THE SHROPSHIRE WROUGHT-IRON INDUSTRY c1600-1900
A STUDY OF TECHNOLOGICAL CHANGE

by

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Abstract

Wrought-iron manufacture in Shropshire is studied over three centuries, encompassing changes in technology arising from the use of vegetable and subsequently mineral fuel. It describes the charcoal-using forges of the seventeenth and eighteenth centuries, discussing their rural locations on tributaries of the River Severn, and their principal market in the Midland manufacturing district. Comparison with other ironworking districts establishes that the industry had a regional rather than a national base. Early processes using coal and coke are discussed, in particular the patent awarded to Thomas and George Cranage, two Shropshire workmen, in 1766, before the adoption of the puddling process in the late eighteenth century. The industry in the nineteenth century is discussed with reference to the market and workplace structure, examining their influence on the technology of iron production. In the light of this, it is argued that in the nineteenth century ironmaking retained a strong regional character, structured by particular historic and geographic circumstances, and that national trends offer a limited understanding of the industry in that period. The thesis also challenges conventional interpretations of technological change, whereby new technology replaces old, arguing for increasing technological diversity until the decline of ironmaking in the late nineteenth century.

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This study really began at Ironbridge in 1996. Wendy Horton, then my colleague in the archaeology team, suggested I was the right person to write up the Upper Forge in Coalbrookdale. I have never really left the subject since. Throughout my period of study Peter Leather has ensured that all the administrative procedures have run smoothly. My academic supervisor, Dr Barrie Trinder, has been consistently encouraging and has always made the right kind of criticisms. Thanks are also due to the staff of numerous libraries and record offices, in particular at the John Rylands University Library, Manchester, the Shropshire Records and Research Centre, and John Powell, librarian at the Ironbridge Gorge Museum Trust.

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A Note on Measurements

Imperial units are used throughout the text and a conversion table is given below.

In the case of distances and building dimensions, an approximate metric equivalent is given.

Precise measurements of iron sections are given without metric equivalent.

When expressing weights, a distinction is made where relevant between shortweight tons of 2240 lb (with 112 lb to the hundredweight) and longweight tons of 2400 lb (with 120 lb to the hundredweight). Most sources, however, do not state which unit has been used.

Prices and wages are expressed as £/s/d without decimal conversion.

Metric Conversion Table	
1 inch	25.4 mm
1 foot	0.3048 m
1 mile	1.609 km
1 lb	0.454 kg
1 cwt (120 lb)	54.48 kg
1 cwt (112 lb)	50.85 kg
1 ton (longweight)	1.089 tonnes
1 ton (shortweight)	1.017 tonnes

1 INTRODUCTION

‘The second manufacture in the kingdom’ was how the ironmaster John Crowley described the iron industry in 1717, acknowledging only the woollen industry as making a greater contribution to the nation’s wealth.[1] By the end of the century iron was an important industry in most of Britain’s coalfields and epitomised the new technological society of the industrial revolution. The industry was dispersed into several regions. It encompassed the smelting and refining of raw material, and the manufacture of a wide range of finished products. These included large-scale items such as engines and ordnance, and smaller items like nails, horseshoes and steel cutlery. Demand for iron exceeded domestic supply, however, and the import of wrought iron reached its peak as late as 1793.[2] Shropshire had become established as an important centre of ironmaking in the eighteenth century, a period chronicled and interpreted by numerous historians. Nevertheless, this is the first detailed study devoted to the history of wrought-iron manufacture in Shropshire, the main secondary branch of the industry after the smelting of iron ore.

Concentrating on a single branch of the industry requires a justification. Ironmaking was an identifiable trade by the eighteenth century, when its first national output statistics were compiled, although as a historical entity it has often been isolated from its close connections with other industries. For example, Nancy Cox has shown the close links between ferrous and non-ferrous industries in the period 1680-1720.[3] In the nineteenth century ironmaking companies expanded their range of interests. Many companies held large enough minerals leases to allow them to sell coal and to mine clay for brick and tile manufacture. This was a characteristic of Shropshire and other coalfields that has been documented in regional studies.[4] Ironmaking was also integrated with other trades consequent upon their products, notably railway and marine engineering. However it has been customary to study the history of iron manufacture by combining the smelting of iron ore in blast furnaces and its subsequent refining into wrought iron at forges as a single industry, and therefore excluding the manufacture of finished items. There are some justifiable reasons for this. It was these two branches of the trade that superseded the bloomery during a protracted period of change from the fifteenth to the seventeenth centuries. Smelting and refining were subject to innovations that offer a self-contained study of technological change in the industrial revolution. There is also a precedent in trade literature of the nineteenth century that treated the smelting and refining sectors as distinct from the manufacture of finished iron.

The tendency to integrate the study of forges with the supply of pig iron has relegated the relationship to the market for the finished product as a secondary issue. This approach has not captured the whole subject. There is potential to increase our understanding of the industry if due weight is also given to the eventual destination of the product. It will allow the forge trade to be understood more fully in its cultural and commercial contexts. The majority of Shropshire forges were either geographically or operationally separate from the blast furnaces that supplied them with pig iron. This was just as applicable to the nineteenth century as it was to the seventeenth. Even at the large integrated Shropshire ironworks like Old Park the forges were always managed separately from the blast furnaces and produced separate accounts.

Some justification is also needed for studying an important national industry in a county context. Nineteenth-century literature of the iron trade always acknowledged regional loyalties, while contemporary statistics compiled by or for the trade from the nineteenth century onwards always structured the data around specified regions, of which Shropshire was one. Shropshire's wrought-iron industry spans the sixteenth to the early twentieth century, the entire era of wrought-iron manufacture, and encompasses both coal- and charcoal-based industries. It has a large enough body of historical sources and archaeological evidence to facilitate detailed analysis. Shropshire therefore offers an ideal case study of an industry which underwent significant technological, economic and geographical changes over a period of three centuries.

1.1 Topography and trade of Shropshire

Shropshire is a varied county in its topography. Its main division is between the northern plain and the southern hills and dales, while the River Severn flows almost as a dividing line between the two. The River Severn was the most important influence on the trade of the county until the nineteenth century, allowing the development of important regional market towns such as Shrewsbury. It facilitated trade over a large area from mid Wales to the English Midlands and provided access to the ports of Gloucester and Bristol. The well-watered tributaries of the Severn provided power for numerous small local industries, especially the corn mill. Largely rural and agricultural in character, Shropshire's industries were concentrated upon small coalfields where suitable minerals were found. The largest and most important was the East Shropshire Coalfield, relatively small by the standards of the major British coalfields, only 10 miles (16 km) square. The River Severn passes through it near its south end. Some 15 miles (24 km) to the east of the coalfield is the Black Country, an area encompassed by Wolverhampton, Birmingham and Stourbridge, one of Britain's most important manufacturing districts in the industrial period, and with which much of Shropshire's iron trade would be associated.[5] In the south of the county are the Clee Hills, 5 miles (8 km) east of Ludlow, where important minerals such as iron ore, coal and building stone were exploited. This area also enjoyed proximity to the Black Country and indirect access to the River Severn.

The remainder of this chapter reviews previous historical and archaeological studies of the iron industry and states the principal aims of the thesis.

1.2 Early historians of the iron industry

Early historians of the iron industry, such as James Weale, Harry Scrivenor and John Percy, identified a 'modern' era of ironmaking that began with the widespread adoption of Henry Cort's puddling process in the last decade of the eighteenth century.[6] The earliest period of wrought-iron manufacture began with the adoption of secondary refining processes in the sixteenth century consequent upon the adoption of the blast furnace. Blast furnaces produced pig iron that required refining before it was made into malleable iron capable of working by smiths. Malleable iron was forged from a finery and chafery where charcoal was the fuel. The search for an alternative, cheaper and better means of forging iron using mineral fuel, of which puddling was the lasting solution, was a subject of much discussion in the nineteenth century and will remain high on the agenda of the present study. Both Percy and Scrivenor were writing in a period before Bessemer steel became established in the 1870s, coinciding with the decline of the wrought-iron industry in the last quarter of the nineteenth century and providing the final main period of manufacturing malleable iron. These periods can be summarised thus:

- The finery and chafery, based on charcoal fuel
- Early refining techniques based on mineral fuel
- Puddling and rolling
- Steelmaking by the Bessemer and open-hearth techniques

The first of these periods has traditionally been treated in a regional context, as in the pioneering studies of the Wealden and Furness iron industries, but the subsequent three have usually been conceived in a national context.[7]

1.3 Economic histories

Nineteenth-century historians chose technological development of the trade as the principal historical theme of the iron industry. Twentieth-century historians were just as preoccupied by technological change, but their concerns have broadened to encompass social, political and economic contexts. Thomas Ashton's *Iron and Steel in the Industrial Revolution*, first published in 1924, was arguably the beginning of modern scholarship in the history of the iron industry. Ashton placed Abraham Darby and Henry Cort as the pioneers of the modern iron and steel industry, in addition to engine manufacturers such as Boulton & Watt, but the iron trade did not prosper simply as a result of specific inventions.[8] War and peace in the eighteenth and early nineteenth centuries, the control of trade by means of combinations and family dynasties, and the impact of steam power in lowering costs of production, all made a significant impact on its economic development.

Ashton identified key events in eighteenth-century history that allowed the iron trade to flourish. These included the restrictions placed upon imports of high-quality Baltic iron and the attempts to control the production of iron in the American colonies. It became apparent to Ashton's generation that 'many of the more catastrophic process associated with the industrial changes of the eighteenth century were the result not of economic but political forces'.[9] The obvious example of this was warfare, because it boosted the demand for iron in conjunction with a decrease in overseas competition. The first great conflict that could be studied in this context was the Seven Years War (1756-1763), during which time numerous ironworks were founded in Shropshire, South Wales and Scotland. Those in Shropshire included Horsehay and Ketley, established by the Darby family and their associates. The opening of hostilities occurred just after Abraham Darby II was claimed to have found a way of making wrought iron from coke pig iron rather than charcoal pigs. Horsehay was specifically established to provide pig iron for forges in the Stour Valley, Worcestershire.

Other conflicts of the late eighteenth century also allowed the iron trade to prosper, including the American War of Independence (1776-1783) and the Revolutionary and Napoleonic wars with France (1793-1815). The latter coincided with the rapid adoption of the puddling process, although later historians have shown that the success of puddling was not as instantaneous as was once supposed and have corrected the omission from earlier studies of a coal-based process known as stamping and potting.

Ashton studied the British iron trade up to the end of the Napoleonic War in 1815. The later period, from the invention of puddling to its supersession by steel, has been surveyed more recently by Alan Birch.[10] Birch described the enormous rise in output of the iron industry in the nineteenth century, principally for civilian rather than military uses, and especially the demand for wrought iron during the railway boom years of the 1830s and 1840s. A greater range of factors was brought to bear upon the explanation of technological change than by earlier historians. It was pointed out that the major technological changes were invented by relative outsiders – neither Abraham Darby (coke smelting), Henry Cort, James Neilson (hot-blast smelting) or Henry Bessemer had much previous experience in the iron trade. The conservative culture of the trade meant that innovations were pioneered by newer firms, a fact that had long-term national consequences. For example, the early widespread adoption of puddling, in addition to vast mineral reserves that could be exploited comparatively cheaply, allowed South Wales to overtake Shropshire as Britain's largest producer of iron in the nineteenth century. This was equally true in the case of steel manufacture during the 1860s and 1870s, when newer firms with large capital resources had less capital invested in puddling, and were located more favourably with regard to the exploitation or importation of raw materials. Birch also considered earlier attempts to improve the puddling process by mechanisation, and resistance to them by workmen who were the indispensable component in what remained a manual operation. His main achievement was therefore to establish that the dynamic of technological change should be understood in economic, cultural and geographical terms, not simply as the product of isolated inventions.

The most influential recent work is Charles Hyde's *Technological Change in the British Iron Industry* (1977). His work studied the period 1700-1870, covering the combined time span studied by Ashton and Birch. An economic determinist, Hyde argued that the iron trade adopted new techniques when it was economical to do so, notwithstanding the influence of individual inventors and acknowledging geographical shifts. His conclusions with regard to the smelting sector have been modified by Philip Riden, who has shown that smelting with charcoal continued long after it was supposed to have been economically disadvantageous, but Hyde's evidence for the wrought-iron industry has been largely unchallenged.[11] Hyde based his arguments upon his own computations of the costs per ton of manufacturing pig and wrought iron, and comparisons with the price of imported iron. For example, in the latter half of the eighteenth century the price of Swedish bar iron experienced a generally steep upward trend, from about £13 per ton in 1750 to a peak of over £26 per ton in 1795.[12] The high cost of imported iron was partly countered by the rising cost of manufacturing bar iron in Britain. Hyde attempted to quantify the substantial increases in the average variable costs of producing wrought iron using charcoal during the second half of the eighteenth century. The obvious need to reduce fuel costs prompted the experimentation with new techniques using mineral fuel in place of charcoal, the most successful of which was stamping and potting. Hyde demonstrated that stamping and potting was a widely used technique in the Midland iron industry. It was argued that its success was based firmly on its delivery of significant cost reductions to the forge masters. A measure of this success was the fact that British bar iron output rose from 18,800 tons in 1750 to 32,000 tons in 1788. In the same period British forge masters increased their share of the domestic market in wrought iron from 45% to 52%.[13] Moreover, the widespread use of coke pig iron over charcoal pigs allowed a corresponding growth in the smelting sector in this period.

Stamping and potting might have continued as the principal method of converting pig to wrought iron were it not for the subsequent invention of puddling. Hyde used account books to calculate average variable costs for producing wrought iron by puddling and stamping and potting. Both methods were in use at Cyfarthfa in Merthyr Tydfil in 1787. Hyde calculated that at this time puddled iron cost £12.12 per ton compared with only £10.92 per ton by stamping and potting. After considerable investment at Cyfarthfa by Richard Crawshay, puddling emerged as the most cost-efficient process and was also able to produce iron of high quality. In 1796-7 average variable costs of puddled iron were calculated at £10.71 per ton at Cyfarthfa, compared with £12.25 for producing stamped iron at Horsehay.[14]

British forge masters were also able to profit from the Revolutionary and Napoleonic wars, because the tariff policy pursued by the government kept wrought-iron prices artificially high and drove foreign competitors from the market. Hyde described the period after 1815 as 'the mature iron industry', a period that has attracted comparatively little interest because in terms of technological innovation it was a quiet period. The trend established during and continuing after the French Wars was for greater concentration of production into increasingly larger units, and for those units to be integrated with smelting operations. The traditional finery and chafery, geographically separate from the blast furnace, had all but disappeared. One of the few changes in forge practice before the 1870s was the adoption of ‘pig boiling’. Introduced by Joseph Hall of Tipton, Staffordshire, this variation of the puddling process obviated the need for a preliminary refining stage and therefore allowed a significant cost reduction. Other secondary innovations included the adoption of steam-powered hammers, three-high mills through which iron could be passed from either direction, and reclamation of waste puddling furnace heat to raise steam. During the nineteenth century the time lag between the invention of new methods and their widespread adoption became progressively shorter as knowledge was disseminated over a wider area in a shorter space of time. It occurred in the wake of initiatives to improve industrial performance, in the form of trade exhibitions, the growth of technical literature and institutions such as the Iron and Steel Institute, founded in 1870. This is significant because whereas it was possible to talk of a Shropshire iron trade in the eighteenth century, it may only be possible to talk of a British iron trade by the late nineteenth century.

Hyde’s central thesis was that the adoption of new techniques was a function of their profitability. This accounted for the rise of puddling in the last decade of the eighteenth century and the relatively rapid decline of wrought iron in the late nineteenth century in the wake of steel manufacture. The general thesis has been challenged in a recent case study by Laurence Ince of the Stour Valley forges, Worcestershire, an important centre of wrought-iron manufacture in the eighteenth century.[15] Ince accounted for the sudden appearance of coke-smelted pig iron in the 1750s as a qualitative difference in the iron rather than the simple cost advantage proposed by Hyde. In particular, he showed that in the early eighteenth century when coke was pioneered as an alternative fuel to charcoal, the pig iron it yielded was too brittle to be used for conversion to wrought iron. Instead it was used for cast iron products. But in the 1750s forges operated by the Knight family in the Stour Valley bought coke-smelted pig iron from the new blast furnaces in the East Shropshire coalfield. Coupled with indirect evidence for improvements in the quality of bar iron, Ince reiterated an earlier case that quality of iron was at least as important as the cost of production as a factor determining technological change.

Hyde's thesis can be challenged in other important ways. He paid little attention to the market for wrought iron, assuming a national market for a uniform product. In fact iron was sold in various grades and in various forms such as bars, rods and plates. Calculations for the cost of wrought-iron production are therefore misleading if they do not take account of these factors. Even from the early eighteenth century iron was graded into what can be termed common iron and best iron. Transportation was also an important factor in the cost of production. Some ironmasters included a price for delivery to a certain location in their prices. For example, Shropshire iron was traditionally priced for delivery to Bewdley on the River Severn in Worcestershire, superseded from the 1770s by nearby Stourport. The cost of such transportation, and to the eventual destination beyond, was a significant factor in the market price of iron and should therefore have been considered in what is essentially a theory of the market place.

Hyde's economic approach has, however, influenced more recent studies of the industry. The most relevant regional study is of South Wales by Atkinson and Baber, but this relies heavily on tonnage of iron shipped down the Glamorganshire and Monmouthshire Canals from the heads of the South Wales valleys.[16] The output statistics it contains are misleading for the same reason that Hyde's figures are misleading: they do not account for the grade or type of iron shipped, and therefore do not take sufficient account of the complexities of the market and of production.

In addition to the economic history of the industry, two other approaches have contributed to the present understanding of the wrought-iron trade. These are technology and workplace culture.

1.4 Technological histories

Hyde demonstrated the importance of stamping and potting in the late eighteenth century, partly facilitated by the work on the transition to puddling by Morton and Mutton.[17] The Morton and Mutton approach was decidedly technical. Twentieth-century knowledge of the chemical processes involved in refining pig iron was transposed to eighteenth-century techniques. For example, Morton and Mutton explained the two stages in the stamping and potting process as 'desiliconising' and 'decarburising', which they assumed were the same as refining and puddling (replacing the earlier term fining) that superseded them. It therefore presented stamping and potting as a stepping stone towards puddling. The problem with this approach is that it assumes that progress follows a linear path and that past techniques were a more primitive version of contemporary techniques. At its worst it introduces a patronising tone to the debate, which surfaces in the desire of Morton and Mutton to award Cort 'great credit' for his invention of puddling.[18]

The technical approach to historical metallurgy can yield different conclusions, however. Reginald Mott questioned the Morton and Mutton scheme whereby puddling was the result of a cumulative development of the refining techniques in the second half of the eighteenth century, but his has been a minority voice.[19] The model of technological change represented by Morton and Mutton confers a role in the invention of puddling to the Cranage brothers of Coalbrookdale, whose work is described below.[20] By contrast, Mott argued that Cort was a true original whose technological achievements have been underestimated – hence his subtitle 'the great finer'. Mott returned to a theme championed by nineteenth-century historians, namely that a technological watershed required a creative genius. The linear nature of technological progress remained unchallenged, and the application of technology involved workmen performing under the technical direction of what by the twentieth century might have been classed as an engineer. It is this theoretical structure that informed Mott's study of the Horsehay Ironworks in Shropshire, discussed below.

1.5 Cultural histories

The economic and technical debates have focussed attention on the ironmasters and a handful of innovative individuals. But the recent work of Chris Evans has suggested that this is too rigid an approach to understanding technological change. Evans has studied workplace culture in Merthyr Tydfil in the period 1750-1815, the very period that saw its rise to prominence in the iron trade with the pioneering of the puddling process.[21] The study was made possible by the special nature and quantity of primary sources available for the local ironworks, principally correspondence relating to the Dowlais and Cyfarthfa Ironworks. In his study, Evans introduced cultural factors in technological change. For example, he argued that new techniques could be introduced more easily in a place like South Wales without a long tradition of ironmaking, whereas they would be more difficult to adopt in established regions like Shropshire where more resistance to new methods might be expected. This expanded the argument advanced by Birch that newer firms were better placed to exploit new innovations. He has also highlighted the special status of forgemen in contemporary ironmaking, pointing out that fining was the most difficult of the metallurgical skills. Whereas Morton and Mutton could confidently claim that the Cranage brothers made good wrought iron as long as they used low-silicon pig iron, Evans eschewed such scientific certainties.[22] He pointed out that forgemen judged the quality of iron not by chemical analysis but by its appearance in the hearth and consistency and shortness under the hammer. A consequence of this was that ironmasters had to rely on their workmen to maintain quality, and that workmen could be pushed only with difficulty into accepting changes they disapproved of. In the light of this, some previous economic arguments have been undermined and Hyde's range of explanation of technological change has come to seem too narrow.

There is a precedent to Evans's approach in Birch and in Keith Gale's study of the Black Country iron industry. Beginning in the 1930s, and continuing through the 1950s and 1960s, Gale made first-hand accounts of forge techniques on the brink of their total demise, mainly in the interests of posterity.[23] In particular he recorded work at the puddling furnace in 1951-2, and provided additional information on the tools used by the workmen and on the operation of the rolling mills.[24] Gale's glossary of terms is similarly an account of ironworking from the factory floor, the recording of which was an end in itself.[25] Less ambitious than Evans, Gale did not attempt to link workplace techniques with the economic performance of the industry. Nor was the possible significance of process recording for understanding the eighteenth and nineteenth centuries critically examined. Such an approach should, however, be brought to bear upon the Shropshire iron industry, should sufficient sources be available, as in Shropshire the significance of a handful of individuals has dominated historical writing about its iron trade.

1.6 Previous studies of the Shropshire iron industry

The literature of the Shropshire iron trade is understandably biased toward the Darby family and their associates at Coalbrookdale. The family has an assured place in the history of the iron industry, largely due to the pioneering of coke smelting by Abraham Darby I (1677-1717) from 1709 and the erection of the Iron Bridge across the River Severn by Abraham Darby III (1750-1789) in 1779. Shropshire is also considered to have been at the forefront of the iron industry in the eighteenth century, driven largely by the Darby and Reynolds families, the leading partners in the Coalbrookdale Ironworks.

Most of its successes were in the smelting and casting branches of the iron trade, but Coalbrookdale is associated with two important events in wrought-iron manufacture. The earlier was the production of wrought iron from coke-smelted pig iron in the 1750s. Previously coke-smelted pig iron had been deemed as unsuitable for wrought iron and was therefore confined to cast iron products, leaving wrought iron to be forged from pig iron smelted with charcoal. The credit for this important development has been ascribed to Abraham Darby II (1711-1763) in about 1754. The second event has already been referred to – the patent taken out in 1766 by two Coalbrookdale workmen, Thomas and George Cranage, for producing wrought iron in a reverberatory furnace.

The claims made for Abraham Darby II and the Cranage brothers have been difficult to consider critically owing to a paucity of primary source material. In fact their standing largely rests upon the claims made by members of the Darby and Reynolds families themselves, with little independent corroborative evidence. Both families were Quakers and have featured prominently in studies promoting the concept of enlightened Quaker industrialists.[26] One of these Quaker historians, Arthur Raistrick, wrote his seminal study of the local iron trade, which has a marked tone of deference towards the Darby family, on the back of a more general study into Quakers in industry.[27] This strain of deferential writing originated in the nineteenth century with authors such as Samuel Smiles and has been reiterated at the end of the twentieth century by Emyr Thomas.[28] The crucial evidence relating to the innovations of Abraham Darby II is supplied in an undated letter by his widow Abiah Darby, written c1775. In it she claimed that c1749-50 her husband had successfully used coke pig iron for making wrought iron and that the forge master Edward Knight urged Darby to acquire a patent for it. Unfortunately, as Raistrick conceded, there are no Coalbrookdale accounts for the period 1748-54 that could have lent verification. However the subsequent years saw the establishment of blast furnaces at Horsehay and Ketley that could be shown to have sold coke pig iron to Knight's forges in the Stour Valley, thus appearing to lend credence to the claim.[29]

Evidence for the adoption of the Cranage method is also principally reliant upon a letter, in this case written by Richard Reynolds in 1766 to Thomas Goldney. Reynolds (1735-1816), who was manager of the Coalbrookdale works at the time, described the success of trials and the intention of acquiring a patent.[30] Raistrick assumed that the process was used at Coalbrookdale until puddling superseded it, presenting the development of the industry as a series of forward leaps characteristic of his contemporaries. Reginald Mott and others could show that the Cranage method was not as successful as Raistrick believed, but some contemporary evidence emerged to show that the Cranage method was in use, or at least undergoing trials, at Coalbrookdale in 1767.[31] The description of the Cranage process by Joseph Banks in that year is one of the earliest of several accounts of ironmaking at Coalbrookdale in the late eighteenth century. Reginald Mott's study of the Coalbrookdale Company's Horsehay forges showed that stamping and potting had been practised from c1784 at Horsehay and other local forges.[32] He used a draft history of the iron industry written by James Weale together with the Horsehay Forge wages book for the years 1796-8 that document a transition to puddling. Mott devoted little attention to the company's other forge, the Upper Forge at Coalbrookdale, although this has been the subject of detailed archaeological investigation.[33]

Other Shropshire forges have received less individual attention. Snedshill forge has been described in a general study of the Lilleshall Company.[34] The only other forges to have received any significant individual attention are those of Hampton Loade and Eardington, partly on the basis of surviving archaeological evidence. Stamping and potting, puddling, and finally manufacture of charcoal iron were undertaken at these forges, which have been interpreted as outside the mainstream of the nineteenth-century iron trade.[35] Both are examples of independent forges that characterised wrought-iron manufacture until the end of the eighteenth century. Another is Wrens Nest forge, operated by John Wright and Richard Jesson, the West Bromwich ironmasters who had obtained a patent for stamping and potting in 1773. Archaeological evidence in the form of fragments of clay pots has been recovered from the site.[36] A general survey of early forges has been provided by Trinder, who has emphasised proximity to water power in their location, and has highlighted the forge at Tern as one of the earliest efforts at integrated manufacture, the forge combined as it was with a brass mill.[37]

Barrie Trinder has provided a survey of coal-based technology in the context of an economic and social history of the East Shropshire coalfield.[38] The importance of the Coalbrookdale works in the second half of the eighteenth century is again stressed, as is its relative decline in the nineteenth century. However, although the Shropshire iron trade declined in relative terms, both in share of the national output and in technological supremacy, its output in real terms rose during the first half of the century.[39] The large forges of this period, particularly Horsehay, Ketley, Old Park and Snedshill, are all considered within the context of larger integrated ironmaking concerns that included the exploitation of raw materials. In economic terms, a broad picture emerged whereby 'before 1790 the [East Shropshire] coalfield had been at the centre of an economic region centred on the Severn. After 1815 it was an outlying part of an economic region centred between Birmingham and Wolverhampton.'[40] It is also reasonable to question whether during the nineteenth century the Shropshire iron trade can be seen as part of the Midland ironworking district centred on the Black

Country. This is certainly how Birch interpreted it, citing evidence that Staffordshire had better wages and lured the best workmen away from Shropshire.[41]

Trinder's study has remained the standard work on the coalfield, and has provided the context for more recent work, notably the sections on the iron industry of the East Shropshire Coalfield in the *Victoria County History*.[42] But the work says comparatively little on the wrought-iron trade, leaving scope for the fuller understanding that the present study intends to provide.

1.7 Aims and methods of the present study

The aim of the present study is to identify particular causes of change rather than follow a general model of growth-maturity-decline. It examines specific reasons why the Shropshire forge trade developed and changed as it did, then compares it with national trends. Much of the literature on Shropshire's iron trade has been focused on the Coalbrookdale partners. But the iron trade was larger than Coalbrookdale, in both physical and metaphorical senses. Meanwhile the heroic exploits of the Darby and Reynolds families, if that is what they were, did not represent the experience of most ironmasters, nor of iron workers in Shropshire. This study therefore seeks to re-establish the wholeness of the Shropshire forge trade as the essential unit of analysis. In order to do this it must study the economic and technological developments of the trade within a broad cultural framework that encompasses the world of ironmaster, workman and merchant. The world of the merchant is particularly significant as it has been generally missing from previous studies of the iron industry. Neither the economic, technical or cultural approaches has given adequate consideration to the significance of the market in technological change. The market for Shropshire iron has mainly been discussed indirectly in the context of Midland manufacturing industries.[43] Hyde took for granted that the market was a passive receiver of new technology but it is an issue that must be addressed more critically. This is equally the case in the matter of regional distinctiveness, where again a national norm has been assumed rather than demonstrated.

The ultimate goal of such an approach is to prompt a re-examination of technological change in the iron industry and the methodology of studying it. Both Hyde's economic determinism and Morton and Mutton's technological model structure the history of ironmaking around individual technological breakthroughs. Both imply a linear development that has been tinkered with by other historians but scarcely challenged; and both imply that change was precipitated by events rather than processes. Gradualists have overtaken revolutionaries in most branches of industrial history, but the iron industry has largely escaped such reassessment.[44] The aim of the present study is therefore to apply close critical analysis to assumptions that lie behind the history of the industry.

1.8 Sources

The most important primary sources to be used in the study are nineteenth-century company and family documents. This is the first study to make comprehensive use of the Botfield family papers, one of the most important collections of material relating to the East Shropshire Coalfield. Documents relating to the family's forges at Old Park and Stirchley, including a large body of correspondence and wages accounts, constitute the largest single collection of material relating to the Shropshire forge trade. By itself, therefore, the Botfield Collection provides an opportunity for gaining a fresh perspective on the subject, as well as bringing a large corpus of information into the debate. Other primary sources that have been used in the studies discussed above will need to be revisited in the light of the specific aims of the thesis. Of these, sources relating to the Horsehay Ironworks have been used by Mott and Trinder, but this study will provide a more detailed analysis of the last decade of the eighteenth century than previous work.[45] Similar accounting records exist for the Eardington and Hampton Loade forges. The workforce and operational structure of the industry can be studied over a long period by comparing wages accounts from the 1790s at Horsehay with those of the Old Park and Stirchley forges in the 1830s and 1840s. Archaeological studies of Shropshire have less of a role to play, because of the paucity of excavated evidence and the limited upstanding remains. The present study is, however, an opportunity to place recent work at the Coalbrookdale Upper Forge into a more detailed and wider context.

A number of recent publications include new information on the Shropshire forge trade that has not as yet been integrated into the general study of Shropshire. These include R.R. Angerstein's travel diary of the 1750s and the La Rochefoucauld brothers' tour of 1785, both of which provide important new information on technology in the eighteenth century.[46] Other publications have provided fresh perspectives with which to review our understanding of Shropshire, such as Evans' work on Merthyr Tydfil discussed above and J.R. Harris's work on technology transfer.[47] To justify a regional study comparative assessment must be made with other regions, coverage of which is uneven. Nevertheless it is possible to investigate the regional character of the forge trade by comparison with studies of the Black Country, Cleveland, Furness, Scotland, South Wales and the Weald.

1.9 Structure of the thesis

The subject matter is to be treated chronologically. Chapter 2 will describe the establishment of the forge trade in Shropshire during the seventeenth century, and examine both sources of pig iron and the destinations of finished bar iron. Comparison will be made with other ironworking districts and especially with the iron industry of the Midlands. The following chapter discusses the technological developments in the latter half of the eighteenth century, all of which were based on techniques using mineral fuel in place of charcoal. It will offer a critical reassessment of the influence of Abraham Darby II and the Cranage brothers. There has been no previous study that traces the establishment of the puddling process in Shropshire, which is the subject of chapter 4. This chapter also discusses the concurrent decline of older methods. The establishment of puddling also offers the most convenient opportunity for an examination of iron industry culture, specifically the external culture of the market and the internal culture of the workplace. These are the subject of chapters 5 and 6. Fortunately the period 1790-1830 is the period for which the greatest quantity of documentary sources is available, which will be used in conjunction with wages books dating from the 1830s to the 1850s. Observation of the everyday workings of the trade is intended to inform the wider debate on the significance of cultural and commercial factors in technological change. In particular, dialogue between ironmasters and merchants and manufacturers of finished iron is intended to enlighten this previously neglected subject.

The period after 1815, by which time puddling had become well established, saw no further major technological advances but there was significant growth in the industry that is covered in chapter 7. Chapter 8 describes the influence of the railway on the location of forges and access to markets. Attention will be given in chapter 9 to how Shropshire forges responded to the emergence of steel and therefore whether the decline of Shropshire forges was principally a consequence of obsolete technology or changing markets. Comparison with other ironworking districts, with particular attention paid to the market for their iron, will greatly assist this. A concluding chapter will suggest a new approach to technological change that can be adopted for other ironmaking regions, as well as adding to our understanding of what forces act for or against change.

2 THE SHROPSHIRE FORGE TRADE TO 1750

This chapter describes the transition from a single direct process of smelting, known as the bloomery, to the separated processes of smelting and refining in the blast furnace and forge. It then describes the development of the Shropshire forge trade to 1750 and places it into several contexts. These include the relationship of Shropshire forges to earlier bloomeries and the relationship between forges and blast furnaces. The source of pig iron for forges is particularly important for the light it throws upon the management and market structure of the forge sector. Given the eventual shift to the coalfield in the nineteenth century, it will also be important to establish and interpret the geographical character of the finery forges. This must account for the availability of water power and of fuel.

It will be essential to consider these themes within a regional and national context, not least because ownership and management was not confined within county boundaries. As the ultimate destinations of Shropshire bar iron were not local, the market must also be examined in a wider context. This in turn raises the important question of whether the forge trade of the seventeenth and eighteenth centuries should be seen as an homogenous national industry, or as a series of discrete regional industries.

2.1 Technology

Until the late medieval period in Britain iron was refined in a single direct process at a bloomery. Iron ore was smelted in a charcoal-fuelled furnace where each smelt yielded iron in the form of a *bloom* that was hammered to squeeze out the residues of slag within it. In a blast furnace, however, iron ore was charged into a tall stack inter-layered with charcoal and limestone (used as a flux) and yielded molten iron. The iron was run out into moulds prepared on the floor of the casting room, usually in the form of a line of ingots known as pigs. Alternatively it was cast into moulds to form finished products such as firebacks or cannon. Pig iron has a carbon content of 3-4%, making it too brittle to be malleable under a hammer, and it consequently required further refining to produce bar iron that was sold to smiths for working up into finished products. The finery and chafery forged wrought iron, which in commercial terms was chemically pure, and was capable of being shaped by hammer or welded.[1]

The technology of the finery and chafery was relatively simple. The complex aspect of refining was the manipulation of the iron by workmen. What is known of the process from contemporary descriptions is therefore concerned with the general principles rather than communicating the workman's virtuosity.[2] The finery was an open hearth fuelled with charcoal (figure 1). (Coal was unsuitable for refining pig iron because it contained sulphur which would have contaminated the metal and made it brittle.) Pig iron was melted in a bath of slag and was kept in motion by stirring with an iron bar. This ensured that the metal was subjected to a blast of air, provided by water-powered bellows, that burned out the carbon, a process known as decarburisation. The skill of the workman was ensuring even decarburisation of the iron and judging when the iron was ready for hammering. The iron was removed and taken to a water-powered tilt-hammer. Repeated blows removed much of the slag trapped in the interstices of the metal, a process known as *shingling*, and shaped the iron into a *bloom* (figure 2). The iron required several heats before it was judged sufficiently refined to be sent to the chafery. The chafery was similar in design to a finery but had a larger hearth. The iron was brought to a white heat, sufficient for it to be drawn into a bar under a hammer, the skill of the hammerman being to draw a long bar to an even thickness.

Most finery forges had two water wheels, one to operate the finery bellows, and another working both the chafery bellows and the tilt-hammer. Availability of water was therefore essential and influenced the relationship between blast furnace and finery. As outlined below, some sixteenth- and seventeenth-century forges were built in close proximity to blast furnaces. Since blast furnaces also needed water power to work the bellows, such an arrangement was only possible in places where there was an ample water supply, or where furnace and forge operated in relay. However, in cases where the iron was allowed to cool at the end of one process and needed to be re-heated before the next process, transport of semi-finished iron was permissible and logical. Geographical separation of finery and furnace was a natural consequence of this. Equally, the finery and chafery hearths could also be geographically separated if necessary.

Two more specialised branches of the forge trade – steel manufacture and slitting mills producing rods for nail making – have some relevance to Shropshire and so are described here. Steel has a low carbon content, between 0.25 and 1.5%. Its combined qualities of hardness without brittleness made it particularly important for hardening the edges of tools. Steel was principally manufactured by prolonged exposure of wrought iron to carbon, in the form of charcoal, in conditions of intense heat, and was consequently expensive to produce. The process was known as cementation, resulting in an alloy known as blister steel.[3]

Nails were forged from long rods formed in slitting mills. A slitting mill was a type of rolling mill where the roll was fashioned with separate parallel grooves (figure 3). A bar, hammered or rolled to a wide, flat section was passed through the mill, and was slit into a number of thin rods of square section. The earliest-known British slitting mill was erected in 1590 at Dartford, Kent. The earliest Midland slitting mill was built c1611 at Cannock Wood, Staffordshire.[4] Slitting mills were comparatively cheap to build and, because the iron was only heated sufficiently for it to be malleable, it was possible to use coal instead of charcoal.

2.2 Development of the forge trade in Britain

By the early eighteenth century the principal districts where forges were concentrated were the Midland counties of Staffordshire, Worcestershire, Shropshire and Warwickshire; the Sussex and Kent Weald; the Forest of Dean and Monmouthshire; and Yorkshire and Derbyshire. Of these, the Wealden district had long been in relative decline, although in the sixteenth century it had been the region where the technology of blast furnace and forge had become established in Britain.

From the late medieval period bloomeries had colonised sites where water power was available and similar criteria determined the location of blast furnace sites.

Bloomeries used water-powered hammers, while their furnaces were not dissimilar to finery hearths. Bloomeries were therefore suitable for conversion to finery forges and employed workmen whose skills could be adapted to the new technology.

The blast furnace originated in the early medieval period but arrived comparatively late in Britain. The first blast furnace in Britain was built in 1496 at Newbridge in the Ashdown Forest district of the Weald. It was built on the site of an earlier bloomery and was constructed by French workmen. Accounts and an inventory dated 1509 show that the furnace worked in conjunction with a finery and chafery. By 1520 there were still only two blast furnaces in the Weald, as well as numerous traditional bloomeries, but by 1548 there were fifty-three furnaces and 'iron mills', all in Sussex, employing a high proportion of immigrant workmen, mainly from the Pays de Bray in France.[5] By 1574 the blast furnace was numerically superior to the bloomery: there were fifty-two blast furnaces and fifty-eight finery forges, the industry having now expanded into Kent and Surrey.[6] From the second half of the seventeenth century the Weald concentrated upon cast iron wares, and maintained its position as the chief producer of ordnance until the 1770s.[7] The seventeenth century was nevertheless one of protracted decline. The Weald was said to have had thirty-six furnaces and forty-five forges in 1653, a small but real contraction from the previous century.[8] The list of forges in England and Wales compiled c1715 show only thirteen forges in Kent, Surrey and Sussex, fewer than in Shropshire.[9]

The Forest of Dean possessed some of the finest haematite ores in Britain, but the blast furnace did not supersede the bloomery here until the seventeenth century. Three blast furnaces had been set up near Dean's woods in the late sixteenth century. Subsequently four blast furnaces were erected in the Forest after 1612 by William Herbert (1580-1630), the Earl of Pembroke, and became known as the King's Ironworks. Three of them – Lydbrook, Parkend and Soudley – supplied a finery forge built downstream of the furnace.[10] Subsequent forges were mostly separated from blast furnaces and by the 1749 Gloucestershire had eight finery forges, including three at Lydbrook.[11] Neighbouring Monmouthshire also saw the development of the indirect process from the late sixteenth century. It was also here that one of the earliest instances of specialisation in the secondary iron trades was developed. Wire was an indispensable component of wool cards, and was therefore required for one of the staple British industries. The earliest iron wire mill was erected in 1566-7 at Tintern in the Wye valley and a second was built in 1607-8 at Whitebrook, also in the Wye valley.[12] Monmouthshire had seven finery forges by 1749, including two at Tintern.[13]

Blast furnaces were introduced into the ironworking district of South Yorkshire and North Derbyshire in 1573-4. During the seventeenth century ownership of furnaces and forges became concentrated into the hands of a group of gentry ironmasters, notably the Spencer and Cotton families. By the second decade of the eighteenth century there were four blast furnaces in Derbyshire, six in Yorkshire, with four and nine finery forges respectively, a combined figure lower than Shropshire.[14]

In the iron industry centred upon Furness in south and west Cumbria the bloomery remained in use throughout the seventeenth century. The first blast furnace in the district, at Cleator, was built in 1694. Eight blast furnaces were built in the period 1711-48, with much of the pig iron sent to local forges. Of these, excavation of Stony Hazel forge suggested that a finery hearth had also been used as a bloomery, demonstrating the close connection between bloomery and finery processes and skills.[15] It has also been argued that the bloomery in seventeenth-century Cumbria derived much of its technology and equipment from the finery forges in the Weald and Forest of Dean.[16]

Blast furnaces appeared in the Midland counties of Staffordshire, Worcestershire and Warwickshire from c1560, and in the seventeenth century forges were built across a wide geographical area in the Midlands and the England-Wales border region. The Midland region was concentrated in the Black Country. There were four blast furnaces, twenty-one forges and numerous slitting mills in Staffordshire and Worcestershire in the second decade of the eighteenth century.[17] The densest concentration of forges in the area, and in Britain, was in the Stour Valley for 12 miles (19 km) upstream of its confluence with the River Severn to Stourbridge.

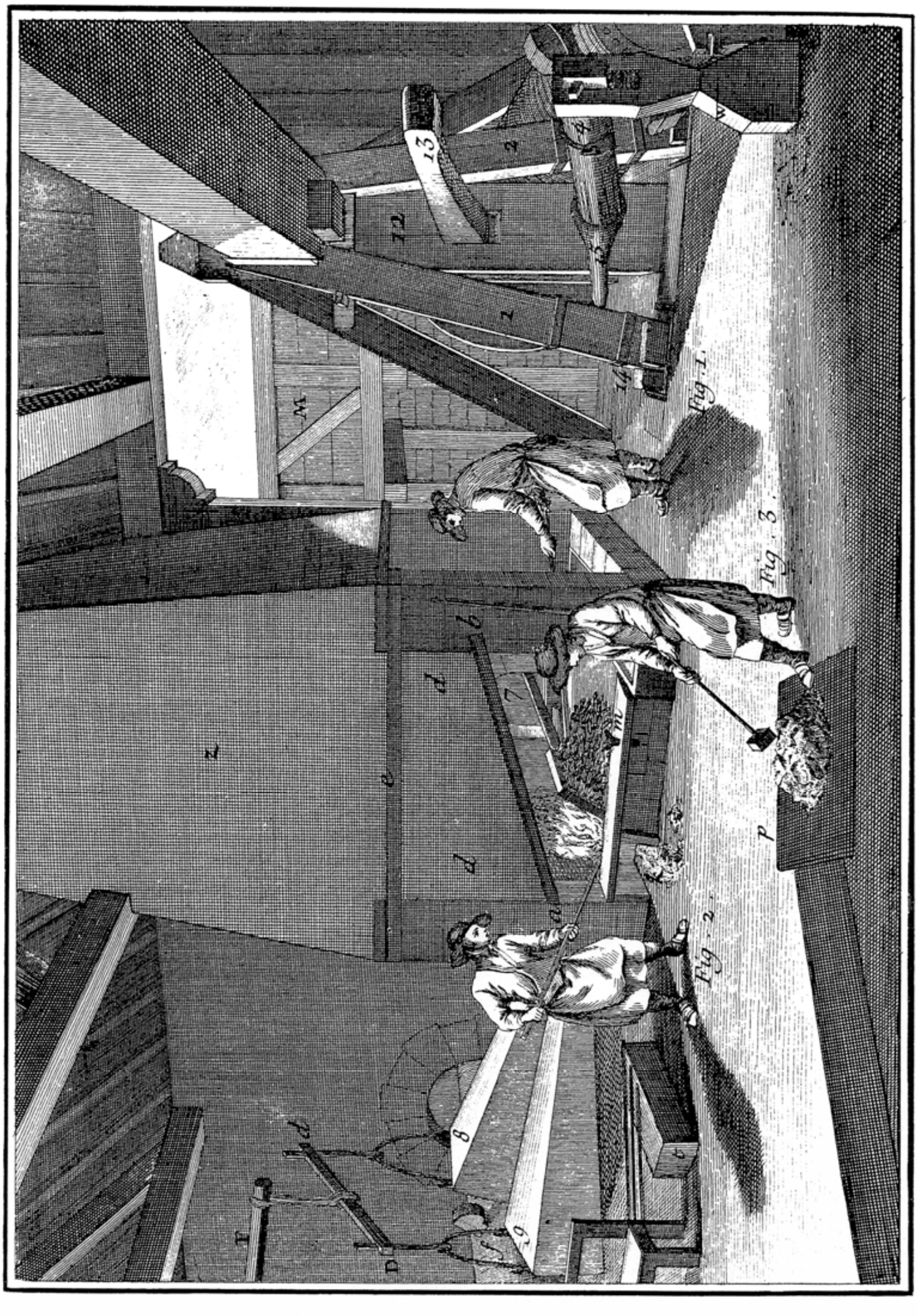

Figure 1 An eighteenth-century finery, from Diderot's *Encyclopédie*.

The furnace is fanned by a pair of bellows on its left side. Pig iron is fed from the rear. When the iron is taken from the furnace, it is first beaten with a sledgehammer to remove slag and to shape it sufficient for it to be placed under the forge hammer.

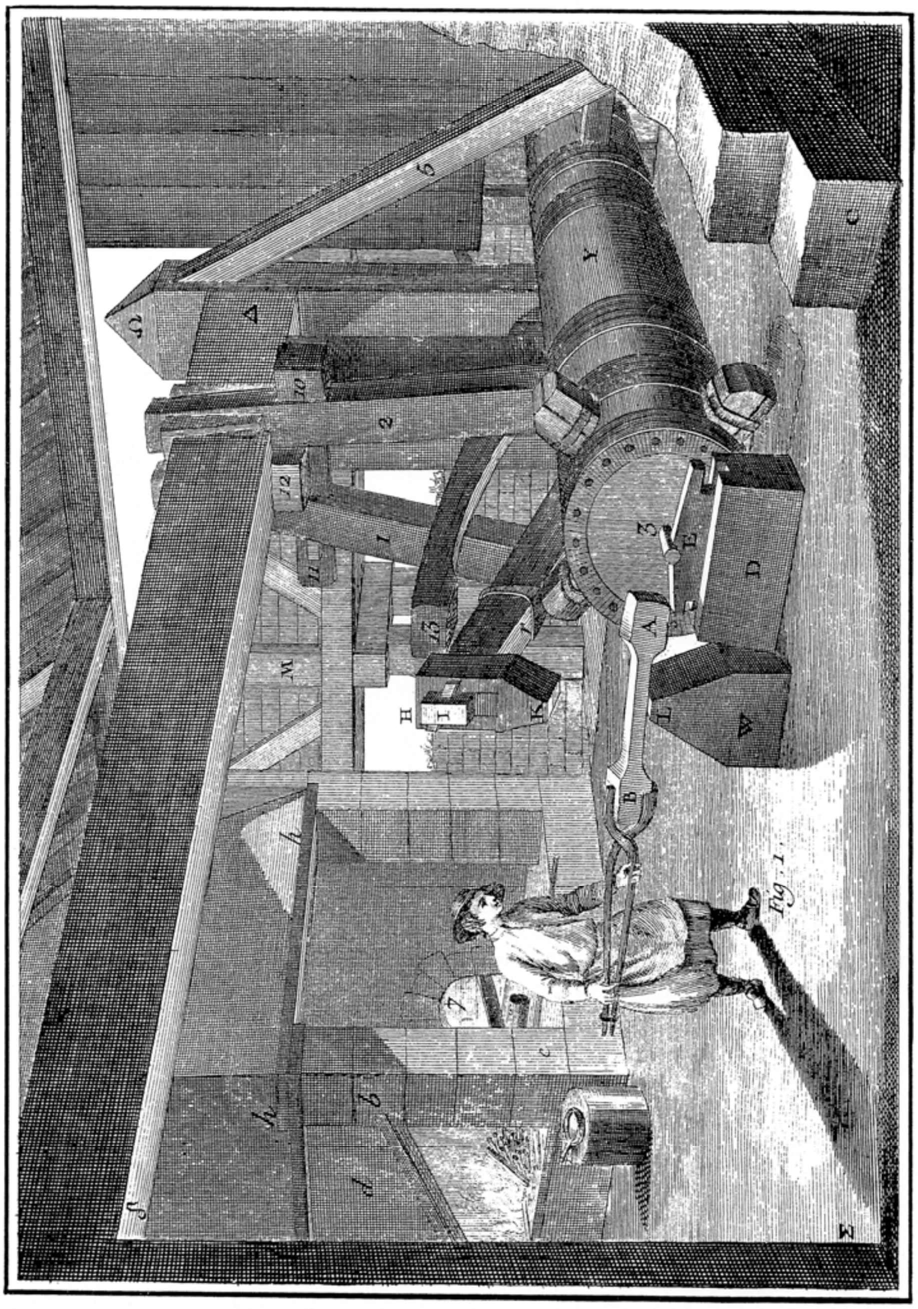

Figure 2 An eighteenth-century forge hammer, from Diderot's *Encyclopédie*.

Iron from the finery is shingled to form a bloom. The forge hammer is water-powered. On the right is the shaft, or axle tree, turned by the waterwheel, which has cams attached at its end. The cams lift the hammer head, allowing regular hammer strokes.

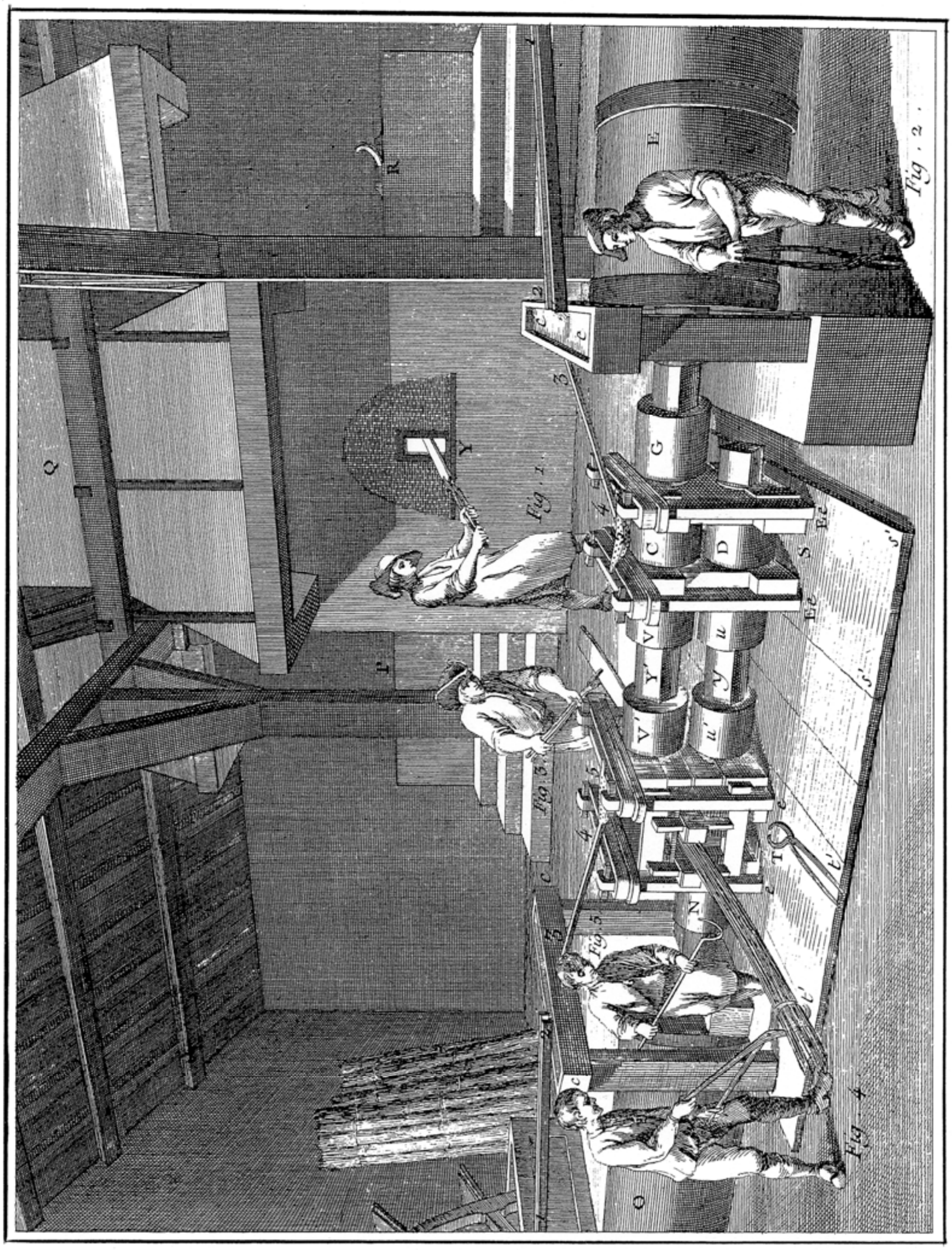

Figure 3 An eighteenth-century rolling and slitting mill, from Diderot’s *Encyclopédie*.

Iron is taken from the furnace, at the rear of the picture, passed through the rollers on the right, to form a long thin bar, which is then passed through the slitter to form a bundle of rods.

2.3 Development of blast furnaces and forges in Shropshire

Evidence for Shropshire demonstrates a similar continuity from the direct to the indirect process that has been observed elsewhere in Britain. Shropshire ironworks of the sixteenth and seventeenth centuries are shown in figure 4. In 1564 a bloomery at Lizard, on the River Worfe near the Staffordshire border, was converted to a finery forge, supplied with pig iron from a blast furnace at nearby Shifnal, both owned by George Talbot (1528-90), the Earl of Shrewsbury.[18] Shifnal furnace remained in blast until c1604. By the mid seventeenth century Lizard was operated by John Turner, a Staffordshire ironmonger, who built a blast furnace at Lawton in Cheshire in 1658, from where Lizard was henceforth supplied with pig iron.[19]

At the south edge of the East Shropshire coalfield, a blast furnace was erected between 1609 and 1618 at Willey by the Lacon family, and was subsequently owned by John Weld.[20] Iron-rich waste from a former nearby bloomery was used in the charge for the blast furnace, a practice that was common in the Forest of Dean and Weald. On the north side of the coalfield was a bloomery at Wombridge, which was probably converted to a blast furnace by 1634 and was leased to Thomas Foley in 1663.[21] There was also a bloomery in Lilleshall parish in the sixteenth century, but there is no evidence of a later blast furnace or forge.[22]

At Coalbrookdale a bloomery was recorded in 1536 and again in 1544.[23] Its exact location has not been ascertained, important because at Coalbrookdale the Dale brook, a tributary of the Severn, provided water for a succession of forges by the end of the seventeenth century, namely Great Forge, Upper, Middle and Lower Forges. The bloomery must have occupied the site of one of these forges, and perhaps one of the forges mentioned in eighteenth-century leases was a disused bloomery. The earliest secure date for a blast furnace at Coalbrookdale is 1658. It was built next to the Great Forge, which may have ceased working then or soon after, as both furnace and forge would have relied on the same reservoir to work their respective waterwheels.[24] In 1718 it retained a forge hammer, however.[25] Of the other forges, the Upper Forge was a finery and chafery and its earliest known date is 1668. The Middle Forge was converted to a mill for boring cast iron steam engine cylinders in 1734. The Lower Forge was a secondary forge used for manufacturing frying pans from as early as 1660.[26]

In South Shropshire, the earliest blast furnaces were erected at Cleobury Mortimer on land granted in 1563 to Robert Dudley (1532-88), later Earl of Leicester. Two blast furnaces, subsequently known as Cleobury Park and Furnace Mill, had been built by 1576. Both were formerly bloomeries. A finery forge was let to Stephen Hadnall in 1571, and another to John Weston in 1576, both on the River Rea and subsequently known as the upper and lower forges. A third forge was built in 1597 by Richard Cook at Boraston on the River Teme, on the border with Worcestershire and less than a mile north east of Tenbury Wells.[27] Cleobury Mortimer manor was purchased by Rowland Lacon soon after 1608, while the adjoining manor of Barnsland to the east was purchased by George Blount in 1601. The Lacon and Blount families, related by marriage, dominated the South Shropshire iron industry in the early seventeenth century. The Cleobury Mortimer furnaces and forges soon came under the direction of the Blount family, although the blast furnaces ceased operation and the last reference to them in parish registers is in 1633. Boraston Forge also ceased work in the seventeenth century.[28]

The cessation of smelting in Cleobury Mortimer necessitated acquisition of other blast furnaces further afield in order to supply its forges. In 1623-4 Francis Walker, a clerk at Cleobury Mortimer, leased the blast furnace and forge at Bringewood on the River Teme in Herefordshire (formerly Shropshire), which stayed in the family until 1698.[29] Sir Walter Blount was the proprietor of a blast furnace at Bouldon by 1647. Built c1644, Bouldon was on the west side of Brown Clee Hill and north of Ludlow. It remained in the family, apart from a short period when it appears to have been sub-let to Richard Knight, until 1795, and after 1798 it was converted to a paper mill.[30] Another Blount furnace was built at Tilsop on the south side of Clee Hill, but it was blown out in the early eighteenth century.[31] The south Shropshire ironmasters therefore supplied their forges with their own pig iron.

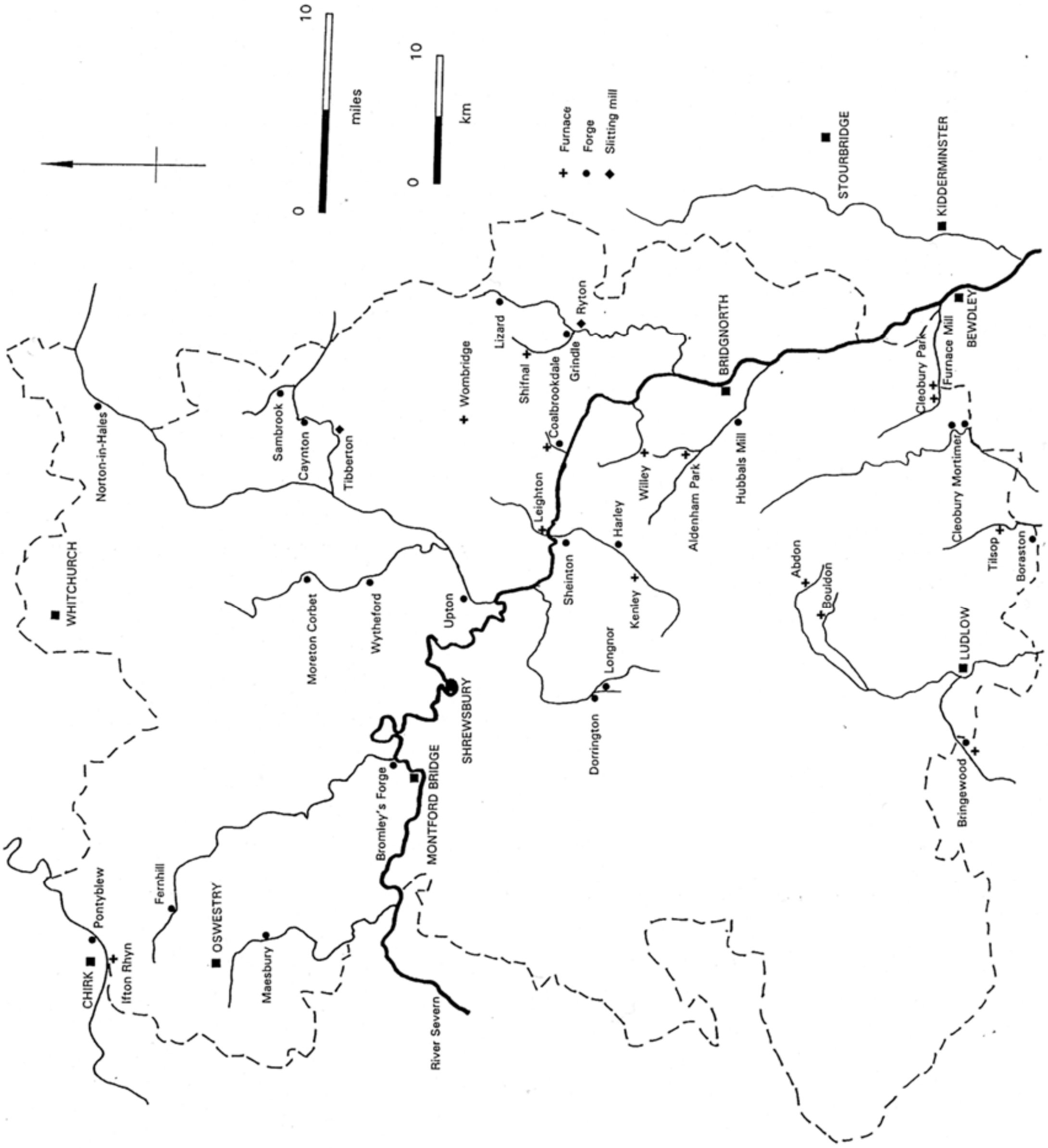

Figure 4 Shropshire Ironworks of the sixteenth and seventeenth centuries

The pattern of integrating furnace and forge was to be repeated elsewhere. A furnace was erected at Kenley, 8 miles (13 km) south east of Shrewsbury and north of Wenlock Edge, by Rowland Lacon, shortly before 1591, when it was occupied by Richard Holbeck. The furnace may later have been leased to William Fownes, sometimes described as of Kenley, who was a partner at nearby Harley Forge in 1638, but the furnace was disused by 1708.[32] In 1638, when it was leased for ten years to William Boycott and William Fownes, Harley forge comprised a chafery, upper and lower finery, and houses for the finer and hammerman. In 1658 it was leased to Cornelius Hallen of Stourbridge (d 1682), who is mentioned below in connection with his pan-making forge. Harley forge was disused by 1664, when two houses on the site were let to a Cardington dyer on condition that he would erect a fulling mill there.[33]

Two forges, at Dorrington and Longnor, were founded by Richard Holbeck on the Cound Brook 8 miles (13 km) south of Shrewsbury. Longnor was built c1605 in conjunction with a blast furnace there, Dorrington c1606. It is not known when the furnace became disused, or even whether it was successfully employed. Dorrington was known as the 'Upper Forge' by 1650 but its subsequent history is obscure and it was no longer working by the beginning of the eighteenth century.[34] A blast furnace was built near Aldenham Park in Morville, south of Willey and 3 miles (5 km) north west of Bridgnorth, which supplied a forge at Hubbals Mill, Morville, from c1631.[35] Hubbals Mill was subsequently held by Thomas Foley and was inherited by Philip Foley in 1669, but ceased working soon after.[36]

Several ironworks in north-west Shropshire and south-east Denbighshire were controlled by two related partnerships. Of these, a forge at Fernhill, north of Oswestry on the River Perry, is dated c1622, and was built in conjunction with a forge at Maesbury, south of Oswestry on the River Morda, and a blast furnace at Ifton Rhyn on the English bank of the River Ceiriog near Chirk. From 1639 Thomas Myddleton of Chirk Castle was a principal partner, with Thomas Mytton and Thomas Kynaston. Myddleton had a slitting mill in the Stour Valley, probably Wolverley, where some of the iron was sent. Myddleton was also a partner in the Denbighshire ironworks that included a furnace at Ruabon and forge at Pontyblew, near the Shropshire border.

Partners in the north-west Shropshire group were Parliamentarians, and the forges are not known to have continued in operation after the Restoration in 1660. Ifton Rhyn furnace had been sold or let to William Boycott and William Fownes by 1635, and perhaps as early as 1624. Fownes and Boycott had interests in other Shropshire ironworks, and the nephew of William Boycott, also William, was to take over Mathrafal Forge in neighbouring Montgomeryshire later in the seventeenth century.[37]

Leighton blast furnace was built in 1632 and was situated 3 miles (5 km) west of Coalbrookdale on the north side of the River Severn, but outside of the coalfield. The furnace supplied pig to a forge at Sheinton, situated on the opposite, south bank of the River Severn on the Harley brook.[38] Fownes and Boycott were the lessees of Leighton by 1638, while in 1666 it was leased to a partnership that included Francis Boycott. By 1696 the partnership is said to have added Sheinton and Longnor Forges.[39] A forge was built at Norton-in-Hales on the River Tern in north-east Shropshire c1646 by Walter Chetwynd. Chetwynd already owned forges at Winnington, over the Staffordshire border a mile east of Norton, and Tib Green in south-east Cheshire, all supplied from his blast furnace at Heighley in north Staffordshire.[40]

All of the above mentioned forges were built in conjunction with specific blast furnaces. However, some of them – Cleobury Mortimer, Longnor, Lizard – would survive as independent forges after their respective blast furnaces had ceased operation. But in the first half of the seventeenth century some forges were erected where no direct link with a blast furnace has been established: Bromley's Forge at Montford Bridge by 1623; Grindle forge on the River Worfe, south of Shifnal, by 1609; Moreton Corbet in 1601; and Wytheford by 1642. Only the latter two, both situated on the River Roden north east of Shrewsbury, were still working by 1700. In the second half of the seventeenth century forges were built on the River Tern at Upton in 1653 and on its tributary the River Meese, in north-east Shropshire, at Caynton by 1694 and Sambrook by 1690.[41]

	Earliest known date	*1715*	*1736-7*	*1749-50*
Lizard	1564	80	140	200
Cleobury Mortimer *	1571-6	180	200	250
Moreton Corbet	1601	140	80	-
Longnor	1605	150	100	140
Sheinton	1637	100	50	-
Wytheford	1642	140	150	250
Upton	1653	200	200	260
Coalbrookdale	1668	80	50	150
Norton in Hales	1685	100	150	150
Sambrook	1690	90	0	-
Caynton	1694	160	180	250
Prescott	1708	120	0	100
Tern	1710	300	150	150
Pitchford	1715	150	70	-
Sutton	1718	-	50	260
Total		**2090**	**1570**	**2260**

* includes Upper and Lower Forges

Table 1: Output in tons of Shropshire Forges listed in national surveys of 1715-1749
Source: P King, 'Early Statistics for the Iron Industry: a vindication', *Historical Metallurgy*, 30/1 (1996), p 36.

The seventeenth century therefore saw a significant growth in the number of Shropshire forges but a significant proportion of them worked for less than a century. Possible reasons for the closure of forges include economic fluctuation, the availability of fuel, expiry of leases and the importance of sites to other industries. Forge sites were valuable properties that could be transformed into fulling, paper or corn mills when existing leases expired. Documented examples include Harley, which was converted to a fulling mill; Grindle and much later Longnor became paper mills; of later forges, Tern and Sutton both became corn mills.

By the second decade of the eighteenth century there were six blast furnaces and fourteen finery forges working in Shropshire (Table 1). The highest output was recorded at one of the newest of the forges, erected in 1710 at Tern, near Atcham (figure 5). Tern was built by a partnership formed in 1710 by the Quaker Thomas Harvey of Stourbridge and several Bristol Quakers, for whom Abraham Darby I of Coalbrookdale acted as agent. It was an unusually ambitious enterprise. It initially combined iron and brass production, incorporating brass rolling mills, a mill for rolling iron barrel hoops and a wire mill, and was justifiably claimed by Thomas Harvey to be the 'first joint works of its kind in England'.[42] By 1713 it also had a finery forge and a cementation furnace for manufacturing steel.[43] Brass rolling lasted less than a decade at Tern, however. By the 1720s, when William Wood of Stourbridge was briefly the tenant, it was a conventional finery forge buying some of its pig iron from Ruabon, Denbighshire, a furnace leased by Wood and Thomas Harvey until their deaths in 1730 and 1731 respectively.[44] The Tern site included access to the River Severn and a road to Upton, a forge managed by Thomas Harvey in the second decade of the eighteenth century.[45] By 1734 Joshua Gee was in control of both Tern and Upton Forges. Upton was given up in 1750 when it was sold to Francis Dorset, while the lease of Tern was not renewed in 1755.[46]

Other forges built during the early eighteenth century include Prescott, built near Stottesdon after a corn mill was let to Peter Hussey, a pan maker from Wolverley in Worcestershire, in 1708 (figure 5).[47] Hussey may have constructed a plating forge either there, or further north at the other forge he founded, known as Hardwick or Rotherham. Prescott was certainly a finery forge by 1715, when it is listed in a national survey (Table 1). The property was later acquired by the ironmaster Richard Knight and George Crump, who managed the lower forge at Cleobury Mortimer. After Hussey's death Knight and Crump let Prescott and Hardwick to Samuel Hallen (1718-86) and his brother Cornelius Hallen (1713-77).[48] A clause in the lease stipulated that neither Prescott nor Hardwick could be used for refining or drawing iron into bars. This suggests that the Hallens were originally intent on operating a plating forge making frying pans, but the terms appear to have been renegotiated as Prescott is listed in 1749 as a producer of bar iron (Table 1).[49]

Pitchford forge was built in 1715 by William Corfield of Harley, on the site of the former Eaton Mascott Mill (Table 1, figure 5). Corfield was followed in 1746 by Richard Jordan, and in 1753 the lease was taken by John Gibbons and Jeremiah Caswell.[50] John Gibbons (1703-78) was a Kingswinford nailer whose acquisition of Pitchford ensured a supply of raw material for his manufacturing business. By 1766 he was also in control of Sutton Forge, Shropshire, and Hyde slitting mill, Staffordshire, as well as establishing a merchant house in Bristol. Sutton Forge, on the River Rea near Shrewsbury, is not listed in the national survey of c1715, but was established by 1718 when it was listed in another national survey (Table 1, figure 5).[51] It was probably built by Thomas Harvey, who was already managing Tern and Upton Forges, and had been a partner in the Coalbrookdale copper works with his brother-in-law Abraham Darby I.[52]

2.4 Geography of Shropshire forges

It was remarked upon above that most forges erected in the sixteenth and early seventeenth centuries were built in conjunction with blast furnaces, continuity with earlier bloomeries being an important but not the sole factor. This is familiar from the Weald and Forest of Dean. Furnace and forge were not always sited close together, as between Lizard Forge and Lawton furnace in Cheshire, which was 35 miles (56 km) distant. Nevertheless in early seventeenth-century Shropshire there were discrete clusters of ironworks, such as Blount's south Shropshire works, the Shropshire and Denbighshire works of Sir Thomas Myddleton, Holbeck's Dorrington and Longnor ironworks, Kenley and Harley, Morville and Hubbals Mill, Leighton and Sheinton, and Walter Chetwynd's furnace and forges spanning the Shropshire, Staffordshire and Cheshire borders. This pattern changed in the latter half of the seventeenth century due to the developing capitalist structure of the trade and the emergence of the trade in pig iron.

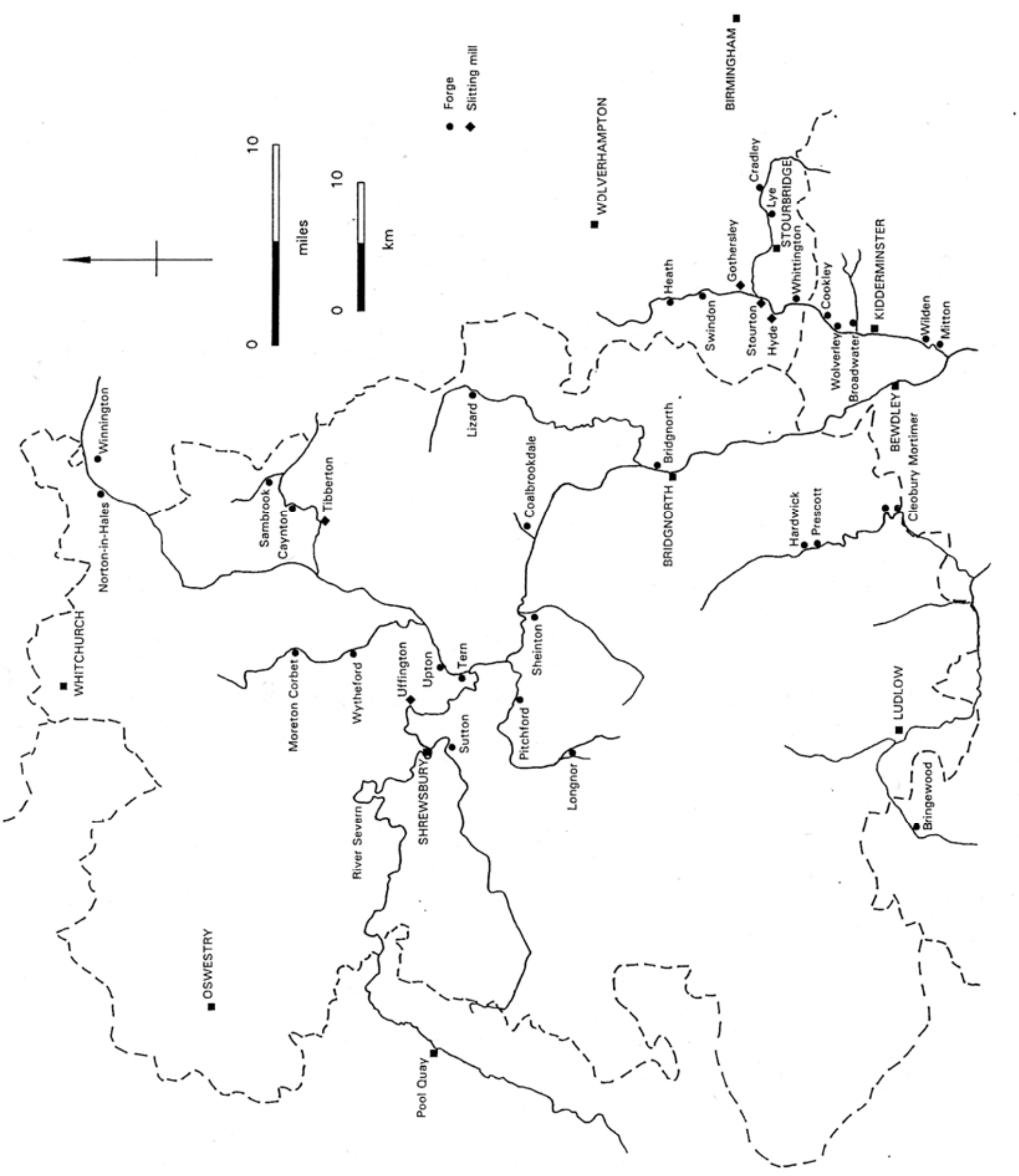

Figure 5 Shropshire and Midland Forges, c1750

None of the forges operated in landscapes that could fairly be described as industrialised or urbanised. They were rural forges. Availability of water power appears to have become the most important factor in their location. Rural forges known to have been erected on the sites of former corn mills include Prescott, Pitchford and Tern. This is familiar from other districts. For example, five forges established on the River Stour in South Staffordshire in the early seventeenth century were all converted from corn mills: Greensforge, Heath, Swindon, Whittington and Stourton (figure 5).[53] Two Montgomeryshire forges on the River Vyrnwy, a tributary of the Severn, at Mathrafal (mid seventeenth century) and Dolobran (1719) were also established on corn mill sites.[54] Prime positions for the exploitation of water power appear to have been occupied by corn and other mills long before the expansion of the iron trade in the seventeenth century. It is arguable that the availability of such sites, usually when a lease was to be renewed, was an influential factor in the development and spread of forges in Shropshire as elsewhere. Access to charcoal appears not to have been a fundamental problem. In 1737 Edward Knight told a Committee of the House of Commons that Shropshire had an excess of wood, and that in recent years the price of a cord of wood had fallen from 16d to 7d. Abraham Spooner, giving evidence to a similar Committee a year earlier, had suggested that there were sufficient stocks of wood in the Midlands to allow a significant increase in iron production.[55]

2.5 Ownership and management of Shropshire forges

In the first half of the seventeenth century most ironmasters combined smelting and refining interests. In the second quarter of the century William Fownes and William Boycott emerged as leading Shropshire ironmasters, and demonstrate a trend seen elsewhere, whereby control of previously disparate concerns becomes concentrated into fewer hands. The Foley family followed by the Knight family demonstrate this tendency in the Midlands, and are discussed below. From the mid seventeenth century there was also interest in managing forges by merchants or manufacturers of finished iron. These men came from Staffordshire and Worcestershire where there was a paucity of suitable sites for water-powered forges.

Backwards integration of the forge trade occurred where established ironmongers or manufacturers in finished iron secured supplies of bar or rod by acquiring their own forges. The shortage of bar iron encouraged many merchants, like Abraham Spooner, to enter the forge trade themselves by the eighteenth century.[56] Nail manufacturers such as the Crowley family of Stourbridge also illustrate this tendency. In Shropshire, John Turner of Lizard Forge is an example of a merchant turned ironmaster from the mid seventeenth century, as was William Wood in the eighteenth. Wood (1671-1730) was briefly tenant of Tern Forge in an eventful career that began in a Wolverhampton ironmongers.[57] In 1715 he had established a co-partnership for the production and marketing of iron in the Midlands and London, with the grand title of the Company of Ironmasters of Great Britain. Thomas Harvey was one of the partners. Wood's ambition to transform the partnership into a public company ended in disaster in the fallout precipitated by the failure of the South Sea Company in 1720.[58] Manufacturers of finished iron who moved westwards to take on finery forges include John Gibbons of Kingswinford in Staffordshire and the Hallen family of Stourbridge. Cornelius van Halen (b 1581) was a Flemish Protestant who emigrated to England c1610 and continued his trade as a pan maker at Wandsworth near London.[59] His descendants, adopting the name Hallen or Holland, colonised the Midland iron trade. Two sons of Cornelius, William Holland (d 1653-4) and Cornelius Hallen (d 1682) set themselves up as frying-pan makers in respectively Newcastle-under-Lyme in north Staffordshire and Stourbridge in south Staffordshire.[60] The latter also leased Harley forge in Shropshire as early as 1658, while his great-grandsons were at Prescott and Hardwick in the early eighteenth century. Like Thomas Harvey and Abraham Darby I, who had interests in copper and brass at Tern and Coalbrookdale, and William Wood, who was involved in a failed project to mint copper coinage, the Hallen family also had interests in non-ferrous metals.

2.6 Sources of pig iron

The pattern of ownership described above in Shropshire and elsewhere indicates that forges acquired pig iron from a progressively wider catchment area. Lizard forge was originally supplied with pig iron from the immediate locality, but by the mid seventeenth century it came from further north in Cheshire, where Lawton furnace was smelting iron ore imported from Furness.[61] Pig iron was not only traded between works held by the same proprietor but was increasingly sold to other concerns. Such a market existed in the first quarter of the seventeenth century – Fownes and Boycott sold pig iron from Ifton Rhyn to Lizard Forge as early as 1624.[62] By the mid seventeenth century Fernhill and Maesbury Forges near Oswestry were using Forest of Dean pig iron. Shropshire furnaces also sent pig iron out of their immediate locality. Bouldon pig iron, for example, supplied the Cleobury Mortimer forges but was also sold to Mathrafal and Dolobran in Montgomeryshire.[63] In the second quarter of the eighteenth century the Coalbrookdale Upper Forge, unable to use the coke-smelted pig iron from the nearby blast furnace, purchased pig iron from Bouldon, Leighton and Kemberton furnaces in Shropshire, Vale Royal in Cheshire (where Furness iron ore was smelted), and from the American colonies.[64] The increase in Shropshire forges in the seventeenth and eighteenth centuries could not have occurred without the open market for pig iron. It allowed new ironmasters, such as the Hallen and Gibbons families, to enter the trade without leasing land with mineral reserves or having to invest in the entire process of manufacturing iron from raw materials.

2.7 Shropshire in the Midland iron trade

Shropshire forges cannot be understood without reference to their wider context within the Midland iron industry. The Midlands became an important ironworking district during the medieval period and was a centre for the manufacture of bridle bits, horseshoes and nails by the early sixteenth century. Belbroughton, Chaddesley Corbett and Clent in Worcestershire specialised in scythe making, Wolverhampton in lock making, and Walsall in harness ware.[65] Nevertheless the Staffordshire and Worcestershire forges were unable to meet the demand for bar iron in the Black

Country and Birmingham manufacturing districts. In 1737 Abraham Spooner, a Birmingham ironmonger and son-in-law of the ironmaster Richard Knight, claimed that 9000 tons of wrought iron were consumed annually in the Birmingham district. Imports accounted for 2100 tons, and according to a national survey of 1736 the combined output of Staffordshire, Worcestershire and Warwickshire forges was 3760 tons.[66] Therefore over a third of the iron consumed in Birmingham came from outlying districts, to which Shropshire forges must have made a substantial contribution, output of wrought iron in the county amounting to 1570 tons in 1736 (Table 1).

The underlying problem for the Black Country iron industry was insufficient sites with suitable water power. The shortage of locally smelted pig iron was rectified by purchasing pig iron from further afield, especially the Forest of Dean. In 1715 the Forest of Dean produced 4950 tons of pig iron but refined only 2000 tons. The surplus was sent to the Midlands, where 2500 tons was refined in the Stourbridge region.[67] This was aided by concentration of ownership in the iron industry, resulting in the dominant inter-regional concerns of the Foley followed by the Knight family.

The Foley family emerged as the leading ironmasters in the Forest of Dean in the seventeenth century and was influential in the development of the Midland trade. Wombridge furnace and Hubbals Mill forge in Shropshire were also worked by members of the family for a brief period in the seventeenth century. Their founder was Richard Foley (1588-1657), succeeded by his sons Thomas Foley (1617-77) and Robert Foley (1627-77), and two sons of Thomas: Paul Foley (1650-99) and Philip Foley (1653-1716). By 1672 Paul Foley held furnaces and forges in the Forest of Dean and shipped iron to Philip Foley's forges in the Stour Valley. The brothers subsequently combined their interests and from 1692 numerous ironworks encompassing the Forest of Dean, Monmouthshire and the Midlands were managed jointly by two concerns: The Staffordshire Works and the Ironworks in Partnership. Co-partners in the Ironworks in Partnership included John Wheeler and Richard Avenant, both of whom had entered the iron trade as wood buyers in the 1650s, before taking on the management of Midland forges for Thomas Foley. The concerns of the Staffordshire Works and the Ironworks in Partnership extended from Mear Heath blast furnace in north Staffordshire, to the Tintern wire mills in the Wye valley. Iron was shipped between these works, establishing a large-scale inter-regional trade in semi-finished iron. The Stour Valley was the focus of the partnership's forge trade. This included four slitting mills, at Wilden, Cookley, Stourton and Wolverley, all working in conjunction with a finery and chafery (figure 5).[68] A further finery and chafery forge was established at Whittington, also on the Stour in Worcestershire.

The Ironworks in Partnership withdrew to the Forest of Dean after 1711. In the Midlands it was superseded by another ironworking dynasty, the Knight family. Richard Knight (1659-1745) was probably born in Madeley, Shropshire, and is said to have begun his career at the Lower Forge in Coalbrookdale. Subsequently he took over the forge at Moreton Corbet in Shropshire, probably when he married Elizabeth Payne of nearby Shawbury. Knight's father-in-law appears to have provided capital for Moreton Corbet and further acquisitions. Knight was running Flaxley blast furnace in Gloucestershire by 1695-6, and from 1698 the furnace and forge at Bringewood. To increase his output of pig iron from the Clee Hills, in 1712 he built a blast furnace at Charlcotte, Shropshire, on the Cleobury brook east of Brown Clee Hill.[69]

The Midland metalware manufacturers benefited from the expanding geography of the trade because they required not only quantities of bar iron but certain qualities. Iron was not regarded as an homogenous product as its strength and malleability varied according to the quality of raw materials, and to a lesser extent on the quality of the workmanship. Forest of Dean ores produced *tough iron*, the highest grade of wrought iron, noted for its strength and malleability under the hammer. Its quality was only rivalled in Shropshire by iron ore from the Clee Hills in the south of the county. The other main source of English tough iron was the Furness district. By the end of the seventeenth century some Furness iron ore was transported to the Midland region, in particular to Vale Royal and Lawton blast furnaces in Cheshire.[70] Most of the Midland blast furnaces produced *coldshort iron* from local ores, which made a bar iron slightly less malleable and liable to break or shear if hammered cold. Nails were typically made from the cheaper coldshort iron, whereas wire and tinplate were manufactured from the more ductile tough iron. By importing selected pig iron forges in the Stour Valley were thus able to broaden the product available to manufacturers by offering common and best grades of wrought iron.

Quality was also taken into consideration in the purchase of imported pig iron. Swedish pig iron was of high quality, although little of it was imported to the Midlands. Russian iron was sent to the Midlands by the 1730s and was generally of lower grade than Swedish iron. By the late 1720s substantial cargoes of American pig iron were imported from Pennsylvania, Maryland, Virginia and Carolina. The Crowley and Knight families of the Stourbridge district sold bar iron and rods to the colonial plantations through merchants in Bristol. These same merchants secured imports of American pig iron on return journeys.[71] In Shropshire, the Coalbrookdale Upper Forge is known to have made use of pigs from the Potomac Ironworks and the Baltimore Company in 1740-1.[72]

The inability of Staffordshire and Worcestershire forges to meet local demand must account in part for the spread of forges into outlying districts of the Midlands, including Shropshire, Cheshire, Mid and North Wales. Forge masters took advantage of the choice of pig iron available, on the basis of quality and cost, to produce bar iron for specific markets. For example, the Lloyd family purchased Furness iron in the eighteenth century for their slitting mill in Birmingham and Wichnor Forge at Burton-on-Trent, which was transported by sea and the River Severn.[73] Midland ironmongers such as Abraham Spooner started buying Russian bar iron of various grades in the 1730s. Imports accounted for 23% of iron used in the Midlands according to Spooner's estimate given above. Imported iron met the demand that the home market could not meet, but it was also cheaper. For example, Moscow, or 'Mullers', iron was sold at £11-13 per ton for making nails when the equivalent English rod iron was selling at £18 per ton.[74]

2.8 Transportation

The River Severn had an important role in the development of the Shropshire and Midland iron trade. The river and its tributaries constituted the most important river navigation system in England in the early modern period. Its chief ports were Shrewsbury, Bridgnorth, Bewdley and Worcester, with important transhipment ports at Tewkesbury and Gloucester. Trade from the Wye valley was carried via Upton-on-Severn until it lost its importance after improvement of the Wye navigation in the 1690s.[75] The port at Bewdley provided a link to the River Severn for the industrialised areas of the Stour Valley and Birmingham. Its importance to the Midland iron trade was therefore crucial. In the late seventeenth century Bewdley boats were responsible for 20% of voyages through Gloucester, rising to 25% in the eighteenth century.[76]

In the seventeenth century Thomas Myddleton had a storehouse at Montford Bridge, west of Shrewsbury, serving his ironworks in north-west Shropshire.[77] The Ironworks in Partnership had a storehouse at Bewdley, which acted as a wholesale agency handling iron for the Birmingham district.[78] Bewdley also had warehouses owned by established families of warehousemen. Other storehouses have been identified in Shropshire at Roundthorn north east of Ludlow and on the west side of the Clee Hills, and at Pimley on the River Severn east of Shrewsbury.[79] Downstream Severn traffic was mainly to Bristol and other Bristol Channel ports. Shipments to London from Bristol or Gloucester were not numerous, although by 1700 goods could be carried by land to Lechlade in Gloucestershire, to which point the Thames was navigable.[80]

2.9 Market for Shropshire bar iron

Bar iron was used for a variety of products. There were large-scale producers in the Midlands and Sheffield, serving national and international markets for hardware and cutlery, and small-scale manufacturers of, for example, nails and locks in every market town. Nails were especially important in the building and ship-building trades, and therefore were manufactured in most of the ironworking districts. The natural market for Shropshire forges was the Midlands. Bristol was second in importance, but was a much more important destination for finished goods. By the early eighteenth century the manufactured iron trades of South Staffordshire and Birmingham included harness wares, scythes and other edge tools, nails, locks, hinges, buckles, toys, swivels, files and chains. Nails were the most important product. Two slitting mills were built in Shropshire in the second half of the seventeenth century, at Tibberton before 1653 and Ryton in 1683, and a further slitting mill was built at Tern in the early eighteenth century, but most iron for nails was sent to the Stour Valley for slitting.[81] This pattern of trade had become established in the mid seventeenth century, when Thomas Myddleton's forges at Maesbury and Fernhill sent iron for slitting at his Wolverley slitting mill, and to Hyde slitting mill, operated by Richard Brindley (figure 5).[82]

Shropshire had other secondary iron trades, but it cannot be taken for granted that they always used local bar iron. Frying pans were first manufactured at the Coalbrookdale Lower Forge by William Hallen (b 1646) who was living at Coalbrookdale in 1660.[83] Apart from his interests in Coalbrookdale, William Hallen also held a forge in Stourbridge, leased to him in 1669 by Robert Foley, and he might have purchased his iron from there. William began a long history of family involvement of pan making at Coalbrookdale, from his son Cornelius Hallen the younger (1673-1744) and cousin, also Cornelius (1653-1737) to George William Hallen (d 1824), who purchased iron from nearby Horsehay.[84] In 1753 frying pans, salt pans, plate warmers and dish covers were made in a number of workshops, and the finished goods were either sent to Bristol or sold in Shropshire and Wales.[85] The Gloucester Port Books make sporadic references to cargoes of pans sent down the Severn from Coalbrookdale between 1666 and 1765.[86] The Lower Forge at Coalbrookdale is the sole known example of a plate forge in Shropshire in the seventeenth century, while in the following century Prescott or Hardwick forge probably produced pans.

Of other specialist forms of wrought iron, tinplate is not known to have been produced in Shropshire in the seventeenth or eighteenth centuries, but for a brief period wire and steel were manufactured at Tern. There is also evidence of early steel manufacture in Coalbrookdale, but not necessarily using local bar iron. In 1615 Basil Brooke, lord of Madeley manor, leased the furnaces and forges at Parkend and Soudley in the Forest of Dean and subsequently obtained a patent for making steel by the cementation process.[87] Iron from these works probably supplied his steelworks at Coalbrookdale, situated between the Upper and Middle Forges, from where steel was transported down the River Severn c1615-80.[88]

2.10 Development of regional markets

Iron merchants, known originally as ironmongers or hardwaremen, aided the flow of iron from forges to smithies. Midland ironmongers sought bar iron from forges in the Midland counties, but also went further afield to Welsh and Derbyshire forges in order to supply the great demand from the manufacturing districts. But there is little evidence that the trade ever grew out of its regional structure. In 1680 an agreement was reached by the Foleys whereby Paul Foley would sell no Forest of Dean bar iron north of Tewkesbury, while John Wheeler and Richard Avenant, managing Philip Foley's Midland forges, would sell no bar iron south of Tewkesbury.[89] It was one of the earliest cartels in the iron trade and acknowledged that ironmasters had regional interests. The agreement was superseded when the Ironworks in Partnership was formed in 1692, when the Forest of Dean and Midlands effectively became a single ironworking region. One of its consequences was to open up Bristol and Gloucester to Shropshire forges.

The potential for a national market was inhibited by modes of transportation. To exploit the London market Ambrose Crowley, a Stourbridge nailer, developed forges in the Derwent valley, County Durham, purchasing most of his pig iron via merchants in London, claiming that transport of finished goods from Sunderland to London by sea was quicker and more efficient than carriage to London from Birmingham.[90] William Wood's efforts to make a significant impact on the London market, of which bar iron from Thomas Harvey's Tern, Sutton and Upton Forges was an integral part, were only partially and temporarily successful.

The Midland metalware trades were an important but not the sole large-scale market for bar iron by 1750. Other markets existed that were served by other ironworking regions. The Wealden iron industry was best known for cannon manufacture, but in the first half of the sixteenth century it also benefited from the growing trade of London. Bar iron was sold to smiths making nails and other components used in the building and ship-building trades, while rural smiths purchased bar iron to make components for ploughs, harrows and wagons. The Weald's market therefore expanded rapidly to encompass the whole of south-east England. Most of the Wealden bar iron was sold to London merchants, however, and was transported by sea from Rye or Newhaven. There was only a small local industry manufacturing finished iron goods. Even in the seventeenth century there is little evidence that significant quantities were traded beyond London, or found their way to the Midlands. Competition for the London market in the seventeenth century came primarily from Spain and the Baltic, from where imports of bar iron trebled between 1588 and 1634, and not from the Midlands.[91]

Forges in the north of England also served a largely regional market. John Fell I, clerk to Wortley and later of Attercliffe Forge in Sheffield, certainly dealt with London merchants, but most of his trade was with market towns in Derbyshire and Yorkshire, or across the Pennines in Liverpool, Manchester and Stockport.[92] Furness iron was also sold locally, although much of its output was sent to Liverpool for use in the shipyards.[93] The Hallamshire district of South Yorkshire, which included Sheffield, specialised in manufacturing cutlery, and was the chief centre of production outside of London by the mid seventeenth century. Allied crafts were the manufacture of scissors and shears, scythes and sickles, files, iron boxes, forks and awls. Edge tools required hard steel edges and in the latter half of the seventeenth century steel had been imported from Germany and Spain, or from native producers in the Weald or Forest of Dean. Home production began in the second half of the seventeenth century. Subsequent expansion of the steel sector was made possible by the import of high-quality Swedish bar iron which found an increasing market in the steel-manufacturing district.[94] Henceforth Sheffield was to dominate the British steel industry, more so after an improved technique of manufacture, known as crucible steel, was developed in the 1740s.[95]

Reinhold Angerstein offers a valuable insight into the iron trade in the early 1750s in his accounts of journeys through Britain. Although not a systematic study of the trade, his wealth of anecdotal evidence illuminates a number of important themes. It emphasises the continued importance of imported iron, despite the rapid growth of the industry in Britain, and that in any given market for bar iron, competition was more likely to come from abroad than from other native ironworking regions. It also highlights the fact that bar iron was not an homogenous product. Wrought iron was of varying qualities that ultimately could only be vouchsafed by the customers who used it. A consensus was not always forthcoming, however, as Angerstein found in Barnsley, Yorkshire, where competing claims were made for the quality of wire drawn from English and Swedish iron. In Exeter he found that iron merchants either purchased English iron transported on the River Severn, or relied on imports. A number of blacksmith's shops made items such as nails, screws for presses, spades, gratings, roasting jacks and fire pokers, but little of it was manufactured from home-produced iron. Swedish iron was preferred for spades and nails, Spanish iron for horseshoes and gun barrels. English iron was cheaper than Spanish and comparable to Swedish prices, but was clearly considered inferior as it tended to be used 'where it does not have to be worked very much and where it is not subjected to heavy stress'.[96]

There is therefore no convincing argument that the iron industry by 1750 was a national industry. Rather, regional industries exploited the nearest large-scale markets, which were London, the Midlands and northern English towns. Of these the Midland metalworking district was the largest consumer of iron by the eighteenth century, and was an important market for Shropshire iron. Certain grades of iron suited certain uses and ironmasters tailored their iron to suit the market. It was upon this regional structure that efforts to introduce technological change in the second half of the eighteenth century were imposed.

2.11 Conclusion

Two main phases characterise the forge trade to 1750. The earlier saw forges emerge in the late sixteenth and early seventeenth centuries to serve specific blast furnaces in an integrated approach to production. The separation of ironmaking into two processes, and their consequent geographical separation necessitated by the availability of water power, created a flexible structure in the refining and manufacture of iron, and led eventually to an independent forge sector. The second phase therefore saw forges emerge geographically or managerially separate from blast furnaces, able to purchase pig iron on the open market, and some of them operated by ironmasters with no direct involvement in smelting.

The open market for pig iron expanded significantly in the second half of the seventeenth and early eighteenth centuries. The emergence of the iron merchant as a trader in finished and semi-finished iron assisted this trend. High demand for iron in the Midlands allowed forges to prosper in relatively remote areas. Shropshire's expanding forge trade was also partly a consequence of the lack of suitable sites closer to the manufacturing districts in Birmingham and Staffordshire. Another consequence of this was the emergence of forge masters whose previous interests had been in manufacturing iron goods or as merchants, men such as Thomas Harvey, John Gibbons and members of the Hallen family. The trade in semi-finished iron allowed iron to be graded according to quality, to suit its eventual use. Shropshire also benefited from access to the River Severn, the most important inland navigation in Britain. It allowed significant quantities of pig iron to be imported from the Forest of Dean, and provided a cheap means of conveying bar iron to its principal markets in the Midlands and Bristol.

There was no unified national iron industry in the seventeenth and eighteenth centuries because there was no national market. The potential for a national market was inhibited by the costs of transportation and therefore the iron industry retained a strong regional character. Shropshire experienced little competition from other ironworking districts such as the Weald, whose natural market was London, or

Yorkshire, whose natural market was the north of England. Shropshire was part of a western region of the iron industry stretching from Cheshire and North Wales to the Forest of Dean and South Wales, with the River Severn forming its spine.

3 THE INTRODUCTION OF MINERAL FUEL, c1750-1800

Mineral fuel came to be widely used in both the smelting and refining sectors of the iron industry in the second half of the eighteenth century. Coke was used for smelting iron at Coalbrookdale from 1709, with sufficient success to justify the building of a second furnace in 1715, but wrought-iron manufacture was unaffected by these developments. Reinhold Angerstein noted at Coalbrookdale in 1753, ‘the iron produced with coke is considered the best for castings, but not fit for making bar iron, although several attempts have been made’.[1] Such attempts continued and proved successful, and by 1760 significant quantities of coke-smelted pig iron were used to make wrought iron. There followed attempts to use mineral fuel to refine pig iron. The advantages of mineral over vegetable fuel were obvious. Coal was more plentiful than charcoal and in the vicinity of collieries it was cheap. Angerstein noted that where fuel was required simply as a source of heat, for example in chafery hearths and slitting mills, coal was already widely used in the forge trade.

This chapter examines the introduction of coke-smelted pig iron into the forge trade, and the methods of refining pig iron using coal that were developed and used in Shropshire before puddling and rolling in the 1790s. It includes detailed case studies of Horsehay and Old Park forges. Changes in the county are considered in the light of national developments. It will not be assumed that coal and coke supplanted charcoal, but the possibility is raised that mineral fuel supplemented the range of processes available and thereby augmented the range of qualities that were required by the market.

3.1 The introduction of coke-smelted pig iron

Charles Hyde argued that coke-smelted pig iron became established in the trade when it was more economical to work than charcoal pig iron. He cited as an example experimentation with coke pig iron at Coalbrookdale in the period 1732-8 that was subsequently discontinued and not taken up again until the 1750s.[2] Angerstein, by contrast, hinted at technical rather than economic problems. Laurence Ince’s study of the Stour Valley forges in Worcestershire, undertaken before Angerstein's diary was published, came to a similar conclusion. It even showed that coke pig iron was initially more expensive to convert into wrought iron when its use was established there in the 1750s.[3] More significant was that the quality of bar made from coke pig iron self-evidently saw a marked improvement in the 1750s, even if any associated technological change remains beyond explanation. There are no known sources that document the introduction of coke pig iron at any of the Shropshire forges, even Coalbrookdale. The further significance of the Knight family forges – Cookley, Whittington, Wolverley, Mitton and Bromford (figure 5) – is therefore that they provide a case study of how the Midland forge trade adapted to change. For that reason it is worth including the main developments in the Stour Valley here.

In 1754-5, 6 tons of pig iron from Coalbrookdale were purchased for Wolverley forge. In the following year the Stour forges purchased 254 tons of coke pig iron from the new blast furnaces at Horsehay in Shropshire, built by Abraham Darby II (1711-63).[4] The suitability of coke pig iron therefore appears to have been rapidly proved, and was initially supplied only by the Coalbrookdale partners. Darby's apparent breakthrough was described in the late 1770s by his widow Abiah Darby, who claimed that successful trials with coke pig iron at the Coalbrookdale Upper Forge encouraged Darby to erect new blast furnaces at Horsehay specifically to supply the forge sector.[5] It is likely that the 6 tons sent to Wolverley were for trial. No new forging technique was associated with this development, however, and no modifications to the smelting process are known to have taken place. The most likely explanation is therefore a fortuitous discovery relating to the quality of the iron ore. The iron ore used for coke smelting at Coalbrookdale in the first half of the eighteenth century had a relatively high phosphorus content. Although it was not described in such scientific terms, in practical terms it would have produced bar iron too brittle for commercial use, but well suited to manufacturing cast iron. Commercially viable wrought iron was refined from low phosphorus pig iron, the best of which were obtained from iron ores outside of the coalfields.[6] Even by the early 1750s smelting with coke accounted for a small proportion of national pig iron output, and so used only a small proportion of available ores. By smelting different ores a better grade of pig for the forge was found. This argument is strengthened by the events of the 1750s. Abraham Darby II built new blast furnaces in order that he could supply forges with competitively-priced coke-smelted pig iron, rather than refine it himself, a process in which he had no special advantage.

Evidence suggests that the rapid success of coke pig iron in the forge trade was one of the factors that saw eight new blast furnaces erected in the East Shropshire coalfield in less than a decade. Coke pig iron was sold to the Stour Valley forges from nearly all of these furnaces: Horsehay (1754), Ketley (1756), Lightmoor and New Willey (both 1758). But the forge trade was not the only factor. Other furnaces, such as the two at Madeley Wood, known as Bedlam (1757), and Coalbrookdale, appear already to have been specialising in coke pig for the foundry, smelting locally mined ores. The outcrop of Crawstone ore in Madeley Wood was acknowledged to produce good foundry iron, and the blast furnaces there concentrated upon foundry iron throughout their existence, earning the Madeley Wood Company a national reputation. By contrast, Laurence Ince demonstrated that the furnace at Charlcotte in south Shropshire, a regular supplier of charcoal pig iron to the Stour Valley, saw a decline in sales from 1756.[7] Charlcotte was only one supplier of charcoal pig to the Stour forges, however, and not a representative one. It is not the case that charcoal-smelted pig iron entered an immediate terminal decline. In the Stour Valley only Wolverley concentrated upon the use of coke pig iron. As late as 1784-5, for example, the Stour Valley forges purchased 1726 tons of charcoal pig iron and 715 tons of coke pig iron, the latter accounting for only 29% of its iron.[8] Cookley and the Upper and Lower Mitton Forges purchased only small quantities of coke pig, which is a convincing demonstration that coke pig iron offered a quality of iron that suited certain specific uses and was not a universal product that supplanted charcoal pig for all grades of bar. Coke pig iron, smelted from coalfield ores, yielded the relatively hard coldshort iron, which was especially suitable for nail making. The continued significance of charcoal pig iron in the latter half of the eighteenth century has also been established in a nation-wide study of charcoal blast furnaces.[9]

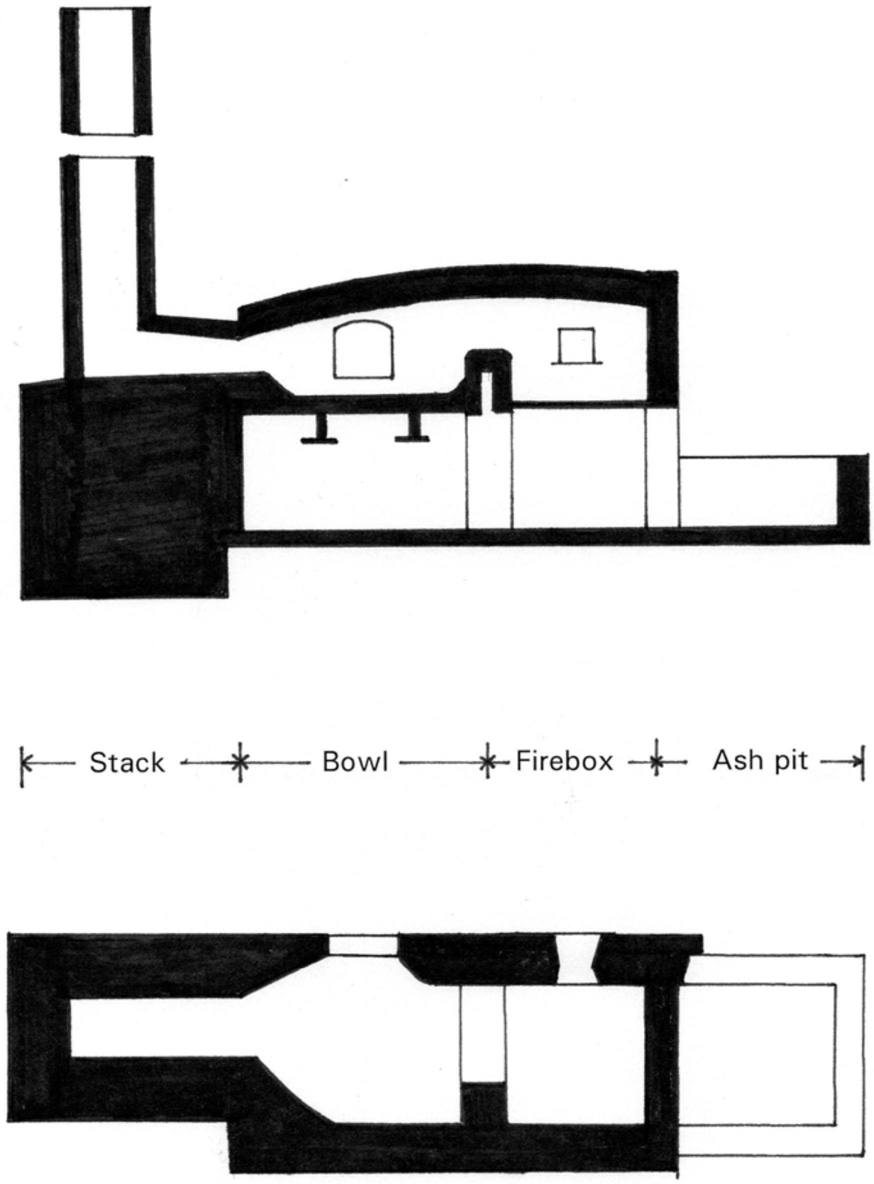

Figure 6 Plan and section of an air, or reverberatory, furnace.

3.2 New finery forges 1750-90

Output of pig iron increased with the rapid expansion of blast furnaces in Shropshire in the 1750s. The Shropshire forge trade did not expand as rapidly, but there was nevertheless an increase in the number of finery and chafery forges in Shropshire over the second half of the eighteenth century (figures 5 and 7). All of these forges were built in the south or east of the county. In 1760 the Coalbrookdale partners leased the Town Mills on the north side of Bridgnorth and built a forge known as Bridgnorth or Rock Forge (figure 5). The site was close to the River Severn but drew its water from the River Worfe. It had been occupied by a mill since the medieval period, the earliest record of it being a charter of 1227.[10] The partners needed a forge on a new site because there was no longer a sufficient water supply at Coalbrookdale. Expansion of ironworking there, including the erection of a boring mill for boring engine cylinders on the site of the earlier Middle Forge, had used up its capacity.[11]

Wrens Nest forge was built on the Dean Brook c1770 by George Matthews. It comprised a forge and slitting mill sited close to a corn mill, the water supply for which was diverted for use at the forge.[12] Matthews had in 1767 built two blast furnaces at Calcutts on the south bank of the River Severn at the south end of the coalfield.[13] When the Calcutts Works was advertised for sale in 1786 it had 'two large forges for making bar iron', which may have been built with the furnaces.[14] However, subsequent to its purchase in 1786 by Alexander Brodie the works specialised in cast iron and the forges probably ceased working. The forges are not shown on a sketch plan of Calcutts of c1800 which, however, shows an earlier corn mill on the site.[15]

In 1776 William Wheeler and his brother John obtained an agreement to enlarge Eardington mill and to use its ponds and leats.[16] By 1778 the mill had been adapted for use as a forge. John Wheeler also controlled Upton forge and a slitting mill at nearby Uffington. A coke-fired blast furnace was erected in 1783 at Cornbrook in south Shropshire by Thomas Botfield (1736-1801).[17] In conjunction with this a forge, known as Cleobury Dale and comprising two fineries and a chafery, and a rolling mill, was erected nearby (figure 7), and was managed by Botfield's son, also Thomas

(1762-1843).[18] Hampton Loade forge is first mentioned in a national survey of the iron trade, for which the evidence for Shropshire was collected c1790 (Table 2). At this time it had a finery operated by William Jones, who was also proprietor of Longnor Forge.[19] The forge was certainly working in 1790 when it was supplied with pig iron from Old Park.[20]

Sources of pig iron for these forges are not known before 1790, but they were originally finery and chafery forges working pig iron with charcoal. Both George Matthews and William and John Wheeler appear to have had a substantial interest in the nail trade and it is not therefore unreasonable to suppose that they purchased coke pig iron. The sites of at least Eardington, Wrens Nest, Bridgnorth and Calcutts were those of earlier corn mills, demonstrating the colonisation of pre-existing sites suitable for water power, a factor that was shared with the rural forges described in chapter 2. In addition, with the exception of Cleobury Dale, these post-1750 forges were all situated close to the River Severn with its attendant advantages in transportation. For that reason they are characterised here as Severn Valley forges distinct from the earlier rural forges.

3.3 Early refining techniques using mineral fuel

The successful adoption of coke pig iron from the 1750s also helped to precipitate, or to accelerate efforts to find, new techniques of refining pig iron. While coke pig iron yielded an acceptable wrought iron, it was still necessary to refine it using charcoal. Several new techniques using mineral fuel were patented between 1761 and Henry Cort's puddling process, patented in 1783 and 1784, all of which have been reviewed by Mott in his study of Henry Cort.[21] Apart from their use of coal or coke, these new techniques also saw the appearance of reverberatory furnaces in the forge. An air, or reverberatory, furnace had separate chambers for the fuel and the metal, and a tall stack at the end that drew the heat from the firebox across the bed or bowl, where the metal was placed (figure 6). Originally used in non-ferrous smelting, air furnaces were used in the iron industry by the early eighteenth century as a means of melting pig iron in the foundry. The simple fact that iron and coal were kept apart made air furnaces particularly attractive to innovators, because the chief problem with coal in the refining stage was that sulphur from coal contaminated the iron.[22]

Charles Wood of Low Mill Forge, Cumbria, and his brother John Wood of Wednesbury Forge, Staffordshire, obtained two patents for a technique known as stamping and potting, in 1761 and 1763. They were sons of William Wood of the Company of Ironmasters of Great Britain and, at Low Mill, continued with their father's efforts to find a direct process of smelting that would yield malleable iron. Stamping and potting endured a long gestation period. When Angerstein visited Low Mill in the 1750s he wrote a detailed account of the working of scrap iron there.[23] To aid the welding together of small pieces of iron, such as nails, locks and keys, they were heated inside clay pots, the technique later adapted to working pig iron. Angerstein's accompanying illustration also clearly shows a reverberatory furnace of the type later used both in stamping and potting and in puddling.

At the Carron Ironworks near Falkirk, which had been built in 1759, Charles Roebuck patented a process in 1763 that, although the patent specification is vague, appears to be little different from the traditional finery and chafery, except that coal was used in the finery and coke in the chafery. Carron at this period is of interest to Shropshire because it was built using English expertise, and one such skilled workmen was Thomas Cranage of Coalbrookdale.

3.4 The Cranage patent, 1766

The Cranage family had a long history of ironmaking in Shropshire. George (b 1701) and Thomas (1711-80) were the sons of John Cranage of Cleobury Mortimer forge. George is said to have worked at the Middle Forge, Coalbrookdale, from 1722, and appears to have continued working for the Coalbrookdale partners throughout his career.[24] The early career of Thomas Cranage is not known, but his presence in Scotland demonstrates how the technology of ironmaking was not as regionally constrained as the market for iron. However, neither Cranage nor his wife seem to have settled well at Carron. His wife was accused of assuming 'an authority over the rest which is disagreeable to them', while her husband, a Methodist, became 'ill of a jaundice and dropsey the consequence of hard drinking'.[25] Furthermore his technical expertise was criticised as being of 'little or no service'. By 1766 Thomas Cranage was back in Shropshire, working at the Coalbrookdale Company's Bridgnorth Forge. His brief period in Scotland had seen him in the midst of a climate of innovation and ambition, but there is no evidence that his own process was influenced by Roebuck.

The personal contribution made by the brothers to the patent that bears their name is, nevertheless, open to question. As two men bred up in the trade, the authority and technical expertise of Thomas and George Cranage can hardly be doubted. However, aged fifty-five and sixty-five respectively when the patent was awarded, it is unlikely that either man was working as a finer on a regular basis, a strenuous job that few men could continue with in their fifties. This raises the important issue of whether their process was really the product of experimentation and discussion among the workmen at Coalbrookdale and elsewhere, and was not an invention with a single inventor.

There are three important sources of evidence for the Cranage process: a letter written by Richard Reynolds, manager of the Coalbrookdale concerns, to his partner Thomas Goldney, in April 1766; the patent specification of 1766; and a description of the process as witnessed by Alexander Chrisholm in 1768.[26] All of them repay close scrutiny. Reynolds stated that Thomas Cranage worked at Bridgnorth Forge, which Alexander Chrisholm stated had been established to draw out iron under the hammer ready for sale and therefore had a chafery but not a finery. In order for Cranage to develop his idea, however, there must have been a reverberatory furnace at Bridgnorth using coal. Such a furnace might have been built for working scrap iron, as Charles Wood had already employed at Low Mill.

According to Richard Reynolds, a trial of the process was conducted at Coalbrookdale in 'Thomas Tilly's air furnace', which is most likely to have been located at one of the two Coalbrookdale foundries. Favourable results then justified 'the erection of a small air furnace at the Forge for the more perfectly ascertaining the merit of the invention'. An excited Reynolds described the second trial as 'one of the most important discoveries ever made', even though it was made using scrap rather than pig iron: 'The iron put into the furnace was old bushes [i.e. scrap], which thou knowest are always made of hard iron, and the iron drawn out is the toughest I ever saw'.

Reynolds expressed his intention of obtaining a patent which described the invention 'in a few words'. The description given in the letter was copied verbatim in the official patent specification, which shows that Reynolds rather than the Cranage brothers was in control. In any case, the official fees and stamp duties required to obtain a patent in the eighteenth century amounted to £70, excluding other gratuities payable, which was roughly equivalent to a year's wages for men of the status of the Cranages. In effect, therefore, the Cranages could not proceed without another source of capital behind them.[27] The text of the patent disingenuously calls itself a 'full, true and perfect description of our said Invention'. It is nothing of the sort and is worth quoting in full to demonstrate the point:

> The pig or cast iron is put into a reverberatory or air furnace, built of a proper construction, and, without the aid of anything more than common raw pit coal, is converted into good malleable iron, and, being taken red hot from the reverberatory furnace to the forge hammer, is drawn into bars of various shapes and sizes, according to the will of the workmen.

The vagueness of the description was not unusual for a patent awarded in the mid eighteenth century. The accuracy and fullness of a specification remained largely the discretion of the patentee, and its purpose was mainly to allow law officers to discriminate between superficially similar inventions.[28] That full disclosure was not essential meant that a patent could be obtained before an invention was perfected. Furthermore, the English patent system was essentially one of registration, and differed from the French system where the authenticity of every invention was examined before a patent was awarded. The Cranage process, as it is given in the specification, is not a process at all and the award of a patent does not imply that the process was ever perfected. The specification has an obvious flaw: Iron was taken from a furnace at white heat, not red heat, an elementary error that shows that the Cranages were not party to the wording. Such careless use of language does not inspire confidence in Reynolds' technical expertise. Iron could not be placed in a furnace and taken out when ready, as if it was just heated in an oven. All techniques of refining iron required the finer to stir the iron in the hearth to ensure consistent decarburisation. The final clause, 'according to the will of the workmen', acknowledges this fact but does not indicate how it was to be achieved. The specification merely sets out the idea of refining iron in a reverberatory furnace and its deliberate vagueness can therefore be interpreted in two ways. The patent could have been taken out hastily, before sustained trials had taken place. This is exactly how it was later seen in the trade.[29] Alternatively, a vague specification allowed the Coalbrookdale partners to argue that any similar future techniques infringed the Cranage copyright. The patenting of an idea rather than a technique was at the root of the Coalbrookdale workmen's future hostility to Henry Cort.

The air of authority surrounding the award of a patent convinced historians for over a century that it entailed a serious technological breakthrough, and was therefore a precursor of puddling. In 1863 Samuel Smiles maintained that 'there can be no doubt as to the originality and the importance of their invention', which he termed puddling, a word never used by the Cranage brothers or Reynolds.[30] A year later John Percy accepted Reynolds' claim that the Cranage process was successfully adopted at Coalbrookdale and, despite conceding that there was no sustained production using the process, offered it as 'strong evidence against Cort's claim to priority in the invention of puddling'.[31] Raistrick confidently stated that the technique produced a better and cheaper iron than the finery and chafery and was used at Coalbrookdale until it was superseded by puddling.[32] To Morton and Mutton it fitted neatly into a pre-conceived model of linear technological development.

Although the list of patents is the only reliable guide to technological innovations in the eighteenth century and cannot therefore be ignored, it cannot be taken innocently as merely an index of inventions. It was also a strategy used by businessmen for their own ends. Furthermore, their association with the Darby and Reynolds families invested the Cranage brothers with an authority in the historical development of the wrought-iron trade that they might not have enjoyed had they been associated with other Shropshire or Midland ironmasters. The Coalbrookdale partners, and to a lesser extent the East Shropshire Coalfield, enjoyed a reputation for technical supremacy in the eighteenth century, largely due to the adoption of coke for smelting and the building of the Iron Bridge across the Severn, both of which were associated with cast rather than wrought iron. Some of this reputation rubbed off on the Cranage brothers.

Mott has argued that the significance of the Cranage process has been exaggerated but there was, nevertheless, some real substance behind the hyperbole. Money was invested in developing the process and a detailed account of it was written in 1768 by Alexander Chrisholm. There were two reverberatory furnaces at the Coalbrookdale Upper Forge, where a mixture of pig and scrap cast iron were heated three times.

> In the first reverberatory, they melt imperfectly, just run together irregular rugged masses; and become less fusible. The workmen say that little or no cinder separates; nor was any cinder to be seen about or near the furnace. During the time we staid [sic] there, not less than a quarter of an hour, the metal continued of a moderate glowing red heat, and was seldom if at all stirred.

The second heat was stronger:

> Cinder melts out in abundance and looks bright like quicksilver. The unmelted iron is continually moved and turned, with straight and crooked ringards, that it may sweat equally. At length it is taken out in one large rugged mass, thrown on the floor, and beaten with sledge hammers, to unite it a little and flatten the protuberances.

The third heat was similar to the earlier chafery and later balling furnaces: 'It is then put in the furnace again among the fluid cinder, after a little time taken out and carried under the great hammer, where it is beaten gently, and for a much longer time than in the charcoal forges.'

This description points up the misleading nature of the patent specification. Of greater significance is that the most authoritative assessment of the process was given not by Richard Reynolds or the Cranages, but by the workmen:

> The workmen say that if the metal has been equally sweated, it proves as tough as any iron can be, and fit for wire, otherwise very brittle; insomuch that in one bar there shall be 8 or 9 inches so tough that it cannot be broke, and other parts as brittle as glass – it is forged chiefly into flat bars for tyres, and for rolling into plates: they do not make wire of it – it seemed to work stiffer and harder under the great hammer than any other sorts of iron I have seen, and throws out much less cinder than that of the charcoal fineries: the Master said, that the more of the cinder was retained in it, the mellower the iron – Their boiling pans are made of plates of this iron, except the bottoms which are brass.

The quality of the iron was inconsistent and the process was wasteful, up to one half of the iron being lost in the working. The process was given up shortly afterwards, the problem being essentially one of technique rather than technology, that of how to ensure that 'the metal has been equally sweated'. The patent was subsequently acquired by the Coalbrookdale Company for £30, a not inconsiderable sum to the workmen, but poor compensation for their loss of regular earnings while they concentrated upon perfecting the process. Thomas and George only stood to prosper by a share in any future profits, which did not materialise.[33] After the trials the Coalbrookdale Upper Forge probably continued with its finery and chafery, which Chrisholm implies had not ceased working.

News of the Cranage patent spread quickly. One of the first people to comment upon it was Charles Wood, who at that time was superintending the erection of a new ironworks at Cyfarthfa in Merthyr Tydfil.[34] Wood noted that the process sounded similar to a process patented in 1724 by Roger Woodhouse which, despite early optimism, was abandoned because it was wasteful of iron. Wood presumed that the Cranage brothers had made significant improvements and was prepared to adopt their process, abandoning the expense and trouble of heating iron in pots, if it proved successful. One of the problems of using a reverberatory furnace, as opposed to a finery where the iron was placed on a bed of charcoal, was what material should be used to line the bottom of the furnace. The Cranage brothers were apparently using a sand bottom, but Wood's own experiments with the same had not been successful, and for that reason he sounded cautious. The momentum towards cheaper and quicker means of refining pig iron using mineral fuel was, however, not doubted. But Wood acknowledged that this climate of development was such that one man's invention would prompt another man's improvement, to the extent that technological change would be achieved not by isolated inventions but the combined efforts of the trade.

It is difficult to judge the long-term significance of the Cranage process because the available evidence is so limited. It was not successfully employed at Coalbrookdale, unlike stamping and potting. The earlier patent of Roger Woodhouse, and the implication that Charles Wood had made similar experiments, suggest that there was little in the Cranage process that was totally new. Henry Cort knew neither of the Cranage brothers and their patent specification gave him no useful information in the development of puddling although, like Charles Wood, he probably learned of their efforts at second-hand. To argue that the Cranage process was a stepping stone on the road to puddling, as numerous authors have done, is not justified by the evidence. Nevertheless, their efforts reinforce the impression of experimentation within the forge trade, in the use of reverberatory furnaces and mineral fuel. The Cranage brothers might also have been influenced by the working of scrap iron and have contributed to a technique known as buzzing in use in Shropshire in the late eighteenth century.[35] The description of Low Mill forge above suggests that working scrap iron was influential to the development of stamping and potting and perhaps Wood's experiments with scrap iron and reverberatory furnaces were well known. In 1754 he journeyed to the Midlands where he visited numerous Shropshire forges and entered into discussion on technical matters.[36] Later, it was an improvement upon Wood's stamping and potting technique that would be widely used in Shropshire.

3.5 Stamping and potting

There is no evidence of any further innovations in the Shropshire forge trade until the adoption of the stamping and potting process of Wright and Jesson. John Wright and his brother-in-law Richard Jesson (1741-1810) were forge masters and among the most prominent nail makers and ironmongers at West Bromwich, Staffordshire. They formed a partnership c1766-7 and by 1768 were buying charcoal pig iron from Aston furnace near Birmingham.[37] The business continued after John Wright's death in the 1770s when his son Richard Wright entered the partnership.[38] In 1773 John Wright and Richard Jesson were awarded a patent for what was essentially a variation on Charles Wood's original process. A further patent, awarded in 1784, specified that the iron could be heated on stacks of clay tiles rather than in pots, known as piling. There are three known contemporary accounts of stamping and potting, written in 1774, 1785 and 1803.

The earlier was written at West Bromwich forge by Marchant de la Houlière, an ironmaster and sometime brigadier in the French army, dispatched by the French government to report on technical developments in British industry. At West Bromwich, de la Houlière found the owners away, but he persuaded the workmen to explain the process, presumably by offering the appropriate remuneration.[39] The pig iron was refined in four stages. The iron, mixed with scale or cinder, was first heated in a traditional finery, but using coal instead of charcoal. At West Bromwich four pigs, weighing approximately one hundredweight each, made up a single charge. It was then removed in a succession of balls and laid on a flat cast iron plate, over which cold water was run. The iron was malleable enough for the hammer to beat the iron into a flat cake up to 1½ inches thick. This was then thrown aside to cool, and when cold was placed under the hammer again and beaten into small pieces (stamping). The 'granulated' iron was then washed to remove extraneous material, including coal cinders, and then was left in a shed to dry. In the final stage the iron was placed into pots approximately 1 foot high and 11 inches diameter, and placed in a reverberatory furnace (potting). This stage took approximately 4-5 hours, after which the pots broke up in the heat and the iron particles inside each pot had coalesced. These were then removed individually and hammered before being placed in a common chafery four or five at a time. From the chafery they could be drawn into bars of the required size.

The second description of the process was written in 1785 by François and Alexandre de La Rochefoucauld, two young aristocratic Frenchmen touring England with their tutor. Detailed notes on English industries by these two apparent novices were intended for their father, Duc de Liancourt, a notable improver who founded industrial schools on his estate in France. The brothers wrote detailed accounts of John Wilkinson's ironworks at Bradley and New Willey, and of the various Coalbrookdale works, where they witnessed stamping and potting at the Upper Forge. After heating in the finery the iron was hammered into a flat cake as at West Bromwich and then placed on one side to cool:

> Then a workman breaks with a great hammer the kind of plates that have formed ... Women put these into pots in such a way as not to lose the place between each lot of iron plates: they insert one of coal all broken up into small pieces. These pots are ... about a foot high and ten inches in diameter.
>
> Once the pots are full they are placed in order in a furnace ... twenty usually go in at a time: they stay there two and a half hours, while the action of the fire raises the iron to fusion point though it remains solid all the time. The coal has vanished: so have the pots, entirely. The workman inspects it from time to time to see whether the iron is ready: his judgement is the only rule. When it is, he takes a long shovel and removes the iron (which has retained the shape of the pot) to the very edge of the furnace. There, another workman grabs it with great pincers and lets it fall on to an iron plate placed to receive it ... Then he drags it ... to another workshop, close by, dumps it on to an anvil, and a hammer even bigger than the first beats it to compress it: it is [forged] on an iron bar already made to manage the job more easily, and it is under this great hammer that the iron, which arrived in the form of the pot in which it was baked, takes the form of a straight bar about ten feet long.[40]

When Simon Goodrich visited Coalbrookdale in 1803 he witnessed stamping and potting at the Upper Forge:

> A quantity of pig iron is heated with cokes upon a hearth called a refinery urged by a blast from one tweer pipe; whilst heating a man stirs up the iron with a poker and suffers the melted scoria to run out at a hole in the bottom of the hearth – the iron is taken out with tongs partly malleable and beaten under a tilt hammer called a shingler and this operation is called shingling … A certain quantity of lumps from the shingler are put into saggars made of clay which are placed in a reverberatory furnace called a balling furnace, when sufficiently hot the saggars are broken and the ball or lump of iron taken out and worked under a forge hammer into pieces about 3 inches square 2 feet long called half blooms, these are heated in another reverberatory furnace and drawn out into bars under the forge hammer.[41]

The language reveals that this account was written after the introduction of puddling. Hence the term 'refinery' rather than finery. Heating the iron in pots is undertaken in a balling furnace, which is not the same as the later and more common sense of the term balling, which is heating the blooms after puddling, i.e. the equivalent of the last of the heats described by Goodrich. But the term balling may have derived from the heating of small pieces of iron in pots to make them weld together in a single ball. The term 'potting' is rarely used in contemporary documents. In other accounts, shingling refers to the hammering of the iron after balling, but Goodrich uses the term to describe the original hammering when the iron is taken from the finery hearth. Again, the use of this term here may be explained by the author's comparison with what he had seen of the puddling process. Taken as a whole, the description by Goodrich shows that terms like balling and shingling were used more loosely than historians might wish and poses an additional obstacle in interpretation of changing technology.

Stamping and potting was successfully applied in West Bromwich and other Midland forges in the final quarter of the eighteenth century. The development of stamping and potting in Shropshire began in the 1770s and needs to be studied in the following contexts:

- Its impact on the geography of the Shropshire forge trade
- The increase in the overall output of bar iron
- The developing relationship between furnace and forge
- The motive power available to the industry, as stamping and potting coincided with the emergence of steam power

The first forge to work the process in Shropshire was probably Wrens Nest, where in 1775 Wright and Jesson purchased the forge, slitting mill and corn mill previously let to George Matthews, with the intention of erecting new buildings on the site.[42] It is possible that the Wheelers followed suit by building Eardington forge specifically for stamping and potting, but there is no proof. The scale of operation at Eardington increased in 1782 when a lower forge was constructed half a mile distant from the original, or upper forge, in order to re-use water from the upper forge, the delayed consequence of which seems to have been that the pool was enlarged six years later in 1788.[43] A similar need to re-use water for waterwheels dictated the linear arrangement of ironworks in Coalbrookdale. 1782 might signal the date when stamping and potting was introduced at Eardington, but it was supplementary to a finery and chafery, which continued in use.[44] Stamping and potting was also introduced at Cleobury Dale in the 1780s, although it reverted to a finery and chafery when Old Park Ironworks was built in 1790.[45]

Forges were built adjacent to coalfield blast furnaces at Horsehay, Ketley, Lightmoor, New Willey, Benthall (where blast furnaces were begun in 1778), Snedshill (1779), Donnington Wood (1783) and Old Park (1790) (figure 7). Some of them are listed in a national survey of the iron industry, for which the information covering Shropshire was collected c1790 (Table 2).[46] The list must be used with caution as it is notable for its lacunae. It lists fineries for stamping and potting only at Ketley, Donnington Wood, Eardington and Wrens Nest. Additions that need to be made to the list are Cleobury Dale, Old Park, Coalbrookdale and Horsehay, which are well authenticated.

Name	***Occupier***	***Forges***					***Mills***		
		finery	*chafery*	*melting fineries*	*balling furnaces*	*built*	*rolling mill*	*slitting mills*	*built*
Ketley	R Reynolds & Co	2		6		1786	1	1	1787
Donnington Wood	W Reynolds & Co			4		1786			
Cleobury Dale	Botfield & Co	2	1				1		
Prescott	Botfield & Co								
Upton	Wheeler & Co	3	1						
Norton	Wheeler & Co	2	1						
Eardington	Wheeler & Co	3	2	2	1				
Wytheford	J Dorset	2	1						
Uffington	Wheeler & Co							1	
Caynton	Hallen	2	1						
Sambrook	Hallen		1		1				
Tibberton	Hallen							1	
Longnor	W Jones	2							
Pitchford	Lawrence & Hazeldine	1	1						
Lizard	Lawrence & Hazeldine	1	1						
Rock Mills	Dale Co								
Wrens Nest	Wright & Jesson		1	2	2				
Cleobury	Sir W Blount	3	2						
Hampton Loade	William Jones	1							

Table 2: Forges and mills in Shropshire c1790. Source: B&W MII/5/10.

The date of the survey is uncertain. It refers to Old Park blast furnaces (but not forges) built in 1790, and Pitchford forge as occupied by Lawrence & Hazeldine, which they took over also in 1790. But it gives Wheeler & Co as occupying Eardington forge, which they sold in 1789. Therefore the date c1790 has been adopted as a working date for the survey.

Two forges mentioned in the list – Halesowen, now in Staffordshire, and Bringewood, now in Herefordshire – are not included here.

The entry for Ketley shows six melting fineries for making stamped iron, which probably denote two each at Ketley, Horsehay and Coalbrookdale. Likewise the rolling mill mentioned is probably at Horsehay. No details of Horsehay or Coalbrookdale forges are otherwise mentioned.

The list gives no information on 'Rock Mills' (i.e. Bridgnorth forge) or Prescott.

Failure to capitalise on the Cranage process did not inhibit the Coalbrookdale partners in investing in stamping and potting. In a letter written in 1784, Richard Reynolds aired some of the background to the investment the partners were then making in wrought iron:

> The nail trade, perhaps the most considerable of any one article of manufactured iron, would have been lost to this country, had it not been found practicable to make nails of iron made with pit coal. We have now another process to attempt [i.e. stamping and potting] … and it is for that purpose that we have made, or rather are making, the alterations at Donnington Wood, Ketley & co.[47]

This dates the founding of stamping and potting forges at Donnington Wood and Ketley to c1784, both of them managed by Richard Reynolds' son William Reynolds.[48] Horsehay forge was built in 1784 and was one of the first forges where the hammer was powered by a Boulton & Watt engine.[49] Its rolling mill was water-powered with the aid of an atmospheric engine to recycle water.[50] Considerable enlargement of the Coalbrookdale Upper Forge followed in 1785 and is discussed below. Investment in forges was one of the reasons that the finances of the Coalbrookdale partners were in a parlous state by the 1790s. In 1796 their business was divided. Horsehay and Coalbrookdale Ironworks remained under Darby control, trading as the Coalbrookdale Company. Ketley and Madeley Wood Ironworks henceforth traded as William Reynolds & Company.

Although Lightmoor blast furnace had been established in 1758, the development of forging there probably took place after its lease was acquired in 1787 by Francis Homfray (1752-1809) and his cousin John Homfray (1759-1827, who in 1792 changed his name to Addenbrooke, his mother's maiden name). The earliest reference to a forge there occurs in 1790 when 'Lightmoor forgemen' were paid for sundry labouring at local collieries.[51] There is no specific reference to stamping and potting at Lightmoor, but it is the most likely process to have been used.

The Homfray family was well established in the Black Country and South Wales iron trade. Members of the family played a significant role in the development of technology in the late eighteenth century, and so it is worth digressing to outline in more detail their network of interests. The first Francis Homfray had interests in Royal Forge, Gothersley slitting mill and Swindon Forge, all in Staffordshire (figure 5), and died in 1737. His concerns were carried on by his wife Mary before passing largely to their son, also Francis (1725-98). This second Francis operated forges and slitting mills at Gothersley, Stourton and Swindon, and after 1782 operated a small cannon foundry at Cyfarthfa in Merthyr Tydfil. He had five sons: Francis (1752-1809), Jeremiah (1759-1833), Samuel (1762-1822), Thomas and Jeston (died 1816). The best known of these sons were Samuel and Jeremiah, since they were the proprietors of the Penydarren Ironworks in Merthyr Tydfil which was established in 1785 and closely followed the neighbouring Cyfarthfa works in the development of puddling. Thomas Homfray was part of the original Penydarren partnership, which had been initiated by their father, but took no active part in the management. In addition to his interests at Lightmoor, Francis had been a partner since 1781 with his aunt, Eleanor Caswell, at Hyde forge in Staffordshire, which had a rolling and a slitting mill (figure 5). John Homfray is listed as the proprietor of Broadwater forge near Kidderminster in Worcestershire, in the national survey of c1790, although it was later owned by his cousin Jeston Homfray (figure 5).[52]

Snedshill Ironworks was founded in 1780 by John Wilkinson (1728-1808). Wilkinson already owned Bersham Ironworks in Denbighshire, New Willey, and Bradley Ironworks in Staffordshire, where there was a large stamping and potting forge. Output at Snedshill was confined to pig iron and the simpler types of casting during the period of Wilkinson's lease, which expired in 1793. Thereafter it was managed by a partnership led by John Bishton, agent to the Marquess of Stafford's Lilleshall Estate.[53] Bishton also acquired Donnington Wood ironworks in 1797 and so it is not possible to tell whether semi-finished iron sent to the Stour Valley forges in that year came from Snedshill or Donnington Wood.[54] Snedshill, as well as Lightmoor, forge is documented by the fact that it sent semi-finished iron to Horsehay for rolling and is most likely to have employed stamping and potting.[55]

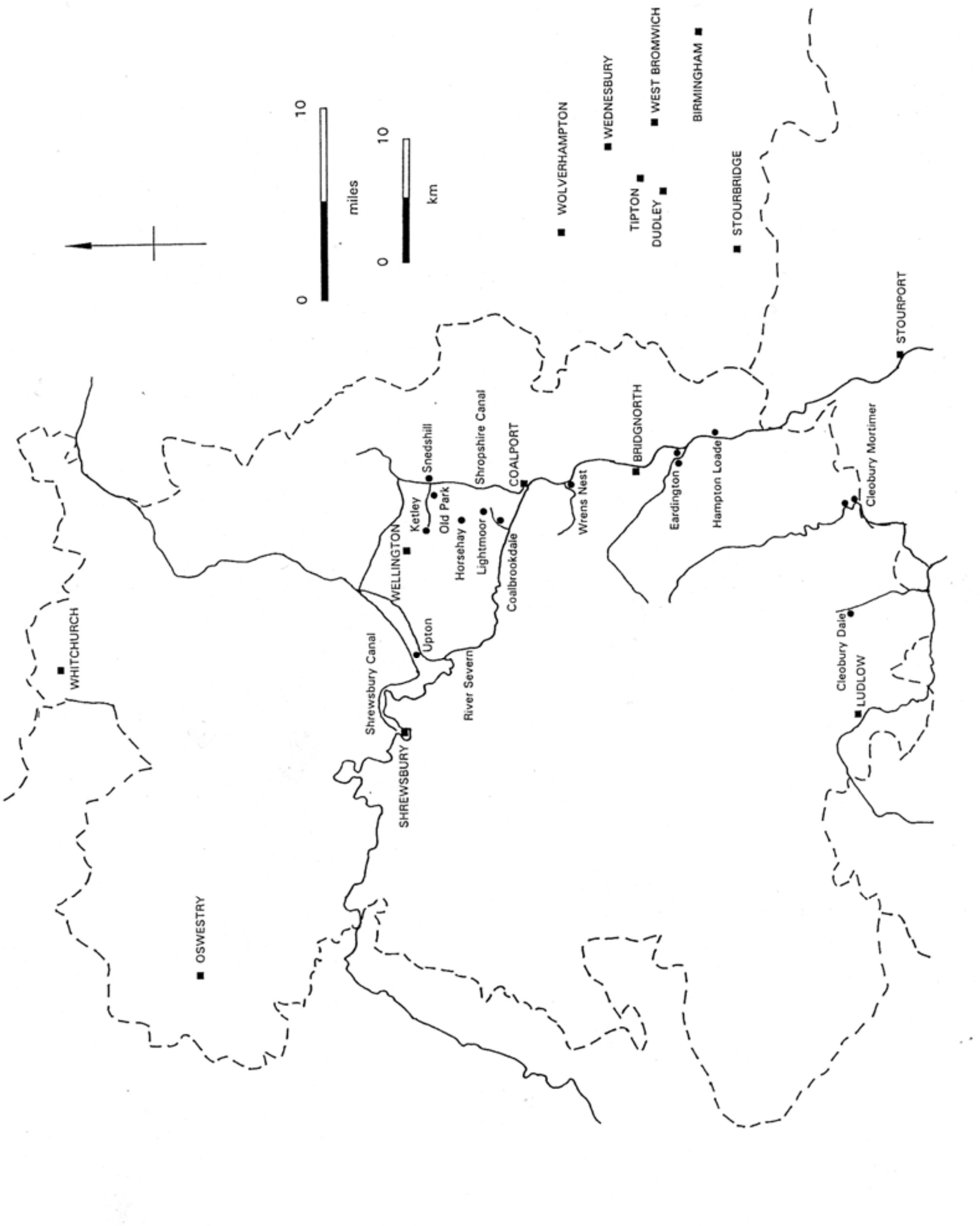

Figure 7 Shropshire Forges, c1810

Two other coalfield forges were probably short-lived. The engineer John Rennie made observations of ironworks in a journey through Shropshire in 1784. Here he saw a forge at New Willey (not mentioned by the La Rochefoucauld brothers), which is most likely to have employed stamping and potting because he mentions vessels of white clay for enclosing the partially refined iron, and that the refining was a two-stage process. Rennie also saw a large hammer at Benthall Ironworks, which is the only known reference to a forge there.[56] Whether stamping and potting was employed at Benthall is speculation.

By the end of the eighteenth century there is good evidence that stamping and potting had been carried out at a minimum of eight ironworks: Cleobury Dale, Coalbrookdale, Eardington, Horsehay, Ketley, Old Park, New Willey and Wrens Nest. Lightmoor, Snedshill and Benthall may also need to be added to the list. All but one of these ironworks had been established after 1750, the exception being the Coalbrookdale Upper Forge. Furthermore only Cleobury Dale, Eardington and Wrens Nest were outside the East Shropshire Coalfield and, like Coalbrookdale, are cases where stamping and potting was introduced to existing finery and chafery forges.

3.6 Stamping and potting at Coalbrookdale

One of the consequences of stamping and potting was an increase in the size of individual forges. This was partly because of the introduction of steam engines, but also because stamping and potting was in some cases operated in the same building as a finery forge. Here it is worth examining the Coalbrookdale Upper Forge as a case study, because its development in the 1780s can be usefully contrasted with descriptions of it from the 1750s. When Charles Wood visited in 1754 it had two fineries and a chafery housed in a single building, probably powered by two waterwheels. In addition a charcoal store and a workshop for manufacturing finished items stood close by.[57] In 1766 two reverberatory furnaces were erected there as part of the investment in the Cranage process, but the principal development took place in the last quarter of the eighteenth century, part of the overall renewal and expansion of ironworking at Coalbrookdale initiated by Abraham Darby III.[58] In 1776 a slitting mill was built adjacent to the forge. Its construction was witnessed by Jabez Maud Fisher and Arthur Young, both of whom confirm that it was powered by a waterwheel.[59] Apparently the new mill proved unsuccessful, for reasons unknown, and the building was converted for forge use c1783.[60] This may mark the time when the works adopted stamping and potting, which was well established by 1785 when the La Rochefoucauld brothers visited Coalbrookdale.[61] The forge had expanded to encompass two buildings. The forging process was undertaken in the old forge building and was drawn out to merchant bar using a hammer erected in the former slitting mill. This mill may have undertaken the work formerly undertaken at Bridgnorth Forge. The scarcity of water that had inhibited further development at Coalbrookdale was alleviated when, in 1781, a pumping engine was constructed to recycle water from below the Upper Forge, serving both the forge and two blast furnaces.

Further major expansion was undertaken in 1785. A blowing engine was added to the converted slitting mill to blow two new fineries on the outside of the building, while a waterwheel continued to work the forge hammer. Two years later a hammer engine was constructed adjacent to the older forge, although it was operational for only a brief period, as it ceased working in 1793. Ten years later the engine had been removed and the building had been converted to a tenement.[62] Unfortunately there are no output figures that can demonstrate the increased production at the Upper Forge, but it is telling that in addition to the two waterwheels two Boulton & Watt steam engines were employed, a substantial investment in the new technology of steam, and also of stamping and potting. In fact the investment at Coalbrookdale was only one component of investment in stamping and potting by the various partners in Coalbrookdale Company which, according to Richard Reynolds, amounted to £20,000. This figure was in large proportion due to the purchase of engines.

3.7 Steam power in Shropshire forges

Steam power became one of the defining characteristics of the coalfield forges, increasing the industry's dependence upon coal and distinguishing coalfield forges from the water-powered rural forges. It should not automatically be assumed, however, that the waterwheel was obsolete. Writing in 1796, Thomas Telford argued that improvement of the River Severn navigation should incorporate locks with reservoirs that could also serve to power forges, replacing the 'trifling brooks' that were currently used by 'this great and increasing business'.[63]

The East Shropshire coalfield was closely associated with developments in engine technology in the latter quarter of the eighteenth century. The Coalbrookdale Company had made parts for steam engines since 1718, complete engines by 1722, and constructed a mill for boring engine cylinders in 1734 when Thomas Savery's patent expired and the company expected an upturn in orders. Abraham Darby III rebuilt the Coalbrookdale boring mill in 1780. Meanwhile John Wilkinson, proprietor of iron works that included New Willey, contracted to make parts of Boulton & Watt engines from 1776. Components and complete engines were supplied by a number of Shropshire ironworks by the end of the century.[64]

Initially steam engines had been employed for mine drainage but they were soon adapted to recycle water to drive the waterwheels that powered the bellows blowing blast furnaces. One of the earliest examples had been erected at Coalbrookdale in 1742. Of the blast furnaces established in the 1750s at Lightmoor, Horsehay, Ketley and Madeley Wood, all had engines for recycling water. At first, engines were used in a similar way at forges, and after 1776 most engines were of the Boulton & Watt type with separate condenser. In strict terms such an engine was not necessarily needed simply for water recycling, but the close association between Shropshire ironworks and Boulton & Watt had reciprocal benefits: The burgeoning Midland engineering industry looked to Shropshire for both technical expertise and markets. The first Boulton & Watt engine built for the iron industry, and used for the direct blowing of a blast furnace, was erected at Wilkinson's New Willey furnace in 1776. The earliest Boulton & Watt engine erected for a forge was at Wrens Nest, where in 1779 an engine was built for recycling water for the wheel driving the forge hammer. This is significant because the 1770s was the last decade when the availability of water supply for wheels was an essential factor determining location. In 1781 the Resolution engine was erected at Coalbrookdale, for recycling water to the blast furnaces and Upper Forge. Other recycling engines were later used in the wrought-iron industry.[65] An engine at Ketley recycled water for the slitting mill that was constructed there in 1796, while at New Willey in 1784 John Rennie saw an engine that raised water for two waterwheels driving forge hammers.

The key development of the early 1780s was to provide rotative motion, since by this means the engine could replace the waterwheel altogether. Although the Boulton & Watt engines were technically supreme there were other experiments. One of these was seen by John Rennie at Benthall in 1784 and was perhaps the first engine applied to work forge hammers directly. It was an atmospheric, or Newcomen, engine that had a rack fixed to the rod below the beam, the teeth of which turned wheels to create a rotative motion regulated by a flywheel.[66] The first Boulton & Watt rotative engines operated with sun-and-planet gear rather than the now universal crank shaft. The earliest was a forge engine erected in 1782-3 at John Wilkinson's Bradley Ironworks. Over the next decade seven more forge engines with sun-and-planet gear are known to have been supplied by Boulton & Watt, all of them to Shropshire forges.[67] They were four at Ketley, two at Horsehay and one at Coalbrookdale. Meanwhile the engine for recycling water at Wrens Nest was converted to a rotative engine in 1791. What type of engine was used at Donnington Wood, Snedshill and Lightmoor forges is not known. Neither was on a site suitable for water power.

In addition to the forge engines it should be noted that some means of power was also required for blowing the fineries. At Horsehay air was provided by the engine built to blow the blast furnaces. This may also have been the case at Donnington Wood, where the purchase of a blast engine is well attested.[68] At Coalbrookdale the engine of 1785 was specifically constructed for blowing two fineries, but this is the only known example of direct blowing for fineries.

3.8 Old Park Ironworks

Old Park Ironworks was established by Thomas Botfield and was built in 1790. The works was entirely steam powered from the outset and was constructed on a site that was not dictated by the need to harness water for waterwheels. Botfield had been a member of the original Lightmoor Furnace partnership in 1758, and had established ironworks and mines in the Clee Hills, south Shropshire, in 1783, specifically Cornbrook furnace and Cleobury Dale forge and rolling mill. He was also agent to Isaac Hawkins Browne, on whose estate Old Park was built.[69] The forge was built in 1790 soon after the first two blast furnaces. It had four fineries and two forge engines, one for the stamping forge and one for the drawing forge where the bars were finished off.[70] There is no evidence that an engine was built to blow the four fineries, suggesting that air was blown from the main blast engine. This was one factor in siting the forge close to the blast furnaces.

Although stamping and potting reached Shropshire only in 1776, by 1790 it was already so well established locally that expertise did not need to be sought from further afield. Thomas Botfield's memoranda on the establishment of the Old Park Ironworks reveal how an ironworks was structured and organised, and demonstrate how Shropshire at that time relied upon its own resources in the fields of smelting, forging and engine building. Botfield had to make a capital investment in the forge plant, and a separate investment in the technical expertise to run it. Various details of engines were noted by Botfield, including the forge engine at Horsehay.[71] Francis and John Homfray of Lightmoor Ironworks were contracted to cast the cylinders and other parts for the blast engine and forge engines, while chains and boiler plates were supplied from Cleobury Dale. Various rates of pay for fining, shingling, breaking the iron and 'buzzing' were obtained, with the expected weekly yield. For example John Miner, of Ketley Ironworks, informed him that the price for breaking stamped iron was 21d per ton upon the pig iron, as did Ralph Deakin, a breaker of iron at Horsehay, while 3d per ton was paid for weighing the iron. This information was supplied from workmen as well as managers, all of whom were coalfield men. Botfield did not note any information supplied from Cleobury Dale.

Key workmen were employed on favourable terms and long-term contracts. A house with garden, and domestic coal were the standard additional perks. The most important, or at least the best paid, employee was Edward Cranage (1741-1813) who agreed a twenty-one-year contract as furnace keeper. Edward was the son of the patentee George Cranage, learned his trade in Shropshire and would end his career as agent at Ketley Ironworks.[72] Botfield agreed to pay him £100 per year if each of the two furnaces yielded 80 tons a week, £80 per year if they produced 60 tons each. Botfield was at liberty to dismiss him if he failed to make 3120 tons per year (60 tons a week per furnace), while Cranage could only give notice to quit at seven-year intervals, with a six-month notice period. The high rate of pay and the length of the contract are indicative of the business confidence of the enterprise, and demonstrate that smelting was the core of the ironworking business. Cranage was also required to find suitable workmen for the operation of the furnaces, which may have encouraged him to bring in his own men. It was at this managerial level that the make-up of the workforce was determined.

The forge carpenter was Joseph Finney of Tipton, Staffordshire, who was employed for a year at £80. The role of the carpenter appears to have been in organising the building of the forge rather than a more lowly maintenance role. In fact a second carpenter, James Carnall of Benthall, was employed for three years at 14/- per week (or £36/8/- per annum) and may have been responsible for maintenance. But these men were not necessarily responsible for building the furnaces. At Horsehay in 1796 the forge carpenter was John Weaver, who was paid 2/2 per day, but all furnace repairs, and building of new furnaces, was the work of William Duddell, paid at 4/- per day.[73]

In terms of operating the forge, the first workman to talk to Botfield was Thomas Humphries, a finer from New Willey. He offered to work the finery at 10/- per ton for producing stamped iron, and was prepared to take on the responsibility of employing other men to make 10 tons a week each. The output of the Horsehay forges discussed below shows that 10 tons was an ambitious weekly target that is unlikely ever to have been achieved. In the event Botfield engaged Joseph Williams to superintend the fineries. He was to agree to work for seven years from the time the fineries began working, and had to find twelve men to work the four fineries double-hand (i.e. two shifts per day). He was to be allowed a royalty of 10d per ton of stamped iron. Williams recommended two local men, indicating that he was himself previously engaged in the Shropshire trade: 'Ben the ball-man', who was reckoned to be a good hand at balling, shingling and drawing at Horsehay, and Ralph Deakin, the Horsehay breaker of iron mentioned above. Another finer, William Lem, was recommended by Joseph Madeley of Bridgnorth. Botfield also seems to have engaged two other finers independently: Simms, a finer who worked previously at Donnington Wood, and James Leonard, a finer and hammer-man from Pitchford forge.

The second part of the stamping and potting process, heating the iron in pots, shingling, balling and drawing the iron under the hammer, was superintended by Benjamin Smith, who had previously worked at Horsehay.[74] As early as April 1789 he agreed to work for seven years to the following rates of pay: 1/- per ton for filling pots and 4/- per ton for balling the iron and drawing it into bars. In addition he was to receive an allowance of 7d per ton for keeping the balling and chafery furnaces in repair. This could be calculated in two ways: if it was measured according to the blooms, then it was to be a longweight ton, if measured as bar iron it was a shortweight ton. Labouring by both himself and his men would be paid at 2/6 per day.

Evidence of the Coalbrookdale Upper Forge in 1785 and Horsehay later in the 1790s show that Smith must have subcontracted. Filling appears to have been women's work, and thus poorly paid. But Smith was also responsible for finding and teaching skilled men. He was allowed £3/3/- for every man he could instruct to Botfield's satisfaction. A further note from Smith, dated August 1789, confirmed the rates of pay previously agreed and added a figure of 1/0½ for finding firebrick and clay to carry out any repairs.

3.9 Horsehay forge and rolling mill

A clearer picture of the operation of a stamping and potting forge is provided in the wages book of the Horsehay Ironworks for 1796-8. Wages accounts for the period July 1796 to June 1797 refer solely to stamping and potting, although the picture subsequently becomes complicated with the gradual introduction of puddling (Appendix 1). These accounts confirm the general impression of the Old Park works where a hierarchy of workmen was established from the outset. Like Old Park, Horsehay forge was operated by key workmen who sub-contracted other men, most of whom do not appear in the wages book for their normal duties, but in periodic sundry payments for unskilled labour.

The accounts mention two finers, Samuel Purcell and James Skelton. During the period 1796-8 the output of the fineries varied according to a number of factors, but generally averaged approximately 30-33 tons over a four-week period. The fineries never reached a figure of 40 tons each that would have meant the expectations at Old Park in 1790 of 10 tons per week. The iron from the fineries was known misleadingly as 'stamped iron' before it had undergone the stamping process. In July 1796 stamped iron was paid at 9/- per ton from pig iron, but in November that year the two grades 'good' and 'bad' were introduced. The latter term is also misleading because it did not mean that bad stamped iron was not suitable for shingling. In 1797 bad stamped iron was paid at 8/- per ton while only 10/- per ton was paid for good iron.[75] The output of bad iron was generally 2-4 tons per four-week period.

The breaking (or stamping), washing and weighing of stamped iron was paid by the ton of pig iron, the custom noted by Thomas Botfield. The Horsehay wages accounts also confirm the account written by the La Rochefoucauld brothers at Coalbrookdale that filling pots was women's work. At Horsehay it was the responsibility of Fanny Hazlehurst. After heating the iron in pots it was shingled to blooms for drawing into bars, or slabs for rolling into plates. In 1796 John Lambert senior & Co were paid 8/- per ton for shingling to bloom, and 16/- for shingling to slabs.[76] This confirms other sources that imply that the best workmen were put on to making slabs, a more skilled process and a more valuable finished product.[77] Blooms were drawn under the hammer into bars in the shingling forge, and were graded merchant and mill iron. The merchant iron was reheated in the drawing forge (in the process described in 1774 by Marchant de la Houliere as the chafery), and was finished off under the planishing hammer, a light hammer to give a smooth even surface to the metal. The mill iron was sent to the rolling mill. Likewise the slabs were invariably sent to the rolling mill for the making of boiler plates.

Rolling mills were particularly suited to making wrought-iron boiler plates, the market for which expanded rapidly in the last quarter of the eighteenth century. It has been calculated that just over 200 engines were built in the 1770s, but in the 1790s over 1000 new engines were built, each requiring at least two boilers.[78] Botfield's Cleobury Dale rolling mill has already been mentioned as an example. The only other rolling mill in Shropshire until the end of the eighteenth century was at Horsehay.

In the period 1796-8 the Horsehay mill was worked by two teams under Sampson Eadon and William Hazlehurst.[79] The products of the mill were generally bars rolled from mill iron delivered from the shingling forge, or the rolling of bars already drawn out under the hammer. This included 'faggoting', the rolling into a single bar of bundles of small rods. These rods were often delivered from the forges at Ketley and Coalbrookdale. In fact Ketley continued to send iron to the Horsehay rolling mill after the holdings of the Coalbrookdale partners were divided in 1796. Several consignments of stamped half blooms or common stamped iron were sent for rolling at Horsehay from Ketley in 1796. Half blooms, rods and bar were also sent regularly from Coalbrookdale, a typical example being 'casement rods' for rolling into barrel hoops.[80]

Boiler plates have already been alluded to among the rolling mill's special products. Boiler plates were rolled for a number of engines in the coalfield, including engines at Hadley in 1796, Old Park in 1796-7, Donnington Wood in 1798 and for the collieries at Madeley Wood.[81] In 1796 boiler plates were supplied to the Wombridge Company made up partly by supplying plates from an old boiler for re-rolling.[82] From 1797 the rolling mill received several consignments of slabs from Snedshill forge that were rolled into boiler plate, and likewise from Old Park and Ketley.[83] The thickness of the plates varied from $^{3}/_{16}$ to ½ inch, while the area was variable. For example, plates for a boiler rolled in 1796 included a crown plate of 4 feet 1½ inches diameter, while the largest of the plates were 4 feet 10½ inches long, 13 $^{5}/_{8}$ inches at the wide end and 12 $^{3}/_{8}$ inches at the narrow end.[84] In order to produce such a trapezoidal shape it was necessary to use mechanical shears. The mill scale and offcuts were valuable commodities, they having been produced by the more expensive slabbing process, and were returned to the customer along with the finished boiler plates.

The other specialist product was plates for frying pans and salt pans. For example, in June 1794 317 pan plates of different sizes were sent to George William Hallen at the Coalbrookdale Lower Forge, together with 12 bars of handle iron.[85] Similar consignments are mentioned for 1795 and pan plates appear until 1797 in the output of the rolling mill.[86] These pan plates, as well as thinner sheet iron, were annealed after rolling. Iron for handles was also produced. One consignment was sold to M & S Richardson in 1796, but otherwise all handle iron went to the Lower Forge at Coalbrookdale.[87]

Previously the drawing of iron into plates of flat section required 'nests' of several plates to be hammered *en masse* but without them welding together. The rolling mill was able with ease to roll plates to a consistent thickness. The advantage of the rolling mill therefore seems clear, but much of the iron produced at Horsehay was still drawn under the hammer rather than rolled in the mill. The continuing market and regard for iron drawn under the hammer is also testified by the fact that most of the forges established for stamping at potting relied solely on the hammer.

This provides an important context for the Horsehay rolling mill at the end of the eighteenth century. The rolling mill operated as an independent entity, receiving semi-finished iron from a number of local forges for what was at that time still a specialised process. In its manufacture of boiler plates it worked in a similar manner to the secondary forges where nails and frying pans were made, producing a finished product. In the last decade of the eighteenth century the most germane parallel of the rolling mill was the slitting mill, the distribution of which after 1750 has already been discussed. The Ketley slitting mill, which was working by October 1796, provided a specialised service in the slitting into rods of bars from other forges in the same manner as the Horsehay rolling mill.[88] Until a slitting mill was built at Horsehay in 1798 bars from Horsehay and Coalbrookdale were sent to Ketley for slitting during the period 1796-8 for which figures are available, and included the slitting of iron from Coalbrookdale for pan handles to be sent to the Lower Forge.[89] In this context the rolling mill operated in the same way as Cleobury Dale in Shropshire and other small Midland rolling mills that had served finery forges. The mill did not therefore supplant an existing operational structure of the trade but added to it. Although stamping and potting had seen large increases in output of wrought iron, the trade continued to undertake its business as it had done when the finery and chafery was the sole available technique.

3.10 Integrated ironworks in the late eighteenth century

The integration of furnace and forge at a single site was not new, but it became a marked trend in the coalfield during the final quarter of the eighteenth century.[90] It was aided by the introduction of steam power but was not entirely intended as a more efficient line of production than the isolated forges. The larger works supplied pig iron to their own forges. Horsehay also appears to have supplied most of the pig iron used at the Coalbrookdale Upper Forge. But there is also evidence that the Horsehay forge occasionally received pig iron, for example from Donnington Wood.[91] An overall pattern is, however, clear. Despite adopting the stamping and potting process, the forges were unable to keep pace with the output of pig iron from the blast furnaces, so the principal Shropshire ironworks like Horsehay, Ketley and Old Park, for which there are some reliable sources on output, were also suppliers of pig iron on a large scale. Much of it went to the small Midland forges, including those of the Stour Valley controlled by the Knight family, who regularly purchased Shropshire pig iron into the 1820s. Even as late as the 1820s less than half of the forge pig iron smelted at the Old Park furnaces was converted to wrought iron at the company’s own forge. In 1797, for example, Old Park furnaces sold 5686 tons of forge pig iron, of which the Old Park forge took only 1382 tons, while the principal external customers were 803½ tons sold to Wrens Nest and 885 tons to Eardington.[92] It was not in the interests of coalfield ironmasters to see small independent forges go out of business because they were an important market for pig iron. The interests of the ironmasters were therefore better served in efforts to increase the market for iron products to match the increased capacity of the industry.

The relative qualities of coke pig iron are demonstrated by the case of Wrens Nest forge. Wrens Nest continued to purchase Old Park pig iron, despite the fact that Wright and Jesson had built their own blast furnaces at Barnetts Leasow in 1797 and 1800. Barnetts Leasow was in theory well placed to supply Wrens Nest with forge pig, being situated only 2 miles (3 km) north west of Wrens Nest close to the River Severn, but it seems to have concentrated on foundry pig and even had a small foundry of its own. The Barnetts Leasow furnaces should consequently be interpreted as an ironworks in its own right exploiting a market quite distinct from wrought iron. Therefore, although it made sense to site a forge close to blast furnaces, giving it a readily available supply of pig iron and coal, the integration that is implied by the close proximity of furnace and forge can be misleading. The organisation of production was more complex and in the case of Wright and Jesson's interests show the influence of the quality of materials. As with Barnetts Leasow, all of the Shropshire blast furnaces for which details are known produced foundry pig iron, which was clearly a profitable market for Shropshire ironmasters and remained so well into the nineteenth century. The coalfield already had a reputation for foundry and engineering work, having pioneered the construction of steam engines in the eighteenth century, and also of cast iron for civil engineering purposes.

The pattern of siting a foundry with the blast furnace also benefited the forge master. As the output of wrought iron increased so did demand for the cast iron components of finery hearths and hammers. A small foundry at Old Park made parts for its own forge. It also supplied parts for hammers at Cleobury Dale and Wrens Nest, and finery and chafery plates for Wrens Nest and Hampton Loade.[93] Likewise Ketley foundry supplied Horsehay with rolls, stamping and other hammers, and anvils, and its turning mill was used to keep existing rolls smooth.[94] After the Coalbrookdale partners divided their business empire in August 1796, the foundry at Coalbrookdale was used for castings and its turning mill for smoothing the rolls.[95]

3.11 Rural forges in the late eighteenth century

Despite the proliferation of stamping and potting forges in the final quarter of the eighteenth century, there was no precipitate decline in the charcoal-using rural forges by 1800. Four forges probably did close before 1800, but in the seventeenth and early eighteenth centuries water-powered sites were occasionally adapted to different uses and so a small number of closures would be expected. There is no known date when Prescott, Wytheford or Norton-in-Hales forges ceased working, as the last record of them is the national survey of c1790 (Table 2).[96] The last known mention of Moreton Corbet was in 1794, when it was advertised for sale with only five years remaining on its lease.[97]

The implication of a progressive coalfield and conservative non-coalfield cannot be taken for granted, even though no rural forges in Shropshire are known to have converted to stamping and potting. Rural forges were not isolated from developments in the coalfield. According to the list of forges made c1790 two of three slitting mills in Shropshire were situated at rural sites – Uffington and Tibberton – and may well have slit bar from the new coalfield forges, since stamped iron was deemed to be particularly suited to nail making (Table 2).

Some of the rural forges were owned by coalfield forge masters. John Wilkinson and his father-in-law Edward Blakeway acquired the lease of Moreton Corbet in 1757, and during their tenure they became partners in the Dowlais Ironworks in South Wales. In 1759 Moreton Corbet was let to another partnership that included George Perry, the leading partner in the Lightmoor blast furnace.[98] In 1769 John Gibbons passed on the lease of Pitchford Forge to his sons Thomas, William and Benjamin Gibbons, who owned stamping and potting forges at Lye, Cradley and Level

Ironworks, all in Staffordshire. Their father owned Sutton forge from 1766.[99] It is possible that Pitchford was maintained by the Gibbons family to work with charcoal just as Thomas Botfield continued with Cleobury Dale after Old Park was established.

Tibberton was owned by members of the Hallen family, which probably included Samuel, William (d 1832) and George (1763-1838), all sons of Samuel Hallen of Prescott.[100] The younger Samuel Hallen owned Wednesbury Forge in Staffordshire where stamping and potting was said to have been introduced in 1786.[101] In 1794 Upton was managed by John Wheeler, but was owned by a partnership that included George, William and Samuel Hallen, to whom Wheeler was related by marriage. Wheeler and William Hallen leased Moreton Corbett forge in 1790.[102]

By 1794 Upton had three fineries, two balling furnaces and two 'puddling' furnaces.[103] The exact nature of the latter, which seems rather early for the adoption of puddling in Shropshire, clearly refers to reverberatory furnaces, although they could have been furnaces used for working scrap iron. Upton was clearly a substantial operation by contemporary standards. It had more hearths than, for example, Horsehay forge, and in 1793 employed forty workmen at the forge and related activity.[104] The case of Uffington slitting mill is equally interesting. Owned by Wheeler & Company, it was a water-powered mill where water was raised by a windmill and was described as 'new' in 1794 when it was advertised for sale with Upton.[105]

Another rural forge that had reverberatory furnaces by the 1780s was Pitchford, since Henry Cort was able to make a trial of his puddling process there in 1784.[106] Again this might refer to a furnace working scrap, but Pitchford may also have been adapted to stamping and potting – in 1790 one of its finers, James Leonard, took a job in the forge at Old Park.[107] In 1796 William Jones was using a 'patent balling furnace' at one of his forges, either Hampton Loade or Longnor.[108] This widespread use of reverberatory furnaces demonstrates that mineral fuel was used at the rural forges and consequently that forging techniques were modified to make use of it.

In summary, there is no evidence that the rural forges or the finery and chafery were threatened by the emergence of stamping and potting. This period was therefore one of increasing complexity in the forge trade. Evidence shows that many coalfield ironmasters operated both coal and charcoal technologies at different sites. Even if they were not associated with them directly, coalfield blast furnaces produced a surfeit of pig iron that was purchased by independent forges, most of which were rural forges on older sites.

3.12 Conclusion

The structure of the forge trade did not change radically during the latter half of the eighteenth century. The principal markets were still the Midlands and Bristol Channel ports. Increasing importance placed on access to transportation is demonstrated by the emergence of the Severn Valley forges. The introduction of coke-smelted pig iron in the 1750s was followed by a viable coal-based method of refining pig iron in the final quarter of the eighteenth century. The development of steam technology ran parallel to the adoption of stamping and potting, making some contribution to its success, but was essentially independent of it.

Stamping and potting heralded a shift in the centre of gravity to the coalfield, and saw ironmasters expand their interest from pig and cast iron to include wrought iron. At the same time, many coalfield ironmasters acquired rural forges for working with charcoal, giving them an increased repertoire in the manufacture of wrought iron. Stamping and potting produced a grade of iron suitable for manufacturing nails, whereas charcoal iron remained important for wire and tinplate, where high quality was required. It set a trend where coal-based technology dominated the market for common grades and charcoal technology remained important for higher grades. Most of the iron that was shipped to customers was still shaped under the hammer. The rolling mills at Horsehay and Cleobury Dale were engaged in specialist work such as boiler plates, and worked in a similar way to slitting mills.

The use of coal saw a substantial increase in forge output. In 1796-7 the two Horsehay finery hearths produced 814 tons of iron refined from pig, yielding 694 tons of slabs and blooms.[109] In the national survey of 1749, the largest of the charcoal forges in Shropshire were said to have an annual output of 260 tons of bar iron (Sutton and Upton Forges).[110] Figures for finery output extrapolated from David Mushet's list of forge production in 1788 give an average of 90 tons per finery per year for Shropshire. The corresponding figure for Worcestershire was 130 tons, but the fineries of the Knight family's forges made an average of nearly 175 tons, probably because they worked two shifts.[111] However, this is still only half the output of Horsehay.

4 THE TRANSITION TO PUDDLING, c1790-1815

Puddling was the single most important innovation to occur in the wrought-iron industry during the industrial revolution period. The background and events relating to its introduction have been covered elsewhere, but it is necessary to examine those events again here in the Shropshire context, and in the light of the discussion of the Cranages and stamping and potting in the previous chapter.[1] Economic and technological historians have argued for a rapid adoption of the process in the 1790s, albeit after initial technical difficulties had been overcome. Evidence from Horsehay and Old Park, and to a lesser extent Ketley, allow the transition to puddling in Shropshire to be examined in specific rather than general terms. Previous historians have taken for granted that puddling was the norm by the early nineteenth century and not without contemporary evidence to support it. William James, clerk to the Old Park Ironworks, gave output figures for bar iron in Shropshire during the period 1816-20 from only the three major puddling forges – Horsehay, Old Park and Ketley – as if there were no other forges of consequence.[2] Other evidence, however, shows that some charcoal forges continued in operation during the early nineteenth century, but the persistence of old technology in such a period of change has not been studied in detail before. The extent to which the older technologies of charcoal and stamping and potting persisted into the nineteenth century informs one of the key issues of the thesis: whether the model of linear development, implicit since the time of Scrivenor, can be challenged by a more complex, less deterministic interpretation.

4.1 Antecedents of puddling

Some of the antecedents of puddling were described in the previous chapter, but two methods of re-working scrap iron, one of which was known as buzzing, and the patent awarded in 1783 to Peter Onions, are all relevant to the introduction of puddling in Shropshire.

The working of scrap iron has been almost entirely overlooked by historians of eighteenth-century technology. However, it offers an insight into the forgeman's craft that provides a fresh perspective on the development of puddling. The working of scrap cast iron objects had a long history. By the seventeenth century all manner of scrap items such as broken hammers, firebacks, forge plates, anvils and rejected pig iron, mainly reclaimed from slag tips, were worked into wrought iron. The resulting iron was especially hard and required many more heats in the chafery than ordinary fined pig iron. In Staffordshire and Sussex in the sixteenth century, hammermen were consequently paid at double the rate for working scrap iron.[3] By the late eighteenth century scrap cast iron was regularly added to the fineries or puddling furnaces. For example, in the early nineteenth century Horsehay forge received regular consignments of old rails, wheels and sundry broken castings.[4]

The use of clay pots in coal-based methods of wrought-iron manufacture emerged from the working of scrap wrought iron. Reinhold Angerstein at Low Mill in Cumberland in the 1750s and Marchant de la Houlière at Wednesbury in Staffordshire in 1775 were told that the Wood brothers imported large quantities of wrought-iron scrap from France, the Netherlands and Germany. The iron was cleaned in a scouring barrel, granulated and heated in clay pots. The cost of importing the materials was evidently offset by the high quality of the finished product. Iron forged from scrap iron was always of a superior grade. Marchant de la Houlière heard that the iron produced at Wednesbury was considered to be as good as Swedish iron and was sought after for musket-barrel manufacture.[5]

Buzzing was a different technique. It clearly bore some resemblance to the Cranage and puddling processes because the iron was stirred in a reverberatory furnace, but the similarity may be superficial. Buzzing and the Cranage process came out of the same workmen's environment in the second half of the eighteenth century and therefore either could have influenced the other. The earliest known reference to a buzzing furnace in Shropshire is at Old Park in 1790, probably long after the technique was established.[6] The term appears regularly in documentary evidence in the 1790s where it refers to working scrap wrought iron. The word, and presumably therefore the technique, appears to have had a wider Midland context and its later form, recorded by Keith Gale in the 1950s, was known bustling or bushelling.[7]

That buzzing was widely practised in Shropshire is implied by the existence of reverberatory furnaces at rural forges that did not adopt stamping and potting. Its use in Shropshire was cited to argue that Cort's process was not an original invention. Samuel Homfray claimed, during the 1812 parliamentary enquiry into the validity of Cort's patents, that puddling was another name for buzzing, that it had been practised at Coalbrookdale and Eardington and was a Shropshire invention.[8] The foregoing evidence suggests that working scrap iron in a reverberatory furnace was a significant part of the forgeman's repertoire that was in widespread use in the second half of the eighteenth century. No one ever claimed to have invented a technique of working scrap iron in this way, presumably because there was no commercial advantage in doing so.

In 1783 Peter Onions was awarded a patent for refining pig iron in a reverberatory furnace using coal. Onions' furnace was more complicated than Cort's in that it was blown with a blast of cold air, making it a special type of reverberatory furnace. It was not the same as a common finery because the iron and fuel were kept in separate chambers. The difference between the Cranage, Cort and Onions methods was primarily a matter of workmanship. Cort differed from Onions in that he found a way of decarburising the iron without the aid of an oxidising blast of cold air.

'Onions' is a common Shropshire name but evidence that would place Peter Onions as a native of the East Shropshire coalfield is elusive – he does not, for example, appear in parish registers of Dawley or Madeley. During 1783 and 1784 he was associated with both the Dowlais and Cyfarthfa Ironworks in Merthyr Tydfil, but during this period conducted trials of his process at Ketley, before investment was made there in stamping and potting. Ketley was by this time managed by the young William Reynolds (1758-1803), son of Richard Reynolds, who expressed his disappointment with the Onions trials in two letters to Henry Cort.[9]

> 17 January 1784, I am much chagrined that Peter Onions has not yet been able to succeed in the furnace, he is going to try one built some time since by the

> Dale Company [the Coalbrookdale Upper Forge?] which I hope will prove more propitious to his wishes.
>
> 17 February 1784, I am sorry to say Peter Onions has not succeeded & has with us entirely given up the point, however he seems confident of succeeding elsewhere, but this I doubt …

William Reynolds did not take up the process, and there is no evidence that any other Shropshire ironmaster took any subsequent interest in it.

4.2 Puddling and rolling

Henry Cort (1740-1800) had been a Navy Agent in Portsmouth, where the Royal Dockyards consumed immense quantities of wrought iron for anchors, bolts, spikes and nails. This was a potentially lucrative market for British ironmasters, except that the Navy Board was loath to accept iron from home producers when Swedish iron was of higher quality. Cort took over a forge at Fontley, near Portsmouth, previously owned by his uncle, and entered into a partnership with Samuel Jellicoe. Jellicoe's father, Adam, was Deputy Paymaster of the Navy and advanced them money from the balance of public funds he held. Cort then set about trying to compete with Swedish iron, a matter of improving the quality of iron rather than reducing its cost. The result was puddling, for which Cort was awarded patents in 1783 and 1784. It is worth looking at the details of his techniques, because the process that was eventually adopted by the trade differed in small but significant ways.

His first patent was partly concerned with the working up of scrap or bad iron that had already been refined. As shown above, this was already a common practice in contemporary forges. The patent covered three processes: the working up of semi-finished or scrap wrought iron in a reverberatory furnace rather than a common finery; the working up of 'scull iron' (i.e. iron spoiled by burning in the finery) in a reverberatory furnace; and the working up of cast iron in a common finery using mineral fuel. The patent specification described several ways of working scrap in different forms. For example, scull iron could be piled up on old iron plates in a balling furnace; alternatively old salt pan plates and other plates were cut up, formed into coffin shapes and filled with scraps of nut and bracket iron. Enclosing the small pieces of iron in a makeshift container was similar to heating granulated iron in a pot, just as placing small iron on plates was derived from the practice of piling. In these respects Cort built on existing practices. The radical element was that by passing the iron through a rolling mill a superior quality of iron could be produced. Cort claimed that 'mooring-chain links, ships' knees, and other iron decayed or eaten by rust, being cut into proper lengths, duly heated and passed through the rollers, will produce exceedingly good iron without any other process'.[10] The rolling mill produced a consistent size and shape of bar, but also aided the removal of slag, which had hitherto been achieved by forgemen entirely under the shingling hammer.

The principal element of the second patent was the conversion of pig iron in a reverberatory furnace using coal. During the heating and stirring of the pig iron it was found efficacious to add in small amounts of fragmented scull or scrap iron. Once the iron had become fused it was removed from the furnace. It could then be stamped and heated again in pots or piles, exactly as in the stamping and potting process. Cort's preferred technique, however, was to return the iron to the furnace and bring it to a white heat. Subsequently the iron was shingled into half blooms or slabs. From this point the iron could be heated in a common chafery, but the best results were obtained when the blooms were heated again in another or the same reverberatory furnace, and were then passed at a white heat through the rollers, the effect of which was that the iron 'will be discharged of the impurities and foreign matter which adheres to them when manufactured in the methods commonly practised'. Cort claimed that the major advantages of his process were in eliminating the need for charcoal, coke, blowing cylinders and bellows.

Like the Cranage method, Cort used coal and the reverberatory furnace, but whereas the Cranage patent specification offered no account of how the iron was worked in the furnace, Cort provided a detailed description. The difference in the wording of these specifications was determined by changing practice in the award of patents between

1766 and 1784. It did not signify a desire to enlighten or mystify on the part of either party. This has provided difficulties for historians of technology and has proved favourable to the long-term reputation of the Cranage brothers. In the context of a linear model of technological development, expressed most recently by Morton and Mutton, the Cranage process has fitted neatly as an intermediate stage in the search for a viable process using mineral fuel, of which puddling was the lasting solution.

Was the Cranage process really the 'process now technically called puddling', as Hannah Mary Rathbone, Richard Reynolds' granddaughter, claimed in 1852?[11] What little evidence is known of the Cranage process does not suggest any direct link with puddling. The account written by Alexander Chrisholm in 1768 offers the best evidence for comparing the two techniques.[12] After a preliminary stage, the Cranage method was similar to Cort, except that no use was made of a rolling mill. What cannot be known is what induced the workmen at Coalbrookdale to judge that the iron was ready to be shingled. In Cort's process a blue flame signalled that decarburisation was taking place, which was accompanied by a more vigorous stirring of the metal. The Cranage method was not used outside Coalbrookdale and was discontinued soon after 1768, well before Cort took a practical interest in forge techniques. So far as is known, he was unacquainted with the Cranage brothers and had no known connection with Shropshire, while the Cranage patent specification offered him no useful information. Their similarity is that that they were derived from the same environment of accumulated manual skills.

The essential characteristic of the two processes is their reliance on manual dexterity. This is a crucial point because it sets innovation in the forge sector apart from those of the smelting sector, the former being a question of technique, while the latter depended primarily upon the correct application of raw materials. It also distinguishes puddling from other contemporary technology like the steam engine. Whereas an engine's motion was predictable and repeatable, the product of a puddling furnace varied according to a host of factors, not least the skill and judgement of the workman.

4.3 Trials of puddling in Shropshire

Cort sought to persuade ironmasters to take up the process. The earliest demonstration of puddling in Shropshire appears to have been at Pitchford Forge, where he visited on 10 and 11 November 1784.[13] A month later, on 15 December, Cort's men demonstrated puddling at Ketley. An anonymous note concerning the Ketley trials recorded that just over 27/12 tons of pig made 20 tons of half blooms, which compared favourably with the Cranage process where 40 cwt of pig made only 20 cwt of blooms.[14]

The Ketley workmen were less than impressed with Henry Cort, however. Cort required written confirmation that his men had demonstrated his technique, which was signed by Thomas Jones and Thomas Cranage, 'hammermen to Messrs Reynolds & Co at Coalbrookdale'.[15] Thomas Cranage (b 1751) was the son of the patentee George Cranage, while in 1780 Thomas Jones had been one of the executors of the will of the patentee Thomas Cranage.[16] Given that Cort's men were working iron in a reverberatory furnace just as the Cranage brothers had done, to achieve a superior bar iron from Ketley pig iron could only mean that Cort had developed a superior technique. As forgemen with an obvious loyalty to the Cranage brothers, Cranage and Jones are unlikely to have conceded the point. In fact the evidence of his trials at Ketley and elsewhere suggest that Cort was unable to persuade workmen bred up in the iron trade that he, a relative newcomer, could work iron with more dexterity and economy than they. In an often repeated anecdote said to have derived from William Reynolds' younger brother Joseph, Thomas Cranage bested Henry Cort by proving that his technique was nothing new to Coalbrookdale workmen: Apparently, 'Cranage put in some white iron – cold-blast mine iron – and soon brought out a ball of puddled iron'.[17] Such anecdotal, probably apocryphal, evidence demonstrates that pride was at stake. Nevertheless, Cort failed to licence his process to any Shropshire ironworks. The Coalbrookdale partners had, a few months previously, invested capital in the new stamping and potting forge at Horsehay with its Boulton & Watt hammer engine, and had already introduced stamping and potting to Coalbrookdale. Further investment in stamping and potting at Coalbrookdale, Donnington Wood and probably Ketley came after Cort's trials.

Cort also demonstrated his process in Staffordshire, for example at Shut End and at Francis Homfray's rolling and slitting mills at Hyde. At the Carron Ironworks, near Falkirk, the experienced workmen were said to have been equally unimpressed by Cort's claims. After Cort's first round of public trials the only ironworks that agreed to take up the process and pay a royalty was the Rotherhithe Company of London.

4.4 The 'Welsh Method'

Cort's efforts were subsequently directed toward South Wales as the most likely chance of success. Cort disappeared from the scene, however, when he was unexpectedly declared bankrupt in 1789. The consequent loss of his patent rights was at one time considered to have precipitated the widespread adoption of puddling, since a premium would no longer be payable on the production of iron using the process. But there is no evidence of widespread interest in puddling until the mid 1790s. By contrast, the development of the new process is well documented at the Cyfarthfa Ironworks in Merthyr Tydfil, under the direction of Richard Crawshay (1739-1810).

Experiments began in 1787 and in 1789 Cort oversaw the construction of a forge and rolling mill at Cyfarthfa. Crawshay's letter books show continued experimentation with the new process after 1789. This was not, as has been claimed, a matter of proving the economic superiority of puddling over stamping and potting, but of ensuring consistent quality.[18] Both Crawshay and Samuel Homfray, at the neighbouring Penydarren Ironworks, experienced difficulty with the design of their plant: modifications were made to the design of the furnaces, which were built with iron tops, and quality improved when the furnace bottoms were lined with washed sea sand. Homfray was forced to suspend rolling at Penydarren because, according to Crawshay, his mill was not strong enough. Not until December 1791 did Crawshay claim to have 'at last overcome the evils of puddling'.[19]

During 1792 Crawshay's investment began to pay dividends, the key to which was the preliminary re-melting of the pig iron in a refinery, also known as a running-out fire. This was a simple melting furnace, blown with tuyères on either side, from which molten iron was run out to form a flat plate. The process removed some of the silicon content in the pig iron, with a result that once cooled the iron changed in appearance from grey to white. Morton and Mutton argued that the running-out fire was a more advanced version of the finery used in stamping and potting.[20] This placed stamping and potting within a clear sequence of linear development in eighteenth-century iron technology. Close examination, however, shows these preliminary processes to have been quite different. Pig iron was melted in a running-out fire and was tapped in molten form. In the coal-fuelled finery the pig iron was partially decarburised. The iron was removed with tongs and was malleable enough for it to be hammered to a flat cake, allowing the iron to be subsequently stamped. At Horsehay, finers in 1798 were paid 11/- and 8/- per ton at the finery, depending on the grade of iron produced, but only 4/- per ton at the running-out fire.[21]

In the last decade of the eighteenth century puddling was adopted nationally as the newest successful method of manufacturing wrought iron. As it had been pioneered in South Wales it was known colloquially as the 'Welsh Method'. The conventional interpretation has been that once the technical difficulties of puddling had been overcome and as soon as it could be made profitably, the remainder of the iron trade speedily adopted it. The evidence for the 1790s relating to the key Shropshire forges is sporadic, but sufficient to question previous interpretations.

4.5 The introduction of puddling to Shropshire ironworks

Puddled iron was not produced commercially at Ketley in the early 1790s. This was in spite of the fact that Richard Crawshay was a close associate of William Reynolds and urged him to adopt the process. Before building his rolling mill at Cyfarthfa, Crawshay intended to look at Horsehay rolling mill, while Crawshay directed James Cockshutt to speak with a James Birch regarding the technique of using finery cinders, which Birch had seen in use at Ketley.[22] This evidence suggests that if Crawshay knew what Reynolds was doing then the reverse was likely also to be the case. From a letter written in 1790 it appears that William Reynolds was at least experimenting with puddling, as Crawshay asked whether Reynolds had managed to achieve any improvements in the process.[23]

The earliest evidence for commercial production in Shropshire occurs at Old Park and begins in the accounts of the foundry. The first reference to a 'new puddling furnace' occurs in February 1794 and from then until 1801 there are increasing references to the casting of doors, frames, bottoms and other parts for puddling and balling furnaces and running-out fires, while a third blast furnace was built in 1796, presumably partly in the expectation of increased forge output.[24] Evidence suggests the gradual adoption of puddling at Old Park, alongside and not supplanting stamping and potting. A 'new finery' is mentioned as late as 1800, by which time most references are to puddling furnaces and running-out fires. Initially the puddled iron was hammered rather than rolled, or alternatively was sent elsewhere for rolling. The most usual method was probably for the puddled iron to be stamped and heated in clay pots, for which there is also evidence at Ketley and Horsehay, discussed below. Mention of a 'new rolling mill' at Old Park does not occur until August 1797, although when and for how long it was operational is uncertain.[25] Mill rolls and coupling boxes were cast for a 'new rolling mill' in May 1798, but this early mill was possibly short-lived as in 1800-1 substantial investment was made at the Old Park forge under the direction of Gilbert Gilpin, when a new rolling mill engine was installed.

Horsehay already had a mill that could be put to rolling puddled iron. However, the only references to Old Park iron being sent to Horsehay for rolling occur in June 1798, just before its own mill came into operation.[26] There is some indirect evidence that Horsehay rolled puddled iron from other forges, but the evidence is ambiguous as 'half blooms' could refer equally to iron made by the stamping and potting process. In 1796 came the first of many consignments of half blooms from Lightmoor forge.[27]

Puddling was certainly adopted at Lightmoor. In 1802 the Swedish metallurgist Svedenstierna wrote less precisely of Lightmoor than historians might have wished, but the mention of refineries indicates that puddling was in use there. According to Svedenstierna, Lightmoor iron was noted for his its high and consistent quality; most of the Lightmoor blooms were sent to Homfray's other forges for working into sheets, bars or nail rods.[28] The Homfray family still had interests in forges, rolling and slitting mills in Staffordshire, with which Lightmoor forge appears to have been well integrated. Hyde forge had a rolling and slitting mill. With his brother Jeston, Francis Homfray purchased Gothersley slitting mill and Swindon forge in Staffordshire from their father in 1790, although they sold Gothersley in 1798 (figure 5). In the late 1780s Swindon had been a forge with stamping and potting and finery and chafery. Francis Homfray continued to operate it until his death in 1809. Subsequently his son Jeremiah continued its operation, but only briefly. When it was sold in 1810 it included a steam engine (built in 1797), forge, rolling and slitting mill, as well as workmen's cottages. It was purchased by Francis' brother, Thomas, who was declared bankrupt in 1819.[29]

Therefore, although there is evidence that Lightmoor adopted new technology, the conveyance of semi-finished iron between forges over a long distance continued a well-established pattern of working wrought iron, in contrast with Samuel and Jeremiah Homfray's scheme at Penydarren, where the rolling mill stood next to the puddling furnaces. The last recorded consignment of Lightmoor half blooms rolled at Horsehay was in January 1807.[30] The cessation of forging at Lightmoor is not documented and perhaps it was discontinued after Francis Homfray's death in 1809. A forge was not mentioned by Thomas Butler, who visited Shropshire ironworks in 1815.[31] The practice of sending semi-finished iron elsewhere for rolling was also used at Snedshill. In 1806 'common puddled half blooms' were sent from Snedshill to Horsehay for rolling, which is the only evidence that puddling furnaces were built there.[32]

Puddling had been adopted at Ketley by 1796, the year it was witnessed by Joshua Gilpin. Horsehay adopted puddling from 1797, as documented in its wages book.

Detailed evidence for these forges shows that the adoption of puddling was a piecemeal process, as had been the case at Old Park.

At Ketley Joshua Gilpin saw the refineries at work, a process that he claimed took approximately two hours. The iron was run out into a trough then was immediately doused in cold water in order to break it up ready for the puddling furnace. Puddling took an hour and a half after which, instead of passing the iron through the roughing rolls as was the standard practice, the iron was rolled out into flat cakes, then stamped and placed in a reverberatory furnace inside clay pots ('sackers'), after which it was hammered into bars.[33] In other words a variation of the stamping and potting method was in use at Ketley, whereby the refinery and puddling furnace replaced the finery, unlike John Wilkinson's Bradley Works in Staffordshire where Gilpin saw the puddled iron rolled into blooms. Half blooms sent from Ketley for rolling at Horsehay appear therefore to have been made under the hammer. At the rolling mill the iron would have been placed in a balling furnace before final rolling. The use of stamping and potting in conjunction with puddling had been an alternative suggested by Cort. It had also been used at Cyfarthfa where, in 1791, Richard Crawshay described the process in operation at that time:

> when the metal is brot into nature, instead of Hammers, we put it between a pair of rolls, & crush it like a paste about ¾ inch thick – then break it into small pieces, pile up to 60 to 80 lb wt on a cake of baked clay, heat 20 of those piles at a time in [another] air furnace, then shingle them under a hammer … the blooms thus finished is [sic] again heated in an air furnace & brot into a very handsome bar by groov'd rollers.[34]

It was a similar pattern of working that appears to have been adopted at Ketley, with the final rolling undertaken at Horsehay.

In 1797 Horsehay had two finers, Samuel Purcell and James Skelton, each working with two assistants, and the conversion to puddling principally affected these workmen (Appendix 1). The 'stamping' forge at Horsehay had two fineries, while the ‘shingling’ forge had reverberatory furnaces for heating iron in pots and piles. The latter forge also evidently had reverberatory furnaces for working scrap iron before puddling was introduced, at which time the terms puddling and buzzing were interchangeable. For example money was paid in 1797 for converting ‘buzz balls into half blooms’ and for ‘puddling iron from small iron dust into balls to be manufactured again’, which was the responsibility of John Lambert senior, evidently one of the most skilled men in the forge as he was also responsible for making boiler-plate slabs.[35] But Lambert was not one of the men taught to become a puddler.

In June 1797 Samuel Purcell was sent to Ketley to learn about the running-out fire. In the following month William Duddell built the first running-out fire at Horsehay, when 13 tons of pig were refined, followed by 20 tons in September. Puddling began in September when John Lambert, the workmen responsible for working scrap mentioned above, was paid for an ‘experiment on the refined iron in the puddling furnace’.[36] Rather than being paid by the ton, as would be the normal practice for commercial production, he was paid for two days’ work. The next workmen to experiment with the refined iron was John Hazlehurst, who was paid for eight days’ work, assisted by William Thomas and Edward Lamb.[37] Hazlehurst was Samuel Purcell’s assistant and a member of one of the most prominent families of forgemen at Horsehay, but Thomas and Lamb are not otherwise recorded. During October 1797 both Purcell and Skelton continued their normal work at the fineries, producing 22 and 23 tons respectively of stamped iron, in addition to experimenting with the new process. Samuel Purcell continued working at the running-out fire while James Skelton was paid for seven days working at the puddling furnace.[38]

The Horsehay forgemen did not have the wherewithal to convert to puddling without outside assistance, despite their experience of working scrap iron in a reverberatory furnace. Expertise came not from South Wales but from Old Park. From November 1797 Joseph Williams was employed at Horsehay, initially instructing the finery men how to puddle.[39] It may be a coincidence that Williams’ seven year contract with Thomas Botfield would have expired at about this time, but it does seem likely that Williams was at Old Park during the development of puddling.

In November 1797 James Skelton and his assistants Robert Callear and Richard James were all instructed in puddling for between eighteen and twenty-three days. Production of stamped iron from the fineries did not cease, however, although output declined, as only 32 tons were made by Samuel Purcell.[40] In the following month Williams taught other workmen to puddle – Edward Tranter, Charles Weaver, [Edward?] Llewellyn and Joshua Norton – none of whom are recorded as having previously worked in the finery. In this month 23½ tons of puddled iron was sent for stamping, compared with 28 tons from the fineries. This is, therefore, the first evidence of commercially produced puddled iron. Joseph Williams made stamped iron from refined iron at 12/- per ton, a higher price than the 10/- Purcell and Skelton were paid for stamped iron from the finery hearth.[41]

By January 1798 the Horsehay men were still not masters of the process. Samuel Purcell and his men Thomas James and John Hazlehurst spent a further twelve days learning to puddle, including five days' instruction from Joseph Williams. Subsequently Purcell continued to work the running-out fire, but Skelton and his team disappeared from the wages accounts after January 1798. Thereafter only Joseph Williams was paid for making stamped iron, which is occasionally referred to as worked from pig iron in the puddling furnace.[42] There are two reasons for arguing that the iron made by Williams was worked in the puddling furnace rather than the finery. First, almost all of it was made from refined iron. Second, the Horsehay Day Book records the purchase of large quantities of puddling sand in 1798. In 1797, during the early experimental stage, sand had been purchased from Ketley.[43] In 1798 it was purchased from a pit in Lawley and between March and July twenty deliveries were received at Horsehay amounting to over 40 tons.[44] The same price of 11/- per ton was paid for stamped iron produced from pigs and refined iron, with 8/- per ton paid for the inferior grade described variously as bad or second best. There was no decline in the heating of stamped iron in clay pots in the shingling forge to correspond with the rise in production of puddled blooms. Therefore, although it could be argued that puddling was established at Horsehay in 1798, Horsehay nevertheless retained the character and operation of a stamping-and-potting forge.

Like Ketley and probably Old Park, at Horsehay the running-out fire and puddling furnace had replaced the finery, but otherwise the process was the same as it had been when stamping and potting was introduced in the 1780s. The fineries were not demolished, however, as there were two working fineries at Horsehay as late as 1805, which are discussed below. Nevertheless, 1798 must still be seen as a period of experimentation, whether it be a case of ironing out technical difficulties, or of ensuring a consistent quality. Joseph Williams was paid for eleven days of experiments as late as April and May 1798.[45] By June stamped iron from refined iron, i.e. puddled, was classed as 'best', while stamped from pig was classed as 'good'.[46] By September iron was simply classed as No 1 or No 2, but both paid at 11/- per ton.[47] There was no difference in the rate of pay for work at the fineries and the puddling furnaces.

It is unfortunate that the surviving wages accounts end in September 1798, as important issues are left unresolved. More than a year after experiments with puddling began none of the Horsehay forgemen can be shown to have become puddlers. Samuel Purcell did not because he worked at the running-out fire. But why, in spite of efforts to teach them, did none of the other workmen become puddlers in their own right? The disappearance of James Skelton and his assistants from the wages accounts is particularly intriguing. Did Skelton resist the new technique and find employment elsewhere? In September 1798 nearly 50 tons of stamped iron were produced at the puddling furnace, a figure too high for a single workman. Clearly, therefore, there were other puddlers at Horsehay working under Joseph Williams whose names do not appear in the accounts, and probably included men who had been taught by him. Nevertheless during the same month of the previous two years 62 and 64 tons respectively of stamped iron were made from the fineries, demonstrating that an initial fall in output accompanied the introduction of puddling, even nine months after an experienced master-puddler had been employed.[48]

The evidence of Horsehay is significant because it demonstrates that there was no smooth transition to the new process. The argument that puddling was adopted when it became commercially expedient underplays the practical difficulties that were encountered, the root of which appears to have been the development of new skills among the workmen.

Granulating and heating the iron in pots, followed by drawing under the hammer, was not the full implementation of Cort's process because it did not utilise the rolling mill. Here it is worth noting the marked contrast between the Shropshire forges and what is known of the main puddling works in South Wales. At Cyfarthfa, substantial investment was made in 1789 in a new puddling forge and rolling mill, while a new puddling forge and rolling mill was also built at the Penydarren works. Both had previously been stamping and potting forges. Joshua Gilpin's account of John Wilkinson's Bradley Ironworks in Staffordshire also spoke of rolling mills through which the shingled blooms were passed.[49] But in Shropshire the take up of puddling was not only later, it was slower, lacked the initial high investment and it overlapped with elements of the earlier stamping-and-potting process.

4.6 Further investment in Shropshire puddling forges

The period between 1798 and 1802 saw major new developments at Ketley, Old Park and Horsehay, but the evidence is mostly indirect. When Svedenstierna passed through Shropshire in 1802 he offered no more than a brief note that Horsehay was principally engaged in puddling and that he was unable to inspect the Ketley Works. However, a year later Simon Goodrich provided a detailed account of Ketley forge that shows considerable advances since Joshua Gilpin's account of 1796. A slitting mill had been built at Ketley in 1796, which was originally water-powered, aided by a Boulton & Watt pumping engine.[50] But it emerges that this engine had been superseded by 1803, suggesting a substantial investment in puddling and rolling in the intervening period.

The Ketley refineries were charged with half a ton of pig iron each and, when molten, the iron was run out to form a thin plate. While still red hot the iron was submerged in water allowing it to break more easily under the sledgehammer. The broken refined iron was fine-grained and white. The puddling furnaces were charged with approximately 5 cwt of broken refined iron, and

> in about 20 minutes it begins to melt and effervesce; it is then occasionally stirred about with an iron rod during about an hour longer and separates into lumps which are taken out and run between rollers into lumps called half blooms, which are about 2½ feet long and 3 inches square – the half blooms are heated again in another reverberatory furnace and rolled out into bars – Iron thus manufactured is called common iron … There were two forge hammers each worked by a single engine of Boulton & Watt of 26 inches in diameter – A 36 inch double engine works two pairs of rolls, the first for drawing out bars, the second for slitting them into rods … the rolls made 60 revolutions per minute.[51]

The layout of the works, comprising refineries, puddling furnaces, hammer, rolls and balling furnaces was the standard arrangement for a puddling forge, and this had been established in the period 1796-1803. It appears also that much of this development was on a fresh site. The first forge at Ketley subsequently fell into ruin and after 1815 was buried by an embankment built for the Holyhead Road.[52]

A similar pattern is found at Old Park where, after a period of experimentation and adaptation of a stamping and potting forge from 1794-1800, substantial investment was made in a new purpose-built puddling forge and mill. In January 1800 Gilbert Gilpin was employed to manage the Old Park works at a salary of £15 per month.[53] Gilpin (1766-1827) was already well established in the iron trade. In 1786 he succeeded his father in the management of Bersham Ironworks and oversaw the manufacture of parts for Boulton & Watt engines.[54] After falling out with the autocratic John Wilkinson he moved first to work for Boulton & Watt at Soho, then in 1796 to South Wales, where he was involved in a number of enterprises, including management of the Sirhowy Ironworks and a proposed development of a marble quarry at Pont Neath Vaughan. He was also closely acquainted with the Merthyr ironworks. Possessed of a dry wit, his satirical asides in letters to his friend William

Wilkinson poke fun at the posturing Merthyr ironmasters but they also place Gilpin in the midst of the most important contemporary developments in the British iron trade. Acquainted socially with both Richard Crawshay and Samuel Homfray, then arguably Britain's leading ironmasters, there is no doubt that he was familiar with their works. In a letter of October 1796 he described in detail the large waterwheel and blowing arrangements for the Cyfarthfa blast furnaces, as well as brief details of furnaces and forges at Sirhowy, Beaufort, Ebbw Vale, Nantyglo, Clydach, Llanelly, Blaenavon and Glangrwyne.[55] It must be assumed that Gilpin took plans of South Wales forges, either on paper or in his head, to Shropshire. This tendency to watch closely developments elsewhere continued even after the new forge and mill were completed. In 1807 Gilpin had decided that 'we shall not make any alteration in our forge … unless we can obtain a better account of the rolling plan than we have had from our neighbours'.[56] Gilpin was also acquainted with the agent at Ebbw Vale who in 1810 had obtained plans of forges from Shropshire and Staffordshire.[57]

Gilpin first met the Botfields in 1796 in South Wales. They were negotiating the possibility of erecting an ironworks at Aberdare, but in the event could not agree terms with the landowner. Although Gilpin was employed from 1800 it was over two years before the mill and forge had been completed. Gilpin had been employed by Thomas Botfield, after whose death in 1801 he continued to work for his three sons, Thomas (1762-1843), William (1766-1850) and Beriah (1768-1813). According to William Wilkinson, who stayed at Old Park as the guest of William Botfield, Botfield 'likes Mr Gilpin very well and I think would wish to keep him but Gilpin says there is so much distance kept between them, that he is not happy and I should not be surprised if he did not quit him when the mill and forges are complete'.[58] In the event Gilpin stayed until 1814.[59] The crowning glory of the new Old Park Works was a rolling mill engine with cast iron beam. It was purchased from Boulton & Watt and installed for a total cost of £1475, together with two smaller engines, the purpose of which is not made clear.[60] A Mr Taylor was sent from Soho in September 1801 to supervise the erection of the rolling mill engine.[61] The engine was William Botfield's pride and joy. In a letter of 1802 William Wilkinson remarked that Botfield was so pleased with it 'he keeps a woman at 8/- per week to wash the engine house every day more than once and to keep the ironwork well black'd and everything clean which is a difficult task in a place where there is so much dust as in a forge & rolling mill'.[62]

The scale of the new forge and mill can only be estimated because there is no inventory giving the number of puddling furnaces. But the forge clearly occupied new buildings.[63] Parts for the puddling furnaces, rolling mills and shears were cast in the Old Park foundry. In 1808 Gilbert Gilpin could remind Robert Ward, the clerk at Penydarren Ironworks, whose mill was probably based on Cort's design of Cyfarthfa mill, that 'our mill is more powerful and roomy than yours'.[64] To complement its new forge a fourth blast furnace was built in 1801.[65] William Botfield, the partner who oversaw the day-to-day operation of the works, was ambitious to build up the business. By 1807 Old Park was already the largest ironworks in Shropshire and was a major supplier of pig iron to small Midland forges. Using information or opinions supplied by Gilbert Gilpin, William Wilkinson remarked that 'last year [Old Park] made 9200 tons of pig iron one half of which is converted into bars, they are going to erect two other furnaces in that neighbourhood and propose to govern the iron trade of Shropshire in conjunction with the Bishtons & others with a lordly sway'. John Bishton (d 1807) was the leading shareholder in the Lilleshall Company, controlling Snedshill, Wrockwardine Wood and Donnington Wood Ironworks, and was William Botfield's father-in-law. According to Gilpin it was the intention of Botfield and Bishton

> to drop bar iron this quarter to £3 per ton, and [they] are resolved not to sell any pig iron to any of the Staffordshire ironmasters who use any other than Shropshire pigs, this they presume will put a stop to the greatest part of the Staffordshire forges as many of them cannot do without Shropshire pigs to mix with their own, and the intended drop of iron will disable them from working to profit.[66]

Evidence of investment in puddling at Horsehay relies mainly on output figures. These show a steady increase in production of common puddled iron. In May 1802 93 tons of common puddled iron were manufactured, with 55 tons the following month.[67] Production remained between these extremes consistently until a sustained rise in output began in March 1806, when 161 tons of common puddled iron were produced. Output remained at a comparable level, with peaks of 325 tons and 276 tons in August and September 1806, rising again in 1808, the first three months of which seeing a output of 295, 275 and 354 tons respectively.[68] A third running-out fire, first mentioned in July 1807, was a necessary part of this increase in production.[69] In the first decade of the nineteenth century two of the shingling hammers were worked by a Newcomen engine, while the roughing rolls were worked by waterwheel. The original rolling mill, built in 1784, was replaced by a new mill in 1809, which had four trains – for boiler plate, rod slitting, and large and small sections of bar – and a pair of shears.[70]

4.7 Rural and Severn Valley forges in the early nineteenth century

Little has so far been said on the subject of the non-coalfield forges in the early nineteenth century. A consensus of opinion has hitherto been that once puddling was established, the rural finery forges found themselves unable to compete and accordingly declined in the first decade of the nineteenth century.[71] There are comparatively few sources that document this decline directly. The ambition of the Botfield and Bishton families, quoted above, to dominate the trade appears to spell out the fate of the small, vulnerable forges. In reality the large pig iron producers needed small forges because their own forges did not have the capacity to consume the output of the blast furnaces. The most informative guide to the survival of these small forges is the customer accounts and business correspondence of Old Park Ironworks. They document the remarkable longevity of some of the small forges in Shropshire, Staffordshire and Worcestershire, including the Knight family's Stour Valley forges. Were similar accounts available for other large-scale pig iron suppliers, such as Ketley, then the evidence of longevity of the rural forges might be even stronger.

William Hazeldine (1763-1840), the Shrewsbury iron founder, was an important figure in the iron trade by the early nineteenth century, and is best known for his civil engineering works. His principal ironworks was the Coleham Foundry in Shrewsbury. He cast parts for Thomas Telford's Poncysyllte Aqueduct of 1805 at his Plas Kynaston foundry near Wrexham, and he later owned the Calcutts Works from 1817-28.[72] Hazeldine also owned forges, which supplied the wrought-iron components for his engineering works. Pitchford forge was leased in 1790, when the Gibbons' lease expired and was not renewed. Hazeldine was still its tenant when it was last mentioned c1800.[73] Longnor forge was leased to Hazeldine in 1801 and was subsequently converted to a paper mill.[74] Hazeldine also owned Upton Forge in the early nineteenth century and it was probably for Upton that Hazeldine & Company purchased forge pig from Old Park in each year between 1812 and 1817, including 250 tons in 1813.[75] In 1821 William Hazeldine contracted to manufacture iron for the Menai Bridge in North Wales. The wrought iron was forged at Upton and was sent to the Coleham foundry and engineering works for finishing. The forge supplied chain bars and connecting plates, but delivery was hampered by floods at the forge during the winters of 1822-3 and 1823-4.[76] This was high-quality wrought iron subjected to rigorous testing and was almost certainly forged with charcoal rather than coal. There is supporting evidence for this, as in 1825 an enquiry from the Botfields at Old Park asked whether Hazeldine had any spare charcoal cinder at any of his forges.[77] Upton Forge was still working in 1831, when it is mentioned in a description of the Shrewsbury Canal.[78] The canal had been built in the period 1793-7 to link the East Shropshire coalfield with Shrewsbury, and fortuitously passed by Upton Forge (figure 7). The presence of the canal was undoubtedly a factor in Upton's survival into the second quarter of the nineteenth century.

William Hazeldine is also listed as the tenant of Lizard forge in the survey of c1790 (Table 2), although in September of that year Thomas Barker was the proprietor as he purchased pig iron from Old Park.[79] Barker also owned Congreave and Coven, two finery and chafery forges in Staffordshire. By 1806 Lizard's tenant was John Bishton of the Lilleshall Company and its upper forge was at least operational if not operating, since in an agreement to raise the level of the upper forge pool it was stipulated that the proposed improvement should not hamper the working of the forge waterwheel.[80]

However, in 1813-14 the upper and lower forges were described as 'lately taken down'.[81]

Of the forges at Caynton and Sambrook, and the slitting mill at Tibberton, all occupied by members of the Hallen family c1790, little is known. Caynton is last recorded c1820, Tibberton in 1804.[82] Sambrook was probably owned by Richard Hallen (c1738-1821), since he is known to have lived there, but is unlikely to have continued working after his death in 1821.[83] Cleobury Mortimer forges, the proprietor of which was Sir Walter, succeeded by Sir Edward Blount, continued to take forge pig from Old Park until after Blount's death in 1825, after which the works was managed by J.G. Lewis.[84] There were three fineries and two chaferies at upper and lower forges c1790, which is unlikely to have changed very much over the next thirty-five years or so that saw the rise of both stamping and potting and puddling. Cleobury Mortimer was still making charcoal iron in 1828.[85] The Botfields' forge at Cleobury Dale is less well documented than Old Park. However, it certainly purchased iron from Old Park in 1815, when the Botfields remained its proprietors, and is probably the forge that is described elsewhere in the account books under the heading Cleehill & Hopton, and which still received iron, of unspecified type, in 1818.[86] There are no later references to the forge, suggesting that it closed soon after.

Hampton Loade forge was the only Severn Valley forge that was not associated with stamping and potting. In 1796 it was acquired by John Thompson, who apparently enlarged the works, but was superseded in 1803 by the Hampton Loade Iron Company. The forge remained a customer for Old Park pig iron until 1804 and continued in production after it was purchased by James Foster in 1820.[87]

Six rural forges ceased working in the first quarter of the nineteenth century. The survival of other charcoal-using rural and Severn Valley forges should be seen in a regional context. In 1825 Old Park was selling pig iron to numerous other Midland forges, such as Drayton, Stourton and Aston Junction in Staffordshire, and Wilden in Worcestershire, which are known to have worked with charcoal.[88] Their survival highlights a continuing market for charcoal iron, suggesting that the demise of most of the rural forges in Shropshire was not the result of backward technology but of their comparative isolation. Hampton Loade, Eardington and Upton all had good transport links, while Cleobury Mortimer had the advantage of close proximity to Stourport and the Stour Valley. Iron forged with charcoal was of a higher grade and was in demand for certain kinds of iron – such as the chains mentioned above – and the continued demand for it should be seen in the context of charcoal fineries at the coalfield forges discussed below.

4.8 Stamping and potting in the early nineteenth century

Just as charcoal iron has been considered by historians to have been rendered obsolete by puddling, so the outdated technology of stamping and potting should have declined as soon as puddling became more profitable. The two Severn Valley forges most associated with stamping and potting were Eardington and Wrens Nest. Both forges were regular customers of Old Park, to the extent that between 1795 and 1800 both forges purchased over 500 tons of pig iron per annum.[89] By 1802 Wrens Nest was managed by Richard Jesson's brother Joseph Jesson (1736-1816), and smaller quantities of pig iron were delivered from both Old Park and Horsehay.[90] Pig iron was last supplied to Jesson Wright & Company from Old Park in 1813 and there is no evidence that the forge continued working after Joseph Jesson's death.[91]

In 1789 William and John Wheeler gave up Eardington Forges and the lease was assigned to George and Benjamin Stokes. At a later stage Thomas Stokes and Samuel Pemberton joined the partnership (trading as Pemberton & Stokes), but the latter was dead by 1805 when the lease was assigned to Samuel Twamley. Twamley purchased refined iron from Horsehay but lasted only two years before bankruptcy forced him to return Eardington to a partnership still trading as Pemberton & Stokes. George Stokes became the sole proprietor in 1811, but was himself declared bankrupt in 1814, although it had been sub-let to John Bradley (1769-1816) and his half brother James Foster (1786-1853) since 1809. Bradley and Foster acquired the lease in 1813. Eardington was integrated with their larger concerns at Stourbridge, but seems to have survived because it concentrated on manufacturing charcoal iron, with charcoal supplied from the Wyre Forest.[92]

A useful comparison can be made between Eardington and the Stour Valley forges in Worcestershire, owned by John Knight, a regular customer for forge pig from Old Park, Horsehay, and probably elsewhere. His Mitton Upper and Lower Forges were converted for stamping and potting during 1796-8, where a refinery was also built. The Upper Forge had puddling furnaces by 1800, while the Lower Forge eventually concentrated on stamping puddled iron, with other outlying forges used for drawing, slitting and rolling. But in 1817 the partnership returned to making charcoal iron for tinplate manufacture and the Upper Forge was abandoned.[93]

Other Shropshire forges relying on stamping and potting seem to have disappeared sooner but not necessarily for the same reason. Donnington Wood was purchased by John Bishton and John Onions in 1796.[94] Thereafter there is only evidence of expanded pig iron production at the works. Bishton and Onions had also acquired Snedshill furnaces in 1793 and operated the forge there that sent blooms and slabs to Horsehay for rolling.[95] In 1804 blooms were sent from Snedshill to John Knight's Cookley Forge, on the River Stour, for rolling.[96] Snedshill blooms were also rolled at Old Park in 1806.[97] No known sources document the survival of this forge into the second decade of the nineteenth century, although Gale and Nicholls have stated that it ceased working c1818.[98] There was, therefore, no continuity between the late eighteenth-century forge and the new forge built at Snedshill in the early 1830s.[99] There are likewise no known sources documenting the closure of the Willey forge, which is not mentioned in the national survey of c1790.[100] John Wilkinson concentrated wrought-iron production at Bradley, where stamping and potting as well as puddling were adopted on a large scale, whereas production at Willey concentrated upon cast iron.

Ironically, evidence for the survival of stamping and potting is strongest at the forges that adopted puddling. Horsehay and Old Park are documented by accounts, while a fair amount is known about Ketley through the visitors who went there. It was demonstrated above that the introduction of puddling at Horsehay was a protracted affair. This may have been due partly to the difficulties of the new technology, but it is also evident that the two processes overlapped. Simon Goodrich wrote his account of stamping and potting at Coalbrookdale in 1803 to contrast it with the use of puddling at Horsehay. Other sources reveal a much more complex picture.

A small amount of stamping and potting continued alongside puddling at Horsehay, in addition to the survival of the process at Coalbrookdale. In 1805 the main blast engine provided blast for two refineries and two fineries. As will be shown below, the fineries were partly used for the manufacture of charcoal iron, but numerous references to stamped iron from common fineries show that stamping and potting remained in use. Finery half blooms are mentioned in accounts until 1807, but it should be stressed that latterly they represented trifling amounts. In the year 1806-7 only 16½ tons of common finery half blooms were manufactured, compared with over 2382 tons of common puddled iron.[101] Simon Goodrich was told that stamped iron was called 'best hammered iron' and was 'said to be better than that made in the new way [puddling] but not made so cheap'.[102] This contradicts received wisdom, backed up by some contemporary evidence, that stamping and potting produced an inferior form of iron best suited to common uses such as nail manufacture. Unfortunately 'best-hammered iron', a term Goodrich also picked up at Ketley, does not appear as one of the superior grades of half blooms in the output figures for Horsehay forge, but it is possible that some of the iron graded best tough, best best tough and boiler plate slabs were made by stamping and potting. Best tough accounted for a significant proportion of Horsehay iron in the early nineteenth century and production was especially high in 1803. The output in tons of best tough compared with common puddled iron for the first ten months was 38/54, 31/64, 47/59, 39/31, 52/60, 65/62, 30/38, 40/152, 44/156, and 20/120.[103] Best iron could have been made from selected pigs, but evidence from Ketley suggests that a higher grade of iron was made by stamping puddled iron and heating it in pots.

When Simon Goodrich visited Ketley in 1803 he noted that common iron was made by passing it through the roughing rolls to make half blooms, then returning it to the balling furnace and passing it through the rolling mill to produce bar. But

> to make a better sort of iron instead of making the half blooms from the puddling furnace the lumps are run between rollers into flattened plates, which are broken up and packed in parcels of about ½ cwt upon flat plates of burnt clay [piles] or in pots and heated in a reverberatory furnace called a balling furnace. These lumps or balls are taken out and run between rollers into half blooms, these half blooms are again heated and made into bars as before – this makes best rolled iron. In other cases the iron instead of being made by rollers is made by the forge hammer if it is drawn out into half blooms immediately from the puddling furnace, it is called common hammered iron, if it undergoes the additional operation of balling after being shingled it is called best hammered iron.[104]

There are few direct references to stamping of puddled iron at Horsehay, but its continued significance is demonstrated by the delivery of pots and piles from the Horsehay potworks, and of stamping hammers from the foundry. Figures for pots and piles are ranged over the period 1796-1807 when accounts are available, although not all represent complete years, and show a slow decline in output (Table 3). In 1797 2833 dozen pots and 78 dozen piles were delivered to Horsehay at a time previous to the introduction of puddling.[105] In 1804 the figure had fallen to 425 dozen pots and 74 dozen piles, and in 1807 271 dozen pots and 109 dozen piles.[106] Given that to charge a furnace twenty pots or twenty piles were required, then the figure for 1807 represents 227 charges. By this date, therefore, puddled iron was routinely passed through rollers to form blooms, with the stamping reserved for special grades, of which boiler plate slabs is the most obvious example. Stamped iron was seen at Horsehay in 1815 by the Yorkshire forge master Thomas Butler.[107] A fuller account was provided from memory in 1876 by W.G. Norris, then manager of Horsehay and recalling the state of the works before modernisation in the 1830s. Horsehay was divided into upper and lower forges. At the upper was a balling furnace reserved exclusively for making boiler-plate slabs from stamped iron. In the lower forge, whose hammer and a pair of roughing rolls were worked by waterwheel,

> there were four puddling furnaces and one for heating scraps, which at this time were principally done in clay pots, made for that purpose at the Company's Brick Yard in Coalmoor Lane. Two or more of these puddling furnaces were always used for making best stamped iron, which was broken by a small 'Break Iron' on the premises and then taken to the piling bench in the Upper Forge.[108]

	Horsehay Forge		*Coalbrookdale Upper Forge*	
	Pots (dozens)	*Piles (dozens)*	*Pots (dozens)*	*Piles (dozens)*
1796	1499*	16*		
1797	2833	78	1144	
1798	736**	979**	1016**	115**
1802	369	286		
1803	350	144		
1804	425	74		
1805	284	49		
1806	234	70		
1807	271	109		

* six months
** nine months

Table 3: Pots and piles delivered to Horsehay and Coalbrookdale forges 1796-8 and 1802-7
Source: SRR 6001/334, Horsehay Daybook 1794-8; SRR 6001/336, Horsehay Journal 1802-5; SRR 6001/337, Horsehay Journal 1805-8.

The Coalbrookdale Upper Forge was also mentioned briefly by Thomas Butler. Unfortunately there are no figures for the delivery of pots and piles to Coalbrookdale in the first decade of the nineteenth century, but it is clear that iron was still stamped there. Consignments of refined iron to Coalbrookdale are recorded as late as 1807, although it does not mean that pig iron was not sent there at a later date.[109] In the half year July 1805 to February 1806 49 tons of common finery stamped iron were sent from Horsehay to Coalbrookdale, along with other types of iron, suggesting that Coalbrookdale became a forge undertaking small-scale specialist work, of which heating and hammering stamped iron was one. A reference to the supply of six puddling furnace doors to Coalbrookdale is the only evidence that puddling was adopted there, although the reference could conceivably refer to any type of air furnace.[110]

The more sporadic evidence for the Old Park forge at this period gives a similar impression to Horsehay. The foundry continued to cast stamping hammers until as late as 1814, despite investment in puddling, and especially the new mill after 1800, although fineries probably ceased working c1803, when references to them disappear.[111] Nevertheless, granulating the iron for certain grades appears to have continued since, as late as 1822, the forge could offer 'a superior kind of iron from stamped iron which we call best and charge an additional price of 15/-'.[112] As with Horsehay, the stamped iron was probably mainly intended for making boiler-plate slabs.

4.9 Charcoal iron and scrap iron at Horsehay and Coalbrookdale

The other two classes of wrought iron produced at Horsehay were charcoal and iron made from scrap. Numerous references in the Horsehay wages accounts are given for working scrap, including converting 'buzz balls into half blooms', working 'bottom iron and dust', 'balls of iron dust to half blooms', and 'puddling iron dust into balls to be manufactured again'.[113] References such as 'iron bottoms got up and made into half blooms' suggest that old cast iron finery plates were worked in a similar manner to scrap wrought iron, while it is clear that iron dust could also be heated and stamped.[114] Much of the scrap was derived from offcuts, such as scraps from making boiler plates, horseshoe moulds and 'mill iron rolled from old offal half blooms'.[115] When slabs were sent to Horsehay for rolling, the offcuts were sent back as scrap to the forge that originally made them.[116] Nut and ship bolt scraps and plate were purchased from William Horton at Coalport.[117] The term scrap also encompassed scull iron.[118] Scrap accounted for a small but not insignificant proportion of overall output. In May 1802, for example, over 9½ tons of scrap iron – common, best tough and slabs – were produced, compared with 93 tons of common puddled and 30 tons of boiler plate slabs.[119] In the following month 8 tons of scrap were worked, compared with 55½ tons of common puddled iron.[120] In 1802 common puddled iron was charged at £13 per ton, common scrap at £14, at the same time as scrap iron was bought from Benjamin Edge, chain maker of Coalport, at £10 per ton.[121] Output of re-worked scrap remained at 5-10% of common puddled iron during 1802-3. In the accounting year 1806-7 427 tons of iron from scrap was produced out of a total forge output of 3207 tons of half blooms and slabs.[122]

During 1798, the period when puddling was developed at Horsehay, consignments of charcoal cinders were acquired from 'Lidgetts' (Lizard?) Forge by Joseph Williams and Samuel Purcell.[123] Although forge slag was sometimes added to the charge of blast furnaces, the involvement of Williams and Purcell suggests that the cinders were intended for the forge. It is most likely to have been acquired in preparation for making charcoal wrought iron at Horsehay, but given that there are no references to the manufacture of such iron there until 1804 there must be some doubt. However, charcoal iron was certainly made at Coalbrookdale in 1797, when 1½ tons of 'stamped iron made with charcoal' were sent to Horsehay. There are no further references until both Coalbrookdale and Horsehay started making charcoal iron in 1804.

Production was small-scale, beginning at Horsehay in July 1804 with 5 tons drawn under the hammer rather than passed through the mill.[124] The following month half a ton of charcoal iron was rolled at Horsehay and in the remaining three months of the year over 28 tons of charcoal half blooms were made.[125] Production was henceforth stepped up. In 1805 185 tons of charcoal iron half blooms were sent to the mill for rolling, but all of it between January and August.[126] Some charcoal iron was also stamped and reheated in pots or piles at Coalbrookdale. Between July 1805 and

February 1806 124 tons were sent from Horsehay for stamping and potting, of which 9 tons had been made from refined iron.[127] Although the production seems minor compared to the output of puddled iron, in the fourteen months from January 1805 over 300 tons of charcoal iron can be accounted for at Horsehay, which compares favourably with the output of the rural forges in the mid eighteenth century (Table 1). Production then fell in 1806, during the remainder of which 23 tons were sent to Coalbrookdale for stamping and only 6 tons were worked into half blooms and sent to the rolling mill. 1807 saw a further decline, with only 4 tons worked into half blooms and 2½ tons worked up as best best slabs.

The Coalbrookdale Upper Forge also made charcoal iron in fineries, evidence of which is sporadic, but includes the delivery in 1806 of 120 tubs of charcoal from Horsehay at a cost of £44.[128] It is likely that charcoal iron at Coalbrookdale and Horsehay did not meet expectations. Agreement for the supply of charcoal had probably been made which was no longer wanted. This explains why in 1807-8 charcoal was regularly sold to Hornblower & Smith for their forge in Brockmoor, Worcestershire, to John Knight, owner of several Stour Valley forges, and to Lightmoor.[129] The local market for charcoal iron was from Benjamin Edge and William Horton, separate chain-making concerns at Coalport. In 1806 both purchased best best tough charcoal bar of small diameters for making chain links. In the following year both were also prepared to buy bundles of best tough and best best tough iron of similar dimensions but refined with mineral fuel.[130]

There is some evidence for a similar pattern of working scrap and making charcoal iron at other principal forges. The reference above to Lightmoor is the only evidence that its forge might have included a charcoal finery. In July 1796, 5 tons of 'charcoal scrap stamped iron' were sent from Ketley to Horsehay rolling mill 'to be kept separate and not used till further orders'.[131] In 1790 Botfield made an agreement with William Taylor, forgeman, who was 'to coal all the cordwood at the Park & Stirchley at 6/6 per dozen'.[132] There is no evidence of charcoal iron production at Old Park during this period, however, despite purchases of charcoal recorded in 1797.[133] When, in 1803, the works received a request for charcoal iron from a Liverpool merchant, Gilbert Gilpin replied that ‘we do not make any best charcoal iron at Old Park but have a small forge at Cleobury [Dale]’.[134] References to buzzing furnaces at Old Park, as distinct from puddling furnaces, occur in 1794.[135] Scrap was evidently worked at Old Park over a long period. Scrap blooms were sold to Wichnor Forge in 1814-15, although one order could not be met and the shortfall was made up with best iron.[136]

4.10 Conclusion

The period 1790-1815 saw radical changes in the scale and technology of the wrought-iron industry. Economic and technological historians, writing in a national context, have argued for a generally smooth transition to puddling that inevitably seems too general when the industry is studied at close quarters. The advantage of a regional approach is that it has allowed closer examination of sources, where the sheer complexity of the industry has become apparent. Here, technological change can be explained as a continuum rather than a sequence of forward leaps and there is no norm to which the forges adhere.

As a technique, puddling was new to Shropshire forgemen when it was introduced in the 1790s. Evidence from the Horsehay wages book undermines arguments that puddling was similar to buzzing or to the earlier Cranage method. The first phase of puddling in Shropshire occupies the years 1794-1800, when iron was generally granulated and re-heated in pots, rather than being passed through a rolling mill. A second phase is discernible after 1800. Substantial investment was made in additional puddling furnaces, with steam-powered rolling mills incorporated at Ketley and Old Park, and a new mill at Horsehay in 1809.

The forge trade continued to hold in high regard the practice of granulating partially refined iron and reheating it in clay pots or piles. The overlap between stamping and potting and of puddling and rolling demonstrates how technological change was not an either/or option but the gradual incorporation of new techniques alongside established practices. Stamping and potting was valuable beyond the self-contained process patented by Charles Wood and Wright and Jesson. In Shropshire it was applied to iron taken from both the puddling furnace and charcoal finery in order to make a superior grade of bar or plate.

Evidence for the continued production of charcoal iron suggests that it remained a mainstream product in spite of its decline in relative terms. Reasons for the closure of rural and Severn Valley forges are most likely to have included their comparative isolation from the main Midland markets, and the extra expense in acquiring pig iron. The unsuitability of small water-powered sites for the development of larger steam-powered forges and rolling mills may also have been a factor. It is important to stress, however, that the decline of rural forges was not synonymous with the decline of charcoal iron.

Evidence of Shropshire ironworks has shown that the three processes of finery and chafery using charcoal, stamping and potting, and puddling and rolling, were not mutually exclusive technologies. Rather, they codified a range of techniques that were utilised by forgemen in various combinations to produce iron of specific qualities. All of these techniques were current in the early nineteenth century. The survival of what has been termed obsolescent technology was not governed by a conservative resistance to change, but by the eventual use of the iron produced, be it charcoal iron for chain links or stamped iron for boiler plates. Technological change was therefore influenced by the demand of the market, which in consequence must be examined in more detail.

5 IRON TRADE CULTURE, c1790-1830

The purpose of the next two chapters is to observe at close quarters the daily workings of the iron trade. They examine the extent to which the character and development of the Shropshire forge trade was determined by factors other than technology and the economics of production. This chapter concentrates on how businesses were conducted, while the following chapter discusses workplace culture. The period 1790-1830 allows an analysis of how iron industry culture changed during the transition from vegetable to mineral fuel. The subject is constrained by a paucity of direct sources. Ironmasters did not write manuals that detailed how they established themselves, how they organised production and made decisions on new investments. National surveys of the industry glossed over the complexities of iron manufacture, which is why numerous counts of blast furnaces and their output need to be examined critically. Available documentary evidence for the early nineteenth century is largely confined to the Old Park Ironworks, for which a large amount of business correspondence has survived from as early as 1802, but particularly from the period 1814-29. The Old Park evidence is important because the partners participated in trade organisations, dealt with other ironmasters as suppliers, and because its forge had a wide range of products.

5.1 Business relationships

The iron industry needed a market place which, by the second half of the eighteenth century, was served by quarterly or more regular meetings of ironmasters and merchants. These were regionally based, Shropshire ironmasters doing much of their business at meetings of the Midland trade. As an institution, the quarterly meeting appears to have evolved in the eighteenth century from regular gatherings at fairs in Stourbridge, Bristol and Chester, where outstanding accounts were settled. The Stourbridge meeting was established before there were significant numbers of blast furnaces in the Black Country. By 1731, Edward Knight, owner of several Stour Valley forges, was already talking of setting prices on a quarterly basis.[1] Iron merchants and carriers also attended quarterly meetings at Birmingham, which were a firm fixture of the trade by the time Thomas Botfield built the Old Park Ironworks in 1790.

Quarter days were Lady Day, Midsummer, Michaelmas and generally two weeks after Christmas. Ironmasters like Botfield used the opportunity to request payments and as the principal forum for receiving orders: ‘our method of doing business is we generally take at quarter day orders for nearly the whole make of our iron, to be delivered in the course of the quarter which we do as regular to each house as we can’.[2] This allowed an ironworks to organise its production over a three-month period, which was clearly desirable for a complex operation. It also informed ironmasters what grades and types of iron were in demand, and presented choices to them of either producing a variety of special products, or risking production on regular types of bar in the hope that the price would remain profitable. Old Park routinely turned down orders once its productive capacity had been reached.

Quarter days were also partly a social occasion. They ensured that an ironmaster had a fairly good idea of what his competitors within the region were doing. Such contacts were also useful when ironmasters needed to unite in defence of their interests. A succession of measures that proposed to levy increased taxes on iron and coal production, in 1785, 1796 and 1806, were successfully defended by ironmasters who could draw benefit from well-organised district or regional societies.[3] They provided a forum for shop talk but not, apparently, for the dissemination of technical knowledge. In 1800, Joseph Dawson, managing partner of the Low Moor works in Yorkshire, attempted to introduce a formal discussion of metallurgical science at the meetings of the Yorkshire and Derbyshire ironmasters, but to no avail. No one but himself was prepared to read a paper on the subject.[4]

In 1799 and 1800 William Botfield attended meetings of Shropshire ironmasters at Shifnal and at the Tontine Inn in Ironbridge.[5] Shropshire ironmasters sometimes set prices and wages different from the Black Country. They also had some other shared interests. They were a regional group with a national reputation in the industry, and locally they formed a lobby on social issues in relation to landowners and magistrates.

Occasionally the Midland trade (where Black Country ironmasters were numerically dominant by the early nineteenth century) met the South Wales ironmasters at Gloucester.[6] William Botfield attended such a meeting in 1818 after a period of lapse, and wrote to Barnard Dickinson of the Coalbrookdale Company agreeing to the suggestion of the Welsh trade that more regular meetings would be beneficial.[7]

Prices of iron and coal, and wages for iron workmen and colliers, were fixed at quarterly meetings. None of the major ironworks kept significant stocks of iron, and so it was permanently in their interest to keep the price of iron at a profitable level. Quarterly meetings facilitated this as they were a way of checking the pulse of the trade. From the early eighteenth century the price of iron was decided by the largest producers – Edward Knight, for example, was already setting prices for Midland bar iron in 1731.[8] The custom persisted into the nineteenth century. As late as 1824 Shropshire prices were still decided by the 'principal' makers, but some flexibility remained necessary as price differentials were used as a bargaining tool.[9] In 1820 the London iron merchants Crawshay & Company were able to obtain a price of £9/10/- instead of a previously agreed price of £10/5/- on Old Park bar iron in consequence of the reduction of Staffordshire bar iron.[10] In 1824, although the price of Shropshire forge pig had been fixed at quarter day, 'in consequence of an advance in Wales & Staffordshire we have since sold at an advance – however as you were a regular customer we think you were entitled to be supplied at the last Quarter day prices'.[11] A special meeting of the Shropshire iron trade was held in April 1826 to readjust prices for the quarter 'in consequence of circulars from Wales and prices quoted in Staffordshire'.[12] An indication that price wars hurt the local trade is suggested by the defensive tone of a letter to John Knight in April 1826: 'it appears to us a measure likely to be injurious to the trade and not at all necessary'.[13] Truculent replies to bartering merchants were common in the 1820s. An example is a letter written in 1827 to the Bristol merchants Protheroe & Hunt, who had evidently requested a lowering of the Shropshire prices:

> We are very sorry to observe … that other Welch houses have followed the whimsical example you before informed us of, viz a reduction of 10s per ton of

> bar iron … they may soon see their error & retrace their steps by putting an advance of 20s per ton – we are not so whimsical … in Shropshire & do not apprehend that any alteration will take place.[14]

Competition was strong between Shropshire works in the difficult years following the end of war with France in 1815, when the unity of the trade came under strain. William Botfield, having increased colliers' wages in response to the Lilleshall Company's unilateral wage rises in 1818, lamented that 'it has always been usual amongst us when any party thought an alteration of any kind necessary to call a meeting to discuss the proposed alteration; our quarterly meetings were I think very serviceable and kept up that spirit of unanimity which is so essential to all our interest'.[15] As a group, ironmasters lived with a tension between unity and competition.

The interests of the ironmasters were not always in maximising production and price fixing was an attempt to control output. Gilbert Gilpin wrote to the clerk at Penydarren in 1808 that if all the ironworks in Britain followed the myth that maximising production would reduce the cost of making it,

> iron would soon feel a greater depression in price from the augmentation in make still more exceeding the consumption. It is on this account that we confine our mill … to eight or nine hours work per day, and roll 50 tons of bar iron per week. In lieu of selling large quantities at prime cost, my employers conceive it best to do less at a small profit.[16]

Ironmasters did not therefore appear to be in a headlong pursuit of economies of scale.

Like other ironworks, Old Park employed a traveller to solicit orders. James Sheward carried printed lists of the sizes and grades of iron produced by the forge and mill. In 1815 he was in Yorkshire with instructions to promote an introductory offer on orders for best iron, and to persuade forge masters ordering common iron to accept a small quantity of best iron as a trial.[17] Price lists were also sent out to existing customers.

The Old Park forge produced a variety of products such as bars, rods, hoops, plates, and sheets in various sizes, and all in response to the demand from merchants and secondary forges.

Several sources give a fair impression of the range of customers who were served by Old Park, although there are no definitive lists of customers. Customers can be divided into primary and secondary forges and merchants. Primary forges are those that purchased pig iron or iron in various stages of further refinement. Almost all were in Shropshire or the Midlands, and many of them were mentioned in the previous chapter.[18]

Other secondary forges purchased bars or rods for conversion to specific products. Among these were numerous chain makers across the Midland region, such as William Gilpin of Wedges Mill near Wolverhampton, Simkis & Ashfield, John Andrew of Congleton, and Benjamin Edge and William Horton of Coalport. Even small-scale forges such as that operated by Elizabeth Clarke, file manufacturer in Bilston, and the Wood brothers, shovel manufacturers of Stourbridge, purchased iron direct from Old Park.[19] By the 1820s the trade with wire mills had been established on a national basis, where iron was dispatched to the Midlands, Derbyshire, North Wales, Lancashire and Yorkshire.[20]

Trade beyond the Midlands was mostly handled by merchants. Iron merchants were wholesalers who stocked not only bar iron but also pig iron, and small quantities of blooms and slabs. All of the secondary forges referred to above could have purchased iron from merchants. The advantage of dealing with merchant houses was that, unlike the forges, they kept iron in stock and so it was not necessary to order iron three months in advance. Anecdotal evidence provided by its business correspondence suggests that most of the output of Old Park forge and mill was sold to merchants, and therefore its eventual destination and use is not known. Many of the merchants, such as those of London, Bristol and Liverpool, purchased iron destined for export.[21]

5.2 Organisation of production

By taking orders at quarterly intervals, ironmasters could ensure that no iron was left unsold that had to be stored in a warehouse. Business was organised in such a way that the finished product was in circulation between producer and consumer for as short a time as possible. Short-term strategies were adopted to cope with price fluctuations where stockpiling might have been an alternative longer-term strategy. In 1816-17, the price of forge pig iron fell considerably. Old Park responded by cutting production of forge pig iron, from 5501 tons in 1815 to 3987 tons in 1817. Of this, 2323 tons and 2247 tons respectively were refined in the company's own forge, which therefore saw no significant decrease in its work. At the furnaces a rise in the production of foundry pig iron compensated for the drop in forge pig iron output.[22]

Old Park liked its orders large and regular. This could put the smaller independent forges that relied on pig iron from the major producers at a disadvantage. For example, in 1814 as regular and long-term a customer as William Blount of Cleobury Mortimer found that Old Park was to charge a premium of 2/6 per ton on pig iron orders per quarter less than 100 tons.[23] If a small forge had the capacity to refine that quantity of pig iron it applied pressure on them to purchase the pig iron from a single source which, as will be shown below, was a risky strategy to adopt when supplies were not always guaranteed. In 1826 William Graham, an iron merchant based in Thames Street, was approached as a potential sole merchant handling Old Park iron sent to London, the outcome of which appears to have been negative.[24] From the same year, however, Old Park developed a close business relationship with the Bristol iron merchants W.D. and W.E. Acraman, and its Liverpool branch, trading as Acraman & Stitt.

In theory it was in the interest of the works to have a principal large-scale customer with regular orders, but the disadvantage of the arrangement with Acraman soon became apparent. The rolling mill had separate trains for different types of iron – bar of large and small sections, plate, sheet, hoop and rod – that were coupled up only when they were in use. Rolling mill engines could not work all the mill trains simultaneously and so organising the efficient use of the mill to fulfil its quarterly orders was a fine calculation. Botfield reminded his principal client of this very point: ‘it is a great convenience to us to have sizes at the commencement of a Quarter, when the same rolls will do for many customers without the loss of time and expense in so often changing them’.[25] Not to have prior orders severely hampered its operation and profitability. This is what happened in February 1827 when, over a month into the first quarter of the year, a specification from Acraman had not been received. This affected not only the mill but the forge, and caused pig iron to be stockpiled:

> having contracted with you previous to last quarter day for 500 tons long weight of bar iron … prevented us of course accepting orders from others more than to take the remainder of our make & consequently reserved pig iron accordingly; under these circumstances it would now at this period of the Quarter be very inconvenient & injurious to us to relinquish any part of your order – as our other customers are no doubt engaged elsewhere it would therefore either throw us into that much stock which we never yet had & do not intend to have or throw our people out of employment which we never do if it is possible to avoid it.

Not having any specifications meant that the rolling mill was worked ‘entirely for others at a great loss & inconvenience to ourselves as some rolls may have been used for you as for others’.[26]

Wrought iron was not an homogenous product. The different forms in which it was produced at Old Park in 1803 are given in Table 4. This shows that the price of iron differed according to its grade and to what section it was rolled. The difference can be accounted for by the variable quality of materials required and the cost of manufacture. In 1808, rollermen were paid 2/6 per ton for producing all sizes of merchant iron, but this was to change by the 1820s.[27] Some of the smaller sections required at least two heats because they could not be passed through the rolls fast enough before the iron had cooled. An example of the sections of bar rolled at Old Park in 1832 shows not merely their variety, but also the differential cost in paying the workmen to produce them (Table 5). These sizes were subject to frequent change.

In 1827 the forge had been rolling octagon iron at different sizes and at different prices. The larger sections from ¾ inch to 1 inch were charged at £10 per ton, whereas ½ inch was charged at £11, and $^{7}/_{16}$ inch at £11/10.[28] The variable price of bar iron is not therefore a reliable guide to the profitability of the refining process, and nor can the profitability of a forge be measured simply as a statement of output of bar in tons.

	Price per ton (shortweight)
Common merchant iron	£14
Common bars	£16
Best bars	£20
Common flats	£17
Tyre iron	£15
Common rods	£17 (longweight)
Tough rods	£21 (longweight)
Best tough rods	£22 (longweight)
Boiler plate	£23

Table 4: Prices of iron from Old Park forge, delivered at Stourport, 1803.
Source: BOT 1/6/1, T, W & B Botfield to J Sword & Co, Glasgow, 26/1/1803.

Regulations were agreed that only one tenth of an order for bar iron could be of those deemed to be small sizes, although merchants sometimes tried to bend the rules. Small sizes were costlier to produce. Responding to an order from T & P Price of Birmingham in 1808 it was argued that: 'Were we to manufacture a greater proportion of [small sizes] at the prices mentioned in the list, we should sustain a loss of at least £4 per ton upon the excess, arising from extra waste of iron, additional expense of workmanship, and their employing our machinery five times as long as the same weight of assorted sizes'. In 1808 small sizes included square bars of ½ inch, flat iron of between 1 and 1¼ inches thickness, and round iron between $^{3}/_{8}$ and ¾ inch.[29]

		Price per ton	
	Size in inches	*Heating*	*Rolling*
Round iron	¾	2s 3d	2s 10d
	½, $^{9}/_{16}$, $^{5}/_{8}$	2s 9d	3s 2d
	$^{5}/_{16}$	3s 8d	5s 6d
Bar iron	$^{5}/_{8}$ square	2s 3d	2s 10d
Flat iron	$^{7}/_{8}$, 1, $1^{1}/_{8}$	2s 3d	2s 10d
	¾	3s	4s
Wire rods		4s	5s 6d
Horsenail rods		5s 3d	7s 6d

Table 5: Payments to John Hyde & Co and George Brazier & Co for heating and rolling iron at Old Park forge, 1832.

Source: BOT 2/8/4, Old Park forge wages accounts, 1832-3.

Of unforeseen events that affected production the most common were accidents. Breaks in production at the blast furnaces also had an effect on customers of pig iron. For example Joseph Jesson at Wrens Nest was unable to obtain any pig iron from Old Park in the final quarter of 1804 due to an accident at the furnaces.[30] This would potentially have a serious effect on those forges who relied on buying pig, because it was not always easy to secure an alternative supply at short notice without paying the higher prices charged by merchant houses. Requests to Old Park from several forges at various times were turned down when pig iron or blooms were required at short notice, simply because the proposed quarterly make of the furnaces had already been accounted for. Serious disruption of pig iron output was rare, occurring for example in 1815 and 1817, and is unlikely to have caused Old Park's own puddling furnaces to cease production.[31]

The nature of puddling, whereby production was spread among numerous puddling furnaces, was such that problems with individual furnaces made little impression upon overall output. By contrast, disruption of the mill was a serious and urgent problem, almost invariably caused by a breakage in the machinery. Such a case occurred in 1815, as outlined in a letter to Hazeldine Rastrick & Company of Bridgnorth Foundry: 'the screws of the pillars of the rolls in this mill are in immediate want of repair & will thank you to say by return of post whether you can re-cut them, & if you can in how short a time can you do them?'[32] In this case there was evidently a delay as over a week later a letter was sent to the Coalbrookdale Company on the same subject of repair.[33] Again, in 1827, 'we met with a serious accident at our rolling mill on Saturday which had broke the engine & machinery, and which will not be at work again of a week or nine days'.[34] In the event it caused disruption of the mill over the Quarter, with a consequence that orders were not met.

Nearly two months after the accident it was admitted to Walker & Brothers of Bury that 'we have met with several accidents in our machinery which with the illness of our plate roller has prevented our executing your order'.[35] This was not the only case where stoppages were caused by illness of key workmen who could not be replaced at short notice. After extensive repair to the mill in 1825 the company found it necessary to employ a temporary principal roller on account of the illness of the permanent roller.[36] A month later output of rolled iron had stopped, 'a very serious accident having occurred in our rolling mill which has broken the machinery in a way that cannot be repaired for some time'.[37] Where the specific cause of an accident in the mills is mentioned workmen were invariably blamed. Gilbert Gilpin noted in October 1807, before writing to Boulton & Watt for a replacement rod, that 'last night the connecting rod of the mill engine was broke from the carelessness of Felton the forge carpenter, in leaving one of the wheels on the slitting side out of gear, and not sufficiently secured, by which means it got into gear when the machinery was in full motion.'[38] Joseph Felton did not endear himself to Gilpin when, three weeks later and the mill still idle for want of repair, Felton was 'off all this morning drinking' with his friend Jack McGosh, who arrived drunk at 11 o'clock, while Felton showed up drunk at 2 o'clock.[39]

The Old Park foundry continued to cast replacement parts for the forge and rolling mill. These included basic items like stamping hammers, furnace doors and bottoms, but also more precision items such as chilled and slitting rolls.[40] The foundry also cast rolls for other works, having received an order for chilled rolls from the Wichnor Iron Company in Burton-on-Trent in 1826.[41] Old Park foundry was not an engineering works and was therefore limited to producing the simpler castings, in contrast to the Coalbrookdale Company whose foundries had been manufacturing steam engines since the early eighteenth century. From as early as 1807, however, Old Park looked elsewhere for foundries and contractors to cast and fit new rolls. Foundries asked at various times to cast rolls, screws and cylinders included the Bridgnorth Foundry of Hazeldine Rastrick & Company, Foster Rastrick & Company of Stourbridge and Joshua Walker & Company of Gospel Oak.[42] Rolls required periodic replacement not merely to repair breakages, but because wear and blemishes in the grooves gradually diminished the quality of the bar.

5.3 Language and custom of the iron trade

Dialogue between masters and merchants depended for its technical nomenclature on the language of workmen. Its use in contemporary documentary sources is always at one remove from its source, since these documents were written by managers and ironmasters. Moreover, as an oral culture the language of the workplace was never definitively codified. For these reasons the use of terms can seem idiosyncratic and are not always susceptible to definitive interpretation.[43] Meanings also changed over time and so a term must be interpreted within its specific context.

It has already been noted that in the last decade of the eighteenth century the term *puddling* could refer to the working of refined iron or scrap. Similarly *balling* was a general term applied to the heating of semi-finished iron. Although it commonly referred to the reheating of puddled iron after it had been passed through the roughing rolls, its use pre dated the introduction of puddling. William Botfield understood it to have been used in the stamping and potting process for heating the iron in pots, where the term probably originated.[44] The term *potting* was rarely used to describe that part of the process. Balling furnaces also appear to have been applied to finery and chafery forges where the chafery had been replaced by a reverberatory furnace, for example at Hampton Loade.[45] Balling can therefore be seen as a term that spanned different techniques, the common factor being that it was used by workmen to refer to the re-heating of semi-finished iron. Reverberatory furnaces in rolling mills that had been known as balling or mill furnaces were by 1830 known as heating furnaces, however.[46] By contrast, heating granulated iron on clay tiles was known as *piling* in the contemporary trade, and was used by Crawshay in describing the process at Cyfarthfa in 1791, but is not the more familiar and subsequent meaning of the term, whereby wrought iron bars were stacked in the balling furnace for re-heating.[47] In 1817 a new term, *puddlers billets*, entered the vocabulary of the Old Park forge after a request to supply them was refused on the basis that the forge did not make them.[48] According to W.G. Norris in 1876, billets were iron ready for rolling and differed from blooms, which had to be broken up before they were ready for the mill.[49] When Old Park did begin selling billets in 1820, they were charged at the same price as blooms and slabs.[50]

Bloom, *shingling* and *slab* are also terms that survived developments in technology. Slabs were made by the stamping method into the 1820s so the persistence of the term is logical. *Bloom* is of medieval origin, pre-dating the introduction of the blast furnace. Both *bloom* and *shingling* encompassed the charcoal finery and the puddling furnace, and therefore survived a period of significant technological change. Other terms disappeared from common usage. At Horsehay in the 1790s the grading of stamped iron as *good*, *bad* and *second best* is similar to terms such as *good iron* and *better iron* used by nailers at Wednesbury in 1785 in trials with puddled blooms.[51] Such terms appear to have declined slowly. By 1802 the output of Horsehay forge was categorised mainly in terms of *common* and *best tough*, but small quantities of *second best* or *second best tough* blooms and slabs continued to be made in the period 1802-8.[52]

The grading of iron according to its malleability and strength remained a constant in trade, but the language of quality did not. *Cold-short* and *tough* iron, familiar in eighteenth-century technical speak, faded away in the nineteenth century. *Best tough* was eventually abbreviated to *best*. In 1802-5 Old Park bar was graded *common*, *tough* and *best tough*, while *common*, *best tough* and *best best tough* were the equivalent grades at Horsehay as late as 1808.[53] The categories were simplified by the second decade of the nineteenth century, at least at Old Park, to common and various grades of best. Although the terms *common* and *best* are found in the eighteenth century they became universal in the nineteenth.

Grading of iron changed in an ad hoc manner, and it is not clear whether masters, merchants or both were responsible for initiating them. In 1826 two Bristol iron merchants ordered *No 2* and *No 3* bar iron, to the confusion of the clerk at Old Park who eventually discovered that No 3 referred to best: ‘We beg to observe we do not know what numbers mean for bar iron, always distinguishing ours by Common, Best & Best Best, and shall be obliged by your so describing it in future’.[54]

Nothing illustrates the conservative tendency of the iron trade better than its concurrent employment of two standards of measurement. Both shortweight and longweight tons were in common use. At Old Park in 1808 forgemen were paid in longweight tons for every process, which appears to have been the general rule.[55] At the same time weights used at Horsehay, although generally measured longweight, were inconsistent. Small consignments of stamped iron, and occasionally scrap, could be measured in either scale.[56] In April 1806 several consignments of semi-finished iron were sent from Horsehay to the Upper Forge in Coalbrookdale, some shortweight and some longweight, although paid at the same price.[57]

Whatever units were adopted within individual companies, sales of iron in the market place were governed by custom: Pig iron, blooms and slabs were generally sold in longweight tons, while bar iron and plate were sold shortweight.[58] In other words, slabs sent from Lightmoor or Snedshill to Horsehay for rolling into boiler plates were accounted for in longweight tons, but when they were sent back to the customer they were accounted in shortweight. Some special grades, such as scrap bars, slit rods, rolled horsenail rods and 'horseshoe moulds', were also sold longweight.[59] But some confusion was inevitable when the rules were not known, and when the ironworks sent an advice note to the customer in longweight but the final invoice in shortweight: In one instance William Botfield had to send a customer's solicitor 'the wharfingers account at Stourport, which you will observe corresponds with our account, after reducing it from long to short weight, which is the weight at which all merchant bar iron is sold'.[60]

5.4 Quality of iron

The type of machinery introduced into the forges and rolling mills also significantly affected the output of the works. The building of slitting mills at Ketley and Horsehay in 1796 and 1798 respectively has already been referred to and increased the range of products that the works could offer. It was also an important consideration in the building of the new forge and rolling mill at Old Park from 1800. A knowledge of the technology and the market was important in judging the type of rolls or hammers to be installed, and what should be left out. For example, despite its high investment under the direction of Gilbert Gilpin, the forge could not 'make hammered bar iron less than ¾ inch square on account of the great weight of our tools'.[61] Much later, in 1826, an order for planished iron was turned away because there was no longer a light planishing hammer in the forge and it was not economically viable or sensible to stop the shingling hammer so that it could be used to hammer the iron cold.[62] By contrast, in 1826 new rolls were installed for making 'gunnel iron', and a few months later the mill began rolling octagon iron, a type not previously made there.[63]

Reference has already been made to regulations concerning iron denominated as small sizes. Occasionally orders for anomalous sizes were received that required some negotiation. For example, because of the size of blooms and slabs, individual bars were of a finite length, even allowing for the welding of two bars together. Old Park could roll iron at 4½ inches square, but only 'if the bars do not exceed 6 feet' in length.[64] In 1819 an order for bars 6½ x 1 inch was impossible to execute since there were no grooves wider than 6 inches, and as there were no other orders for such sizes it was deemed not worth casting rolls especially. Assuming that the iron was required for rolling into sheets, it was argued that the slightly smaller size would be suitable and advised on the grade of iron suitable for making sheets. The ability to discuss technical issues with merchants and masters of secondary forges was a necessary part of doing business. Large forges were given to experimentation to answer specific problems, the most notable example being the rolling of 800 tons of wrought-iron plates at Horsehay for I.K. Brunel's SS *Great Britain* in 1839.[65] Experimentation was usually for less illustrious aims. There is no evidence as to the precise details of the iron required by Osborne & Gunley of Bordesly Mill, Birmingham, in 1816 except that having made trials on the iron 'to suit the purpose wanted by you' it was impossible 'without an extra process in the manufacturing which will make it so expensive as we presume will not suit either your purpose or ours'.[66] But it does indicate forge management was a continuing process of solving problems in response to innovations made by customers.

The topic that dominated communication between forges and merchants was the quality of iron. In the early nineteenth century common bar iron was made at Old Park from common pig, best from selected pig. But there were other ways of producing high-quality iron. Simon Goodrich noted in 1803 at Ketley that best iron was made by reheating iron after it had passed through the roughing rolls. At Old Park best best iron was reheated and reworked, while best best best, or treble best, was reheated a third time. Later in the nineteenth century 'best iron' is said to have denominated iron that had undergone two heats.[67] There was still a market for hammered iron as late as 1828.[68] Stamped iron continued to be used to make best iron into the 1820s, as described above, although this may have been confined to slabs rather than bars.[69]

Quality was also in part determined by the quality of the raw material. Superior classes of pig iron produced superior grades of bar. Blending of pig iron from different sources was a common method of achieving this in the eighteenth century and was also widely practised in the nineteenth.[70] Details of blast furnace output at Horsehay and Old Park record three standard types of pig iron, of which No 1 and No

2 were grades of foundry iron. Iron for the forge was generally classed as 'grey forge pig', although 'common' was an alternative name used at Horsehay, where another grade of pig iron delivered to the forge was termed 'strong pig'.[71] By 1822 Old Park was offering 'a description of pigs which we call selected forge or No 3 Melting, which are generally used for best purposes'.[72] Best iron was made from selected pigs, while common grades of iron were not.[73] In 1820 Old Park was selling forge pig at £5/5/- per ton, and £5/10/- for selected pigs.[74] Quality was not a matter of a scientifically verifiable standard, but a matter of judgement on the part of furnace keepers and forgemen. Iron was broken and assessed according to its degree of greyness, its grain, and its hardness.

The ultimate test of a pig iron came in working it, and the reputation for quality could ultimately only be regulated by the satisfaction of the forgemen. Forges that purchased Old Park pig iron occasionally complained of the quality of the pigs. Such complaints signal problems that must have periodically occurred in the Old Park forge itself. For example in 1815, at Wedges Mill in Wolverhampton, the chain-making forge of William Gilpin, Old Park iron was found to be of insufficient quality when the puddlers came to work it.[75] A dissatisfied Jeston Homfray of Broadwater was also told in 1816 that the clerk at Old Park would in future ensure that he would be sent 'good open-grained forge pigs'.[76] Ultimately, however, quality of pig iron could only be established by negotiation between furnace and forge. Furnace men were not necessarily prepared to accept that their judgement was at fault. It was also a generally accepted fact that 'it is impossible to have every bar of equal quality as the pig iron will vary', but the acceptable degree of variation was contested.[77] A good example of a negotiated agreement on quality occurred in 1821, when James Foster, owner of numerous forges including Eardington and Hampton Loade, found deficiencies in Old Park pig iron. William Botfield investigated the matter personally. Neither the Old Park furnace clerk or forge clerk would accept that there had been a change in the quality of the pig iron smelted in the furnaces, and at the furnaces Botfield himself

> examined the pigs then there and found the different descriptions of iron when broke same as usual. I therefore apprehend it must have arisen in the inattention

> of the furnace clerk in not selecting your iron properly, either sending it too hard or too grey that is approaching to melting – if you will have the goodness to inform me or desire your clerk to ride up to describe the sort he wishes, it shall be attended to.[78]

Forges that purchased puddled blooms from the larger forges were also wont to complain if the quality fell below expectations, and for the same reason. Isaac Spooner of Park Mill, Staffordshire, was a regular customer for both pig and semi-finished iron, and received an apology for blooms sent from Old Park in 1816, the inferior quality of which was established by the Old Park forge clerk who travelled there in person to inspect them.[79] But no apology was forthcoming following complaints in 1816 from Benjamin Mold of Wichnor Ironworks, Burton-on-Trent, regarding scrap blooms. It was pointed out that the regular quality of scrap blooms could not be guaranteed, especially as not all of the iron was scrap from Old Park's own forge.[80] The later the stage of working, the more scope there was for poor workmanship accounting for the loss of quality. Puddlers and shinglers were not prepared to accept criticism without an opportunity to defend themselves. The trouble with the purchase of blooms was that they were not marked by individual workmen. A typical case occurred in 1819 when a request that a workman inspects bad blooms himself was batted away by the forge clerk: 'we conceive it can answer no purpose to send over the person who made the blooms to see the quality of them, unless they had been marked, which was not the case, as he will not be disposed to allow they belong to him if they are bad'.[81]

Just as the quality of pig iron was negotiable, so was there room for debate about the quality of wrought iron. In a sense, iron was as good as a forge master could persuade the customer that it was. In 1815, when the British wrought-iron trade was at a low ebb, Old Park introduced a new grade, common-best, in the hope that it would boost orders. The clerk at Old Park, William James, claimed that Old Park common rods were equal in quality to common-best rods from Staffordshire, and that Old Park common-best was as good as Staffordshire best.[82] For certain kinds of iron common was considered to be unsuitable. For example, 'we presume these bars are for rolling into sheet iron, if so we should recommend you should have them of common-best iron instead of common as the quality cannot always be depended upon for such purposes – we use the common-best ourselves for sheet iron'.[83] In other instances it was not practical: 'the common iron the size specified we cannot make at one heat more than from 6 to 8 feet long, if you wish the bar longer they must be made at a double heat in the same manner as we make our common-best iron, consequently the quality will be better and the price 25/- per ton more'.[84]

The purchase of common iron was often a false economy. The Old Park rolling mill found that too much waste was incurred when common iron was rolled wider than 4 inches.[85] Generally speaking, the higher the grade of iron, the smaller in section it could be worked. Iron rods intended to be drawn into wire were always best iron. The highest grade of iron was charcoal iron which could be worked to the thin section of a needle or rolled into a thin plate for coating in tin. The grade required also depended upon the eventual use. Nails were made of a lower grade of iron than chains, where strength was especially important. When Old Park sent its agent, James Sheward, to Yorkshire in 1815, he was given specific instructions to gain as many orders for best as possible. If orders were placed for common iron he was given specific instructions to

> prevail upon them to take a small quantity of best on trial … if they will only take half a ton it will give them an opportunity of deciding which answers best their purposes, for many Ironmongers are quite ignorant of the difference in quality and only judge by the lowness of the price, which is not a fair criterion in as much as the lowest priced iron must be of inferior quality and will waste much more in working than the best and by which means in most instances will prove much dearer in the end than the best.[86]

A different approach was taken to making boiler plates. Replying to a complaint about defective plates in 1828, the following description illuminates some of the skill and judgement required in rolling plates of a large surface area that had to be of uniform thickness and quality. It also highlights the difficulty of judging the quality of boiler plates before the boiler had been assembled: any defective parts had probably been

> rolled hotter than the others where the slag marks appear, but the plates are if anything better than if they had been rolled cooler and the slag into them; the surface would have appeared smoother, but the plate in reality no better. You will generally find the ½ and $^3/_8$ thick plates not so smooth on the face as those that are rolled thinner. We are not aware of any cracks or that there was any defect in the cutting of the sizes given … we can only add that our boiler plate rollers are considered two of the best workmen in that line in the trade.[87]

Quality control would have no effect without the ability to mark the iron clearly. Bar iron was stamped using steel dies, which were made for Old Park by Edward Thomason & Company of Colemere Row in Birmingham or Edward Beddard of Coalbournbrook, near Stourbridge. A variety of marks were used to denominate the source and grade of the iron, but they were frequently changed. In 1815 Old Park used 'TWBB' (Thomas, William and Beriah Botfield) for common and 'OP BEST' or white paint to denote best.[88] The smallest sizes could not be stamped and so were marked with red paint, but iron as small as rods was stamped with a punch no more than $1^1/_8$ inch wide.[89] In 1827 Old Park adopted the practice of marking their bars with a crown, apparently in response to requests from merchants, by which time 'BB' and 'P' (i.e. 'Botfield' and 'Park') denominated best iron and 'OPC' common.[90] The crown mark denoted common iron.[91] Special marks were reserved for cable iron, while the Acraman merchant house was allowed its own stamp.[92]

Disputes over the quality of wrought iron were as common as they were over the quality of pigs and blooms. Complaints abound in the Old Park letter books although this does not appear to have been unusual – the business correspondence of the Dowlais Iron Company contains a similar litany of complaints.[93] Poor quality could result from something as simple as the iron wrongly stamped, but usually required more protracted investigation.[94] The most likely causes of poor quality bar iron were poor materials or workmanship. Answering a complaint in 1803 about the variable quality of bars, it was stated that 'the materials of manufacture are exactly the same – the fault must thereof be in the workman, which we have this day given our clerk particular direction to attend to', while a similar conclusion was reached regarding the quality of cable iron sent to Daniels & Company in Bristol in 1827.[95]

After Old Park negotiated to send large consignments to Messrs Acraman of Bristol in 1826, a barrage of complaints about quality was forthcoming. A particular problem was sending iron intended for drawing into cable, and one that could only be resolved by travelling to and from Bristol and Shropshire:

> We are much concerned to observe … such heavy complaints against the quality of our iron and have in consequence … examined it this day and are at a loss to discover the defect – it appears to us very good best iron. We have therefore, to prevent further complaints, thought it most advisable to send our clerk who attends to the making of it, to see the defects you complain of, so as to remedy them and learn exactly the description of iron that you most approve. From your description we have reason to think that best iron which others use for cable will not suit your purpose, we therefore strongly recommend you to have the remainder of your order of best best iron.[96]

A sample of the iron sent to Bristol initially seems to have vindicated the customer: the iron was 'as hard as iron can be' and 'not fit for any purpose, much more cables; we could not have supposed our common iron would have broke so hard'. The suggested solution was 'allowing your foreman to see our mode of working and to give directions to our manager'.[97] However, the rollerman found no difficulty in defending the quality of the iron: 'Upon seeing the link you returned our Roller declared that piece of iron was never rolled at these Works', because

> we have no groove that would roll this iron, and also that no piece of iron from our rolls can have the same rough appearance that this now bears. Our Manager and Roller are both perfectly satisfied that this piece of iron was never roll'd at this works … to strengthen this we never had an order for you for this size $1^{3}/_{16}$

> except the one we have now in hand and are making upon a different process. We trust this mistake will now be found out so as to relieve us from an imputation that does not belong to us.[98]

This difficult episode in the relation between forge and merchant illustrates the same willingness on the part of the forge to solve problems that was evident elsewhere. It also shows the difficulty of ascribing iron to a particular source once it has undergone another process and the degree of mutual good faith needed for the trade to operate successfully.

5.5 Transportation

Transport was a major concern of Shropshire ironmasters and until the building of railways in the mid nineteenth century they were dependant upon on the canal and river. The importance of the River Severn as a trading route has already been outlined in chapter 2. The canal network developed during the last decade of the eighteenth century. The Shropshire Canal was begun in 1788 and its major shareholders were the most prominent ironmasters of the time – Richard Reynolds, Joseph Rathbone, John Wilkinson, the Lilleshall partners and the Marquis of Stafford – and became fully operational in 1793 (figure 7). Its 8-mile (13 km) route across the coalfield incorporated junctions with the shorter and earlier Donnington Wood Canal and Ketley Canal. The south end of the canal was Coalport, where a canal-river interchange was built. At the north end it linked with the Shrewsbury Canal, completed in 1797. The latter was later linked to the national canal network by an extension of the Birmingham and Liverpool Junction Canal, completed in 1835, from which time most of the Shropshire ironworks dispatched wares from Wappenshall Wharf. But the river Severn remained the principal transport route in the first half of the nineteenth century, with important transhipment points at Coalport, and Stourport in Worcestershire. The latter developed in the early the 1770s as the junction of the River Severn and the Staffordshire and Worcestershire Canal. It became the principal link for goods sent from Shropshire to Birmingham and the Black Country, superseding Bewdley, and was the initial destination of the majority of Shropshire iron.[99]

Old Park and other companies operated their own tub boats on the Shropshire Canal, but were forced by custom to use established carriers on the River Severn. Canal tolls were incorporated in the price of iron, which varied according to its place of delivery. All contracts to supply iron specified a place of delivery, the most important of which were wharves at Coalport, Stourport, Gloucester or Bristol. Contract was never made to deliver to the ultimate destination. The Severn carriers therefore had an important role as arbiters of goods sent and were at a pivotal position between supplier and customer. By the time Old Park was built it had become a 'long-established rule' that all iron was weighed at its delivery point along the river, and that weights were transmitted back to the source of the iron and the invoice drawn up on that basis.[100] The weights transmitted from the wharves did not always correspond with those from the works, where all iron was weighed before dispatch: 'We invariably weigh the iron at our Works and make out an advice from that weight, it having to pass along a Canal for several miles to Coalport, and [is] frequently pilfered before it arrives there – of which we are at the loss.'[101] In 1818 a Wellington attorney, Mr Nock, was asked to represent the Botfields at the trial of a Mr Browne of Watling Street, who was charged with having stolen Old Park iron in his possession.[102]

Iron was forwarded daily to Coalport, there being no stockpiles kept at Old Park, although iron was occasionally stockpiled at Coalport and Stourport.[103] The need to transfer cargoes between vessels at Coalport, and again at Stourport, was the cause of some of the losses. All contracts incorporated a certain discount to cover breakage in transit.[104] Once the iron had been weighed on delivery the carriers were liable for any losses incurred in the delivery to the customer. Old Park hired an agent at Coalport, George Pugh, to weigh the iron and see that it was properly sent on the correct vessels. Pugh left the employ of the company in 1820 at the age of eighty.[105] One of his successors, George James, incurred the wrath of William Botfield when he was discovered to have used the company's canal boats for the private dealing of beans and hay.[106]

Numerous carriers were employed by the ironmasters but, given that the ironworks were a considerable distance from the river, they usually only met the carriers at quarter-day meetings.[107] Regular carriers in the 1820s included William and George Devey of Bewdley, Danks & Company, J.G. Amies, Matthew Heath, Belsham & Company and York & Worthington, all of Stourport, and Thomas Nevett of Bridgnorth. These carriers delivered freight far afield, including Liverpool, Manchester, Gainsborough, Hull, Birmingham and Bristol.[108] Competition between these carriers offered limited leverage to the ironmasters. Judging by the complaints made against carriers the service they offered was similar. Carriers were employed on at least quarterly contracts but in 1827 Thomas Nevett was sacked and in his place 'we have engaged Devey who is the only respectable carrier direct from Coalport'.[109]

Weather caused delays on both canal and river, the commonest form being the low level of the river in dry summers. In winter ice and floods could be severe enough to halt all traffic, while 'contrary winds' also caused delays.[110] Special hazards associated with the canal were caused by the fact that steam-powered inclined planes were employed to traverse steep terrain instead of locks. This occasionally resulted in delays, as in 1826 when a boiler burst at the Hay Inclined Plane near Coalport, effectively closing the canal until it could be repaired.[111]

It has been argued that the effectiveness of the river as a means of transportation diminished from the late eighteenth century, in inverse proportion to demands placed upon it by the ironmasters. For example, proposals put forward in 1786 to improve the navigation were not carried out.[112] Failure to secure an effective mode of transport may have impeded the development of the Shropshire iron trade, but other ironworking districts relied upon similar modes of transport and the effectiveness of, say, the Monmouthshire and Glamorgan Canals should not be taken for granted. The river remained a relatively cheap form of transport and it was noted in 1827 that 'we have always delivered to the Severn and will continue to as long as demand is there'.[113] During the second half of the 1820s complaints against the carriers increased, possibly as a result of increased traffic. A similar problem of delay and congestion affected the South Wales ironmasters.[114]

Reliability of the carriers appears to have been as important as the reliability of the river. Following a lead taken by the Botfields with their own canal vessels, carriers were persuaded from 1827 to cover their boats to keep the iron dry.[115] In the 1820s complaints were made about dirty or rusty iron and indicate a raising of standards in the transport of iron during that period.[116] These complaints arose from the need to unload vessels, usually at Stourport, and the degree of care taken with the cargo. A letter to York & Worthington suggested the solution:

> We have frequent complaints of the rusty state in which our iron is delivered & have had our boats covered to Coalport and a shed erected there … but as we understand it is there unloaded upon the wharf and exposed to all weather till loaded into your boats it is of little use for us to take such precaution except you will also do the same at Stourport – by erecting a shed to unload the iron into … to keep it dry till put into your *covered boats* – we mean all the best iron and all small sizes of common iron – the best wharfingers at Gloucester have agreed to erect sheds for what we may consign to their care there, and we trust you will do the same as soon as possible – if not we must consign the iron to those who do.[117]

The most common shortcoming of the carriers was in the delivery of the wrong iron, or failure to deliver at all. Deliveries that fell short of the amount specified on the invoice were the fault of the carriers, who were liable to reimburse the customer.[118] Inattention during transhipment could cause iron to become mixed, complaints against which suggest that even in the 1820s not all iron bars were effectively marked. In some cases the wrong type of iron was sent, although this was partly rectified by adopting a letter code for pig and a number code for bar, whereby iron was marked according to principal customers.[119] Poor attention to detail reflected badly on the forge supplying the bar iron, and was one of the principal complaints made to Old

Park by Acraman of Bristol in 1827. This led to the termination of the contract with Thomas Nevett. An exasperated letter from Old Park explained the problem:

> We have letter after letter from Messrs Acraman and Messrs Protheroe & Hunt of Bristol complaining of the shameful manner in which their iron was delivered last quarter by you. Messrs Acraman say they never shall be able to separate the lots and quality that are all mixed together, therefore we must beg you will go and take your own men down to Bristol and sort out the iron, as we shall of course charge you with any loss and all expenses attending the same.[120]

Once iron had been delivered to Stourport the supplier had no direct control over the shipment to its final destination. The anecdotal evidence provided by the letter books does suggest that this was an increasing problem when the destination diverted from the principal markets of the Black Country, Bristol, London and Liverpool. This might have hampered the ability of the Shropshire iron makers in their attempts to exploit markets in the north of England and Scotland, although they did regularly trade with those districts and the letter books suggest that the trade with these areas increased in the 1820s. For example, 'William Farmer of Gainsborough writes he can gain no intelligence of his iron, though in great want of it; please therefore do your utmost to expedite its transportation to him', while Thwaites, Cochrane Hick & Company complained about slow delivery from Stourport to Bolton.[121] In 1819 James Robertson & Company of Glasgow received none of the iron delivered from Old Park to Bristol. Eventually the dispute was settled by an independent arbitrator, who found in favour of the Botfields, they having fulfilled their contract by delivering the iron to Bristol. As noted in a similar case above, the supplier was blamed even though the iron was clearly lost in transit between Bristol and the Clyde, over which the Botfields had no control and no responsibility.[122]

5.6 Conclusion

By the 1830s the iron trade conducted its business in much the same way as it had done half a century earlier, despite a period of significant change and expansion at the beginning of the nineteenth century. This period had also seen the focus of the industry shift from rural to coalfield forges. Ironmasters such as Thomas Botfield who entered the forge trade at the end of the eighteenth century could not act as they pleased. They had to fit in to a well-established culture in order to house and secure the services of suitable workmen, to sell iron of a tolerable quality and to effect its transportation.

The iron industry was a conservative culture that operated according to customs and unwritten rules regardless of their economic logic. Relations between ironmasters and their customers proceeded by negotiation. Some old-established rules, such the sale of bar iron in shortweight tons and the payment of workmen in longweight, highlight the industry's conservative disposition, and show that historical factors could militate against ruthless commercial efficiency. Old-established rules were not always of the iron industry's making. Traffic on the river Severn was governed by custom but ironmasters were able to exercise little direct control over its operations, and had limited opportunity to exploit competition between carriers.

Although historians have written the history of the iron industry in terms of technological trends, to the ironmaster technology was a tool in the management of a profitable business. The wrought-iron trade was driven less by technological developments than by the provision of specialist products in an environment influenced by custom as well as economics. Ironmasters had an ingrained short-term outlook. Their principal focus was upon gaining orders for their quarterly make of iron, and to secure an acceptable and realistic level of profit on their investments. Profit was not always achieved by maximising production. The interpretation of the iron industry in terms of output therefore gives only a limited understanding of the trade.

No ironworks served the entirety of the market. The widespread adoption of the rolling mill after 1800 brought a proliferation of sizes of bar, plate, sheet and rods. Ironmasters had to calculate which were the most suitable types of iron in which to invest, which was determined by the market. The market was such that decisions about investment in new technology concerned not simply the quantity but the quality of the product. Differences in the grade of iron had always affected the cost of production. These differential costs increased with the rolling of iron in different sizes and sections. In that sense all ironworks sold specialised products, the essential difference being that some were large-scale, others small-scale producers.

6 IRONMASTERS AND IRON WORKMEN

It has been argued above that the adoption of new technology in iron forges was evolutionary rather than revolutionary. Workplace cultures were obviously subjected to change when new processes were introduced, but they were also shaped by long-established customs. The purpose of this chapter is to analyse the interaction between ironmasters, introducing new methods of production, and workmen, proud of the skills that shaped their identities in the workplace, and concerned to protect their rights and privileges.

Most of the direct information concerning the iron industry workforce in Shropshire is found in wages books for the Horsehay forge in the last decade of the eighteenth century (Appendix 1) and the Botfields' Old Park and Stirchley forges in the period 1832-51 (Appendices 3-4). Inclusion of earlier material will allow the structure of personnel in the trade to be considered over a long period and specifically the period of greatest change in the late eighteenth and early nineteenth centuries. The principal elements of the finery forge sector are considered first.

6.1 Finery forges

Establishment of a forge required a high capital outlay that encouraged the formation of partnerships. The men who ran them were called ironmasters, an imprecise term. It has been shown that landowners pioneered the industrial exploitation of their property but subsequently withdrew from direct control by leasing works and mineral rights to professional ironmasters as early as the late sixteenth century.[1] Ironmasters generally took on the responsibility of finding markets and negotiating prices and credit agreements with iron merchants or direct customers. An ironmaster may also have supervised production where a partnership controlled only a single forge. Richard Knight must have started thus at Moreton Corbet in the late seventeenth century before he acquired too many geographically separated interests. As forges became concentrated into fewer hands it is self-evident that ironmasters would have been unable to supervise day-to-day operations, resulting in the delegation of managerial responsibilities.[2] This created a role for the clerk, sometimes described as the agent, who would be better described as the manager. The clerk organised the production, expedited its transportation, acted as cashier responsible for collecting payments, and hired and paid workmen. John Wheeler was chief clerk to the Ironworks in Partnership, and is the best known of such clerks, but he was an exception in taking so wide-ranging a role in the seventeenth century.[3] Usually the clerk was a paid employee, but his importance was such that he was sometimes offered the status of a full partner. In the seventeenth century Francis Walker and Richard Baldwin were both clerks at Cleobury Mortimer forges but subsequently rose to the status of ironmaster, at Bringewood Ironworks and Willey blast furnace respectively.[4]

Although reference has been made to the continuity of skills between bloomery and finery forge, there is strong proof that the introduction of the finery process in Britain was accompanied by the arrival of immigrant workmen. Between the 1490s and 1540s over 500 furnace and forge workers arrived in the Kent and Sussex Weald, mostly from the Pays de Bray in Normandy.[5] Their descendants continued to diffuse the new technology throughout Britain but the dynamic of blast furnace and finery development in Britain was essentially capitalist. It was landowners, and the ironmasters to whom they leased out ironworks and mineral reserves, who created the geography of the British iron trade.

The principal men at the forge were the finer and the hammerman. The finer was responsible for refining the iron in the finery hearth while the hammerman was responsible for drawing it into bars. Both terms had a historical context, as finer and hammerman were used in late sixteenth-century Lilleshall to describe the workmen at a bloomery, which is logical given that the skills required for both tasks were adaptations of bloomery skills.[6] Inventories of finery forges indicate that all of the tools and implements were the property of the forge and not the workmen. Inventories also indicate the common practice of providing houses for the clerk and workmen.[7] The number of men employed at a forge remained small, however. Between 1673 and 1688 the number of workmen at the Cleobury Mortimer forges varied between seven and ten.[8] In the late eighteenth century Thomas Botfield calculated that a finery forge would need six finers, three hammer men, a carpenter, smith and stock-taker, making twelve permanent employees.[9] In addition to this was the sporadic use of unskilled labour. Little is known of such workmen and women in the seventeenth and eighteenth centuries. Evidence from the nineteenth century suggests that they included young persons learning the trade and skilled men too old for the most strenuous jobs. Unskilled labour in a forge was principally engaged in carrying and charcoal burning.[10]

The commodity that forgemen traded was their skill. Their property was in the broadest sense intellectual property, in which context they can be seen as part of a larger category of artisans in eighteenth-century Britain. These included metal workers such as cutlers, as well as textile workers, printers and artisans in other manufacturing trades.[11] In other respects, however, ironworkers were different. The division of the finery forge into two processes of fining and hammering, requiring separate skills, ensured that there could not be a master craftsman responsible for the overall production. The refining of iron was therefore always a collaborative process. These circumstances set iron workmen apart from other metalworking trades, including those craftsmen engaged in manufacturing iron, whose investment amounted to more than just their skill. In the Midlands, makers of nails, locks, buckles, saddlers' iron and scythes were independent craftsmen leasing or renting their own workshops, plant for which was normally no more than a single hearth and bellows. Production was organised around the family unit, ensuring continuity of work from father to son, while industrial work was combined with arable farming and animal husbandry.[12] Cutlers in South Yorkshire were similarly independent, with smithies attached to cottages, as were sickle and scythe makers in the same district, who operated water-powered grinding wheels at their smithies. Having served an apprenticeship, a cutler could establish himself in the trade at little cost, given that smithies were humble buildings often erected as lean-tos at the rear of cottages.[13] Their rural situation allowed them to supplement their income with farming.

Acquired skills and knowledge in the finery forge were inherited by subsequent generations. Iron workmen controlled their trade and their family interests by passing on their skills to whom they chose, usually sons or other close family members. It bred a closed, male-dominated, inherently traditional and empirical culture. There were no formal apprenticeships. Instead, men were said to have been 'bred up' in the trade. Ironmasters and clerks remained dependent upon the skills of their workmen, and could exercise only limited leverage when there was no pool of alternative labour to draw upon. Examination of the Cleobury Mortimer forges show the domination by generations of the Maybury and France families, but other common workman families at Cleobury Mortimer included Hall, Leonards, Gittins, Phillips, Hart, Griffiths and Cranage.[14]

Workmen were able and willing to transfer skills across a wide geographical area. A branch of the Cranage family of Cleobury Mortimer moved to Coalbrookdale in the eighteenth century.[15] A case has also been cited of the Lavender family, of French origin, who settled in the Weald in the early sixteenth century. Subsequent generations colonised the Midland and Yorkshire iron trade. James Lavender, born at Wilden in Worcestershire in the early 1760s, had a career that took him to Bradley Ironworks in Staffordshire, then to numerous small forges in Monmouthshire and Glamorgan.[16] The family also moved into Shropshire. In 1793 Thomas Lavender was working at Upton Forge, and in 1807-8 Samuel, Joseph and James Lavender were all puddlers at Old Park.[17] The closed world of the forge meant that there was little spare capacity in the pool of available workmen. Mobility of skilled men and temporary absences were serious problems faced by ironmasters of small forges. Charles Lloyd of Dolobran Forge, Montgomeryshire, records many workmen taken on who subsequently gave notice, and records stoppages of work occasioned by illness of the finer or hammerman.[18]

6.2 Skill in the Transition to Puddling

Some ironmasters looked to new technology as an opportunity to displace traditional skill. John Bedford established an ironworks at Cefn Cribwr, Glamorgan, in the 1780s, having previously managed a forge at Trostre, Monmouthshire. By the late 1780s he was proposing to introduce a new technique of refining iron in a reverberatory furnace. Bedford thought he could bypass established forgemen and train a local unskilled labour force. The anticipation was that the use of mineral fuel would simplify the refining process, with a result that he would no longer be at the mercy of a skilled elite.[19] Richard Crawshay of the Cyfarthfa Ironworks, Merthyr Tydfil, had been attracted to Cort's puddling process for a similar reason. Hope evaporated with the arrival at Cyfarthfa of Cort's workmen, themselves bred up in the traditions of the iron trade.[20]

It has been shown that puddling emerged from the existing repertoire of forgemen's techniques. It was not an alien technology that could supersede old methods like a steam engine could replace a waterwheel. In Shropshire there was a long period of transition between the introduction of puddling and the demise of older techniques. Men brought up with puddling worked alongside older men who still valued the practice of stamping iron and reheating it in pots. A protracted period of change militated against a revolution in forgemen's culture.

There is no evidence that the status of skilled forgemen was seriously threatened by new techniques. All techniques of refining iron remained dependent upon the judgement of the workman. Visitors to Shropshire ironworks in the late eighteenth and early nineteenth centuries were able to witness the operation of new processes. Coalbrookdale and Ketley workmen appear to have discussed quite openly new techniques and the problems associated with them to Alexander Chrisholm in 1768 and Simon Goodrich in 1803.[21] But forgemen could be confident that the ability to describe a process in no way signified the capacity to perform it. Ironworking techniques could only be learned empirically. If the required level of skill in refining iron did not change over time, then we should not expect status and workplace expectations in the forge to have undergone any significant change.

6.3 The puddling era – organisation of work

Growth of integrated ironworks from the late eighteenth century saw many forges as part of larger mining and smelting concerns. Such growth demanded additional tiers of management for effective operation. The clerk remained in charge of the day-to-day running of an ironworks, and was the intermediary between ironmaster and workmen. John Gibbons (1777-1851), ironmaster of Level and Corbyns Hall Ironworks in Staffordshire, described the three main attributes required of such a man in order of importance: 'character, capacity, and technical knowledge'.[22] Clerks such as Gilbert Gilpin of Old Park were personnel manager, stock-taker and cashier, but the larger an ironworks became, the more necessity there was for separating responsibilities for furnaces and forge. By the 1830s the Old Park forge and mill had a superintendent, Thomas Hodgkiss.[23] When Stirchley Forge began work in 1832 it had a superintendent, Thomas Hyde, who was still working in the same role in 1850 at the age of seventy-one.[24]

Workforce structure at the end of the eighteenth and the first half of the nineteenth century is recorded in various wages books. A case study of three of these, for Horsehay in 1796-8, Old Park 1832-3, and Stirchley 1849-50, allow the workforce to be examined over a comparatively long period (Appendices 1, 3 and 4). In addition, information is available for the Old Park forge in the early nineteenth century from notes made by Gilbert Gilpin in 1807-8 (Appendix 2). Although it is incomplete, it is useful because it is the earliest record of the workforce at a Shropshire puddling forge.

Of the principal workmen employed at the establishment of Old Park forge in 1790, none are mentioned by Gilpin nearly two decades later, although a finer named Simms mentioned in Thomas Botfield's notebook may have been related to John Sims, a rollerman in 1808.[25] New puddlers must have been employed when the works was expanded in 1800. David Griffith is described as a 'Welsh puddler', and presumably therefore moved from South Wales. Others have names, or merely surnames, that suggest that they came from established ironworking families in Shropshire. For example, 'Skelton the puddler' might have been James Skelton, the Horsehay finer who was taught puddling in 1797 and who disappeared from the Horsehay wages accounts in 1798, or perhaps a close relation.[26] In 1793 a list of workmen at Upton Forge was published in the *Shrewsbury Chronicle* as part of a declaration of loyalty to the constitution.[27] In it John Swift junior, one of three members of the Swift family at Upton, may be the same J Swift who became one of the principal rollermen at Old Park after the departure of John Sims. The Lavender family, already described, suggests a similar link between Upton and Old Park.

There is no evidence that expertise was imported to Old Park from South Wales beyond the employment of Gilbert Gilpin. Although puddling is said to have been pioneered in South Wales, in fact events were centred on only two of the Merthyr ironworks. South Wales saw an expansion in puddling in the last decade of the eighteenth century that paralleled the take up of the new process in Shropshire. For example, Dowlais took men from Penydarren and Nantyglo ironworks when it established its puddling forge from 1800.[28] Anecdotal evidence, however, suggests that there continued to be a drift from Shropshire to South Wales in the early nineteenth century among iron workmen in general. In 1807 Gilbert Gilpin did not know of any Shropshire furnace keepers out of work, 'those who were discharged from the reduced establishments in this vicinity having obtained berths in South Wales'.[29]

It is worth comparing the workforce of the Horsehay stamping and potting forge in 1796 with Old Park in 1832 (Appendices 1 and 3).[30] The most obvious difference is the greater scale of operation at Old Park. Where Horsehay had only two finers in its stamping and potting forge, Old Park had two men at the refineries, between eleven and thirteen puddlers and four charcoal finers in 1832-3. Old Park mill had five rollermen working on specific products, compared to the three men at Horsehay.

Although the size of the workforce increased appreciably between 1796 and 1832, the organisation of work saw no radical change. At both works the finers, puddlers, refiners, shinglers and rollermen employed their own assistants whose names do not appear directly in the wages books. The only difference is that Old Park had a master puddler, whose output of bar and plate was as much as seven times as high as the other puddlers, and who clearly therefore sub-contracted other puddlers and unskilled assistants to work with him. For example, in April 1832 the four-weekly production of the Old Park puddlers varied between 18 and 23 tons each, but William Boden was paid for producing over 78 tons of puddled iron and over 76 tons of plates.[31] At both Horsehay and Old Park the other major processes – the shingling, puddlers' rolls, heating and rolling of bars, and heating and rolling of plates – were subcontracted to one or two master workmen who employed their own teams. In this way ironmasters continued to recognise the authority of a core group of men in the organisation of production.

Wages books largely conceal the existence of lesser skilled workers, whose existence was usually acknowledged only when they were paid for sundry work at a day rate. This means that the accounts give a workforce structure biased in favour of skilled men. Other workers included labourers too old for strenuous jobs such as puddling and rolling, boys labouring or learning the trade, and women. With the exception of office work, no women are mentioned in the wages accounts for Old Park or Stirchley. They do appear, however, in the Horsehay wages accounts where they corroborate evidence of visitors. The La Rochefoucauld brothers had noted in 1785 that women worked in teams at Coalbrookdale stamping and potting forge filling the pots with granulated iron.[32] This was also the case at Horsehay in 1796, when it was organised on an informal sub-contracted basis, and it continued to be women's work until granulating of iron ceased at Horsehay c1830.[33] The absence of women in the Stirchley and Old Park wages accounts is corroborated by the census returns for 1841 and 1851, which indicate that women no longer worked in forges. They did, however, work in sub-contracted gangs picking ironstone from the pit banks.[34] Boys were employed for a variety of light jobs into the mid nineteenth century. In 1842 Robert Bailey, superintendent of the Horsehay mills and forges, said that boys were employed from the age of eight upwards, according to the strength required to carry out the tasks. In the rolling mills young boys straightened iron bars with wood hammers, older boys were employed in piling up bars for the heating furnaces and as catchers who returned the iron to the rollerman so that he could make another pass. The forges and mills offered 'such a variety of work that a person may be employed from an early period of life to old age'.[35]

Both Horsehay and Old Park had strong family groups. Continuity from one generation to the next was aided by the employment of young and old in the forges. The workforce at Horsehay had dominant families such as the Hazlehurst, Lambert, Norton and Tranter families, where younger members of the family are documented as such. Old Park also had its conspicuous families – Ellis, Morall, Tipton – and continuity with the early nineteenth century in the Tart, Swift and Lees families.[36]

Comparison of workforce structure can be taken further forward to the much larger Stirchley forge in 1849 (Appendix 4). There is no significant difference in its organisational structure and, with strong family groups such as Holmes and Davies, it has obvious similarities to Horsehay in 1796. Some of the families, such as Tart and Swift, had a long pedigree in the trade. Inevitably, however, given the expansion of the iron industry in the early nineteenth century, many new surnames appear in the list. Most came from either the East Shropshire Coalfield, rural Shropshire or the Black Country. Only one came from another ironworking district: John Wittingham, born c1824 at Llanwenarth, was perhaps the son of a workman at nearby Garnddyrys forge, but it is not a Welsh name. The age structure shows puddlers principally in their twenties and thirties, and as young as eighteen, in other words in the prime of life. But there was a wide variation at the upper end of the age scale, with six puddlers over fifty. Of these men, Edward Parker and Simeon Holmes had been at Stirchley from 1832, while Joseph Southern, Richard Moral (or Morhall) and Richard Pitchford had at the same time been puddlers at Old Park.[37] By contrast, none of the principal Stirchley rollermen were born in Shropshire and none of them are listed in the Stirchley wages book for 1834-6.[38] All had migrated at some time from South Staffordshire or Warwickshire. Three of them were experienced men in their forties; the fourth, John Millington, was perhaps the son of William Millington, a rollerman at Old Park in 1834.[39]

Puddlers were numerically dominant among skilled men in the forge but, in spite of their status and numbers, they were not treated with special deference by their employers. Gilbert Gilpin made a note of needing a night watch ‘when the mill is standing, to prevent the puddlers from stealing the blooms’.[40] Puddlers were employed in numbers, so their individual impact on the ability of the forge to meet its orders was lessened, whereas their collective impact was strengthened. This was not the case with the master workmen in the rolling mill. Printed lists giving various shapes of iron depended not only upon having rolls with the necessary grooves, but having the workmen with sufficient skills to roll the iron to a high standard. Reference was made in the previous chapter to the inability to meet some orders due to 'the illness of our plate roller'.[41] Hoop rolling was introduced at Old Park in 1807. Classed separately from the usual sizes of merchant iron, hoop iron was trapezial rather than rectangular in section, and was used for strengthening casks and barrels, ships' masts and coach work. There was a steady market for hoop iron, which was a standard product of the nineteenth-century iron trade. At Old Park, the initial problem with hoops concerned the workman rather than the machinery: 'The manufacture of hoops being a new business here, and not finding our present roller a complete hand in that line, we are under the necessity of deferring that trade until we meet with a better workman.'[42] The workman concerned was John Sims, who had been one of the principal rollermen at Old Park, but who tendered his notice less than a month later. Despite appointing a successor, customers were turned away because 'having lost our hoop roller we cannot make any at present'.[43] It seems, therefore, that men with skill in rolling specialised products could not always be easily replaced. The mill could only roll sizes for which it had rollers, and for types of iron for which it had the skilled labour. An order received in 1817 for ploughshare moulds was turned down on the basis that they were not normally made at Old Park and a small order would not justify a workman learning it.[44]

6.4 The puddling era – workplace culture

Relations between masters and workmen continued to be regulated by well-established customs. By the mid nineteenth century workmen still traded skill as their property and passed their skills to the next generation without formal apprenticeships. Inventories show that puddlers' tools belonged to the furnace and not the workmen.[45] Skilled work was still paid for by the ton, and an allowance of beer was given to the men to distribute among their assistants. W.G. Norris, manager at Horsehay in the

1870s, singled out allowances of beer as one of the customs he most disapproved of, the workmen being 'pretty liberally supplied with beer on all special occasions (which were not a few)'. The company had its own brewery at Pool Hill House north of Horsehay.[46] At the Level Ironworks, Staffordshire, in the 1840s, forgemen were allowed 6 quarts of ale per week, mill men 7½ quarts.[47] At Old Park in 1832 most skilled workmen were provided with accommodation of a standard suitable to their status, as demonstrated by the fact that rent was deducted from their wages, but the custom dated from the establishment of the works in 1790.[48] Botfield's memorandum book of 1790, already cited in detail, records such information as housing and payment in coal.[49] When John Sims handed in his two-months' notice in 1808 he was given equal notice to quit his house or pay 2/- per week rent.[50] Sims probably lived at Forge Row, a row of fifty houses built piecemeal from the 1790s for workmen at Old Park. The houses varied in their standard of accommodation, reflecting the hierarchy among workmen. The largest had four bedrooms, making them among the best of workmen's houses of the period. Company houses were a characteristic of coalfield industrialisation, especially marked where the iron industry developed, and have been studied elsewhere.[51] Provision of dwellings was also a feature of non-coalfield forges in the eighteenth century, when suitable accommodation had been one of the expectations of skilled men. Upton, Moreton Corbet and Eardington forges all had associated workmen's cottages that are well documented.

The Old Park Ironworks also retained the services of a medical practitioner to attend to injured workmen. Evidence of their activity suggests the arrangement was far from satisfactory and that the surgeons did not always attend diligently to their duties. Complaints were made in 1819 that an Old Park workman had been burned on Saturday evening but despite pleas for him to receive urgent treatment the surgeon, Mr Gwyn of Broseley, did not attend him until the Monday.[52] William Edwards, resident at Coalbrookdale, was dismissed from Old Park in 1825 for his negligence: 'From the numerous complaints from our workmen as to your inattention to them when burnt & co, we beg to state that in consequence, we are under the necessity of discontinuing you after Midsummer as we cannot allow them to be neglected.'[53]

It has been argued that the unwritten rules governing relations between ironmasters and workmen generated tension between them.[54] Where workmen had considerable authority in the technology of iron production, it was ironmasters who controlled the economy of the industry. Ironmasters had an interest in lowering production costs by means of wage control and improved performance, and by the same token workmen had an interest in resisting any erosion of their status. Only with difficulty, therefore, did ironmasters succeed in breaking traditional working practices. John Gibbons conceded that coercion of iron workmen was futile and that new methods should always be introduced in a conciliatory manner.[55]

The most drastic form of resistance was the withdrawal of labour, wages being the usual trigger. Old Park forge and mill were standing idle in June 1820 because of a dispute over wages, threatening the ability of the company to meet its orders for that quarter.[56] Other, more subtle strategies could also affect output. In 1828 the Botfields had to concede to the Bristol merchants Protheroe & Hunt that 'in consequence of a notice of reduction in wages our men are at present extremely unsettled and awkward'.[57] Unfair conditions also prompted industrial action. A month-long strike at Horsehay in 1837 arose over the grievances of the assistants at the puddling furnaces. They complained that their workload was excessive. They were required to wheel in the fettling for lining the beds of the furnaces, wheel away the ashes, raise the furnace doors and assist at the mills. The company eventually agreed to bring in the fettling at its own expense.[58]

Investment in forges in the 1830s ran parallel with efforts to modernise working practices. Until the 1830s Horsehay puddlers had been paid by the ton and were expected to work to a given yield, although they were not penalised if they did not reach it.[59] The practice of awarding a bounty if the yield rose above a set monthly level may also have been in use at Horsehay. It was certainly practised at Old Park, although in 1832-3 only once was the bounty paid out: in December 1833 William Attwood & Company made over 20½ tons of puddled iron from best pig and thereby earned a 'puddlers yield' of 2 guineas. Puddlers were not penalised if for any reason the puddled iron was of poor quality. The shingler at Old Park, John Edge, was paid a fixed rate of 8/- a week for returning bad puddled iron.[60] It removed any incentive to send bad iron to the rolling mill.

Horsehay Ironworks was said to have been given a new lease of life when two young ironmasters, Alfred Darby I (1807-52) and Abraham Darby IV (1804-78), became active participants in the management of the works from 1830. Improvements at the forge were documented in 1876 by its then manager, W.G. Norris. Writing in the wake of newly formed trades unions, Norris may have allowed current preoccupations to sour his estimation of an earlier generation of men. Their resistance to change was characterised as 'prejudice and ignorance'. New rules bound puddlers to a minimum yield, a regular number of heats per shift and a good quality of iron when tested. At its root, these efforts were intended to improve time discipline in the workplace when in many other industries the pace of work was regulated by machines. Targets and fines were two methods of regularising the working day.[61] Similar new rules had been introduced at Old Park. In 1833 two puddlers, Richard Pitchford and James Swift, were fined for being absent and for not starting their furnace on time.[62] In 1836 two puddlers, A. Davies and Richard Pitchford, were fined at the rate of 1/- per heat for the ill-discipline of leaving their work to their assistants.[63]

There were two inherent problems with the imposition of a minimum yield. First, it subtly diminished the puddlers' sense of technical authority. Second, the line separating good from inferior quality was negotiable. Puddlers found themselves in a difficult situation. Working iron to the highest quality required time, but if they worked it too long and were unlikely to make their yield, they were tempted to work it for a shorter time at the risk of a loss of quality. The strategy adopted by the puddlers was to supplement the charge by acquiring any brand of iron they could lay hands on to improve the quality of the charge: 'It was immaterial to the puddler what it was, cast or best iron, tools or anything else, so that he could safely get it into his furnace without being detected'. The new rules therefore proved counter productive because quality declined, damaging the reputation of the works.[64] A chain of blame formed itself from merchant to mill, mill to forge, forge to furnaces, and furnaces to field, all complaining of having to work with inferior material. However misguided or unenforceable the new rules may have been, Norris offered no evidence that the Coalbrookdale Company ever effectively settled the problem.[65]

6.5 Conclusion

Although this chapter has been based upon a narrow range of sources, there is justification for thinking that it offers a valid picture of the industry as a whole. Technological change was not accompanied by a revolution in working practices. The workplace remained a relatively stable environment over a period of change and considerable expansion from the end of the eighteenth to the mid nineteenth century. Although the number of workmen and assistants multiplied – Stirchley had twenty-nine puddling furnaces in 1852, whereas in the previous century most forges had two fineries and a chafery – the established hierarchies and customs remained intact.[66] The fact that technological change was incremental rather than abrupt meant that it could easily be accommodated by existing workplace culture. A more revolutionary technological change might have met with greater resistance. It can be argued, therefore, that the transition to puddling was eased by the existence of a well-established forge culture.

The iron industry was one of a variety of work structures in industrial Britain, based upon social and cultural precedent.[67] It represents a specific case, not a general model. The iron industry did not experience the greater transformations seen in the textile industries over the same period, with its attendant social, cultural and economic consequences, such as the move to the sweating system of the London silk weavers or the factory system of cotton, worsted and linen production.[68] The iron industry can also be contrasted with smaller trades such as the Birmingham metalware manufacturers, where old-established custom was consistently challenged by the logic of the market and fresh innovations.[69] This and the previous chapter have shown how new technology and economic expansion were accommodated successfully within a set of rules and customs established well before the end of the eighteenth century.

7 THE IRON INDUSTRY IN PEACE, c1815-50

This chapter considers in more detail developments in the iron industry in the first half of the nineteenth century, some of which have been referred to in passing in chapters 5 and 6. It has been argued above that the market dictated the types and grades of iron produced by the forges in Shropshire. In the light of that discussion, special attention will be focused on the production of charcoal iron in the second quarter of the nineteenth century.

7.1 Recession and recovery in the coalfield

In 1815, during the slump in the iron trade that coincided with the beginning of war with America in 1812, and exacerbated by the end of the Napoleonic war, there were three principal makers of wrought iron in Shropshire that were integrated with blast furnaces – Horsehay, Ketley and Old Park. Five smaller forges worked with a variety of charcoal and coal techniques – Eardington, Hampton Loade, Upton, Cleobury Dale and Cleobury Mortimer. Neither was integrated directly with smelting and were therefore typical independent Midland forges. But the major casualty of the depression was one of the larger works, Ketley, which was closed and then sold in 1818 by Joseph Reynolds, brother of the late William Reynolds.

Strategy for withstanding the depression at Old Park can be understood from surviving correspondence. Ironmasters did not stockpile iron and so when the manufacture of wrought iron was unprofitable the ironmasters were predisposed to reduce their output. For example, in the second quarter of 1817 numerous orders for bar iron were turned away by Old Park.[1] This in turn caused unrest among workmen, which delayed orders already in hand: ‘We are sorry to say serious disappointments at our works owing to workmen and other causes have so long delayed yours and most of our other orders’.[2] In 1818 Old Park suspended the manufacture of rods, a significant if not crucial branch of its trade.[3] The harsh conditions in the wrought iron sector were partially cushioned by adjusting the relative output of foundry and forge pig iron, which at least allowed the blast furnaces to continue working as normally as possible. Output of forge pig fell from 5501 tons in 1815 to 3987 tons of forge pig in 1817, when 1615 tons of foundry pig iron were smelted, accounting for nearly 29% of blast furnace output.[4]

The circumstances that led to the closure of the Ketley ironworks in 1817-8 are known only from indirect sources. However, as late as the 1870s John Randall could still taste the bitterness that it had engendered.

> Iron from £18 per ton had gone down to £7 … Mr Reynolds believed the trade would never again rally, and resolved to blow out the furnaces at Ketley. This was in 1817. In 1818, at an immense sacrifice of property, consisting of the usual apparatus for making and manufacturing iron, he sold off at an immense loss, and removed to Bristol. Language cannot paint the deep distress which accompanied and followed this.[5]

The distressing events surrounding the closure of Ketley may have given a false impression of the long-term future of the trade as viewed from that period. Joseph Reynolds was acting in his own interests and it should not be taken for granted that other ironmasters thought his judgement sound. Ketley was purchased in 1818 by a new company whose partners included Henry Williams, engineer to the Shropshire Canal Company and designer of its inclined planes, William Hombersley, former underground bailiff of the Ketley mines, and Richard Mountford of the Wrockwardine Wood Glassworks.[6] Output of pig iron from three blast furnaces had reached almost 5000 tons by 1823, although this was well below the output of over 7500 tons in 1805.[7] The company also built a new furnace at Lawley in 1822.[8] The Ketley forge and rolling mill was not redeveloped immediately, however, as an order for bar iron sent to the Ketley Company in 1821 had to be re-directed to Old Park.[9] Pig iron was the staple output of the new Ketley Company, since Ketley and the Lilleshall Company were described in 1824 as the principal Shropshire suppliers of pig.[10]

The mid 1820s saw an upturn in the British iron industry and renewed confidence stimulated investment in a number of other new concerns (figure 8). In Shropshire investment was initially focused on smelting, of which the Ketley Company was a typical case. The Lilleshall Company was the dominant industrial concern in the northern part of the coalfield by 1815, when it had six blast furnaces. Its interests were expanded by the building of the Lodge blast furnaces in 1825, a mile east of Donnington Wood.[11] The Botfields built four new furnaces at Stirchley, a mile south of Old Park, in the 1820s, three of which were in blast in 1825.[12] The first of the Stirchley furnaces began smelting iron in 1824 and a year later running-out fires, blown from the main blast engine, produced refined iron for the Old Park forge.[13] Stirchley furnaces were followed by two more furnaces at Dark Lane in the 1830s, situated half a mile south east of Old Park. Two new blast furnaces were built at Langley Field, immediately west of Stirchley Ironworks, by John Bishton and Adam Wright, the first of which was in blast by 1825. Of other established smelting concerns, the Madeley Wood Company built a new blast furnace at Blists Hill, close to the Shropshire Canal, in 1832, while James Foster of Stourbridge, in partnership with Thomas Jukes Collier of Wellington, built a pair of blast furnaces at Wombridge, a mile north east of Ketley, in the period 1818-20, and added a third in 1824.[14]

Where it occurred, investment in the forge trade came after investment in smelting. The Botfields considerably expanded their wrought iron output by building a new forge at Stirchley in 1828-9, close to the Shropshire Canal (figure 8). Investment is also likely to have been made in improving the Old Park forge although direct evidence is more difficult to identify, except in the case of the charcoal fineries which are discussed below. In 1826 reference was regularly made in business correspondence to recently ‘having lately erected machinery‘, while in 1827 it was stated that ‘we are now preparing to commence the erection of a new mill’, which might refer to Old Park rather than Stirchley.[15] Output from the new Stirchley forge was confined to a mere 36 tons of blooms sent to Old Park in 1828-9. The first sales of hoops, sheets, bar and boiler plate from Stirchley occurred in 1830, with an output of 3644 tons in its first full year. The forge and mill had twelve puddling furnaces and four heating furnaces. Its mill was equipped for rolling sheets, plates, merchant bar and hoops, and was therefore intended to serve a market in which the company had already established itself. The plant was gradually increased, the forge having sixteen puddling furnaces by 1839, and a new boiler-plate mill in 1842.[16]

Developments at Horsehay were documented in 1876 by W.G. Norris. The account begins by describing the works in 1827 when Joseph Dickinson became manager. At that time it had three refineries blown from the main blast engine, with an output of about 650 tons per month. Its upper forge had eleven puddling furnaces and a balling furnace, its lower forge had four puddling furnaces and another reverberatory furnace in which scrap iron was heated in clay pots.[17] The forge was disadvantaged by an outdated engine and the need to utilise two separate sites on different levels, a throwback to the time when water power dictated that gravity be exploited to use water at different levels. The forge was ripe for renewal by the end of the 1820s, especially in view of the more modern layout of the new Stirchley forge. Even Eardington had discontinued its upper forge after 1820.[18]

Considerable improvement was made at Horsehay under the direction of Alfred Darby from 1831. The upper and lower forges were replaced by a single large forge. Initially some six or eight new puddling furnaces were added at the upper forge and a new engine, built by James Evans of Coalbrookdale, replaced the old atmospheric engine. The new engine worked the shingling hammer and roughing rolls that could roll billets or bars up to 5¼ inches wide. The lower forge was subsequently demolished and the ground level raised, allowing further expansion of the existing forge on a large flat site. By 1832 there were said to have been seventeen puddling furnaces and two balling furnaces, rising to twenty-six puddling furnaces by 1835, making it larger than either the Old Park or Stirchley forges. With the increase in output of the puddling furnaces the single shingling hammer was inadequate. It was therefore supplemented by a pair of mechanical squeezers which, having been found to be inefficient, was eventually replaced by another hammer in the drawing-out forge.[19]

A separate drawing-out forge and charcoal fineries represent small-scale specialist production at the works. Charcoal is discussed in detail below. The drawing-out forge, serving a market for hammered rather than rolled iron, was built in 1833-4 and its two hammers were powered by a second-hand atmospheric engine. Two hammer men, Thomas and William Lewis, were brought from the Lower Forge at Coalbrookdale to undertake orders, but work was discontinued at the end of 1835 and the larger hammer was put to shingling puddled balls.[20] There is no further evidence of hammered iron being produced at any of the Shropshire forges, and it was also at this period that heating stamped iron in clay pots appears to have been discontinued.

No wholesale changes were made to the rolling mill at Horsehay, although alteration had been made to the mill trains over time. Like Old Park and Stirchley, the policy was to continue rolling sections for which the company already had an established market. The most significant changes were made in 1833 by Thomas and John Stevenson, two wire drawers from Staffordshire (the wire mill is discussed below). The Stevensons introduced guides, in the form of bars or channels, to the mills.[21] Rolling by hand had required the catcher to take hold of the front end of the bar as it was passed through the rollers, who therefore had to run back to pass the bar back over the top of the rollers (known as a dead pass). The rollerman also had to take the front end of the bar as it was passed over, only to run back and guide the opposite end through a narrower groove to make the next pass. By adopting guides, the rear end of the bar could be taken by the rollerman and catcher, saving a considerable amount of leg work over a single shift.[22] No mention is made in Norris' account of three-high mills at Horsehay, but they were in use at Stirchley from 1831 and allowed iron to be passed through the mill in either direction. [23]

The other development in technique was pig boiling, sometimes referred to as 'wet puddling'. This had been developed by Joseph Hall (1789-1862) of Tipton, Staffordshire, c1816. Instead of sand, iron-rich slag was used to line, or 'fettle', the puddling furnace, and being rich in iron oxide it caused a violent reaction with the iron charged into the furnace, with a result that the contents of the furnace appeared to boil. Hall founded the Bloomfield Ironworks at Tipton, Staffordshire, and from this works two men, Mathers and Danks, travelled to Shropshire in 1832 to instruct the Horsehay men in the new process.[24] Initial difficulties with the process were eventually overcome, but when it became established it was no longer necessary to refine the iron before it was charged in the puddling furnace. Previously all but the highest grade of pig was refined.

The wages accounts of Old Park and Stirchley forges provide the best documentation of how protracted the introduction of a new technique could be in an established forge. Workmen were paid different rates for puddling pig iron or refined iron, or a mixture of the two (sometimes known as ‘pig and plate’ and the most common way of puddling iron). Old Park began pig boiling in April 1833, when six of its thirteen puddlers were credited with using the new technique. A month later its principal refiner of pig iron for the puddling furnace, James Browne, had left the works, and only one refiner was thereafter retained, but only until 1835 and largely because refined iron was still required for charcoal fineries. Subsequently refined iron probably came solely from Stirchley.[25] The evidence of Stirchley forge is more ambiguous. From July 1833 the puddling furnaces were charged only with pig iron, implying the new process, but at the end of 1834 and beginning of 1835 is a five-month period when most of the charges were mixed pig and refined. ‘Boiled iron’ is not mentioned specifically until 1836.[26] This suggests a lengthy period of perfecting the new process, in which case it parallels the earlier experience at Joseph Hall’s forge at Bloomfield. Here, after initial success, the iron-rich cinder was found to erode the cast iron bottom of the furnace, a problem not solved until the furnace was lined with roasted cinder, known as bull-dog. A patent for roasting the cinder was awarded in 1828.[27]

Two other forges were established in the East Shropshire coalfield in the 1830s – at Ketley and Snedshill – neither of which is well documented. A forge and refinery at Ketley is mentioned in the 1840 Tithe survey.[28] The Lilleshall Company’s blast furnaces at Snedshill were blown out and demolished soon after 1830. Snedshill forge was built on the same site, but the exact date of founding is not known, the earliest known lease of the site being dated 1837 (figure 8).[29] Its original partners were W. Horton, W. Blount and J. Hombersley but traded under the name Horton, Simms & Bull and was nominally independent of the Lilleshall Company.[30] William Simms is said to have entered the trade as an employee of James Foster at Stourbridge.[31] By

1827 he was the manager of the Old Park forge.[32] His overall role in the development of charcoal forges at Old Park and the company's forge at Stirchley is not entirely clear. Nevertheless he must have possessed technical knowledge that made him an asset to the Snedshill partnership. Snedshill is therefore likely to have been built using locally available expertise. In 1839 Samuel Horton inherited a third share of the business, and bought out Simms and Bull in 1854 for £18,000. In 1855 a new partnership of the Snedshill Bar Iron Company was formed, in which it formally became part of the Lilleshall Company.[33] It continued to use the Horton-Simms trademark 'HS', however.

7.2 Charcoal iron manufacture – Rural and Severn Valley forges

There was an independent forge sector in the Midlands, including Shropshire, until the late nineteenth century. These forges relied on surplus pig iron produced by the larger smelting concerns. The fact that they had been a traditional market for Shropshire pig iron from the latter half of the eighteenth century made some contribution to their survival. But not all Shropshire rural and Severn Valley forges survived. Those that did were no longer exclusively water-powered or charcoal using forges. They used coal, steam and had access to the main transport routes.

Upton forge is not recorded after 1831, although William Hazeldine's foundry in Shrewsbury continued working after its owner's death in 1840. Cleobury Mortimer forges were owned by Sir Edward Blount until 1825, after which they were managed, and perhaps leased, by James Lewis (c1801-87). From 1828 Lewis was at Knowbury Ironworks, to where his forging operations appear to have been moved. Cleobury Mortimer forges probably closed then or soon after. By 1841 there was only one man in Cleobury Mortimer parish who was engaged in the iron industry.[34]

A blast furnace had been built at Knowbury, 3 miles (5 km) east of Ludlow in the South Shropshire coalfield, by 1804.[35] A forge was later added, details of which are given in advertisements offering the works for sale in 1845, 1851 and immediately prior to Lewis's emigration to New Zealand in 1853. In 1845 its forge had a refinery, two puddling furnaces, a furnace for working scrap iron, and a charcoal finery, while its engine had been built by the Coalbrookdale Company. The mill incorporated puddled bar rolls, and rolls for merchant bar, rods and wire iron.[36] A second advertisement in 1851 offered engines and rolls for sale, implying that production had already ceased.[37] The final advertisement in 1853 offered the same equipment for sale, in addition to which was a quantity of charcoal. It indicates that charcoal iron was manufactured until the works ceased operation.[38] Knowbury was a coalfield forge, despite the comparative isolation which is most likely to have been its undoing. Investment in its forge in the second quarter of the nineteenth century expresses confidence in the regional industry and its charcoal branch.

At first sight, Eardington and Hampton Loade look like exceptions to the rule that forges were concentrated in the coalfields. They have previously been portrayed as archaic survivors, even though they came under the control of two leading figures in the Midland iron trade. James Foster and John Bradley had taken over Eardington in 1809. After Bradley's death in 1816 James Foster entered into partnership with Thomas Jukes Collier and built the blast furnaces at Wombridge.[39] In 1820 they purchased Hampton Loade forge from the Hampton Loade Iron Company, managed at that time by Robert Ward.[40] Considerable investment was subsequently made at both Eardington and Hampton Loade, under the direction of the engineer John Urpeth Rastrick.

By 1819 Hampton Loade was a small puddling works with three furnaces. Two new furnaces were added by Rastrick and two new rolls were installed in the small mill. There were two workmen described as 'senior puddlers' in 1820, named Sturgess and Bamford, but the forge also worked scrap iron and a limited amount of charcoal iron. However, this scheme was altered again in 1822 when the forge was converted to a small tinplate works. New rolls were built and the puddling furnaces were probably dismantled, allowing new charcoal fineries to be constructed in their place. Charcoal was commonly used to make high-grade tinplate during this period. But the works only lasted for four years in that guise, as in 1826 the charcoal fineries continued in use but made charcoal iron for Midland metalware trades.[41] Eardington forge was also modified in 1820 by Rastrick.[42] Eardington had been a charcoal forge since 1813 and it was described as 'the largest of the kind in the kingdom' in 1851, which has encouraged the view that Eardington and Hampton Loade should be seen as small anomalous works outside mainstream developments in the trade.[43]

In fact Eardington and Hampton Loade were part of a large industrial enterprise. By the second decade of the nineteenth century Foster and Bradley had become well-established ironmasters. Bradley's main forge was the Stourbridge Forge & Mill, where puddling had been adopted by 1800.[44] In addition to his blast furnaces, James Foster, in partnership with John Urpeth Rastrick, built the New Foundry engineering works in Stourbridge in 1820, one of the largest of its kind.[45] By 1830 Foster had puddling forges at Stourbridge, Brierly, Shut End and Chillington in Staffordshire, and in the following decade acquired additional forges at New Bradley and Capponfield, also in Staffordshire.

7.3 Charcoal iron manufacture – coalfield forges

The principal forges in Shropshire also engaged in charcoal iron manufacture, which was now focused upon the coalfield rather than on rural forges. At Horsehay in 1832 'three or four charcoal fires' were built next to the running-out fires, presumably in order to utilise the same source for the blast. They were mainly used for working scraps for making best charcoal iron, especially for wire, but output lasted only 'two or three years', just as it had done in 1804. Two Staffordshire wire drawers, Thomas and John Stevenson, oversaw the construction of wire rollers and undertook the work. The wire mill was built on the site of the first Horsehay mill, erected in the 1780s, and a separate engine used to drive the mill train was working at the end of 1834. This first engine was subsequently replaced by a more powerful 'marine' engine built by Charles Dawes of Coalbrookdale, and drove the wire mill and a small merchant train. However, charcoal iron became obsolete at Horsehay when wire iron was rolled from puddled balls. Subsequently the Horsehay wire mill was discontinued.[46]

More detailed evidence of more extensive operations is available for Old Park. Preparation for manufacturing charcoal iron took over a year before iron was sold commercially. Three specific requirements needed to be met: a sufficient supply of charcoal, skilled workmen, and a supply of charcoal cinder was needed to add to the charge in the fineries, where it acted as a flux. The fact that neither was on hand demonstrates that the Botfields no longer had an interest in the forge at Cleobury Dale. Local timber merchants in and around the East Shropshire coalfield such as George Clune of Coalbrookdale and Edward Cherrington of Shifnal were sought as potential suppliers of charcoal rather than cordwood suitable for coaling. Later correspondence suggests that local merchants could only supply a limited amount, if any, and negotiations began with Samuel Cooke, described as a charcoal dealer of Tipton, Staffordshire.[47] The problem with Cooke was in part his price, which was perhaps influenced by the difficulty of transporting so fragile a cargo to Old Park over a distance of some 25 miles (40 km). It was suggested that 'there is a canal between this place and Coalport but probably you may wish to carry the charcoal on horses backs'.[48] In the short term Cooke's price was too high and orders were not placed with him.[49] The fact that supplies were sought from some distance, and from a place not noted for its forests, implies that charcoal, or suitable wood, would be acquired from a variety of sources.

Charcoal cinder was sought from working charcoal forges, and related correspondence is an important source for determining the number of forges still working with charcoal in the 1820s. The earliest recorded requests were to J.G. Lewis at Cleobury Mortimer forges and William Hazeldine at Upton Forge in November 1825.[50] 20 tons of cinder were brought from Wilden Wire Works, near Stourport, in April and May 1826, after which there is no evidence of any further supplies until 1827.[51] This suggests that trials were made at Old Park in the middle of 1826 but did not prove auspicious and the project was shelved. One of the difficulties may have been in securing suitable workmen, although there is no surviving correspondence relating to workmen in 1826. In May 1827, when preparations were again under way for developing the charcoal fineries, George Allender of Aston Junction Forge, near Birmingham, wrote asking for work and was employed as the principal finer.[52]

From this period also came fresh orders for charcoal. Samuel Cooke was asked to supply between 20,000 and 30,000 bushels of charcoal per annum from April 1827.[53] Requests for charcoal cinder were made again to Wilden Wire Works, and then to Francis Homfray's Stourton Forge in Staffordshire (figure 5).[54] In its conveyance the cinder was treated like a precious metal. Homfray was requested to send a second consignment of 'charcoal finery cinder provided you will send it free from dirt the same quality as that we have just received – a few tons of the lot sent is at hand but it is dirty'.[55] The carriers were also instructed to take special care: 'We expect a considerable quantity of finery cinder delivered at your wharf which we will thank you to keep free from dirt and take care it is put on a part of the wharf that is free from dirt and put it into clean barges when shipped.'[56] Cinder was also taken from the Cleobury Mortimer forges.[57]

The Old Park foundry is first recorded as casting parts for new charcoal fires in August 1827, with regular references thereafter.[58] In the same month slit and rolled charcoal rods were offered for trial to Withymoor Works in Derby, and in October an order was received for charcoal rods from Thomas Jones in Wrexham.[59] Charcoal rods, charcoal bars and horsenail rods were all manufactured from the outset, while charcoal boiler plates were made by February 1828.[60] In addition, trials were made with 'Osborne' (sometimes known as 'Osmond') iron.

Osborne iron was particularly suited to making wire because it could be worked to a very thin section. The wire was used for manufacturing wool cards, needles, birdcages, mousetraps, curtain rings, and chains for keys. Iron was melted down into charcoal lumps in a similar way to a common finery, but the iron was coiled around the staff by the finer so that it formed very thin layers that allowed a more thorough oxidation under the blast of air than was normal. Decarburisation was also aided by dipping the staff into a bath of slag, for which charcoal cinder was brought in from other forges. A ball of about 25 lb was worked under a lighter, faster hammer than normal, which decreased the forging time and obviated the need for a chafery. Osborne iron required a smaller hearth and greater speed of working than common or best iron. The additional heat made by a smaller hearth meant that the finers worked fewer hours.[61]

Osborne iron rods were sent out from Old Park 'flat at each end' to distinguish them from the common charcoal iron.[62] Osborne iron was sent on trial to a number of wire works, such as Thomas Jones in Wrexham, James Royston in Halifax, and Greening & Company of Warrington.[63] As it involved a difficult process and was an expensive product, feedback from the wire mills was deemed important: 'We will forward you 2 tons of Osborne wire rods for a trial at £22/10/- per ton short weight delivered at Preston Brook [for Wheeler Wire Mills, Holywell, Flintshire], we are but new beginners with that article, and should wish you to try and favour us with your opinion (when you call here) of the quality.'[64]

The charcoal fineries were well-established at Old Park by 1832 when wages accounts show something of their workings.[65] In 1832 there were two named finers – George Allender and Paul Edwards – paid at 12/6 per ton, compared to the puddlers who were paid 7/6 for making puddled iron from pigs, and 10/- for making plates. However there must have been other skilled men working as sub contractors because George Allender was paid a premium of 10/- per month for each hearth working, and until September 1832 there were four hearths. In April 1832 nearly 98 tons of charcoal iron was produced from four charcoal fires, which could not have been achieved by Allender and Edwards alone. In September 1832 George Allender was replaced by William Allender, presumably his son but certainly the finer who inherited George Allender's privileges – William Allender henceforth received a monthly premium of 10/- for each working hearth.[66]

There is a resemblance between the terms of agreement with the Allender family and with the original agreement between Thomas Botfield and Joseph Williams for the forge in 1789, Williams being entitled to 10d per ton on all stamped iron.[67] In each case considerable authority and discretion was invested in a master workman. In 1832, only William Allender made Osborne iron, which was rolled into billets for drawing into wire, and he is likely therefore to have been regarded as the most skilled workman. From November 1832 five charcoal fires are listed. A third charcoal finer, Joseph Matthews, is first mentioned in April 1833.[68] A James Matthews worked at Hampton Loade in 1828.[69] There were other personal connections between the two forges (Appendices 3 and 5). Finers employed at Hampton Loade in the first half of the 1830s include members of the Allender and Edwards families.[70] Of twenty-two finers, nine were capable of making Osborne iron, and it is possible that William Allender of Old Park had learned the technique there. In 1875 the clerk at Eardington forge was John Allender.[71]

By 1832 supply of charcoal to Old Park came not from Samuel Cooke but from Thomas Holloway, Robert Lloyd and W. Glaze, although in neither case is their place of business given in the wages account book.[72] Small quantities of peat were also added to the charge. Here it is worth comparing the information for Hampton Loade, which was established only a year before Old Park. Hampton Loade acquired charcoal from at least fourteen different sources, mainly in the Severn and Wye valleys, ranging from Buildwas near Coalbrookdale in the north to Abbey Tintern, 57 miles (92 km) to the south. Evidence of the latter invites speculation that charcoal was acquired from woodland managed previously for the Abbey Tintern forge and wire mills.[73] Small quantities of peat came from Whixall Moss, owned by James Foster and situated 36 miles (58 km) north west of Hampton Loade close to the Ellesmere Canal. The forge also purchased 'stewed charcoal', probably from wood distillation plants.[74]

Old Park appears to have used pig iron from its own furnaces, but pig from various sources was used at Hampton Loade. In the 1830s and 1840s it was mainly purchased from Foster's own works such as Wombridge, Madeley Court (built in 1843 and superseding the Wombridge furnaces) and Shut End. Of external sources, the Lilleshall Company in Shropshire was the most prominent, with smaller quantities from Netherton and Withymore in Staffordshire, Cinderford and Lydney in Gloucestershire, Lawley and Madeley Wood in Shropshire, and Blaenavon in Monmouthshire. Pig iron that had been smelted with charcoal was used in only minuscule amounts.[75]

	Output in tons
1829	1669
1830	1269
1831	1049
1832	2197
1833	2631
1834	2561
1835	2721
1836	1868
1837	861
1838	214
1839	1897
1840	1443
1841	1543
1842	2059
1843	2002
1844	988
Total	**26972**

Table 6: Output of Hampton Loade forge, 1829-44.
Source: SRR 5586/10/1/2, Hampton Loade Account Book, 1835-46

At both Old Park and Hampton Loade the pig iron was refined before it was sent to the fineries. At Old Park iron refined for the charcoal fineries and puddling furnaces was graded separately. Hampton Loade had its own running-out fires, from which the refined iron was graded separately if it was to be used to manufacture Osborne iron. From 1835 most of the pig for making Osborne iron was refined at Stourbridge.[76]

Charcoal iron from Eardington and Hampton Loade was used for making horsenail rods, best wire iron, tinplate, gun barrels, as well as plates from which edge tools such as scythes were manufactured.[77] Old Park, Eardington and Hampton Loade were therefore serving the same market. Output of these charcoal forges was considerably higher than it was for the finery and chafery forges of the eighteenth century. This could only be achieved by importing fuel from a wide catchment area, which was partly made possible by the decline of other Midland charcoal forges. Aside from the greater demand for iron of all types in the nineteenth century, the other main difference from the eighteenth century was the use of steam power. Engines allowed multiple fineries to be worked simultaneously. Each of the works mentioned benefited from this. The guarantee of power supply also allowed the fineries to be worked in a double-turn for twelve months of the year. Between 1829 and 1844 26,972 tons of charcoal iron were made at Hampton Loade, an average yearly output of 1686 tons. The highest recorded output was 2721 tons in 1835 (Table 6).[78] This should be compared with the survey of the forge trade in 1749, when eleven finery and chafery forges in Shropshire were estimated to have produced an aggregate output of 2260 tons, the largest producers being Upton and Sutton forges with only 260 tons each (Table 1). Old Park produced 983 tons of charcoal iron in 1833 from five fires, at a mean of 3.78 tons per week per hearth, compared with 4356 tons of puddled bar.[79] Stirchley forge produced 3453 tons of puddled iron in the same year.[80]

7.4 Conclusion

Examination of the industry between 1815 and 1850 shows some predictable features, such as the adoption of pig boiling, the increasing use of steam power and increasing size of individual works. Investment in coalfield forges also included a significant outlay in the manufacture of charcoal iron, a new and largely unexpected discovery. Although the charcoal forge sector declined in relative terms in the early nineteenth century, overall output had risen by the 1830s. Such evidence forces a revision of the argument that Eardington and Hampton Loade represented the last vestiges in

Shropshire of an obsolete technology. The market for charcoal bar iron remained comparatively stable into the nineteenth century despite the availability of cheaper puddled iron. It does not therefore follow that the advent of puddled iron signalled the demise of rural forges. In the long term output increased but it became concentrated into fewer but larger productive units, of which Old Park, Eardington and Hampton Loade appear to have been the most significant in Shropshire by 1850 (the scale of charcoal ironmaking at Snedshill and Ketley is not known). In 1833 charcoal iron accounted for 11.2% of the output of the Botfield forges.

Upton and Cleobury Mortimer were the last of the rural forges to cease working. Their demise coincided approximately with the investment of charcoal iron production in the coalfield, raising the possibility that they were too small and isolated to compete with the newer works. Cleobury Mortimer was superseded by Knowbury, an outlying and late example of a coalfield ironworks that invested in charcoal iron manufacture. Although its forge was integrated with smelting, it was nonetheless erected in a place with no advantages in transportation. The other surviving forges outside the coalfields were Eardington and Hampton Loade. Both were part of the larger ironworking concerns of James Foster, with easy access to the River Severn for transportation, and represent investment in charcoal iron by James Foster equivalent to the investment made at Old Park.

8 THE MATURE IRON INDUSTRY, c1835-1880

Charles Hyde defined the period after 1815 as the 'mature iron industry' on the basis that the principal technological developments had by this time all been made. It was argued that little changed of real significance in the wrought-iron industry until steel superseded it in the late nineteenth century. During this period, however, the British iron industry expanded considerably, with new ironworking districts such as Scotland and Cleveland accounting for an increasing share of the national output. Shropshire also saw a significant wave of new forges in the mid nineteenth century, built following the improvement in the county's transport infrastructure provided by the railways. Chapters 5 and 7 demonstrated that by the 1830s Shropshire had established a mature market for its iron. The purpose of this chapter is to examine how the market developed in the remainder of the nineteenth century. It will need to consider Shropshire's contribution to new markets for wrought iron, such as railway and marine engineering, and the manner in which new ironworking districts competed with the Shropshire forges. This will contribute to a characterisation of the Shropshire iron industry, portraying its scale, technology and products within a national context.

It will be important to establish to what extent the British iron industry was a national entity by the mid nineteenth century. The discourse is able to build on evidence already discussed of specialisation in the puddling era, implying significant regional differences. If in fact there was no unified national iron industry it follows that the decline of the wrought-iron industry cannot be understood simply in national terms. The character of the Shropshire iron trade is therefore crucial to the analysis of the end of wrought-iron manufacture, which will be the subject of chapter 9.

8.1 Improvements in transport – the railway age

The first significant improvement in transport in the early nineteenth century was in the canal network. Acts of Parliament were passed in 1826 and 1827 for the building the Birmingham and Liverpool Junction Canal between Wolverhampton and Nantwich, which incorporated a branch from Norbury to the Shrewsbury Canal at

Wappenshall (figure 8). Wappenshall, near Wellington, was comparatively well situated to serve the ironworks on the north side of the East Shropshire coalfield – Old Park, Ketley, Snedshill and Horsehay were all within 5 miles (8 km) of it – and as soon as its wharf opened in 1835 it was used by all of the ironmaking concerns.[1] It made access to the Midlands and the north of England far more convenient than had been possible with the canal-river interchange at Stourport. For this reason the coalfield could be seen by the 1830s to be oriented towards the northern manufacturing districts rather than south to the older Severn ports of Gloucester and Bristol. Despite its advantages, deliveries and shipments of iron on the canal network remained, as W.G. Norris noted, 'an expensive and troublesome supplement to the cost of iron making at Horsehay up to the time when the Wellington & Severn Junction Railway opened for traffic'.[2] Iron from Horsehay was taken to the Shropshire Canal via Dawley Castle furnaces, loaded into tub boats, then transhipped at Wappenshall, although subsequently the iron was taken by road directly to Wappenshall. The most significant beneficiary of the new canal was the Lilleshall Estate. Its owner, the Duke of Sutherland, was one of the promoters of the BLJC, and as the owner of Wappenshall benefited from tolls collected there.[3]

The Shropshire Union Railway & Canal Company (SURCC) opened its railway between Shrewsbury and Stafford in 1849. It shared the line between Shrewsbury and Wellington with the Shrewsbury & Birmingham Railway, which was fully opened to Wolverhampton by 1850 and was then completed to Birmingham. Both companies were taken over by the Great Western Railway (GWR) in 1854. Ketley, Old Park and Snedshill were well-positioned to make use of the new railway. Other forges did not benefit directly until branch lines were built. Stirchley Forge was served by an extension of the London and North Western Railway (LNWR) from Oakengates to Coalport, built 1857-61. Horsehay was able to utilise the Wellington & Severn Junction Railway when it opened from Ketley on the Shrewsbury & Birmingham Railway to Horsehay in 1857. To the south of the coalfield, the Severn Valley Railway from Hartlebury near Worcester to Shrewsbury was opened in 1862 and passed close to Eardington forge. The Severn Valley Railway was absorbed by the GWR in 1863.[4]

By the 1850s few of the main customers for Stirchley iron were in the south, the main destination for Stirchley iron being the Liverpool and Manchester district, although it continued to trade with three Bristol iron merchants – Daniels & Company, Mather Roscoe & Finch and McArthur & Company. The Severn trade declined rather than collapsed, although it is said that pig iron was last conveyed by river in 1869.[5] One of the advantages of railways was that railway companies quoted for delivery from station to station. Goods were, therefore, easier to deliver to a greater variety of destinations than was possible on the canal network. The railway network also provided a new dimension to the geography of industrial Shropshire.

8.2 Expansion after 1850

Several small forges were established on the north side of the East Shropshire coalfield after 1850, all of them close to the railway (Table 7, figure 8). The Wombridge Iron Company had a small forge built in 1854 by John Bennett to the design of John Peplow, on the site of the former Wombridge blast furnaces. By 1877 it had a plate mill and also drew wire rods.[6] The Eagle, or Hollinswood, Ironworks was in operation by 1856. Owned by Onions Shepherd & Taylor in 1863, it was described at that time as working tinplate, and as such was the sole tinplate manufacturer in Shropshire. Five years later it was owned by the Hollinswood Company, and the works was now making best puddled and charcoal iron wire rods, for drawing into springs and screws.[7] The forge was subsequently owned by the Eagle Iron Company, had sixteen puddling furnaces by 1873 and produced iron for shovel manufacture.[8] Lawton Iron & Steel Works, near Shifnal on the east side of the coalfield, was owned by William Taylor in 1863, when it was described as making sheet, hoop and rivet iron, and wire rods.[9] The works was not mentioned in Slater's 1868 directory of Shropshire and was 'standing' in 1871, but it was brought back into operation under a new owner, probably Bullivant & Allen, who purchased puddled iron from Stirchley in that year.[10] Bullivant & Company had eight puddling furnaces and a rolling mill by 1873, and in the same year the chain-making firm Edge & Sons moved into the forge from Coalport, and re-named the site the Coalport Works.[11]

	Owner	*Puddling furnaces*	*Forges & mills*
Horsehay	Coalbrookdale Co	42	2
Stirchley	Leighton & Grenfell	30	4
Ketley	Ketley Iron Co	20	3
Trench	Shropshire Iron Co	24	3
Wombridge	Wombridge	10	3
Castle	Nettlefold & Chamberlain	10	2
Lawton	Bullivant & Co	10	1
Haybridge	Haybridge Co	10	1
Old Park	Old Park Iron Co	30*	3*
Snedshill	Snedshill Bar Iron Co	40	5
Hollinswood	Eagle Iron Co	16	3
	Total	**232**	**30**

* denotes furnaces and forge 'standing'.

Table 7: Shropshire forges in 1873.
Source: *Griffiths Guide to the Iron Trade of Great Britain* (1873), pp 276-7.

The Haybridge Iron Company was named after a small forge erected close to the Wellington-Stafford railway in 1864 by local businessmen. Benjamin Talbot, 'engineer of Wellington', was its managing director. It raised further capital when it became a limited company in 1870, new shareholders including local timber merchant Richard Groom, and three Yorkshire clothiers who were probably related to Talbot by marriage.[12] By 1873 it had ten puddling furnaces. The output of the Haybridge Iron Company was mainly wire rods – the company had a wire-drawing works at Warrington by 1885 – but it also had bar and plate mills.[13]

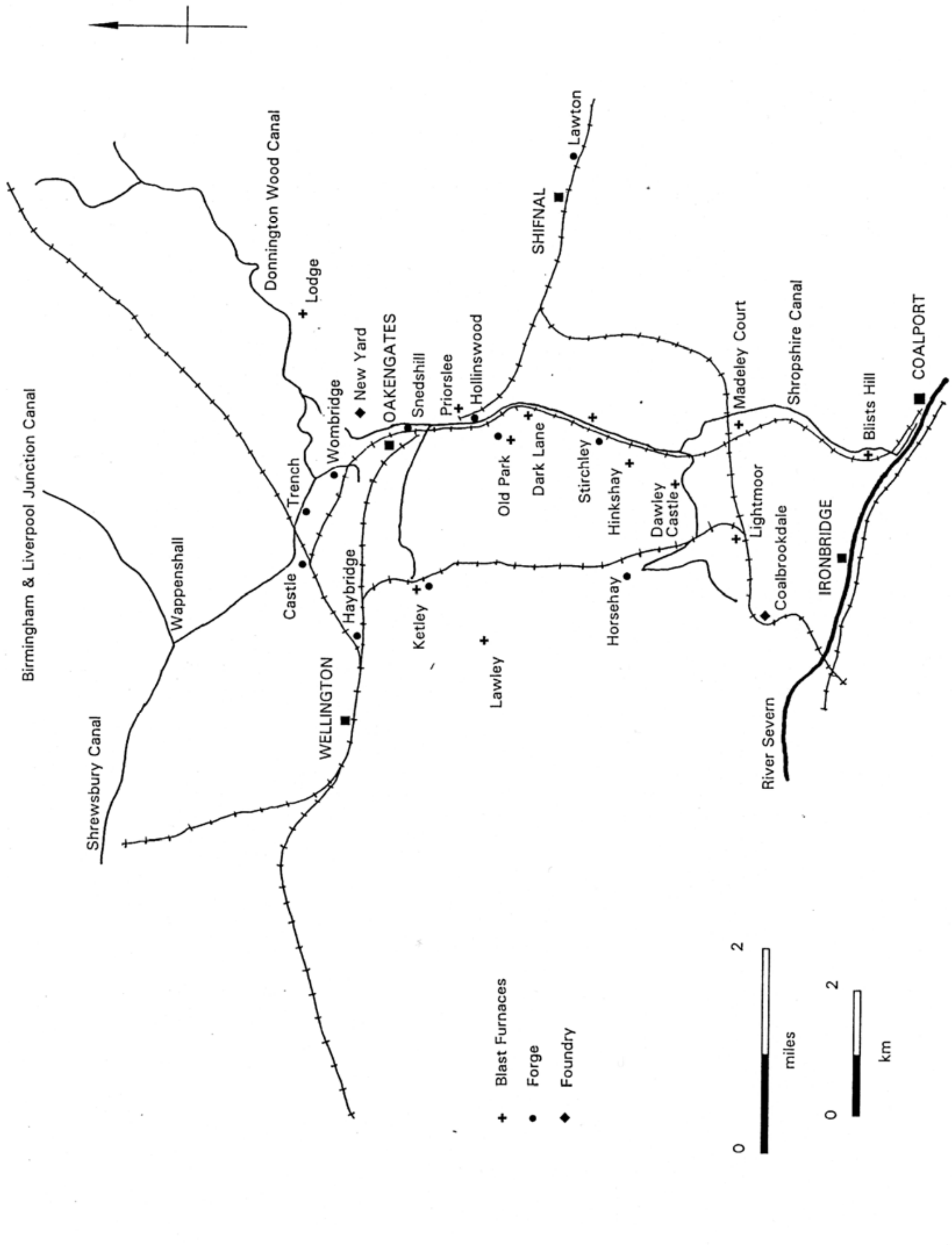

Figure 8 Ironworks in the East Shropshire coalfield, 1872

Nearby was Trench Ironworks, built in 1866. The original company failed after three years and the site was bought in 1872 by the Shropshire Iron Company who resurrected the works, which had twenty-four puddling furnaces, wire rod and hoop mills, and was powered by six steam engines.[14] Its principal shareholder was George Patchett, a Halifax wire merchant who had been one of the members of a provisional wire-makers association in 1867.[15] The forge was supplemented by a wire-drawing mill built in 1873, the first order for which was to supply the Western Brazilian Telegraph Cable. By 1877 it was managed by James Patchett (1851-1927) and had worker shareholders.[16] In addition to its twenty-eight puddling furnaces were two charcoal fineries. The Trench Ironworks was the largest of the Shropshire wire mills, as by 1879 it could produce 400 tons of rods and draw 100-150 tons of wire per week.[17] Supplied with Lilleshall pig iron, it was refined and drawn into wire rod, which was pickled in a bath of sulphuric acid and then cleaned by lime water. The wire rod was then drawn cold to various degrees of fineness, the finest being from charcoal iron. This could then be galvanised, or twisted to form strands or cable. The works also made fencing wire for the Australian, Buenos Aires and Montevideo markets. A similar works, but with neither puddling furnaces nor the facility to galvanise the iron, was the Crown Works at Hadley, managed by George Wilkes.[18]

The last forge to be built in Shropshire was Castle Ironworks near Wellington. The background to its development has been studied in detail by Edgar Jones in his history of GKN, and illustrates the state of the Midland iron trade and its relationship to the trade in finished iron. The firm of Nettlefold & Chamberlain was founded in 1854 with the building of the Heath Street Works between Smethwick and Birmingham. It was among the leading British manufacturers of wood screws. J.S. Nettlefold had established a screw-making business in Birmingham in 1834. He subsequently took his brother-in-law, Joseph Chamberlain, into partnership to raise £10,000 capital for investment in a new works, manufacturing a product with increasing mechanisation in what was an expanding market. The Heath Street works was managed by their respective sons J.H. Nettlefold (1827-81) and the politician Joseph Chamberlain junior (1836-1914). The business subsequently expanded to include a second screw works at King's Norton, Birmingham, in 1865, and in 1869 a wire mill was built at

Ashtree Works in Smethwick, where coiled iron was drawn into wire of specified gauges. Bar iron had initially been purchased from small Midland forges, but in 1871 a purpose built forge was erected near Wellington, Shropshire, known as the Castle Works (and occasionally as Hadley Castle). The name derived from a local landmark (in fact a disused windmill rather than a castle), and a castle became the firm's trade mark.[19] In 1874 Joseph Chamberlain dissolved the partnership, which traded subsequently as Nettlefolds and became a limited company in 1880.[20] The Castle works was designed by Karl Siemens (1829-1906) and was notable for its use of 'gas puddling and heating furnaces' on the model of furnaces designed by his brothers William Siemens (1823-83) and Frederick Siemens (1826-1904).[21] The furnaces, patented by Frederick Siemens in 1856, are better known as open-hearth furnaces and were adapted to various kinds of ferrous and non-ferrous applications, including puddling, before their association with steel making. Gas puddling furnaces were a transitional phase between iron and steel making and are discussed in more detail in chapter 9. In 1873 Castle Ironworks had ten gas puddling furnaces, and expanded to twenty-seven by 1877.[22] Ironwork for the furnaces, as well as the rolling mill at the Castle Works, was supplied by the Lilleshall Company's New Yard engineering works.[23]

Common denominators among these new works were their proximity to the railway and access to local supplies of coal. All of them, as well as Snedshill and Ketley, sold semi-finished wire rods to the wire-making centres of Birmingham and Manchester, while the Castle and Trench works, and later Haybridge, were integrated with a manufacturer of finished iron.

Changes occurred to the established forges after 1850. Of the Botfield brothers, Beriah II had died in 1813 and Thomas II in 1843, although neither was associated directly with the ironworking side of the family interests. William Botfield died in 1850, having overseen the day-to-day operation of the family's Old Park and Stirchley concerns since his father's death in 1801. It was William's death that marked a decisive change in the family business. The business was inherited by Beriah Botfield III (1807-63) of Norton Hall, Northamptonshire. Beriah III had no direct experience of the iron trade, although he had been a partner since 1828. In 1856 he failed in his negotiation to renew the lease of Old Park, when the landlord, Robert Cheney, took over the works and established the Old Park Company, owning Old Park furnaces and forge, and Stirchley furnaces. Capitalised at £100,000, over three quarters of the shares were taken by the Cheney and Capel Cure families.[24] The Botfield family's other concerns, including Stirchley forge, were on freehold land, and these now became the focus of family interest. After Beriah III's death in 1863 his affairs were managed in trust for his wife Isabella. The trustees were her brother Stanley Leighton MP, and Henry Grenfell MP, the member for Stoke, and the business traded under the name Leighton & Grenfell. The Coalbrookdale Company blew out the Horsehay blast furnaces in 1861-2 and henceforth pig iron was obtained from the company's other furnaces at Lawley, Lightmoor and Dawley Castle. Lilleshall remained the strongest of the Shropshire ironmaking companies. The Snedshill Bar Iron Company remained a quasi-independent concern, however. In 1873 it was the largest of the Shropshire forges, although not large by national standards, with forty puddling furnaces and eight charcoal fineries.

8.3 The character of the Shropshire iron trade

The emergence of new forges after 1850 subtly altered the character of the Shropshire forge trade. Superficially nothing had changed: there had been no new technological breakthrough comparable with hot blast and the recycling of waste heat which had affected the smelting sector. The new forges produced high-quality, specialised iron, especially for drawing wire, which had been one of the main products of the charcoal fineries at Old Park from the late 1820s. However, the new forges were not associated directly with blast furnaces, and in this respect they were like the smaller forges that had long characterised the Midlands. They were also located on the north side of the coalfield with access to the railway, shifting the geographical focus away from the River Severn and the south end of the coalfield.

The products of the Stirchley forge in 1872 were little different from those of 1832, comprising general-purpose wares such as plates, sheets, merchant bar and hoop iron, although probably specialising in higher grades. The only significant new product was angle iron used in marine engineering and the construction industry, while the significant absence from its list of products was wire rods.[25] Continuity indicates a stable market for its products during the mid nineteenth century, and there is no evidence that other forges did not also concentrate on general purpose wares, in addition to wire rods. The local market for iron products does not appear to have been any more significant than it had been in 1800. There remained chain makers in the coalfield such as Edge & Sons and W.S Lewis of St George's. But the vast majority of the iron produced in Shropshire was shipped to manufacturers in the Midlands and the north of England, or merchants in Bristol, London and the north.

The importance of charcoal iron up to 1850 has already been discussed, and it continued to be of importance in the third quarter of the nineteenth century. Charcoal iron is the epitome of a business strategy based upon quality. Although charcoal iron looks insignificant compared with puddled iron in terms of output, numbers of men employed and profit level, it is misleading to interpret it as an unimportant sideline. Mutton's argument that Eardington and Hampton Loade were kept going by James Foster, and his eventual successor in 1853, his nephew William Orme Foster, purely for 'moral and social reasons' should be given up.[26] In his 1873 survey of the British iron industry Samuel Griffiths noted a number of works making charcoal iron elsewhere in the Midlands – these included Wilden Wire Works near Stourport, Darlaston Iron & Steel Company, and Monway Ironworks at Wednesbury in Staffordshire.[27] Iron refined with charcoal was of sufficient importance for large forge concerns such as Old Park, Snedshill and the geographically scattered enterprises of James Foster, to invest in its development. It added to the range of products offered by iron makers, and it highlighted the reputation for high quality sought by many of the ironmasters, and which the Midland iron trade sought to identify itself with.

It is not known whether charcoal iron was discontinued at Old Park before the forge closed, but it was still selling charcoal wire iron in 1846-7, and an inventory made in 1856 when the Botfields moved out lists a wire mill warehouse and three charcoal fineries (described as 'lumping fires').[28] Evidence for the existence of charcoal fineries at the Shropshire Iron Company's forge at Trench has been alluded to above. Snedshill was selling wire iron by 1846.[29] In 1873 Snedshill advertised the sale of charcoal wire rods, while Griffiths described it as having an 'unrivalled reputation' for making plates, hoops and wire rods and having 'contributed so much to the fame of Shropshire plates and wire rods'. Ketley was also described as having a good reputation for making wire rods, and may therefore also have had a charcoal iron department.[30] Charcoal iron can therefore be seen as an important component in sustaining and developing the reputation of Shropshire iron even in the second half of the nineteenth century.

8.4 The wire industry

Charcoal iron was closely associated with the manufacture of wire rods. The market for wire expanded rapidly in the nineteenth century and Shropshire can be regarded as specialising in its manufacture, although it was exported to other districts like Birmingham and Warrington in the form of rods for final drawing, or else it was coiled and used in the manufacture of small wares. When the Iron and Steel Wire Manufacturers Association was established in 1882 it had ten members, of which three were from Shropshire, although when the association was reconstituted in 1898 it had twenty-one members, of which only one, the Shropshire Iron Company, was from Shropshire.[31]

Wire, whether it was drawn from charcoal-refined or puddled iron, was used as the basis for manufacturing a number of products in addition to wire fencing. The most important were telegraph wire, wood screws, cables for suspension bridges and ships' rigging, and smaller wares like springs, bolts, rivets, hooks and eyes, cotter pins, bottling wire, button hooks, knitting needles and skewers. It could be galvanised, tinned or coppered, giving it additional versatility.[32]

Expansion of the wire industry occurred in the mid nineteenth century following the mechanisation of what had once been hand labour. But this was a quiet revolution:

> There are a number of … articles, such as wire, nails, pins, staples, cotters, and many similar articles, which are now no longer made by hand, but which in their manufacture exhibit no particular points of interest, though they are additional instances of the ingenuity of the manufacturers … and of the extraordinary results of machinery in lessening the cost of production.[33]

Birmingham was the destination of much of the wire drawn in Shropshire, which competed with many other wire works centred around Smethwick on the north-west side of the city. It was estimated in 1866 that more than 1000 tons of wire annually were used for making springs for mattresses and other furniture, while 100,000 miles of wire were applied to tying down the corks of soda-water bottles.[34] Halifax and Warrington were other foci of wire drawing and their links with the Shropshire Iron Company and Haybridge Iron Company have been alluded to above.

8.5 Diversification by Shropshire ironworking companies

Consideration of the wider business interests of companies associated with forging shows a characteristic pattern. After 1850 the Lilleshall Company, Coalbrookdale Company, Ketley Company, Old Park Company and Beriah Botfield all diversified into the sale of coal and manufacture of bricks and tiles, in addition to their forging and smelting interests. The Haybridge Iron Company and John Bennett & Company of the newer iron companies also engaged in selling coal and manufacturing bricks. The extent to which such diversification affected the operation of the Shropshire forges requires a detailed study of company accounts and policy beyond what is possible here. However, certain general points and questions can be raised.

Clay could be won easily from local coal measures. Bricks and tiles had a wide market after 1850, brick makers were paid at a lower rate than ironworkers, and brick-making processes and machinery were less complex than ironworking. This suggests that the manufacture of bricks and tiles could turn a larger profit with less investment than working iron. Certainly by the 1870s the Ketley Company found brick making more profitable than ironmaking, while the Shropshire brick industry in general continued to be profitable into the twentieth century, long after working wrought iron had ceased.[35] The market for coal could be met with comparatively little additional investment, and also outlived the wrought-iron trade in Shropshire. It is reasonable to question, therefore, whether the investment in bricks and coal used up resources that might otherwise have been invested in ironmaking, and whether the comparatively easier profits to be made from these industries discouraged long-term thinking in the forge trade. Against this it should be pointed out that after 1850 the forge trade in Shropshire continued to expand until the early 1870s, albeit independent of the smelting of raw materials. The foundry business also expanded. The diversion into art castings from the late 1830s by the Coalbrookdale Company was a significant factor in the company's history. From its Coalbrookdale foundry a variety of cast iron domestic wares and architectural work were produced profitably into the twentieth century, again long after wrought-iron manufacture had ceased. The Lilleshall Company also expanded its engineering interests. The New Yard works was built in 1861 and gained a reputation for manufacturing stationary engines and locomotives.[36] It has been argued elsewhere that prospects for manufacturing finished iron goods were brighter than they were in the smelting and refining sector by the 1870s and this affected the ensuing history of the Shropshire forge trade.[37]

8.6 Shropshire in the British wrought-iron industry

The Shropshire iron industry in the nineteenth century can only be understood within a national context. The mid nineteenth century saw the opening up of new ironworking districts across Britain, concurrent with the expansion of well-established regions such as the Midlands and South Wales. The introduction of hot-blast smelting had a marked impact on the geography of the British iron trade. It was patented by James Neilson (1792-1865) of Glasgow in 1828 and, despite initial resistance and the necessity of paying a royalty for its use until 1842, was widely adopted by the mid nineteenth century in established ironworking regions like Shropshire, Staffordshire and South Wales. Its first great impact was in Scotland, where the rise in output of pig iron expresses it in the starkest terms. In 1830 Scottish blast furnaces smelted 37,500 tons of pig iron from twenty-four blast furnaces, which had risen to 195,000 tons from fifty-four furnaces by 1839.[38] The development of smelting in Cleveland followed for similar reasons, exploiting cheap local iron ores, and in both places the wrought-iron trade developed after the establishment of the smelting sector.

The wrought-iron trade in 1850 was still dominated by South Wales and the Midlands. In addition to the regular forms of bar, plate and sheet, one of the more fastest growing end uses for wrought iron was in tinplate manufacture. Hampton Loade is typical of the tinplate industry of the 1820s insofar as it was a small self-sufficient works able to refine pig iron and to produce a finished product by rolling the bars into thin plates (known as black plates), then to clean and anneal them before dipping them in tin. A number of similar small works, some of them concentrating on the production of black plates, continued in the tinplate trade to the 1870s, including Cookley and Broadwater in the Stour Valley, both of which were originally finery and chafery forges (figure 5).[39] The rapidly growing British tinplate industry was from the 1830s dominated by works in South Wales. Its geographical focus was on the western side of the South Wales Coalfield, from the valleys of Neath and Swansea and extending to Llanelli in Carmarthenshire, rather than the northern rim from Merthyr Tydfil to Blaenavon, where the largest iron producers were situated. Most of the tinplate works purchased bar iron but could also refine iron for special grades if necessary. For example, the Treforest Tinplate Works in Glamorgan, opened in 1836, had four charcoal fineries in 1842.[40]

A new market emerged at the end of the 1820s for iron rails. The earliest contracts for the supply of wrought-iron rails had been for the Stockton & Darlington Railway from 1821. Most of its rails were rolled by small forges in north-east England, such as the Bedlington Ironworks near Newcastle, where the Birkinshaw rail originated, which refined pig iron purchased on the open market. The same firm won orders for rails for the Liverpool & Manchester Railway in 1829, as did the Penydarren Ironworks in Merthyr Tydfil and Bradley & Company of Stourbridge.[41] The trade expanded rapidly in the railway boom years of the 1830s and 1840s. By the latter period the principal rail-manufacturing region was South Wales where Dowlais, Cyfarthfa, Plymouth and Rhymney in Glamorgan, Ebbw Vale, Tredegar, Nantyglo, Blaina, Abersychan, Pontnewydd and Blaenavon in Monmouthshire were the leading makers and served a national market.[42] The Rhymney Company had supplied rails to the London & Birmingham, Hull & Selby, York & North Midland, Glasgow & Ayrshire, Edinburgh & Glasgow railways; Dowlais, the largest producer, included the Great Western, Bristol & Exeter and Sheffield & Rotherham Railways among its clients.[43] Midland forges also enjoyed a large share of the regional market for rails. The London & Birmingham Railway had a predominance of suppliers from the Midlands, including Bradley & Company's Capponfield and Chillington Works at Wolverhampton, the Tividale ironworks at Dudley and the Butterley Company of Alfreton, Derbyshire.[44] Cleveland and north-east England retained a strong rail-manufacturing tradition that was maintained as the region's iron industry expanded after 1850, the chief makers including Bolckow & Vaughan of Middlesborough and Consett Iron Company of County Durham, formed in 1864 after the collapse of the Derwent Iron Company.[45] Rails became one of the most important products of the Consett Iron Company, where there were ninety-nine puddling furnaces in 1863 and 139 in 1871.[46]

This trade marked a significant shift in business practice. The works were now usually supplying finished iron direct to customers rather than semi-finished iron that was distributed via merchants, although a few merchant houses such as the Bailey Brothers of Liverpool dealt regularly in rails. It was in the export of rails that merchants played a key role, the chief foreign markets being France, Germany and the USA. South Wales works were the chief suppliers of rails for export until domestic competition achieved the required capacity to receive large orders. Dowlais, for example, supplied railways in Germany, Russia, Canada and the USA in the 1830s and 1840s, while both Dowlais and Cyfarthfa supplied rails to the East India Company.[47]

Rails were a high-volume product – by 1836 Dowlais already produced 20,000 tons of rails per annum – and individual contracts were consequently on a large scale. In 1839 the Pentwyn & Golynos Iron Company in Monmouthshire won orders for 1500 tons from the Taff Vale Railway in Wales and 14,000 tons from Russia, which has been estimated to have occupied the works for over a year.[48] A distinct advantage for rail manufacturers was that rails were rolled to a standard section, thereby simplifying the layout and operation of the rolling mill. However, entry into the rail-making trade required investment in new mills on flat sites. During the same period that mills for bar, hoop, plate and sheet iron were built at Stirchley, Horsehay and Snedshill, at Dowlais the Big Mill was built in 1830, supplemented by the Little Mill in 1840, both with their own puddling furnaces and steam-powered mill trains, specifically for the market in rails.[49] Rail mills required more powerful engines than had hitherto been required for rolling bar. In 1857-9 the Goat Mill was built at Dowlais, which the works' engineer William Menelaus claimed had three times the power of any existing mill, although its source of power was still a beam engine powered by two high-pressure cylinders.[50] Rail mills also required larger sites because more powerful machinery was intended to facilitate the rolling of progressively greater lengths of rail. For the Great Exhibition of 1851 the Cwmavon Works at Port Talbot rolled a rail 62 feet (18.9m) long, while a decade later the new Goat Mill at Dowlais rolled a 120 feet (36.6m) rail for the 1862 International Exhibition.[51]

It has been estimated that in the peak year of 1848 27% of puddled iron from British ironworks was rolled into rails for the domestic market.[52] The figure is not universally accepted, but even so there is no evidence that Shropshire forges competed in any significant way in the market for rail manufacture. A contract for the supply of 600 tons of rails for the Middlesborough & Redcar Railway was awarded to the Coalbrookdale Company in 1845. In the event, the railway company was dissatisfied with an initial consignment and the contract was transferred to Bolckow & Vaughan, who received all future orders.[53] In 1855 either Old Park or Stirchley was rolling rails for a private railway at the Flint Marsh Colliery in north-east Wales, and may have undertaken other similar small-scale orders.[54] But rail manufacture was hardly part of the Shropshire culture. Nor did Shropshire firms participate significantly in the production of cast-iron chairs and wrought-iron spikes for rails, although the Snedshill forge contracted to supply spikes to the London & Birmingham Railway.[55]

It is misleading to express rail manufacture as a proportion of national output when districts such as Shropshire did not engage in their manufacture and whose trade was of an entirely different character. The growth of railways also created a demand for various grades and types of wrought iron as component parts of locomotives and rolling stock. Locomotive manufacture was concentrated in Glasgow, Lancashire and the West Riding, with a scatter of other manufacturing centres, including London, Swindon, Ashford and Bristol. Components such as springs and couplings had been made in the West Bromwich area since the 1830s. There were large Midland firms such as Round Oak Works near Brierley Hill, where locomotives and machinery were manufactured, and the Patent Shaft and Axletree Company of Old Park, Wednesbury, Staffordshire, who manufactured parts for the railway industry.[56]

The manufacture of ships' plates was most closely associated with the forges of Scotland. The engineers John Laird at Birkenhead, William Fairbairn and Robert Napier began constructing iron ships in the 1830s.[57] Horsehay had been one of the ironworks that pioneered rolling of ship plates. It received an order for 800 tons of plates for I.K. Brunel's SS *Great Britain* in 1839, and rolled plates for the iron sailing ship *Richard Cobden*, launched in 1844.[58] Significantly, however, Shropshire forges did not supply plates for the marine engineering sector when it expanded after 1850. Ships required high volumes of plates and angle iron, although the growth of the Scottish forges that supplied them was steady rather than spectacular. A typical early example was the Mossend Iron Company's forge at Holytown near Coatbridge, which was built with only eight puddling furnaces in 1840-1 and grew slowly, specialising in plates and angle iron.[59] Until the 1870s the largest Scots puddling forges were the Motherwell and St Rollox forges of the Glasgow Iron Company, with sixty puddling furnaces in 1873.[60] The Blochairn Ironworks at St Rollox near Glasgow, owned by Hanney & Sons from 1867, had large banks of puddling furnaces, fifty in 1873, on either side of the Monkland Canal to exploit the market for ship plates. Its capacity was said to be 1500 tons per week by the 1870s.[61]

Other Scots forgemasters erected forges to manufacture marine fittings like crank and propeller shafts, stern and rudder posts, in addition to ship and boiler plates. Parkhead Forge in Glasgow, for example, was established for this purpose by the shipbuilder Robert Napier & Sons.[62] The rise of engineering firms in Glasgow and the west of

Scotland making bridges, gasworks plant and gasometers, floating docks, landing and promenade piers, allowed a number of other small works to become established in the vicinity, some making as little as 250-300 tons per month. Examples are the Merryston Ironworks (1851), Coats Ironworks (1854), Rochsolloch (1858), Drumpeller (1859, Phoenix and Clifton (both 1861).[63] In 1873 Scotland was said to have 565 puddling furnaces at twenty-one forges.[64] These forges were generally not integrated with larger smelting concerns, but they were sited with convenient access to the Clyde shipyards. In 1872 only three Scots firms – Baird & Company at Muirkirk in Ayrshire, William Dixon's Govan Ironworks and the Glasgow Iron Company's Motherwell and St Rollox Works in Glasgow – operated blast furnaces as well as forges.

The forge trade of north-east England gathered momentum in the second half of the nineteenth century. During this period the region became the leading producer of pig iron – Cleveland alone had 104 blast furnaces in 1873 – and the refining sector followed.[65] By 1873 several ironworks – Consett in County Durham, Teeside and Britannia ironworks in Middlesborough, Darlington Iron Company, and Witton Park near Bishop Auckland – had more than one hundred puddling furnaces each, at a time when the combined total of puddling furnaces in Shropshire was 232.[66] Characteristically the ironworks of the north east were established as companies with limited liability, made possible by the Companies Act of 1862. They were large-scale concerns, often integrated with blast furnaces. Rails, ship plates and other marine and engineering work were their principal output.

Again, the Midlands, and Shropshire in particular, did not compete in the marine engineering market, except perhaps in the manufacture of boiler plates. Ship plates and angle iron were high-volume products and so the most likely source of competition faced by northern and Scottish forges came from firms specialising in rail manufacture. The Rhymney Iron Company, for example, was soliciting orders for ship plate and angle iron in 1857-8 in an attempt to diversify its product range away from rails.[67] A related trade was the provision of armour plates for naval vessels. By the early 1850s Samuel Beale & Company of Park Gate Works near Rotherham rolled

4-inch thick plates for the early ironclads. John Browne & Company of Atlas Forge, Sheffield, invested £250,000 in 1863 in a new armour plate mill capable of rolling armour 12 inches thick.[68]

All classes of iron were produced to some extent by the forges of the Midland iron district, of which rails and railway engineering sections were most prominent in Staffordshire. The Black Country wrought-iron trade had a diverse character. Many of its smaller forges were specialist producers. One such was the Wilden Wire Works near Stourport, Worcestershire, a regular purchaser of Old Park pig iron in the early nineteenth century. By 1873 its owners were J.P. and W. Baldwin and it had introduced puddling furnaces, but its principal output remained charcoal iron, mainly for tinplate.[69] Other small forges of long standing continued working, such as Cookley, Broadwater and Hyde in the Stour Valley, the first two as part of the tinplate trade, the latter making wire rods, plates and bars and having two gas puddling furnaces by 1873 (figure 5). Wedges Mills near Walsall, another customer for Old Park pig iron in the early nineteenth century, also remained in production in 1873 in the ownership of the Gilpin family.[70]

A survey of the South Staffordshire iron industry in 1865 recorded ninety-nine forges, of which only twenty had above thirty puddling furnaces. South Staffordshire was at that time described as comparatively old-fashioned. Its output was concentrated upon iron of superior quality, including bar, rods, hoops, tinplate and boiler plate, which accounts for its survival in a large quantity of smaller units than the newer ironworking districts.[71] Shropshire resembled South Staffordshire in the nature of its iron industry, but whereas in 1873 there were 122 forges in the Black Country of South Staffordshire and Worcestershire, there were only eleven forges working in Shropshire (Table 7).

Given Shropshire's absence from the major new markets for wrought iron, it is worth questioning whether the success of the Shropshire iron trade and its reliance on a mature and secure market ended in entrepreneurial inertia. The close ties that had been developed with customers based on service and quality at first seems a desirable aim, but it might have been an impediment to radical transformation. To what extent did the risk of compromising their reputation for quality inhibit firms from making major investments in new markets? Most of the new markets required high-volume output, which might have further inhibited existing moderately-sized forges. Shropshire's mature iron industry was sustained by its existing market, but had little room for manoeuvre when new opportunities presented themselves.

8.7 Conclusion

The Shropshire wrought-iron industry expanded after 1850, reaching its peak in the early 1870s. The building of the first railway in 1849 greatly improved communications and encouraged new investment in the Shropshire forge sector. One of its consequences was a shift in the geographical emphasis of the Shropshire iron industry more firmly toward the north end of the coalfield. The new forges that were erected after 1850 – Haybridge, Trench, Lawton, Wombridge, Hollinswood – were all situated close to railways, purchased pig iron on the open market, and specialised in the output of bar, plate, wire or wire rods. In other words investment was directed towards products that had already become characteristic of Shropshire.

Investment was not made by Shropshire ironmasters in wrought iron for railway and marine uses, concentration upon which was to characterise other ironworking districts such as South Wales, Cleveland and Scotland. The new engineering sections required larger mills with more powerful machinery, served by larger banks of puddling furnaces than were required for merchant bar. Shropshire forges therefore became characterised by their comparatively small scale, similar to many Midland forges. The character of the Shropshire iron trade can therefore be defined in terms of its geography, its markets, and its historical context as a region where a mature ironworking culture had emerged by the first quarter of the nineteenth century.

9 DECLINE OF WROUGHT IRON IN SHROPSHIRE, c1870-1900

Wrought-iron production in Shropshire declined rapidly after 1870. The most common explanation for this decline has been that it was unable to compete with steel, which was superior in its physical properties and cheaper in its mechanised production.[1] The situation was compounded by the complacency of those ironmasters who failed to adopt new technology.[2] Given the importance already placed upon a stable market and an established workplace and business culture, a broader range of criteria must be included in the explanation of this decline. It must consider the market for wrought iron, competition from steel, availability of raw materials, transportation and labour. In addition, critical attention must be given to innovations such as mechanical puddling and new rolling-mill and steam technology. New technology was a significant factor in shaping the character of the iron industry in the early nineteenth century and the potential significance of later innovations, even if less significant than puddling, should not be automatically underestimated. Technological developments that occurred in the second half of the nineteenth century are described first, followed by an analysis of their impact on the wrought-iron trade.

9.1 New technology after 1850

Henry Bessemer (1813-98) read a paper to the mechanical section of the British Association at Cheltenham in 1856, outlining a new method of making malleable steel from pig iron, for which no additional fuel or labour was required. The principle of the process was that molten pig iron was run into a large vessel, or converter, through which a stream of cold air was passed. The action of the air caused the decarburisation of the metal, which was then cast into an ingot. The process attracted immediate and widespread interest from ironmasters, many of whom obtained licences to use it. Instant success was elusive, however, largely due to contamination of the pig iron from phosphorous, derived either from the use of phosphoric ores, or from puddling furnace cinders containing phosphorous that were frequently added to the charge of blast furnaces to improve their yield. Bessemer established a steelworks in Sheffield in 1858 to pioneer the process, which began to achieve commercial success in the mid

1860s. The first Midland works to convert successfully to steel manufacture was the Old Park Works at Wednesbury, Staffordshire, in 1864.[3]

The open-hearth furnace was patented by Frederick Siemens in 1856, and was improved in a further patent of 1861 when an associated gas producer obviated the need to use solid fuel. The gas producers were entirely separate from the furnaces and yielded combustible gases from solid fuel – often of inferior grades such as slack coal, coke dust, lignite or peat – in a similar manner to a gas retort. The furnaces worked on a regenerative principle whereby two chambers, known as regenerators, were piled with bricks in order to build up a large surface area. Exhaust gases were passed from the furnace through one of the chambers, in order to build up heat, and then the draft was reversed, so that gas now passed though the heated chamber and entered the hearth at a high temperature where it combusted. Meanwhile the products of combustion were passed through the other ‘cold’ chamber. By continuously alternating the direction of the draft, the furnace could be maintained at a high temperature and constant flame.[4]

Early gas-fired open-hearth furnaces were used for glass making, the melting of crucible steel, and were occasionally adapted as puddling furnaces, of which the example of Castle Ironworks has already been described. A further technical advance was achieved by Pierre and Emil Martin of Sireuil, France, who were able to make malleable steel by melting cast and wrought iron in a bath of molten pig iron in the open-hearth furnace. The Siemens-Martin method was a cheap way of making malleable steel using a bath of pig iron into which all manner of scrap, notably iron or steel rails, were melted.[5] In 1866 William and Frederick Siemens established their Sample Steelworks in Birmingham in order, as its name suggests, to experiment with the new process. William Siemens then built a steelworks at Landore, near Swansea, in 1868-9, and in 1868 the LNWR Crewe Works adopted the open-hearth process for manufacturing rails.[6]

The potential of the Bessemer and Siemens innovations was not lost on ironmasters. Both allowed a significant reduction in fuel consumption, and bypassed the need to have a refining stage based on manual dexterity. Both processes cast a fresh perspective on puddling as a cumbersome process, time consuming, wasteful of fuel and, as was argued, wasteful of iron as well. Whereas during the nineteenth century the capacity of individual blast furnaces steadily increased, the puddling furnace was no larger than it had been in 1800 and an increase in output could only be achieved by building more furnaces and hiring more puddlers. But there were other considerations in the appeal of Bessemer and Siemens, ostensibly intended to improve the welfare of workmen. The physical strength, and the capacity to withstand intense heat and the brightness of the flame, shortened the active life of the puddler. Exposure to the heat of the furnaces was exacerbated during hot summers, as happened in August 1871, when some works suspended production, 'for not even the trained English puddler can stand the fearful toil'. It is debatable, however, whether 'masters and men' were both

> anxiously watching the advent of a mechanical contrivance which will supersede such exhausting work as that performed by the puddler, and no object can be of greater importance to the trade than a consideration and discussion of whatever may be presented to their notice which has for its object the abolition of this well-known evil.[7]

Several improvements to the puddling furnaces were attempted, with varying degrees of success, to compete with open-hearth and Bessemer steel. Adaptation of the open-hearth furnace, the so-called gas puddling furnace, was one example. Double puddling furnaces were in use by the early 1860s, whereby the furnace had a double-sized bed with opposing doors, allowing two puddlers to work it simultaneously, with a consequent fuel saving. Other attempts were made to recycle the waste heat of blast furnaces for the puddling furnaces. Among several mechanical systems of puddling was a method introduced by Tooth & Yates as early as 1860, while another was advanced by James Nasmyth, and a rotating furnace was under experimentation at Dowlais in 1865.

Mechanical puddling was being tried at Wombridge Ironworks in 1863-4, where there were six experimental furnaces, plus another on trial at Horsehay and two at the

Patent Shaft and Axle Company's Old Park Works in Wednesbury.[8] The Wombridge furnaces included single furnaces built in pairs and placed back-to-back, in the customary manner, and double puddling furnaces where the iron could be stirred from two sides. The iron was stirred mechanically to ease the burden placed on the workman, and to accelerate the process and therefore reduce fuel costs. However, the most important stage, ensuring even decarburisation by exposing the iron to the current of air as the metal came to nature, was still performed manually. Mechanisation could not therefore supersede the workman's judgement. Nevertheless the proprietor of Wombridge forge, Henry Bennett, and his manager, Mr Fisher, claimed great fuel savings and a higher yield from the furnace. An average yield per shift by mechanical puddling was 28¾ cwt, compared with 22¼ cwt by hand. The double puddling furnaces were reckoned more efficient, as a ton of puddled iron was said to require 28 cwt of coal in a single furnace but only 17 cwt for a double furnace. A similar mechanism was said to be undergoing trials at the Victoria Works in Derby.

According to John Percy none of the mechanical puddling systems had achieved any commercial success by 1864, despite initial optimism and the fact that 'our ironmasters would only be too glad to dispense with the manipulation of puddlers, with whom so many difficulties have from time to time arisen'.[9] The most significant advance in puddling in the 1860s was made in the steel industry centred on Sheffield. John Brown's Atlas Forge, Cammell & Company's Cyclops Forge and Thomas Firth's Whittington Forge in Derbyshire all successfully employed puddling furnaces for steel making, increasing their yield and expanding their market into the engineering trades.[10]

A little more success was forthcoming in the 1870s – between 1865 and 1875 389 patents were taken out for improved puddling furnaces.[11] The Casson-Dormy mechanical puddling furnace was pioneered at some of the larger Staffordshire works such as Round Oak, Chillington, and the Darlaston Iron & Steel Company's works at Darlaston Green and King's Hill, but is not known to have been used in Shropshire. One of its inventors, Edward Smith-Casson, was manager of Round Oak.[12] 'Howatson's' patent puddling furnaces used waste heat to supply hot air to the furnace, thereby accelerating the process and decreasing fuel costs, and also underwent trials at the Round Oak Works in 1871.[13] The Iron and Steel Institute sent a commission to the USA in 1871, which returned with a favourable report on the puddling furnaces used by Samuel Danks of the Cincinnati Railway Ironworks, Ohio, where the iron was stirred mechanically.[14] Subsequently Danks puddling furnaces were built in Britain, mainly in north-east England, but totalling only seventy-four by 1873.[15]

Mechanical contrivances never succeeded in replacing the puddler. They could work only to a predetermined cycle, and as there was no scientific control over the materials charged into the furnace it was not possible to programme a machine to make the crucial judgements that would supersede the experienced eye. Interest in mechanisation of puddling dwindled in the later 1870s as it became clear that embracing new technology would be more profitable than improving old technology. But there was not necessarily a consensus within the trade as to the desirability of continuing with puddling. J.S. Jeans, secretary of the Iron and Steel Institute, condemned the traditional puddling furnace in 1881 as ‘crude, barbarous and wasteful’. Seven years later at a meeting of the South Staffordshire Institute of Iron & Steelworks Managers ‘a round of applause’ followed the suggestion that the puddling furnace still had a future before it.[16]

Steam hammers came into widespread use in the British iron trade after 1850 to replace tilt-hammers in the shingling process. The earliest was the invention of James Nasmyth (1808-90), introduced in 1842, followed by several other variants by engineers such as John Condie and W. Naylor. The extent of their adoption in Shropshire is not known directly. Trench Ironworks had two steam hammers in 1877, while Castle Ironworks is unlikely to have used old-fashioned tilt-hammers when a single steam hammer would have been sufficient to serve all the puddling furnaces at the works.[17] Of the older established forges, neither Old Park in 1856 nor Stirchley in 1872 had steam hammers, both having retained their traditional tilt-hammers.[18] Horsehay had three steam hammers by the time of its closure in 1886.[19] The Lilleshall Company manufactured steam hammers by 1873 and could therefore have supplied such hammers to Snedshill.[20] One of the initial obstacles to wholesale adoption of the steam hammer was that it was more complicated than the simple tilt-hammer. Parts for tilt-hammers, as for puddling and other furnaces, could easily be obtained from local foundries. The steam hammer was a more complex machine requiring more specialised components and skills in maintenance, and was supplied by engineering works.

There was also resistance to steam hammers on the part of the shinglers and perhaps also conservative ironmasters, evidence for which has been discussed elsewhere in relation to the Black Country.[21] As it fell by gravity, the tilt-hammer provided blows of a constant force, which enabled the shingler to judge the quality of iron from the puddling furnace according to its malleability and how much iron was lost during the hammering. By contrast, the force of a blow could be controlled when using a steam hammer, and an insinuation developed that it could successfully shingle inferior iron where a tilt-hammer could not, with a consequent loss of final quality.[22] The disadvantage of the tilt-hammer was that the power of the blow decreased as the size of the ball placed under it increased, simply because the head fell a shorter distance. The steam hammer, by contrast, could deliver a heavy blow whatever the size of ball placed under it. This made it particularly suitable where iron of large scale or section was being forged, for example for rails, engineering sections and ship plates, but less attractive for the smaller-scale sections produced by the Shropshire forges. Nor was the tilt-hammer immediately displaced as obsolete technology. The Round Oak Ironworks at Brierley Hill, Staffordshire, was the most modern plant in the Midlands when it was built for the Earl of Dudley in 1855, yet the tilt-hammer was preferred to the steam hammer. At its closure in 1894, the Congreave Ironworks at Cradley Heath, Staffordshire, operated both a steam hammer and a traditional tilt-hammer.[23]

Another advantage of the steam hammer was that a single hammer could cope with the output of approximately thirty puddling furnaces. Coupled with the building of steam engines of greater power, it allowed more powerful and larger mills to be erected, as has already been demonstrated above in the discussion of rail mills. A further innovation was the development of continuous mills. Charles While, of the

Taff Vale Works in Pontypridd, Glamorgan, patented in 1861 a continuous mill whereby iron was guided through consecutive pairs of rolls to produce bars or blooms of the required thickness, thereby bypassing much of the manual labour required for the old process. Dowlais installed a continuous mill in 1867-8. An alternative to the three-high roll, which had been in use at Stirchley in the early 1830s, was the reversing mill, pioneered by John Ramsbottom at LNWR's Crewe Works in 1866. The mill was geared in such a way that it reversed every few seconds and was especially suitable for heavy work. A continuous mill was also devised in 1861 by Charles Bedson of the Manchester Wire Works for drawing wire rods.[24]

Various modifications to the design of the works could be used in order to maximise efficiency and reduce fuel costs. Utilisation of waste heat to raise steam and for hot blast was among the most widespread. Molten iron from the blast furnaces could be channelled direct to the puddling furnaces. At Round Oak, the forge was redesigned with the puddling furnaces erected in a semi-circle around a shingling hammer.[25] But it was not necessarily the case that failure to adopt such new innovations was fatal. None of the new Shropshire ironworks erected after 1850 was served directly from a blast furnace, while the evidence of Wombridge suggests that conventional layout of the forge with its linear arrangement of puddling furnaces, mainly in pairs, was still adhered to. The reversing mill was designed, as stated above, for the kind of heavy work that Shropshire did not specialise in. None of the Shropshire works adopted the continuous wire-rod mill, but then nor did other British works until the last decade of the nineteenth century. Its development was to occur more rapidly in the USA and Germany than in Britain.[26] Nevertheless, 'diminishing sophistication' has been cited as one of the factors that led to the failure of Shropshire forges.[27]

The manner in which certain sections of the British iron and steel industry did not adopt best-practice technology has been considered by Elbaum more generally in the context of the early twentieth-century steel industry.[28] Some of the theoretical logic of the early twentieth century is applicable to the Shropshire iron industry in the nineteenth century, throwing certain issues into stronger relief. As argued above, failure to adopt new technology was not necessarily a sign of ignorance or prejudice.

Existing markets had reached maturity in Shropshire by 1830 and investment was only made in improved methods or greater capacity when prospects of a secure market for the increased output were judged sufficiently good. This accounts for the growth of the number and capacity of forges in the early 1830s, and the significant increase in the charcoal iron sector among forges that had no established charcoal culture. The prospect of entering new markets, such as the rolling of rails and later of steel ingots, was constrained by the need to adopt new technology embodied in capital-intensive plant. It was also influenced by the prospect of finding a sufficient market for the new products at the entry-level capacity, in addition to maintaining the existing market. Where there was a delay in capitalising on growth markets, competitors were able to gain a foothold, increasing the risks for firms who hesitated. It was also argued that the institutional structure of the British steel industry, despite its apparent adherence to free trade principles, constrained the actions of individuals. The policy by 1914 was to attempt co-ordinated action. Such policies had only been partially successful in the iron industry, and were almost always organised on a regional basis. But the institutional structure was a significant a factor in technological change in both the iron and steel industries. The customs of the forge militated against improvement of management organisation and provision of technical education, but the family-run firm was an equally rigid structure that promoted a conservative outlook.

9.2 The end of wrought-iron making in Shropshire

In 1871 there were eleven ironworks making wrought iron in Shropshire, but only two of these had survived by 1900. The closure of forges is examined on a case-by-case basis, followed by a discussion of more general factors in that decline.

When the lease of Old Park Ironworks expired in 1855 Beriah Botfield III initially negotiated a one year extension. In subsequent negotiations Botfield could not agree terms with the landlord, Robert Cheney, over the further renewal of the lease. A lack of previous business experience, and specifically experience of the iron trade, has led to an argument that he was guilty of poor judgement in losing the lease of the Old

Park Estate, thereby exposing the inherent limitations of family-run industrial dynasties.[29] This presupposes that, from the perspective of 1856, ironworking at Old Park was likely to have remained profitable for the foreseeable future. In fact most of its best reserves of ironstone and perhaps coal had already been exhausted. Seeking lower terms may have simply expressed Botfield's lack of confidence in the long-term future of the Old Park Estate, which clashed with a landlord's over-optimistic forecast of its long-term profitability. Furthermore, ironworking tied up capital that might have been better invested elsewhere. Thomas Botfield in 1790, as well as his three sons in 1801, looked to the iron trade for their best prospect of advancement in a manner that was not automatically the case in 1856. Beriah Botfield probably had higher and broader expectations. He was a land owner, scholar and MP, demonstrating the considerable social advancement made possible largely through a successful family business. To continue with a strategy devised for the late eighteenth century may have been judged too risky. A similar quandary faced William Crawshay II of the Cyfarthfa Ironworks in Merthyr Tydfil, when the lease there expired in 1864: should he renew it or retire from the iron industry having made substantial profits that could be invested elsewhere?[30]

The ensuing history of Old Park shows that if Botfield erred in losing the lease then the error was not catastrophic. The new Old Park Iron Company failed in 1872 and following liquidation the Old Park Estate was sold to Edward Henry Thomas in 1873.[31] The new owner promptly leased it to the Wellington Iron & Coal Company.[32] The collieries were kept working and the furnaces remained in blast until 1877.[33] Significantly, however, the forge ceased working altogether in 1872 and was the first component of the industrial enterprises at Old Park to close. The forge buildings were demolished in 1874.[34] As early as the 1850s Old Park could no longer be classed as a large-scale forge. In 1856 it had fourteen puddling furnaces and three charcoal fineries, while the figure of sixteen furnaces in the *Mineral Statistics* for 1861 probably refers to a combination of puddling furnaces and charcoal fineries.[35] Some investment appears to have been made subsequently, as the forge was said to have thirty-one furnaces (a combination of puddling furnaces, charcoal fineries and perhaps even heating furnaces) in 1871, but adding puddling furnaces did not necessarily signify a new modernising era.[36] The evidence of the Old Park blast furnaces is probably more revealing of the culture at Old Park. In 1869 the four blast furnaces were described by Thomas Plum, the works manager, as nearly fifty years old and all approximately 45 feet (13.7m) high. One of these furnaces was rebuilt and raised to 60 feet (18.3m) in height, but continued to smelt with cold blast.[37]

Stirchley forge fared little better. It remained part of Beriah Botfield's extensive industrial concerns, although the loss of the Old Park Estate was said to have hampered the routine access to different parts of Botfield's remaining estate, which also included blast furnaces at Dark Lane and Hinkshay, in addition to collieries and ironstone mines. Hitherto minor requirements like the supply of water to the Stirchley forge could now only be secured by paying a yearly rent on the forge pond to the Old Park Company.[38] In 1873 the trustees of Botfield's estate were instructed to sell by Isabella, Beriah Botfield's widow who had subsequently married Alfred Seymour MP. The intention was presumably to retire from industry rather than risk future capital investment or continuing to operate at a loss. By 1872 neither the forge nor the furnaces were profitable and the forge was working at a reduced capacity.[39] The estate was purchased in 1873 for £25,000 by the Haybridge Iron Company, who continued to operate Dark Lane and Hinkshay furnaces.[40]

Pig iron, coal and clay industries continued as before but the Haybridge Iron Company does not appear to have taken any interest in maintaining production at the forge. In 1874 the company built a nailworks on the site of Stirchley forge, employing Samuel Vowles as manager.[41] The nailworks was sold for £2500 in 1876 to John Maddock, formerly one of the partners.[42] In 1878 Maddock moved to the Great Western Works close to the railway at Oakengates, and subsequently diversified into manufacturing malleable castings for the engineering trades. The Haybridge Iron Company's purchase of the former Botfield family holding was probably an opportunity to take possession of its working collieries, although a decision was taken to close six collieries in 1874 because the cost of raising it exceeded the sale price. It also operated brickworks at Randlay and Hinkshay.[43]

An 1872 inventory of the Stirchley forge lists twenty-nine puddling furnaces on two sites, including a 'new forge', but all this was included in an earlier inventory of 1852. Similarly the merchant, hoop, sheet and plate mills had already been built by 1852.[44] It has already been noted above that the output of Stirchley forge changed little throughout the whole period of its operation. There is no evidence, therefore, that any significant investment had been made in the forge during its final two decades of operation. Was this a failure, or a calculated move to treat wrought-iron manufacture as viable only in the medium rather than the long term? It may be significant that the site was redeveloped, albeit briefly, to make finished rather than semi-finished iron. It is also worth noting that the Haybridge Iron Company considered other branches of the business viable. Smelting continued at Dark Lane to 1874 and Hinkshay to 1876, after which the company relied on the coal and clay industries.[45]

A similar picture emerges with the closure of the Ketley Ironworks. The forge ceased work in 1876 when the Ketley Company offered the entire enterprise for sale. The forge was comparatively small, having only twenty puddling furnaces in 1873, suggesting that it had not been subject of recent investment. It was singled out by potential buyers as not worth continuing. The works manager, John Williams, suggested that demolition of the forge would make the Ketley concern a more attractive proposition: 'Everyone who has been to look over the Ketley Works condemns the forges and mill plant. They say Best Bars can be made cheaper in South Staffordshire. There is no doubt they are correct in what they state – under these circumstances it would, in my opinion, be advisable to sell off the plant without further delay.'[46] Ketley was eventually purchased by Nettlefolds, retaining John Williams as estate manager and also installing him as manager of Castle Ironworks. There is no evidence that Nettlefolds had any interest in maintaining the blast furnaces at Ketley, which did not work again, the firm's principal interest being access to its mineral reserves.[47]

Horsehay is alone among the integrated furnace-forge ironworks of the late eighteenth century where the forge outlasted the furnaces. The Horsehay furnaces had been blown out in 1862. The last of the Coalbrookdale Company's furnaces were

Lightmoor and Dawley Castle, which were blown out in 1882 and 1883 respectively (figure 8).[48] Henceforth the forge had to rely on supplies of pig iron purchased on the open market, which undermined the logic of a large forge at Horsehay, sited there in 1784 because of its proximity to the furnaces. The forge closed in 1886 and the site was converted to the manufacture of parts for bridges.

James Foster died in 1853 and his ironworking interests, including Eardington and Hampton Loade forges, were inherited by his nephew William Orme Foster. The Staffordshire forges in which James Foster had had an interest were subsequently managed by John Bradley & Company. Foster's main interest in Shropshire by 1853 was the blast furnace site at Madeley Court (figure 8). Hampton Loade Forge continued working until 1866 when its lease expired. Eardington continued to work until the expiry of its lease in 1889 and therefore outlived all the larger puddling works of eighteenth-century origin.[49] Reasons for the closure of Eardington and Hampton Loade are not difficult to understand. Both were detached from the coalfield, were sited in the eighteenth century to make use of water power, with easy access to the River Severn. After 1850 the river trade declined and the site of neither forge was attractive enough to make future investment there worthwhile.

The most profitable of the Shropshire ironworking concerns was the Lilleshall Company. Snedshill probably benefited from being part of a large and prosperous business empire. The company built Bessemer converters at its Priorslee furnaces in 1881, and in 1898 moved a mill there from Snedshill in order to roll billets and bars. These were then re-rolled into smaller finished sizes at Snedshill, comprising wire, bar and boiler plate, the plates being required for the company's engineering works at New Yard (figure 8). Snedshill survived as a wrought-iron works into the twentieth century, retaining eighteen puddling furnaces and four furnaces for balling and working scrap by 1908, although its wire mill closed in 1902. Production continued until 1925.[50] The forge, described as 'semi-ruinous', was purchased by John Maddock & Company of Oakengates in 1939.[51] The relative importance of wrought iron to the Lilleshall Company must have declined slowly, especially as open-hearth steel making supplemented Bessemer steel at Priorslee in the early twentieth century.

Castle Ironworks also converted briefly to steel manufacture. The works prospered in the 1870s, having twenty-seven puddling furnaces, two wire mills and a merchant mill by 1877.[52] Under the management of Edward Steer, further improvement was made by erecting a Bessemer steel plant in 1883-4. Jones' statement that there had been a blast furnace at Castle is contradicted by the evidence in *Mineral Statistics*, and it seems likely therefore that the converters were charged from pig iron melted in a cupola furnace.[53] Charging the converter with selected pig iron melted in a cupola was common in the 1870s.[54] The Bessemer plant at Castle Ironworks was working early in 1884, a second converter soon being added, but a decision was subsequently taken to move the plant closer to a source of pig iron. In 1886 the steel plant was dismantled and moved to a new site at Rogerstone, near Newport, Monmouthshire. Castle Ironworks was sold to Benjamin Talbot, formerly of the Haybridge Iron Company, and his son, also Benjamin, for £13,000.

Castle was subsequently under the technical direction of Benjamin Talbot junior (1864-1947). Some or all of the gas puddling furnaces were converted to conventional open-hearth furnaces for making steel. Talbot clearly considered this an important step forward for small Midland forges. In a lecture given in 1888 he specifically drew attention to the fact that ingot steel was superseding puddled iron in many branches of the industry, unfortunately without being more specific. The Siemens-Martin process was ideal for small forges making 200-300 tons per week, and could work small ingots of 7-8 cwt rather than the larger 15-30 cwt ingots used for girders and plates, which needed more powerful rolling mills. Small open-hearth furnaces could easily be added to puddling forges to use existing mills and to allow a phased transition to steel.[55] Unfortunately Castle Ironworks failed in December 1888 when Benjamin Talbot senior was declared bankrupt.

Talbot's bankruptcy was not necessarily a failure of long-term strategy, as it could have been caused by failure to satisfy creditors in the short term. Clearly there was no lack of enterprise in adapting to new technology, as the ensuing career of Benjamin Talbot junior demonstrates. After moving to the USA in 1890 Talbot initiated open-hearth steel making at the Southern Iron & Steel Company of Tennessee. By the end of the decade he had moved to Pencoyd Steelworks in Pennsylvania where he developed an improved method of making steel in the open-hearth furnace known as the Talbot process. This was introduced to Britain from 1901 when Talbot was employed as a consultant to the Cargo Fleet Iron Company of Middlesborough, becoming its managing director in 1906. The Talbot process was to be influential in steel technology in the first half of the twentieth century.[56]

The departure of Nettlefolds from Shropshire has been interpreted as a failure of management.[57] This is hard to sustain given that Edward Steer managed both the conversion to steel and the subsequent move to South Wales. Nor is the argument that a move to South Wales was needed to gain closer proximity to sources of pig iron entirely satisfactory. Pig iron was still available in the Midlands, even if there was a decline in output.

The Eagle Iron Company of Hollinswood is also said to have made steel on a small scale, but failed in 1887 when it was in liquidation. The company was wound up in 1890.[58] Of other forges, Lawton and Haybridge diversified away from wrought-iron manufacture. Lawton, renamed the Coalport Works, was taken over by Edge & Sons as part of its chainworks, and continued to manufacture wire rope and chains, which it supplied to mining companies in Europe, North and South America, Australia and India.[59] However, the firm had already diversified its output, making agricultural implements at Madeley by 1863.[60] The Haybridge works turned to the manufacture of finished steel, including wire rods, and as Flather Bright Steels Ltd continued to 1983.

The Shropshire Iron Company at Trench continued to make wrought iron into the twentieth century, having thirty-nine puddling and other furnaces in 1908, and wire, hoop, drawing and galvanising mills. It also installed plant for the manufacture of brass, copper and steel wire.[61] James Patchett continued managing the works until 1926. It closed in 1931.[62]

9.3 Factors in the decline of Shropshire forges

Shropshire ironworks can be loosely divided into the old family concerns and the newer limited companies. The old family concerns were of eighteenth-century origin and integrated smelting and refining, then branched out into sales of coal and the clay industries after 1850. The limited companies, often with a strong family core, operated the newer forges that purchased pig iron from external sources. The Lilleshall Company is the only ironworking empire that spans both categories. Certain general characteristics are common among the former category. The diminution of mineral reserves that had been worked over a long period affected all but the Lilleshall Company. In 1871, when the Iron and Steel Institute visited Shropshire, it observed that the Lilleshall Company 'make altogether much more than a third of the iron made in the county … for which they have a greater variety of ores at command than any other firm.'[63]

The decline of iron ore reserves, especially when it is contrasted with the richer reserves of the north of England where the iron industry was rapidly expanding, explains the decline of Shropshire iron in general terms. But it does not explain specifically why the forges declined when they did. Old Park and Stirchley forges closed in 1872, an otherwise buoyant year in the wrought-iron trade. But closer examination shows this to have been coincidence. Both Old Park and Stirchley were sold to new companies who did not see the forges having any long-term future. From this perspective, lack of investment was not a failure of management but a calculated long-term strategy. Old Park had been developed from 1790 to exploit the mineral resources of Isaac Hawkins Browne's estate. It can be argued that this policy was followed consistently throughout its industrial history, but that by the 1870s its most viable resources were coal and clay rather than iron. Investment in the forges always followed investment in the smelting branch of the trade, it never preceded it.

There is no evidence that either Old Park or Stirchley was significantly affected by competition from steel. Nor was Ketley when four years later its forge was declared no longer viable. Evidence quoted above makes it clear that it was with Staffordshire wrought iron that the Ketley forge struggled to compete, not with steel. Again, lack of investment was not necessarily a matter of poor management but long-term prospects. The logic of Horsehay forge was undermined by the cessation of smelting by the Coalbrookdale Company, although its manager, W.G. Norris, cited problems of transportation and labour costs as reasons for the difficulty of the local forge trade.[64] These will be considered below.

It may not be a coincidence that some of the forges that closed were superseded by firms making finished iron products – bridges at Horsehay, nails at Stirchley, tramcars at Castle – while the Haybridge and Lawton Ironworks diversified away from wrought-iron manufacture. The Coalbrookdale Company and Lilleshall Company foundries both also survived the difficult economic conditions of the late nineteenth century. It suggests that the market for finished iron was more profitable during the depressed years of the 1870s and 1880s than semi-finished iron. This is crucial to understanding why investment was directed away from the traditional products. It should not be assumed that a company's best chance of making a profit was to continue in businesses set up to compete in the trade of the late eighteenth or mid nineteenth centuries.

It has already been demonstrated that the decline of Shropshire's older established forges happened independently of competition from steel. Studies of the growth of the steel industry have focused on high-output products at large-scale works. These have shown that steel was produced commercially from the mid 1860s and that steel rails were found to be more durable than wrought-iron rails and were superseding them in the 1870s. For marine engineering, steel ship plates superseded wrought iron somewhat later. Open-hearth steel for ship plates was first purchased by the Admiralty from Siemens' Landore Works in 1875. In 1880 15% net tons of ships were built with steel plate, but by 1888 the figure had risen to 91%.[65] Consett Ironworks could produce 1700 tons of finished iron per week, mainly ships' plates, by the mid 1870s, but by 1886 over half of Consett's plate production was steel.[66] It was also in the 1880s that steel replaced iron for tinplate and boiler-plate manufacture.[67]

These were markets that did not affect Shropshire, with the exception of boiler plates. In the traditional markets for Shropshire wrought iron – merchant bar for manufacturing tools, locks and other hardware products, and wire for manufacturing screws and nails – steel did not triumph until after 1900. For certain uses where resistance to corrosion was important, like chains, cable, and ships' nuts and bolts, wrought iron was still preferred up to 1914.[68] The Black Country wrought-iron trade declined in the last quarter of the nineteenth and first quarter of the twentieth century, as did many of the hardware trades it served. By 1883 one fifth of its iron forges had diversified to roll steel billets purchased on the open market, but iron and steel were not competing for the same market at this time.[69] Le Guillou has argued that the decline of iron forges in the Midlands, and by extension therefore Shropshire, was accelerated by competition from imported iron. From the 1870s Belgian bar, sheet and wire was sold into the Midlands below the price offered by Black Country ironworks, followed by the rise of cheap German nails and wire in the 1880s.[70]

The impact of more general factors in the decline of wrought iron also needs to be considered. W.G. Norris, of Horsehay, described a period of depression in the iron trade that began in the mid 1870s and had not lifted by the time the Horsehay forge closed in 1886. Norris cited the policy of railway companies, restrictions on labour as a result of government legislation, leading to higher wages costs, and the expansion of the steel industry.[71] None of these factors was exclusive to Shropshire, as they affected all of the ironworks in Britain. They were not, therefore, fundamental reasons for decline, only factors that exacerbated an already unfavourable predicament.

It has been argued both that wages in the Shropshire iron industry were too high to compete economically, and too low to retain sufficient skilled men.[72] Although there have been no studies that compare actual wages paid (which would also have to look at peripheral benefits and length of the working week), the use of wages to gauge competitiveness does not stand up well to scrutiny, not least because wage levels were notoriously volatile. Given that Shropshire ironworks specialised in specific products and did not compete in high-output markets such as rails and marine engineering, any national comparison is of limited significance. The 'Thorneycroft' scale that regulated wages at works producing high-quality Staffordshire marked bars was introduced in 1848. This was part of a long tradition of equalisation of wage rates in South Staffordshire that had begun at the quarterly meetings. By the 1870s Shropshire ironmasters maintained the tradition by engaging in informal discussions on wage levels and conditions such as the length of the working week and time off during shifts.[73] Shropshire ironmasters were opposed to trades unions, but there is no evidence that they were more antagonistic than any other ironmasters. When in 1873 W.G. Norris heard of a union forming in the Horsehay forge he determined to root out the activists and get rid of them.[74] The sound of ironmasters and managers complaining of troublesome puddlers was a familiar refrain across the British iron industry. Their complaints are countered by the fact that one of the puddling works that survived the depression of the 1880s was the Shropshire Iron Company, which had worker shareholders.

During the economic depression of the 1870s and 1880s the South Staffordshire ironmasters adopted a largely successful strategy of collective bargaining. Wage rates were negotiated through conciliation boards made up of an equal number of employers' and trades union representatives, plus an independent arbitrator. A sliding scale tied workmen's wages to the market price for iron, and proved workable once the levels had been defined to the satisfaction of both parties. In 1874 the 'Derby scale' was introduced, whereby puddlers' wages could vary between a maximum of 12/6 per ton and a minimum of 9/6. Wage bargaining worked in the employers' favour by giving them flexibility over pay rates. By offering a compromise it imposed responsibilities on trades unions to maintain production at all times and thereby reduce any losses incurred by militant action. It was the combined effect of this more complex strategy that allowed longer-term stability for South Staffordshire. It also shows that wages constitute a crude an unreliable index when studied in isolation. But the 'Mill and Forge Wages Board for South Staffordshire' was confined to that strict geographical area. It was undermined in the 1880s when other Midland firms tried to undercut Staffordshire prices by reducing their own wages bills. The result was that the wages board was reorganised in 1887 to include firms in Shropshire, North

Staffordshire and Worcestershire.[75] By this time, however, most of the Shropshire forges had already ceased working.

The question of transportation affected the iron trade regionally insofar as Britain's numerous railway companies set their own freight rates. A dispute between Midland ironmasters and railway companies who charged higher rates for the transport of freight from the Midlands, as opposed to goods from South Wales and Middlesborough, was settled in 1884.[76] In the market for bar iron such price differentials mattered, but in the comparatively specialised market for wire and wire rods, competition from South Wales and Middlesborough was less significant. Again, such arguments assume or at least suggest an homogenous national output of iron, which this and the foregoing chapter have demonstrated was not the case. Moreover, Shropshire was in no worse a position than Staffordshire.

9.4 Conclusion

Steel was not the most important factor in the demise of wrought-iron manufacture in Shropshire, as has been commonly supposed. In fact, a variety of factors contributed to the closure of forges after 1870. The older-established industrial estates invested in sale coal and brick and tile manufacture from local clays after 1850. Diversification meant that wrought iron was no longer the spearhead of economic activity on estates such as Ketley and Old Park as it had been previously. The discontinuation of forges at Ketley, Old Park, Horsehay and Stirchley can therefore be seen in part as the consequence of a wider strategy of diversification. They cannot be dismissed simply as victims of conservative management. All of the industrial estates were hampered in the late nineteenth century by diminishing mineral reserves, with the exception of Lilleshall, whose Snedshill forge continued to work into the twentieth century while there was still a market for wrought iron.

Reasons for the demise of the railway-era forges were numerous and not all are found in common, except that they occurred in the 1870s and 1880s during a depression in the forge trade, and when competition with Belgian and German iron was increasing.

The Haybridge Iron Company, in switching to the manufacture of finished iron, highlights the higher profitability of this sector of the industry, and was one of a number of works that specialised in finished iron. Closure of forges and blowing-out of blast furnaces left a pool of skilled labour that may have encouraged investment in these industries, although some men emigrated to the USA.[77]

On present evidence it is unclear why forges failed to convert successfully to open-hearth steel manufacture, although such a conversion would have necessitated penetrating new markets. It is not clear whether the bankruptcy of Talbot at the Castle Ironworks and the liquidation of the Eagle Iron Company at Hollinswood were a consequence of long-term trends or short-term misadventure. It is not clear why Nettlefolds moved their steel-making plant out of Shropshire, or why open-hearth steel manufacture did not attract enough investment. But similar questions remain unanswered for the Midland iron industry generally, where only a minority of ironworks converted to steel making, or purchased steel billets for re-rolling. Although there is no national stereotype into which Shropshire can be fitted, it was similar to and its fortunes were related to the Midland iron trade in general, operating at about 10% of the capacity of the Black Country. The decline of Shropshire was part of the general decline of the Midland iron trade.

10 CONCLUSION

This study has described the wrought-iron industry over three centuries. It has discussed well-known technological developments – the transition from charcoal to mineral fuel, the introduction of steam power, the shift to the coalfield and the steady increase in capacity – but has sought to explain them in a broad technological, economic and cultural context. This approach has paid dividends in that it has highlighted factors other than technology that were important in shaping the industry. Examination of the market has been important in explaining the longevity of older technology such as charcoal iron. Examination of its business culture has shown how Shropshire developed a regional identity in the eighteenth century and maintained it in the nineteenth century.

The most significant factors in the Shropshire forge trade were the existence of blast furnaces in the county, the regional market for wrought iron and transport facilities that linked forges with customers. In the seventeenth and early eighteenth centuries Shropshire forges used the River Severn to serve mainly the Midland manufacturing district, when individual forges had often been established by ironmasters or other men already connected with that Midland trade. This regional character had not significantly changed by the early nineteenth century, when the River Severn remained the dominant mode of transportation for Shropshire iron. Shropshire forges constituted a mature industry with a reasonably settled culture by the mid nineteenth century, but were not static. The specialisation in charcoal wire, used for an increasing number of articles manufactured in Birmingham and in the north of England, is an example of change within an established market structure.

By the mid nineteenth century the Shropshire forge trade retained a strong regional identity, in spite of rapid expansion of the iron industry elsewhere in Britain, including South Wales, Cleveland and Scotland, and the potential for a national market offered by the railway network. There is little evidence that newer ironworking districts provided serious competition for Shropshire. Despite being a small-scale producer, investment was justified in six new Shropshire works after

1850, all of which served traditional markets for Shropshire iron, with their standard products such as wire, plates and merchant bar. Other regions targeted specific areas of the market, such as shipbuilding and the railway industry, and therefore it is not possible to speak of a universal or national iron industry except in general terms.

One of the principal aims of this study has been to use a regional perspective to inform a wider debate about technological change. It has challenged technologically determinist views of the wrought-iron industry, arguing that technological change cannot be understood by isolating it from its broader context. Change in the iron industry did not occur simply by the application of new technology, except where tardy management inhibited it, concurrent with the obsolescence of earlier technology. Such an approach has had an impact on the way that the history of the iron industry has been written. The technological approach to iron industry history has, in effect, been to identify successful technology and then to consider the preceding years as following a path to the ultimate destination. There is no evidence that technological development moves in such a straightforward way.

The importance of technology should not, however, be underplayed. The East Shropshire Coalfield was quick to take advantage of the new technology of both mineral fuel and steam in the late eighteenth century. It emphasises how particular regional conditions can be crucial to specific technological advances. The coalfield adapted with comparative ease to mineral fuel because it already used coke in the smelting of iron ore, and therefore coal was already part of the ironworking economy. Similarly, some of its ironworks were manufacturers of steam engines and were closely involved in corresponding technological developments. These conditions allowed a significant expansion of the forge trade in Shropshire in the late eighteenth century, in both the number of forges and their capacity.

It has been customary to talk of an industrial revolution in the iron industry in the latter half of the eighteenth century, but this is questionable. Although this study has documented well-known developments, it has also revealed unexpected evidence, such as the survival of charcoal iron techniques, and the longevity of workplace and business culture. Evidence of the forge trade shows that technological developments were established slowly, and were used in conjunction with earlier technology. Study of workplace and business operation has shown that new technology made little impact on the way the trade conducted its business or organised its labour force. By the mid nineteenth century ironmasters continued to invest technical authority on a core group of skilled men, just as they had done a century earlier.

Previous studies of technological change have stressed the importance of individuals. It is difficult to give an unqualified endorsement to this, especially where it concerns the manual processes of working iron. The trend began with nineteenth-century historians such as Percy and Smiles, and was cultivated by the Reynolds family in respect of the Cranage brothers. It was continued in the twentieth century by historians who based their narrative of change on the award of patents. Within the context of the history of the industrial revolution, it belongs to a well-defined tradition of the heroic inventor.[1] However, a forge was essentially a collaborative culture and all the technology that has been discussed in this study was based on manual operation. That any individual can claim to have 'invented' any of the techniques seems less certain when placed under close scrutiny. Henry Cort and his men at Fontley perfected a technique – Cort never claimed to have invented the working of iron in a reverberatory furnace. The basic principles of stamping and potting and puddling were known before either of them became widely used but, as the case study of puddling at Horsehay showed, familiarity with basic principles was a long way from mastery of a specific technique. What is certain is that the manual techniques of the forge should be treated differently from developments in furnace technology by, for example, Henry Bessemer and the Siemens brothers.

The economic approach that has dominated thinking about the iron industry, whereby the progress of technology was directly linked to the costs of production, must be broadened to take account of the complexity of the market. Evidence from Shropshire has shown only limited evidence for a national market, at least in the kinds of iron produced in the county, even in the nineteenth century. It has also shown the importance of differential grading of iron according to specific market requirements.

The cost of puddling iron was only one cost among many, including the variable cost of rolling iron to the required section, and the cost of transportation. It has also been shown that the grades of iron affected the adoption of new technology or the continuing viability of older technology. Large-scale investment was made in the charcoal iron trade by coalfield ironworks in the 1820s and 1830s on the basis of market conditions. Granulating iron and reheating it in pots or piles outlived the patent processes of the Wood brothers and Wright and Jesson because it produced high-quality iron for boiler plates. By contrast, there was a comparative lack of interest in steam hammers among most of the established Shropshire forges in the mid nineteenth century, largely because it was not needed for the type of iron produced in the county. The new technology of steel was not primarily responsible for the decline of wrought-iron making in Shropshire. In the wire and hardware manufacturing industries that Shropshire served, iron was still preferred well after most of the Shropshire forges had closed.

It is the sustained market for charcoal iron in the nineteenth century that most persuasively forces us to rethink assumptions about new and obsolescent technology. Historians and archaeologists of the iron industry must acknowledge technological diversity, based upon market requirements and regional historical conditions.

Appendix 1

Workmen and women at Horsehay forges and rolling mill, July 1796

Forges

Samuel Purcell	finer
James Skelton	finer
Enoch Callear	helping finers
Elizabeth Onions	helping finers
Daniel Williams	breaking iron [stamping], washing & weighing stamped iron
Fanny Hazlehurst	filling pots
John Lambert & Co	heating & shingling
Benjamin Norton & Co	planishing
William Bird & Co	drawing out bar iron, weighing
William Jourdan	weighing half blooms and bar iron
Joseph Baugh	wheeling pigs & castings to finery forge
William Jones	tending water engine
Thompson Callear	attending hammer engine
William Fletcher	attending hammer engine
James Tranter	picking black scraps, wheeling slack from forge
James Tranter junior	learning to work the hammer engine
Richard Purcell	wheeling stamped iron to shingling forge and taking cinders
John Weaver	forge carpenter
William Duddel	repairing furnaces
William Thompson	weighing
James Corfield & Co	loading
Edward Tranter junior	writing in the office
William Ball & Co	loading and unloading
John Hazlehurst senior	tending the forges on Sundays
Joseph Bell	tending the forge engines
Francis Driscoe	loading iron
David Jeffrey	sawing helves
John James	weighing
John Bowen	weighing

Other employees engaged in labouring or other menial work were Robert Callear, Richard James, Thomas James, John Hazlehurst, John Lambert junior, Charles Lambert, Thomas Baugh, Samuel Shepherd, Thomas Jones, John Wilcox ('a boy'), Richard Underwood.

For weighing plates a number of workmen are mentioned included Benjamin Norton senior, who may have employed them and may be referred to under planishing: Benjamin Norton Junior, Joshua Norton, Michael Jones, Samuel Deakin, Daniel Williams.

Rolling Mill

John Swain & Co	rolling bars & co
William Hazlehurst & Co	rolling bars, round iron, pan plates and boiler plates
Sampson Eadon & Co	rolling bar iron from faggots and round iron

Source: SRR 245/145, Horsehay Ironworks wages book, 1796-8.

Appendix 2

Workmen at Old Park forge 1807-8

John Richards	running-out fire
Robert Dabbs	running-out fire
Skelton	puddler
Samuel Lavender	puddler
David Griffith	puddler
Edward Harris	puddler
Joseph Lavender	puddler
James Lavender	puddler
S Matthews	puddler
Thomas Matthews	puddler
R Morgan	puddler
D Williams	puddler
John Tart	
John Tyler	
Forrester Picking & Co	
J Hodgkiss	
Lloyd & Poole	
John Ball & Co	
John Sims	roller
J Swift	roller
Richard Lees	roller
James Lees	apprentice roller
J Tilley	
Joseph Felton	forge carpenter

Source: BOT 1/6/1, compiled from notes made by Gilbert Gilpin.

Appendix 3

Principal workmen at Old Park Forge & Mill 1832-3

Running-out fires

James Browne & Son	(to April 1833)
James Williams & Co	(to Aug 1832)
Haden & Adams	(Sept-Oct 1832)
James & Thomas Tyrley	(from Nov 1832, & usually called J Tyrley & Co)

Puddlers

Thomas Astbury	Richard Tart	Moses Lees	
David Lloyd	William Attwood	+William Jones & Co	George Ellis
Richard Morrall	Thomas Morrall	William Ellis	Leonard Ellis
+William Boden & Co	+Isaac Tipton & Co	Charles Perry	Joseph Southern
Richard Thomas	John Ellis	Tipton & Ellis	Samuel Priest
Samuel Lee	Thomas Colley	Isaac Tipton jnr	*R Pitchford
*[James?] Swift	J Perrings	G Bucknall	

Charcoal finers

George Allender & Co	(to Aug 1832)
Paul Edwards & Co	
William Allender	(from Sept 1832)
Joseph Matthews	(from April 1833)

Other principal workmen

John Edge & Co	shingler
*Lane	shingler (May 1833)
John Ayers & Co	rollerman, puddlers' mill
John Hyde & Co	heating bars
William Hill & Co	heating bars
John Lloyd & Co	heating bars (May 1832)
Thomas Hodgkiss & Co	heating plates
George Brazier & Co	rolling bars and wire rods
Robert Parker	rolling bars (from July 1832)
William Millington & Co	rolling and slitting bars and rods
Samuel Guest	plate roller
Michael Tart	blacksmith
William Simms	bricklayer
Samuel Skelton	iron cutter
Benjamin Garbett	engineer
James Sadler & Co	roll turner
William Williams	making cutters, and sawyer

Carriers of iron

William H Franks	Thomas Wright	Hugh Cullis

* denotes men who are not listed specifically in the wages accounts but who were fined for neglect of work. Lane presumably worked for John Edge, while Swift and Pitchford were probably employed by the principal puddler, who was William Jones in May 1833.

+ denotes puddlers who also made plates

The list gives eleven puddlers per month in April 1832 rising to thirteen in February 1833. Two names are given for refining iron until James Browne & Son departed in April 1833. Browne refined iron for the puddling forge only. Thereafter only one name is given and more than half of the iron refined was for the charcoal fineries.

Source: BOT 2/8/4, Old Park forge wages accounts 1832-3.

Appendix 4

Principal Workmen at Stirchley Forge and Mill, 1849

		Year of birth	*Age in 1849*	*Place of birth*
ROWLEY, George	puddler	1813	36	Wellington
TART, Edward	puddler	1814	35	Dawley
GRIFFITHS, John	puddler			
BOOTH, Jeffrey	puddler	1810	39	Staffordshire
TART, Thomas	puddler	1825	24	Shifnal
HOLMES, Simeon	puddler	1798	51	Dawley
HOLMES, William	puddler	1802	47	Dawley
POULTNEY, Richard	puddler	1822	27	Shropshire
PITCHFORD, Richard	puddler	1795	54	Wellington
CUXON, Thomas	puddler			
DODD, Hugh	puddler	1821	28	Stirchley
HISTON, Joseph	puddler			
MILLWARD, George	puddler	1825	24	Dawley
PRICE, Samuel	puddler	1812	37	Stourbridge, Worcs
TUDOR, William	puddler	1828	21	Wellington
DAVIES, Eli	puddler	1819	30	Dawley
BAMFORD, John	puddler			
JONES, Richard	puddler	1823	26	Wellington
PERRY, Edward	puddler	1825	24	Dawley
HAZELDINE, Thomas	puddler	1823	26	Dawley
DYAS, Samuel	puddler	1822	27	Madeley
STRINGER, Benjamin	puddler	1813	36	Madeley
ROWLEY, William	puddler	1813	36	Kinnersley
CHEADLE, John	puddler			
PARKER, Edward	puddler	1793	56	Wellington
BAILEY, Michael	puddler			
EDGE, Henry	puddler			
PARKER, Thomas	puddler	1812	37	Dawley
MAIDEN, Thomas	puddler	1828	21	Dawley

WITHINGTON, William	puddler	1829	20	Dawley
DAVIES, John	puddler			
ONIONS, Joseph	puddler	1824	25	Dawley
MADELEY, John	puddler			
MILLWARD, Samuel	puddler			
VAUGHAN, Enoch	puddler			
BISHOP, Richard	puddler	1831	18	Dawley
HILL, Joseph	puddler			
KITE, Francis	puddler			
POWELL, Edward	puddler			
WITTINGHAM, Samuel	puddler	1822	27	Wellington
PITCHFORD, Luke	puddler	1826	23	Dawley
ROWLEY, John	puddler	1824	25	Kinnersley
MEERES, John	puddler			
ROBERTS, John	puddler	1827	22	Little Wenlock
GARBETT, Thomas	puddler	1812	37	Dawley
POOLE, John	puddler	1820	29	Wednesbury, Staffs
GRIFFITHS, Edward	puddler			
PERRINS, Thomas	puddler	1823	26	Kidderminster, Worcs
SMITH, Henry	puddler	1825	24	Dawley
DUNKEY, Benjamin	puddler			
BAMFORD, Robert	puddler			
EVANS, John	puddler			
DAVIES, Edward	puddler	1820	29	Wellington
JOHNSON, Richard	puddler			
WITTINGHAM, John	puddler	1824	25	Llanwenarth, Monmouth
ELLIS, George	puddler	1826	23	Dawley
POYNTON, Richard	puddler	1795	54	Staffordshire
MATTHEWS, John	puddler			
PHILLIPS, Joseph	puddler			
SWIFT, James snr	puddler	1803	46	Wellington
ELLIS, George snr	puddler			
MORAL, Thomas	puddler	1829	20	Dawley
ELLIS, George jnr	puddler			
ELLIS, Leon	puddler			
RUSHTON, Mark	puddler			
MORAL, Robert	puddler	1805	44	Dawley

SOUTHERN, Joseph	puddler	1797	52	Sedgely, Staffs
JONES, William	puddler	1819	30	Dawley
MORAL, Richard	puddler	1793	56	Wellington
ATTWOOD, John	puddler	1828	21	Dawley
MORAL, George	puddler	1824	25	Dawley
SOUTHERN, Abraham	puddler	1828	21	Dawley
ELLIS, William	puddler			
SWIFT, James jnr	puddler	1826	23	Bilston, Staffs
BARNES, William	puddler			
GARROTT, James	puddler			
ATTWOOD, William	puddler	1802	47	Dawley
NAYLOR, Thomas?	shingler	1810	39	Rowley, Staffs
DEAKIN, Thomas	shingler	1806	43	Dawley
BALL, Samuel	shingler	1815	34	Dawley
MOSES, Edward	shingler	1818	31	Dawley
TITTLEY, Isaiah	hoop & bar roller	1808	41	Darlaston, Staffs
GUEST, Henry	sheet & plate roller	1805	44	Birmingham, Warks
LONGMORE, William	sheet & plate roller	1822	27	Kingswinford, Staffs
PHAYSEY, John	hoop & bar roller	1807	42	Tipton, Staffs
MILLINGTON, John	hoop & bar roller	1811	38	Wednesbury, Staffs
POOLE, Charles	plate & sheet roller	1810	39	Bilston, Staffs
PERKS, John	iron heater	1819	30	Kingswinford, Staffs
RAY, Thomas	iron heater	1807	42	Dawley
SPEED, William	iron heater	1817	32	Wellington
MEDLICOTT, Thomas	iron heater			
KEAY, Noah	sheet & slab heater	1823	26	Dawley
CRUMPTON, Robert	iron cutter			
KETLEY, Francis	iron cutter	1830	19	Kinver, Staffs
CORFIELD, John	iron cutter			
CORBETT, William	iron shearer	1822	27	Tipton, Staffs
TEECE, C	hoop bundler			
GREEN, William	bar straightener	1824	25	Dawley
OWEN, Edward	smith	1811	38	Broseley
SADLER, James	Roll turner	1803	46	Halesowen, Staffs
PRESTWWOD, William	bricklayer			
BRAY, James	engineer	1810	39	Dawley
EVERAL, John	stock-taker			

PITT, Thomas	mill stock-taker			
FLETCHER, William	superintendent			
HYDE, Thomas	superintendent	1779	70	Hartlebury, Worcs

Source: BOT 2/11/1, Stirchley forge and mill wage accounts, 1849-51; 1851 census returns for Dawley, Madeley, Stirchley and Wellington parishes.

Appendix 5

Finers at Hampton Loade forge 1831-6

	Mark	
Edward Allender*	A	
Thomas Cook	7	
Joseph Daw*	D	
Samuel Daw	D	
Peter Edwards*	P	
John Harrison*	L	
John Huffin*	H	
James Newall	6	
Jeremiah Scott	S	
Thomas Turley*	T	
William Turley	Y	
John Allender*	2	
William Cook*	C	
Joshua Daw*	K	
John Eastwood	W	
James Gretion	II	
William Hazeldine	C	
John Jackson	J	
Samuel Priest	B	
Benjamin Turley	B	
Thomas Turley junior	BM	
(Thomas Gouburn	K	employed only 4 weeks)

* denotes finers capable of making Osborne iron

Source: N Mutton, 'The forges at Eardington and Hampton Loade', *Transactions of the Shropshire Archaeological Society*, 58 (1965-8), p 242.

NOTES AND REFERENCES

The following abbreviations have been used:

B&W	Boulton & Watt Collection, Birmingham Central Library
BOT	Botfield Collection, John Rylands University Library, University of Manchester
BPP	British Parliamentary Papers
BUL	Birmingham University Library
IGMT	Ironbridge Gorge Museum Trust
KUL	Keele University Library
NLW	National Library of Wales
PRO	Public Record Office
SML	Science Museum Library
SRO	Staffordshire Record Office
SRR	Shropshire Records & Research Centre
VCH	*Victoria County History*
WRO	Worcestershire Record Office

1 Introduction

[1] MW Flinn, *Men of Iron: The Crowleys in the Early Iron Industry* (1962), p 3.
[2] BR Mitchell & P Deane, *Abstract of British Historical Statistics* (1962), pp 140-1.
[3] N Cox, 'Imagination and innovation of an industrial pioneer: the first Abraham Darby', *Industrial Archaeology Review*, 12/1 (1990), pp 127-44.
[4] B Trinder, *The Industrial Revolution in Shropshire* (3rd ed 2000); I Gregory, *The East Shropshire Coalfield and the Great Depression, 1873-1896*. MA thesis, University of Keele (1978).
[5] For convenience, the Black Country ironworking district will be taken as including ironworks on the South Staffordshire and North Worcestershire coalfield, and its periphery, including the lower Stour valley in Worcestershire.
[6] SML 371/1-4, J Weale, 'An Historical Account of the Iron and Steel Manufactures', c1779-1811; H Scrivenor, *History of the Iron Trade* (2nd ed 1854); J Percy, *Metallurgy, Section 1: Iron and Steel* (1864).
[7] A Fell, *The Early Iron Industry of Furness and District* (1908); E Straker, *Wealden Iron* (1931).
[8] TS Ashton, *Iron and Steel in the Industrial Revolution* (1924). All references cited here are from the second edition, 1951.
[9] Ibid., p 128.
[10] A Birch, *The Economic History of the British Iron and Steel Industry 1784-1879* (1967).
[11] P Riden, 'The final phase of charcoal iron smelting in Britain, 1660-1800', *Historical Metallurgy*, 28/1 (1994), pp 14-26.
[12] C Hyde, *Technological Change in the British Iron Industry* (1977), fig 5.1.
[13] Ibid., pp 92-3.
[14] Ibid., pp 101-3, table 6.1.

[15] L Ince, *The Knight Family and the British Iron Industry* (1991).
[16] M Atkinson & C Baber, *The Growth and Decline of the South Wales Iron Industry 1760-1880* (1987).
[17] CR Morton & N Mutton, 'The transition to Cort's puddling process', *Journal of the Iron and Steel Institute*, 205 (1967), pp 722-8.
[18] Ibid., p 727.
[19] RA Mott, *Henry Cort: The Great Finer (1983)*.
[20] JR Harris, *The British Iron and Steel Industry 1700-1850* (1988), p 40.
[21] C Evans, *'The Labyrinth of Flames': Work and Social Conflict in Early Industrial Merthyr Tydfil* (1993). Workplace culture was also considered more generally in Birch, *Economic History*, especially pp 244-76.
[22] Morton & Mutton, 'Transition', p 725.
[23] WKV Gale, 'Researching iron and steel: a personal view', *Industrial Archaeology Review*, 16/1 (1992), pp 21-35.
[24] WKV Gale, *The Black Country Iron Industry* (2nd ed 1979), pp 125-32, 156-7, 163-5.
[25] WKV Gale, *The Iron and Steel Industry: A Dictionary of Terms* (1971).
[26] The mythology of Quaker industrialists is discussed in Trinder, *Industrial Revolution*, p 83.
[27] A Raistrick, *Dynasty of Ironfounders* (1953); idem., *Quakers in Science and Industry* (1950).
[28] E Thomas, *Coalbrookdale and the Darbys* (1999).
[29] Raistrick, *Dynasty of Ironfounders*, pp 68-9. There are no company records of the period, as many such records were destroyed by the Darby family in the 1850s.
[30] Patent No 815, 1766. See Raistrick, *Dynasty of Ironfounders*, pp 86-7; S Smiles, *Industrial Biography: Iron Workers and Tool Makers* (1863), pp 86-9.
[31] B Trinder (ed), *The Most Extraordinary District in the World: Ironbridge and Coalbrookdale* (2nd ed 1988), pp 29-30.
[32] RA Mott, 'The Coalbrookdale Group Horsehay Works: Part 2', *Transactions of the Newcomen Society*, 32 (1959-60), pp 43-55.
[33] R Hayman, W Horton & S White, *Archaeology and Conservation in Ironbridge* (1999), pp 39-57.
[34] WKV Gale & CR Nicholls, *The Lilleshall Company Ltd* (1979).
[35] N Mutton, 'The forges at Eardington and Hampton Loade', *Transactions of the Shropshire Archaeological Society*, 58 (1965-8), pp 235-43.
[36] DG Hurst, 'Apley forges', *Post-Medieval Archaeology*, 2 (1968), p 193.
[37] B Trinder, *The Industrial Archaeology of Shropshire* (1996), pp 15-17.
[38] Trinder, *Industrial Revolution*.
[39] Ibid., pp 139-46.
[40] Ibid., p 146.
[41] Birch, *Economic History*, p 258.
[42] *VCH Shropshire*, 11 (1985), pp 48-50, 121-2, 163-4, 191, 261, 271-2, 293-5.
[43] WHB Court, *The Rise of the Midland Industries* (1938); MB Rowlands, *Masters and Men in the West Midland Metalware Trades before the Industrial Revolution* (1975).
[44] M Berg, *The Age of Manufactures, 1700-1820* (2nd ed 1994). For a case study of the West Midlands, see MB Rowlands, 'Continuity and change in an industrialising

society: the case of the West Midlands industries', in P Hudson (ed), *Regions and Industries* (1989), pp 103-31.
[45] SRR 245/145 and 6001/334, 335, 336, 337, cover the period 1794-1808, plus 245/140, an important account of the Horsehay works c1830.
[46] *RR Angerstein's Illustrated Travel Diary, 1753-1755*, translated by T & P Berg (2001); N Scarfe (ed), *Innocent Espionage: The La Rochefoucauld Brothers' Tour of England in 1785* (1995).
[47] Evans, *Labyrinth of Flames*; JR Harris, *Industrial Espionage and Technology Transfer* (1998).

2 The Shropshire Forge Trade to 1750

[1] The finery and chafery forge is sometimes referred to as a Walloon forge. This is distinct from a German forge where the iron was refined in a single hearth. The latter technique was used in Britain to a limited extent to forge high-quality wrought iron known as Osmond or Osborne iron and is described in chapter 7.
[2] For example, one of the best-known eighteenth-century accounts is found in CG Gillispie, *A Diderot Pictorial Encyclopaedia of Trades and Industry* (1959), plates 95-8. For the description of the process here I have referred to A den Ouden, 'The production of iron in finery hearths, part 1: The finery process and its development', *Historical Metallurgy*, 15/2 (1981), pp 67-71; and HR Schubert, *History of the British Iron and Steel Industry* (1957), pp 282-9.
[3] KC Barraclough, *Steelmaking Before Bessemer, Vol 1: Blister Steel* (1984).
[4] PW King, 'The development of the iron industry in South Staffordshire in the seventeenth century: history and myth', *Transactions of the Staffordshire Archaeological and Historical Society*, 38 (1997), p 71.
[5] H Cleere & D Crossley, *The Iron Industry of the Weald*, (2nd ed 1995), pp 111-13, 117.
[6] Ibid., p 130.
[7] Ibid., p 187.
[8] Ibid., p 166.
[9] PW King, 'Early statistics for the iron industry: a vindication', *Historical Metallurgy*, 30/1 (1996), p 37.
[10] C Hart, *The Industrial History of Dean* (1971), pp 9-11.
[11] King, 'Early statistics for the iron industry', p 36.
[12] Schubert, *Iron and Steel Industry*, pp 292-5.
[13] King, 'Early statistics for the iron industry', p 36.
[14] Ibid., pp 36-7.
[15] M Bowden (ed), *Furness Iron* (2000), pp 7-10, 75.
[16] BG Awty & CB Phillips, 'The Cumbrian bloomery forge in the seventeenth century and forge equipment in the charcoal iron industry', *Transactions of the Newcomen Society*, 51 (1979-80), pp 31-5.
[17] King, 'Early statistics for the iron industry', pp 26-7, 36-7.
[18] Schubert, *Iron and Steel Industry*, p 180; T Rowley, *The Shropshire Landscape* (1972), p 217. The Earl of Shrewsbury also built a furnace at Whitchurch, on the north side of the Forest of Dean in Herefordshire, in 1575. See Hart, *Industrial*

History of Dean, p 8. For Shifnal Furnace see J Cherry, 'Post-medieval Britain in 1972', *Post-Medieval Archaeology*, 7 (1973), pp 115-16.
[19] P Lead, 'The north Staffordshire iron industry 1600-1800', *Historical Metallurgy*, 11/1 (1977), p 3.
[20] P Riden, *A Gazetteer of Charcoal-fired Blast Furnaces in Great Britain in use since 1660* (2nd ed 1993), p 62.
[21] *VCH Shropshire*, 11 (1985), p 293; Riden, *Charcoal-fired Blast Furnaces in Great Britain*, p 63.
[22] *VCH Shropshire*, 11 (1985), p 163.
[23] Ibid., p 48; SRR 245/1.
[24] R Hayman, W Horton & S White, *Archaeology and Conservation in Ironbridge* (1999), p 14.
[25] SRR 6001/300.
[26] Hayman et al, *Archaeology and Conservation in Ironbridge*, pp 16, 39; M Wanklyn, 'Industrial development in the Ironbridge Gorge before Abraham Darby', *West Midlands Studies*, 15 (1982), p 5.
[27] KWG Goodman, *Hammerman's Hill: The land, people and industry of the Titterstone Clee Hill area of Shropshire from the sixteenth to the eighteenth centuries*, PhD thesis, University of Keele (1978), pp 97-8.
[28] Ibid., pp 98, 106; M Baldwin, 'Ironworking in Cleobury Mortimer', *Cleobury Chronicles*, 3 (1994), pp 40-3.
[29] DG Bayliss, 'The Effect of Bringewood Forge and Furnace on the landscape of part of northern Herefordshire to the end of the seventeenth century', *Transactions of the Woolhope Naturalists Field Club*, 45/3 (1987), p 722.
[30] Goodman, *Hammerman's Hill*, p 106; *VCH Shropshire*, 10 (1998), p 150; Riden, *Charcoal-fired Blast Furnaces in Great Britain*, p 55.
[31] Goodman, *Hammerman's Hill*, p 107.
[32] *VCH Shropshire*, 8 (1968), p 96.
[33] Ibid., p 89.
[34] Ibid., pp 49, 112.
[35] B Trinder, *The Industrial Archaeology of Shropshire* (1996), pp 13, 16.
[36] *VCH Staffordshire*, 2 (1967), p 115.
[37] I Edwards, 'The early ironworks of north-west Shropshire', *Transactions of the Shropshire Archaeological Society*, 56 (1957-60), pp 186-90.
[38] Trinder, *Industrial Archaeology*, p 20.
[39] Riden, *Charcoal-fired Blast Furnaces in Great Britain*, p 62; *VCH Shropshire*, 10 (1998), p 150.
[40] Lead, 'North Staffordshire iron industry', pp 3-5.
[41] Trinder, *Industrial Archaeology*, p 16.
[42] N Cox, 'Imagination and innovation of an industrial pioneer: The first Abraham Darby', *Industrial Archaeology Review*, 12/2 (1990), pp 130, 133.
[43] B Coulton, 'Tern Hall and the Hill Family 1700-75', *Transactions of the Shropshire Archaeological Society*, 66 (1989), pp 99-100.
[44] Riden, *Charcoal-fired Blast Furnaces in Great Britain*, p 72.
[45] JM Treadwell, 'William Wood and the Company of Ironmasters of Great Britain', *Business History*, 16/2 (1974), p 98.

[46] Coulton, 'Tern Hall and the Hill Family', pp 101-2; R Chaplin, 'A forgotten industrial valley', *Shropshire Newsletter*, 36 (1969), p 3.
[47] Goodman, *Hammerman's Hill*, p 274.
[48] Their father was Cornelius Hallen (1673-1744), pan maker of Coalbrookdale. Samuel had been apprenticed as a pan maker in Stourbridge but had married Mary Mather of Stottesdon. His brother Cornelius continued to live at Coalbrookdale and was buried at the parish church in Madeley. See AWC Hallen, *An Account of the Family of Hallen or Holland* (1885), pp 34-6.
[49] Goodman, *Hammerman's Hill*, p 281.
[50] NLW Pitchford Hall 952, 955; *VCH Shropshire*, 8 (1968), p 121; WA Smith, *The Gibbons Family: Coal and Ironmasters 1750-1873*, PhD thesis, University of London (1978), p 34.
[51] King, 'Early statistics for the iron industry', p 32.
[52] Cox, 'Imagination and innovation of an industrial pioneer', p 131.
[53] *VCH Staffordshire*, 20 (1984), pp 145, 213.
[54] H Lloyd, *The Quaker Lloyds in the Industrial Revolution* (1975), pp 39, 48.
[55] M Flinn, 'The growth of the English iron industry 1660-1760', *Economic History Review*, 11 (1958), p 149.
[56] M Rowlands, *Masters and Men in the West Midland Metalware Trades before the Industrial Revolution* (1975), pp 59-60.
[57] Trinder, *Industrial Archaeology*, p 17.
[58] Treadwell, 'William Wood', pp 97-109.
[59] Biographical information is drawn from Hallen, *Family of Hallen or Holland*, pp 27-34, supplemented by information in M Marchant, *The Hallen Family and their association with frying pan manufacture*, BA dissertation, Wolverhampton Polytechnic (1990).
[60] Pan making was a skill at which the Hallen family specialised and was described by Robert Plot, who visited Newcastle forge in the late seventeenth century. The pans were forged in piles or 'nests' of up to seven plates, of which the lower was the largest, the skill being to hammer the plates to the required thickness without them becoming welded together. See R Plot, *The Natural History of Staffordshire* (1686), pp 335-6.
[61] Riden, *Charcoal-fired Blast Furnaces in Great Britain*, p 82.
[62] Edwards, 'Early ironworks of north-west Shropshire', pp 188-9.
[63] *VCH Shropshire*, 10 (1998), p 150.
[64] B Trinder, *The Industrial Revolution in Shropshire* (3rd ed 2000), p 29.
[65] Rowlands, *Masters and Men*, pp 1-2.
[66] Ibid., p 54; King, 'Early statistics for the iron industry', pp 36-7.
[67] BLC Johnson, 'New light on the iron industry of the Forest of Dean', *Transactions of the Bristol and Gloucestershire Archaeological Society*, 72 (1953), p 138.
[68] Rowlands, *Masters and Men*, pp 56-7.
[69] R Page, 'Richard and Edward Knight: Ironmasters of Bringewood and Wolverley', *Transactions of the Woolhope Naturalists' Field Club*, 43/1 (1979), pp 7-17; Goodman, *Hammerman's Hill*, pp 277-8; L Ince, *The Knight Family and the British Iron Industry* (1991), p 2.
[70] Edwards, 'Early ironworks of north-west Shropshire', p 186; Riden, *Charcoal-fired Blast Furnaces in Great Britain*, pp 82, 84-5.
[71] Rowlands, *Masters and Men*, pp 63-4.

[72] Trinder, *Industrial Revolution*, p 29.
[73] Lloyd, *Quaker Lloyds in the Industrial Revolution*, pp 101, 194-5.
[74] Rowlands, *Masters and Men*, p 63.
[75] M Wanklyn, 'The impact of water transport facilities on English river ports, c1660-1760', *Economic History Review*, 49/1 (1996), pp 22-4.
[76] AP Wakelin, *Pre-industrial Trade on the River Severn: a computer-aided study of the Gloucester Port Books*, PhD thesis, Wolverhampton Polytechnic (1991), pp 104-5.
[77] Edwards, 'Early ironworks of north-west Shropshire', p 191.
[78] BLC Johnson, 'The Foley Partnerships: the iron industry at the end of the charcoal era', *Economic History Review*, 4/3 (1952), pp 332-3.
[79] Trinder, *Industrial Archaeology*, p 17.
[80] Rowlands, *Masters and Men*, 99, 101.
[81] Trinder, *Industrial Archaeology*, p 16.
[82] Edwards, 'Early ironworks of north-west Shropshire', pp 190-1.
[83] His partner at Coalbrookdale was John Spencer, who was perhaps related to Mary Spencer who in 1671 married William Hallen's brother, also Cornelius (died 1731). See Hallen, *Family of Hallen or Holland*, pp 31, 61; M Wanklyn, 'Industrial development in the Ironbridge Gorge before Abraham Darby', *West Midlands Studies*, 15 (1982), p 5.
[84] Hallen, *Family of Hallen or Holland*, pp 34, 61.
[85] *RR Angerstein's Illustrated Travel Diary, 1753-1755*, translated by T & P Berg (2001), p 335.
[86] Marchant, *Hallen Family*, pp 34, 46. The exact years when frying pans are referred to are 1666, 1674, 1713, 1720, 1724, 1731, 1734, 1753 and 1765.
[87] Hart, *Industrial History of Dean*, pp 12, 168.
[88] Schubert, *Iron and Steel Industry*, pp 323-4; Wanklyn 'Industrial development in the Ironbridge Gorge', p 5; Hayman et al, *Archaeology and Conservation in Ironbridge*, p 13.
[89] RG Shafer, 'Genesis and structure of the Foley Ironworks in Partnership', *Business History*, 13/1 (1971), p 32.
[90] MW Flinn, *Men of Iron: The Crowleys in the Early Iron Industry* (1962), p 37, quoting a letter by A Crowley 2/10/1684.
[91] Cleere & Crossley, *Iron Industry of the Weald*, pp 118, 159-62, 181.
[92] D Hey, *The Fiery Blades of Hallamshire* (1991), pp 172-3.
[93] Bowden, *Furness Iron*, p 10.
[94] KC Barraclough, *Steelmaking Before Bessemer, Vol 1: Blister Steel* (1984), pp 55-6, 58-9; Hey, *Fiery Blades of Hallamshire*, pp 183-94.
[95] KC Barraclough, *Steelmaking Before Bessemer, Vol 2: Crucible Steel* (1984), especially pp 1-3.
[96] *Angerstein's Illustrated Travel Diary*, pp 218-19, 76-7.

3 The Introduction of Mineral Fuel, c1750-1800

[1] *RR Angerstein's Illustrated Travel Diary, 1753-1755*, translated by T & P Berg (2001), p 330.
[2] C Hyde, *Technological Change in the British Iron Industry 1700-1870* (1977), pp 38-40.

[3] L Ince, *The Knight Family and the British Iron Industry* (1991), pp 39-41.
[4] Ibid., pp 21, 39.
[5] Quoted in A Raistrick, *Dynasty of Ironfounders* (1953), pp 68-9.
[6] See chapter 2.
[7] Ince, *Knight Family*, p 12.
[8] WRO 899:310/3.
[9] P Riden, 'The final phase of charcoal iron smelting in Britain, 1660-1800', *Historical Metallurgy*, 28/1 (1994), pp 14-26.
[10] JFA Mason, *The Borough of Bridgnorth, 1157-1957* (1957), pp 13, 41.
[11] KUL, Wedgwood MSS 28405-39, f 70.
[12] SRR 3614/1/251
[13] *VCH Shropshire*, 10 (1998), p 275.
[14] *Shrewsbury Chronicle* 18/2/1786.
[15] SRR 6001/2366.
[16] N Mutton, 'The forges at Eardington and Hampton Loade', *Transactions of the Shropshire Archaeological Society*, 58 (1965-8), p 54.
[17] B&W MII/5/10.
[18] IGMT E1983.2616.
[19] B&W MII/5/10.
[20] BOT 2/24/1.
[21] *Henry Cort: The Great Finer* (1983).
[22] For the early use of air furnaces in the foundry, see N Cox, 'Imagination and innovation of an industrial pioneer: the first Abraham Darby', *Industrial Archaeology Review*, 12/2 (1990), p 128.
[23] *Angerstein's Illustrated Travel Diary*, pp 287-8.
[24] IGMT E1977.85.
[25] RH Campbell, *The Carron Company* (1961), pp 31, 52.
[26] S Smiles, *Industrial Biography: Iron Workers and Tool Makers* (1863), pp 87-8; patent 851, 1766; KUL, Wedgwood MSS 28405-39, ff 69-70.
[27] C MacLeod, *Inventing the Industrial Revolution: the English patent system, 1660-1800* (1988), p 76.
[28] Ibid., pp 48-51.
[29] SRO D695/1/12/36.
[30] Smiles, *Industrial Biography*, p 88.
[31] J Percy, *Metallurgy, Section 1: Iron and Steel* (1864), p 636.
[32] Raistrick, *Dynasty of Ironfounders*, pp 87, 225.
[33] SML MS 371/3, f 153.
[34] J Gross (ed), *The Diary of Charles Wood of Cyfarthfa Ironworks in Merthyr Tydfil, 1766-7* (2001), 28 June 1766, pp 72-3.
[35] 'Buzzing' is explained in chapter 4.
[36] C Hyde, 'The iron industry of the West Midlands in 1754: observations from the travel account of Charles Wood', *West Midlands Studies*, 6 (1973), pp 39-40.
[37] WRO 899:310/3.
[38] Biographical detail is from D Dilworth, *The Tame Mills of Staffordshire* (1976), pp 47-8.
[39] W Chaloner, 'Smelting iron ore with coke and casting naval cannon in the year 1775: Marchant de la Houlière's report on English methods', *Edgar Allen News*, 27

(1949), p 213; JR Harris, *Industrial Espionage and Technology Transfer* (1998), pp 245-6.
[40] N Scarfe (ed), *Innocent Espionage: The La Rochefoucauld Brothers' Tour of England in 1785* (1995), pp 98-9.
[41] SML, Goodrich MSS E2, 'Journey to the North in 1803', f 43.
[42] SRO D845/4.
[43] SRR 5586/10/1/16.
[44] B&W MII/5/10.
[45] IGMT E1983.2616, ff 44, 59; Ibid., f 61 gives an estimate for converting the rolling mill to a finery and chafery forge.
[46] B&W MII/5/10.
[47] HM Rathbone, *Letters of Richard Reynolds* (1852), p 280.
[48] The date when Ketley forge was founded is not certain because experiments with other forging processes were conducted at Ketley earlier in 1784, and are discussed again in chapter 4.
[49] B&W portfolio 238.
[50] SRR 245/140, f 7.
[51] BOT 2/43/1, 30 September 1790.
[52] Biographical details are drawn from *VCH Staffordshire*, 20 (1984), pp 145-6, 213-14. The forges are also listed in B&W MII/5/10.
[53] B Trinder, *The Industrial Revolution in Shropshire* (3rd ed 2000), p 81.
[54] WRO 899:310/4.
[55] SRR 6001/334, ff 141, 144, 149, 158, 162, 165, 198, 203-4, 211 (Lightmoor), 375, 382, 386, 393, 419, 420, 451 (Snedshill).
[56] B Matkin, *John Rennie's Diary of a Journey through Northern England, 1784* (1986), pp 23-5.
[57] B Trinder (ed), *The Most Extraordinary District in the World: Ironbridge and Coalbrookdale* (2nd ed 1988), p 20; IGMT, plan of Coalbrookdale in 1753 by Thomas Slaughter; R Hayman, W Horton & S White, *Archaeology and Conservation in Ironbridge* (1999), pp 39-40.
[58] Hayman et al, *Archaeology and Conservation in Ironbridge*, p 37.
[59] K Morgan, *An American Quaker in the British Isles* (1992), p 266; Trinder, *Most Extraordinary District in the World*, p 34.
[60] PRO C12/1693/97.
[61] Scarfe, *Innocent Espionage*, pp 98-9.
[62] Hayman et al, *Archaeology and Conservation in Ironbridge*, pp 41-2; B&W, engine book.
[63] Quoted in J Plymley, *General View of the Agriculture of Shropshire* (1803), p 288.
[64] Trinder, *Industrial Revolution*, pp 49-50.
[65] L Ince, 'The Boulton & Watt engine and the British iron industry', *Wilkinson Studies*, 2 (1992), pp 85-8.
[66] Matkin, *John Rennie's Diary*, pp 24-5.
[67] Ince, 'The Boulton & Watt engine and the British iron industry', p 86, with some qualification.
[68] Ibid., p 85.
[69] Trinder, *Industrial Revolution*, pp 80, 82.
[70] BOT 1/8.

[71] Ibid.
[72] IGMT E1977.85.
[73] SRR 245/145.
[74] IGMT E1983.2616, f 61.
[75] SRR 245/145, f 150 for example of piece rates per ton.
[76] SRR 245/145, f 3.
[77] C Evans & G Hayes (eds), *The Letterbook of Richard Crawshay* (1990), letter number 18. Henry Cort wrote to James Cockshutt of Cyfarthfa in 1788 urging him to set his best men to making blooms rather than slabs.
[78] J Kanefsky & J Robey, 'Steam engines in eighteenth-century Britain', *Technology and Culture*, 21/2 (1980), p 169, table 2.
[79] SRR 245/145.
[80] SRR 6001/334, ff 8, 11, 31, 47, 55, 62, 78, 178, 205, 391, 393.
[81] Ibid., ff 55, 143, 161, 451, 99.
[82] Ibid., f 86.
[83] Ibid., ff 375, 382, 386, 393, 415, 419, 443, 451, 453, 380, 395, 408, 141, 143, 178.
[84] Ibid., f 127.
[85] Ibid., preliminary unfoliated pages.
[86] Ibid., ff 11, 41.
[87] Ibid., ff 68, 177.
[88] Ibid., f 129.
[89] Ibid., ff 129, 133, 149, 175, 412.
[90] This subject has previously been discussed in B Trinder, 'The development of the integrated ironworks in the eighteenth century', *Institute of Metals Handbook* (1988-9), pp 217-26.
[91] SRR 6001/334, ff 16, 21.
[92] BOT 2/24/1.
[93] Ibid., ff 44, 69, 90, 119.
[94] SRR 6001/334, ff 1, 3, 4, 23, 26, 44, 54, 64, 95, 115, 120, 121, 138.
[95] Ibid., ff 210, 218, 222, 224, 341, 345, 353, 431.
[96] B&W MII/5/10.
[97] *Shrewsbury Chronicle* 18/4/1794.
[98] R Chaplin, 'A forgotten industrial valley', *Shropshire Newsletter*, 36 (1969), p 5.
[99] B&W MII/5/10; WA Smith, *The Gibbons Family: Coal and Iron Masters 1750-1873*, PhD thesis, University of London (1978), p 34.
[100] AWC Hallen, *An Account of the Family of Hallen or Holland* (1885), p 36 and genealogical tables.
[101] B&W MII/5/10.
[102] Chaplin, 'A forgotten industrial valley', pp 3-5.
[103] *Shrewsbury Chronicle* 18/4/1794.
[104] *Shrewsbury Chronicle* 11/1/1793.
[105] *Shrewsbury Chronicle* 18/4/1794.
[106] SRO D695/1/12/36.
[107] BOT 1/8.
[108] BOT 2/38/1.
[109] SRR 245/145, 30/7/1796 to 29/7/1797.

[110] P King, 'Early statistics for the iron industry: a vindication', *Historical Metallurgy*, 30/1 (1996), p 36.
[111] Ibid., p 38, taken from Ince, *Knight Family*, pp 116-17.

4 The Transition to Puddling, c1790-1815

[1] RA Mott, *Henry Cort: The Great Finer* (1983).
[2] SRR 245/102.
[3] HR Schubert, *History of the British Iron and Steel Industry* (1957), pp 288-9.
[4] SRR 6001/336.
[5] WH Chaloner, 'Smelting iron ore with coke and casting naval cannon in the year 1775: Marchant de la Houlière's report on English methods', *Edgar Allen News*, 27 (1949), p 213; *RR Angerstein's Illustrated Travel Diary, 1753-1755*, translated by T & P Berg (2001), pp 287-8.
[6] BOT1/8.
[7] WKV Gale, *The Iron and Steel Industry: A Dictionary of Terms* (1971), p 34.
[8] Quoted in Mott, *Henry Cort*, p 68.
[9] SML, MS 371/3, ff 153-4.
[10] Quoted in Mott, *Henry Cort*, p 97.
[11] HM Rathbone, *Letters of Richard Reynolds with a Memoir of his Life* (1852), p 27.
[12] KUL, Wedgwood MSS 28405-39.
[13] SRO D695/1/12/36; WA Smith, 'The contribution of the Gibbons family to technical development in the iron and coal industries', *West Midlands Studies*, 4 (1970/71), p 47.
[14] SRO D695/1/12/36.
[15] SML MS 371/3, f 205.
[16] IGMT E1977.85.
[17] J Percy, *Metallurgy, Section 1: Iron and Steel* (1864), p 636. It is not made specific that this was a demonstration of the Cranage process.
[18] M Atkinson & C Baber, *The Growth and Decline of the South Wales Iron Industry* (1987), p 38.
[19] C Evans & G Hayes (eds), *The Letterbook of Richard Crawshay* (1990), letter numbers 420, 427, 438, 439, 447.
[20] CR Morton & N Mutton, 'The transition to Cort's puddling process', *Journal of the Iron and Steel Institute*, 205 (1967), pp 723-5.
[21] SRR 245/145, f 209.
[22] Evans & Hayes, *Letterbook of Richard Crawshay*, letter numbers 131, 136.
[23] Ibid., letter number 237.
[24] BOT 2/24/1.
[25] BOT 2/38/1.
[26] SRR 6001/334, ff 439, 442, 446.
[27] Ibid., f 141. 20 tons were delivered from Lightmoor in November 1796.
[28] M Flinn (ed), *Svedenstierna's Tour of Great Britain 1802-3* (1973), pp 72-3.
[29] *VCH Staffordshire*, 20 (1984), pp 145-6, 213-14. The forges are also listed in B&W MII/5/10, where the proprietor of Swindon Forge is given as 'Finch'. Finch also had interests in Heath forge and Tipton slitting mill. Sales of Old Park pig iron to Swindon are recorded in BOT 2/24/1.

[30] SRR 6001/337, f 1562.
[31] A Birch, 'Midlands Iron Industry during the Napoleonic Wars', *Edgar Allen News*, 31 (1952), p 232.
[32] SRR 6001/337, f 1522.
[33] BUL, Microfilm of J Gilpin, 'Journals and Notebooks 1790-1801', Vol 33.
[34] Evans & Hayes, *Letterbook of Richard Crawshay*, letter number 329, Richard Crawshay to Baron Demidov, 3/3/1791.
[35] SRR 245/145, ff 59, 94, 103.
[36] Ibid., f 119.
[37] Ibid., f 120.
[38] Ibid., f 128.
[39] Ibid., f 136.
[40] Ibid., ff 136, 137.
[41] Ibid., ff 143, 150.
[42] Ibid., ff 160, 171, 179.
[43] SRR 6001/334, f 368.
[44] Ibid., ff 399, 400, 405, 411, 414, 417, 419, 422, 427, 428, 430, 433, 437, 439, 443, 446, 448, 449, 450, 452.
[45] SRR 245/145, ff 187, 196.
[46] Ibid., f 209.
[47] Ibid., f 243.
[48] Ibid., ff 11, 118.
[49] The description of Bradley Ironworks is in BUL, copy of J Gilpin, 'Journals and Notebooks 1790-1801', Vol 33, and quoted in H Hancock & N Wilkinson, 'Joshua Gilpin: an American manufacturer in England and Wales, 1795-1801', *Transactions of the Newcomen Society*, 32 (1959-60), p 25.
[50] SRR 6001/334, f 144; L Ince, 'The Boulton & Watt Engine and the British Iron Industry', *Wilkinson Studies*, 2 (1992), p 87.
[51] SML, Goodrich MSS E2, 'Journey to the North in 1803', ff 46-8.
[52] B Trinder, *The Industrial Revolution in Shropshire* (3rd ed 2000), p 127.
[53] BOT 2/38/1.
[54] Biographical detail is drawn from C Evans, 'Gilbert Gilpin: A witness to the South Wales iron industry in its ascendancy', *Morgannwg*, 34 (1990), pp 30-8.
[55] SRR 1781/6/22.
[56] BOT 1/6/1, Gilbert Gilpin to Hazeldine & Co, 8/12/1807.
[57] SRR 1781/6/30.
[58] B&W Box 22/22, W Wilkinson to J Watt junior, 17/1/1802.
[59] BOT 1/4/2, T, W & B Botfield to Daniels, Harford, Bally & Payne, 28/6/1814.
[60] B&W business letter book 25, f 208. The two smaller engines might have served the mines rather than the works.
[61] Ibid, f 88.
[62] B&W Box 22/22, W Wilkinson to J Watt junior, 17/1/1802.
[63] BOT 2/38/1. They are described as 'new buildings' in November 1802.
[64] BOT 1/6/1, Gilbert Gilpin to Robert Ward 18/1/1808.
[65] BOT 2/24/1, f 296.
[66] B&W Box 22/22 W Wilkinson to J Watt junior, 28/3/1807.
[67] SRR 6001/336, ff 918, 928.

[68] SRR 6001/337, ff 1415, 1493, 1506, 1775, 1789, 1805. These figures do not represent the entire output of the puddling furnaces as they exclude small quantities of higher-grade iron, scull and use iron, and slabs.
[69] Ibid., f 1676.
[70] SRR 245/140, ff 5-10.
[71] B Trinder, *The Industrial Archaeology of Shropshire* (1996), p 16.
[72] Trinder, *Industrial Revolution*, p 75.
[73] *VCH Shropshire*, 8 (1968), p 121.
[74] Ibid., p 112.
[75] BOT 3/1/1, 3/1/2.
[76] RA Paxton, 'Menai Bridge, 1818-26: evolution of design', in A Penfold (ed), *Thomas Telford: Engineer* (1980), pp 103-6.
[77] BOT 1/4/5, T, W & B Botfield to W Hazeldine 18/11/1825.
[78] J Priestley, *Navigable Rivers, Canals and Railways Throughout Great Britain* (1831), p 605.
[79] B&W MII/5/10; BOT2/24/1.
[80] SRR 1781/2/297.
[81] SRR 1781/2/304.
[82] Trinder, *Industrial Archaeology*, p 16.
[83] AWC Hallen, *An Account of the Family of Hallen or Holland* (1885), p 30.
[84] BOT 1/4/5, bill dated 18/1/1826. Later it appears that Cleobury Mortimer was incorporated with J.G. Lewis's ironworks at Knowbury.
[85] BOT 1/6/1, T, W & B Botfield to J.G. Lewis, Knowbury Ironworks, 14/2/1828.
[86] BOT 3/1/2. 'Cleehill & Hopton' refers to the branch of the brothers' business interests overseen by Thomas Botfield. He lived at Hopton Court from 1803.
[87] N Mutton, 'The forges at Eardington and Hampton Loade', *Transactions of the Shropshire Archaeological Society*, 58 (1965-8), pp 235-43; BOT 2/24/2, f 37; N Mutton, *The Foster Family: A study of a Midland Industrial Dynasty*, PhD thesis, University of London (1974), p 101.
[88] BOT 1/4/5, 1/4/6, 1/6/1.
[89] BOT 2/24/1.
[90] SRR 6001/336, f 934; BOT2/24/2.
[91] BOT 3/1/1.
[92] SRR 5586/10/1/16; 6001/337, ff 1405, 1416; Mutton, *Foster Family*, p 97.
[93] L Ince, *The Knight Family and the British Iron Industry* (1991), pp 42-5, 60.
[94] Trinder, *Industrial Revolution*, pp 80, 81.
[95] Ibid., p 81; SRR 6001/334; SRR 6001/336.
[96] Ince, *Knight Family*, p 44.
[97] BOT 2/38/2.
[98] WKV Gale & CR Nicholls, The Lilleshall Company Ltd (1979), p 26.
[99] The later forge at Snedshill is discussed in chapter 7.
[100] B&W MII/5/10.
[101] SRR 6001/337, f 1679.
[102] SML Goodrich MSS E2, 'Journey to the North in 1803', f 43.
[103] SRR 6001/336.
[104] SML Goodrich MSS E2, 'Journey to the North in 1803', ff 47-8.
[105] SRR 245/145.

[106] SRR 6001/336; 6001/337.
[107] Birch, 'Midlands Iron Industry', p 232.
[108] SRR 245/140, ff 6-7.
[109] SRR 6001/337, f 1751.
[110] Ibid., f 1499.
[111] BOT 2/24/2, ff 320, 60.
[112] BOT 1/4/4, T, W & B Botfield to Protheroe & Hunt, 31/1/1822.
[113] SRR 245/145, ff 59, 94.
[114] Ibid., f 59.
[115] SRR 6001/334, ff 104, 106.
[116] Ibid., ff 408 (to Old Park), 419 (to Snedshill).
[117] SRR 6001/336, ff 940, 1031.
[118] Ibid., f 1087 et seq.
[119] Ibid., f 918.
[120] Ibid., f 928.
[121] Ibid., f 971.
[122] Ibid., ff 1679, 1684.
[123] SRR 245/145, ff 198, 222.
[124] SRR 6001/336, f 1212.
[125] Ibid., ff 1218, 1229, 1238, 1240, 1218.
[126] Ibid., passim.
[127] SRR 6001/337, f 1415.
[128] Ibid., f 1464.
[129] Ibid., ff 1675, 1720, 1736, 1751, 1777, 1792, 1808.
[130] Ibid., ff, 1447, 1460, 1464, 1488, 1557, 1664.
[131] SRR 6001/334, f 86.
[132] BOT 1/8.
[133] BOT 2/38/1.
[134] BOT 1/4/1, T, W & B Botfield to W Jevons, 21/4/1803.
[135] BOT 2/24/1, ff 90, 105.
[136] BOT 1/4/2, T, W & B Botfield to B Mold, 10/11/1814 and 17/1/1815.

5 Iron Trade Culture, c1790-1830

[1] MB Rowlands, *Masters and Men in the West Midland Metalware Trades before the Industrial Revolution* (1975), pp 72-4.
[2] BOT 1/4/4, T, W & B Botfield to Eaton & Sons, Bristol, 20/1/1821.
[3] WA Smith, 'Combinations of West Midlands ironmasters during the industrial revolution', *West Midlands Studies*, 11 (1978), pp 1-10.
[4] C Evans & G Rydén, 'Kinship and the transmission of skills: bar iron production in Britain and Sweden, 1500-1860', in M Berg & K Bruland (eds), *Technological Revolutions in Europe* (1998), p 199.
[5] BOT 2/38/1.
[6] Smith, 'Combinations of West Midlands ironmasters', p 7.
[7] BOT 1/4/3, William Botfield to Barnard Dickinson, Coalbrookdale Co, 2/5/1818.
[8] P King, 'Early statistics for the iron industry: a vindication', *Historical Metallurgy*, 30/1 (1996), pp 28-9; Rowlands, *Masters and Men*, p 72.

[9] BOT 1/4/5, T, W & B Botfield to Crawshay & Co, London, 30/3/1824.
[10] BOT 1/4/4, T, W & B Botfield to Richard & William Crawshay 17/4/1820.
[11] BOT 1/4/5, T, W & B Botfield to Thomas Banks, Ettingshall, 1/11/1824.
[12] BOT 1/4/6, T, W & B Botfield to George Gilpin, Wedges Mill, 13/4/1826.
[13] Ibid., T, W & B Botfield to John Knight, Cookley Ironworks, 15/4/1826.
[14] Ibid., T, W & B Botfield to Protheroe & Hunt, 10/2/1827.
[15] BOT 1/4/3, William Botfield to Barnard Dickinson, 7/5/1818.
[16] BOT 1/6/1, G Gilpin to Robert Ward, Penydarren Ironworks, Cardiff, 18/1/1808.
[17] BOT 1/4/2, T, W & B Botfield to James Sheward, 18/2/1815.
[18] BOT 1/4/1, 1/4/2, 1/4/3, 1/4/4, 2/24/2, 3/1/1, 3/1/2; *VCH Staffordshire*, 20 (1984), pp 145-6. Old Park's long-term regular customers included Jeston Homfray of Broadwater near Kidderminster (who also owned the rolling mill at Stourton from 1804, who purchased pig iron until his death in 1816), Sims Tildesly Adams & Co of Aston Junction Forge, Jesson Wright & Co of West Bromwich until 1813, Isaac Spooner of Park Mill, Birmingham, Benjamin Mold of Wichnor, Joshua Walker of Rotherham and Gospel Oak, Hornblower & Smith of Brierly Hill, Hopkins & Livesage of Lea Forge, Edward Barker of Rugeley, Turner Botton of Kinver Mill, Thomas Homfray of Hyde, Burlingham & Co of Evesham and Henry Hodgson of Gothersley.
[19] BOT 1/4/5, 1/4/6, 1/6/1.
[20] These included Henry Turner of Wilden Wire Works near Kidderminster, three Birmingham wire makers – William Fox, J Sunderland of Oxford Street Wire Mills and John Cornforth – James Griffin & Son of Withymoor Works in Derby, Thomas Jones & Co of Wrexham, Greening & Co of Warrington, James Hammerton of Wheeler Wire Mills, Flintshire, as well as at least three wire makers in Halifax – John Ramsden of Gateshead Wire Works, James Royston and Sharp & Browne.
[21] BOT 1/4/1, 1/4/2, 1/4/3, 1/4/4, 1/4/5, 1/4/6, 1/6/1.
[22] Output figures are in BOT 2/24/2. Comment on the relative price of bar to pig is in BOT 1/4/3, T, W & B Botfield to W Hancocks, Lea Castle, 23/10/1817.
[23] BOT 1/4/2, T, W & B Botfield to J Bourne, agent to W Blount, 15/7/1814.
[24] BOT 1/4/6, T, W & B Botfield to W Graham & Son, 15/4/1826.
[25] Ibid., T, W & B Botfield to Acraman & Stitt, 17/3/1827.
[26] Ibid., T, W & B Botfield to WD & WE Acraman, 8/2/1827.
[27] BOT 1/6/1, G Gilpin to Robert Ward, Penydarren Ironworks, Cardiff, 18/1/1808.
[28] BOT 1/4/6, T, W & B Botfield to John Webb, 1/2/1827.
[29] BOT 1/6/1, T, W & B Botfield to T & P Price, Birmingham, 22/1/1808.
[30] BOT 1/4/1, T, W & B Botfield to Joseph Jesson, 3/11/1804.
[31] BOT 1/4/2, T, W & B Botfield to Daniels Harford & Co, 18/2/1815; BOT 1/4/3, T, W & B Botfield to Daniels Bally & Payne, 5/9/1817.
[32] BOT 1/4/2, T, W & B Botfield to Hazeldine Rastrick & Co, Bridgnorth, 31/1/1815.
[33] Ibid., T, W & B Botfield to Coalbrookdale Co, 9/2/1815.
[34] BOT 1/6/1, T, W & B Botfield to Protheroe & Hunt, 29/10/1827.
[35] Ibid., T, W & B Botfield to Walker & Brothers, Bury, 19/12/1827.
[36] BOT 1/4/5, T, W & B Botfield to J & T Sherratt, Salford, 23/11/1825.
[37] Ibid., T, W & B Botfield to William Hazeldine, Shrewsbury, 24/12/1825.
[38] BOT 1/6/1, note dated 21/10/1807.
[39] Ibid., note dated 14/11/1807.

[40] BOT 2/24/2; 2/24/3, ff 85, 195. Chilled rolls were cast in sand and therefore had a relatively soft surface. They were used for finishing sheets.
[41] BOT 1/4/6, T, W & B Botfield to Wichnor Iron Co 1/9/1826, 3/3/1827.
[42] BOT 1/6/1 Hazeldine & Co, Bridgnorth 24/11/1807, BOT 1/4/2, T, W & B Botfield to Hazeldine Rastrick & Co 31/1/1815; BOT 1/4/5, T, W & B Botfield to Foster Rastrick & Co, 3/12/1825; BOT 1/4/4, T, W & B Botfield to Joshua Walker & Co 8/6/1821.
[43] A similar problem is noted in C Evans & G Hayes (eds), *The Letterbook of Richard Crawshay* (1990), p 174.
[44] BOT 1/8.
[45] BOT 2/38/1.
[46] BOT 2/24/3, f 204.
[47] WKV Gale, *The Iron and Steel Industry: A Dictionary of Terms* (1971), p 153.
[48] BOT 1/4/3, T, W & B Botfield to Bingham Hampson & Co, Derby, 11/10/1817.
[49] SRR 245/140, ff 7, 11.
[50] BOT 1/4/4, T, W & B Botfield to Christopher Pope & Co, Bristol, 23/9/1820.
[51] Joseph Amphlett to H Cort, 17/1/1785, quoted in RA Mott, *Henry Cort: The Great Finer* (1983), p 49.
[52] SRR 6001/336, 6001/337.
[53] BOT 1/4/1; SRR 6001/337.
[54] BOT 1/4/6, T, W & B Botfield to Protheroe & Hunt, 20/12/1826, and WD & WE Acraman, 7/9/1826.
[55] BOT 1/6/1, G Gilpin to Robert Ward, Penydarren Ironworks, Cardiff, 18/1/1808.
[56] SRR 6001/337, ff 1415, 1416, 1449, 1462, 1495.
[57] Ibid., f 1438.
[58] BOT 1/4/1, T, W & B Botfield to Benjamin Mold 10/11/1814; BOT 1/4/3, T, W & B Botfield to Harford, Croker & Co 13/1/1817; BOT 1/4/3, T, W & B Botfield to Joshua Walker 16/4/1817; BOT 1/4/3, T, W & B Botfield to P George junior & Son 19/1/1818; BOT 1/6/1, T, W & B Botfield to Jenkins & Bache, Birmingham 10/1/1829; SRR 6001/337.
[59] BOT 1/4/2, T, W & B Botfield to Mr Brookes, Hinckley, 18/5/1816; BOT 1/6/1, T, W & B Botfield to Jenkins & Bache, Birmingham 25/10/1828 and 10/1/1829.
[60] BOT 1/4/4, William Botfield to Thomas Salt, solicitor, Shrewsbury, acting for Mr Benson, 5/2/1822.
[61] BOT 1/6/1 T, W & B Botfield to Handleys & Reynoldson, Newark, 1/3/1808.
[62] BOT 1/4/6, T, W & B Botfield to WD & WE Acraman, Bristol, 27/10/1826.
[63] Ibid., T, W & B Botfield to Bailey Brothers, Liverpool, 17/11/1826, and John Webb, Bristol, 27/1/1827.
[64] BOT 1/4/2, T, W & B Botfield to John Andrew, Congleton, 8/8/1815.
[65] RL Brett (ed), *Barclay Fox's Journal* (1979), p 148.
[66] BOT 1/4/3, T, W & B Botfield to Osborne & Gunley, Bordesly Mill, Birmingham, 9/11/1816.
[67] Gale, *Dictionary of Terms*, pp 21-2.
[68] BOT 1/6/1, T, W & B Botfield to Charles Harratt, Glasgow, 29/2/1828.
[69] BOT 1/4/4, T, W & B Botfield to Protheroe & Hunt, Bristol, 31/1/1822.
[70] L Ince, *The Knight Family and the British Iron Industry* (1991), p 35.
[71] SRR 6001/336.

[72] BOT 1/4/4, T, W & B Botfield to J Ramsden, Gateshead, 1/5/1822.
[73] Ibid., T, W & B Botfield to Daniels, Bally & Payne, Bristol, 6/5/1819, and Joshua Walker, Gospel Oak, 17/5/1819.
[74] Ibid., T, W & B Botfield to Edward Barker, Rugeley, 25/3/1820.
[75] BOT 1/4/2, T, W & B Botfield to William Gilpin, 24/1/1815.
[76] Ibid., T, W & B Botfield to Jeston Homfray, 20/2/1816.
[77] BOT 1/4/3, T, W & B Botfield to Gibson & Son, Birmingham, 11/2/1819.
[78] BOT 1/4/4, William Botfield to James Foster, 29/5/1821.
[79] BOT 1/4/2, T, W & B Botfield to Isaac Spooner, 22/4/1816 and 26/4/1816.
[80] Ibid., T, W & B Botfield to Benjamin Mold, 26/4/1816 and 6/5/1816.
[81] BOT 1/4/4, T, W & B Botfield to Trustees of Edward Barker, 30/4/1819.
[82] BOT 1/4/2, W James to John Andrew, Congleton 20/10/1814, and Samuel & John Davies, West Bromwich, 29/11/1815.
[83] BOT 1/4/4, T, W & B Botfield to Thomas Sharp & Co, Manchester, 26/4/1819.
[84] BOT 1/4/5, T, W & B Botfield to Benjamin Mold, 23/3/1824.
[85] BOT 1/4/3, T, W & B Botfield to Thomas Gibson & Sons, Birmingham, 21/1/1819.
[86] BOT 1/4/2, T, W & B Botfield to James Sheward, 18/2/1815.
[87] BOT 1/6/1, T, W & B Botfield to WD & WE Acraman, 12/6/1828.
[88] BOT 1/4/2, T, W & B Botfield to Edward Thomason, 28/12/1815, and Thomas Gibson, Birmingham, 1/3/1816.
[89] BOT 1/4/6, T, W & B Botfield to Acraman & Stitt, 26/5/1827; BOT 1/6/1, T, W & B Botfield to Edward Thomason, 25/10/1827.
[90] Ibid., T, W & B Botfield to Acraman & Stitt, Liverpool, 16/1/1827 and 20/1/1827; BOT 1/6/1, T, W & B Botfield to WD & WE Acraman, 29/10/1827. Request for steel stamps is made in BOT 1/4/6, T, W & B Botfield to Edward Thomason, 20/1/1827.
[91] Gale, *Dictionary of Terms*, p 57.
[92] BOT 1/6/1, T, W & B Botfield to Edward Thomason, 21/10/1828; BOT 1/4/6, T, W & B Botfield to Edward Beddard, 24/4/1826.
[93] M Atkinson & C Baber, *The Growth and Decline of the South Wales Iron Industry 1760-1880* (1987), pp 73-4.
[94] BOT 1/6/1 T, W & B Botfield to Acraman & Stitt, 8/9/1827.
[95] BOT 1/4/1, T, W & B Botfield to James Bateman & Co, 21/4/1803; BOT 1/6/1, T, W & B Botfield to Daniels & Co, 30/11/1827.
[96] BOT 1/4/6, T, W & B Botfield to WD & WE Acraman, 1/7/1826.
[97] Ibid., T, W & B Botfield to WD & WE Acraman, 10/8/1826.
[98] Ibid., T, W & B Botfield to WD & WE Acraman, 12/8/1826.
[99] B Trinder, *The Industrial Revolution in Shropshire* (3rd ed 2000), pp 56, 64-73, 28-9.
[100] BOT 1/4/3, T, W & B Botfield to Thompson & Co, 12/8/1816; BOT 1/6/1, T, W & B Botfield to William Douglas, Coventry, 20/11/1807.
[101] BOT 1/4/6, T, W & B Botfield to WD & WE Acraman, 21/9/1826.
[102] BOT 1/4/3 T, W & B Botfield to Mr Nock, Wellington, 29/9/1818.
[103] BOT 1/4/6, T, W & B Botfield to WD & WE Acraman, 26/9/1826, Yorke & Co, Stourport, 30/4/1827.
[104] Ibid., T, W & B Botfield to WD & WE Acraman, 8/7/1826.
[105] BOT 1/4/4, T, W & B Botfield to Daniels & Co, Bristol, 30/9/1820.

[106] BOT 1/4/6, William Botfield to George James, 27/10/1826.
[107] Ibid., T, W & B Botfield to WD & WE Acraman, 3/5/1827.
[108] Ibid., T, W & B Botfield to John Worthington, Stourport, 21/2/1827.
[109] Ibid., T, W & B Botfield to WD & WE Acraman, Bristol and Thomas Nevett, Bridgnorth, both dated 18/1/1827.
[110] BOT 1/6/1, T, W & B Botfield to Yorke & Worthington, 3/2/1808; BOT 1/4/6, T, W & B Botfield to Acraman & Stitt, Liverpool, 21/2/1827; BOT 1/4/5, T, W & B Botfield to James Jackson, Eardington, 28/12/1824; BOT 1/4/4, T, W & B Botfield to Graham & Sons, London 13/5/1820.
[111] BOT 1/4/6, T, W & B Botfield to Acraman, 14/12/1826.
[112] Trinder, *Industrial Revolution*, pp 57-8.
[113] BOT 1/4/6, T, W & B Botfield to WE Acraman, 1/1/1827.
[114] Atkinson & Baber, *South Wales Iron Industry*, pp 75-6.
[115] BOT 1/4/6, T, W & B Botfield to Acraman & Stitt, 14/5/1827.
[116] BOT 1/4/4, T, W & B Botfield to William Devey, Bewdley, 6/9/1821; BOT 1/4/6, T, W & B Botfield to Amies & Co, Stourport, 14/2/1827.
[117] BOT 1/6/1, T, W & B Botfield to York & Worthington, Stourport, 25/6/1828.
[118] For example, see BOT 1/6/1, T, W & B Botfield to John Soule, Flaxley Ironworks, Gloucester, 4/2/1808.
[119] BOT 1/4/5, T, W & B Botfield to Baldwin & Co, Stourport, 22/5/1823, for an example of delivery of the wrong iron; BOT 1/4/6, T, W & B Botfield to York & Worthington, Stourport, 4/11/1826, regarding proposed letter and number code.
[120] BOT 1/4/6, T, W & B Botfield to Thomas Nevett, Bridgnorth, 18/1/1827.
[121] BOT 1/4/1, T, W & B Botfield to York & Worthington, Stourport, 17/12/1807; BOT 1/4/2, T, W & B Botfield to Thwaites, Cochrane, Hick & Co, 8/8/1814.
[122] BOT 1/4/3, T, W & B Botfield to James Robertson & Co, Glasgow, 27/1/1819; BOT 1/4/4, T, W & B Botfield to James Robertson & Co, Glasgow, 10/6/1819.

6 Ironmasters and Iron Workmen

[1] MB Rowlands, 'Continuity and change in an industrialising society: the case of the West Midlands industries', in P Hudson (ed), *Regions and Industries* (1989), p 108; see also PW King, 'The development of the iron industry in South Staffordshire in the seventeenth century: history and myth', *Transactions of the Staffordshire Archaeological and Historical Society*, 38 (1997), p 75.
[2] S Pollard, *The Genesis of Modern Management* (1968), p 40.
[3] MB Rowlands, *Masters and Men in the Midland Metalware Trades before 1750* (1975), pp 72-5.
[4] KWG Goodman, *Hammerman's Hill: The land, people and industry of the Titterstone Clee Hill area of Shropshire from the sixteenth to the eighteenth centuries*, PhD thesis, University of Keele (1978), pp 106, 281; *VCH Shropshire*, 10 (1998), p 456.
[5] BG Awty, 'The continental origins of Wealden ironworkers, 1451-1544', *Economic History Review*, 34 (1981), pp 524-39.
[6] *VCH Shropshire*, 11 (1985), p 163.
[7] HR Schubert, *History of the British Iron and Steel Industry* (1957), pp 412-26.
[8] Goodman, *Hammerman's Hill*, p 205.

[9] IGMT E1983.2616, f 38.
[10] Pollard, *Genesis of Modern Management*, p 46.
[11] J Rule, 'The property of skill in the period of manufacture', in P Joyce (ed), *The Historical Meanings of Work* (1987), p 104.
[12] Rowlands, *Masters and Men*, pp 39-44.
[13] D Hey, *The Fiery Blades of Hallamshire* (1991), pp 94-6, 102-3.
[14] Goodman, *Hammerman's Hill*, pp 204-5.
[15] See chapter 3.
[16] C Evans & G Rydén, 'Kinship and the transmission of skills: bar iron production in Britain and Sweden 1500-1860', in M Berg & K Bruland (eds), *Technological Revolutions in Europe* (1998), pp 197-8.
[17] BOT 1/6/1; *Shrewsbury Chronicle*, 11/1/1793.
[18] H Lloyd, *The Quaker Lloyds in the Industrial Revolution* (1975), p 50.
[19] P Riden, *John Bedford and the Ironworks at Cefn Cribwr* (1992), pp 68-70.
[20] C Evans, *The Labyrinth of Flames: Work and Social Conflict in Early Industrial Merthyr Tydfil* (1993), pp 96-9.
[21] KUL, Wedgwood MSS 28405-39, ff 69-70; SML Goodrich MSS E2, 'Journey to the North, 1803', ff 43, 46-8.
[22] WA Smith, *The Gibbons Family: Coal and Iron Masters, 1750-1873*, PhD thesis, University of London (1978), p 147.
[23] BOT 2/8/4, 2/8/5.
[24] Appendix 3; BOT 2/8/12, 2/11/1.
[25] Gilbert Gilpin's notes on Old Park workmen in 1807-8 are in BOT 1/6/1. They are summarised in Appendix 2.
[26] SRR 245/145.
[27] *Shrewsbury Chronicle*, 11/1/1793.
[28] Evans, *Labyrinth of Flames*, pp 80-1, 86.
[29] BOT 1/6/1 T, W & B Botfield to Thomas Wright, Bersham Ironworks, 26/10/1807.
[30] BOT 2/8/4; SRR 245/145.
[31] BOT 2/8/4, 14/4/1832.
[32] N Scarfe (ed), *Innocent Espionage: The la Rochefoucauld Brothers' Tour of England in 1785* (1995), p 99.
[33] SRR 245/140, f 6.
[34] BPP 16 (1842), *Report of the Children's Employment Commission*, p 41.
[35] Ibid., p 80.
[36] BOT 1/6/1.
[37] BOT 2/8/12, 2/8/4 (for which, see Appendix 2), 2/8/5, 2/8/6.
[38] BOT 2/8/13.
[39] BOT 2/8/5.
[40] BOT 1/6/1, note dated 1/1/1808.
[41] Ibid., T, W & B Botfield to Walker & Brothers, Bury, 19/12/1827.
[42] Ibid., T, W & B Botfield to Thomas Walcot, Birmingham, 16/12/1807.
[43] Ibid., T, W & B Botfield to Handleys & Reynoldson, Newark, 30/1/1808.
[44] BOT 1/4/4, T, W & B Botfield to William Emery, 21/3/1817. The mould was probably a semi-finished ploughshare that received further hammering to the required specification by the manufacturer.
[45] BOT 2/25/1.

[46] SRR 245/140, f 4.
[47] Smith, *Gibbons Family*, p 302.
[48] BOT 2/8/4.
[49] BOT 1/8.
[50] BOT 1/6/1.
[51] B Trinder, *The Industrial Revolution in Shropshire* (3rd ed 2000), pp 137-53, with reference to Forge Row on pp 149-51. For the South Wales ironworking district see J Lowe, *Welsh Industrial Workers Housing 1775-1875* (2nd ed 1985).
[52] BOT 1/4/4, T, W & B Botfield to Mr Gwyn, 6/8/1819.
[53] BOT 1/4/5, T, W & B Botfield to William Edwards, 10/6/1825.
[54] Evans, *Labyrinth of Flames*, p 71.
[55] Smith, *Gibbons Family*, p 147.
[56] BOT 1/4/4, T, W & B Botfield to Protheroe & Hunt, Bristol, 19/6/1820.
[57] BOT 1/6/1, T, W & B Botfield to Protheroe & Hunt, Bristol, 16/4/1828.
[58] SRR 245/140, ff 39-40.
[59] SRR 245/140, f 9.
[60] BOT 2/8/4.
[61] EP Thompson, *Customs in Common* (1991), p 394. A general discussion of methods of imposing workplace discipline is in Pollard, *Genesis of Modern Management*, pp 183-92.
[62] BOT 2/8/4, 11/5/1833.
[63] BOT 2/8/6, 16/1/1836.
[64] SRR 245/140, ff 41-2.
[65] Ibid., f 44.
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[67] M Berg, *The Age of Manufactures, 1700-1820* (2nd ed 1994), p 281.
[68] Ibid., pp 231-2.
[69] C Behagg, *Politics and Production in the Early Nineteenth Century* (1990), especially pp 142-55.

7 The Iron Industry in Peace, c1815-1840

[1] BOT 1/4/3.
[2] Ibid., T, W & B Botfield to B Mold & Son, 12/1817.
[3] Ibid., T, W & B Botfield to T Catchett, Leicester, 3/12/1818.
[4] BOT 2/24/2.
[5] J Randall, *History of Madeley* (1880), p 95.
[6] B Trinder, *The Industrial Revolution in Shropshire* (3rd ed 2000), p 114.
[7] P Riden & J Owen, *British Blast Furnace Statistics, 1790-1980* (1995), p 42.
[8] Trinder, *Industrial Revolution*, p 114.
[9] BOT 1/4/4, T, W & B Botfield to Robert Davy, Topsham, 31/12/1821.
[10] BOT 1/4/5, T, W & B Botfield to Tipton Furnace Co, 24/9/1824.
[11] Trinder, *Industrial Revolution*, p 121.
[12] Riden & Owen, *Blast Furnace Statistics*, p 47.
[13] BOT 2/18/1, ff 22, 33.
[14] Trinder, *Industrial Revolution*, pp 123-4; Riden & Owen, *Blast Furnace Statistics*, pp 42, 47.

[15] BOT 1/4/6, T, W & B Botfield to Graham & Sons, 15/4/1826; BOT 1/6/1, T, W & B Botfield to WD & WE Acraman, 16/10/1827.
[16] BOT 2/25/1.
[17] SRR 245/140, ff 4-7, 9-10.
[18] Ibid., f 16.
[19] Ibid., ff 34-8; see also C Clark, *Horsehay Ironworks, Shropshire: an archaeological and historical evaluation* (1989), unpublished report, Ironbridge Institute.
[20] SRR 245/140, f 45.
[21] Ibid., f 47.
[22] Ibid., f 10.
[23] BOT 2/25/1.
[24] WKV Gale, *The Black Country Iron Industry* (1979), pp 66-7; SRR 245/140, f 36.
[25] BOT 2/8/4; BOT 2/8/5.
[26] BOT 2/8/13.
[27] Gale, *Black Country Iron Industry*, p 67.
[28] SRR, Wellington Tithe map and apportionment, part 8: Ketley township, 1840.
[29] IGMT Lilleshall Collection, 25.75.561.
[30] WKV Gale & CR Nicholls, *The Lilleshall Company Ltd* (1979), p 28.
[31] S Griffiths, *Guide to the Iron Trade of Great Britain* (1873), p 108.
[32] BOT 1/4/6, T, W & B Botfield to George Allender, Aston Junction Forge, 28/5/1827. William Simms should not be confused with his namesake who worked as bricklayer at Old Park.
[33] Trinder, *Industrial Revolution*, p 121; Gale & Nicholls, *Lilleshall Company*, p 43; IGMT Lilleshall Collection 25/75, item 561.
[34] SRR, copy of Cleobury Mortimer census return, 1841.
[35] B Trinder, *The Industrial Archaeology of Shropshire* (1996), p 96. This was not the Botfield furnace at nearby Cornbrook, both of which were sometimes referred to as Cleehill Ironworks.
[36] *Eddowes Shrewsbury Journal*, 11/6/1845.
[37] *Shrewsbury Chronicle*, 18/4/1851.
[38] *Eddowes Shrewsbury Journal*, 20/4/1853. An alternative argument, not supported by direct evidence, is that Lewis took over the Botfields' Cleobury Dale forge and did not build a new forge at Knowbury. See P Hewitt, *The Mining, Quarrying and Allied Industries of the Cleehill Region*, MPhil thesis, Wolverhampton Polytechnic (1991), p 58.
[39] N Mutton, *The Foster Family: A study of a Midland Industrial Dynasty*, PhD thesis, University of London (1974), p 101.
[40] N Mutton, 'The forges at Eardington and Hampton Loade', *Transactions of the Shropshire Archaeological Society*, 58 (1965-8), pp 236-7.
[41] Mutton, 'Eardington and Hampton Loade', p 239; N Mutton, 'James Foster and Tinplate Manufacture in Shropshire 1822-6', *Iron & Steel*, (April 1969), pp 88-92.
[42] Mutton, 'Eardington and Hampton Loade', p 236.
[43] S Bagshaw, *History, Gazetteer & Directory of Shropshire* (1851), p 654.
[44] Mutton, *Foster Family*, p 91.
[45] M Stratton & B Trinder, *Industrial England* (1997), p 77.
[46] SRR 245/140, ff 33-4, 47-9.

[47] BOT 1/4/6, T, W & B Botfield to G Clune, Coalbrookdale and Edward Cherrington, Shifnal, both dated 11/5/1826; T, W & B Botfield to Samuel Cooke, Tipton, 19/5/1826.
[48] Ibid., T, W & B Botfield to Samuel Cooke, 23/5/1826.
[49] Ibid., T, W & B Botfield to Samuel Cooke, 11/7/1826.
[50] BOT 1/4/5, T, W & B Botfield to JG Lewis, Cleobury, and W Hazeldine, Shrewsbury, both dated 16/11/1825. The demand for forge slag may also explain the scarcity of slag in archaeological investigations of forge sites.
[51] BOT 1/4/6, T, W & B Botfield to Henry Turner, Wilden Wire Works, 28/4/1826 and 8/5/1826.
[52] Ibid., T, W & B Botfield to George Allender, charcoal fire man, Junction Forge, 28/5/1827.
[53] Ibid., T, W & B Botfield to Samuel Cooke, Tipton, 30/4/1827.
[54] Ibid., T, W & B Botfield to Wilden Wire Works 23/6/1827; BOT 1/6/1, T, W & B Botfield to Wilden Wire Works, 8/8/1827; Homfray & Son, Stourton, 20/10/1827.
[55] BOT 1/6/1, T, W & B Botfield to Francis Homfray, 22/11/1827.
[56] Ibid., T, W & B Botfield to York & Worthington, Stourport, 24/11/1827.
[57] Ibid., T, W & B Botfield to J.G. Lewis, 3/12/1827.
[58] BOT 2/24/3, ff 106, 110, 118.
[59] BOT 1/6/1, T, W & B Botfield to James Griffin & Son, Withymoor Works, Derby, 29/8/1827; T, W & B Botfield to Thomas Jones, Wrexham, 23/10/1827.
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[63] Ibid., T, W & B Botfield to Thomas Jones, James Royston, and Greening & Co, all dated 3/12/1827.
[64] Ibid., T, W & B Botfield to James Hammerton, Wheeler Wire Works, 26/2/1828.
[65] BOT 2/8/4.
[66] William Allender was born c1801 at Redbrook, Monmouthshire, at which forge his father had probably been a charcoal finer. See SRR, copy of Dawley census, 1851. George Allender may have been the son of William Allender, keeper of Aston blast furnace in 1783-4. See WRO 899:310/3.
[67] BOT 1/8.
[68] BOT 2/8/5. In 1834-5 the wages accounts refer to him as James Matthews.
[69] SRR 5586/10/1/1.
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[80] BOT 2/25/1, output for 1832-3.

8 The Mature Iron Industry

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[13] *Eddowes Shrewsbury Journal* 7/10/1885, p 5.
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[21] Jones, *History of GKN*, pp 143-4; Gregory, *East Shropshire Coalfield*, pp 20, 50; *Wolverhampton Chronicle* 14/5/1879.
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[23] *Mining Journal* 2/9/1871.
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[25] BOT 2/25/4.
[26] N Mutton, *The Foster Family: A study of a Midland industrial dynasty*, PhD thesis, University of London (1974), p 160.
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[65] Ibid., pp 259-60
[66] Ibid., pp 272-3, 276-7
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9 Decline of Wrought Iron in Shropshire, c1870-1900

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[13] *Mining Journal* 9/9/1871, p 797.
[14] S Danks, 'Description of Danks Patent Revolving Puddling Furnace', *Mining Journal* 2/9/1871, pp 776-7.
[15] Carr & Taplin, *British Steel Industry*, pp 56-7. Danks was a common Midlands name but no evidence has been found that Samuel Danks of Cincinnati had any connection with Shropshire. He is not known to have been related to one of the barge owners on the Severn of that name and no evidence was found that he was the same Samuel Danks who managed Old Park for the Old Park Company and subsequently for the Wellington Coal & Iron Co.
[16] Carr & Taplin, *British Steel Industry*, p 57; *Wolverhampton Chronicle* 17/10/1888, p 5.
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[18] BOT 4/4; 2/25/4.
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[38] BOT 1/6/11, Leighton & Grenfell to Old Park Co 17/10/1872.
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[40] SRR 1265/261.
[41] Williams, 'The Botfields', p 26, *VCH Shropshire*, 1 (1908), p 478. *Griffiths' Iron Trade Exchange* 14/3/1874, p 1549; SRR 1265/263.
[42] SRR 1265/264.
[43] Williams, 'The Botfields', p 26; Gregory, *East Shropshire Coalfield*, p 37n.
[44] BOT 2/25/3; 2/25/4.
[45] Riden & Owen, *Blast Furnace Statistics*, pp 40, 41.
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10 Conclusion

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30/13	Drawing of rolling & slitting mill at Halesowen 1781.
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1.16.113	proposal to sell Snedshill ironworks to Earl Gower, 1793.
29.90.655	agreement between Lilleshall Co & Snedshill Co, 1876.

JOHN RYLANDS UNIVERSITY LIBRARY, University of Manchester, 150 Deansgate, Manchester M3 3EH

Botfield Collection:

BOT 1/4/1	Old Park Ironworks letter book, 1802-5 and 1834-5.
BOT 1/4/2	Old Park Ironworks letter book, 1814-16.
BOT 1/4/3	Old Park Ironworks letter book, 1814-19.
BOT 1/4/4	Old Park Ironworks letter book, 1819-22.
BOT 1/4/5	Old Park Ironworks letter book, 1822-6.
BOT 1/4/6	Old Park Ironworks letter book, 1826-7.
BOT 1/6/1	Old Park Ironworks letter book, 1807-8 and 1827-9.
BOT 1/6/3	Old Park & Stirchley Ironworks letter book, 1855-7.
BOT 1/6/11	Stirchley Forge letter book, 1872-3.
BOT 1/8	Botfield Memorandum Book, 1788-91.
BOT 2/1/1	Botfield annual accounts, 1837-52.
BOT 2/1/2	Botfield annual accounts, 1853-63.

BOT 2/1/3 Leighton & Grenfell annual accounts, 1864-70.
BOT 2/8/4 Old Park Forge wages accounts, 1832-3.
BOT 2/8/5 Old Park Forge wages accounts, 1834-5.
BOT 2/8/6 Old Park Forge wages accounts, 1836.
BOT 2/8/12 Stirchley Forge and Mill wages accounts, 1832-3.
BOT 2/8/13 Stirchley Forge and Mill wages accounts, 1834-6.
BOT 2/11/1 Stirchley Forge and Mill wages accounts, 1849-50.
BOT 2/18/1 Old Park and Stirchley Forges ledger, 1822-36.
BOT 2/18/2 Old Park and Stirchley Forges ledger, 1836-71.
BOT 2/19 Stirchley Forge and Mill ledger, 1831-71.
BOT 2/24/1 Old Park Furnaces journal and inventories, 1790-1801.
BOT 2/24/2 Old Park Furnaces journal and inventories, 1801-24.
BOT 2/24/3 Old Park Furnaces journal and inventories, 1824-32.
BOT 2/25/1 Stirchley Forge and Mill journal and inventories, 1830-42.
BOT 2/25/3 Stirchley Forge and Mill journal and inventories, 1829-68.
BOT 2/25/4 Stirchley Forge and Mill journal and inventories, 1868-72.
BOT 2/38/1 Old Park cash book, 1795-1804.
BOT 2/38/2 Old Park cash book, 1804-10.
BOT 2/38/3 Old Park cash book, 1810-15.
BOT 2/43/1 Lightmoor Coal Company receipt book, 1790-4, 1829.
BOT 3/1/1 Old Park Furnaces customer account book, 1812-14.
BOT 3/1/2 Old Park Furnaces customer account book, 1815-18.
BOT 4/2 Valuation of Lightmoor Furnace, 1787.

KEELE UNIVERSITY LIBRARY, Keele ST5 5BG

Wedgwood MSS:
28405-39 'Specimens & Observations in a Journey thro' some parts of England, July 21 to August 6 inclusive – 1768', by William Lewis & Alexander Chrisholm.

NATIONAL LIBRARY OF WALES, Aberystwyth SY23 3BU

Pitchford Hall papers:
952 Lease of Coopers [Eaton Mascot] Mill, 1715.
955 Lease of Pitchford Forge, 1746.
2101 Lease of Pitchford Forge, 1769.
2104 Lease of Pitchford Forge, 1790.

PUBLIC RECORD OFFICE, Ruskin Avenue, Kew, Richmond TW9 4DU

C12/1693/97 Chancery proceedings, Rathbone & Co versus John Powis Stanley, 1786.

SCIENCE MUSEUM LIBRARY, Imperial College Road, South Kensington, London SW7 5NH

Goodrich E2 Simon Goodrich, 'Journey to the North in 1803'.

MSS 371/1-4 James Weale, 'An Historical Account of the Iron and Steel manufactures', with miscellaneous papers.

SHROPSHIRE RECORDS & RESEARCH CENTRE, Castlegates, Shrewsbury SY1 2AQ

Coalbrookdale Company accounts and correspondence:
245/1 Sale of Madeley Manor to Robert Brooke, 1544.
245/102 William James to Barnard Dickinson 20/2/1821.
245/140 An account of Horsehay Ironworks by W.G. Norris.
245/145 Horsehay Ironworks wages book 1796-8.

Charlton Collection:
625/15 Accounts of Wytheford Forge, 1687-8.

Sutherland Collection:
972/172 Iron and goods received at Wappenshall Wharf, 1844-52.

Littlewood, Pearce & Lanyon Collection:
1265/261 Purchase of Hinkshay, Dark Lane, Stirchley & Langley by Haybridge Iron Co.
1265/263 Employment of Samuel Vowles at Stirchley nailworks.
1265/264 Sale of nailworks at Stirchley by Haybridge Iron Co to John Maddock.
1265/280 Liquidation of Old Park Iron Co and sale to Edward Henry Thomas.
1265/285 Lease of Old Park iron works, collieries etc to Wellington Iron & Coal Co Ltd.

Shackerley Collection:
1781/2/297 Agreement between G. Durant and J. Bishton regarding Lizard forge pools, 1806.
1781/2/304 Title to premises including Lizard forge.
1781/6/22 Gilbert Gilpin to William Wilkinson, 24/10/1796.
1781/6/30 William Barrow to Gilbert Gilpin, 16/11/1810.

Kenyon-Slaney Collection:
2224/1 Shropshire Ironworks in 1817.

John D'Arcy Collection:
3614/1/251 Lease of Wrens Nest forge and slitting mill, 1771.

Apley Estate Records:
5586/10/1/1 Hampton Loade Forge account book, 1828-35.
5586/10/1/2 Hampton Loade Forge account book, 1835-46.
5586/10/1/3 Hampton Loade Forge pig iron accounts, 1743-55.
5586/10/1/16 Abstract of leases relating to Eardington Forges, 1782-1832.

Shrewsbury Borough Library Collection:
6001/300 Inventory of Coalbrookdale Works, 1718.

6001/328	Coalbrookdale Ironworks account book 1709-10.
6001/329	Coalbrookdale Ironworks cash book 1718-32.
6001/330	Coalbrookdale Ironworks stock book 1718-27.
6001/331	Coalbrookdale Ironworks cash book 1732-49.
6001/334	Horsehay Ironworks Day Book 1794-8.
6001/335	Horsehay Ironworks blast furnace weekly accounts 1798-1807.
6001/336	Horsehay Ironworks Journal 1802-5.
6001/337	Horsehay Ironworks Journal 1805-8.
6001/2366	Plan of Broseley Hall Estate, including a plan of Calcutts Ironworks c1800.
6001/2481	Survey of the Shropshire Estates of the Earl of Craven.
6001/3190	Letter book of Richard Ford.

Copies of Tithe maps and apportionments.
1841 and 1851 census returns.

STAFFORDSHIRE RECORD OFFICE, Eastgate Street, Stafford ST16 2LZ

Sutherland Collection:

D593/K	Estate correspondence.
D593/M/17/6	Schedule of plant at Ketley Ironworks and collieries, 1878.

Harward & Evers Collection:

D695/1/12/36	Note concerning trials of Cort's puddling process in Shropshire, 1784.

Dawes family papers:

D845/4-5	Partnership in Wrens Nest and West Bromwich forges, 1809.

WORCESTERSHIRE RECORD OFFICE, Spetchley Road, Worcester, WR5 2NP

Knight family papers:

899:310/3	Stour Works General Accounts, 1753-1796.
899:310/4	Stour Works General Accounts, 1796-1817.
899:310/5	Bringewood Works General Accounts, 1756-1779.

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