified iron-master produced a twenty-nine page report on the Cannock Chase (Staffs) iron industry. (It is published by A C Jones and C J Harrison in **The English Historical Review**, xciii (1978), 795-810). It is, inter alia, a full description of each part of the new indirect process of iron-making from the provision of the raw materials to the production of raw iron. It is the earliest, most complete and most authoritative English account of English iron-making. It confirms modern historians' reconstructions of the industry, it demonstrates that by 1590 the industry had already reached the limits in basic production techniques, and is evidence of an expertise in the written exposition of technical matters in advance of its time. S H Beaver

J Haslam: A Middle Saxon Iron Smelting Site at Ramsbury, Wiltshire. *Med Arch 1980,* **24,** *1-68. With contributions by* **L Biek** *and* **R F Tylecote.**

Excavations on a site in the High Street, Ramsbury revealed an iron smelting and smithing site datable by radiocarbon determination and analysis of the finds to the late 8th and early 9th centuries. The industrial structures consisted of bowl furnaces and associated features of at least three phases, and included a timber-framed shelter. A 'developed bowl' furnace with slag-tapping facilities was built in the last phase, and had survived to a sufficient height to exhibit an unfamiliar 'funnel' shape. Besides being unique for its date, the site is important because of its relatively good state of preservation, and because the furnaces show a sequence of technological innovation over a short period. Iron ore was brought some distance to the site. Associated finds included quantities of animal bones, as well as some pottery, bronze and iron artifacts and fragments of imported lava querns. This and other evidence hints at patronage by an important royal estate. Author

B Johnson: Excavation of the Bell-Founding Pit and Restoration of a Bell Mould from Norton Priory, Cheshire. *The Conservator, 1981,* **5,** *20-2.*

Excavation yielded *c* 200 pieces of the outer portion of the bell mould within a casting pit; the conservation and re-assembly processes are described. BAA

C McCombe; Geared Crane Ladles – an Historical Note. *Foundry Trade Journal, May 7 1981,* **150,** *(3212) 825-828.*

James Nasmyth invented the first geared ladle in 1838. The ladle incorporated a skimmer device to improve the safety and efficiency of keeping back the slag. Instead of patenting the invention, he circulated drawings and descriptions of the safety foundry ladle to all principal foundries at home and abroad, and he was awarded the large silver mould (sic) of the Society of Arts in Scotland for his work. APG

J G Rollins: Forge Mills, Redditch, Worcestershire. From Abbey Metalworks to Museum of the Needlemaking Industry. *Industrial Archaeology, Summer 1981* **16,** *(2) 158-169.*

The site was used as a forge from about the latter half of the 14th century until about 1722: it was used as a needle scouring mill from about 1728 until 1899. The probable developments in techniques and equipment at the mill during this period are outlined. It is hoped that the restored mill will be open to the public late in 1982. APG

B G Scott: The Occurrence of Platinum as a Trace Element in Irish Gold. Comments on Hartmann's Gold Analyses. *Irish Archaeological Research Forum, 1976 3 (2) 21-24.* **Reply by A Hartmann and further comments by B G Scott;** *ibid, 1977, 4 (2) 35-38.*

Hartmann's grouping PC of gold artefacts is characterised by a silver content ranging from 16-40%, copper between

2.5 and 11.0%, tin between 0 and 0.11% and platinum between 0 and 0.020%. 44 Irish objects are grouped as PC, of which 34 contained detectable platinum. A Rhenish source was suggested for the metal, because no platinum was reported in the 5 samples of gold from Wicklow which were analysed.

Scott points out that in 1850 platinum was reported as being associated with Wicklow alluvial gold, and the presence of platinum in the PC group of objects is thus not good evidence that the metal was imported.

Hartmann denied he had suggested a Rhenish source for this Irish gold, and because of the high silver. However, the strikingly similar compositions of gold objects of the La Téne period found in Ireland and in Central Europe strongly suggests a common origin for the metal: somewhere in the Eastern Mediterranean is suggested. The Wicklow gold samples analysed by Hartmann were nuggets and ore, and contained only 6-8% silver, and so could not have been the source of the Irish PC gold with 20% silver content. The use of Wicklow gold cannot have been widespread during this period as indicated by the analysis of nearly 500 Irish gold objects. APG

A R Williams: Four Helms of the 14th Century Compared. *J Arms Armour Soc, 1981,* **10** *80-102.*

Reports non-destructive metallographic studies on the Pembridge Helm and other pieces; one was merely wrought iron but most had been heat treated in some way after fabrication. BAA

J J Taylor: Bronze Age Gold Work of the British Isles. *Cambridge, Cambridge Univ Press, 1980, xiv +199 pp, pls, figs, tables, refs, indexes.* Price £45.

Chapters treat laboratory analytical techniques for the study of gold, the earliest evidence for gold use in these islands, lunulae, the culmination of EBA linear sheetwork, the emergence of the massive gold ornament tradition of the Later BA, and indigenous Later BA goldwork. The geographically arranged corpus contains *c* 1600 items. BAA

EUROPE

G D B Jones: The Roman Mines at Riotinto. *The Journal of Roman Studies, 1980,* **70**, *146-165.*

The geography and geology of the area are briefly outlined. Recent discoveries underneath Roman remains have indicated that the scale of exploitation in early days was much greater than formerly believed. Remains from the Roman period indicate that mining activity was greatly reduced at some time in the period AD 170-180, probably associated with loss of Roman administrative control at this time. The resulting loss of gold, silver and copper production is probably the principal reason for the changes in coin production at this time, notably the debasement of the denarius and a severe decrease in the production of all bronze denominations. APG

R Morelli: The Medici Silver Mines. *Journal of European Economic History, 1976,* **5**, *(1) 121-139.*

Using documentary sources, the article traces the evolution of silver production from the reopening of the mines in 1539 until 1593 when production virtually ceased. The silver mines was reported to be a mixture of silver, lead and antimony.

Miners' wages in the 16th century accounted for more than half the total. Tables showing the annual production of silver show a high output at the start of operations, after which the production rate while fluctuating considerably, remained much the same. Lead production figures are also tabulated for the different grades. Production costs were generally rather high, and tended to increase. Despite evidence of attempts to use mercury for an amalgamation process, no significant technical innovations were introduced, and the mines were unable to compete with the arrival of silver in large quantities from South America from about 1550 onwards. APG

ASIA

P T Craddock: The First Brass: Some Early Claims Reconsidered. *Masca Journal, 1980,* **1**, *(5), 131-133.*

Small worthless corroded pins from Gezer, Palestine, approximately 2000 years old, were reported to contain up to 21% zinc, but for a variety of reasons, the results of the analysis should not be accepted. Material from early Cypriot tombs at Vounous Bellapais, sampled and analysed spectrographically by Desch, included sixteen samples containing between 1% and 8% zinc. However, samples from earlier excavations on the same site contained no zinc, so nine 'brasses' were re-analysed. None was found to contain more than a trace zinc. Circumstantial evidence indicates that Desch probably took samples from incorrectly labelled specimens from another source. Finally two Luristan cheek-pieces in the collection of the Ashmolean Museum, Oxford, reported to contain 17-18% zinc, proved on close examination to be fakes. APG

V L Derzhavin and B G Tikhonov: A MBA Burial of a Smith in the Stavropol Area. *Sov Ark, 1981,* **3**, *252-258.*

The burial contained stone moulds for shaft-hole axes, an awl and a bronze dagger as well as some metal beads (Cu?) and Bronze Age pottery. ECJT

A D Pryakhin, A T Sinyuk and Yu P Matveyev: The LBA Tereshkovo Hoard from the Middle Reaches of the River Don. *Sov Ark 1981, (3), 281-285.*

The hoard contained fragments of stone moulds (for ingot bars?) and several two-looped palstaves with incised decorations a razor, leaf-shaped and several curved saws with a rat-tail loop. ECJT

V P Darkevich and V G Putsko: The Medieval Metal Castings from Staraya Ryazan (Finds of 1970-1978). *Sov Ark 1981, (3), 218-232.*

The article describes the 12th-17th century cast crosses and small ikons found in the Siaraya Ryazan settlement. According to dating and typology they show close connections with the Kiev founders and smiths of the pre-Mongol period. Some of the finds are unique samples of Russian art. ECJT

S N Korenevsky: Chemical Analyses of the Bronze Artefacts from the Tly Cemetery. *Sov Ark 1981 (3), 148-162.*

Analysis has shown that in the early period from the 16th-14th century BC the Tly cemetery in the south of Ossetia yielded artifacts consisting of As and As-Sb copper, whilst tin bronzes are rare but became predominant in the period from the 14th to the 7th century BC. ECJT

P N Starostin and LS Khomutova: Ironworking among the Tribes of the Imenkovo Culture. *Sov Ark 1981 (3), 208-217.*

A systematic study of iron working has been carried out in the Kama region and the neighbouring Volga basin dating to the 1st millennium AD. Metallographic examination of iron tools and weapons found in the Shcherbet Island settlement and the Maklasheyevo II settlement show the many complex methods of metalworking employed by the Imenkovo craftsmen. They were familiar with medium carbon and high carbon steel obtained through case carburizing. Thermal treatment varied according to the purpose of the object. They employed piling and welding-on techniques. The specimens show that the Imenkovo ironworking technique was at a fairly high level. Comparison is made with the iron working of the Mordvinian tribes who only used iron and mild steel in the 5th-7th century.
ECJT

NORTH AMERICA

D A Scott: The Conservation and Analysis of some Ancient Copper Alloy Beads from Colombia. *Studies in Conservation, 1980,* **25,** *157-164.*

Radiography showed that a hard compact mass originating from the Narino district contained the remains of ten rounded copper beads still threaded on textile fibres, the beads being cemented together by the corrosion product malachite. The techniques used for extracting, cleaning and conserving the beads are described. One bead was examined metallographically and shown to have been formed from strip copper alloy with a final annealing operation. Physical techniques of analysis showed that all the beads contained appreciable arsenic (average 2.66%) and silver (average 0.1%), but no detectable cobalt manganese bismuth or zinc. One bead contained 3.71% tin, but no tin could be detected in the other beads examined. These compositions suggest that the metal had been produced in Peru or Ecuador.
APG

AFRICA

R Haland: Man's Role in the Changing Habitat of Mema during the Old Kingdom of Ghana. *Norw Arch Rev, 1980* **13,** *(1), 31-46.*

The Mema area, Mali, situated climatologically within the Sahel zone, carries extensive traces of ancient settlements. Material from the author's 1978 excavation indicates environmental conditions similar to the present day inland Niger delta during the old Kingdom of Ghana (AD 800-1150). This centralized political power controlled gold trade from the south and salt from the north. The iron smelting in Mema was too extensive to be explained as local supply alone. It probably constituted an important basis for political centralization. The iron production seems to have caused deforestation, and the Kingdom may therefore have been weakened by ecological deterioration connected with iron production.
Author

TECHNIQUES

J N Green, G Henderson and N North: A Carronade from the Brig James: its History, Conservation and Gun Carriage Reconstruction. *Int J Naut Archaeol Underwater Explor, 1981,* **10,** *101-8.*

Description of the gun, with details of its conservation (Multiwax 180M) and restoration.

J Paiskowski: Metallographic Examinations of Ancient Iron Objects Perspectives in Palaeonthropology: *D Sen Festschrift: A K Ghosh (Editor). Firma K L Mukhopadhyay. Calcutta, 1973, 321-329.*

In metallurgy generally, the chemical composition of a given alloy produced at one centre is characterised by a probability curve for the concentration of each component, which may be analysed statistically to find the most probable concentration and the standard deviations of the concentrations found. When these results have been obtained for several centres, the probability of a find being manufactured at one of these centres can be determined.

The concentration and distribution of carbon in iron artefacts can indicate how they were made, and whether the smith was aware of the effect of varying carbon content on mechanical properties and able to control the concentration and distribution of carbon in his iron. Similar evidence shows that ancient smiths could distinguish between irons with different phosphorus content. The structure of slag inclusions may give information on the kind of iron ore used. Vicker's hardness is a useful general guide to properties, and the grain size should be recorded on the ASTM standard scale. APG

J B Rae: The Herbert Hoover Collection of Mining and Metallurgy. *Technology and Culture, October 1980,* **21,** *(4) 614-616.*

This brief note is inspired by the publication of a definitive catalogue of the collection compiled by C S Smith and a available from the Honnold Library, Claremont, California, 91711 for $125.
APG

A Rinuy and F Schweizer: Methodes de conservation d'objets de fouilles en fer. Etude quantitative comparee de l'elimination des chlorures [Conservation methods for excavated iron objects. Quantitative comparative study for chloride removal]. *Stud Conserv, 1981,* **26,** *29-41.*

In the search for a satisfactory method of desalination of very corroded iron objects, the alkaline sulphite treatment developed by North and Pearson was studied within the framework of a quantitative study of chloride removal and compared with five other methods. It was found that the alkaline sulphite method removed the maximum amount of chlorides and stabilized and consolidated. Research was also done on quantitative distribution of chlorides in a corroded iron object, the quantity of chlorides remaining after different treatments, and the chloride concentration threshold at which corrosion starts to become dangerous.
BAA

The abstracts are now being edited by Dr Paul Craddock and the Honorary Editor would like to acknowledge his help and that of many others. He is very grateful to the following who are actively participating:- D R Howard, J W Butler, P S Richards, H F Cleere, H W Paar, N Mutton, M Goodway. A P Greenough, J K Harrison, W A Oddy, M M Hallet, J Piaskowski, D G Tucker and E C J Tylecote. Some of the abstracts are taken from the periodical 'Art and Archaeology Technical Abstracts' and we are grateful to the International Institute for the Conservation of Historic and Artistic Works, London and New York, for allowing us to reproduce them. We are also grateful to the Council for British Archaeology who allow us to use material from their abstract journal, British Archaeological Abstracts (B A A) and to Miss C Lavell the editor. Finally, through the courtesy of Dr R Pleiner, honorary secretary of the Iron Committee of the International Union of Prehistoric and Protohistoric Sciences (CPSA) we are allowed to reproduce items from the Bulletin of that Committee.