Early iron ore production from the Forest of Dean and district

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Introduction

Much has been written on the iron mines and ironworks of Dean and district, but due to lack of records the early output of this ancient industry is very difficult to assess.

One method currently in hand is to measure the volume of open-cast excavations or Scowles, which in spite of centuries of random in-filling, are still visible in many parts of Dean and even beyond its borders. Making certain assumptions these volumes can be translated into ore and over 1,000,000 tons have been estimated from surface workings in Noxon Park and Wigpool areas.[1] However, the figures are difficult to equate with any definite time-span.

Another approach is to assess the ore from the quantities of bloomery slag or cinders which accumulated over 2,000 years from the Iron Age up to the introduction of the charcoal blast-furnace near the end of the 16th century. This paper sets out to explain and illustrate the method, which can be refined in various ways.

We have it on the authority of Andrew Yarranton writing in 1677 that 'in the Forest of Dean and thereabouts as high as Worcester are great and infinite quantities of cinders . . . which will supply the ironworks some hundreds of years . . .'

His assertion was no exaggeration, and it is well known that these iron-rich cinders formed the basis of the charcoal blast-furnace era in the locality which endured into the early years of the 19th century - and even then the deposits had not been exhausted.

From the known number of furnaces and their approximate operating spans and from existing accounts of certain typical furnaces, we can estimate by extrapolation the total of bloomery cinders consumed. Hence the corresponding amount of ore and metallic iron produced can also be gleaned for the pre-charcoal blast-furnace era. There are however some qualifications which will be apparent later.

Sources of Cinders and Ore

The localities where substantial amounts of bloomery cinders have been reported in the vicinity of Dean are very numerous, and a proper explanation is wanting as to why so many of the sites are considerably removed from the well known iron ores in the limestones of Dean. The old assumption that these ores supplied all the bloomeries for miles around is at best dubious, and as an example we may cite the cinder deposits near Newent, which for well over a century fed the Elmbridge (Newent) Furnace, c1639-1751. The bloomeries from which the cinders derived presumably obtained their ores from the hematites and goethites associated with the Newent Coalfield, and perhaps also from the Silurian hematites at Aston Ingham, which were extensively worked for the Newent Furnace and since forgotten.[2] Thus the question must be addressed, whether most if not all of the bloomeries outside Dean derived their ores locally, rather than from the Forest itself. Certainly there would seem little logic in carting ores for miles when ample wood for charcoal existed close to the Forest mines. Therefore, local ores must be suspected to account for bloomery cinders wherever they occurred in quantity, and an important source could have been bog iron ore. Bog ore was reported in Herefordshire in the last century,[3] and when many low-lying areas were swamps it was probably widespread. Unlike the Scowles or ancient opencast excavations on the outcrops of the iron lodes of Dean, its exploitation would leave no testimony at all. This is a field worthy of further study.

Another consideration is that bog ores may have been easier to smelt than the rather stubborn hematites/limonites of Dean.[4] According to H G Bull, writing in 1889, immense beds of bloomery cinders 'up to 20ft thick' had been found at Ariconium, Peterstow, Bridstow, Birch, Hentland, St Woenard's, Tretire, Llangarron, Walford, Welsh Bicknor, Ganarew and many other places in Herefordshire.[5] The Foley Partnership accounts[6] also refer to numerous sites, and research into field names as well as field-work itself would probably supply more. According to David Mushet, the earliest operations were probably air bloomeries relying on natural draught, thus explaining those sites in high and exposed situations.[7]

Though incomplete, the accompanying map will give an idea of the wide distribution of cinder-heaps. Known sources of ore are also indicated, and the general lack of correlation between the two will be noted.

Charcoal Furnaces In and Around Dean

The following list in order from north to south is compiled from published sources.[8] Where the total years in operation may be questioned it is felt that any optimism in this respect will be countered by unrecorded periods of use and even unrecorded furnaces, so that the end result should be roughly correct.

Charcoal Furnaces

Name	Years in Use	Total
Elmbridge (Newent)	1639-1751	112
Linton	1677-1690	13
Walford (Ross)	1590-1659	69
St Weonards	1645-1731	86
Bishopswood	1590-1614, 1620-50, 1674-1728, 1747-51, 1770-1814	156
Longhope	1656-1682	26
Whitchurch	1633-1680	47
Lydbrook	1613-50, 1662-74	49
Guns Mill	1629-44, 1683-1732	64
Flaxley	1674-1802	128
Cannop	1612-1644	32
Soudley	1613-1650	37
Parkend	1612-35, 1654-73	42
Blakeney	1680-1718	38
Redbrook, Upper	1604-1634	30
Redbrook, Lower	1634-1798, 1801-16	179
Brockweir (Coedithel)	1628-1680	52
Rodmore	1629-1680	51
Lydney	1606-1775, 1780-1809	198
Tintern	1651-1796	145

Average life = $\frac{1554}{20}$ =78 years Total 1554 years

Table 1

Cinder Consumption

From the Foley Partnership accounts, four of their furnaces made returns virtually every year from 1702/3 to 1714/5 inclusive. These were Blakeney, Bishopswood, Redbrook and Elmbridge (Newent), and regarding iron output were probably typical. However, in terms of cinder consumption Elmbridge is better excluded because of its remarkably low cinder/ore ratio.[9]

The consumption and output figures have been averaged as follows:-

Statistics for the whole Charcoal Furnace Era

Iron (tons)	Ore (Doz bushels)	Cinders (doz bu)	Charcoal (loads)
1,075,000	971,000	2,342,000	2,204,000

To determine the equivalent weight of ore and cinders it is necessary to know their specific gravities. This however was variable. In the case of cinders, in Roman and pre-Roman times the recovery of iron was small, so that SG = 4 probably applied in round figures. Later the extraction improved giving SG = 3.5 or thereabouts. Therefore an average SG = 3.75 will be assumed.

An ore running 40-45% iron will also have a similar SG and so 3.75 will be taken to apply for both cinders and ore. Any error here will not greatly influence the final result.

On this basis calculations show that for a struck Winchester bushel (1.28 cu ft) with 55% solid content the weight of both cinders and ore is 0.88 tons per dozen bushels. Hence:

Total weight of cinders = 2,342,000 x 0.88 = 2,060,000 tons
Total weight of ore = 971,000 x 0.88 = 854,000 tons

Estimation of Ore Smelted in the Bloomery Period

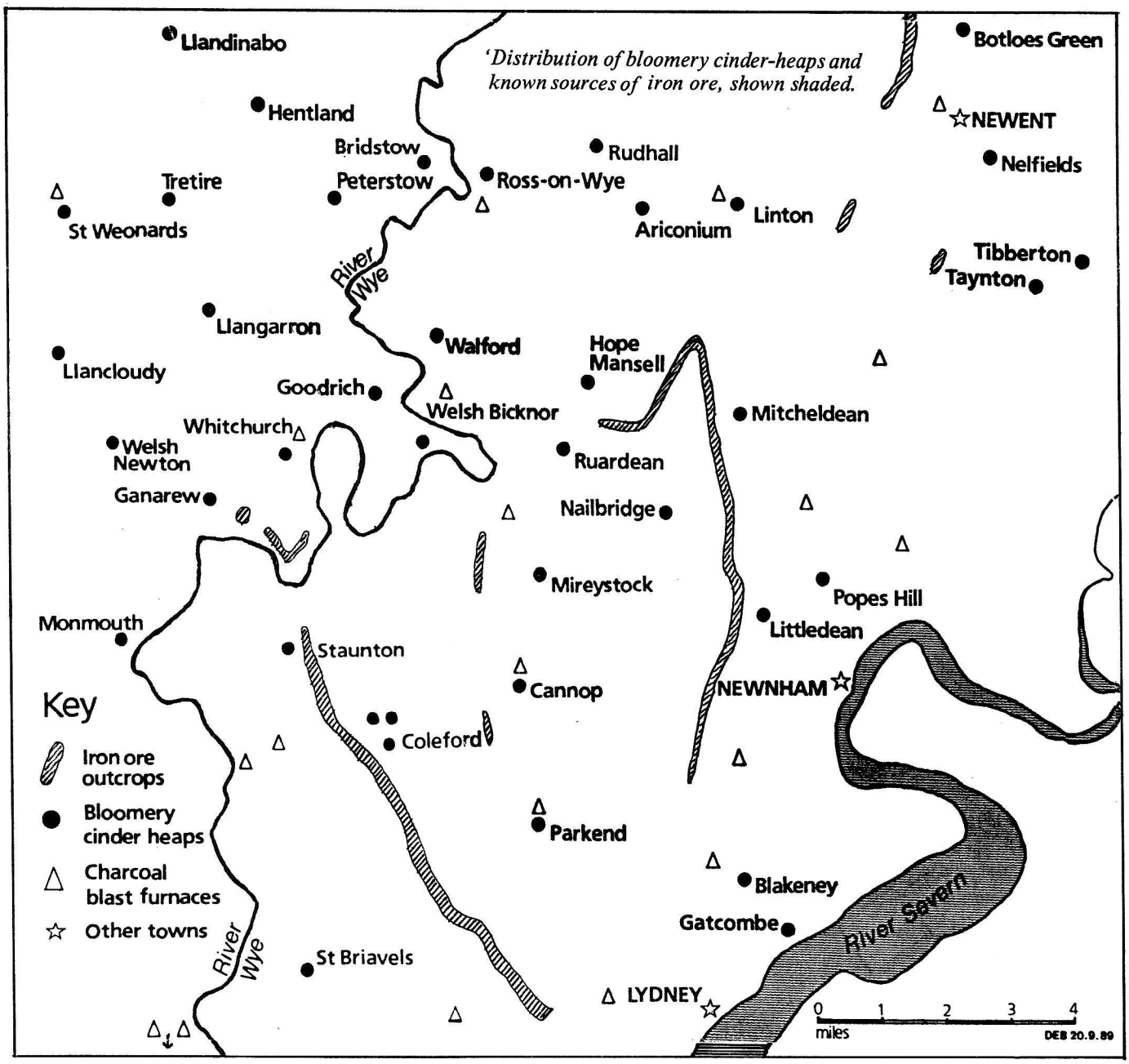
It has proved difficult to find published information as to the amount of cinders produced from smelting a given amount of ore in bloomeries. The figure would depend on many factors, but some representative value must be chosen in order to arrive at an estimate of the corresponding quantities of ore consumed from the Forest of Dean and elsewhere in the area.

Furnace Statistics 1702/3 - 1714/5 Table 2

Name	Iron (Tons)	Ore (Dozen bushels)	Cinders (Dozen bu)	Charcoal (Loads)	Ore Cinder Ratio
Blakeney	8745	8126	20,041	16,254	.41
Bishopswood (out of blast 1708/9)	6898	6954	15,281	13,632	.43
Redbrook	8565	7140	17,434	9,734	.41
TOTAL	24,208	21,860	52,756	49,620	
Average per furnace-year	692	625	1,507	1,418	

Notes: Total furnace-years = 35. Charcoal consumption is given for reference only.

The following totals for the charcoal blast-furnace era are gained by multiplying the average per furnace-year by 1,554, Table 1 refers. (It should be mentioned that in the last half of the 18th century the Forest ores were to some degree augmented by imports from Lancashire; these however, have not been deducted.)



A normal yield in Medieval times would release 20% of metallic iron from the available iron in the ore, 80% going into the slag. If the ore ran about 55%, one ton would give 0.11 tons of iron and about 0.9 tons of slag.[10] In earlier times the ratios would have been somewhat different due to even less efficient smelting.

Actual experiments using bloomeries have confirmed that a ton of ore produces about a ton of slag (cinders), though the amount is sometimes much less, depending on the ore.[11] Taking the evidence as a whole the ore/cinder ratio will be assumed 1:1.

Thus, ore smelted in bloomery era = weight of cinders = 2,060,000 tons.

The study can be readily extended to estimate the amount of metallic iron corresponding to the cinders, provided the yield or iron/ore ratio is known.

Iron output = ore smelted (2,060,000 tons) x iron/ore ratio.

Current opinion suggests the ratio would have varied between 1:6 (0.166) and 1:10 (0.10), the mean being 0.133. Thus is provided the following figures:

Iron/ore ratio	0.166 (max)	0.10 (min)	0.133 (mean)
Bloomery Iron Output	343,000 tons	206,000 tons	274,000 tons

The results obtained can be assembled as follows:

Ore smelted in bloomery era	= 2,060,000 tons
Ore smelted in charcoal blast-furnaces	= 854,000 tons
Iron produced in bloomery era	= 274,000 tons
Iron produced in charcoal furnace era	= 1,075,000 tons

Thus arises the interesting conclusion that far more ore was consumed in bloomery times than in the charcoal blast-furnace, though the latter yielded far more iron than the former.

Qualifying Remarks

It is important to remember that the above figures are based only on the actual quantities of cinders re-smelted in the blast-furnace era. There is no doubt that the total tonnage of bloomery cinders was originally much in excess of the estimated values, and for several reasons:

1 Some sites of cinders were never exhausted, and others may not have been used at all. There are huge quantities still at Ariconium and Peterstow, and reputedly at Whitchurch not to mention elsewhere, which have yet to be evaluated.

2 Large volumes of cinders have from time immemorial been used for road-making and hardcore, and there are few fields within miles of Dean where traces of bloomery slag may not be found.

3 Large tonnages were exported up-country and to Ireland for re-smelting in charcoal furnaces.

In short, it is not unlikely that the true quantity of bloomery cinders and corresponding ore and iron, amounts to double the estimate. This is an avenue deserving a thorough research.

However, even taking the figures as they stand, we are left with the surprising conclusion that the iron ore consumed in bloomeries far exceeded subsequent tonnages in charcoal furnace times. What percentage derived from the limestone deposits of Dean and what from elsewhere is at present very difficult to estimate.

Total Ore Raised From All Sources in Dean and District

To complete the picture, according to official *Mineral Statistics,* some 4,500,000 tons of ore have been raised from Dean since 1854, earlier figures not being given. If we estimate 500,000 tons after the charcoal furnace era until 1854, the following figures are obtained:

Bloomery era	2,060,000 tons
Charcoal Furnace era	854,000 tons
Coke Furnace era	5,000,000 tons
	7,915,000 tons, or 8,000,000 in round figures.

In view of the quantities of cinders that were never re-smelted, this total may be considered conservative.

As a final word, it cannot be denied that the method of estimation described here is liable in greater or lesser extent to error. But the steps have been explained, and the reader is invited to make whatever amendments he pleases.

Acknowledgements

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References

1 **Paul Wildgoose, Surface Mining of Iron Ore at Wigpool,** *The New Regard,* 1988, 4, 5-11. Ian Standing, forthcoming paper.

2 **David Bick, The Mines of Newent and Ross,** Newent 1987, 58-64.

3 This is vouched for in *Trans. Woolhope Field Club,* though much searching has failed to re-locate the reference. Bog ore has been worked in the Old Red Sandstone of Pembrokeshire; see P. Claughton, *Northern Mines Research Soc. Newsletter,* May 1989, 2-3.

4 **David Mushet, Papers on Iron and Steel, London 1840,** 389. The west Dean ores were the worst; see the *Mining Journal,* 1876, 427.

5 **H G Bull, Trans. WFC, 1882, 258.** See also **N P Bridgewater,** *Bulletin of the HM Group,* 1968, **2,** 27-30. **Ian Standing, The New Regard,** 1985, 37; 1986, 60.

6 *Glos. Records Office,* MF215-216. Unfortunately in many cases only the land-owner's name is given - not the site.

7 **David Mushet,** 371-372.

8 **H R Schubert, History of the British Iron and Steel Industry,** London 1957, 358-359, 366-392. **Cyril Hart, The Industrial History of Dean,** Newton Abbot 1971, 1-118.

9 **David Bick,** 60-64.

10 Information from Dr R F Tylecote.

11 Information from Peter Crew.

Summary

A method of estimating the iron ore raised in the Forest of Dean and district before the 17th Century is based on the quantities of bloomery cinders later re-smelted in charcoal blast-furnaces.

A surprising conclusion is that much more ore was raised in bloomery times (over 2,000,000 tons) than in the charcoal furnace era. It is also concluded that various forgotten sources of ore were exploited, thus explaining the large accumulations of cinders well away from the limonites/hematites in the limestone periphery of Dean.

About the Author

David Bick gained an honours degree at Leeds University before becoming an engineering designer and inventor with the Dowty Group, where he served for 35 years. He has written and lectured widely on industrial archaeology, with particular emphasis on mining in Wales and the Border. He is a Fellow of the Society of Antiquaries of London.