HISTORICAL METALLURGY

1963|64|65|66

Bulletins 1,2,3,4,5 and 6 of the Historical Metallurgy Group

Historical Metallurgy Group Bulletins

Published by the Historical Metallurgy Society, Registered office 1 Carlton House Terrace, London SW1Y 5DB, September 1982 .

Enquiries relating to the contents should be addressed to the Honorary Editor: Professor Ronald Tylecote, Yew Tree House, East Hanney, near Wantage, Oxford OX12 0HT.

Requests for back copies of Bulletins and Journals should be sent to Roger Wood , 99 High Lane West ,West Hallam, Derbyshire DE7 6HQ who could also supply details of membership.

After the formation of the **Historical Metallurgy Group** in 1962, research material collected by members began to be published from April 1963, in a duplicated and stapled *Bulletin*. Six issues were produced in this way during which time they increased in size from eight pages (Number 1) to seventy-one pages in January 1966, Number 6. They were printed on Foolscap size paper (8¼ by 13 inches) and illustrations had to be restricted to line drawings.

During the latter part of 1965 an agreement was reached between the officers of the **HMG** and the Council of the **Iron and Steel Institute** who undertook to produce and distribute the *Bulletin* from Number 7. This appeared in July 1966 and in it was a note stating that the **Institute of Metals** had also agreed to become associated with the Group. Number 7 included the first 'half-tone' reproductions and macrograph and the start of the **Abstract** service.

Number 8 (January 1967) and Number 9 (July 1967) completed what has become known as Volume One and from 1968 there has been a new Volume in two sections, produced each year. Part One in the Spring and Part Two in the Autumn. It was now in the International A4 (297 by 210 mm) format.

In 1974 a merger between the **Institute of Metals and the Iron and Steel Institute** resulted in the Metals Society and the HMG became the Historical Metallurgy Society. At the same time the *HMG Bulletin* became the *Journal of the Historical Metallurgy Society*, sub-titled *Historical Metallurgy* and publication continued in what had become an established manner with the numbering of issues unchanged.

Thus it can be seen that the first few duplicated *Bulletins,* being the first productions of an emerging organisation, were not easily integrated into the accumulated store of historical metallurgical knowledge. This situation has been remedied with the publication of this combined volume. The original text has been reproduced whilst in some cases the illustrations have been slightly modified. One or two photographs, which it was not possible to include at that time, have been added and purely ephemeral items such as membership lists have been omitted.

Cover illustration

A 'drying furnace' used in the separation of silver from copper by liquation and described in Book XI of De Re Metallica by Georgius Agricola first published in 1556.

Designed and produced by Roy Day FSIAD and IBM Composer set by Kathleen Taylor

Printed by Lithprint (Avon) Limited , Mivart Street, Bristol BS5 6JF. September 1982

HMG BULLETIN 1
First published April 1963

Contents

Bonawe Blast Furnace 1960. Photograph Crown Copyright.

A. 17-18th Century Blast Furnaces

The existence of about 22 furnaces is now recognised. Most of these are in too decayed a state to warrant preservation but steps are being taken to try and preserve that at Duddon Bridge, Lancs, and turn the existing buildings connected with the operation of the furnace into a museum for equipment from other sites in the locality. This furnace had a number of Lake District forges associated with it and Mr G R Morton, who is investigating their remains with the intention of making a report on the whole concern, would welcome practical help.

The furnaces listed in Table 1 are on record as existing, and many have been inspected by our members in recent months. We would welcome any additions to this list.

As far as can be ascertained the following are unrecorded in the sense that their 'lines' and also their external measurements have not been published.

Whitecliff	Parker's
Heage	Morley Park
Maryport	Gunn's Mill
Ambergate	

One way in which members could help this project, would be to get together in groups to undertake the work of drawing and measuring these furnaces. Some of the furnaces are deteriorating year by year and it will be impracticable to stop this, but early measurement will give us information which will be impossible to obtain if this task is left much longer.

Melbourne Furnace, Derbyshire

This 18th century furnace is being excavated at weekends and public holidays by Mr W H Bailey of Davy-United, Sheffield. He has been working on this site for about 5 years and the situation is getting urgent as it is about to be flooded for a new reservoir. The latest information suggests that water will not start to be impounded until September. There is still much that can be done and practical help would be welcomed by Mr Bailey whose address is given below. The site lies 8.0 miles from Derby market place, 12½$^{\circ}$ East of South, map reference SK/379239.

The site also appears to include a bloomery or finery, more probably the former. But it will not be possible to locate this unless more assistance is forthcoming.

B. Roman Ironworking Site

Henry Cleere is at present excavating the site of a Roman bloomery at Bardown, Wadhurst, Sussex. He will be working on the site on the 1st – 4th June and from 29th July to 17th August this year. He would welcome any help and may be contacted at his home address (given below) or at the Iron and Steel Institute. Mr James Money will be excavating a similar site at Orznash.

R F Tylecote has been invited by the National Trust to excavate the site of a Roman or Early Medieval bloomery on the ridge between Cromer and Sheringham, Norfolk. It is expected that this will take place in July 1964 and further details will be announced later.

C. Miscellaneous

If sufficient help is forthcoming and permission can be obtained it is proposed to excavate the remains of the 17th century blast furnace at Coed Ithal during Easter 1964.

Members may be interested to know that Mr Philip Rahtz, excavating on behalf of the Ministry of Works, uncovered a bell casting pit on the site of the Saxon and Early Medieval palace at Cheddar, Somerset, last year. This is the second bell casting pit to be found in this country, the first being that excavated at Thurgarton, Notts, by P W Gathercole and B Wailes in 1954-5. This latter agrees closely with that described by Theophilus in his 12th century work.

It is proposed to dismantle the cementation furnace at Derwentcote, Co Durham and re-erect it in the grounds of the Durham County Council site at Akeley Heads, Durham. The curator, Mr Atkinson, would welcome an early blast furnace, preferably one in the North, for similar treatment. Cementation furnaces are becoming rare and, therefore, also in danger of extinction. Specimens are known from Sheffield and Coalbrookdale, but the convener would be glad to have any further information regarding others that may exist.

April 1963

R F Tylecote
King's College
Newcastle upon Tyne 1

Table I

17th-18th Century Blast Furnaces still in Existence

Part 1

County	Name and Alias	Dates First and Last Worked	Date Inspected	By Whom Inspected	Map Reference	Present Owner	Details and Conditions	Report Published	Remarks
Yorks WR	Rockley near Barnsley	Erected 1652 still working in 1736	1962	R F T	SE/337021	Sheffield Trades Historical Society	Hearth lost. Shaft good. sandstone 20' x 20' x 15' high	None. (Photo T N S 1938/39 **19.** Pl.)	Preserved (subject to vandalism)
Yorks N R	Rievaulx; par. Helmsley	1st mentioned 1577; lasted until 1647	1962	R C B R F T	SE/5785		No remains above ground. ? Foundations	Ref in Schubert App X	
Glos F of Dean	White-cliff	1798-1810	1962	H W P	SO/568102		Photo. Shaft well preserved. Hearth area filled with rubble		
N Lancs	Duddon Bridge	Built 1736 last c 1866	1962	G R M	SD/197883		Well-preserved but tree growing from it	J I S I 1961 **200,** June, 444-452	
Scotland (Argyl)	Bonawe	1753-1874	1962	G B C	NN/518320			Steel & Coal 1962, **184,** 801-803	

Part 2

County	Name and Alias	Dates First and Last Worked	Date Inspected	By Whom Inspected	Map Reference	Present Owner	Details and Conditions	Report Published	Remarks
Monmouth F of Dean	Coed Ithal 1 ml north of Tintern	1651-1796	1962	R F T	SO/527027		Only a vertical section remaining; site worth excavating	Schubert, p 389 Johnson.Ec.H R 1951, 4, 324	Presumably that said to be at Tintern
Yorks	Low Mill nr Silk-stone. Parish of Cawthorne	1761 - ?	1962	R F T	SE/2907	E MacGuinness Low Mill Farm, Silkstone, Yorks (tenant)	Excellent; should be considered for preservation	Photo and drawing in T N S 1938/39 **19,** 65 and described in Baker's paper T N S 1943/45, **24,** p 115, Fig 11	
N Lancs	Nibthwaite	1736-1755	Aug 1962	G R M	SD/293898	Mr Satter-waite of Etna, Nibthwaite	Lower part good		
N Lancs	Newland	1747-1891	1962	R C B			Part remaining. Mostly dismantled 1903		
N Lancs	Backbarrow	1711 to date		G R M	SD/355847			W H Sansom, Metallurgia, April 1962, p 165-170	Out of blast 1967 owner hopes to preserve lower part
Scotland (Argyl)	Goatfield (Loch Fyne)	?	1962	Adams, McCallum R C B					

Part 3

County	Name and Alias	Dates First and Last Worked	Date Inspected	By Whom Inspected	Map Reference	Present Owner	Details and Conditions	Report Published	Remarks
Derbys	Melbourne	1725-c 1780	Excavation in progress (Reservoir will flood it)	W H B	SK/379239	Dove River Board	Foundations of Furnace and outbuildings		
Derbys	Heage nr Alfreton	?				Stanton Iron Works Ltd	Preserved by the firm		Inf by G R M
Staffs	Newcastle-under-Lyme	1597? - 1800	1962	B M H			Being investigated by B M H	Ref? Schubert, p 181	
Staffs	Coalbrookedale *	O B F 1638 (Rebuilt 1777) Ceased 1812 (?)				Allied Ironfounders Ltd	Preserved by the firm	Raistrick; Mott, etc	N B F Erected 1792 (never finished)
Cumberland	Maryport	1752-1783	1956	C R B	NY/035362		Bad state of preservation	Schubert, J I S I 172, 162	demolished
Derbys	Ambergate	1764-	1962	W H B R F T		R Johnson & Nephew	Shaft to full height. ¾ lining		demolished

Part 4

County	Name and Alias	Dates First and Last Worked	Date Inspected	By Whom Inspected	Map Reference	Present Owner	Details and Conditions	Report Published	Remarks
Yorks	Cawthorne		1922				Known as Parker's furnace		
Worcs	Littleshall (? two)	? 19th century		W Gale					
Derbys	Morley Park	? 1700 - 1870	1960	W H B	Preservation by Stanton Ironworks	?	Drystone. In very good condition	?	W H B has a photo
Glos	Gunn's Mill (Nr Cinderford)	1683 (acc to beam)	1925	Newcomen Society			Seems to have been built into a house which has later been pulled down	T N S 1924-5 5, 87, Plate XXI (No details)	
Denbigh	Plasmadoc (Ruabon)	1670-1760 & possibly later	1962	I Edwards	SJ/288436	?	Little but low wall in pond; 2 ft above water & 8-9 ft dia.	Tr Denbigh Hist Soc 1960, 1961	

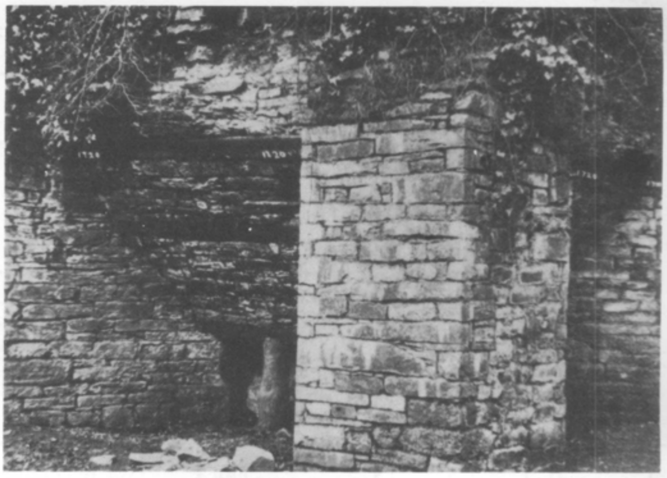
Retrospective comment

At the end of the Group's first year of existence twenty-seven names appeared in the first Membership List, twelve of which also appeared in the Historical Metallurgy Society's 1981 list.

HMG BULLETIN 2

First published December 1963

Contents



Brecon, River Honddu, blast furnace. Picture by courtesy of W E Minchinton

17th-18th Century Blast Furnace Survey

Additional information has come in regarding blast furnaces which may still be extant and corrections have been made to the information contained in the first issue of the Bulletin. These are now incorporated in Table I. The previous entries regarding Heage and Morley Park relate to the same furnaces, one 18th and the other 19th century. Unfortunately the dimensions of these are still unrecorded. Maryport is now demolished and has been deleted. We would be glad to have further information regarding the furnace at Sharpley Pool, Astley, Worcs, which was recently the subject of a letter in Country Life (May 9th, 1963) by Miss M Wight. This was photographed by Schubert but has deteriorated lately and if details are to be obtained the work must start soon. Miss Wight reports a furnace at Charlcote, Salop, and there may be another at Brecon.

It is very doubtful whether any remains of Parker's furnace still exist. None could be seen by J Turton and R F Tylecote. On the probable site of the Upper and Nether Bank furnaces at Elmley, Yorks (WR), slag heaps and the remains of dams are visible. There may be the foundations of furnaces, and since this area is going to be open cast mined in the near future it is important to survey it and to watch the progress of the mining.

Table I

17th-18th Century Blast Furnaces still in Existence

Part 1

County	Name and Alias	Dates first and Last Worked	Date Inspected	By Whom Inspected	Map Ref.	Present Owner	Details and Condition	Report Published	Remarks
Glos	Gunn's Mill Nr Cinderford	1683 (acc to beam)	1925 1964	Newcomen Soc R F T	SO/675159		Built into a farm	T N S 1924-5, 5, 87, Plate XXI (No details)	
Denbigh	Plasmadoc (Ruabon)	1670-1760 & possibly later	1962	I Edwards	SJ/288436	?	Little but low wall in pond; 2 ft above water and 8-9 ft dia	Tr Dynbigh Hist. Soc 1960, 1961	
Worcs	Sharpley Pool, Astley	1652-	c. 1960	M Wight		A Cowley Esq Beechcroft, Pedimore, Stourbridge	Vertical section only – rapidly deteriorating	Trans Worcs Arch Soc 1929, 4, 92, Photo in Schubert, opp p 199.	
Salop	Charlcote, Wrickton, Clee Hills	?		M Wight			Complete, though overgrown	None	
Brecon	Brecon, R Honddu	1720						Breconshire, p 66 J Lloyd. Historical Memoranda of Breconshire, Vol 2 1904.	Inf. from C Blick

Part 2

County	Name and Alias	Dates first and Last Worked	Date Inspected	By Whom Inspected	Map Ref.	Present Owner	Details and Condition	Report Published	Remarks
Monmouth F of Dean	Coed Ithal 1 ml north of Tintern	1651-1796	1962	R F T	SO/527027		Only a vertical section remaining site worth excavating	Schubert, p 389. Johnson Ec H R 1951, 4,	Presumably that said to be at Tintern
Yorks W R	Low Mill nr Silk-stone. Parish of Cawthorne	1761-?	1962	R F T	SE/2907	E MacGuiness, Low Mill Farm Silkstone, Yorks	Excellent; should be considered for preservation	Photo and drawing in T N S 1938/39, 19, 65, and described in Baker's paper T N S 1943-45, 24, p 115, Fig 11	
N Lancs	Nibthwaite	1736-1755	Aug 1962	G R M	SD/293898	Mr Satterthwaite of Etna, Nibthwaite	Lower part good		
N Lancs	Newland	1747-1891	1962	R C B			Part remaining. Mostly dismantled 1903.		
N Lancs	Backbarrow	1711 to date		G R M	SD/355847			W H Sansom, Metallurgia, April 1962, p 165-170	
Scotland (Argyll)	Goatfield (Loch Fyne)	?	1962	Adams, McCallum, R C B					

Part 3

County	Name and Alias	Dates first and Last Worked	Date Inspected	By Whom Inspected	Map Ref.	Present Owner	Details and Condition	Report Published	Remarks
Derbys	Melbourne	1725-c.1780	Excavation in progress (Reservoir will flood it)	W H B	SK/379239	Dove River Board	Foundations of furnace and outbuildings		
Derbys	Morley Pk Heague, nr Belper	Two furnaces (1) 1780-1874 (2) 1818-1874	1961	G R M W H B F S		Stanton Iron Works Ltd	Preserved by the firm: Dry stone, in very good condition	F Nixon. The Stantonian 1961. 22. 259. Derbs Countryside. 1951 April/June	
Staffs	Newcastle-under-Lyme	1597?-1800	1962	B M H			Being investigated by B M H	Ref? Schubert, p 181	
Salop	Coalbrooke-dale	Old B F 1638 (Rebuilt 1777) Ceased 1812(?)				Allied Iron-founders Ltd	Preserved by the firm	Raistrick; Mott etc	New B E. Erected 1792. (Never finished)
Derbys	Ambergate	1764-	1962	W H B R F T		R Johnson & nephew	Shaft to full height. ¾ lining		
Yorks	Cawthorne	1799-	1922	J Turton			Known as Parker's furnace		
Denbigh	Brymbo	18th cent	1962	W Gale		Brymbo Steel Works (GKN)	Used as a sand bunker; stack repaired with brick		

Part 4

County	Name and Alias	Dates first and Last Worked	Date Inspected	By Whom Inspected	Map Ref.	Present Owner	Details and Condition	Report Published	Remarks
Yorks W R	Rockley near Barnsley	Erected 1652 still working in 1736	1962	R F T	SE/337021	Sheffield Trades Historical Soc.	Hearth lost. Shaft good; sandstone 20' x 20' x 15' high	None. (Photo T N S 1938/39 19, Pl)	
Yorks N R	Rievaulx; par. Helmsley	First mentioned 1577; lasted until 1647	1962	R C B R F T	SE/5785		No remains above ground. ? Foundations	Ref in Schubert	
Glos F. of	Whitecliff	1798-1810	1962 1964	H W P N B R F T	SO/568102		Now inscribed 1806. Photo. Shaft well preserved. Hearth area filled with rubble. Probably steam blown.		
N Lancs	Duddon Bridge	Built 1736 last c.1866	1962	G R M	SD/197883		Well preserved but tree growing from it	JISI 1962, **200**, June, 444-452.	Now scheduled
Scotland (Argyll)	Bonawe	1753-1874	1962	G B C	NN/518320			Steel & Coal 1962, **184**, 801-803.	

It would appear that the following furnaces still require a fully dimensioned survey. Some are not threatened in any way and these have been put at the bottom of the list.

1. Astley
2. Plasmadoc
3. Ambergate
4. Whitecliff
5. Brecon
6. Bonawe
7. Goatfield
8. Gunn's Mill
9. Morley Park (2)
10. Charlcote

Reports of Work in Progress

(1) Blast Furnaces

(a) Melbourne

The work on Melbourne is nearly completed and very soon the water level will be rising sufficiently to drown the lower part of the site. A contour map was made during Easter covering the main area of the site, and Mr Bailey is now completing the excavation of the furnace structure. The tuyere consists of two externally hemispherical and internally conical blocks of stone and traces of the foundations of the bellows (about 17 ft long) are just visible. The hearthstone has been exposed, together with some traces of iron embedded in the casting floor. The hearth appears to be 'D' shaped in plan, about 4 x 4 ft in area and 6 ft high, and the remains show the beginning of a square bosh. It thus appears that we have the bottom part of the furnace with a parallel hearth and flared bosh. This is the part that is so often missing in the better preserved furnaces such as Rockley.

As mentioned in the first issue of the Bulletin, there appears to have been a bloomery on the site which was in use at the same time as the blast furnace or before it. The latter seems to be more likely. Unfortunately the season's digging has failed to unearth anything more than cinder and slag.

Higher upstream are remains of another blast furnace site. This has been supplied with water by means of a mill race at a fairly high level above the stream. There seems to be no pond, the water presumably being allowed to work an overshot wheel directly. No trace of the structure is available at the moment although there is plenty of slag and other debris. It is possible that this is Calke furnace, sometimes confused with Melbourne. The fact that this is so far upstream means that it will not be flooded for some time; the remains of the mill race will probably never be flooded as they are just about on the high level of the reservoir.

(b) Maryport, Cumberland

During June 1963 the Convener was informed that this blast furnace had been demolished a few weeks previously. The fact that this sort of thing can occur shows how careful the Group must be to ask the owners of such antiquities to inform members of the Group of such a possibility so that the structure can be inspected and recorded before demolition. All we now have in our possession is a full set of photographs of the exterior, seven lintel beams and one tap hole plate, a large lump of mixed slag and metal (a bear?), some bricks and possibly some very small pieces of slag. We have interrogated the demolition workers with not very successful results and we have a considerable amount of historical evidence. Unfortunately all this does not allow us to reconstruct the interior with as great a degree of certainty as we would like. Distington Engineering Company Limited have kindly analysed the beams and 'bear' with the results given below.

Table II

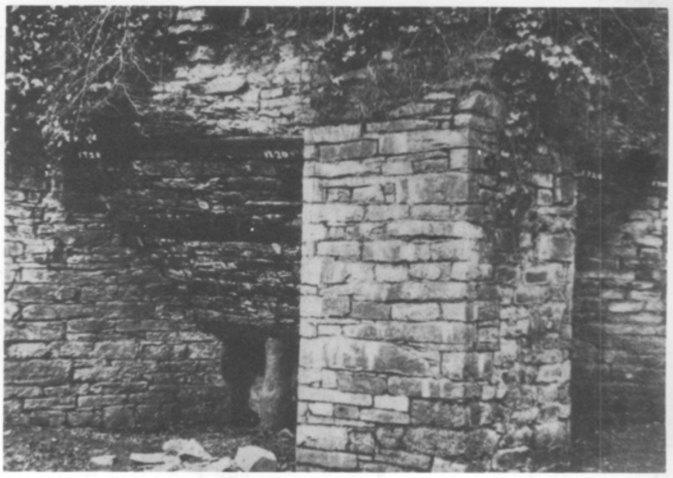
Composition % of Cast Iron Lintel Beams

	Tc	Si	Mn	S	P
Lintel	4.05	0.74	0.10	0.023	0.152
Lintel	3.81	0.46	0.11	0.073	0.121
Lintel	3.74	0.54	0.10	0.023	0.125
Lintel (Burnt)	3.94	0.66	0.07	0.014	0.120
Tap hole Plate	3.03	1.88	0.29	0.15	0.422

HMG BULLETIN 2

First published December 1963

Contents



Brecon, River Honddu, blast furnace. Picture by courtesy of W E Minchinton

17th-18th Century Blast Furnace Survey

Additional information has come in regarding blast furnaces which may still be extant and corrections have been made to the information contained in the first issue of the Bulletin. These are now incorporated in Table I. The previous entries regarding Heage and Morley Park relate to the same furnaces, one 18th and the other 19th century. Unfortunately the dimensions of these are still unrecorded. Maryport is now demolished and has been deleted. We would be glad to have further information regarding the furnace at Sharpley Pool, Astley, Worcs, which was recently the subject of a letter in Country Life (May 9th, 1963) by Miss M Wight. This was photographed by Schubert but has deteriorated lately and if details are to be obtained the work must start soon. Miss Wight reports a furnace at Charlcote, Salop, and there may be another at Brecon.

It is very doubtful whether any remains of Parker's furnace still exist. None could be seen by J Turton and R F Tylecote. On the probable site of the Upper and Nether Bank furnaces at Elmley, Yorks (WR), slag heaps and the remains of dams are visible. There may be the foundations of furnaces, and since this area is going to be open cast mined in the near future it is important to survey it and to watch the progress of the mining.

Table I

17th-18th Century Blast Furnaces still in Existence

Part 1

County	Name and Alias	Dates first and Last Worked	Date Inspected	By Whom Inspected	Map Ref.	Present Owner	Details and Condition	Report Published	Remarks
Glos	Gunn's Mill Nr Cinder-ford	1683 (acc to beam)	1925 1964	Newcomen Soc R F T	SO/675159		Built into a farm	T N S 1924-5, 5, 87, Plate XXI (No details)	
Denbigh	Plasmadoc (Ruabon)	1670-1760 & possibly later	1962	I Edwards	SJ/288436	?	Little but low wall in pond; 2 ft above water and 8-9 ft dia	Tr Dynbigh Hist. Soc 1960, 1961	
Worcs	Sharpley Pool, Astley	1652-	c. 1960	M Wight		A Cowley Esq Beechcroft, Pedimore, Stourbridge	Vertical section only – rapidly deteriorating	Trans Worcs Arch Soc 1929, 4, 92, Photo in Schubert, opp p 199.	
Salop	Charlcote, Wrickton, Clee Hills	?		M Wight			Complete, though overgrown	None	
Brecon	Brecon, R Honddu	1720						Breconshire, p 66 J Lloyd. Historical Memoranda of Breconshire, Vol 2 1904.	Inf. from C Blick

been carried out on the slags and cinders. In many respects this site bears comparison with that at Walney Island, Lancashire. Little fuel was available and the nearest ore was some miles away inland. It would almost seem that the local inhabitants made a practice of using the most out of the way sites for their smelting operations. These seem to be most primitive. No large pieces of tap slag have been recovered and most of the material seems to be pieces of bowl furnace bottoms, suggesting a furnace diameter of about 10 in.

James Cherry also reports a bloomery site at Ennerdale Shieling which appears to have a date later than the 14th century. This lies on the banks of Smithy Beck about ½ mile above a stone built bloomery on the banks of the lake itself. Open cast mining is visible about ½ mile above the Shieling site.

(e) Muncaster Head

This appears to be the site of a very late bloomery perhaps 1636, or of a later forge. It has been recently surveyed by Cherry. The site lies near a mill race and contains large pieces of tap slag, some well baked red clay and yellow fire brick . Two stone structures were found; one the foundations of a circular stone building 30 ft diameter, and the other a rectangular structure, 10 by 20 ft overall, which may have been the furnace. The situation of this latter structure is such as to render the application of water power difficult and it is clear that the date and method of working of this site will have to await excavation.

(f) Glaisdale, Yorks

A medieval bloomery has been unearthed on Postgate Hill, Glaisdale, about 5 miles inland from Whitby and has been reported by Mrs G Stainthorpe. The structure consists of a partly rock cut, partly stone lined, hollow about 6 ft by 3 ft. In shape this reminds one of the smelting pits found by Spurrell on the Holt-Crommer Ridge in Norfolk which it is hoped to excavate in the coming season.

The hearth lies at one end with cinder still **in situ**. Leading into or out of this hearth is a 'flue' which is unlikely to be an exit of exhaust gases and more likely to indicate the position of the tuyeres now withdrawn. This passage is covered by a large stone slab reddened on the inside. The slag has been tapped into a hollow in front of the hearth. Tap slag covers a large area around the furnace and the pottery found at a depth of 12 to 16 ins is dated to the 12th century or early 13th century. This agrees with the documentary evidence that the Guisborough Canons had 'forges' in this area from 1223 onwards for a number of years.

Notes

Duddon Furnace has at last been scheduled by the Ministry of Works and Public Buildings. This means that it is not likely to be demolished without warning as in the case of Maryport, but this form of preservation is negative in character and does not mean that the structure will be well preserved. It is hoped that the owner will give permission for preservation work to be done.

The cementation furnace at Derwentcote has been cleared of overgrowth prior to its removal to the open air museum at Akely Heads, Durham.

The Council for the Preservation of Sheffield Antiquities is hoping to raise £50,000 to restore the Abbeydale Works which have recently been saved from demolition. It is hoped that this site will soon be scheduled as an ancient monument. It lies on the banks of the Sheaf, three miles out on the Derbyshire side of the city and comprises furnaces, grinding house, forges, store rooms, a counting house and tilt-hammers. The site is at present owned by the Sheffield Corporation who used it until recently for the storage of equipment from the parks department (The Guardian, November 21st, 1963).

A Late Bronze Age habitation site at Weston Wood, Surrey has yielded a bronze awl and pieces of plano-convex bun ingots. These have been examined by Mr Stubbington of the RAE, Farnborough, who reports that the awl consists of a tin bronze, and the pieces of plano-convex ingot of pure copper.

Further excavations by Mrs M U Jones on the Early Iron Age site at Old Sleaford, Lincs have produced more pieces of clay coin moulds and crucibles.

Excavations in 1964

Excavations are planned for the blast furnace at Coed Ithal for Easter; on the bloomery site at West Runton, Cromer during the last two weeks of July, and at Bardown and Minepit Wood on the dates indicated above. Volunteers are wanted for all these excavations.

The Convener would be glad to have from any member or other person information relating to any type of site of metallurgical significance, particularly those threatened by immediate demolition.

R F Tylecote

Recent Publications of Members of the Group and Others

Anon — **Roman Britain in 1961. (Photo of Pickworth, Lincs shaft furnaces excavated by Ian Smith.** *Journal of Roman Studies ,1962,* **52** *, 173).*

G Jobey — **An Iron Age Homestead at West Brandon, Co Durham. (Early Iron Age rock-cut bowl furnaces).** *Archaeologia Aeliana, 1962,* **40**, *1 - 34.*

R F Tylecote — **The Method of Use of Early Iron Age Coin Moulds.** *Numismatic Chronicle, 1962,* **2** , *101-109.*

N S Angus, C T Brown and H F Cleere — **The Iron Nails from the Roman Legionary Fortress at Inchtuthil, Perthshire.** *JISI 1962,* **200**, *956 - 968.* (Also ref to Cranbrook bloom).

R F Tylecote — **The Roman Anvil from Sutton Walls, Herefordshire.** *Trans Woolhope Nat Field Club, 1961,* **37**, *56-61.*

J W Anstee and L Biek — **A Study in Pattern Welding.** *Medieval Archaeology, 1961,* **5**, *71.*

G R Morton — **The Products of Nibthwaite Ironworks.** *The Metallurgist, 1963,* **2**, *259-268.*

G R Morton — An 18th century Ironworks. *The Metallurgist, 1963,* **2**, *299-300.*

J R Spencer — **Filarate's description of a 15th century Italian Iron Smelter at Ferriere.** *Technique and Culture, 1963,* **4,** *201-206.*

Z Hegedus — **Iron Blooms in Hungarian Museums.** *Rev Hist Siderurgie, 1962-3,* **3,** *197-207.*

H F Cleere — **Primitive Indian Ironmaking Furnaces.** *Brit Steelmaker, 1962,* **29,** *April. 154-158.*

J H Chaplin — **Notes on Traditional Smelting in N Rhodesia.** *S African Archaeological Bull 1961,* **16,** *62. June. 8 pp.*

W E Bardgett and J F Stanners — **The Delhi Pillar; a study of the corrosion aspects.** *JISI 1963,* **201,** *Jan 3 - 10. (Letter 1963,* **201,** *May, 454).*

C C R Pile — **Cranbrook (Finding of Roman Fe bloom).** *Arch Cant 1958,* **72.** *XLVII, LX-LXII.*

Historical Note

Some Details of an Early Blast Furnace

Geo R Morton

> *'The first furnace was established in the Chase of Cannock in Staffordshire, by William Lord Paget between 1561 and 1563, after a ten-years' lease of a bloomsmithy built in 1542 at Risom Bridge in the same district had expired.' – H R Schubert, 'History of the British Iron and Steel Industry'.*

In discussing the above statement Schubert, making specific reference to the Midlands, made use of a survey of Lord Paget's possessions compiled in 1543 and later[1].

To those interested in industrial archaeology the above statement offers a challenge, and it is this challenge that prompted the writer to undertake the work leading to the production of this note.

The charcoal era of the blast furnace ended around 1730 with the introduction of iron smelting by coke as a result of the invention of Abraham Darby, thus the furnace on Cannock Chase must have ceased operation at least some 250 years ago. The Chase, situated on a coal-field and on the borders of the Black Country, is somewhat influenced by industrialisation, and considerable doubt existed regarding the possibility of finding any remains of the furnace site. Examination of the Ordnance Survey map does not reveal a 'Risom Bridge' – there is, however, a 'Rising Brook' and the close connection of these two terms suggested a line of exploration.

Whilst working on similar projects in the Lake District it was interesting to find that a wild plant – persicaria – appeared to be associated with such sites, and in particular where charcoal was to be found. Details of this plant are given in fig 1.

Fig 1 Persicaria (Bistort)

The blast used to blow charcoal furnaces was provided by a pair of bellows, usually driven by a water wheel, and a 'furnace pool and race' controlled the rate of flow of water past the wheel. The slags produced in charcoal blast furnaces have melting points in the order of 1350°C and have a lime/silica ratio of approximately 0.5 with an iron content of some 3.5%. Such slags are readily identified by their bottle-green to green–blue colour, and their glassy nature.

Armed with the above information, an exploration of the course of Rising Brook revealed, at a point about a mile on the Rugeley side of Hednesford, a partially removed slag heap with a well-defined mill race, and traces of the remains of furnace hearth stones – these details are shown in fig 2.

The bottle-green slag is similar to that found at Duddon Bridge and gave analysis as in table 1.

%	Cannock	Duddon Green Slag
SiO_2	49.66	56.40
Al_2O_3	23.16	12.40
MnO	3.29	9.8
CaO	11.92	14.60
MgO	7.16	3.60
FeO	4.37	2.60
P_2O_5	0.07	
S	0.10	

Table 1 Analysis of Cannock and Duddon Slag

Part of a section through the hearth was taken and set, on a reduced scale, along with a portion of the 'bear' which remained after the last tap before a re-line, in plaster of Paris. This bear contained small amounts of iron and lumps of charcoal embedded in a refractory-rich slag.

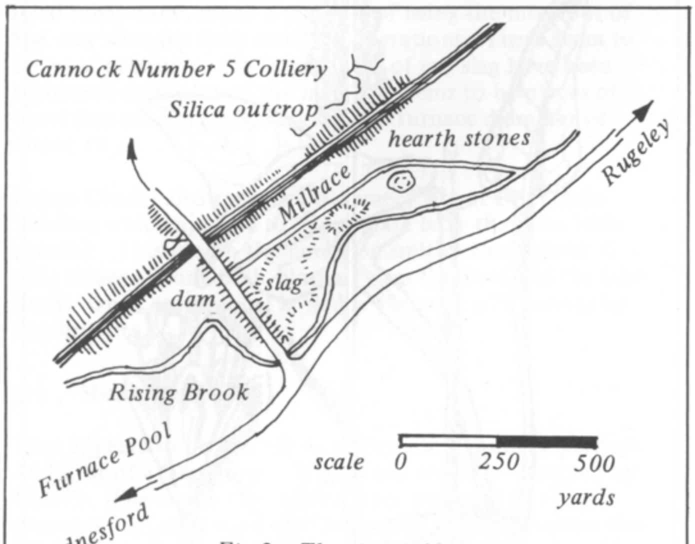


Fig 2a The site in 1963

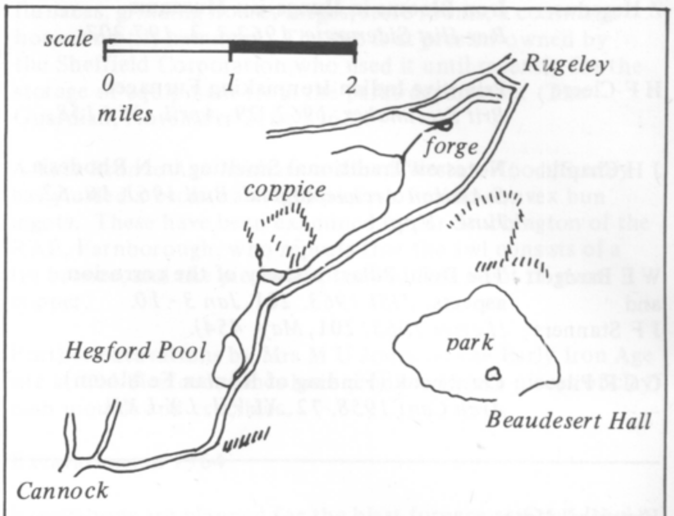


Fig 2b From Shaw's 'History of Staffordshire' 1798

of penetration of iron and slag. In the vicinity of the bottom, ie the portion in contact with the bear, considerable attack had taken place and the stones were affected to the centre.

In the area where the slag heap had been partially removed (possibly for road-making), a layer of sandy material was exposed in section, and it was decided to trench through this section in order to examine what might have been the discard from an early re-line of the furnace. This sandy material was undoubtedly the weathered remains of a hearth and side walls and sufficiently large pieces held together by the glazed surfaces (due to the action of slag) and the metal penetration at the joints, were obtained to reconstruct the structure. In addition, bricks made of local marl, and showing the effects of heat, provided details of the structure above the lintel.

The Hearth

Sufficient of the hearth was uncovered to show the nature of the build-up of the sandstone blocks used, and the type

The white sandstones were coloured from deep yellow at the edges to a buff at the centre, and the exterior was covered with a layer of metal-rich slag. As the depth of the hearth became further from the source of heat the attack was considerably less until very little alteration of the original stone was noted. Unfortunately, due to the removal of a great part of the structure, the actual depth of this penetration could not be ascertained. Details of a charcoal furnace and the materials of construction of that at Cannock are given in figs 3, 4 and 5 .

The Side-walls

That the section of the hearth was square could be readily seen by the nature of the metal-impregnated joints and the angles they made with the vertical glazed faces. At the corners considerable metal penetration had taken place, a

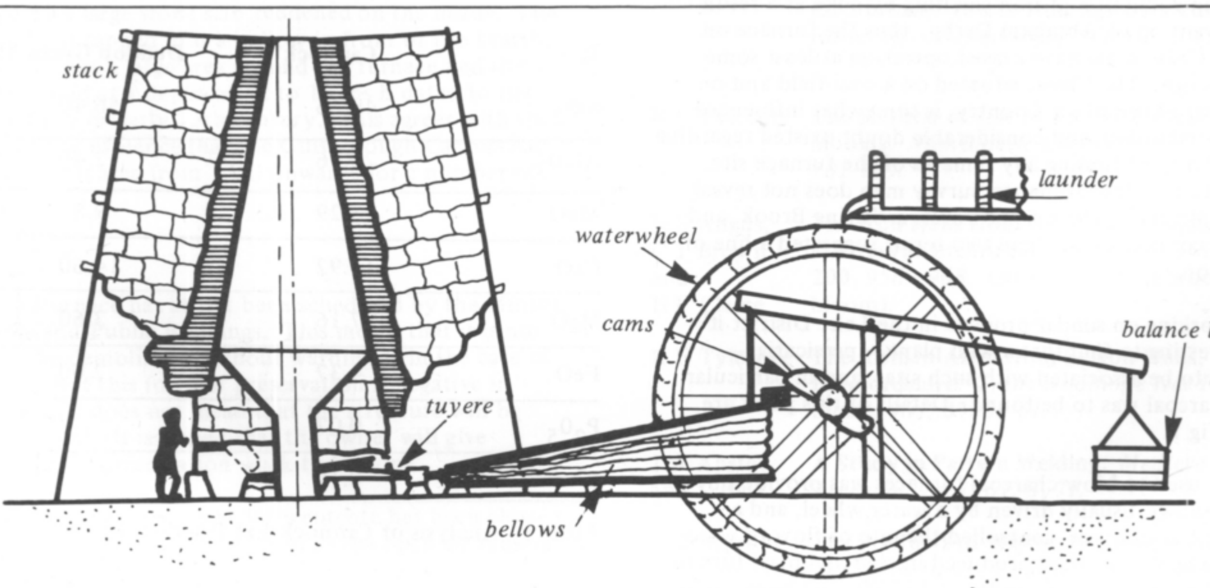


Fig 3 Early charcoal blast-furnace

fact which might have been the deciding factor in changing the shape of furnace hearths from square to round. Erosion mainly at weak joints was considerable, but the glazed nature of the surface was maintained with little slag attack immediately behind the glaze – this was in marked contrast to the attack of the hearth blocks. The height of the hearth could not be established.

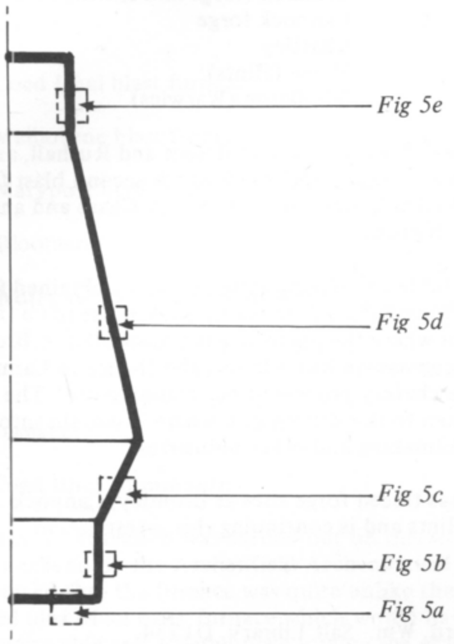


Fig 4 Positions of sections detailed in Fig 5

The Bosh

In the weathered mass from the slag heap one stone was found in which the angle of the glazed face to the joint was not a right angle, and it was assumed that this stone was from the region of the bosh. The stone was so fragile that it was decided to mount it in plastic and then section it in order to measure the angle between the sloping side and the horizontal joint line, – this was 78°. Owing to the small size and amount of this stone, the shape of the bosh could not be determined.

The Stack

Flat bricks of section 2 in. x 4 in. and made of crude marl in which large pebbles are to be found appear to have been used in the construction of the stack. Many bricks of this type were found, and the appearance of the heat-affected ends suggests that they were used in step formation in order to provide the 'batter' of the stack.

Rather unusual curved shaped bricks appear to have been used in the region of the throat – many bricks of the type shown in fig 5e and bonded with similar bricks of larger diameter were uncovered. When these were assembled and an arc struck and measured, the diameter of the throat works out to between 2 ft 6 in and 3 ft.

General

From the foregoing it appears that the hearth section was

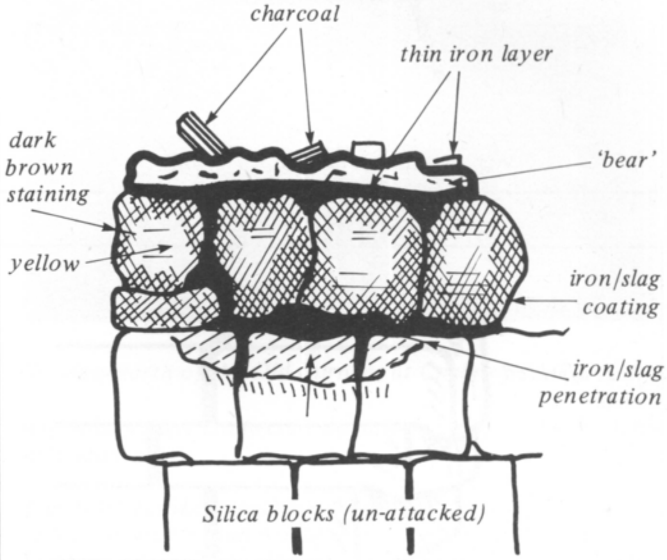


Fig 5a Section through hearth

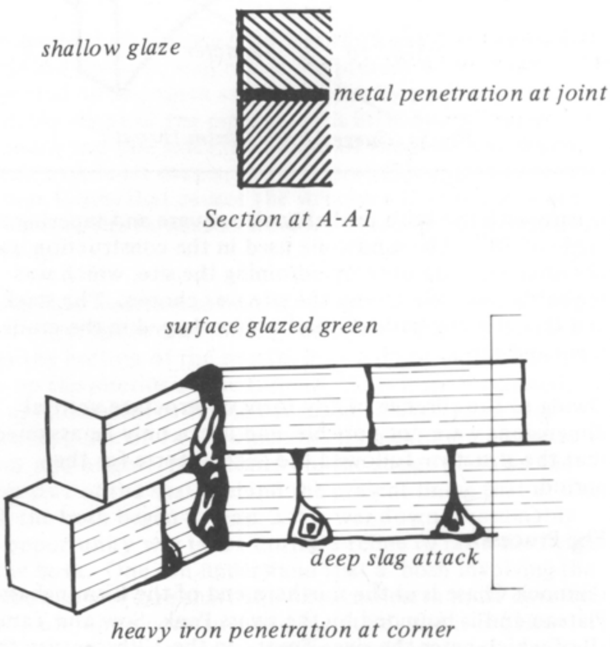


Fig 5b Section of side-wall

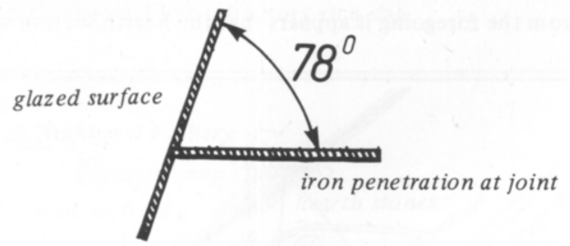


Fig 5c Side view of 'bosh' stones

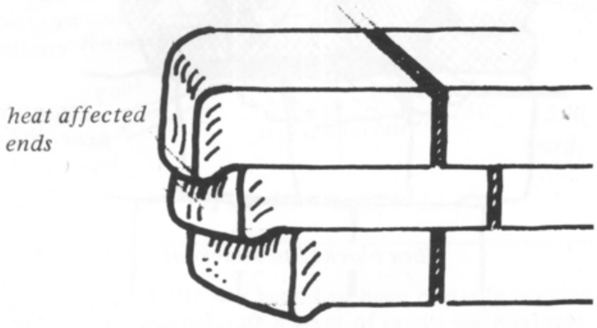


Fig 5d Bricks from stack

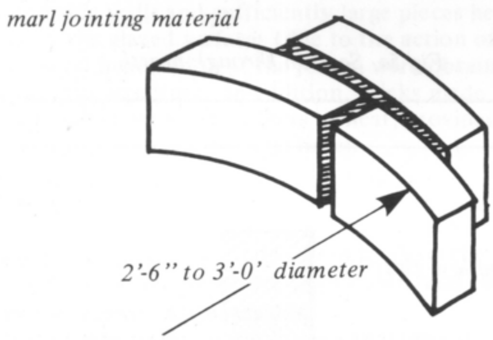


Fig 5e Curved bricks from throat

square with the bosh probably also square and tapering at an angle of 78°. The sandstone used in the construction was obtained from an outcrop adjoining the site, which was probably one reason why the site was chosen. The stack and throat were made of marl bricks shaped in the crude form and fired.

Owing to the absence of any form of structure vertical dimensions were not possible, and it can only be assumed that the structure followed the general form for the period.

The Process

Cannock Chase is at the northern end of the Birmingham Plateau and is bounded by the rivers Penk, Sow and Tame, all of which enter the river Trent. In the 17th century the area was heavily wooded and because of its distance from the sea the wood was declared unsuitable for naval use and thus available for use in ironmaking[2]. It was for this reason that the iron industry of the Midlands developed in the region of the river Tame. The 1717 list of furnaces and forges[3] names the following:-

a.	Furnaces	Nil
b.	Forges	Aston (Little Aston) Bromley Bromich (forge and slitting mill) Cannock forge Chartley Hince (Hints) Middleton (Warwics)

Other sources[4,5] show forges at Bescot and Rushall, and slitting mills at Rugeley and Weeford. A second blast furnace was established at Teddesley on Cannock Chase and another at Aston, nr Witton.

Iron ore, suitable for making tough iron was obtained from Rushall (nr Walsall)[6] and carried by pack horse to Cannock furnace from where the pig iron was transported to Bromley furnace for conversion into blooms and thence to Cannock forge for the chafery process of bar manufacture. The bar was then taken to the slitting mill where it was slit into rod for use in nailmaking and other industries.

The writer has traced forge sites at Bromley, Cannock ,Little Aston and Hints and is continuing this investigation.

References

1 Stafford, Wm. Salt Library, D1734.

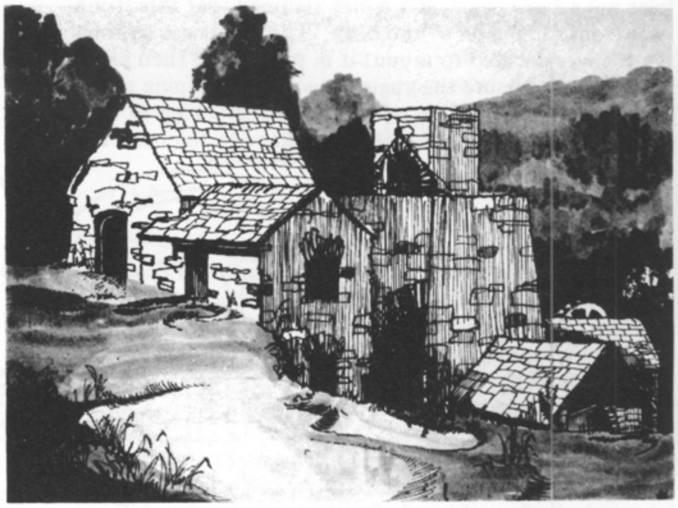
2 Hackwood F W. Chronicles of Cannock Chase (1903) 71.

3 Hume E W. Transaction of the Newcomen Society (1928-29) 12.

4 Johnson B L C. Economic History Review (1952) Vol IV, No 3, 338.

5 Shaw S. History of Staffordshire, Vol 1, Facing Page 1.

6 Plot R. Natural History of Staffordshire (1686), 161-164,



An impression by John Morton of the original layout and construction of the Cannock charcoal blast furnace of 1561.

HMG BULLETIN 3

First published June 1964

Contents

Photograph Ironbridge Gorge Museum Trust.

The forehearth of the Old Furnace at Coalbrookdale.

1. **Blast Furnaces**

(a) Coed Ithel, Monmouth

A successful excavation was carried out on this site over the Easter weekend by the Archenfield Archeological Group. This showed that the furnace was quite unlike the normally accepted idea of an early furnace which would have a separate crucible and a flared bosh joining the shaft well below the half way mark.

The furnace at Coed Ithel today consists of a vertical section nearly through the diameter showing the square shaft and a circular hearth. This clearly dates it to the second phase of British furnace construction, following the period where both shaft and hearth were square.

The prime purpose of the excavation was to examine the hearth, and to obtain a diametral section from top to bottom since the furnace seemed to be, with our limited knowledge, of unique shape. Two trenches were cut, one through the centre of the furnace, and the other some 7 ft to the east which was intended to cross the casting floor. Trench 2 (that through the centre of the furnace) disclosed the tuyere system and the upper levels of the hearth. The hearth was cleared and a section at 37^{o} to the line of Trench 2 gave the 'lines' of the furnace (Figure 1). This angle was chosen as that giving the best vertical section of the furnace structure since at no point was the remaining structure an exact diametral section. The section shown in Figure 1 is 9 ins from the vertical axis of the furnace.

Trench 1 intersected the south-east corner of the furnace and it was possible to obtain a full outline of the south-east buttress, or 'pillar', which stood to a height of some 4 ft. The large amount of fallen stone, however, made the casting floor somewhat difficult to examine. It consisted of about 12 ins of red sandy soil underlain by about 6 ins of black soil. The first layer above this contained a large amount of stone roof tile and was therefore the first layer containing the products of decay of the furnace.

The southern end of this trench disclosed a gully cut into the red sub-soil of the site. This appears to have drained rain water from the roof of the blowing house. It must have been allowed to silt up early in the history of the site as it contained a pair of mason's or carpenter's compasses. In this part of Trench 1 were found three cast iron runners which may have connected the main casting stream with the individual pigs.

The outer furnace structure is not regular but approximates to a 24 ft square, and would appear to have had a maximum height of about 20 ft. Its departure from the perfect right angle at the south-east corner may have something to do with the small amount of space available on this very restricted site.

Some of the fallen stones in the rubble fill were chamfered for use in corbelling, and it is clear that these stones had been used in the two openings. These openings, therefore, had not been arched but must have contained cast iron lintel beams, as may be seen in the still-standing furnace at Gunns' Mill. The angle of the chamfer shows that the openings had a vertical angle of 50^{o}, and therefore reached a maximum height of about 15 ft. This is normal and compares with the recently demolished 18th century furnace at Maryport.

The square shaft was made of 3 in thick grey sandstone and continued down to well below the present bosh, to be supported on the north and west sides by packed stone. From the shape of the pillar there is little doubt that at the south and east sides the weight of the shaft was taken on cast iron lintel beams, and it is probably the early removal of these beams that caused the structure to collapse, since the shaft of the furnace at Rockley of similar date is still standing.

The circular hearth was built up from the bottom with 6 in thick white sandstone, joining the square shaft 11 ft 6 ins from the bottom of the hearth, ie at a point more than half-way up the interior of the furnace. This is most unusual, but approximates to Powle's furnace, illustrated in the Trans Roy Soc of 1678, which has its maximum diameter at about mid-height. It is clear from the slaggy glaze on the lower part of the shaft behind the present lining that at one time the bosh began at least 2 ft lower down. Presumably the opportunity was taken during a reline to raise the height of the bosh. One can understand that a bosh involving the junction of a square shaft and circular hearth must have been a difficult job to construct and maintain, and it is quite possible that hanging or scaffolding problems suggested to the operators that it would be a good idea to raise this point to a level where the charge would not be so sticky. The bosh angle of 77^{o} compares well with that of 78^{o}, found by Morton for the furnace at Cannock (see Appendix to Bulletin No 2).

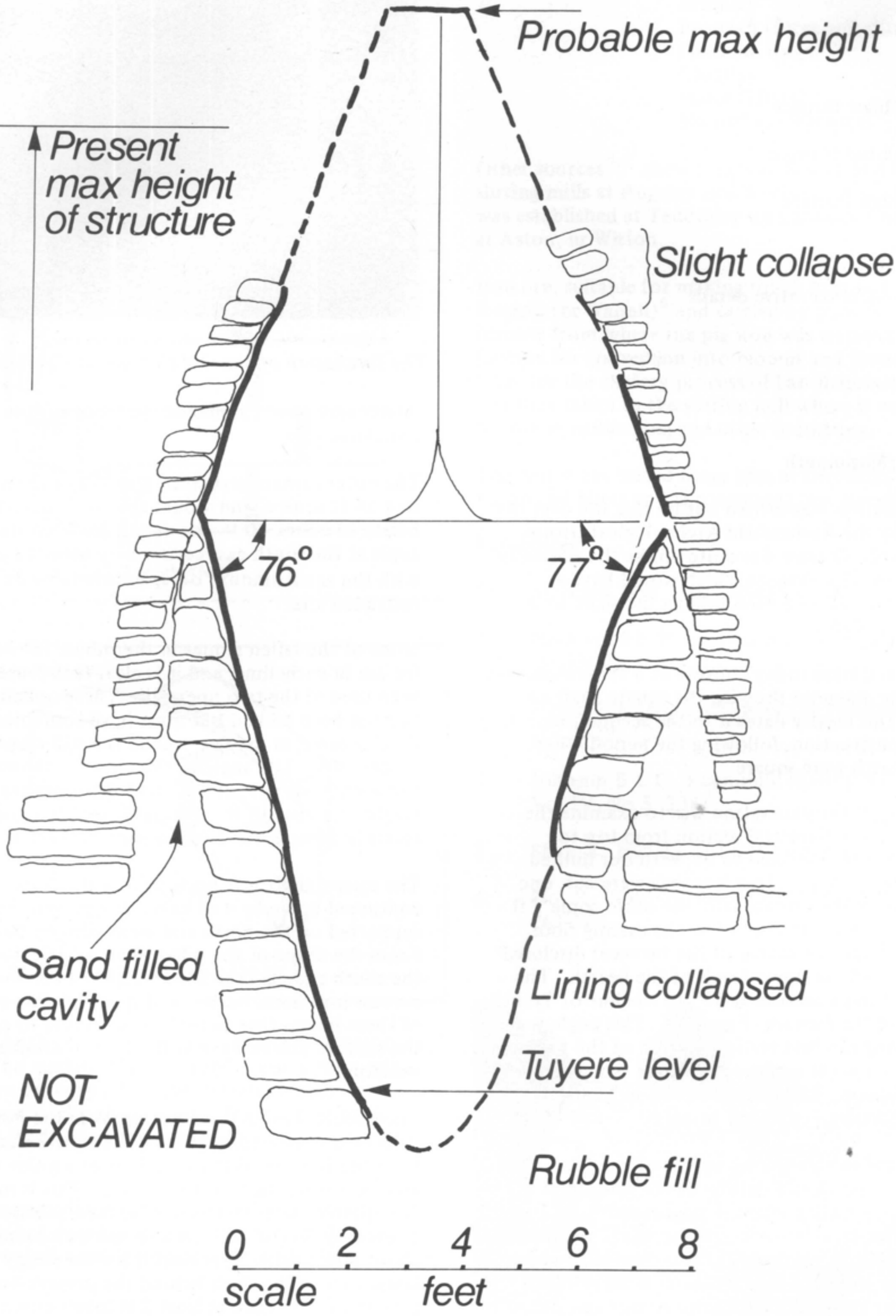


Fig 1 Coed Ithel Blast furnace as excavated 1964

Sufficient of the tuyere had escaped general destruction to show its level and its construction. It is in the form of an arch, unlike the conical tuyere from Melbourne. The base of the tuyere would be about 18 in above the bottom of the hearth.

The overall capacity of the furnace would have been 421 cu ft. The capacity of the hearth below the tuyere level is 8 2 cu ft, equivalent to about 1.65 tons of iron. The presence of a fore-hearth, for which there was no evidence due to the general destruction, but which must have surely existed, would double this volume. Some slag volume must be allowed for, and it would seem that the volume available for iron could not exceed about 2½ tons.

(b) Melbourne

Mr W H Bailey has supplied the following information on his now completed excavation at Melbourne. The remains yielded the plan of a typical 17th-18th century blast furnace with a hearth or crucible. All the furnace structure above this level had disappeared. But the arrangements for driving the wheel, and the ponds, were well preserved.

There appeared to have been two ponds of different dates. The first pond was on the same side of the stream as the furnace itself, and may have been used for an earlier bloomery. At some later stage the water storage facilities were improved by building a dam 160 ft upstream of the old dam and right across the valley. This water was led to a breast wheel, a system that makes the most economic use of water. The wheel was 2 ft wide and 17 ft diameter and operated bellows on the down stream side of the furnace, the water passing under the charging bridge.

The bellows terminated in a conical tuyere consisting of two semi-circular stones. The tap-hole consisted of a circular hole about 18 ins diameter and the base of the hearth was a large piece of sandstone. On the bottom of the hearth was a 'bear' consisting of a saucer-shaped piece of cast iron which is being examined by J Turton. All traces of the fore-hearth had gone.

The hearth itself was originally square in plan and about 5 ft high, but was now 'D' shaped due to slag accretion. The remains showed the beginning of the well-flared bosh and it would seem that this furnace belongs to the normally accepted type, like that of Lamberhurst, Kent, shown in Swedenborg's 'De Ferro', of 1724.

One feature that was well preserved in the remains was the ventilation system. This comprised a series of brick built passages running horizontally round the structure and set inside the rubble core of the masonry. These were connected by vertical passages at intervals.

Analysis of the slag is given in Section (c), and both roasted and unroasted remains of the local Coal Measure nodules were found on the site. The low lime content of the Coal Measure nodules suggests that limestone or dolomite additions were made to the burden, but no limestone was found on the site.

(c) Slag Analyses

The analyses shown in Table I have been kindly supplied by the Margam Laboratory of the Steel Company of Wales.

With the exception of Parker's Furnace, which gives a typical 19th century coke smelted slag, the sulphur contents are low and represent charcoal practice. However, the slag from Ambergate contained small pieces of carbonaceous material which seemed to be coke, and it is possible that this furnace used a low sulphur coal similar to that used

Table I

Blast Furnace Slag Analyses (%)

Sample	Melbourne A	Parker's Furnace B	Rievaulx C	Rockley D	Ambergate E
Silica (SiO_2)	41.60	38.00	45.30	45.90	53.70
Alumina (Al_2O_3)	22.73	17.17	22.48	19.07	36.55
Ferric Oxide (Fe_2O_3)	2.57	0.43	3.72	2.43	8.15
Lime (CaO)	14.12	34.04	22.80	18.40	0.96
Magnesia (MgO)	14.19	6.52	3.69	9.19	0.30
Phosphorus Pentoxide (P_2O_5)	0.023	0.011	0.055	0.50	0.09
Sulphur as Sulphide (S)	0.117	1.86	0.032	0.102	0.010
Sulphur as Sulphate (S)	0.11	0.24	0.19	0.058	0.024
Manganese Oxide (MnO)	3.01	1.25	1.17	2.95	0.09
Total Iron (Fe)	1.80	0.30	2.60	1.70	5.70

by Derby at Coalbrookdale (Mott gives 0.5% S). It is well known that certain seams of Derbyshire coal have low sulphur content. It is clear that Ambergate did not use lime, the high alumina content being sufficient to produce a fluid slag; it is not surprising that this slag has the highest Fe content. The CaO plus MgO contents of the other slags are of the same order, and it is possible that dolomite has been used as a flux at Melbourne and Rockley. Rievaulx presumably used a Cleveland type of ironstone.

(d) Maryport

Historical research is still in progress on this site, but it is expected to present a final report in the near future. Meanwhile the following analyses of irons from Maryport and neighbouring furnaces have been made available by D R Wattleworth.

Table II

Analyses of Pig Irons (%)

	Maryport	**Barepot**	**Clifton**
Total C	2.60	3.80	3.36
Graph C	2.12	1.56	2.73
Comb C	0.48	1.24	0.48
Silicon	3.26	2.10	1.54
Sulphur	0.12	0.15	0.16
Phosphorus	0.06	0.36	0.37
Manganese	0.40	2.45	0.71

These supplement those given in Table III of the last issue of the Bulletin. The Mn contents are not typical of Furness ore, and show that some additions of Coal Measure or bog iron ore were being made.

(e) Blast Furnace Survey

The blast furnace survey is going well and G R Morton is compiling a register. Duplicated sheets for adding relevant dimensions may be obtained from him at 38 Buchanan Road, Walsall.

Further information has been provided on the furnaces at Eglwysfach on the Dovey in Cardiganshire, and Chesterton near Newcastle, Staffs. The furnace at Eglwysfach, was inspected and recorded by Mr Luther Griffiths in 1953. A plan, section and elevation are available together with a set of photographs. This stone-built furnace was erected in 1755 and consists of a circular shaft 15 ft high to the charging floor, but the lining and crucible have been removed. It had a conical bosh 4 ft 6 ins diameter and was blown by means of a single tuyere from a blowing house under the bridge house, a 15 ft diameter water wheel being alongisde. Arched openings served the tuyere and the tap hole

The structure was restored between 1963 and 1964, the wheel being removed and the roof covered over. It was clearly a small furnace for its time.

Springwood Furnace at Chesterton, Newcastle, Staffs, was inspected by B M Hardman and the convener on 18th May. This furnace was erected about 1780 and is square and mainly brick built with a single tuyere entering the furnace by means of a stone Gothic arch. The shaft is conical, brick-lined and in good condition, but the hearth has gone. It appears to have been built to work the local Coal Measure ore, and since there is no water supply nearby, it must have been steam blown. The area where the blowing house would have been expected to be is now a cottage, but about 50 yards from the casting side of the furnace is a brick cottage that is said to have been converted from an engine house. This is certainly possible, but the blast would have had to be led rather a long way if this is the case.

This furnace could be conserved with little more than repairs to the exterior brick work, particularly at the rear where the charging ramp has been pulled down. Hardman is working on the historical side of the furnace.

D W Crossley is going to excavate the remains of the furnace at Panningridge, Sussex (TQ/687275) from July 25th to August 9th. The remains are below ground in rather water-logged soil, but the site is well documented. Crossley would welcome volunteers. Please write to him at the Department of Economic History The University, Sheffield, 10.

We have been informed that the remains of the furnace of 1720 near Brecon have been demolished. Schubert has left us a pencilled sketch of one of the openings showing that this was supported with cast iron lintels. This furnace should therefore be deleted from the list of furnaces standing included in Bulletin No 2. In its place should be inserted the Dingle Furnace at Llanelly, which was built about 1790, and the Dovey Furnace mentioned above. Apart from the flooding of Melbourne these are the only changes in this list.

2. Bloomeries

(a) Stamford, Lincs

In January the convener visited the remains of an early medieval bloomery (not later than 10th century) in the middle of Stamford which was being excavated by Alan Burchard of the Birmingham Museum.

The remains consisted of the base, about 7 ins deep, of a bowl or shaft furnace with a slag tapping pit. These were both set in clay, and the whole area was covered with a thick layer of red 'ore fines' showing that smelting had continued in the vicinity after the disuse of the furnace that was excavated.

The red ore fines contained about 30% Fe_2O_3, 4% H_2O and 5% of carbon after drying at 150°C. The reconstruction suggested is a low shaft furnace about 1 ft diameter, bellows blown from behind with slag tapping facilities in front. It used a nodular ore, no doubt obtained locally.

(b) Ariconium

N Bridgewater has completed his excavation at New Ariconium, Herefordshire. The remains consisted of a number of furnaces of the Roman period, probably of the Ashwicken type, but only the bases and slag tapping pits remained. These had been cut into rock. In some cases slag was still in situ as it had flowed out of the furnace. It is probable that these furnaces were bellows blown, and that the bellows were situated over the tapping pit and were withdrawn when it was necessary to tap slag towards the end of the smelt.

There is no indication, and little possibility, of there being bellows behind the furnace, as thought possible at Stamford. Other pits were cut into the rock and some of these were probably hearths for working up the smelted blooms.

(c) Rockley Smithies

D W Crossley is at present excavating at weekends the remains of medieval and post medieval forges a few hundred yards to the east of Rockley Furnace, Yorks (WR). This area is to be covered by the embankment of a new motorway, and Crossley would be glad to have volunteers at weekends. It is possible that there was originally a bloomery here before the building of the blast furnace in 1652 . After this the bloomery was either discontinued or converted into a finery and chafery to convert some of the cast iron from Rockley.

(d) Corby Glen ,Grantham, Lincs

Alan Rogers of Nottingham Adult Education Department, has been finding pieces of cast iron cauldron or cooking pot on bloomery slag heaps in which the only datable material is Roman pottery. It should be emphasized that this is not stratified in the archaeological sense and therefore the two may not be related, but it is at least the second case of a cast iron article being found in a Roman context, and brings up again the old question: Was cast iron used in the Roman period in the Western hemisphere? Meanwhile we would be glad to have any information relating to medieval or later cast iron cauldrons and cooking pots.

(e) Baysdale, North Yorks (NZ/645075)

Alan Aberg of the Adult Education Department, Leeds University, Middlesborough has been excavating a medieval bloomery site in Baysdale. This probably belongs to about 1300 AD. Aberg has so far excavated at least four hearths, clearly of the same type as in Glaisdale further south, which was reported in the last issue of the Bulletin. These seem to consist of clay and stone low hearths of a Catalan or Corsican type, hand blown and provided with slag tapping facilities. They were probably blown from behind or towards one side. Again some of the ore used was nodular but some of it seems to be more like the usual Cleveland type.

3. Journal of Industrial Archaeology

This journal has now been started under the Editorship of Kenneth Hudson. The Journal is interested in field work at two stages:-

1) At or close to the beginning in which case the Editor would like a paragraph or two, and

2) When the results have been analysed and studied in which case he would like an article of between 3000 and 6000 words. If members have any suitable material would they please write to the Editor, at Long Batch, Ditcheat, Shepton Mallett, Somerset.

4. Engine Houses

The existence of a possible engine house at Chesterton, suggests that blowing engine houses themselves might be a fruitful subject of study. At least two early 19th century engine houses are known to the convener, those at Maesteg, Glam and Ridsdale Northumberland (1830). The latter is an empty shell and might well be photographed and recorded before it falls down. There must be many more of these. Percy gives incomplete drawings of that at Corngreaves, Staffs, which contained a lift. A detailed examination of those remaining might show what they contained and the general arrangements.

A Constitution

A number of members met over the Whitsun holidays in order to set up a constitution. It is proposed to have a working committee consisting of a president, a chairman, a secretary, treasurer and three local or regional secretaries.

A provisional committee to run the Group until the first Annual General Meeting, probably Easter 1965, is as follows:-

President	Sir Frederick Scopes
Chairman	G R Morton
General Secretary	R F Tylecote
Treasurer	M M Hallett
Scottish Regional Secretary	Vacant
South Western Regional Secretary	Vacant
Southern Regional Secretary	H H Coghlan
Auditor	W I Pumphrey

The draft constitution is as follows:-

1) **Name**

The group shall be called The Historical Metallurgy Group.

2) **Aims**

To encourage the study of the prehistory and history of metallurgy in all its aspects and to co-operate in practical work with other organisations working in the same field.

3) **Membership**

Membership shall be open to all those in agreement with the above aims, paying the minimum annual subscription upon election and on the 1st January each year.

4) **Management**

The business of the group shall be managed by a committee consisting of the officers of the group. These shall be a president, a chairman, a secretary, a treasurer and three regional secretaries.

The committee shall be elected at the Annual General Meeting to be held between 25th March and 25th April. Nominations shall be received by the secretary fifteen days before the date fixed for the AGM.

An account and balance sheet should be presented by the committee to the AGM.

5) **Subscriptions**

Subscriptions shall be fixed at the AGM.

The subscription will be 10/- per year from 1st January 1965. This replaces the present fee of 5/- to cover secretarial expenses. Members are reminded however, that a further 5/- is due for the current year on receipt of this Bulletin.

HMG BULLETIN 4
First published January 1965

Contents

Whitecliff, Gloucestershire blast furnace c1798.

Bell Casting at Winchester

While excavating on the Cathedral Green in September, Martin Biddle unearthed the site of a bell casting place which had probably been used for the bells of the late tenth century minster, ie the church before the present one. All that remained was the trench in which the fire for melting out the wax or tallow and drying the inside of the mould was placed. Part of the mould was still in position across the sides of the trench. There were also pieces of metal which had probably broken away from the parting line between core and cope. One piece of the mould seems to be inscribed SC or ISC, which is more likely to be part of a Saxon inscription than a Latin one. This is the earliest find of its type; no Saxon bells survive in Britain but it is probable that the bell cast here bears some resemblance to those illustrated in an illuminated page from the c980 Benedictional of St Ethelwold.

Unlike the find at Cheddar and the description given by Theophilus the bell was cast at ground level, amidst the ruins of an earlier church. The ruined walls of this earlier church had been used for a shield. These remains resemble in many ways those on the medieval site at Thurgarton, Notts.

Albury, Surrey

Miss Joan Harding has been continuing her excavation on this Bronze Age site which is continuing to produce metal ware.

Blast Furnaces

(a) 16th Century. Excavations at Panningridge Furnace, Sussex.

This is one of the most closely dated of the 16th century Weald Iron Furnace sites, and was chosen by D W Crossley for trial trenching firstly to obtain slags certain to be from early working for analysis, and secondly to attempt to recover the plan of what must be regarded as a first generation blast furnace.

The site was leased by Sir William Sydney in 1542 and the furnace built there in that year was worked by the estate until 1563, in conjunction with the forge at Robertsbridge. It was abandoned by Sir Henry Sydney in 1562, and subsequently leased by William Relfe and Bartholomew Jeffery, who had other interests in iron-working in the area, for some years before 1574, when it was in the hands of John Ashburnham. It was only vaguely remembered in 1611.

The site is a low-lying overgrown area bounded on the north by a dam, breached in two places, which marks the southerly limit of a drained pond. Two parallel cuttings were made, one at the foot of the dam, the second 15 feet to the south. It was found that the area to the west of the present stream, which runs through the easterly break in the dam, is covered by slag heaps. Here the northerly trench was taken down through slag, and through the fringe of the dam, which was found to rest on a corduroy of large logs, still in an excellent state of preservation. The south cutting was used for the collection of slag samples, a sequence of which was recovered from a deposit about 10 feet thick. These await analysis.

The area to the east of the stream was trenched similarly, and was found to be free of slag heaps. The cuttings intercepted disturbances which appeared to be due to thorough stone robbing, and several sherds of 16th century pottery were found. A further season's work will be required, both to follow these features and to cut trenches further away from the dam.

(b) 17th - 18th Century Blast Furnace Survey

Dovey Furnace at Eglwysfach

This furnace was recently inspected and it was found that there was an error in the scale of the drawing which means that the figures given for this furnace in Bulletin No 3 are wrong by a factor of 2. All measurements given should therefore be multiplied by two.

The furnace and outbuildings are in good condition although the hearth and bosh are missing. A 30 ft waterwheel is still on the site and this has an inner gear ring of very much less diameter, which would mean that it could have been used to drive bellows as long as 27 ft. Steps are being taken to preserve the remains.

Loch Fyne, alias Goatfield

This furnace was also inspected during the year. According to local inhabitants, there was the possibility of it being pulled down to allow the widening of the road that runs past it to a neighbouring quarry. Letters were written to the appropriate Scottish authorities and it appears that it is in no immediate danger. This furnace is built of granite and is in excellent condition, although the storehouse is being used as a garage. What is more important, is that the tuyere is still in position which suggests that the hearth is complete, unlike that of the other remaining Scottish furnace at Bonawe. This fact has been made known to the Scottish authorities. Although both these furnaces should be preserved, on metallurgical grounds that on Loch Fyne has priority.

Sharpley Pool, Worcs

Midlands' members are still active in clearing this site. A photograph of the furnace was published by Schubert in his book. Work now being carried out shows it to have a round hearth-cum-bosh, built into a square cavity in the beautifully made sandstone body which is about 20 ft square. Only one tuyere opening was provided and in many ways this furnace is similar to that at Coed Ithel.

Analyses of slag, and bloomery tap slag used as part of the charge, are as follows:-

	Sharpley Pool Slag	Forest of Dean Bloomery Slag
Fe_2O_3	nil	35.7
FeO	2.7	24.4
SiO_2	49.3	31.5
Al_2O_3	11.4	5.76
CaO	22.8	1.8
MnO	0.84	tr
MgO	12.00	1.1
S	tr	tr
P	tr	0.03

The composition of pig iron from the same site is:- Total C, 3.90; Si, 0.49; Mn, 0.05; S, 0.068, P, 0.31%.

Other blast furnaces

G T Brown of Penn, Wolverhampton is investigating the furnace at Charlcote. This furnace is 20 ft high, is in fairly good condition but has a tree growing out of it. Brown hopes to get permission for the owner to clear it and record it next year and will need help. We know very little about this furnace and Brown would be glad of any historical information or references.

An electron diffraction and microscopical examination has been made on a piece of carbonaceous material embedded in the low sulphur slag taken from the centre of the furnace at Ambergate. This is definitely a coke with low ash ($< 1\%$) and low S content which has been up to $1500^{o}C$. This shows the use of a coal of extremely low ash and low S content.

We have recently been informed that the remains of the furnace at Ambergate have been demolished.

19th Century Blast Furnaces

A number of early 19th century furnaces are still in existence and in danger of being demolished in the near future. Although there is a good deal of published information relating to these it is a pity to let any furnace go before a proper record has been made.

Dyffryn (c1845) of Plymouth Ironworks is one of these, and P G Rattenbury would like help in recording it. He also reports the existence of a plan of the Blaenavon Company's works where there are some furnaces gradually being covered by tipping. Also the site shows evidence of calcining kilns not unlike those at Whitecliff, Glos. Professor W E Minchinton has provided a photograph of what look like roasting kilns at Ynyscedwyn.

P Hillyar-Russ has provided some details of the Napoleonic period (c1815) furnace erected by Lord Moira at Moira, Leicestershire. This was coke fuelled, and is built mainly of brick with stone relieving arches. It is square and built into the gable end of the blowing and bridge house. As it has four openings it might have been blown through 3 tuyeres.

Bloomeries and Forges

Withyham, Kent

The excavation started last year has been continued and the furnace almost completely excavated. This proves to be one of the most interesting furnaces so far found. One reason is that the type seems to be more at home in a Medieval context rather than in the Roman period of the site. If its Roman dating is proved it shows that one of our Medieval types was used in the Roman period and was not introduced by Anglo-Saxon peoples.

Essentially, the furnace found at Withyham is built into the end of an elongated pit or trench 3 ft wide. It was served by 3 or 4 tuyeres at 90^{o} to each other, placed at ground level about 18 inches from the bottom of the furnace, and pointing downwards. There seems to have been a front wall of clay, which is now missing, and a slag tapping pit in front of this. This is a form of developed bowl furnace – a 3 or 4 tuyere version of the single tuyere furnace at Chelm's Combe which can be seen in the Museum at Wells.

These remains would fit very nicely into the furnace hollow at Glaisdale, and are probably the same type as is represented by the remains at Baysdale.

The Bloomery Site at West Runton, Norfolk

North-Eastern Norfolk has produced many examples of early iron smelting and some of the material evidence of these operations from Hevingham and Aylsham may be seen in the Castle Museum at Norwich. One of the problems has been to find the ores from which the metal and slag have been obtained. North-Eastern Norfolk consists of quaternary deposits which appear at first sight to be almost barren of usable iron ore. But in some early medieval churches and in the cathedral at North Elmham there is a great deal of building material which is in fact fairly high grade iron ore almost certainly obtained locally.

This is a very hard 'iron pan' or ferruginous conglomerate, containing in some cases flint and in others shells. Its use as a building material seems to have ceased in medieval times. It is certainly not worked out as it is still present in the sands that are being washed out of the cliffs at West Runton and other places. It is now almost certain that this material was a by-product of iron working in Saxo-Medieval times.

Two previous workers, Harrod and Spurrell have written about the presence of bloomery slag on the ridge a mile or two south of a line from Cromer to Weybourne. They have attempted to connect the slag with the pits that occur in profusion in this area. Harrod has left us a very detailed plan of more than a 1000 pits in the neighbourhood of Weybourne station. He noted that they varied from 8 to 20 ft in diameter and from two to six ft in depth.

Sites excavated

Area I consisted of a 40 ft x 6 ft trench designed to give a section through two of these pits. The grid reference for this site is TG/183414.

This was essentially a geological excavation. 19th century pottery was found in the topsoil but this soon gave way to a typical soil profile. In the areas between the pits after removal of the upcast there was a layer of leached sand varying from 5 to 18 inches in thickness underlain by a very dark manganiferous iron pan. This pan had formed round carbonate nodules, but the nodules were found to be distributed in all levels of the excavation. The iron pan did not extend to a depth more than about 2 ft from the original surface.

No iron pan occurred in the pits themselves, although a few nodules were found. The pits had been back-filled soon after they had been dug since no humus or silt had been allowed to collect in them except on their present surface. The absence of upcast to the south of pit 2 suggests that this pit had been filled in during the digging of a pit to the west or east. Pit I had probably been filled by upcast from Pit 2.

Isolated concentrations of nodules were found in the banks between the pits, but the general nodule concentration in the sands bordering these pits was low. It was clear that mining nodules by means of these pits would have been a very speculative business – some pits giving a poor yield, others a high yield. Still, this tends to be the lot of any mining enterprise. Calculation shows the volume of material removed from each of these pits to be about 10 cu ft (50 cu ft has been dug from each of the pits but 40 cu ft of this is represented in the upcast and infill). It would seem that half of that removed was iron pan, and no pan has been returned to the pit, nor is it present in the upcast. Thus, the volume of nodules would be about 5 cu ft which would weigh about 600 lbs.

Area II

(G ref TG/174417) lay about 1200 yards to the west of Area I and was excavated on a 10 ft grid system with 2 ft baulks. Not all the squares were excavated however, and work was started on those giving magnetometer anomalies.

The east end of this site contained a ditch filled in with occupation debris. This ditch yielded the larger part of the pottery of the site, but no traces of dwellings were found nearby, although it is clear that it was the main habitation area of the site. All the pottery was Saxo-Norman to Medieval and would come within the period 1000-1200 AD. Dwellings of industrial workers of this period were very flimsy and this site is not alone in failing to provide even scant traces of them.

Magnetic anomalies near the centre of the site were found to be pits filled in with slag. These pits could have been made in search of ore, but if so, had not been filled in with upcast from neighbouring pits as in Area I. The larger part of the slag had broken into small pieces less than 4 inches, but some pieces were larger and showed that this slag had been tapped into small hollows. It was very similar to that from Ashwicken, High Bishopley and other sites, but there were pieces which indicated that some of the slag at least had been tapped from a height. These resembled a piece of unknown provenance now in the museum at Scunthorpe, Lincs.

The principal area of smelting was found on the western edge of Area II. Here the boundary bank had been slightly cut into by a bulldozer, showing areas of darkened sand or ore fines. The excavation of a series of trenches showed the remains of two well-burnt clay floors and a pit. The more southerly burnt area was clearly the remains of a roasting hearth and it had been covered and surrounded by a layer of red ore fines. The more northerly area was all that remained of the furnace itself.

The furnace hearth was very flat and the fact that it showed no vitrification due to slag shows that it was protected by a layer of tiles or stones that have been removed. Several pieces of vitrified stone have been found on the site which have formed part of other furnaces. The larger pebbles to be found in the gravels of the area are flint, and since flint cracks on heating it would be of little use for furnaces. It seems that the reason why there is so little debris from this furnace is due to the fact that pebbles other than flint are scarce and much valued. Once smelting operations had ceased in this area, the stones themselves would be removed and taken elsewhere.

Some sherds of pottery of the same type as elsewhere on the site were found almost under the centre of the hearth of the furnace. There is no doubt that this excavated area belongs to one period probably Saxo-Medieval (1000-1200 AD).

Conclusions

The site was an iron smelting site of the Saxo-Normanto Medieval period. It worked ironstone pebbles obtained from pits dug into the glacial sands of the surrounding area. These were roasted before smelting and probably charged hot into a domed-low shaft furnace which was built of clay and large pebbles and which had a clay lining. Slag was tapped from a height of 6 or so inches above the tapping pit. The large amount of slag found on the site gives very little clue as to the length of the period worked, since it was probably the result of the working of many furnaces now completely destroyed. The large number of pits in the vicinity and the narrow period of the pottery suggest fairly intensive working over a few hundred years. The amount of slag and the number of pits in the two areas examined suggest a total output of 50 tons of iron from 1000 pits. This is based on each pit yielding 400 lbs of roasted ore giving a yield of 100 lbs of finished iron. There would be 300 lbs of slag produced from each pit ie a total weight of 150 tons. This amount is certainly concentrated in Area II, and it would seem that this comprises the principal smelting site for an area enclosing 1000 pits.

Excavations at Bardown

Excavations at the Romano-British bloomery (ironworks) at Bardown in the Parish of Ticehurst, Sussex (Nat Grid Ref TQ 663294) were continued by H F Cleere from 16 to 19 May and 1 to 16 August 1964. Operations were again confined to the west field, which is on the edge of the site, since the main field was once again under barley.

Two areas were investigated, one on the east side of the field, beside the hedge separating this from the main barley field, and the other in the centre of the west field and higher up the slope.

The eastern trenches showed similar features to those found in this area in 1963, namely a complex of rubbish pits and gulleys. Fragmentary traces of the slag-metalled road running diagonally across the field were also found, but these had been cut into by later ditches. The finds from these trenches were principally of pottery, but included one bronze coin and a fragment of a finger ring made of jet.

The trenches in the centre of the field, which were in the neighbourhood of the cobbled surface found in 1963, were dug to investigate a rectangular feature revealed by probing. This proved on excavation to be the very fragmentary remains of a timber building, most of the floor of which had been removed by deep ploughing. Part of the plan was reconstructed from the identification of post holes.

On the southern (uphill) side of the building, between the building and the cobbled surface, a further stretch of which was uncovered, was found a furnace or hearth similar to that found in the main field in 1962. This was a rectangular structure, internally 6 ft long x 1 ft wide, lined with large stones on both sides and one of the short sides. The stones in turn had been coated with clay, and the fragments of this clay lining that remained, and also the stones, showed evidence of having been raised to a very high temperature. One end of the structure was open, and in front of this open end was a semi-circular layer of burnt clay.

The exact nature of the structure is still under discussion. It is unlikely to have been used for smelting, since there is no central depression in which the iron could have collected. The absence of pottery 'wasters' (imperfect pots) rules out the possibility that this was a pottery kiln, although it closely resembles horizontal draught kilns of a type known from the Farnham area of Surrey. It has been suggested that this was a forging hearth or bloom heating furnace, similar to the types described as such by Pleiner from Czechoslovakia. However, the structure seems unnecessarily large for working up a bloom which probably weighed little more than 10 lbs. A more likely suggestion is that this was a hearth for roasting or calcining the local carbonate ore. A mixture of ore and charcoal would have been placed inside the structure and ignited, probably with a blast being supplied from the open end. The walls would have prevented uneven calcining of the ore. This interpretation is still provisional, and is under active discussion amongst experts in the field.

The furnace or hearth was earlier than the timber building beside which it was sited. It had been deliberately filled in and the clay floor of the building overlay it. The building in its turn was destroyed by fire and reconstructed at a later time. The finds of pottery in this area suggest that the three stages that are indicated covered a relatively short period of not more than 50 years.

Through the kindness of a local farmer, the opportunity was taken of viewing the site from the air at heights varying from 150 to 1000 ft. A number of photographs were taken of the area, and certain markings in the barley field will be investigated in 1965, when this field will be reverting to pasture. The main objectives in 1965 will be a further exploration of the area, first dug in 1962, which revealed a furnace structure similar to that found this year, and exploration of the areas indicated by the air photographs. It is hoped to be able to carry out a resistivity survey of part of the main field in the hope of tracing the outline of roads and buildings believed to be there.

Excavations at Rockley Smithies

A rescue excavation has been conducted by D W Crossley at Rockley, Yorkshire (NGR SE 340023) throughout the 1964 season, to recover structural and dating evidence of a 16th-17th century ironworking site. Work has been made necessary by plans to extend the M1 and has been carried out on behalf of Sheffield City Museum with the aid of a grant from the Ministry of Public Buildings and Works.

Surface evidence indicated a small finery, perhaps with water power for bellows and hammer. Excavation has partially confirmed this. A flat area built up with successive working floors lies to the north of a silted water course. The floor levels are composed partly of finery cinder, but also of red dust, suggesting that the area was periodically used as an ore-burning floor. On one of the levels the remains of a hearth was found, and on a further two were footings of small buildings. The deposits have produced a series of pottery whose range is suggested as 1550-1700, and a long cross halfpenny unlikely to have been in circulation much after 1544.

The silted watercourse, buried beneath cottage gardens, is apparently of two periods, the first a narrow channel, the second wider, forming the neck of a pond, and fed from a stream half a mile to the south by means of a leet. Both ran eastwards past the working floors, and there is no evidence of their use for power for operations at this point. Level with the eastern end of the floors the channel was dammed, and immediately further east lay a deep hollow from which a narrow goit ran to join a stream some hundred yards further east. It is not clear whether water ran down a weir into this hollow and thence into the narrow channel towards a wheel or whether a trough led from the dam's top to an overshot wheel; but the possibility that this hollow is itself the robbed remains of a wheel-pit cannot yet be entirely ruled out.

On either side of the entry to the narrow channel a small furnace was found. That on the south side was badly damaged, but the one on the north side, though robbed of its superstructure, remained as a hearth-bottom of iron and slag standing in a ring about 2 ft 6 ins in diameter 12 ins - 15 ins high; gaps appeared for a tuyere and for the tapping of slag, which on present indications ran north into a bed formed by a gap in the vestigial surrounding stone footings, which have been robbed almost to the level of the furnace bottom. The area between the furnace and the watercourse remains to be excavated.

The channel leading eastwards ran between clay banks, the northerly of which was held by substantial timbering, while the southerly one had been cut by a field drain at the point excavated. The timber lining appeared to have been replaced by a dry stone-lined channel which still acted as a drain. Its original purpose would seem to be otherwise, as it was topped by timber rather than the normal and more durable stone slabs. 10 feet to the south of the channel there lay a section of tree-trunk, mounted on lengths of large plank, and wedged in a pit, forming the probable base for an anvil. The ferruginous working floor to the east of this feature has been seen in a test section but not yet cleared.

Excavation will continue at weekends until July 1965 and the major questions outstanding are the association of the furnaces and anvil base with the working floors. The latter produced an excellent series of early modern pottery which provides a reference for the rest of the site.

Experimental Iron Smelting

As part of a BBC Television programme an experimental smelt was done on a Roman Ashwicken type shaft furnace at Swalwell near Newcastle. Hematite ore and hard wood charcoal was used but unfortunately slag separation was not obtained. The product was a mixture of reduced ore lumps and partly liquated slag. The latter was not sufficiently free-running to tap as was clearly done at Ashwicken . This may have been due to the type of ore, that at Ashwicken being nodular carbonate.

A good deal was learnt about the running of this type of furnace. Its cycle of operations was about 20 hours and the rate of fuel consumption about 5 lbs/hr.

The air supply required was of the order of 80 l/min. The charcoal had to be carefully graded to pass this air without severe back pressure.

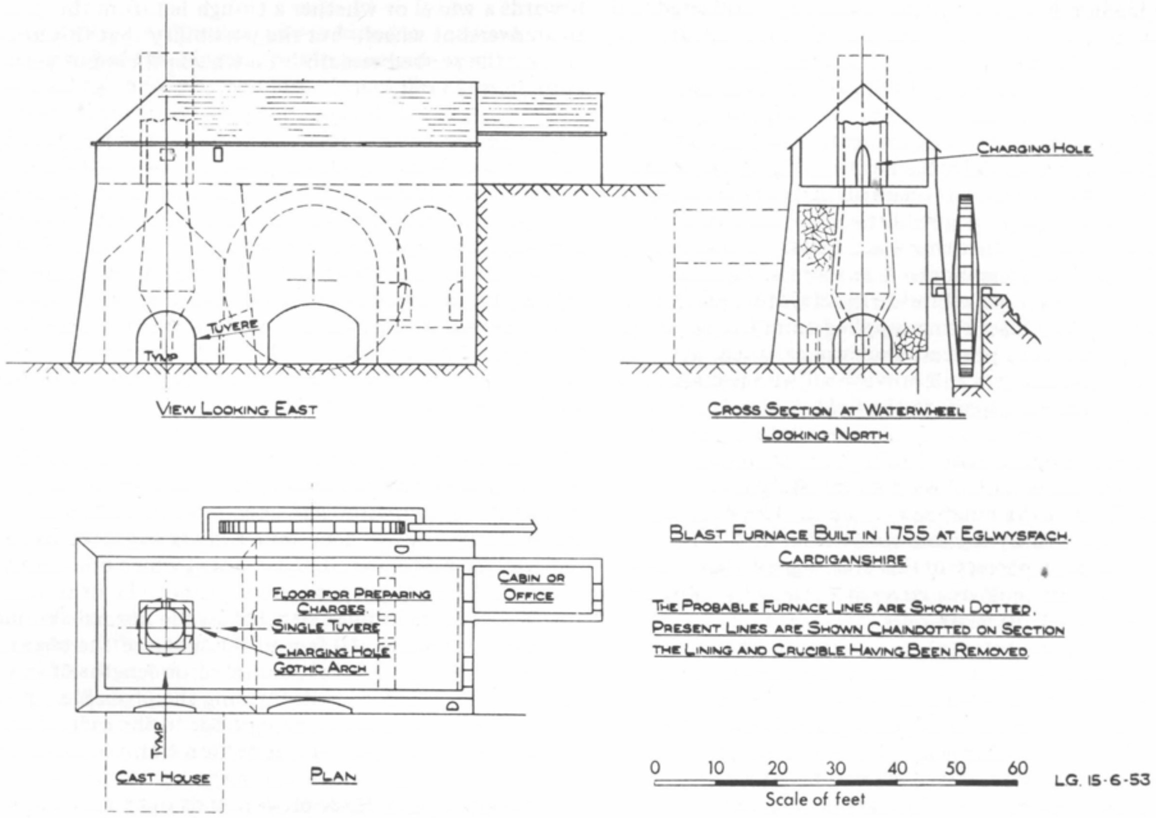
These experiments only lasted for about 80 hours; the furnace has now been reassembled in the laboratory and further trials will be made under more controlled conditions.

The Czechs and Poles have been carrying out similar experimental work this summer. Their trials were made on two types of furnace peculiar to their region, the first being the so-called Scharmbeck type of shaft furnace yielding an 'ofensau' such as that found at Aylsham in Norfolk and the second, a type restricted to the Slav area known as the Zelechovice type.

Little Aston

Gould, with the help of the Chairman and other Midlands' members has been examining the site of the forge at Little Aston. The remains are mostly on the bank forming the dam of a mill pond and amongst them has been found a full-size pig, a ham bone (with coal) (similar to those reported by Professor T Turner in the JISI) and finery slag. One of the more interesting finds is a slagged limestone which may have something to do with a patent process for sulphur removal by means of limestone. In 1761 John Wood patented a process involving the refining of pig in a coal fired finery (which increases S) followed by a further refining operation in clay pots. Gould has found traces of these pots at Little Aston. According to the patent, the partly refined metal was 'heated in pots or other closed vessels in an air furnace by means of a strong coal fire until the impurities contained in the iron and fluxes are run together into a cinder or slag'. The slag on the inside was a fayalite type (SiO_2 22 6, Al_2O_3 12.4, Mn0 0.06, Ca0 nil, Mg0 O.15, S 0.08 and Fe 45.2%. The pots were mullite with a glossy exterior.

The composition of the pig was:- Total C, 3.37; Si, 0.28; Mn, 0.91; S, 0.081 and P, 1.01%. This would make a cold short iron unless the process was capable of removing phosphorus. Further details are given in the Appendix to this Bulletin.



This drawing of the Blast Furnace at Eglwysfach (SN 685952) was produced by Mr Luther Griffiths. It is relevant to the note on page 16, *Bulletin 3* and subsequent correction on page 18, *Bulletin 4*. The scale shown here **is correct** and the drawing was reproduced in *HMS Newsletter 2* of December 1976, by permission of the late Morgan Rees in whose book *Mines, Mills and Furnaces, HMSO 1969* it appears..

Little Aston Forge – c AD 1574 – AD 1798

J Gould and G R Morton

Forge Lane, Little Aston (Staffordshire SK 092019) takes its name from an early forge whose site, Fig 1, can be still easily found. Yates map of 1769, Fig 2, marks this as Aston Forge as it was often called.

It stood on the edge of the 'Colefield', a district which stretched from Barr Beacon to Sutton, where charcoal burning had been carried on since the Middle Ages[1]. Indeed, some documents refer to 'Little Aston in Colefield', whilst other medieval references are to a smith there[2]. The site of the forge is well-known and today is approached by the Roman Ryknield Street, here known as Forge Lane. Turner has stated that 'In 1560, a decayed forge with a chaffery existed at Little Aston, but there does not appear to have been a furnace there'[3]. He gives no authority for this statement but would seem to be quoting Hackwood, who had written earlier that 'In 1560 a decayed forge with a chaffery, but not a furnace existed at Little Aston belonging to Roger Fowke.'[4] Hackwood's statement is manifestly incorrect since the Fowkes did not obtain the property until 1574. The original deed, now in the Birmingham Reference Library[5] gives an exhaustive list of the property at Little Aston when Thomas Fowke, father of Roger Fowke bought the manor there. There is no mention of the forge. Later when Roger Fowke had inherited from his father, a lease dated 1600 AD[6] from Roger Fowke to Thomas Parkes speaks of 'that forge, chafferie and hammer mill nowe beinge verie ruynous and lately decayed'. This lease, which is also quoted by Turner, would seem to be the source of Hackwood's information, 42 Elizabeth (1600 AD) having been taken as 2 Elizabeth (1560 AD). This date is important as a forge in 1560 AD would imply that ironworking in Staffordshire was more advanced at that date than was the case. The first forge then was built after 1574 AD and was 'lately decayed' by 1600 AD. That it was 'verie ruynous' after such a short space of time suggests destruction by fire.

Parkes secured the lease of the forge for 21 years on payment of £40 down and six shillings and eightpence per annum thereafter. He was an elderly man, having been born in Wednesbury in 1532 of reputedly humble parents. During the years immediately preceding the signing of the lease, he and his son Richard, had been involved in a series of riots with other ironmasters, involving attacks on each others' works[7], and only a month earlier, Richard had been bound over in the sum of £40 to keep the peace against William Whorwood, one of their rivals[8]. It is not surprising then to find written into the lease the condition that Parkes shall:

> *'peacablie and quietlie have . . and enjoye the property without anie maner of trouble, disturbance or gaynsayinge or interupcion of the said Roger Fowke or anie other person or persons'.*

The property leased was ill-defined in such terms as:

> *'to a little woller or woller bushe whereof the Toppe was latelie cutt of for a marke and where now a greate stake for a marke is set and placed and from there to another woller or woller bush . . .'*

Parkes was to have power:

> *'to Repair Redyfie or make new the said forge, chaferie and hammer mill and to erect . . . one or two finerie or fyneries and one house or shoppe commonlie called an Iron house or Iron shoppe, for the Keepinge and the layinge in of iron, To be adjoyninge to the said forge or hammer mill now there beinge to be Repaired, Redyfied or made newe . . . and also one reasonable and necessarie house of two Bayes for the workmen or servants of the said Thomas Parkes . . . to dwell in wch shall work at the said forge, fyneries chaferie or hammer mill'.*

The dam also was to be repaired and Parkes was given permission to take all necessary 'Turves and Cloddes' but was not to 'quayre' up the water beyond the bounds agreed to. Provision was made for access to the forge from various directions with 'wayne, carthorse or otherwise', for scouring the pool and disposing of the resulting 'earth, gravel, myre and suchlike' on the surrounding land, 'to digge and gette all such claye and sand of lytle Aston aforesaid as shall necessarlie be used on or about the premises', to use the surrounding land up to twelve poles in breadth 'for the amendinge of the wheels' and so on.

Roger Fowkes also agreed that he and his wife Lucy would:

> *'at theire owne proper coste and charges at and upon reasonable request of the said Thomas Parkes deliver within the lordshipe of Aston aforesaid all such sufficient and convenient Trees and Rough Timber as shall together with the olde Timber now beinge at the saied forge or hammer mill serve to make and be used for the makings and buildinge of all and everie the said forge fyneries chaferie and hammer mill and the said two bayes of howsinge, fludgates, grates whytches and Troughes before mentioned (the shafte or hammer beam and bendes for all and everie the wheels of the same forge fyneries chaferie and hammer mill onlie excepted) and will also thensforth upon like request assign appoint and deliver to the said Thomas Parkes . . within the said lordshippe or within three mylles thereof all such sufficient and convenient Trees or rough Timber as shall afterwards be needfulle . . . for the Repayringe . . . of all and everie the same buildings'.*

provided these were not:

> *'burned spoyled or destroyed by fyer by the negligence wilfulnes or carelesnes of the said Thomas Parkes his Executors or Assignes or his or their workmen or servants or some of them'.*

On the expiration of the lease, Parkes was to leave the forge in good condition; thus did the landowning family secure a valuable works.

The lease has been quoted from at length, to give a picture of the forge, to show how local material was used, and the very real risk of fire. The houses for the workmen still stand though they have been so extensively rebuilt as to give little indication of the accommodation once provided.

It is presumed that the output of the forge was not sold to the smiths, etc, direct, but went to the chapmen, who the craftsmen of Walsall accused in 1603 of cornering the iron supplies[9].

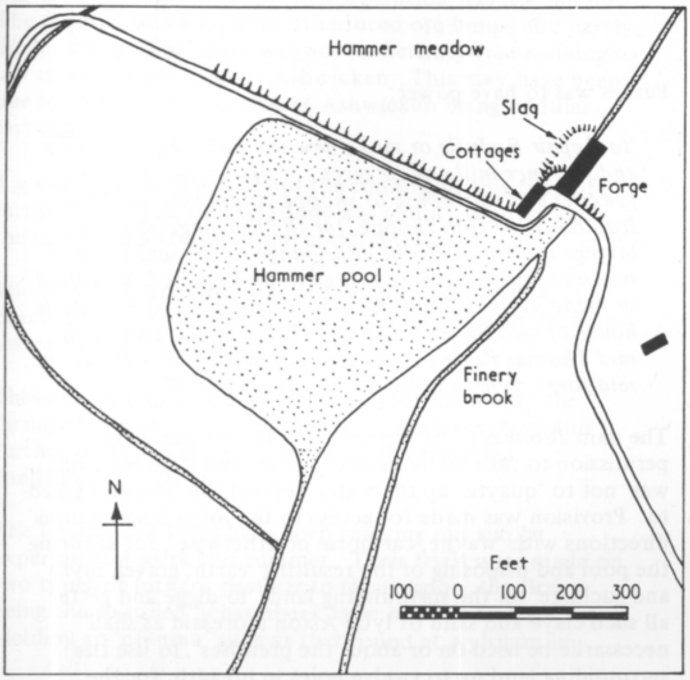


Fig 1 Little Aston Forge

In 1602 Thomas Parkes died, a wealthy man as witness his monument in Wednesbury Parish Church, his endowing of a school there, and the provision of an almshouse. His son Richard, who received a grant of arms in 1615, also died before the expiration of the lease, and the forge passed to a Richard Middleton. In 1621 the lease was renewed to him [10] for nine years at a rent of £66 every three years. Most of the clauses in the former lease were retained but one exception was that John Fowke (who had succeeded to the Manor), reserved to himself the 'fishinge of the greate poole' and the right to take the fish from there during the first week of Lent at four yearly intervals. He was also to:

> *'erect sett up and mayntayne grate or grates att or to the said greate poole for the better preservation of the fish thereof soe as thereby there be no hindrance or annoyance to the said ironworks.'*

The fish were important and a little later fish stews were built on the stream below the forge on land known as Forge Moor. Sanders, writing in the 18th century[11], stated that the rivers here were noted for exquisite trout and that good pike, gudgeon and chubb were once plentiful.

Middleton did not hold the forge long and in 1622 it was leased for eight (or twelve – there is an alteration) years to a Thomas Nye at a rent of £12. 15. 0d. per half year[12].

There is no indication of the fate of the forge during the Civil War, and there is no mention of it in the Order Book of the Staffordshire Committee, but by 1667 it was in the control of the Foley combine, in which Mrs Fowke was now a partner.

In 1669 Philip Foley took over some of the Foley works from his father Thomas, and a further lease of that date[13] shows him as renting the 'forge, chuferie and ffinery and hammer mill' for 21 years at £22 p.a.

In the County Record Office at Hereford are a series of account books which belonged to Philip Foley and which cover the years 1667-1672. Details of the works under his control are listed under the names of the various managers. William Spence was manager of Little Aston forge but as he was also responsible for the Wednesbury and Bromwich forges it is not possible in all cases to isolate the Little Aston entries from those of the other forges. Nevertheless the main facts are clear.

Little Aston was producing 'bar iron for the mill' almost the whole ouptut going to the Bustleholme (West Bromwich) slitting mill.

A few tons were sold retail at the works as was also a little tough iron. This latter was not made there but was specially sent from the Whittington Forge for sale at Little Aston. The tonnage of bar iron made at the Little Aston Forge was as follows:

	t.	c.	q.	lbs.	Sent to Bustleholme
March 1667 to March 1668	110	2	2	23	95 tons
1668 1669	100	10	3	0	108
1669 1670	121	18	2	0	107
1670 1671	104	10	0	0	110
1671 1672	130	0	0	0	109
1672 1673	129	11	0	0	146

The raw materials were sow iron from the Foley furnaces at Hales(owen) and Coven, and charcoal, the source of which is not shown. The material supplied for the year commencing March 1672 was as follows:

	Sow Iron	Charcoal
From last year	78 tons	100 loads
Supplied		398 tons
from Coven	101 tons	
from Hales	37 tons	
Left Over	26 tons	130 loads
Consumed	190 tons	366 tons (a load of charcoal seems to have been 21 1/3 cwts.)

Thus to make a ton of bar iron at Little Aston 29 cwts of sow iron and 56 cwts of charcoal were used. The charcoal cost 23/4 per ton (in other years it varied between 20/6 and 25/6 per ton). The cost of the sow iron is not given, but since the value of the 26 tons left over at the end of the year is given as £147.6.8d. it must have cost (with carriage) approximately £5 13.0d. per ton. The cost of carriage in 1672 cannot be isolated from the figures for the other forges but in 1671, when Hales sent 54 tons and Coven 41 tons, it amounted to £70.7.9d.

These figures should be compared with the rough calculation Philip Foley made in 1669 when he took over. His estimates were then as follows:

	To make one ton of Bar Iron							
	Charcoal				Sow Iron			
Forge	t.	c.	q.	lbs.	t.	c.	q.	lbs.
Brewood	3	3	6	0	1	8	0	6¾
Bromwich	2	1	1	14	1	10	1	1
Wednesbury	2	3	5?	0	1	9	2	21
Little Aston	3	3	0	14	1	8	0	13

He also estimated the cost at Little Aston as follows:

	£ s. d.
Charcoal at 20/6¼	3.11. 0½
Pig iron at 109/- carr. paid	7.13. 1
Common charges	1.17. 7
Int. per ton	9. 7¼
Total	13.11. 3¾
Sold at	15. 9. 0½
Annual profit from Little Aston	179.14.11

The common charges are elsewhere stated to be the cost of running the forge including rent and 'Clarks wadges'. The common cost at Little Aston in 1667 was £199.9s. but by 1672 it had risen to £278.6s.4d. The reason for the rise is not apparent. The stock at Little Aston on March 29th 1673 was as follows:

		£ s. d.
Bar iron for the mill 5t.9c.3q.27 lbs.		82. 9. 6
Merchant Bar Iron	3 17 2 19	69.18. 0
Sow Iron	26 0 3 24	147. 6. 8
Old Iron	5 0 0 0	3. 0. 0
Working tools	4 2 25	4. 4. 9
Charcoal 130 load at 25/-		162.10. 0
Beams, scales & weights		5. 0. 0
Timber of all sorts		24 .2 .0
Grease 114 lbs		1.10.11
Riddles, colemeasures, barrows, ladders		1.16. 6
Colebaskets		1. 7. 0
Nayles		1. 6
Hides and pieces of leather		15. 0
Bellows with harness		value not shown
Cole sacks and cole carts		12.10. 0
In the Workmens house		2.10. 0
Total		519. 1.10

Although the accounts give no indication as to the source of the charcoal, documents in the William Salt Library, Stafford[14] show the Foleys buying up land in Little Aston, in association with a John Birch, over whom Thomas Foley had some hold, arising from a debt of £120, due through a legal case. Most purchases were between 1669 and 1673, but by 1679 some of the property bought ten years earlier was being disposed of. Whilst there is no indication of the reason for these deals it is possible that woodland suitable for charcoal burning was involved. If this was so, it is understandable that Birch was used as a 'front man' as the Foleys had been in trouble elsewhere over the destruction of woods (including saplings).

Sanders stated that Thomas Foley, during the reign of Charles II, resided at a half-timbered house called the Bosses which was near the forge, so that he could keep an eye on matters there. This is difficult to credit since the Foley connections were very extensive and in 1669 Thomas Foley resided at Witley Court, Worcester. Nevertheless the Foleys did own the Bosses, and the accounts show £20 p.a. rent being received for it.

In the early 18th century, the forge was in the hands of Richard Scott, who also held the manor. From him it passed to his nephew, Scott Craddock, who, Sanders states, carried on the ironworks at the forge. By 1740 Scott Craddock had sold the works to Andrew Hackett and by the time of the sale they had been leased to John Wood of Wednesbury.

During this period various assessments were made of the output of the English ironworks. Hulme[15] quotes three of these. The MSS of John Fuller of Heathfield, Sussex, lists outputs for 1717, and shows that of the Little Aston forge as 100 tons p.a. The two pamphlets **The Interest of Great Britain in Supplying Herself with Iron, Impartially Considered** (1736) and **The Case for the Importation of Bar Iron from our own Colonies in North America** (1756) show the Little Aston output as 50 tons p.a. and 100 tons p.a. respectively. How much reliance can be put on these figures is problematical as those who compiled them may not have known Staffordshire intimately, and in any case they had a political axe to grind.

The last tenant of the forge, John Wood of Wednesbury, was concerned to produce malleable iron from pig iron, using coal as a fuel. In this he was carrying on the work of his father, the well-known William Wood. This appears to be the only period when coal was used, and the coal-containing slag heaps and 'hambones' (see below) must be assigned to his tenure. Parkes would not be using coal at the beginning of the 17th century, and the accounts show conclusively that the Foleys did not, though they are known to have used coal in a chaffery elsewhere[16]. There remains the brief tenure of the Scotts. These were landowners, holding the manor of Little Aston and much nearby property. If suitable wood for charcoal burning remained, they are likely to have owned it and it is very difficult to think of them making innovations such as the use of coal. They are not known to have had any other connection with the iron trade or with coalmining.

John Wood had extensive ironworks at Wednesbury which he had inherited from his father. Following up his father's work he took out patents in 1761 and 1763 though there appears to be little difference between the two patents. In the official **Abridgements of Patents Specifications, Manufacture of Iron and Steel**, Second Edition, Vol VI, 1883, appears the following:

AD 1761 Feb 5 No 759
WOOD John Making malleable iron from cast iron
Pig or other cast iron 'I flourish or heat and work in a 'common finery with a blast and a fire of raw pitt coal. 'until it is refined in some measure from its dross and

'brought near to a malleable state' ie 'into nature'. the metal (sometimes with the addition of pieces of malleable iron and fluxes) is then heated in pots or other closed vessels in an air furnace by means of a strong coal fire, 'until the impurities contained in 'the iron and fluxes' applied thereto, 'are fused and 'run together into a cinder or slag, and the iron 'is brought into a tough and malleable state', whereupon it is hammered into bars or other forms.

Or the cast iron may be smelted in an iron furnace, and granulated by pouring it into water upon a revolving wheel or roller. Or the cast iron may be formed into thin plates and then broken into small pieces. The granules or small pieces are afterwards mixed with fluxes and heated in pots, as above described to obtain malleable iron.

The fluxes employed may be 'iron slag or cinder, scaled 'or scoria of iron, fuisible sand, and lime, kelp, 'Soapers waste'. The pots are made of refractory materials such as pure clay, 'clay earth, horse dung and 'other mixtures' and are baked before use. They are closed by covers of the same materials, which are 'used 'wet'.

After the tenure of John Wood (died 1779) the works seem to have gone out of use. In 1798 Sir Robert Peel bought the forge, only to sell it in 1802 to William Tennant, then the lord of the manor. It was converted into a corn mill and appears as such on the Tithe Map (1838). This was destroyed by fire at the beginning of the present century and has not been since rebuilt. The Forge Farm was bought by a Mr Pearson, who reclaimed huge quantities of iron-containing slag in the shape of 'hambones' during the First World War. Prisoners of war were used to extricate them from marshy land where they had been dumped. A local resident, Mr C Bassford, remembers being employed with a horse and cart

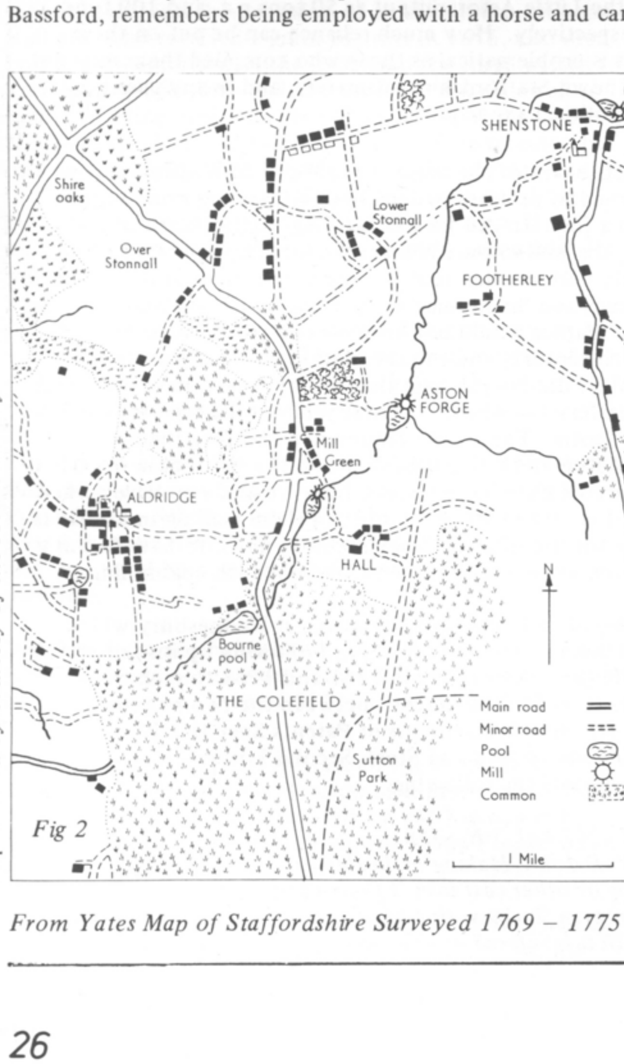


Fig 2

Reproduced by courtesy of the Metals Society

From Yates Map of Staffordshire Surveyed 1769 – 1775

hauling these to Aldridge station. He knew them as 'pot bottoms' and claims four or five horses were used over a long period in transporting them. Today 'hambones' can still be found anywhere within a mile or so of the forge. They were used for metalling farmtracks and are often ploughed up and thrown into the nearest hedgebottom. Some are as far from the forge as Mill Green where they can be found alongside the Bourne Brook.

Technical Aspects of the Process

G R Morton

The Pig Iron

Among the 'finds' taken away from the slag heaps and the surrounding area, several will assist in reconstructing the metallurgical processes operated at the forge. The methods by which pig iron was converted into the malleable bar form during the period under consideration, has been detailed elsewhere [17] – the present work however introduces variations to the process and thus constitutes a stage in the development of the industry.

The raw material used at the forge comprised in general, the two types of pig iron mentioned by Plot [18], and termed respectively 'tough' and 'coldshear'. During the early period of the works such irons were readily available at the Cannock Chase ironworks of William, Lord Paget, as quoted in the 'Provision rem' the 23rd February, 1570 [19] as:

'Sowes tough 111 cont' 55½ tons at 66s.8d.

and

'Sowe coldshewe 33s.4d.

During the later life of the Little Aston works, pig iron was obtained from the Foley furnace at Hales (Owen). Two pigs, one found by Gould at Little Aston and the other by Morton at Duddon Furnace (N Lancs) are seen to be one of each type. The analyses of these pigs are given in Table 1, showing the effects of the element phosphorus, which when passed into the refined iron produces cold shortness.

	Duddon Furnace	Little Aston
C	4.3	3.37
Si	0.65	0.28
Mn	0.10	0.91
S	0.023	0.081
P	0.124	1.01

Table 1 – Analysis of Tough and Coldshort Pig Iron

In describing the ores used to produce these irons Yarranton [20] states: '. . . the Sow Iron made of the Iron Stone and Roman Cinders in the Forest of Deane for that metal is of a most gentle, pliable, soft nature, easily and quickly to be wrought into Manufacture, over what any other iron is, and is the best known in the World', and he follows with 'And now in Worcestershire, Shropshire, Staffordshire, Warwickshire and Derbyshire, there are great and numerous quantities of

Iron-Works, and there much Iron is made of Metal or Iron Stone of another nature quite different from that of the Forest of Deane. This iron is a short soft iron, commonly called Cold-shore Iron, of which all the nails are made, and infinite other Commodities'.

Conversion to the Bar Form

The pig iron was melted in a charcoal fire when the impurities silicon and manganese were oxidised to produce a fusible slag with the iron oxides formed at the same time. The impurities sulphur and phosphorus merit special consideration – in particular sulphur, which if present in quantities greater than those which can be balanced by manganese to form MnS, tends to form low melting sulphide of iron which makes the metal brittle (short) at elevated temperatures, and which would crumble under the hammer. Thus Plot [21], when discussing the iron ores of Staffordshire states: '. . . of the above mentioned Ores they make several sorts of Iron, differing in goodness according to the richness or poverty of the ores, and having names somewhat agreeable to the qualities of each metal. The first is the meanest whereof, they call Yellow Share an ill sort that runs all to dirt and is good for nothing, and such is the Iron made of Cannock or Cannot Stone, the lowest measure of the Iron Ore about Dudley, which is so very sulphureous and terrestial, that it is not fit to make Iron'.

In order to prevent the sulphur of the ore and fuel finding its way into the pig iron during the smelting process in the blast furnace, a high furnace temperature and a slag with a high lime content would be necessary. High lime slags require a high temperature to melt and retain in a sufficiently fluid state to enable separation from the molten metal. Thus since the charcoal blast furnace temperature was limited by the amount of blast available, it follows that in the furnace, with a pair of leathern bellows and a single tuyere, temperatures higher than 1500°C would not be possible. This means that only ore and fuel low in sulphur would ensure that the final bar iron was low in sulphur. This fact placed a severe limitation on the use of mineral coal in any operation involving iron in the molten condition. Thus charcoal, very low in this element, was the accepted fuel for all operations of smelting and fining – limited amounts of coal being used in reheating operations, ie in the chafery fire.

Phosphorus on the other hand, was less deleterious than sulphur since the metal worked well at elevated temperature, but contained a degree of shortness at normal temperatures dependent upon the amount of phosphorus in the metal – thus, cold-short (cold-share, coldshewe etc) and tough brands.

During the period covered by the Foley accounts, tough iron was not made at Little Aston, cold-short pig iron of analysis Table 1, being used for the production of refined bar.

Little Aston Slags and Fuel

It has been shown that the works at Little Aston were in existence as a chafery and hammer mill prior to 1600, and were still in operation as a finery forge for the following 200 years. During this period large quantities of slag would have been made, a large part of which was in later years, taken for resmelting in the blast furnace. It is well known that during the early part of the present century Midland Iron-masters scoured the district for high iron containing slags, and finery and chafery slags were considered an excellent substitute for the depleted clay ironstone deposits upon which 19th century South Staffordshire iron industry prospered.

Total H_2O	7.30
VM	26.50
FC	38.60
Ash	27.6
S	1.10

Table 3 – Analysis of Coal found in Hambone Slag

Hambone, showing section of cleavage

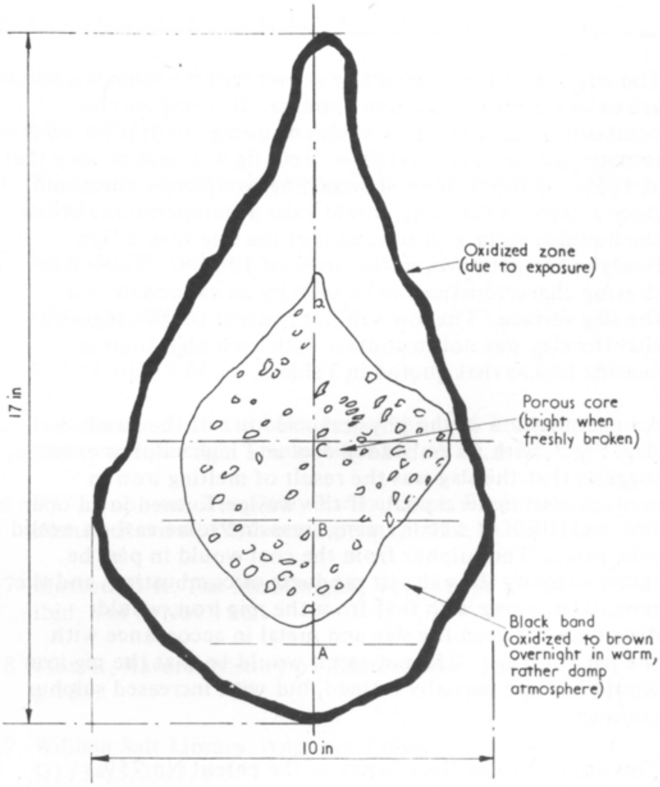


Fig 3 Little Aston Ham-Bone

Two small apparently undisturbed slag heaps remain on the NW side of the wheel race (fig 1) and the large number of pieces of burnt and unburnt clay portions of what were probably clay pots, together with coal remains, suggest that the heaps belong to the period after Wood secured the tenancy, which includes the period of the patent No 795 of John Wood.

In the heaps two types of slag can be identified, one in granular lumps, samples of which were easily dissolved in dilute HCl, and the other of the 'hambone' type referred to by Turner [22], but insoluble in HCl, and only soluble with some difficulty in HF. Typical analyses of these slags are given in Table 4, from which it will be seen that in the hambone slag the sulphur decreases progressively from the outside towards the centre, fig 3.

	Slag soluble in HCl	Hambone slag		
Position		A	B	C
SiO_2	22.62	27.0	27.80	27 52
Al_2O_3	12.38	8 9	7.62	8 40
MnO	0.06	0.06	0.06	0.06
CaO	nil	nil	nil	nil
MgO	0.15	tr.	tr.	tr.
S	0.08	3.62	0.82	0.59
Fe	45 2	29.2	25.84	26.96

Table 4 — Analyses of Little Aston Slag

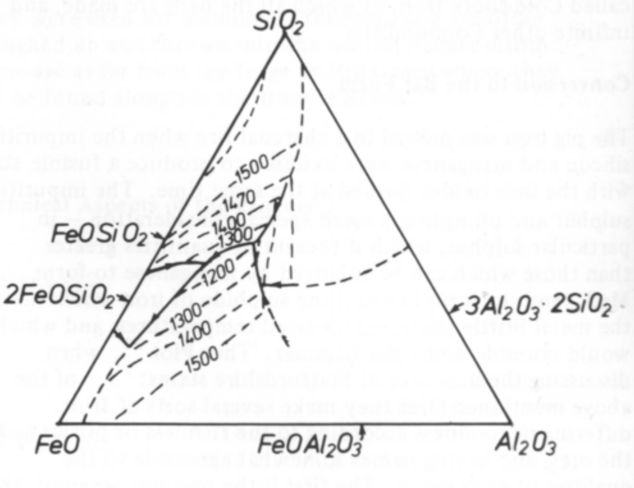


Fig 4 The $SiO_2 - Al_2O_3 - FeO$ System

The analysis of the soluble slag shows that the main constituents are oxides of iron, silica and alumina. If therefore this composition (assuming all oxides of iron as FeO) is set on the ternary system $SiO_2 - Al_2O_3 - FeO$, fig 4, it will be seen that at 1250 – 1300°C the slag would be completely fluid, and since a degree of fluidity would exist at temperatures below the liquidus surface, it follows that the slag would flow freely at temperatures in the order of 1200°C. These free-flowing characteristics can be seen by an examination of the slag surface. The low sulphur content (0.08) ,suggests that the slag was not in contact with such high sulphur-bearing fuel as that quoted in Table 3.

An examination of the physical structure of the hambone slag, Fig 3, with its embedded coal and high sulphur exterior, suggests that the slag was the result of melting iron in contact with mineral coal. If this was performed in an open fire, oxidation of silicon, manganese and some carbon would take place. The sulphur from the coal would in part be taken away by the exhaust products of combustion, and the remainder, along with that from the pig iron, would distribute between the slag and metal in accordance with the partition law. The net result would be that the pig iron would become partially refined, but with increased sulphur content.

This appears to be the essence of the patent No 759, Feb 5 A.D.1761, of John Wood, and the hambone material was the slag formed by this refining operation. Thus 'I flourish or heat and work in a common finery with a blast and a fire of raw pitt coal, until it is refined in some measure from its dross and brought near to a malleable state' ie 'into nature' means that the pig iron was melted under oxidising conditions, in a coal-fired finery hearth. During the melting stage, silicon, manganese and some graphitic carbon would be oxidised and pass into the slag. As the droplets fell through the incandescent coal, sulphur pick-up would take place. The metal collected under a layer of slag in the hearth, where distribution of sulphur between metal and slag would take place. Due to the lower temperature in the hearth, the metal would assume the form of a semi-molten pasty mass which would require raising (working) into the oxidising zone and remelting, when further oxidation of the metalloids would occur bringing the metal 'near to a malleable state' ie 'into nature'.

The hambone slag thus appears to be the slag formed during this part of the operation, and was from time to time tapped into a hollow depression in the sand floor. During tapping some coal would be carried out with the slag and since this appears to be concentrated around the outside of the hambone it probably accounts for the high sulphur content in that zone.

Clay Pots

Before further consideration of the soluble slag is made it will be well to consider the small pieces of 'pot material' found in the slag heaps.

A section through a freshly broken piece reveals what appears to be a fired high-alumina clay product, coated on either side with slag. In order to ascertain the exact nature of these products, selected areas were powdered and subjected to X-ray crystallographic analysis.

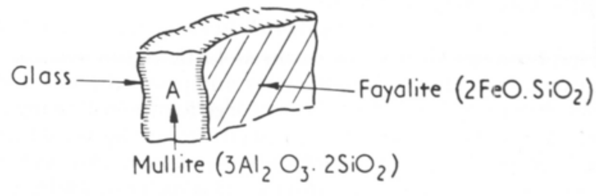


Fig 5 Details of Pot Structure

The centre portion, A Fig 5, revealed the structure of mullite, with occasional unidentified lines with d values of 4.20, 3.10, 1.53 and 1.33. The mullite lines were well defined on the powder photograph. In a similar way a small portion of the inner surface of the pot was removed and subjected to crystallographic analysis. In this case the mineral fayalite ($2FeO.SiO_2$) predominated with an occasional Mullite line (d value 3.4) – this latter line was probably due to a small amount of mullite being detached from the sample during the preparation of the powder specimen. The presence of fayalite suggests that silica, as excess in the kaolinite clay material used in the original manufacture of the pot (and above the amount required to produce mullite in the fired product) had combined with FeO from the metal being refined in the pot.

Some idea of the diameter of the pot can be obtained by taking the radius of curvature from a large piece of unburnt pot. Bisecting this curve produces a diameter in the order of 6 ins.

The height of the pot cannot be directly ascertained, but if it is assumed that the total weight of the charge was approximately 100 lbs, and reasonable volume allowed for slag, then the height would probably be in the order of 10 to 12 inches.

Referring back to the patent: 'the metal (sometimes with the addition of pieces of malleable iron and fluxes) is then heated in pots or other closed vessels in an air furnace by means of a strong coal fire 'until the impurities contained in the iron and fluxes' applied thereto: 'are fused and run together into a cinder or slag, and the iron is brought into a tough and malleable state'. Thus it appears that the refined iron was broken into pieces of convenient size, and with a suitable flux, charged into clay pots and heated in a fire of mineral coal. Since the products of combustion were now out of contact with the charge, no further sulphur pick-up by the metal would take place.

The variety of fluxes used suggests that considerable variations of condition were encountered, eg oxidising conditions would result from the use of scale, or cinder containing oxides of iron, whereas sulphur removal was enhanced by the addition of lime. The use of 'physic' fluxes continued into the present century, and reference is made to Schaffhault's powder – a mixture of oxide of manganese, salt and clay, and Scheerer's powder was a mixture of calcium chloride and salt, and soda ash[23].

In this way the iron was finally 'brought to nature', when it was taken from the furnace, consolidated by hammering and wrought into rod and bar.

Little evidence can be found to relate the soluble slag with the type which would have been produced inside the pot – in fact the low sulphur content of this slag suggests that, unless the volume was exceedingly great, little sulphur would have been removed from the metal. The exact origin of this slag must therefore still remain a mystery.

Acknowledgements

Thanks are due to Mr Loescher who allowed access to his land, as did Mr Rimand of the Lichfield RDC. The staff of the Birmingham Reference Library made photostat copies of deeds available, officials of the William Salt Library, Stafford, were helpful as was Miss Jancey of the Hereford CRO. Thanks are also due to Mr J Brangan, who, over sundry pots of ale, sought information as to the more recent past from the more elderly local residents, and to the many friends who assisted with the various analyses, and who offered constructive suggestions in connection with the technical detail of the paper. The writers would also express their thanks to Mr M M Hallett for his constructive suggestions.

References

1 J Gould, **Men of Aldridge** (1957), p 34.

2 S Shaw, **History and Antiquities of Staffordshire**, Vol 2, 1801, p 50.

3 T Turner, Notes on some Remains of Early Iron Manufacture in Staffordshire, **Journal of the Iron and Steel Institute**, XXXV, 1912, p 203.

4 F Hackwood, **Olden Wednesbury**, 1899, p 31.

5 BRL 276735.

6 BRL 276732.

7 Staffs Historical Collections, Quarter Session Rolls III, 1933, pp 295-300, 329, 339, 340 and 341.

8 Ibid, Quarter Session Rolls, IV, 1935, p 260.

9 Ibid, Quarter Session Rolls, V, 1940, pp 19-22.

10 BRL 276756.

11 W Sanders, **History and antiquities of Shenstone**, 1794, p 343.

12 BRL 276749.

13 BRL 276727.

14 Ref 11/61/25/60.

15 E W Hulme, Statistical History of the Iron Trade, **Newcomen Society Transactions IX**, 1929, p 12.

16 B C L Johnson, The Foley Partnerships, **Economic History Review**, IV, Second Series, 1952, p 322.

17 Morton, G R, **The Metallurgist**, Vol 2, Sept 1963, ibid, Vol 2, Nov 1963.

18 Plot, R, **Natural History of Staffordshire**, 1686, p 159.

19 William Salt Library, Anglesey Collection. D1734/3/3/22, p 5.

20 Yarranton, Andrew, **England's Improvements by Land and Sea**, 1676/7, pp 57-58.

21 Plot, R, op cit, page 160.

22 Turner, T, ibid.

23 E L Rhead, **Metallurgy**, 1895, p 173.

HMG BULLETIN 5
First published June 1965

Contents

Glaisdale Bloomery site, see page 31.

17th-18th Century

1. Blast Furnace Survey

Work on this survey has continued, and the results to date are given in Table 1.

C R Blick reports the possibility of there being another furnace at Shustoke, near Nuneaton. P G Rattenbury has sent us the following list of Welsh blast furnaces, out of T W Booker's book of 1835, together with his comments on the present position. Many of these furnaces were first blown in the 19th century.

T W Booker 'Prize Treatize on the Mineral Basin of Glamorgan and the Adjoining District' (1835), p 29.

Iron Works in 1834	Owners	No of Furnaces
Sirhowy[1] & Ebbw Vale[2]	Harford Davies & Co	7
Nantyglo[3]	J & C Bailey	7
Beaufort[4]	J & C Bailey	4
Abersychan	British Iron Co	5
Varteg	Kernicks	5
Blaenavon[5]	Hills & Wheeler	4
Clydach[6]	Frere & Co	3
Pontypool	C Hanbury Leigh	3
Pentwyn	Hurst Bros & Co	2
Coalbrook Vale[7]	Brewer & Perkins	2
Blaena	Brown & Co	2
Ynisardwin[8]	Crane & Co	2
Maesteg	Buckland Jones & Co	2
Pontrhydyven	Renolds & Col	2
Cwmbychan	J Vigurs & Co	1
Pentyrch[9]	R Blakemore & Co	1
Gadlys	Williams & Co	1
Rudry[10]	Pope & Co	1
Cefn Cribbir	Bryant & Co	1
Cyfarthfa 9-)		
Hirwaun[11] 4 }	W Crawshay	13
Dowlais	Guest Lewis & Co	12
Plymouth[12]	R & A Hill	7
Penydarren[13]	Thompson & Foreman	5
Rumney & Bute[14]	Thompson & Foreman	4
Tredegar	S & W Homfray & Co	5
Aberdare[15]	Thompson & Foreman	6

Notes

1 Sirhowy. Site of works clearly visible. Water-course has iron dam virtually intact.

2 1834 site now separate from newer works.

3 Remains of one furnace still in railway embankment.

4 Site located but no remains.

5 Five furnaces still there. Two in very good condition. (1850 vintage).

6 Bases of four furnaces were there until recently when they were covered with road metalling for the Head of the Valleys Road, Near Abergavenny.

7 Office block was there three years ago. Converted into dwellings but outbuildings built of refractory brick!

8 I think Booker means Ynyscedwyn Nr Ystradgynlais, as that was Crane's works. Site since used by a bottle manufactury, and later by a forge.

9 Completely demolished. Tips now a housing estate. One shed of the forge, a little lower down the valley. still remains.

10 No trace of furnace. Wheel pit and pond remains.

11 All still possible to locate.

12 One (in part) left.

13 Site clearly discernable. No trace of furnace.

14 Rhymey Iron Co Works indicate Rhymey & Bute as separate works at this date. Earlier furnace (1802) still discernable.

15 One still apparent.

2. Bloomeries and Forges

a) Excavations of Roman Bloomeries

H F Cleere will be continuing his excavation at Bardown, Ticehurst, Sussex, for 3 weeks starting on Monday 2nd August 1965. Members interested in helping should contact Mr Cleere direct.

Excavations during the last 3 years have shown that this was the site of a large industrial complex, operated in the 2nd century AD. So far, operations have been confined to the fringes of the site, but this year it is hoped to locate and excavate part of the ironworking area.

On various weekends, and from 21st August to 12th September, with the kind permission of the owners, Mr and Mrs Patrick Gibson, a final section of digging will take place at the early iron-working site in Minepit Wood, Withyham, Sussex. The work, which is under the auspices of the Sussex Archaeological Society and will be directed by Mr James Money, FSA, will be carried out by members of the Tunbridge Wells and District Archaeological Group and others from further afield.

The site, which is in a dense wood, is particularly important because, owing to its remoteness it has escaped the demolition suffered in later times by so many other bloomeries. During 1963 and 1964 a section was cut through the extensive slag-heap, which lies in front of the working area; behind the slag-heap a hard-standing was uncovered; and, most important of all, a small furnace, which is considered by the experts to be unique in British archaeology, was found more or less intact. The nearest parallels to this furnace are of Saxo-Norman to Medieval date. The circumstantial evidence, however, which consists of considerable quantities of Romano-British pottery and includes nothing of later date, suggests that the furnace is also of this period and that a tradition of iron-working continued from Roman times, through the Dark Ages, to the later period. It is hoped that a Carbon 14 dating test will be done on the charcoal which was recovered from the base of the furnace and that its place in the history of the industry will thereby be definitely established. Digging also uncovered a piece of hard sandstone which had been used for sharpening metal implements, part of a rotary quern (corn grinder) and a spindle whorl.

Work in 1965 will concentrate on recovering further material in the living and working areas; excavating what appears to be another furnace and examining a suspected Roman road which runs past the site and seems to link Ashdown Forest with the Tunbridge Wells area.

b) Roman period Forge at Catcote, West Hartlepool, Co Durham

During 1964, C D Long found the remains of a forge on this site. It was found in the eastern half of a 33 ft diameter hut on a native site of the 1st-2nd century AD, and therefore has certain affinities with the pre-Roman site at Kestor, Devon, found by Lady Fox. The remains consisted of pieces of baked clay which resemble the Indian forge furnace described by F Buchanan in his 'Journey from Madras' which was published in 1807. It seems to be the same type as that in the Museum at Grantham.

It was found in a heap of burnt clay fragments in a shallow pit 10 ins deep and 3 ft diameter in the natural sand. One piece contained the remains of a tuyere hole.

c) Bloomery and Finery Sites recently investigated by members and others

Site	Period	Excavator or Investigator
West Brandon (Co Durham)	EIA	G Jobey
Bardown, Sussex	Roman	H F Cleere
Withyham, Sussex	Roman	J H Money
St Neots, Hunts	Medieval	C F Tebbutt
Stamford, Lincs	Medieval	A Burchard
Cromer, Norfolk	Medieval	R F Tylecote
Rockley Smithies Yorks (WR)		D Crossley
Muncaster Head (Cumberland)	17th Century	J Cherry
Bourne Pool	17th Century	J Gould
Little Aston	17th Century	Gould & Morton
Baysdale Yorks (NR)	Medieval	A Aberg
Glaisdale Yorks (NR)	Medieval	Mrs Stainthorpe G Harland
Excavations Completed		
High Bishopley (Co Durham)	Medieval	R F Tylecote
Harthope Mill (Co Durham)	Medieval	R F Tylecote

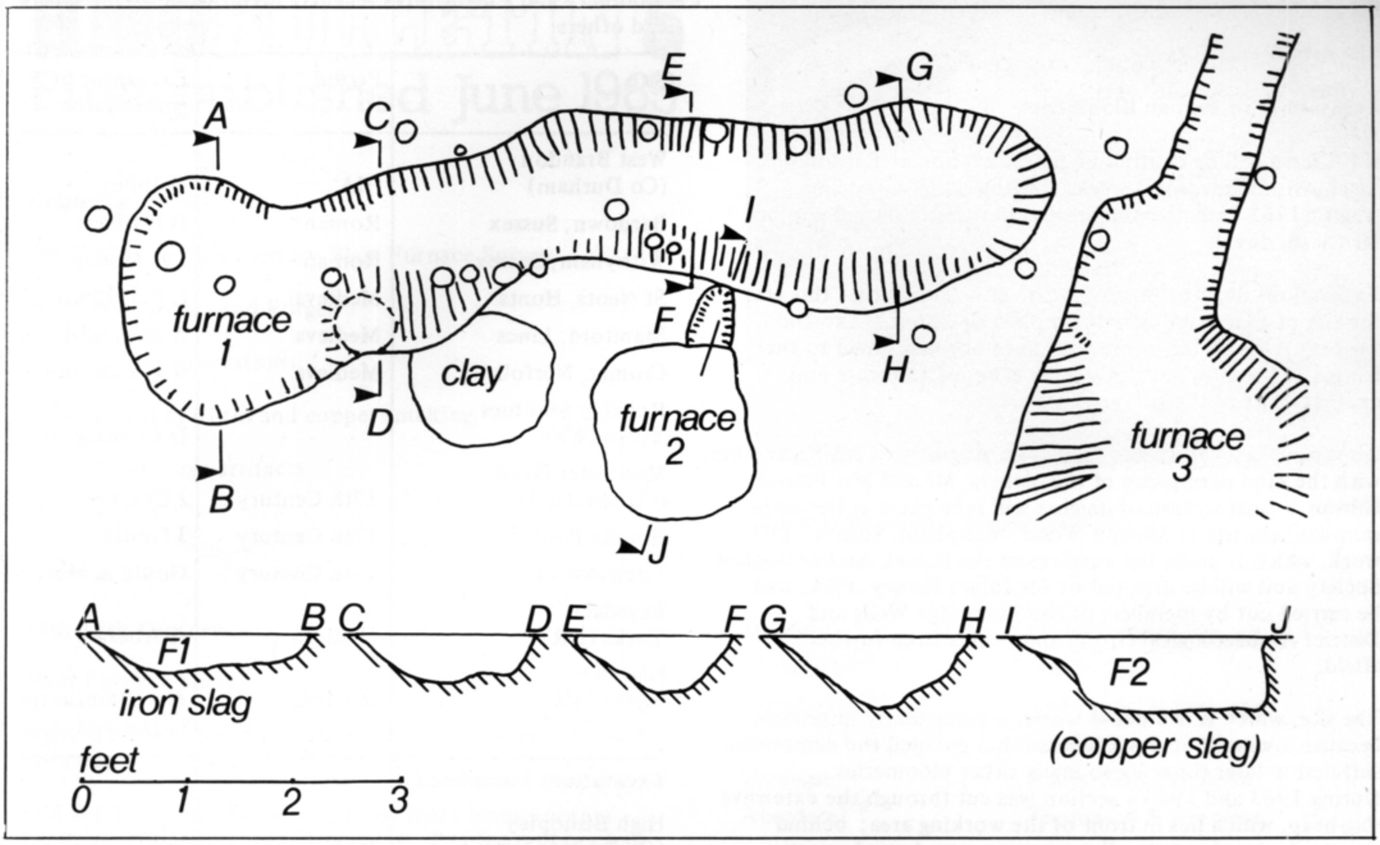
d) St Neots, Huntingdonshire

In the course of a rescue excavation in 1964, C F Tebbutt unearthed a number of hearths belonging to the second half of the 13th century. These appear to have been the bottom parts of iron smelting and copper-base melting furnaces (Figure 1).

Furnace 1 seems to be a clay lined iron smelting furnace of a type that is proving fairly common in the Medieval period. It has evolved from the EIA bowl hearth and might be termed a 'pit' or 'trench' furnace since it is a bowl furnace situated at the end of a trench. The furnace at St Neots has affinities with those at Baysdale, N Yorks, excavated by Alan Aberg, at Glaisdale, N Yorks, reported by Mrs Stainthorpe, and with a furnace recently found by James Money at Withyham in Sussex. The latter is tentatively dated to the Roman period ,but may well prove to be later, and was supplied with air through 3 or 4 tuyeres at 90° to each other, and sloping downwards.

The fuel would be charcoal and the ore probably carbonate nodules from the Greensand (about five miles away). The air would be supplied by manually operated bellows. The slag would be tapped into a hollow in front of the hearth.

Furnace 2 appears to have been a melting furnace for copper-base alloys. A crucible would be used to contain the metal and would be placed in a hollow surrounded by charcoal and urged with manual bellows. Considering the positioning it is unlikely that it was exactly contemporary with Furnace 1. The only heavy metals contained in the slaggy dross from this furnace were copper and iron.



3. Excavations on the South Gate Exeter, 1964

Lady Aileen Fox has kindly sent us a report on her excavations on this site from which the following has been abstracted:-

'Demolition of a mass of early 19th century properties in March 1964 revealed an unexpected length of the City Wall extending from the Inner By-Pass to within 30 ft of South Street adjacent to the known site of the medieval South Gate which was taken down in 1822 . For the most part the full width of the wall was intact, standing 15-20 ft high, and although the external face had been patched in medieval times, the Roman chamfered plinth was present. Since the area behind the Wall was needed for redevelopment and for the widening of South Street, the Ancient Monuments branch of the Ministry of Works arranged for a small excavation, which was carried out from July 22 - August 8.

A section cut at the back of the Wall showed that the earliest occupation was by metal-workers who had constructed a small furnace lined with bone ash; in the surrounding debris decorated Samian of Antonine date and a Castor-ware gritted beaker were found as well as a clay tuyere. This was covered by soil tips of the rampart, which therefore can now be confidently dated within the period AD 150-180. The rampart had been cut through when the Wall was built **circa** AD200 as had been apparent in Bedford Street in 1950.'

4. Remains of Cornish Tin and Copper Smelting

A good deal of attention has been given to the history of Cornish mining and engines but very little to the history of tin and copper extraction. Although most of the extraction of copper was carried out in S Wales, up to the end of the 19th century almost all the tin smelting was carried out in Cornwall itself. Yet very little sign of this remains today.

During September 1964 a brief survey of the possibilities was carried out by the Secretary. Museums were visited to examine the tin ingots, slag heaps located and the most metalliferous looking slags analysed semi-quantitatively and metallographically. It should be noted that metal contents are not necessarily typical and therefore they should not be taken as an indication that there is a large amount of slag of high metal content in Cornwall. Clearly, many of these slags have been moved from other places since, for example, United Mines are not believed to have had a smelter. The samples were taken because they often showed metal visible to the naked eye and were therefore considered to be more typical of early extraction. Very small quantities of such slags remain.

No 1 was a copper slag; all the rest were tin slags.

A. Analysis of Copper and tin smelting slags

Semi-quantitative analyses of Copper and Tin slags obtained by X-ray fluorescence spectroscopy (%)

No:	Provenance	Sn	Pb	Zn	Cu	Mn
1	Hayle (Cu)	7.4	11	14.4	1.1	0.65
2	United Mines	0.8	1.3	0.17	0.015	0.40
3	Seligan (East)	0.5	-	0.10	0.22	0.70
4	Seligan (West)	22	-	0.5	0.04	0.50
5	Bissoo	60	0.3	0.3	tr.	0.40
6	Carnelloe	2.8	-	0.5	0.7	0.50

Rest FeO, CaO and SiO_2. There was rather more FeO in the Hayle slag than in the rest of the specimens. A typical modern tin smelting slag would contain:- SiO_2, 35; FeO, 18; CaO, 28; MgO + Al_2O_3, 17.0; and Sn 2.5 – 3.0%.

Metallographic Examination and Comments

1. Copper present as globules. Fayalite-wustite laths and complex eutectic structures.

2. Not examined metallographically. Not a copper slag. Probably a late tin slag.

3. A late (? 19th century) tin slag. Round particles of Sn-Fe (?) phase dispersed evenly throughout. Thin laths or plates in fayalite glass.

4. A rich tin slag. Large globules clearly visible with the naked eye. Laths and a third lightish cubic phase (? SnO). The tin globules are two-phase (probably hardhead, Fe-Sn) and some are within the laths.

5. Not examined metallographically.

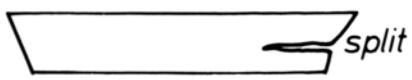
6. Almost structureless. Highly reflecting which suggests opaque SnO evenly dispersed. Very fine light phase in some areas. No metallic tin.

General Comments

The Hayle copper slag has a fairly normal copper content for the period. All copper was present as globules. The tin content is interesting and supports the analyses given by Coffey showing that black copper smelted in Swansea in 1900 from Cornish ores contained 0.7% tin. One of the Cornish ores smelted at this time contained 0.94% tin and 12.3% copper. Lead and zinc are common impurities in copper ores and are normally present as oxides in the slags.

B Examination of Cornish Tin Ingots

1



Various marks and holes.

1 Fowey (Truro Museum). Medieval. One of five, about 300 lbs each. 24 x 12 ins.

2

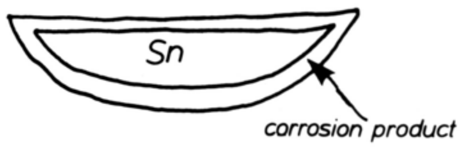
2 Carnanton Ingot (Truro). Cannot now see DDNN, doubtful whether the letters ever existed. More like the Trereife ingot in shape. 5 x 18 ins. 39 lbs weight.

3

3 St Mawes Ingot (Truro). Much corroded. 150 lbs.

4

Oval
9 x 12 ins
x 3-4 ins thick



4 Plano-Convex Ingot (Truro). Block of 'Jews' tin from Tremathack Moor – Madron.

'Crust' is dense and ¼ in thick. Some of it is flaky.

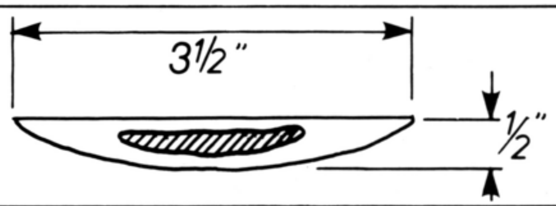
5

5 Chun Ingot (Truro). Tin, coated with slag or corrosion product. Weight 11 lb 1 oz. Oval. 8 x 6 ins. Thickness 1½ ins. Also with it, was a small piece of melted tin.

6 Plano-Convex Ingot (Helston). From Vellin Antron Farm, Mabe. Found in 1913. One of 'half a dozen'. Tin content = 96.88%. Oval. 4 x 5 ins x about 2 ins thick.

7 Plano-Convex Ingot (Penzance Geological Museum). Ingot of 'Jews House' tin found while building railway near St Austell in 1858 .Boat-shaped. 18 x 12 ins x 2-3 ins thick.

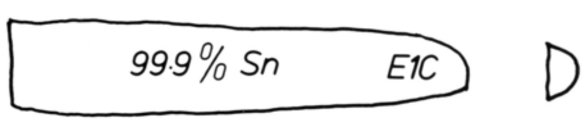
8



8 Plano-Convex Ingot (Penzance; Morrab Museum). Thin and much corroded.

Corrosion product is dense, but metal core is highly ductile and therefore pure. One of a number of finds on the shore line of Par Sands in St Martins, Scilly. Dated to c.300 AD Found in a circular hut. Accompanied by a number of flaky pieces of (?) tin corrosion product.

9



9 Trereife Ingot (Penzance; Morrab Museum). 29.5 lbs. 16½ x 8 ins x 2 ins thick.

There was some question whether the 'crusts' encasing these ingots were slags or corrosion products. A quantitative chemical examination of crusts from St Martins (Scilly), Chun Castle, and Tremathack gave low iron and silica contents and high tin contents, and there is therefore no doubt that these are oxidation products often contaminated with iron from the soil. They resemble the analyses given by Tylecote (Metallurgy in Archaeology, p 70-71) of oxidation products from tin artifacts.

There is little doubt that there is a considerable amount of metallurgical material in Cornwall which would repay investigation. The subject of the sites of the earlier blowing houses and their layout has never been touched. Worth, in his book on Dartmoor, shows what can be gained from such an examination. Not all traces have been destroyed by later mining activities, as many blowing house sites were well away from the mining areas.

The group gratefully acknowledges the help of A Hamilton Jenkin, F B Michell and others in Cornwall for most useful discussions, and the help of Dr J D Gilchrist and Dr M H Battey with the analyses.

5. Metallographic Examination of Middle and Late Bronze Age Artifacts by C B Burgess and R F Tylecote

The Problem

The transition from Middle Bronze Age to Late Bronze Age in the British Isles is marked not so much by the development of new implement types or cultural changes, as by a major technological development in bronze-working. In the Early and Middle Bronze Ages the metal used was a straight tin-bronze; in the Late Bronze Age lead was deliberately added The adoption of leaded bronze can be dated fairly closely in southern and eastern England to c 10th century BC. This has been determined by analysis of relevant implements from these areas. At the same time as leaded bronze was introduced there, a new range of Late Bronze Age implement types replaced the old Middle Bronze types, apparently completely.

The situation is entirely different for the Highland Zone. Here there appears to have been no total replacement of Middle by Late Bronze Afe types. Many Middle Bronze types apparently continued in use down to the 8th century BC, though they were joined by some of the new Late Bronze Age types which had taken over completely in the south. Thus in the Highland Zone we have a lingering Middle Bronze Age as far as implement types are concerned. The more important problem, whether the leaded-bronze process was introduced here as early as in the south, or whether its introduction was delayed, as the implement evidence suggests, is unresolved. No analysis of relevant Highland Zone material has been undertaken.

The solution of this problem is best sought in the north of England. Only here in the Highland Zone are the lingering Middle Bronze, and the new Late Bronze implements, found repeatedly together. There is a series of hoards, mostly from Northumberland, combining these two traditions, and broadly contemporary with the southern early Late Bronze Age, ie c 10th – 8th centuries BC. By analysing implements from these northern hoards it is hoped to determine whether local metal industries were lagging behind those of the south, technologically, in this period.

1st Series

Examination of Bronze Age Material from the Joint Museum of the University of Newcastle and the Society of Antiquaries.

A. **1892.5** From socket of a socketed, leaf-shaped spearhead of single looped type. Medomsley Hoard, Co Durham. Much delta, and therefore probably contains about 15% of tin. There is some slaggy grey phase and there are a few strain markings near the edge which suggest a limited amount of cold work.

B. **1947.6.2** From socket of a spearhead, probably of basal-looped, furrowed blade type (cf Sample F below: these two might be from the same implement). Hoard, Farnley, Near Corbridge. A cast structure showing slight coring. It has probably been heated after casting. There is considerable inter-granular corrosion and some delta which would suggest a tin content of about 10%. It contains no lead.

C. **1947.4b** From septum, just above the stop, of a 'transitional' looped palstave. Found with E below at Haydon Bridge, Northumberland. Strain markings and bent twins show that this has been considerably worked, certainly in the cold state and probably also hot worked. The edges have been worked more than the inside. Heating and working have eliminated all signs of coring and there is no lead visible. Again there are signs of a greyish slag phase. The absence of the alpha/delta eutectoid suggests that the tin content is probably less than 10% . Some hardness tests were carried out. The edge, ie the cold work area, had a hardness of 161 (DPN 5Kg) and the inside a hardness of 139.

D. **1947.6.A.2** From socket of a 'protected opening' spearhead. Farnley Hoard, Near Corbridge. This specimen suffers from very considerable inter-granular corrosion giving a grey and red coloured in-filling, ie corrosion product. Neither delta nor lead is visible. But the specimen may have suffered some destannification in the corrosion process.

E. **1947.4a** From the side, below the collar, of a 'bag-shaped' socketed axe, with 'rope moulded' collar. Found with C at Haydon Bridge. This consists of an 'as cast' structure showing coring. Lead is present in considerable quantities and there is some slaggy grey phase. The amount of delta present suggests a tin content of about 10-12%. This specimen has received neither hot nor cold work.

F. **1947.6.1** From near the point of a large furrowed-blade, basal-looped spearhead. Fragment only, but probably of the type with long, triangular blade. (This and B above might be fragments from the same implement. There would be a few inches between the two samples if so). Farnley Hoard, near Corbridge. Here again there is a considerable amount of inter-granular corrosion between the grains. It does not seem to have received any hot work but strain markings suggest a slight amount of cold work which may, in this case, have been imparted in the sawing off process. This speciment contains no lead and the fact that no delta is visible would suggest a tin content of less than 10%.

2nd Series

238. Rapier with notched butt and flat mid-section, of Mrs Trump's Lisburn type. Found with spearhead No 249 below ,about 1 mile NE of Corbridge.

A piece was removed from the edge of the blade near the hilt. It was a cored fine-grained bronze containing about 10% of tin and some slag and no lead. It had a twinned structure showing that it had been worked and strain markings near the edge of the blade showed final cold work. The hardness near the centre was 127 HV5 and near the tip 164 HV5.

249. Blade of a large protected-opening spearhead. Found with rapier 238 about 1 mile NE of Corbridge.

This showed slight residual coring and some slag. It was a tin bronze of slightly lower tin content than the above. No lead was visible but there was intercrystalline corrosion which had led to slight destannification. The presence of twins showed that it had had some working after casting. The hardness was 113 HV5.

243. Plain pegged, leaf-shaped, socketed spearhead. Found with palstave 196 below, at Denwick in 1832.

The structure was as cast and contained degraded delta eutectoid showing the presence of about 10% of tin. There were some slag globules but no lead. The hardness was 86 HV5.

196. Looped, narrow-bladed ,palstave, probably of 'transitional' type. A very worn and pitted specimen, with only the stubs of the loop remaining. Found at Denwick with spearhead 234 in 1832.

This specimen had received a considerable amount of heating after casting and no trace of the original as cast structure was visible. There were no twins showing that little work had been done on it; it was porous and contained no lead. The tin content was probably in the range 12-15% and the hardness was 106 HV5.

260. (2) Upper part of a socketed axe of markedly rectangular section ,with deep, flat collar surmounted by a worn cable moulding. Of Irish provenance.

This was a fairly poor casting showing considerable porosity and a fairly low tin content of about 8% . It suffered from inter-granular corrosion and could have been leaded, but if so the lead was very globular. There were also traces of a grey slag. The hardness was 62 HV5 .

Pieces from the hoard found at Farnley, near Corbridge

195 . Looped, narrow-bladed palstave with median rib decoration, of 'transitional' type. Deeply undercut stops and the form of the heavy casting fins at the sides, suggest Irish influence. End of the butt probably missing.

Like the palstave from Denwick 196, this specimen had received considerable heating after casting and was very coarse grained. It contained no lead but the presence of some delta eutectoid indicated a tin content in the range 8-10%. There was a considerable patch of slag in the centre of the specimen which had come from the septum. The harndess was 124 HV5.

239. Length of blade from a dirk or rapier with flat midsection. Probably from a weapon of Lisburn type like No 238 above.

A fine grained bronze which had received considerable heating after casting. It had a tin content in the range 12-15% a small amount of slag and no lead. It had received some work near one edge but had been heated afterwards. The hardness was 124 HV5.

250. Blade only of a small, protected-opening spearhead. This was very badly corroded but consisted of a cast structure containing large amounts of grey slag. Some delta eutectoid was apparent and the tin content was therefore probably in the range 8-10%. The lead content was uncertain but lead could be present.

25 1. A piece from the blade of a small protected-opening spearhead which had the point missing.

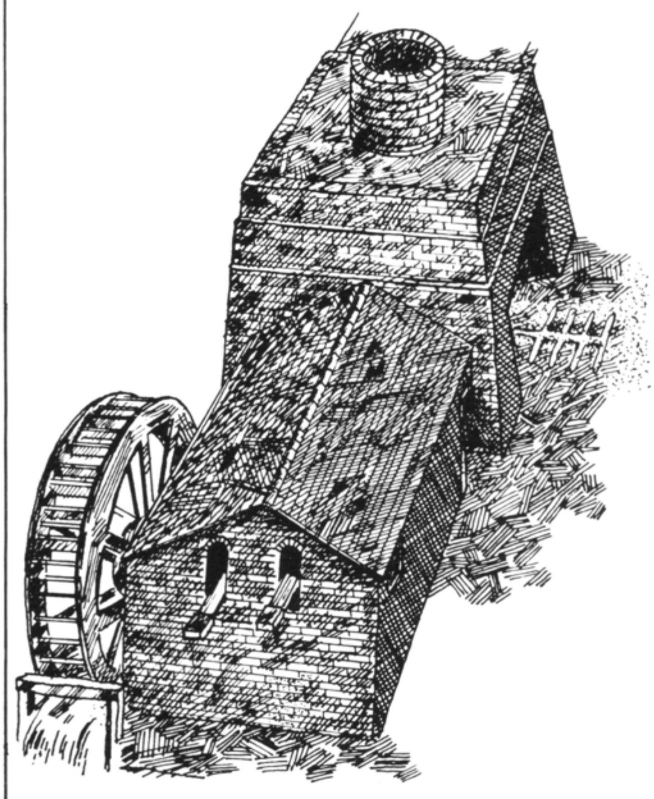
This also had suffered from considerably intergranular corrosion and the delta eutectoid was present showing a tin content of 10-15%. The structure was more equiaxed than the above (25) and had received considerable heating after casting. It contained no obvious lead although in view of the heavy corrosion the presence of lead must be considered doubtful.

252 . Part of the lower blade and upper socket of a plain, pegged, leaf-shaped spearhead.

A piece from the socket of badly corroded equiaxed structure containing considerable delta (10-15% Sn) and showing signs of destannificiation. There was no obvious lead.

No number. A blade fragment, towards the point, of a leaf-shaped spearhead.

A piece from the blade showed a highly corroded equiaxed structure with some delta in the grain boundaries. (10-15% Sn). There was no obvious lead.



The Old Furnace at Coalbrookdale (see Table 1, page 36) as it probably appeared to Abraham Darby I in 1709.

Drawing by permission of the Ironbridge Gorge Museum Trust

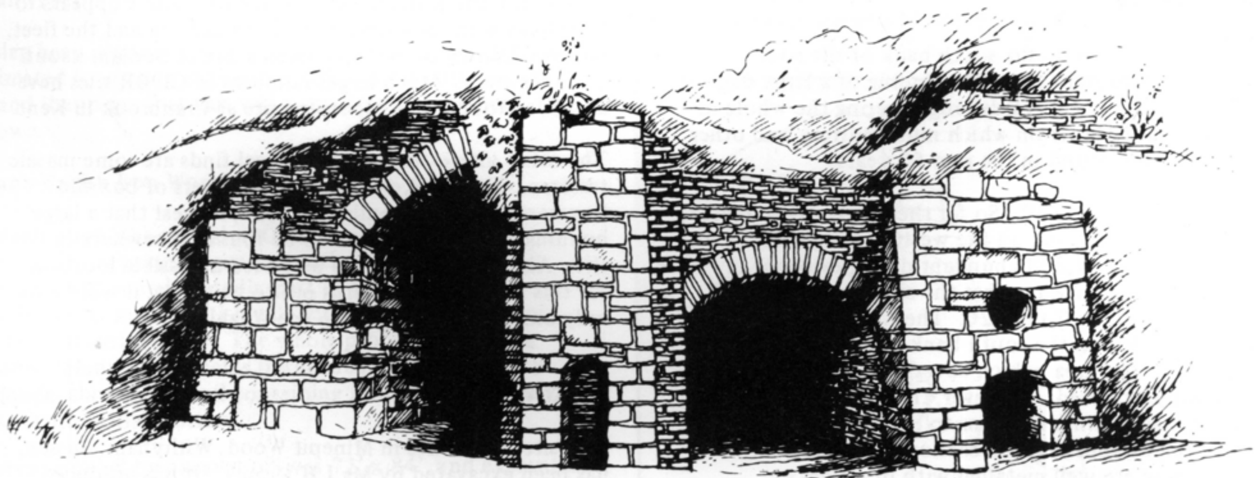
Table 1

17th-18th Century Blast Furnace Survey

State of Work on 1st May, 1965

County	Name and Alias	Blown In	Out	Map Reference	Details and Remarks
England					
Yorks (WR)	Rockley, Near Barnsley	1652	After 1736	SE/337021	Hearth lost. Shaft good; sandstone 20 x 20 x 15' high. Preserved.
Yorks (WR)	Low Mill Cawthorne	1761	?	SE/297068	Excellent. Should be preserved.
Yorks (NR)	Bievaulx, Helmsley	Before 1577	1647	SE/5/5852	No remains above ground. ? Foundations.
N Lancs	Duddon Bridge	1736	c 1866	SD/197883	Fairly well preserved. Scheduled.
N Lancs	Nibthwaite	1736	1755	SD/293898	Lower part only.
N Lancs	Newland	1747	1891	SD/299798	Mostly dismantled in 1903.
N Lancs	Blackbarrow	1711	-	SD/355847	Still blowing with modifications.
Derbyshire	Melbourne	1725	c 1780	SK/379239	Submerged in 1963 after excavation.
Derbyshire	Ambergate	1764	?	SK/3452	Demolished in 1964.
Derbyshire	Morley Park	1780	1874	SK/3650	Preserved; more information still required.
Staffs	Chesterton Newcastle-u-L	1783 (?)	?	SJ/821499	Brick built. 1 tuyere. Square outside circular shaft. Deteriorating externally.
Salop	Coalbrookdale	1638 (rebuilt 1777)	1812 (?)	SJ/6804	Well preserved by Allied Ironfounders Limited
Salop	Charlcote (Wrickton)	?	(after) 1825		Overgrown. Being investigated by Midlands members.
Worcs	Sharpley Pool	1652	?	SO/8065	Being excavated by Midlands members.
Glos	Gunns Mill	1683	?	SO/675159	Built into a farm. Surveyed by Glos Arch Soc.
Glos	Whitecliff	1798	1810	SO/568102	Stone on furnace dates it to 1806. Structure cracked but well recorded by Archenfield Arch Group.
Cumberland	Maryport	Soon after 1752	by 1783	NY/034361	Dressed sandstone. 1 tuyere. Shaft square outside, circular inside. Demolished 1963.

Salop	Madely Wood (Bedlam)				In ruins.
Salop	New Willey				In ruins.
Wales and Monmouth					
Denbigh	Brymbo	1798	?	SJ/2953	Well preserved; used as a sand bunker in a steel works.
Denbigh	Plasmodoc (Ruabon)	1670	1760 (?)	SJ/288436	Base only in pond. Circular shaft.
Brecknock	Brecon	1720	?		Demolished about 1950.
Cardigan	Eglwysfach (Dovey)	1755	?	SN/6896	Restored in 1963. Well preserved. Hearth lost.
Carmarthen	Llanelly (Dingle)	c 1795	c 1815	SN/504015	Single tuyere. Square externally.
Glamorgan	Defn Cribwr	1773	?	SS/851835	18 ft high. Hearth intact.
Monmouth	Coed Ithel	Before 1652	c 1796	SO/527027	Excavated in 1964. Vertical section. Still standing.
Monmouth	Woolpitch Wood	17th century		SO/487048	Sandstone. 24 ft square. Also outbuildings.
Brecknock	Llanelly	Late 17th century		SO/235143	26 ft square. Collapsed on S & E sites.
Scotland					
Argyll	Furnace, Lock Fyne	1753	1813	NS/025998	Excellent condition. Hearth intact. Well worth complete preservation. Dated lintel beam.
Argyll	Bonawe	1753	1874	NN/018320	Still standing. Hearth lost, but probably worth preserving.



Bedlam Furnaces at Madeley Wood on the north bank of the River Severn about 300 yards downstream from the Iron Bridge. Built in 1757-58 they are now being excavated and consolidated by the Ironbridge Gorge Museum Trust to whom we are indebted for the use of this sketch.

HMG BULLETIN 6

First published January 1966

Contents

Ariconium (see page 40) Area A from east

The Iron Industry in the Roman Period

H F Cleere, BA and N P Bridgewater, BSc

The Wealden Industry

Caesar testifies to the existence of an ironmaking industry in the Weald before the Roman invasion. During the first century AD, a number of large sites were established in the area between Hastings and Battle. These include Beauport Park, Oaklands Park, Crowhurst Park etc. All have large slag heaps and rubbish dumps remaining, even though much has been quarried away for 19th century roadmaking.

In the 2nd century, perhaps owing to deforestation in the southern area, new sites were established in the central Weald, among them those at Bardown (Ticehurst), East Grinstead, and Maresfield. Most of these appear to have been operated from the mid-2nd century for about 70-100 years.

The Bardown Site

The Bardown site lies on the south bank of the river Limden. It was recognised by the finding of a large slag and refuse tip about 100 yards long covering the whole of this bank of the river, from which much pottery and other objects have been found in the past 50 years.

Excavations began in 1960. So far these have taken place only on the refuse tip and on the western fringes of the site. These have produced abundant dating evidence in terms of pottery, indicating that the site was operated between about AD 140 and 220. The working and residential area lay on the south bank of the stream, above the refuse tip. The area, which covers some 8 acres, has not been fully explored. However, the existence of a number of road communications to the south, east, and west has been established, and sections have been uncovered. These are well metalled with iron slag.

No smelting furnaces have yet been found. However, two types of double tuyere (Fig 1) have been found, and also fragments of single tuyeres. Furnace bottoms found on the rubbish tip suggest that the furnaces were about 1 ft in diameter. There is no evidence as to whether these were bowl or shaft furnaces.

Two structures have been found, the purpose of which is not yet fully determined (Fig 2). These consisted of low walls, about 1 ft high and 1 ft in width, forming a structure about 8 ft in length and 1 ft internal breadth; one of the shorter ends was open. The interior was lined with clay, which had been raised to a high temperature. Associated with one of these features was an area (about 8 ft in diameter) of red roasted iron ore fines, which formed a bed 8 to 10 inches thick. In this bed were found the necks of three flagons, which had been shaped to form tuyeres or vents. Various interpretations of the structures have been put forward, including forging hearths, tile or pottery kilns, or corn drying ovens. The most plausible interpretation, however, is that they were used for ore roasting. In a structure of this kind, the ore could be calcined more evenly, and with less risk of reduction, than in the bonfire type hearth previously known from this area.

Two archaeological finds of importance have been made on this site. Three tiles with the stamp CL BR (or fragments of this) have now been found. This stands for Classis Britannica, the Roman Fleet of Britain. There appears to have been some connection between the site and the fleet, which is known to have occupied a site at Bodiam about 12 miles away. Much larger numbers of CL BR tiles have also been found on a bloomery site at Cranbrook in Kent.

The other interesting archaeological finds are some masaic tesserae. These, taken with large numbers of box tile fragments and other building debris, suggest that a large building of the villa type is to be found somewhere in the site. Air photographs have indicated a possible location for this building. If it turns out to be a villa, it will be the only one so far known from the Weald.

The Orznash Site

This site, which lies in Minepit Wood, Withyham, Sussex, has been excavated by Mr J H Money. It has produced remains of a large smelting furnace, of about 2'6" internal diameter, which appears to be of the domed Engsbachtal type. The structure, which was built of sandstone lined with clay (showing signs of several relines) was blown with three tuyeres, opposite and flanking the tapping arch, which has broken away. Two smithing hearths have also been tentatively identified.

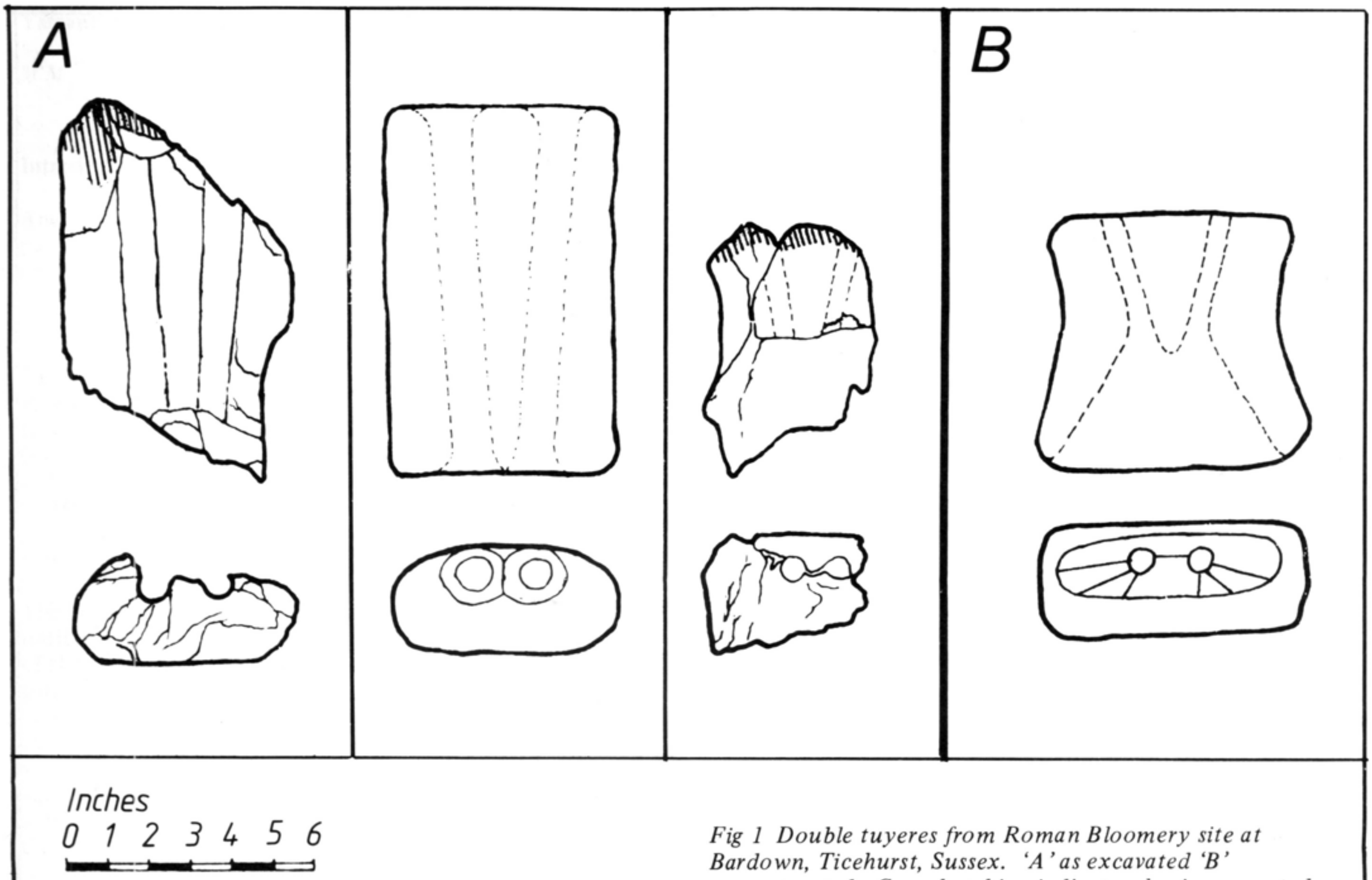


Fig 1 Double tuyeres from Roman Bloomery site at Bardown, Ticehurst, Sussex. 'A' as excavated 'B' reconstructed. Cross-hatching indicates slag impregnated portions.

The dating of the site is still obscure. The furnace is the largest of its type known from Roman Britain, and on purely typological grounds would be assigned to the Dark Ages or the Middle Ages. There is no specifically Roman pottery from the site, such as Samian, Nene Valley, or New Forest ware, and no finds of coins have yet been made. However, one flagon neck from the site seems to be of a Roman type.

The slag heap is much smaller than that at Bardown, which is estimated to contain between 5,000 and 10,000 tons of slag, and it appears that this was a smaller establishment than Bardown.

Romano-British Iron Working near Ariconium

This excavation was carried out near Ariconium, the traditional ironworking town in South Herefordshire, and the area chosen is undoubtedly part of the complex consisting of Romano-British villa settlement encircled by extensive industrial zones. The whole probably occupies 250 acres. Many of the fields in the area, when turned by the plough, show black soil containing iron slag, burnt clay, and Romano-British pottery.

The area sampled by excavation was 72' x 84', and excavation to bedrock yielded remains of six furnaces, with associated slag pits and many working hollows. A reasonable picture emerges of smelting and smithing activities in the second century, leaving major hollows, some partly filled but most left open. During the following centuries the hollows and surrounding slag heaps must have become domestic rubbish dumps of the Ariconium inhabitants, but later the land reverted to a scrubby waste.

Considerable quantities of the Roman slag were re-used in the 17th and 18th centuries, when the larger slag lumps were picked out, leaving behind the finer material and domestic rubbish. When the land was required for cultivation, this material was backfilled into the hollows and the land was generally levelled.

Four major hollows (Fig 3) (A-D) were excavated. In area A the main features (3 and 4) formed a complete unit,

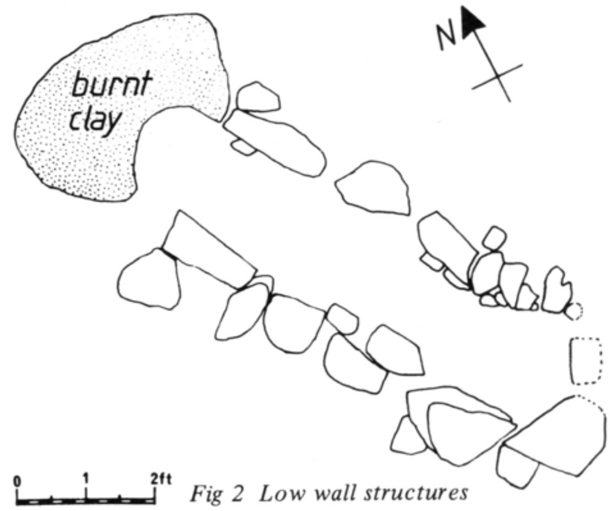


Fig 2 Low wall structures

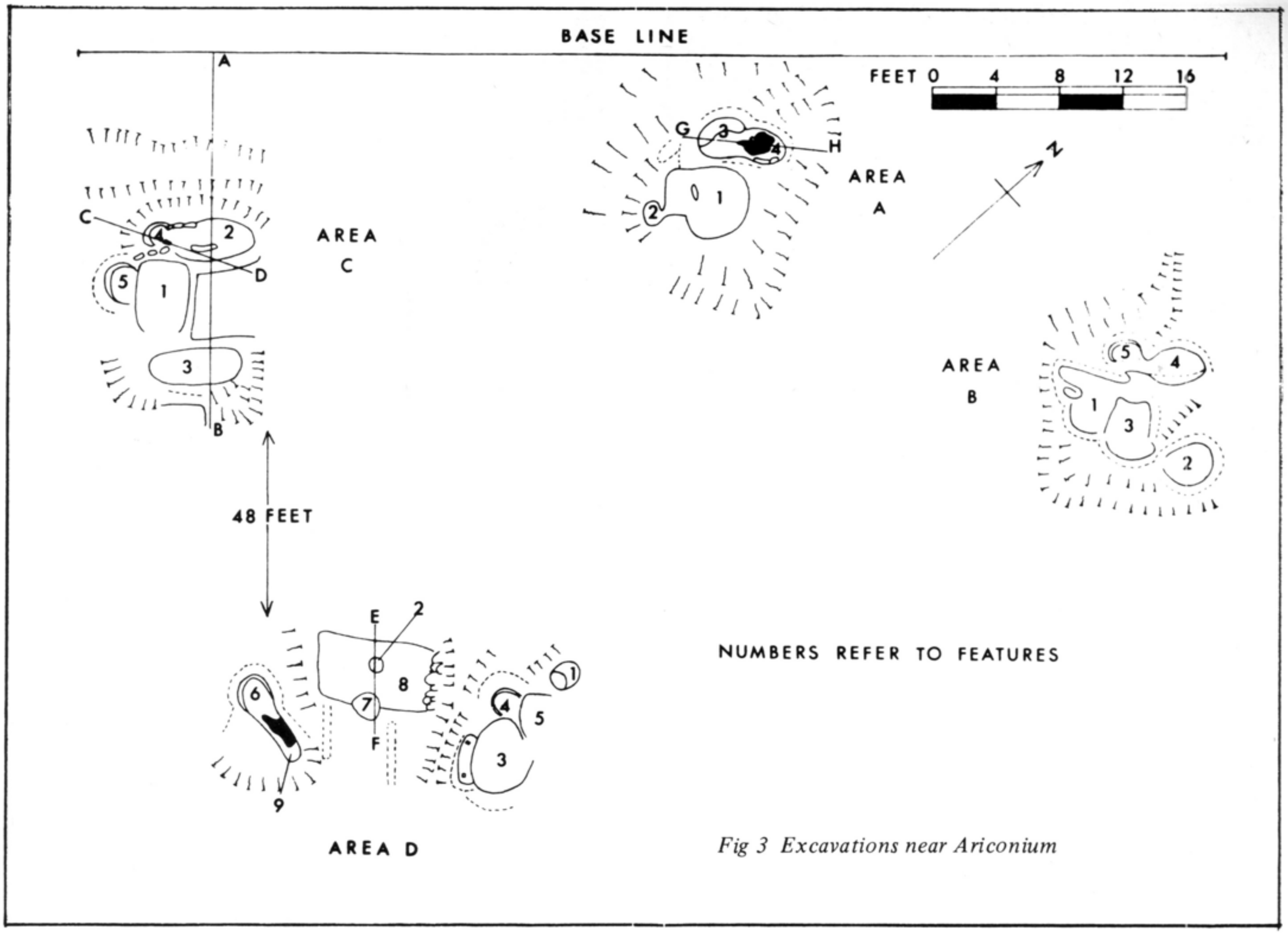


Fig 3 Excavations near Ariconium

consisting of a single scooped hollow which contained the furnace, joined to a slag-collecting pit. The furnace had been mostly demolished, but the remains of burnt and unburnt clay suggest that it was of the shaft type, worked by forced draught from bellows supported over the slag pit. In this particular instance it is believed that the hollow may have been originally a bowl furnace, later reduced in diameter by clay packing and with a shaft furnace built into its southern sector. The slag pit of area A contained a large mass of bloomery slag with an attached runner. In this area a small hollow was found which Dr Tylecote considers to have been a working-up hearth. In primitive smelting the bloom from the main furnace was actually an agglomeration of reduced metal, slag, partly reduced ore lumps, and charcoal. The metal particles were picked out of the mass, heated in the small hearth, and finally hammered together.

Area B contained another furnace with similar features; in addition there were three shallow hollows which appear to have been general working areas.

Area C contained remains of two furnaces and slag pits. It is of particular interest because Samian ware from sealed layers showed that one furnace superseded another, and a terminal date of about AD 170 could be given for the abandonment of the first furnace. Here also, a slag runner was found in situ. The back fill of the main hollows contained portions of clay tobacco pipes.

Area D was of special interest because, in addition to the presence of two more furnaces with slag pits, a rectangular hollow was found cut one foot deep into the bedrock. This was packed with charcoal covered by burnt daub with wattle impressions. These layers also contained decorated Samian ware, probably deposited by the end of the second century. This feature is considered to have been a charcoal store which supplied the two furnaces in this area.

Two large post-holes were discovered in area D and, whilst they could not be dated, they definitely antedated the charcoal store; they probably formed part of a large wooden hut structure.

No ore or fines were discovered, indicating that the roasting of the ore was carried out either in an adjacent area or at the ore mines. There is little doubt that the source of the ore was Wigpool Common, in the Forest of Dean, and a previous excavation by the author has revealed a road, metalled with iron slag, leading in this direction[1].

Several cinder lumps were found during excavation but no true hammer scale. There is some evidence for smithing operations by the presence of various pits and hollows ,and the finding of slag containing inclusions of coal. Some of the hollows may have been used for quenching.

Reference

1 N P Bridgewater: Ancient Buried Roads in South Herefordshire, Trans Woolhope Naturalists Field Club, Vol XXXVI (1959), 218.

Yarranton's Blast Furnace at Sharpley Pool, Worcestershire

M M Hallett, M.Sc, FIM, MIBF and G R Morton, FIM, MIBF

Introduction

Andrew Yarranton, an outstanding seventeenth century pioneer in such diverse fields as agriculture, national economics and the construction of canals, records[1] 'In the year 1652, I entred upon Iron-works, and pli'd them several years'. In a later volume of his standard book[2] probably written in 1680, Yarranton makes one of his characters say 'About 28 years since, Mr Yarranton found out a vast quantity of Roman cinders, near the walls of the city of Worcester, from whence he and others carried away many thousand tons or loads up the river Severn unto their iron foundry, to be melted down into iron, with a mixture of the Forest of Dean ironstone'. There is a reference at the same time to the finding of hearths of Roman foot blasts and a pot of Roman coin.

The location of this furnace was unknown for many years until in 1924 an abnormally heavy rainfall led to the bursting of the dams of two of a chin of ornamental pools in the parish of Astley some five miles south of Bewdley (map reference 246.873). The movement of part of the dam of the largest pool revealed the base of a blast furnace, which was soon recognised as such, and was described in an admirable paper[3] by Cantrill and Wight in 1929. It makes a very strong case for the identification of this furnace with that erected by Yarranton. The furnace was recorded by Schubert[4] as being the first furnace erected in England with a round interior plan instead of the earlier square plan.

Yarranton's phraseology implies that the furnace worked only for a few years and as the ornamental pools were erected at about 1700, there is every reason to suppose that the working life of the furnace was short. The known facts of Yarranton's life suggest that he had abandoned the project before the Restoration in 1660. Its examination is therefore of interest, not only because of its status as the first round furnace, but also because any remains can be closely dated without danger of being confused with later working. Study of them can thus provide evidence on the technique at a definite time.

The Site

The general appearance of the site is shown in Fig 1 taken from the paper by Cantrill and Wight[3]. The boat-house is contemporary with the 1700 dam. It will be seen that the stream which ran through the breach in the dam traversed the actual furnace. Before any detailed examination could be made it was necessary to divert the stream through the original dam culvert, in spite of which the site was extremely wet, being situated in the base of a narrow and steep sided dingle. Further difficulties were associated with the fact that the whole area, which is now in the middle of a wood, was heavily overgrown with dense vegetation.

The Structure

The visible remains consisted of the base of the furnace, which was reasonably complete up to the tuyere level, surmounted by about half of the lower bosh region, standing on one half of the circumference to a height of approximately 8 ft above the level of the base of the tuyere. The working surface was glazed with slag and also heavily eroded, some of the erosion valleys being as deep as 2 inches. These probably coincided with original joints in the sandstone blocks but this lining portion was so fused that the joints could not be clearly distinguished. It was possible to trace the main outlines of the base plan of the furnace by excavation; that portion of the base definitely fixed by the existence of the facing stones is shown with full lines in the plan of Fig 2, whereas that which is more conjectural because of the absence of facing stones is shown dotted. The structure is revealed as that of the normal furnace, square on the exterior, with a tuyere arch and a tapping hole arch. Whether in fact they were arched or were supported by cast iron lintels cannot be determined, as on this side of the furnace nothing exists above the height of the base of the tuyere. The furnace outer structure was faced with large well dressed sandstone blocks, varying in length from about 20 to 30 inches, usually about 10 inches high and 10 to 12 inches thick. Blocks of this size were used to form the facing of the dam which was erected in 1700 and it would seem highly probable that the furnace was finally demolished at that time and the materials used in the construction of the dam.

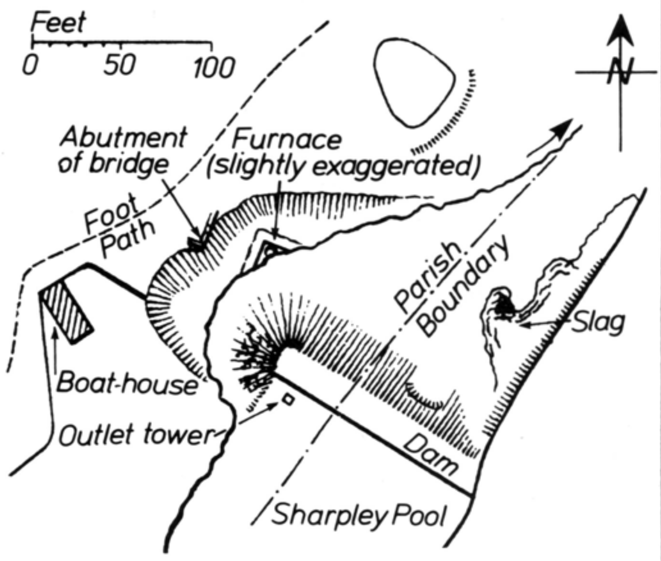


Fig 1
Sketch map of Sharpley Pool dam (Cantrill and Wight)

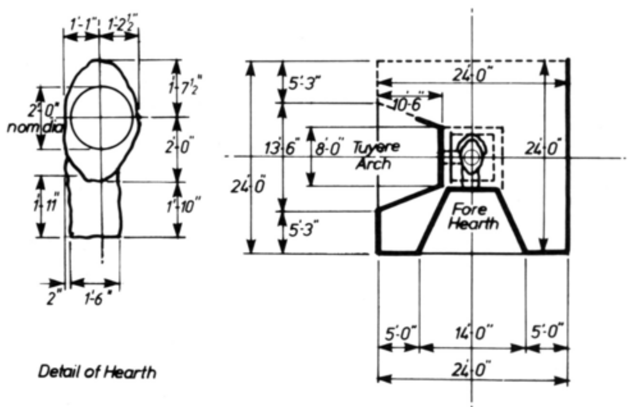


Fig 2 Plan of furnace remains

It will be noted that the furnace hearth, although probably originally circular, had worn into a markedly elliptical form along the axis of the tapping hole. The lining of the furnace consisted of a whitish sandstone approximately 15 inches thickness, the space between the lining and the square support structure being partly filled with a yellow sand. It was noteworthy that the present centre of the furnace did not coincide with the centre of the interior square but was displaced by about 1 ft so that at a height of six feet above the tuyere, the exterior of the lining was firmly in contact with the square support structure on the face away from the pool. It is just possible that the force of the escaping water may have been responsible for part of this displacement and it was conjectural whether the water may also have washed away the remaining upper portion of the furnace above the tuyere and tap hole. Certainly large mounds of earth were washed from the dam across what would have been the casting floor opposite the tap hole..

The average bosh angle was determined as 80^o, in close agreement with values noted on two other nearly contemporary furnaces[5 6]

The plan of the pier supporting the upper structure between the tuyere and the tap hole seems rather slender in comparison with the rest of the structure but the same feature has been noticed in excavations on a contemporary furnace at Melbourne, Derbyshire[7]. The area adjoining the tuyere, on which the bellows would have been situated, was well paved with large flat stones. No indications have been found of remains of the bellows or any of the blowing equipment, though this portion of the site has not been fully cleared of the large amount of residual mud on account of the difficulty with continuous seepage of water. As the leat for driving the water wheel would have been kept away from the tap hole and casting area, the conclusion appears inescapable that the leat would have run between the furnace and the side of the valley ie passing around the north west corner of the structure and under the charging bridge.

The bridge was probably of wooden construction. Its abutment over a width of some 30 ft and of a height of approximately 7 ft is shown at point A on Fig 1, though the short portion at right angles has crumbled away since 1924. The height of the top of this abutment is between 20 and 25 ft above the base of the furnace, pointing to a similar furnace height. A natural terrace along the side of the valley is indicated by the footpath marked in Fig 1 and is the obvious means of access for raw materials..

From an examination of Ordnance Survey maps of early in the present century, the 1700 dam probably covered and concealed the site of the furnace, which may have appeared as a slight knoll adjoining the dam. The original furnace dam would probably have been on the same site as the 1700 dam but need not have been nearly as large as the latter which retained a depth of at least 20 ft of water.

Raw Materials and Products

Many samples of the black bloomery slag used in the charge and of charcoal were found around the site, particularly in the area noted by Cantrill and Wight[3] south west of the bridge abutment, where these two materials had obviously been stored. No traces were found of iron ore or of limestone, though this should certainly not be regarded as proof that they were not used, because the overgrown state of the site hindered detailed searching.

The bloomery slag was typical in appearance, being porous, dark and heavy. Its analysis is shown in the first column of Table I. It differs slightly from that reported by Tylecote[6] at the Coed Ithel furnace in that the present samples were lower in iron and higher in silica and notably in lime, magnesia and phosphorus.

	Bloomery slag Charged	Grey-green slags produced Sample 1	Sample 2
	%	%	%
SiO_2	31.5	49.3	57.0
Al_2O_3	5.76	11.4	9.7
Fe_2O_3	35.7	nil	-
FeO	24.4	2.7	2.87
CaO	1.8	22.8	17.2
MgO	1.1	12.0	8.8
P_2O_5	0.03	trace	nil
S	trace	trace	0.05
MnO	trace	0.84	0.48
K_2O	-	-	2.00

Table I — Analyses of Slags

Samples were taken of the sandstone of which the hearth lining was constructed. This was whitish in fracture and was identified geologically as coming from the Gornal area of the Black Country. Analysis revealed:

Al_2O_3	1.55%
CaO	1.20%
MgO	Trace
Fe_2O_3	2.16%
SiO_2	Remainder

This relatively pure form of silica would have been amply refractory for the operation of the furnace.

The slag produced by the furnace ranged in colour from a relatively grey stony slag tinged with blue, to more green and glassy slags. An analysis of the former type is shown in the second column of Table I and of the glassy slag in column three of the same table. The latter sample was part of a small pile of slag adhering to the wall to the left of the working area in front of the tap hole, as viewed from the outside and was in the natural position for dumping it, if scooped by a right handed workman off the iron just inside the dam. Both slags are notable for their considerable content of lime and magnesia and the relatively low content of iron. The lime and magnesia were obviously present in sufficient quantities to displace the iron from the bloomery slag charged. The considerable proportion of magnesia is interesting and compares with similar contents noted by Tylecote[6] at Coed Ithel and also with another sample from Rockley[8], both these cases being from contemporary furnaces, which however operated until well into the 18th century.

Attention may also be drawn to the 2% of potash noted in the second slag. This has not previously been reported in charcoal blast furnace slags but may well be a typical feature arising from the wood ash. Such a quantity could easily influence the fluidity of the slag.

Several samples of the pig iron were discovered. The largest sample, some 2 ft long, was probably from the bottom of a pig mould that had been filled only partially. This and a shorter piece were found below the bridge abutment. Some smaller pieces were found in the tap hole of the blast furnace where they had solidified in a slight unevenness at the bottom of the tap hole and were obviously a remnant of the last tap. The latter sample was analysed with the following results:

T.C.	3.90%
Si	0.49%
Mn	0.05%
S	0.068%
P	0.31%

This analysis is typical of charcoal blast furnace operation; the phosphorus must have come from the addition of iron ore.

Discussion

Yarranton's blast furnace is similar to other contemporary furnaces in plan, size and the relatively steep angle of 80^{o} in the lower part of the bosh.

Although no iron ore was found, the evidence suggests that Yarranton's description of his charge was correct, though it remains a mystery why he should have discovered large deposits of bloomery slag near Worcester. Possibly they were dumped during the preceding century, using Worcester as a distribution point for river bound traffic.

The most important feature is the evidence of the slags. This shows that there must have been deliberate additions of limestone, unless the iron ore was excessively high in lime. It seems established with some certainty that at this closely defined point in the middle of the 17th century, sufficient lime and magnesia were present in the charge to displace the iron from the bloomery slag, which was therefore no longer required merely as a flux and may have formed the major part of the charge. The simultaneous presence of considerable quantities of magnesia indicates that the 'limestone' was of a dolomitic type.

Acknowledgements

The warmest thanks of the authors are due to Mr Spencer Comley, the owner of the site. Not only did he give the most ready permission to carry out the excavations but he took the closest interest, provided a great deal of labour, and worked enthusiastically himself. Grateful thanks are also due to the British Cast Iron Research Association for carrying out analyses and microscopical examinations and to members of the staff of the Wolverhampton and Staffordshire College of Technology for help and advice.

References

1 A Yarranton: England's Improvement by Sea and Land, Part I, London, 1677.

2 A Yarranton: op cit. Part II, 1861.

3 T C Cantrill and M Wight: Trans Worcestershire Archaeological Society (New Series), Vol VI, 92, 1929.

4 H R Schubert: History of the British Iron and Steel Industry, London, p 205 ,1957.

5 G R Morton: Historical Metallurgy Group Bulletin, No 2 ,1963.

6 R F Tylecote: J I S I, to be published.

7 W H Bailey: private communication.

8 Historical Metallurgy Group Bulletin, No 3, 1964.

Charlcot Furnace 1733 – 1779

Norman Mutton, ACIS

Introduction

Hidden and unsuspected in the valley of the Cleobury Brook on the edge of Brown Clee lie the remains of the charcoal blast furnace at Cinder Hill, Charlcot, which is in the parish of Aston Botterel, but is not far from Neenton and Cleobury North and is near the well-known Wrickton Mill. Less than a mile away runs the Rea Brook which, lower in its course, provided power for Prescott and Hardwick forges and further south still for the Upper and Lower Forges at Cleobury Mortimer. Within a few miles in beautiful Shropshire countryside is the nucleus of an ironworking complex which flourished in the eighteenth century, although its roots may well go back to the seventeenth and its final phase forward into the nineteenth centuries.

The furnace was one of three, Bouldon, Bringewood and Charlcot, which were linked intimately to the carboniferous deposits of the Clee Hills. The ironstones of the Clee, of which Andrew Yarranton spoke highly[1] were found in association with both coal and limestone and provided the main supplies (other than charcoal) for the furnace. The charcoal came from a wide radius in the well-wooded countryside, mainly between the Clee and the Severn.

The fully detailed industrial archaeology of the site is still being undertaken and will be published separately but a roughly comparable site is that at Duddon Bridge, Lancashire[2]. At present the site, in a typical valley setting (see map, Fig 1) consists of a fairly well preserved, stone built furnace approximately twenty feet square and twenty-one feet high with a well-defined high-line and the foundations of an ore house or coal-house to the north of the furnace. Although the hearth has gone the interior of the furnace is in good condition. Huge tree-grown mounds of characteristic charcoal blast furnace slag, grey-black or bottle-green and glassy, surround the site (which covers in all about five acres clearly marked from the farmlands) and have given to the farm its modern name of Cinder Hill. A feature of note is that the site is within two hundred yards of that of a paper-mill which operated contemporaneously (it was built on the site of a former corn mill C.1725 and was still in use in 1816) and which indeed shared the same leat for water, with a proviso that the furnace was to take precedence 'whenever it blows'[3].

It is fortunate that material exists for a detailed economic history of the furnace for much of its known active life and this is here essayed.

The contribution which follows is based upon original work on manuscript sources with reference to relevant printed sources as indicated. The main source of detailed information has been the series of manuscript accounts in the Knight papers in Kidderminster Public Library. These manuscripts are numbered 244 to 268 inclusive and cover without intermission the period from Midsummer 1733 to Ladyday 1779. Indeed ,the years 1770/71 to 1778/79 are duplicated with slight differences, in manuscripts 274 to 282 inclusive. Schubert[4] refers to them only as manuscripts 244 and 245 while Johnson[5] refers to the period only as 1733-42. The accounts, which were prepared to show the partners the financial results of each year's activities and, in the earlier years at least, were seen and signed as accepted by them, run from Ladyday of one year to Ladyday of the next year except for the first account of all which, as a consequence of the retirement from active management of Richard Knight and the taking over of the works by his sons Edward and Ralph Knight, runs from Midsummer 1733 to Ladyday 1735. Such an unbroken sequence of some forty-five years is exceptional.

Both Lewis[6] and Johnson[5] have already made use of these accounts. Johnson only incidentally. Lewis has however traced the main details of the financial and organisational structure of the Charlcot and Bringewood Partnership which during the period covered by the accounts controlled the furnace, forge, rolling mill and tinplate works at Bringewood, on the Teme, near Ludlow, the furnace at Charlcot, and extensive coal, ironstone and limestone mining or quarrying activities and brickmaking on the Clee Hills. It can be seen that Charlcot was not the most important part of the partnership's interests, but nevertheless the accounts are adequate to allow an appraisal of the forty-five years of activity under the same family's ownership and control to be made. It is hoped that a similar analysis of the accounts of the Bringewood complex may be possible, but this will be a much bigger task .

In discussing the economic history of Charlcot furnace as shown in the accounts a number of qualifications must be understood. The accounts are, of course, drawn up in a way different from that used by modern accountants and so profit and loss figures are not directly comparable with those which would have been produced from the same data by a modern accountant. In particular the charging of all capital expenditure to revenue as soon as incurred and the consequent lack of spread-over depreciation means that violent fluctuations in apparent profitability occur. For example, in 1747/48 the charge of £215. 10s. 9d. for 'Building the House' (presumably the present farm house, formerly known as Lower Charlcot and now as Cinder Hill) was included in the furnace running costs. For clarity all amounts are shown in modern form eg £0005 01s 06½d. is shown as £5 1s 6½d. As the accounts are summaries (although with some detailed information, especially about wood-cutting) and no supporting subsidiary books or vouchers are known to exist the detail is less than is often to be found in other accounts of this type and period[7]. The 'common charges' of Bringewood and Charlcot were often paid by a partner or a clerk and then the total was arbitrarily divided between the two accounts. Consequently even though some items are specified it is not possible to produce detailed accounts of common charges. However the accounts specifically refer throughout to limestone 'chippings', a detail of metallurgical importance.

For the periods before 1733 and after 1779 no accounts are known and information is much more scanty. For this reason it has seemed preferable to deal in detail with the accounts, the furnace operation and the profitability of the furnace between 1733 and 1779 first, then to mention briefly the period after 1779. The final part of the paper deals, also briefly, with the period before 1733, and the as yet unanswered questions of when and by whom the furnace was built.

The Accounts 1733 – 1779

The main features of, or to be calculated from, the accounts are to be found tabulated in Appendix I. The notes appended thereto help to make clear the limitations which must be understood when studying these accounts. A more general description follows.

The object of the whole organisation of the Charlcot furnace was, of course, to make pig iron. Selling was not a major problem as most of the output found a ready outlet through the various partnerships. Most of the pig iron was run as sows and pigs in sand moulds but small quantities were also cast as plates and for other uses especially as forge and mill castings for Bringewood. The annual output figures are listed for the whole period and have also been depicted graphically in Appendices I and II. The iron was of two grades, best and ordinary, and was disposed of mainly through the Partnerships ie to Bringewood or to the noted Foley Partnerships which were financially linked to the Bringewood and Charlcot Partnership. By its nature, pig iron production was unlikely to give very consistent outputs year by year but the quoted output of 400 tons per annum (equal to about 30 cwt per day over an average campaign of 40 weeks) in the 1717 list is indeed a fair average figure.

At the end of each campaign when the furnace was blown-out the hearth would have to be demolished and rebuilt and year by year throughout the early period of the accounts there are standard entries in the accounts of £1 1s. for bottoming (ie clearing away the old hearth and its solid contents) and £4 for getting a hearth with or without specific carriage charges. In 1750/51 when the furnace was extensively repaired and as a consequence no campaign took place, the new hearth, still unused, was carried forward to 1751/52 as cost. The source of the hearth stone is not stated ('though petrological examination, which has not been performed, might assist), but is almost certainly the Clee unless the well known hearth sandstones of Alveley, Highley or Stanley (all near to Hampton Loade to which pig iron was sometimes transported) were used.

The stocks of iron held at the year end were kept at a number of places: (1) the furnace; (2) Bridgnorth where at some time in the 1730s or just after a new wharf owned by William Oakes superseded, though not entirely, that used at Hampton Loade; (3) Round Thorn (presumably on the Bridgnorth-Ludlow road in the parish of Bitterley about three miles from Ludlow — whether it was a forge is not clear); (4) the Bewdley Storehouse, the main iron warehouse of the Midlands for a century; (5) Stourmouth, or Mitton (Stourport) where the Stour Partnership had two forges and (6) some places which are mentioned only occasionally and where the precise relationship of the place and its ownership or management to that of Charlcot is not clear eg Bouldon, Cleobury. Most intriguing perhaps is the entry '20 tons lent to Mr Crump' Ladyday 1743. Once stock is stated to be 'on the road' at the year end, the common entry of 'x tons lost in waste, etc.' when accounting for the total output is symptomatic of the general difficulty of breaking bulk, though some of this waste may have been recovered as scrap for re-use but this is not certain (see below on waste and scrap iron).

The three main raw materials for the furnace were charcoal, ironstone, and limestone chippings. The accounts for these ingredients are in some detail. In addition cinders were used from time to time as was waste and scrap-iron.

Charcoal, the most expensive of the raw materials, was obtained from a wide radius and during the period of the accounts almost every parish for miles around (and many a landowner's name) is mentioned. Gregory's account of 'underwood fallen at 18 to 21 years growth for converting into charcoal' would have been applicable to the period of Charlcot's activity[8].

Payment for cutting and cording was done on a piecework basis with cash advances to the men who were in consequence often committed to continued work to repay advances which had been greater than the wages earned. The average annual prices of charcoal per dozen sacks as bought in are shown in detail in Appendix III. A graph of average bought-in prices shows both the spectacular increase in price in 1755/56[9] and the relatively high prices thereafter, which were 'several shillings above the price at other works', and which must have been an important reason for the decline in the use made of the furnace in the second half of the century. Average carriage charges included in these prices were 5s to 6s per dozen.

There is no evidence at all that Charlcot ever used coal or coke for smelting and the only entries for 'pitcoal' relate to payments of a few shillings for coal for employees' domestic hearths. Nor, incidentally, is there any mention of the use of Knight's patent blowing apparatus (Patent No 783 of 1762) rather than bellows.

The usage of charcoal varied within reasonable limits after making allowance for the difficulties of estimating year end stocks and for the different qualities of coals, their water content, etc at around 1¾ dozen per ton of pig produced. The average cost of charcoal for each ton of pig iron made shows a rise from approximately £2. 10s – £3 in the period up to 1754/55 to about £4 after that date. As pig iron prices averaged about £6. 10s and £8 respectively in these two periods the cost of charcoal was fairly consistently about 50% of the selling price.

Small purchases of timber for building repair occur but are obvious and cannot be confused with the cutting and cording of wood for coaling.

Ironstone, at about 16s per dozen strikes (bushels) was cheaper but was used in greater quantity than charcoal. Average consumption at about 2¼ dozen per ton of pig iron produced seems not unlike that obtained elsewhere and gives an approximate cost of £1 16s per ton of pig iron. The source of supply was the Clee and again the miners, working in primitive bell pits or simple adits, were paid piecework rates. A royalty of 2s per dozen of ironstone was paid to the appropriate landowners (as well as a rental of £120 per annum to Lord Craven).

The accounts occasionally differentiate between ironstones, eg 1735/36 'Best @ 16s. 6d.; 'Mr Cresset's' @ 15s. 6d.

A further differentiation occurs in 1736/37 when the stock remaining is shown as 'redshort' ironstone, 325 dozen @ 15s.6d. As redshort ironstone is of a high sulphur content and produces 'hotshort' iron only limited quantities could have been used in each charge, cf. Vale Royal, Cheshire, in

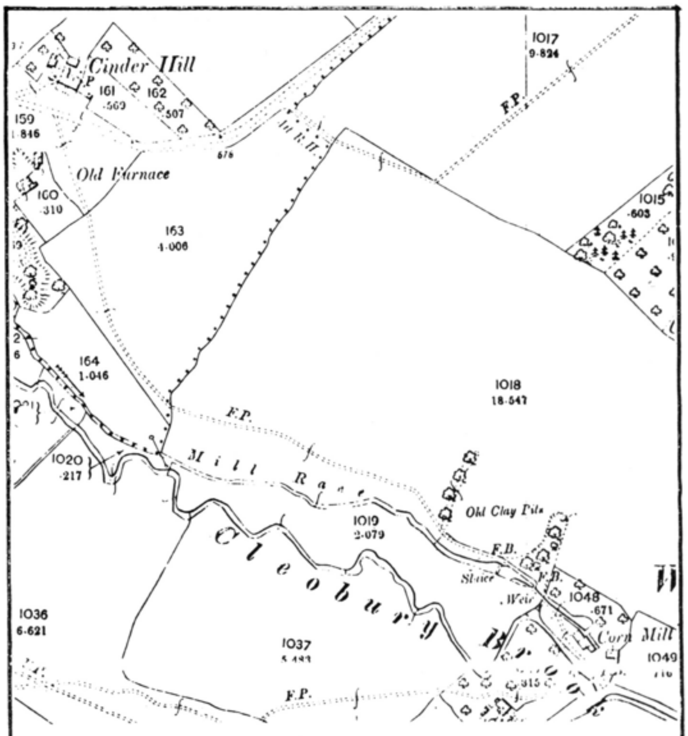


Fig 1 Site of Charlcot Blast Furnace

1701/02 when 'a considerable number of dozens of Flint ironstone got, and when the same came to be made trial of at the furnace it proved redshort and not fit for use so that the greatest part of the said stone was thrown away'[10]. It is of course possible that this ironstone is none other than 'Mr Cresset's' of 1735/36 and that a degree of redshortness was accepted by the ironmasters.

Small amounts paid for waste and scrap iron can not be equated with quantities. The charges may be merely those made to employees who recovered scrap from the stock piles or from washed slag or cinder or they may, though less probably, indicate payment for quantities of scrap bought in from local forges or other sources.

More important than scrap, although a very variable item, was the consumption of cinders. The so-called 'Roman cinders' of the Forest of Dean and other areas, actually the remains of iron-making by the direct or bloomery process, had long provided a source of readily-converted iron of great value to furnace-masters. The availability of cinder from previous iron workings in the vicinity of Charlcot seems unlikely to have been influential in determining the location of the furnace, although Lewis does make reference to a supposed usage of cinders from an 'old furnace or bloomery . . . at Ned's Garden at the bottom of Common Heath by the Southall Bank'[11]. The later ironmasters of the sixteenth to nineteenth centuries used cinders from the forges in which pig iron was remade into blooms and bars, for in this process about 28 cwt of pig was needed to produce a ton of bar, and as the other 8 cwt of cinder was by no means all dross its use in the blast furnace with ore both reduced the quantity of ore needed and in some cases enabled a better quality of pig to be made. The cinder from Mitton in 1738/39 was, presumably, in part at least and probably mainly that produced by the working up of Forest 'tough' pig and so would act to modify the normal coldshortness of the Clee iron and produce a better pig. It is noteworthy that 1738/39 is the first year that the accounts differentiate in the year-end stocks between two kinds of pig – ordinary and best – and it seems probable that the use of cinders was in fact confined to certain 'melts' which consequently produced 'best' pig during the campaign. However as no detail is available the average consumption of cinders has been shown.

Considerable trouble, even including making a new 'crib', was occasioned in getting the cinders from Mitton. There was no charge for the cinders as supplied by the forge, but carriage etc. made the cinders almost as expensive as ironstone although the available iron content was greater. The spasmodic supply is most noticeable.

There is no mention in the accounts of cinder from the reputedly allied forges at Prescott, Hardwick and Cleobury. For much of the period Bringewood Furnace could use all the cinder from Bringewood Forge, and so although much of the pig iron from Charlcot went to Bringewood for subsequent manufacture it seems that no cinder was returned. The accounts do not show what the carriers brought back, but it is unlikely that the cricking horses returned unladen from Bringewood. More information on this would be useful to enlarge our knowledge of the inter-relationships of eighteenth century trade. The cricking horses were often supplied by the Haycox family (the lessees of the farm who, incidentally, received an annual payment of £5 for 'trespass', presumably the equivalent of a modern way leave payment, and who acted also as general carriers and agents for the Knights) and sometimes by other farmers.

The other main raw material was limestone, used as a fluxing material. This, again from the Clee, was always in the form of chippings and every year the accounts show the charges for the chippings and carriage. Small amounts, from time to time, for 'lime' were presumably for building repairs. Consumption of chippings at about 4 strikes per ton of pig produced, so far as can be calculated, was equal to a proportion of about 1:7 limestone to ironstone by volume.

When the profit and loss accounts are studied they reveal that sales to Bringewood and to the Stour Partnership (Worcestershire Partnership) took by far and away the bulk of the output and in some years the whole of it. As the Knights had strong links with the Stour Partnership their debts were cleared each year by a mere bookkeeping entry, one of many affecting the two partnerships. However (except for negligible retail sales) the rest of the sales were effected on long-term credit extending occasionally even to four or five years. In some cases long-standing debts had to be written off when they proved to be bad. This was not a regular accounting activity, nor was the bad debt treated as a deduction in the profit and loss account but was debited direct to the partners' capital accounts. To that extent the bad debts inflate profit figures or reduce losses, by an average figure of perhaps £20 per annum (which is not of great consequence in view of the total sums involved) and also temporarily overstate the partners' capitals but without in fact affecting the ultimate accuracy of the partners' computed capitals. In 1763/64 bad debts of £575. 9s. 10¾d. offset by 'old credits' of £18. 0s. 8d. which give a net figure of £557. 9s. 2¾d. were written off to the partners, or more accurately, to Edward Knight and to Ralph Knight's widow as to £537. 5s. 1d. and £20. 4s. 1¾d. respectively. (In 1754 Ralph had died and Edward carried on the business alone, paying Ralph's widow the value of her husband's holding less bad debts and his cash in hand).

The sales figures shown and the customers named in Appendix VI are those detailed in the accounts and whilst there is no difficulty in placing some of the buyers the locations of others are unknown to the present writer.

A point of interest in regard to the sales to Bringewood is that they are based upon prices 'ex works '(though the expression is not used in the accounts) as may be seen from the accounts for 1751/52. The 'ex works 'price in that year was obviously £6. 3s. per ton and the carriage charges, if any, incurred by Charlcot were then added to give the 'invoice prices' of £6. 13s., £6. 12s and £6. 8s. 13 tons at £6. 3s. were collected by Bringewood and the charges borne directly on the accounts of that part of the partnership's activities.

Castings were usually, but not necessarily, 2s. 6d. per ton more than pigs, and the furnaceman and founder were paid 2s 6d. per ton more for making castings than for pigs. In just two years there is a note of reverse trade with Bringewood castings coming to Charlcot.

The total sums shown in the accounts for costs normally include: (1) the main raw material costs adjusted by normal accounting methods to bring in the value of stocks brought forward and to exclude the value of stocks on hand at the year end; (2) common charges and sundry expenses, eg salaries of clerk ,foundryman's wages, sand, repairs etc.; (3) 'rent' of £40 p.a. less £26 payable by Mr King for the rent of the paper mill *; (4) carriage, freight and wharfage charges; (5) interest charges at 5% p.a. on the money lent to the partnership; (6) 'utensils' (for many years, but not always £70) both brought forward and carried forward; and (7) sundry items, sometimes substantial, of an extraordinary nature, eg major repairs.

The furnaceman was paid 2s.1d. per ton until 1755/6 when 1d. increase was paid (plus 7s. paid as retrospective payment for the 84 tons output in 1754/55) and the founder received 5d. per ton. No lists of furnacemen or founders or other workers are known but presumably the furnace was operated by about six men who occupied cottages and received fuel as well as piecework payments as remuneration. The figures for profit or loss (also shown graphically in Appendix I) are simply obtained by subtracting costs from sales except for one year, 1767/68 ,when there was no output and stock on hand had to be sold for less than its brought forward value so giving a net loss to which the costs were added to give a gross loss. After 1776 the accounts had been compiled with a realisation that although future production was possible it would not necessarily be within the next year and so suspense accounts have been used. In the summary, Appendix I, both the figures as shown in the accounts and those figures recalculated on the same basis as up to 1776 are shown.

The whole period from 1733 to 1779 falls into two main sub-periods. The year 1750/51 has been chosen as representing the end of the first period.

* It is not clear whether this 'rent' is merely a notional charge or whether in fact payment was made to the freeholder, ie Richard Knight or his heirs who were not themselves partners in the ironworks.

A 1733 to 1751

This period was characterised by relatively continuous ** output and by profitability. Only in one year, 1747/48, was a loss made, and almost half of that was accounted for by the charging of the building of a new house to the costs of the furnace (see p44 above).

Charcoal and other prices were low, see Appendix II, and the business appears to have been working in reasonable economic conditions.

The crisis of 1737 leaves no signs in the accounts and appears to have passed unnoticed. The main product was coldshort pig iron which was sent to Bringewood and to the Stour Partnership at Stourmouth and Bewdley through Bridgnorth. Odd local retail sales amounting to only a few hundredweight per annum were also made, and some larger amounts from time to time to other customers (Appendix VI). There is one interesting entry in 1736/37 when there are carriage charges of 10s. for one ton of 'plates to Bringewood', as well as 217 tons of pigs, and as 'cast plates were needed for the floors of furnaces, finery forges and slitting mills and for the hearths of chafery forges', the plates were presumably needed before Bringewood Furnace (which was blown out) could restart. Castings (as opposed to pigs) are mentioned from time to time, eg 1746/47 when the accounts show that production was 689 tons of pig plus 2 tons 10 cwt of castings. Other than the reference to Plates there is no specific indication of what types of castings were produced, merely whether for forge or Mill if they were sent to Bringewood.

In this period is to be found a most interesting point revealed by the accounts. The year 1745/46 was characterised by a very low output of 33 tons after another low output, 46 tons, the previous year. The wages of foundrymen and caster agree with these figures. For the earlier year 1744/45 the usages of charcoal etc. are reasonable for the output, but for 1745/46 there are shown in the accounts quantities which bear no relation to the output figure (see Appendix I). These figures have been carefully checked, the brought forward and carry forward figures compared for the three years 1744/45, 1745/46 and 1746/47, both by the writer and independently, For some, so far inexplicable, reason, the accounts, as agreed by the partners, were incorrect. More work on these accounts in connection with the detailed activities of the Bringewood complex may provide clues to the mystery.

Towards the end of this period major repairs, much more extensive than routine maintenance and the rebuilding of the hearth after each campaign, were becoming necessary. In 1743/44 the cost of 'Repairing the Coalhouse' was almost £70 (£69. 11s. 9d.). That year shows also, incidentally, a specific item about the bellows. While many of the sums regularly spent on nails may be assumed to be for renailing the bellows, and small sums received for 'old leather' to refer also to scrap from the bellows, specific mention is rare so that the item in question 'Wm Taylor, dressing Charlcot bellows £1. 10s., mending them 5s.' is of interest.

In 1749/50, as well as the usual payment for a hearth there was an item 'Inner wall and carriage £20. 15s.' again indicating that repair was becoming essential and this was followed by a complete shut down during 1750/51 when repair to a total of £190. 3s. 11½d. were carried out. During this shut down, out of 476 tons of pig iron in stock at the end of the previous year a total of 195 tons was sold and '1 ton, Wm Oakes, as lost' was charged against the wharfinger. There were 12 tons (at £5. 18s. per ton and so worth altogether £70. 16s.) of the 476 tons held in stock at Bouldon. Earlier, in 1743/44, 20 tons of pig had been sent to Bouldon but had been charged to Bringewood, but these references to Bouldon with one other (charcoal brays in stock at Bouldon in 1736/37) do not help to elucidate the relationship between the two furnaces at that time.

At Ladyday 1751 Edward and Ralph Knight's shares in the Bringewood and Charlcot partnership were worth the not inconsiderable sums of almost £9,750 each.

B 1751 – 1779

This period was characterised by relatively discontinuous output, see Appendix I, and by heavy and frequent operating losses, usually but not always offset by other and still profitable activities of the partnership. Production took place in only seventeen of the twenty-nine years. After a period of continuous and high production for about ten years following the major repairs of 1750/51 the furnace was used less and less. Sales were increasingly confined to the Stour Partnership and Bringewood and in fact the only customers of any size were Messrs Dorsett and Tere Caswell. It is interesting to note that the Dale Co. took one ton of pigs in the year 1770/71.

The reasons for the decline in output and profitability during this period may be deduced. The abnormally high cost of charcoal 'several shillings per cord above the price at others works' [13] coupled with the relative isolation of Charlcot and the increased competition from coke pig led to the works becoming uneconomic. Even though the apparently uneconomic Knight furnaces were kept in blast because the type of pig they produced was desired for blending and mixing at forges owned by the partnership, as was also done by the Foleys [14], a time came when only complete rebuilding would have sufficed to make the furnace efficient and both the general economic climate and the technical progress in the production of iron were against this being profitable in the later eighteenth century, at least until the French wars brought increased demand.

The Furnace after 1779

Until about 1792 the Knights continued to own the furnace. They then sold their land at Charlcot in lots and the furnace was bought before Ladyday 1792 by Thomas Mytton of Shipton Hall in Corvedale, Salop [17]. That the furnace and its surrounding five acres were advertised [18] and sold separately and as one unit, may imply that the furnace was in blast or deemed to be capable of being put into blast again.

It has been suggested that the furnace was in use during the Napoleonic Wars, until 1815 saw 'The Waterloo of the charcoal iron industry' but the author has no definite evidence whatever for Charlcot for this period after the sale to Thomas Mytton. He would be grateful for any information or assistance.

The Furnace before 1733

Belatedly, as it seems, comes a discussion of the origins of the furnace at Charlcot.

The primary reason for the general location of the furnace must be regarded as the proximity of the Carboniferous ironstones of the Clees. Adequate water power even in the driest of

---

** 'Continous' only in the sense that there was an annual campaign and not that there was no intermission in production. As no details are given in the accounts there is no way of knowing the actual lengths of the campaigns nor of the actual outputs per day or week.

summers (the Cleobury Brook flowed steadily in the exceptional summers of 1947 and 1959) and plenty of available woodland within an acceptable radius no doubt helped to fix the location more precisely.

The bulk of this paper has dealt with the well documented period from 1733. The period before that is more scantily documented. Perhaps it would not be amiss to see how Schubert [19] sums up the little he had found. 'Worked by the Childes of Kinlet in the 17th century and later, probably from 1670 to 1730. Furnace finally shut down in 1777'. The information about the Childes is taken from VCH Salop[20] and appears to be unfounded.

In John Fuller's list of 1717 as reproduced by Hulme [21] Charlcot is shown, and is shown as having an output of 400 tons per annum which was quite large for the early 18th century, and which with Bouldon 400 tons and Bringewood 450 tons, gave a combined total for the area of the Clee Hills far greater than the combined demands for the manufacture of bar iron by the local forges, Bringewood 340 tons, Cleobury 180 tons and Prescott 120 tons. The excess output went to the Birmingham Plateau through Bewdley and Stourport and to Central Shropshire and Montgomeryshire.

Now when, and by whom, was the furnace first constructed? Unfortunately there is no definite answer but the writer offers the following evidence.

The abstract of title to the manor [22] from 1620 to C1750 shows that in 1620 the owner was Sir Francis Lacon who conveyed the property to James Grove. It descended in the Grove family until in 1678 it was conveyed to Dame Mary Yate. On 25th February, 1712 it was conveyed by Apollonia Yate to Richard Knight, Iron-master of Bringewood. In the title two corn mills are continuously mentioned until 1712 when the furnace is first mentioned; the paper-mill of 1725 was a conversion of a corn mill, presumably the second corn mill, the other having been converted to a blowing unit for the furnace.

While owned by the Groves the property had been mortgaged to Philip Foley of Prestwood for £430 on 14th August, 1674 but he assigned it almost immediately, 31st October, 1674.

Were the original ownership by the Lacons, and the mortgage by Foley merely fortuitous? Did Knight build under a beneficial lease immediately before acquiring the freehold? Did he acquire a working seventeenth century furnace?

If the furnace were built in the seventeenth century one would expect that it would have figured in the title deeds, although that it did not is not entirely conclusive. Nor is the fact that Johnson found no mention of Charlcot when going through a series of some forty ironworks accounts for the period 1690-1720, including those of the Bewdley Storehouse from 1690-1717 conclusive evidence that the furnace did not exist before 1712, though it may be a pointer.

It seems that the possibility of a seventeenth century furnace can not be altogether ruled out but in the opinion of the present writer this seems a little unlikely. Until more definite information becomes available, the question must be regarded as still open.

Even if both the birth and the death of Charlcot are relatively obscure, its active youth and the declining powers of its later years are well documented. In the mind's eye it is possible to see in the quiet valley of the Cleobury Brook the billowing smoke, the laden cricking horses, and the fiery flow of the tapping and to imagine the heat, and the effort which are the reality behind the seemingly endless, crabbed figures written by the quills of successive clerks, some two hundred years ago.

Acknowledgements

The writer wishes to acknowledge the help he has received from L W Horsfall, Esq. FLA, the Librarian of Kidderminster Public Library, and his staff. He is grateful to the University of Birmingham for permission to use and quote from the theses named and to numerous members of the University for their interest. Finally he has to thank Mr G Mellings, the farmer at Cinder Hill, who has allowed unrestricted access to the site.

References

1 W H B Court: 'The Rise of the Midland Industries', 81, 1938.

2 G R Morton: 'The Furnace at Duddon Bridge', JISI, Vol 200, 444, June 1962.

3 SRO 757/uncat. lease 24th December, 1725, Richard Knight to William King of Ludford.

4 H R Schubert: 'History of the British Iron and Steel Industry', 353, 1957, London.

5 BLC Johnson: 'The Charcoal Iron Trade in the Midlands, 1690-1720', Thesis, University of Birmingham, 1950.

6 R A Lewis: 'Two Partnerships of the Knights', Thesis, University of Birmingham, 1949.

7 B L C Johnson: 'The Foley Partnerships', Econ.Hist. Rev., 2nd Ser, Vol IV, No 3, 322-340, 1952.

8 T Gregory: Shropshire Gazetteer, 1824.

9 R A Lewis: op cit.

10 B L C Johnson: op cit, 63-64.

11 R A Lewis: op cit, chap. IV.

12 B L C Johnson: op cit, 37.

13 R A Lewis: op cit, chap. III.

14 B L C Johnson: op cit, 333-334.

15 R A Lewis: op cit, 8.

16 National Library of Wales: Pitchford Hall Docs.

17 Shrops R O: 757/uncat – Release and conveyance to John Haycox, 25th March 1792.

18 Shrewsbury Chronicle: 20th Jan, 1790.

19 H R Schubert: op cit, 370.

20 V C H Salop: vol.1, 472.

21 E W Hulme: 'Statistical History of the Iron Trade, 1717 - 1750', Trans Newcomen Soc, Vol IX, 1928-1929.

22 Shrops R O, 1298/1.

(1) Years	(2) Prod of Pig Iron	(3) Charcoal Total		Per Ton (9)		(4) Ironstone Total		Per Ton (9)		(5) Cinders Total		Per Ton		(4) Chippings Total		Per Ton (9)	
	Tons	Doz.	Sa.	Doz.		Doz.	St.	Doz.	St.	Doz.	St.	Doz.	St.	Doz.	St.	Doz.	St.
1733-1735	495	857	7	1	8	1035	9	2	1					127			3
1735-1736	261	526	6	2	0	589	2	2	3					78	6		4
7	420	861	6	2	1	1011	10	2	5					150	10		3
8	593	1035		1	8	1342	10	2	3					108	4		2
9	504	985		2	0	1281	3	2	5					16	7		½
1740	470	824	4	1	10	1044	6	2	2					105	7		3
1	503	955	2	1	11	1130		2	2					139	4		3
2	430	713	9	1	8	973	11	2	3					111	6		3
3	479	838	9	1	8	1041	5	2	2					142	7		4
4	410	860	6	2	1	1133	3	2	10					158			5
(10) 5	46	75	8	1		92	4	2	0					10	6		2
6	33	925	8	28	1	1075	4	32	6					151		4	7
7	692	1230	2	1	10	1234	11	1	10					157	6		3
8	60	120	6	2	0	124	11	2	1					14	9		3
9	373	657		1	11	688	6	1	10	133	4		5	75	2		2
1750	763	1553	1	2	0	1473	2	1	11	30			1	207			3
1	.Nil	-		-		-			-								
2	696	1286	11	1	10	1476		2	1	51	9		1	163	10		3
3	Nil	-			-	-			-								
4	649	1174	3	1	10	1492	9	2	4					146	10		3
5	84	140	1	1	8	168		2	0					37	1		5
6	636	1027	8	1	7	1535	6	2	6	10			¼	178	3		4
7	500	646	4	1	4	1203	5	2	5					157			4
8	200	367	4	1	10	452	11	2	4					36	2		2
9	550	601		1	1	1219	11	2	2	30			½	190	1		4
1760	284	437	10	1	6	652	2	2	4					145	9		6
1	Nil	-				-		-									
2	410	615		1	6	1021	9	2	6					195	4		6
3	430	777	4	1	10	871	7	2	0	90	8		2½	130	2		4
4	Nil	-		-		-		-									
5	553	1016	11	1	10	1117	6	2	0	169	3		3½	175	7		4
6	471	803	10	1	8	991	3	2	1	60	5		1½	143	3		4
7	440	687	9	1	7	1094	6	2	6	34			1	123	8		4
8	Nil	-		-		-		-									
9	368	689	2	1	11	977	10	2	8	3				130	10		4
1770	Nil	-		-		-		-									
1	393	572	4	1	6	885	1	2	4					72			2
2	Nil	-		-		-		-									
3	428	579	5	1	5	955	9	2	2					72	9		3
4	Nil	-		-		-		-									
1775	Nil	-		-				-									
6	Nil	-		-		-		-									
7	575	946	1	1	7	1240	9	2	2					49	6		1
8	NIl	-		-		-		-									
9	Nil	-	-			-		-									
1776																	
7																	
8																	
9																	

Appendix I – Summary of Production, Consumptions, Profits, etc. (items 1 to 5)

Years	(7) Amount pd. for wash & scrap iron	Financial results as shown in the Accounts (8) Sales	Costs	Profit	Loss
	£ s. . d.	£. s. d.	£ s. d.	£ s . d.	£ s. d.
1733-1735	5. 3. 6	3478. 19. 9	3117. 15. 5¼	361. 4. 3¾	
1735-1736	1. 17. 6	1888. 8. 8	1758. 2. 8¼	130. 5. 11¾	
7		2890. 2. 4½	2666. 8. 9	223. 13. 7½	
8	7. 8. 6	3869. 11. 6	3151. 2. ½	718. 9. 5½	
9	6 10. 9	3380. 14. 10	3025 .10. 9½	355. 4. ½	
1740	7. 8. 6	2936. 12. 4	2693. 15. 1¾	242. 17. 2¼	
1	6. 16. 6	3264. 15. 7	2953. 4. 7¾	311. 10. 11¼	
2	7. 9. 6	2805. 4	2336. 10. 10¾	468. 9. 5¼	
3	7. 7.	2964. 13. 3	2572. 5. 8	392. 7. 7	
4	7. 7.	3279. 6. 4	2837. 15. 8½	441. 10. 7½	
(10) 5		3315. 19. -	2917. 16. 6	398 . 2 . 6	
(10) 6		3627. 1. 9	3191. 10. 8¾	436. -. ¼	
7	10. 10. 9	4408 .11. 6	3602. 16. 3¼	805 .15. 2¾	
8		521. 18. 10	967. 14. 1¾		445. 15. 5¾
9	7. 8. 6	2509. 8. 10	2214. 18. 8½	294. 10. 1½	
1750	10. 3. 3	4758. 15. 5½	4288. 1. 5	470. 14. ½	
1		47. 6. 6	613. 14. 6		566. 8.
2	8. 19. 3	4499. 16. 11	4040. 1. 8	459. 15. 3	
3		119. 15 . 3	406. 4. ½		286. 8. 9½
4	8. 9. 6.	4323. 13. 10	3834. 6. 8¾	489. 7. 1¼	
5	1. 12. 3	828. 9. 10	908. 7. 7¾		79. 17. 9¾
6	9. 15	4932. 19. 6	4641. 9. 3¾	287. 10. 2¼	
7	9. -. 2	3816. 9. 6	3589. 11. 5½	226. 18. -½	
8	14. 1. 3	1649. 15. 3½	1701. 14. 2¾		51. 18. 11¼
9	10. 1.	4141. 1. 2	3850. 11. 1¾	290. 10. -¼	
1760		1909. 4. 11	2192. 8. 8½		283. 3. 9½
1		7. 6.	374. 16. 1		367. 10. 1
2		2719. 16. 10	3192. 16. -¼		472. 19. 2¼
3	2. 1. 7½	3277. 12	3364. 9. 5		86. 17. 5
4		108. 12	464. 2. 1		355. 10. 1
5		4207. 3. 5½	4055. 17. 2½	151. 6. 3.	
6		3566. 15. 2½	3361. 1. 2¾	205. 13. 11¾	
7		3344. 8. 11½	3365. 18. 7¼		21. 9. 7¾
8		60. -. 3	358. 11. -¼	Net loss (11)	418. 11. 3¼
9		2747. 18.	3308. 8 .10¾		560. 10. 10¾
1770		287. 3. 11	357. 16. 8		70. 12. 9
1		2890. 13. 9	3218. 10. 9¼		327. 17. -¼
2		119. 2. 1¼	440. 9. -¾		321. 6. 11½
3		3415. 16. 8¼	3465. 9. 8¾		49. 13. -½
4		20. 18. 6½	159. 10. 5½		138. 11. 11
1775			252. 16. 10		252. 16. 10
6					
7		4866. 13. 7½	4770. 8 . -¼	96. 5. 7¼	
8		138. 18.	138. 18.		
9					
		Last four years' Accounts adjusted to show comparable figures			
1776			3448. 13. 4¼		3448. 13. 4¼
7		4866. 13. 7½	1321. 14. 8	3544. 18. 11½	
8		138 .18. 0	346. -. 8½		207. 2. 8½
9			1505. 11. 11¾		1505 .11. 11¾

Notes

1. Years are from Ladyday to Ladyday except for the first period, Midsummer 1733 to Ladyday 1735.

2. Pig iron normally. Occasionally there were small quantities of castings, eg 1746-47, 2 ton 10 cwt. After 1765 shown as 'Pigs and Castings' except 1768/69. (See also Sales in Appendix VI).

3. Charcoal figures based on net usage after taking opening and closing stocks and purchases into account. Discrepancies no doubt arose through the estimating of year end figures of stock, (many of which are suspiciously round figures).

4. Ironstone and chippings figures for year end stocks not usually shown before 1743/4. Figures shown assume that 'Nil' stock was correct.

5. Cinders. Possible, but unlikely, change in quantity from Dozens and Strikes to Tons and Cwts. after 1762/3. All cinders figures are assumed to be expressed in Dozens and Strikes.

6. As well as 'Chippings', the accounts show small sums paid for lime, presumably for building repairs.

7. Amounts for Wash and Scrap not always to be found in accounts.

8. The headings 'Sales', 'Costs', 'Profit' and 'Loss' are those used in the accounts, although they do not entirely accord with modern accountancy usages. The last four years show amounts carried forward in suspense and these have been re-calculated to show (separately) the results for those years on a basis comparable with the earlier period.

9. Consumptions per ton fluctuate reasonably around levels of about:-

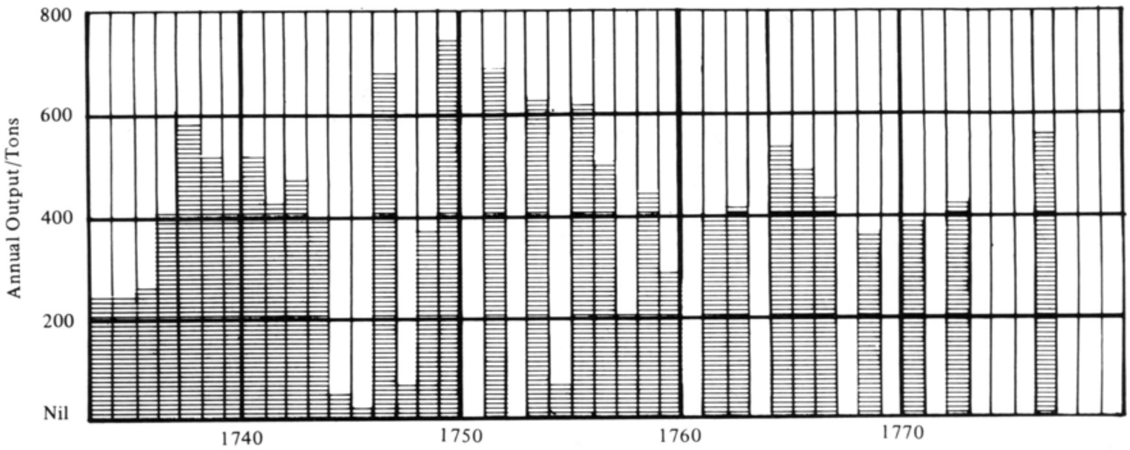
Charcoal	1.7 or 1.8 dozens per ton of pig
Ironstone	2.0 or 2.2 dozens
Chippings	3 or 4 strikes

(But see note 10 for year 1745/46).

10. The year 1745/46 is striking and no reasonable explanation offers itself. The consumption figures are incredible, but a careful rechecking of the accounts shows that all the 'brought forward' and 'carried forward' figures, both quantity and value, for the three consecutive years 1744/45, 1745/46 and 1746/47 are shown consistently in the accounts, which have been signed and accepted by the partners. The output figure of 33 tons, appears to be substantiated by the payments to furnacemen and founder of £4.2s.6d. (ie 33 @ 2s. 6d.) which is payment at the normal rate.

11. 1767/68 shows a net loss before deducting charges through selling for only £2,088. 15s. 3d. stock on hand which had been brought forward at £2,345. 15s. 6d.

Appendix 1 – Summary of Production, Consumptions, Profits, etc. (items 7 and 8)



Charlcot Furnace. Output, 1733-1779

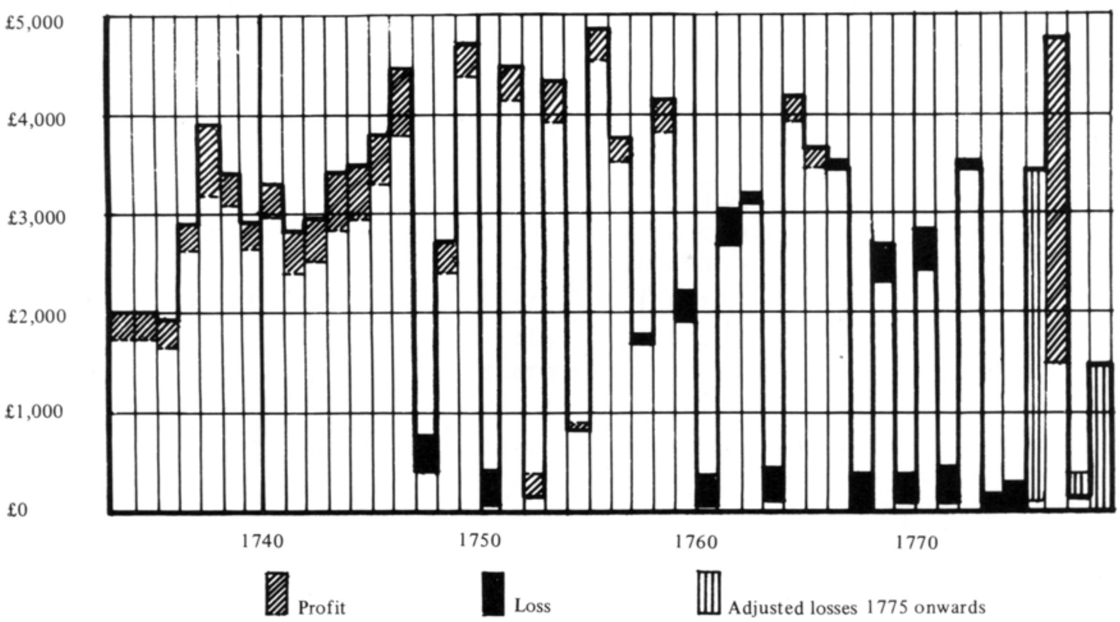
Appendix II

Years from Ladyday to Ladyday (except first period – Midsummer 1733 to Ladyday 1735 – output 495 tons, averaged as c 250T).

Charlcot Furnace, Charcoal Prices 1733 - 1779

Appendix III

Average Prices of Charcoal bought in years from Ladyday to Ladyday (except first period Midsummer 1733 to Ladyday 1735).



Charlcot Furnace. Sales, Costs, Profits, Losses, 1733 - 1779

Appendix IV

Years from Ladyday to Ladyday (except first period Midsummer 1733 to Ladyday 1735 .
Sales and Costs averaged over 1¾ years.

Year	Bought In Doz.	Str.	Cost £ s. d.	Av. Cost £ s. d.	Total Charcoal Cost Charged in Accounts £ s. d.	Charcoal Cost per Ton of Pig Iron £ s. d.
1733-1735	697	7	1071.17. 8	1.10. 9	1368.17. 8½	2.15. 4
1735-1726	476	6	694.18.11	1. 9. 2	794.18.11	3. 0.11
7	1071	6	1485. 3. 9½	1. 7. 9	1176.13. 0½	2.16. 1
8	915	0	1227. 1. 4	1. .6. .9	1397. 8. 0	2. 7. 2
9	1155	0	1644.10. 8	1. 8. 6	1392.10. 8	2.15. 3
1740	1004	4	1441. 8.11½	1. 8. 9	1184.18.11½	2.10. 5
1	840	2	1146. 0. 8	1. 7. 3	1337. 5. 8	2.13. 2
2	898	9	1159. 5. 3	1. 5.10	943.17. 9	2. 3.11
3	608	9	830.16. 4½	1. 7. 3	1107. 0. 2½	2. 6. 3
4	620	6	854. 3.10	1. 7. 6	1231. 2. 6	3. 0. 1
5	425	8	596. 7. 3½	1. 8. 0	106. 7. 3½	2. 6. 3
6	895	8	1270. 6. 2	1. 8. 4	1325. 6. 2	40. 3. 3
7	930	2	1332.16. 2	1. 8 . 8	1752 .16. 2	2.10. 8
8	866	6	1215.10. 4½	1. 8. 1	171. 2. 4½	2.17. 0
9	82 1	0	1182.13. 2	1. 8.10	952. 1. 2	2.11. 1
1750	643	1	940. 3. 1½	1. 9. 3	2215. 3. 1½	2.18. 1
1	454	9	712.19.11	1.11. 4	-	-
2	832	2	1360. 8. 9	1.12. 9	2073. 8. 8	2.19. 5
3	276	8	469.10. 0	1.13.11	-	-
4	897	7	1589.12. 6	1.15. 5	1954. 2. 6	3. 0. 2
5	440	1	842.11. 5¼	1.18. 4	247.11. 5¼	2.19. 0
6	657	8	1844. 2. 7	2.14. 6	2574. 2 . 7¾	4. 0.11
7	676	4	1877.12. 7	2.15. 6	1837.12. 7	3.13. 6
8	759	4	2000. 2. 7½	2.12. 8	700. 2. 7½	3.10. 0
9	629	0	1602.14. 6¼	2.11. 0	2007.14. 6¼	3.13. 0
1760	457	10	1164. 3.11½	2.10.10	984 . 3.11½	3. 9. 4
1	507	9	1248 .9. 5	2. 9. 2	-	-
2	212	3	483. 5. 8	2. 5. 6	1603. 0. 2	3.18. 2
3	272	4	610.10. 1	2. 4.10	1824. 5. 1	4. 4.10
4	316	10	712.16. 4½	2. 5. 0	-	-
5	700	1	1427.13. 3	2. 0.10	2150. 9. 8	3.17. 8
6	723	10	1658. 8. 4	2. 5.10	1708. 8. 4	3.12. 7
7	707	9	1641. 6.11	2. 6. 5	1590. 6.11	3.12. 3
8	404	11	921. 2 . 6¾	2. 5. 6	-	-
9	249	3	679. 7. 3¼	2.14. 6	1648. 9.10	4.10. 4
1770	342	8	948. 9. 9½	2.15. 4	-	-
1	244	8	672. 6.11¾	2.15. 0	1618.16.11¾	4. 2. 4
2	325	11	920.15. 0¼	2.16. 5	-	-
3	354	3	995. 9.11	2.16. 2	1598. 4.11¼	3.14. 8
4	357	5	992.10. 0½	2.15. 6	-	-
5	271	5	795.15. 5½	2.18. 8	-	-
6	46	0	98. 6.11¼	2. 2.10	-	-
1777	157	6	365 94.11½	2. 6. 5	2566. 9. 4¾	4. 9. 3
8	127	10	268.16.11½	2. 2. 1	-	-
9	178	11	417. 9. 3¾	2. 6. 8	-	-

Appendix V **Charlcot Furnace Charcoal Prices 1733 - 1779**

	Other named customers	T	C	Q	L	£ s. d.
1733-35	Thomas Corfield (of Pitchford)	4				29. 0. 0
1736/37	William Corfield (of Pitchford)	10				72.10. 0
38		10				70. 0. 0
39		5				33.15. 0
1733-35	Onians	6				43.10. 0
1733-35	Rd. White		9			3. 7. 6
1733-35	Walter Stubbs	44				313. 0. 0
1736/37		10				70. 0. 0
42		18				116. 0. 0
43		59				383.10. 0
44		51				331.10. 0
45		26				170. 0. 0
1736/37	Thos. Atkis	5				35. 0. 0
1736/37	Round Thorn	93				614. 6. 6
1738/39	Mr Gee (of Tern)	5				32.10. 0
43		30				195. 0. 0
1743/44	Thos. Barker	10				65. 0. 0
1743/44	Lord Foley (of Witley)	34				212.10. 0
44/45		20				123.10. 0
1745/46	Mr Webster	50				325. 0. 0
1750/51	Wm. Oakes (of Bridgnorth) (not really a sale, but a charge for a loss of iron at Oakes Wharf)	1				6. 8. 6
1751/52	Wm. Lacon Child (of Kinlet)		2			16. 0
1751/52	Edward Knight) partners		3	1	27	1. 7.11
	Ralph Knight)		2			16. 0
1751/52	Messrs. Dorset	60				390. 0. 0
1753/54	Mr. Lutwyche (Lutwyche)		1	3	4	14. 3
1754/55	Mr. Walcott (of Bitterley)			2		5.10
1753/54	Mr. Hallen (of Prescott)		2		14	17. 0
1755/56	Tere Caswell	10				80. 0. 0
58/59		20				155 .0. 0
1770/71	The Dale Co. (of Coalbrookdale)	1				7.12. 6

Appendix VI Charlcot Furnace Customers from 1733 to 1770

The Early Coke Era

Geo R Morton, FIM, MIBritF

Introduction

By the middle of the sixteenth century the demands of industry for fuel had caused great denudation of the woodlands, in particular in the southern half of the country. Thus in 1558, ironworks were prohibited from using timber trees, for charcoal making, growing within fourteen miles of any coast or navigable river. An inquisition in 1595[1] showed that Fulke Greville had ruthlessly destroyed the woods of Cannock Chase without replanting, and the industry was on the decline.

Many attempts were made to conserve the charcoal by the use of peat,and whilst several patents were taken out[2], no early records of its successful use are to be found – even the experiments of John Wilkinson about 1765 were reported by Stockdale[3] as being unsuccessful. Two satisfactory results are to be found[4] – at Leighton in 1716, and at Backbarrow in about 1800.

Attempts to use Mineral Coal

Ashton[5] and Mott[6] have endeavoured to show that the claims of Dud Dudley to have successfully smelted iron ore with mineral coal were somewhat exaggerated. Challenor[7], in a 'Bibliographical Note to the 1963 Edition' of T S Ashton's 'Iron and Steel in the Industrial Revolution' quotes:

'Professor Ashton, ... cast doubt on the claims of Dud Dudley to have smelted iron ore successfully with coal to produce merchantable bar iron in the first half of the seventeenth century. These doubts have now been confirmed by Dr. R A Mott:

'Dr Mott submitted to chemical analysis samples of the small coal from the thick seam of the Dudley area which Dud Dudley tells us he used at his furnace and forge. It was found that this coal had a sulphur content too high to allow of its use, in the raw state, to produce sound pig-iron, let alone merchantable bars. Some of the sulphur can be removed by coking. But Dud Dudley makes no mention of coking, and Dr Mott has shown that the small coke from this seam cannot be turned into any form of coke that could be used in the blast furnace. (It is what is now called non-caking coal.) The controversy about Dud Dudley has now been settled not in the library or the muniment room, but in the laboratory'.

'In addition, it was shown by the same methods that the Shropshire 'clod' coal used by Darby has the necessary qualities for producing suitable blast furnace coke'.

In the year 1772, John Wilkinson wrote to John Gilpin[8] as follows:

'Bradley, October 11th 1772, I am happy to acquaint you that I have at last succeeded in using coal in my furnace. The coal is got on my estate, and answers well'.

The coal was the 'thick' or 'ten yard' coal which outcropped at Bradley, and in many other areas of the Black Country. Raw coal was extensively used in the district, and its use continued into the present century both there and in other districts, eg North Staffs, Derbyshire, etc.

In considering coke manufacture in Great Britain, Beaver[9] states:

'The 'clod' coal of Shropshire is not a good coking coal in the modern sense of that term. It is of relatively low rank with a carbon content (dry, ash-free basis) of 78-79 per cent. It contains a high proportion of durain (the hard, dull, matt-surfaced constituent in coal), and is weakly swelling. Thus the slack will not agglomerate or 'cake', but a perfectly good coke can be made by carbonising the coal in large lumps. A further most important property is the extremely low sulphur content – sulphur being undesirable in all forms of iron. In fact, it has been stated that the 'clod' coal would give a more reactive coke and therefore closer in its resemblance to charcoal than almost any other coal in Great Britain'.

He continues later:

'Coals of the 'clod' type (ie with high durain content, 78 to 81 per cent carbon, very low in sulphur, and weakly swelling) are found in several other coalfields. In South Staffordshire there was the famous 'Thick' or 'Ten-Yard' seam, perhaps the most remarkable coal seam ever discovered in Britain'.

The coke-making process, using lump coal, was similar to that of charcoal burning, but the heap was covered with coke dust, wetted to suit the conditions. In 1768, John Wilkinson improved the process by building the coal heaps around a central flue built of loose bricks and with openings to allow exit of the combustion gases. To continue the above discussion, an analysis of the various sections of the Thick coal as determined by Meade[10], gave results as shown in Table 1.

Thus it is seen that the slack from the thick coal is non-caking and of variable composition, in particular with respect to sulphur, dependent upon the position in the seam from which it is obtained. In addition large lumps coke reasonably well, providing a highly reactive coke. Since with a seam some 30 ft thick, large proportions of slack material were made, the economics of coking were low – thus Wilkinson's endeavour to use the coal in its raw state. It therefore appears that if Dud Dudley did not succeed in using raw or coked coal in his furnace, it was because of some reason other than those developed by Ashton and Mott.

Composition, exclusive of water	Ten-Yard or Thick Coal				Heathen coal
	Rooves	Top Slipper	White coal	Brazils	
Carbon	76.12	77.01	76.40	72.13	70.41
Hydrogen	4 83	4.71	4.62	4.32	4.69
Oxygen	16.72	16.72	17.43	17.11	12.47
Sulphur	1.00	0.74	0.55	0.54	0.71
Ash	2.33	1.56	1.55	6.44	2.20
Water					9.52

Table 1 – Analyses of South Staffs Coal

Whereas the reasoning of Challenor has been based mainly on the ability of the coal to coke, and the sulphur content, the lower reactivity with oxygen of these fuels compared with charcoal was perhaps the prime reason for the failure in its application to iron smelting. It is true that the sulphur content could be lowered by coking, and coking did improve the reactivity which would still be much lower than that of charcoal. In order to satisfy this lower reactivity higher blast volume and pressure were required, which would in turn provide a higher bosh temperature, and the ability to use lime as a flux with the consequent elimination of a great proportion of the sulphur contained in the ore and fuel.

The blast volume and pressure were outside the limits of the leathern bellows driven by water wheels with normal heads of water, and two methods were adopted to overcome the difficulty:

i) At Coalbrookdale the increased velocity of the water from the pool to the wheel, due to the considerable fall from the pool, extended the limits of the bellows to that required to provide sufficient volume and pressure to react continuously with the incandescent coke in the bosh. This extended limit was not entirely satisfactory and in 1742 wooden bellows were introduced. Wooden bellows were mentioned by Plot[11] in 1686.

ii) At Bradley – Wilkinson, with the aid of his blowing cylinder driven by a steam engine, and with 'regulating bellys' obtained sufficient blast to use high lime burdens with the consequent reduction of sulphur in the pig iron, and it was in this field of application that rapid developments in furnace design and practice occurred.

Lime

The effects of lime on the melting temperatures of early blast furnace slags are shown in Figs 1 and 2, from which it will be seen that low melting slags can be obtained even with higher lime contents than normally found in those slags.

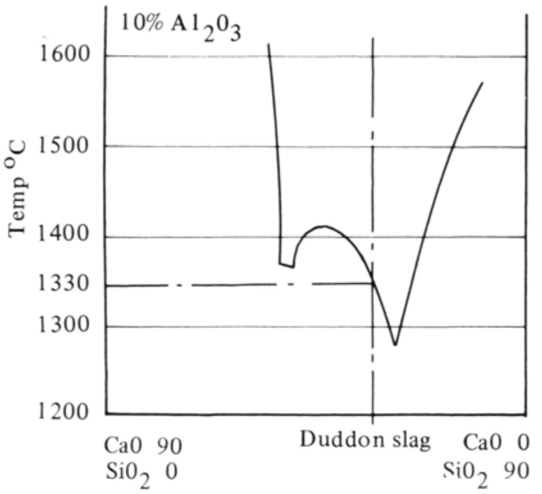


Fig 2 - Liquidus Surface – Duddon Slag

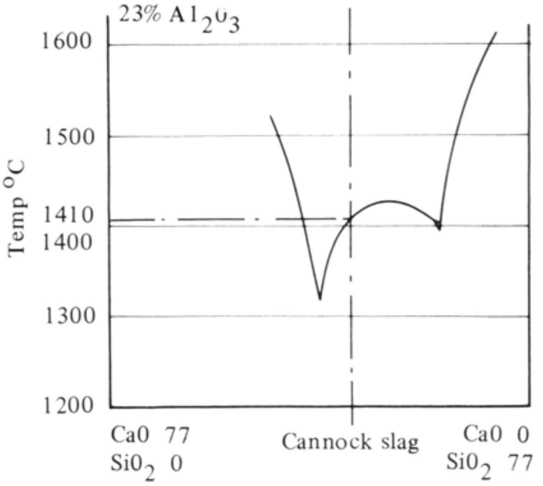


Fig 3 – Liquidus Surface – Cannock Slag

From an examination of the slags found at Sharpley Pool, Hallett and Morton [12] have shown that limestone was added to the furnace burden to act as a base exchange – the iron from the iron-silicate Roman cinder of the Forest of Dean, being replaced by the lime from the stone. This is perhaps the earliest case of lime being intentionally added to a furnace burden, and dates from c1650. The compositions of three charcoal blast furnace slags are given in Table 2.

	Cannock	Sharpley Pool	Duddon
SiO_2	49.66	49.30	57.60
Al_2O_3	23.16	11.40	9.70
CaO	11.92	22.80	23.40
MgO	7.16	12.00	4.18
MnO	3.29	0.84	0.56
FeO	4.37	2.70	3.90
S	0.10	Trace	N.D.
P	0.07(P_2O_5)	Trace	N.D,

Table 2 – Analyses of Three Charcoal Blast Furnace Slags

Mutton [13], also records limestone chippings being used in the burden at Charlcot furnace.

No record of limestone can be found in the accounts of the Cannock furnace, but is found in those of Duddon furnace. No accounts are available for Sharpley Pool. Thus it can be seen that whereas limestone was used as a flux at Duddon, and probably as a base exchange at Sharpley Pool, it was not used at Cannock .

Blast and Lime

Increase in blast volume and pressure raises the temperature of the fusion zone of the furnace, Fig 3, and also produces a greater volume of CO_2 for the purpose of reduction in the stack, thereby tending to increase the output of the furnace. This higher temperature permits some reduction of the SiO_2 in the ore, the silicon entering the metal where it goes into solution with the iron and displaces carbon which separates as graphite, giving the metal a grey fracture. At the same time added lime, over that required to form silicate, combines with the sulphur in the metal and as CaS passes into the slag

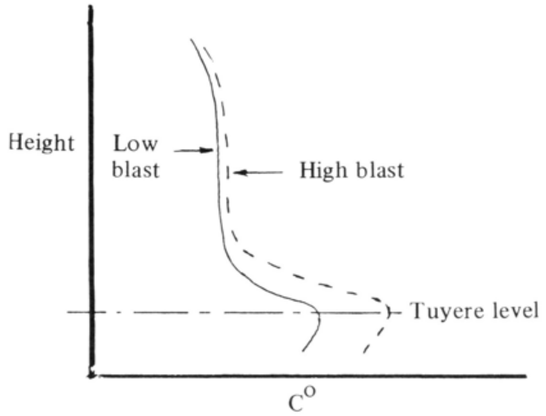


Fig 3 – Effects of Increased Blast Volume and Pressure on Temperature Distribution in the Blast Furnace

In the case of the furnace operation at Duddon and Sharpley Pool, the sulphur was normally low in the raw material, and the lime enabled fluid slag conditions to be maintained which in turn permitted the production of grey pig iron.

Dud Dudley

Returning to the claims of Dud Dudley in 1665 – the South Midlands plateau at Himley falls sharply towards the rivers Stour and Severn, and the brooks running into these rivers are generally fast flowing. In the grounds of Himley Hall, three pools typical of those associated with early ironmaking, provide a head of water comparable with that at Coalbrookdale. This arrangement was shown on Yate's map of Staffordshire 1769, and whilst the pools are still to be seen , considerable landscaping has taken place. The bed of the lower of the three pools is made of slag lumps, which owing to the long period at which water has been flowing over them, have lost their inner slag-like appearance. In the adjoining fields pieces of slagged 'bear' and refractory are occasionally turned up by the plough, along with an unusual slag-coke complex which cannot yet be identified and on which further work is proceeding.

An examination of Dud Dudley's 'Metallum Martis' reveals the following:

i) Before his 'first tryal or blast' he altered his furnace. His second trial produced not more than three tons of iron per week . At Himley he erected a larger furnace (27 feet square), and the bellows 'are larger than ordinary bellows are'. In this furnace he made seven tons per week.

This suggests that he was aware of the necessity for greater blast volumes and pressures, for which ample water supply was available. It also appears that his 'tryal' was not just an individual blast but a prolonged effort which might have been a complete campaign.

ii) He knew the nature of the 'thick' coal deposits, with the underlying ironstone and heathen coal. He also knew of the variable sulphur content of the coal, and its effects on the iron produced.

iii) He does not insist that he 'fined' the iron with coal – in fact a comparison of the selling prices suggests that fining was not carried out with coal. He compares the selling prices of pig and bar made with charcoal and coal as:

Coal pig: £4 per ton.	Charcoal pig: £6 – £7 per ton.
Coal pig fined to bar: £12 per ton	Charcoal pig fined to bar: £15 – £18 per ton.

Therefore the cost of fining coal pig was £8 per ton compared with £9 – £11 for charcoal pig.

This price difference suggests that both types were fined with charcoal, – coal may however have been used for reheating in the chafery.

iv) He was able by observation, to say that later attempts by Williams, Dagney and others would not work.

v) The metallurgy of iron was well understood by him, thus he defines the various types of cast iron as 'Gray Iron', 'Motley Iron" and 'White Iron, this is almost as white as Bell-Mettle'.

vi) He makes no mention of limestone although the Sedgley Beacon outcropped in Himley Park.

vii) He intended to leave his secrets to his kinsman 'Master Francis Dingley'.

His final claim that '. . . the Author hath not yet so fully perfected or raised his invention, to the quantity of Charcole Iron Furnaces, yet the Authors quantity being but seven Tuns **per** week at the most . . .' suggests that Dudley did smelt iron ore with raw coal, using limestone as a flux, but possibly resorted to charcoal for fining, followed by the use of coal in the chafery.

Changes in Furnace Design

The introduction of the steam engine and blowing cylinders by Wilkinson enabled several modifications in blast furnace design to take place. It removed the dependence of the process on water power and by so doing enabled the industry to become sited on or near the supply of the raw materials ore, coal and clay. Since the terrain of the land at Bradley did not lend itself to a high line leading from a hill-side to the top of the furnace, Wilkinson introduced an incline from ground level up which the charge, loaded in wagons was pushed, a development which by 1800 had become mechanised.

In general modifications were applied to the square stone built charcoal furnace, and many of the characteristic features of that period remained well into the 19th century eg, even when the external shape of the furnace changed from square to round, the arched fore-hearth with a dam over which the molten slag flowed continuously still existed.

Because of the quantity of heat carried through the furnace by the ascending gases (air = $0_2 + 4N_2$) and in particular by the inactive nitrogen, an endeavour to reclaim some of this heat tended towards taller furnaces, and the general limit of 20 feet high extended to 30 feet or more. With increased blast availability, the number of tuyeres increased to three (one on each of three sides of the square outside shape), with a consequent rise in output – thus it became necessary to tap the iron at more frequent periods, usually once in each twelve hour shift. The hearth, bosh and side-walls continued to be made from best quality sandstone, but the tendency towards higher lime slags placed a limit on this type of refractory material, and higher refractory fireclay bricks were introduced. With the development of the brick industry the outside shape above the level of the top of the bosh, began to change from the square stone structure to that of a round section made from brick and supported by iron bands.

The Metal and Slag

Due to the higher temperature available the composition of the pig iron produced changes in several important respects. The higher temperature caused the reduction of silica to silicon which dissolved in the molten iron, and which on solidification of the sow and pigs tended towards a coarse grained graphitic iron generally unsuitable for the production of castings when used direct from the blast furnace. Thus resmelting and refining units became a necessity of the foundry, in the form of air furnaces and cupolas. Typical analyses of charcoal and early coke pig iron are given in Table 3.

	Charcoal pig	Early coke pig
Total carbon	2.82	2.72
Silicon	0.39	2.15
Manganese	Trace	1.33
Sulphur	0.054	0.032
Phosphorus	0.45	0.054

Table 3 – Analyses of Pig Irons

The bottle-green acid slag of the charcoal blast furnace suffered an important restriction by its inability to accept sulphur in solution – to remove this element high lime slags were essential, and because lime raises the melting point of the slag, higher temperature in the bosh became an essential requirement. Therefore the coke blast furnace with its higher bosh temperature enabled higher lime slags to be used with the result that a less pure ore could be used, and the sulphur contained in the ore and fuel could be effectively accommodated by the slag. A comparison of these analyses is given in Table 4.

	Charcoal furnace slag	Coke furnace slag
SiO_2	49.66	38.10
Al_2O_3	23.16	11.18
MnO	3.29	1.44
CaO	11.92	41.10
MgO	7.16	2 52
FeO	4.37	1.45 (as Fe)
P_2O_5	0.07	0.02
S	0.10	1.37

Table 4 Analyses of Slags

References

1 Anglesey Collection, William Salt Library, D 1734.

2 H R Schubert, History of the British Iron and Steel Industry, 224, London, 1957 .

3 J Stockdale, Annals of Cartmel, 2 11, Ulverston, 1872.

4 G R Morton, The Use of Peat in the Extraction of Iron from its Ores, Iron & Steel, Vol 38, No 9, p 421.

5 T S Ashton, Iron and Steel in the Industrial Revolution, 10, Manchester, 1924.

6 R A Mott, Dud Dudley and the Early Coal-Iron Industry, Trans Newcomen Soc, Vol XV, 1934-5, pp 17-38.

7 W H Challenor, Iron and Steel in the Industrial Revolution, Third Edition, xi, Manchester, 1963.

8 H W Dickinson, John Wilkinson, Ironmaster, 20.

9 S H Beaver, Coke Manufacture in Great Britain, Trans Inst British Geographers, 133, 1951.

10 R Meade, Coal and Iron Industries of the United Kingdom, London, 1882.

11 R Plot, Natural History of Staffordshire, 165, Oxford, 1686.

12 M M Hallett and G R Morton, Bulletin Historical Metallurgy Group, this issue.

13 N Mutton, Charlcot Furnace 1733-1779, Bulletin Historical Metallurgy Group, this issue.

The Bradley Ironworks of John Wilkinson

W E Smith, BA, Dip Ed

The exact date of the erection of the first furnace at Bradley is in some doubt. Hackwood[1] in his Sedgley Researches states: 'Previously in 1757 he had erected his first iron furnace at Bradley. This pioneer furnace of the great Black Country was to 'blow wholly by the fire-engine'.' This would appear to be the engine later referred to as 'Topsy-Turvey'. James Watt Jnr refers to it, in 1796, as 'an old engine converted into one of ours'[2]. Other evidence, however, points to a date some ten years later. Price[3], a local historian, says: 'In the year 1768, an act was obtained for making a Navigable Canal from Birmingham to Bilston . . . Blast furnaces for the smelting of iron began to be erected about this time in this Township, the first of which was that belonging to the late John Wilkinson esq. near the Fireholes and called the Old Furnace; another was erected by the same gentleman near the Canal at Upper Bradley. Two surveys[4], carried out in 1767, for the intended navigation of the canal show a fire-engine and iron furnace at the site of the works.[4]

A survey of Bilston Township in 1770 lists Wilkinson as the owner of considerable property including a coal-pit and the works seem to have been well established and in production. Dr Small[5] writing to Watt (17th Sept 1770) says 'the people of Colebrook-dell sent us castings for the circular machine only a month ago. They were unsound and totally useless . . . An eminent caster has settled during the summer at Bilston. We were obliged to have recourse to him'. Dr Small is, of course, referring to Wilkinson. Trading relations with Watt were thus established by the superior quality of Wilkinson's wares before the invention of the boring machine in 1774 gave Wilkinson a quasi-monopoly of the supply of the parts for Boulton and Watt steam engines.

The iron industry falls naturally into two main divisions. The first includes the mining, smelting and casting operations, and the second the working of the metal in its endless variety. Wilkinson's Bradley estate possessed all the raw materials, ore, coal, fire-clay, in fact the necessities of the first division. By the application of steam power to engineering method he built up, on one site, the complete process from raw material to finished product. The application of Wilkinson's boring machine to the production of cylinders for the steam engine led to the rapid expansion of the industrial uses of Boulton and Watt engines. Wilkinson was not slow to adapt them to his own use. The Boulton and Watt Engine Book[6] lists the specifications of thirteen engines for the Bradley works between 1778 and 1790. In April 1778 the Bradley works had a Sun and Planet type engine with a cylinder diameter and stroke of 15"/4'0. The remarks added in the Engine Book are 'Double Battery Engine - - - Chain on Beam Engine - - - Coupled to One Shaft'. In 1779 a Single Acting Blowing Engine of 34.1 HP with a cylinder diameter and stroke of 40"/8' was supplied to Bradley. Presumably this was an extra engine as the younger Watt refers to Topsy Turvey as an old engine converted to a Boulton and Watt type.

In 1777 Wilkinson announced his intention of going to work in the forge way and applied to Boulton and Watt for an engine. It was not ,however, until March 1783 that the forge engine was working at Bradley. It seems inconceivable that a man of Wilkinson's impatience should have waited six years to implement his idea. Doubtless he improvised some form of hammer until Watt's rotative engine had been perfected. Watt[7] writing to Mr Hamilton on March 26th 1783 says: 'We have got the forge-engine at Bradley set to work yesterday morning, which performs very well' A month later, further trials were carried out and modifications made. Watt[8] writing to Smeaton reports the event: 'We have a trial of our new forge-engine at Bradley; cylinder 42 ins diameter, 6 ft stroke, Makes from 15 to 50 (even 60) strokes per minute at pleasure, works a hammer of 7½ cwt raised 2 ft high which makes 6 strokes per stroke of the engine, and has struck 300 blows per minute; we are, however, going to make it strike only 4½ blows per stroke of the engine because we want the latter to go 20 strokes per minute, and they want only 90 blows of the hammer in that time; but will increase the weight of the hammer to 10 cwt. NB The engine is to work two hammers of 7 cwt each. A letter dated the previous day explains that the workmen cannot manage the iron under the hammer at more than 90 to 100 blows per minute[9].

Initially the production of pig iron was small. Wilkinson's letter to Gilpin in 1772 speaks of smelting with pit-coal and raising the output of the furnace from 10 to 20 tons per week. Further statistics of the Bradley iron production are found in returns prepared for the government and quoted by Richard Meade [10].

1796

Works	No of Furnaces	Excise Tons	Calc Tons	Actual Tons
Bradley	3	3640	3000	1920

It is unfortunate that there are no interim statistics available but one can safely assume that a rapid increase in production tonnage took place after the installation of the new blowing engine in 1779.

In attempting to build up a picture of the finished products of the works we are constrained, in the absence of ledgers or account books from Bradley, to depend upon the records of Boulton and Watt and the assumption that in the early days the products would be little different from those of the already established Wilkinson plants. From his first ledger at Bersham [11], in 1762, it appears that he made a great variety of products such as box-heaters, calendar rolls, malt-mill rolls, sugar rolls, pipes, shells, grenades and guns. In assuming that the early Bradley products were similar to those of the other Wilkinson works we must, however, remember that although Wilkinson produced large quantities of ordnance, and his patent of 1774 was designed to improve ordnance, Boulton [12] in 1786 writes regretting that Bradley is without a boring machine. It would seem, therefore, that in the first twenty years of its life Bradley produced neither ordnance nor cylinders. During this early association with Boulton and Watt the Bradley works were producing the cast parts of the steam engine, both ferrous and non-ferrous. The Boulton and Watt collection of letters and their order and manufacturing book clearly indicate this. However, in a letter dated May 8th 1789 Watt is asking for a 34 inch cylinder to be made at Bradley, and in 1790 the Engine Book lists an engine for Bradley for boring and turning.

An undated letter from Watt to Wilkinson shows that about 1780 Wilkinson was turning to boiler making, at least in Wales (Bersham). 'There is one John Parker from Coalbrookdale who is a tolerable smith and possesses boiler-making, wages about 12/- per week. I don't know if he would go to Wales for the same'. By 1786 John Wilkinson had begun boilermaking at Bradley, and, thereafter, judging by the correspondence of William Johnson, in charge of boilermaking at Bradley, with John Southern at the Soho Works, Bradley steadily produced boilers for Boulton and Watt or their customers. By 1791 the practice of testing boilers before despatch had been introduced. Johnson writes of an order for Denninsons: 'They have also been filled with water, to prove their tightness, a plan we mean in future to adopt with all our boilers'.

It is sometimes stated that we owe the foundry cupola to Wilkinson. There is no doubt that Wilkinson obtained a patent in 1794 for a small blast furnace, and it seems that such furnaces were employed at the Bradley works. It is clear that the patent is concerned with iron smelting, and the invention consisted essentially in using furnaces not more than 10 ft in height, in place of furnaces 30 to 70 ft as was then the practice. His specification shows a furnace with an iron casting.[13] The Sale Catalogue of 1836 lists a cupola furnace at Hallfields Furnace and at Bradley Furnaces.

Wilkinson, on his death in 1808 left instructions to his Trustees[14] that the Bradley works were to be developed for making the best bar iron. He seems to have pinned his faith in the finery process for the Sale Catalogue has no mention of puddling furnaces, the process so enthusiastically taken up by his competitors. He obviously foresaw a continued development of the works and yet at the time of writing, 1806, the seeds of the dissolution of his empire were already sown. Three factors other than the instructions to the Trustees were to determine the fate of the works; Wilkinson's and his Trustees' neglect of new processes developing in the iron trade, litigation over his attempt to leave his property in Trust for his illegitimate children by Ann Lewis, and the depression in the iron trade which followed the Napoleonic Wars..

References

1 F W Hackwood: 'Sedgley Researches', 101, 1898.

2 H W Dickinson and Rhys Jenkins: 'James Watt and the Steam Engine, 115, 1927.

3 J Price: 'An Historical Account of Bilston', 115, 1835 , Bilston.

4 W A Smith and G R Morton: in preparation.

5 Birmingham Reference Library: Boulton and Watt Collection.

6 Birmingham Reference Library: op cit.

7 Birmingham Reference Library: Boulton and Watt Letter Books.

8 Birmingham Reference Library: op cit.

9 Birmingham Reference Library: op cit, Watt to De Luc, April 26th, 1783.

10 H Scrivenor: 'History of the Iron Trade', p 96, 1841.

11 A N Palmer: 'The Old Bersham Ironworks', 12, 1899.

12 Birmingham Reference Library: Boulton and Watt Letter Books.

13 Rhys Jenkins: 'Collected Papers', 122, 1936.

14 W A Smith and G R Morton: in preparation.

The First Annual Conference

The first conference to be held by the Group took place over the weekend, 3rd - 5th September, at Tor Lodge, Wolverhampton, by permission of the Governors of the National Foundry College. The consensus of opinion of those who took part in it amply confirmed the useful nature of area meetings, and the impressions of a newcomer to the Group may be of interest. The gathering (he writes) had something of the freshness and sociable air of a houseparty. The numbers (about a score) were easily manageable, the accommodation was comfortable and almost domestic, and the welcome extended by the organisers most cordial. By the second day one could match names with faces, introductions had been completed, and one had a fair inkling of the special interests (and hobby horses, perhaps) of most people. The programme – six speakers, two excursions and a session for general discussion – provided a substantial though not excessive diet. The President (Sir Frederick Scopes) opened the first session in a characteristically genial manner, and the subsequent speakers successfully adjusted the length, breadth and depth of their contributions to suit the mixed audience. Excellent colour slides were used to depict recent excavations and exploration.

The two visits – to Coalbrookdale and Iron Bridge on the Saturday afternoon (full marks to Mr Williams, the Allied Ironfounders' director, for producing a splendid afternoon tea) and to Charlcott Furnace on Sunday – fitted appropriately into a programme which was exclusively concerned with iron production. Nor were the members and visitors inclined to stray into other fields on the Saturday night, when a free discussion period brought colour slides from members. If some of us passed the narrow boundary between metallurgical history and industrial archaeology (or biography) these lapses were tolerated.

To sum up, the conference obviously gave the members and visitors a lot of satisfaction, and if the same pattern of programme is adopted for Sheffield in September 1966 there should be an assured demand for places.

Association with the Iron and Steel Institute

Following discussions between the officers of the Group and of the Iron and Steel Institute, the Council of the Institute has agreed to lend its support by the provision of secretarial and editorial services for the Group, and to undertake the production and distribution of future issues of the Bulletin. Research papers emenating from members of the Group will be published in the Journal of the Iron and Steel Institute from time to time, copies of which will be received by members of the Institute via the Journal, and by non-members via reprints with the Bulletin.

Membership of the Group will be offered without extra subscription to all Members and Associate Members of the Institute. Non-members of the Institute will continue to pay the annual subscription of the Group.

By these means it is anticipated that the Group, whilst maintaining its independence, will be able to offer considerably improved services to its members.

The Second Annual Conference

The Annual Conference for 1966 will be held at Sorby Hall, Sheffield, from Friday 9th September to Sunday, 11th September. A committee of members residing in the Sheffield area is being formed to take over the organisation and arrangements of the programme of papers and visits. Further details will be distributed with those for the Annual General Meeting.

Revue Histoire de la Siderurgie

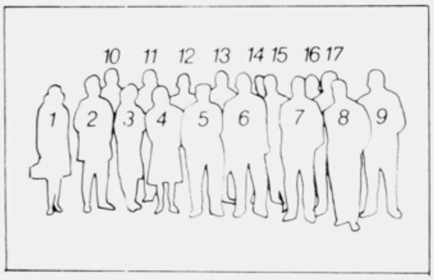
This publication is now being received on an exchange basis and present and back numbers may be obtained on loan from the secretary. Forward and return postage will be paid by the borrower.

Progress Reports

Owing to the size of this issue of the Bulletin, reports of work at present in hand by various members of the Group will be held over to the next issue.

Annual Subscriptions

Those members of the Group who are **not** members of the Iron and Steel Institute are reminded that their subscriptions are now due, and they are requested to send a cheque or postal order for 10/- to the Hon Treasurer, Chamberlin and Hill Ltd, Chuckery Foundry, Walsall, Staffs. Please make postal orders payable to the Historical Metallurgy Group.



We are grateful to Audrey Morton for the photograph reproduced here. It shows the 1st Annual Conference of the Historical Metallurgy Group held in September 1965. In the picture are: Mr and Mrs Norman Bridgewater (3/10), Audrey and Reg Morton (4/5), Norman Mutton (11), John Butler (12), W H Bailey (13), Michael Rix (14), Fred Williams (6), Ken Barraclough (15), Michael Hallett (7), Henry Cleere (8), Alan Shorer (16) and the Coach Driver (9). We do not know the names of 1, 2 and 17.