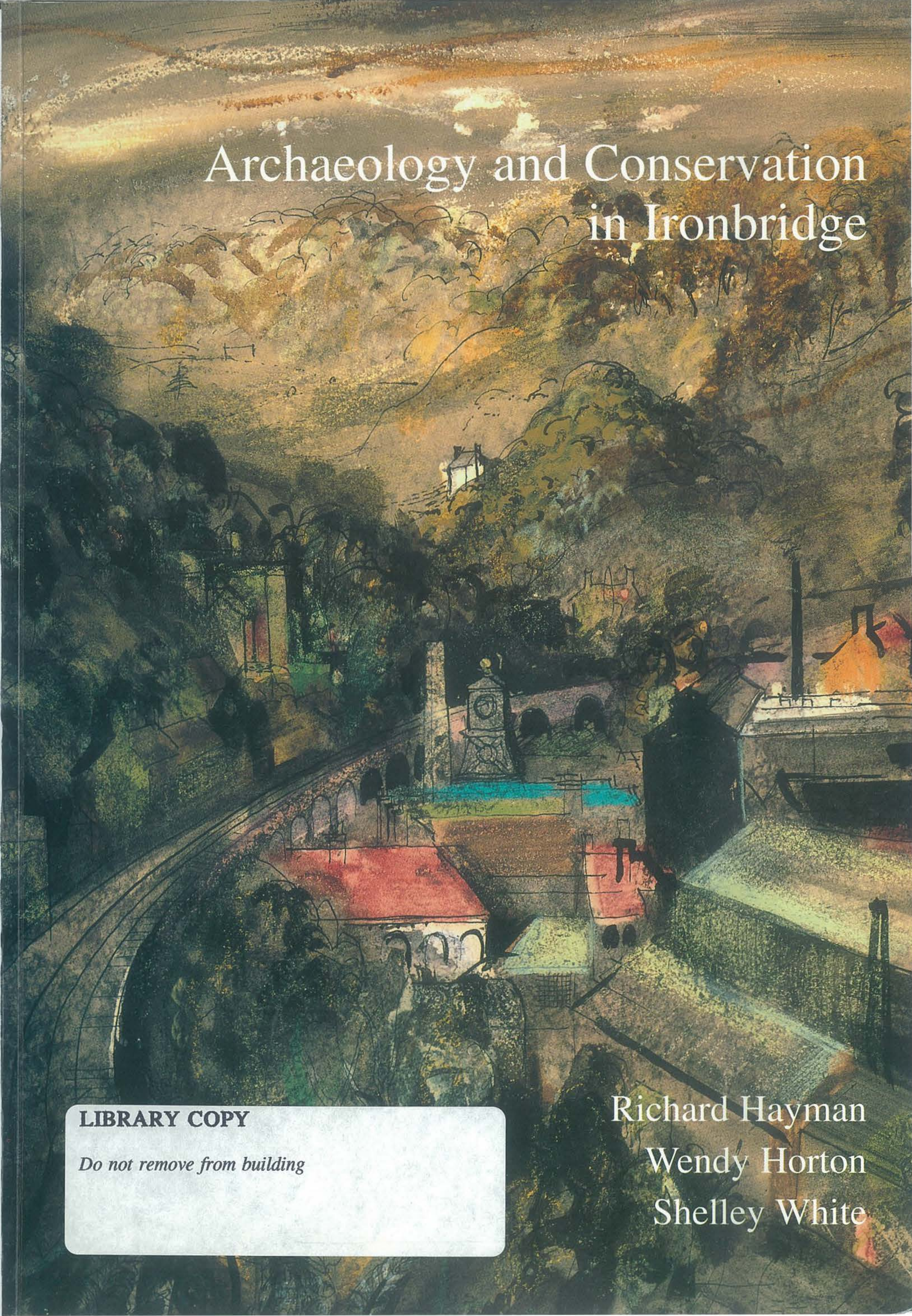


Archaeology and Conservation in Ironbridge

Richard Hayman
Wendy Horton
Shelley White

Archaeology and Conservation in Ironbridge

Archaeology and Conservation in Ironbridge

by
Richard Hayman
Wendy Horton
Shelley White

CBA Research Report 123
Council for British Archaeology
1999

Published 1999 by the Council for British Archaeology
Bowes Morrell House, 111 Walmgate, York YO1 9WA

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN 1 902771 05 2

Typeset by AMA DataSet Limited, Preston

Printed by Thornton & Pearson (Printers) Limited, Bradford

This book has been published with the aid of a grant from English Heritage

Front cover: A view of Coalbrookdale drawn in 1951 by John Piper
Back cover: The Bedlam engine pit, photographed in 1997 after the completion of repairs

Contents

List of figures

List of tables

Illustration Acknowledgements

Science Museum (131, 143, 156); Shrewsbury Museums Service (155); Shropshire Archaeological and Historical Society (153); Shropshire Records and Research Centre (4, 15, 16, 39, 41, 65, 132); Tate Gallery (61, 157, 158, 159). The remaining illustrations are from the Archaeology Unit or the Library and Archives Department of the Ironbridge Gorge Museum Trust.

The cover picture shows a view of Coalbrookdale, drawn in 1951 by John Piper.

Acknowledgements

This volume has taken seven years to complete, during which time many people have contributed to a project in which archaeological conservation has been a team effort drawing on many different disciplines. The project was managed by Wendy Horton and, in addition to the present authors, other members of the IGMT Archaeology Unit who worked on the project from its inception through to completion were Kate Clark, Giles Dawkes, Jeff Morris, Greg Price, Shaun Richardson, Mark Sherratt, Tom Vaughan, and Mick Worthington. Numerous colleagues at the Ironbridge Gorge Museum Trust provided various forms of help and encouragement, especially Glen Lawes (Chief Executive); John Powell, Dianna Tapley, and Joanne Smith in the Library and Archives Department; former Director Stuart Smith; Deputy Director David de Haan; John Challen, Curator of Technology; Mick Ward and Rachel Iliffe, Manager and Curator, respectively, of Blists Hill Victorian Town; Ruth Denison, Curator of Ceramics; and Michael Vanns, formerly curator of the Coalbrookdale Museum of Iron. Dr Barrie Trinder, formerly of the Ironbridge Institute, acted as internal referee and offered advice and constructive criticism throughout the project. The project was funded entirely by English Heritage, who also provided a grant for publication of the results. We are especially grateful to Dr Andrew Brown for guiding the work to its successful conclusion and for ensuring that the results reached a wider audience with this publication. Many English Heritage staff contributed to the project and we would especially like to thank Dr Anthony Streeten and Judith Leigh. In addition, Fred Aldsworth made a valuable contribution to developing the fieldwork methodology.

The multi-disciplinary aspect of the project brought the archaeologists into contact with other conservation professionals and was one of the most enlightening aspects of the work. We would therefore like to extend our acknowledgements to Ian Stainburn, Peter Taylor, John Wheatley, Peter Lines, Julie Widdowson, and Tracey Thomas of Wheatley Taylor Stainburn Lines Architects; structural engineer John Neal; civil engineers Mark Goring and Howard Worth of Barnsley & Associates, and Roger Dixon and David Johns of Scott Wilson Kirkpatrick; quantity surveyors Ken Hodgett of Bond Foster & Partners and the late John Dawkes. Last but by no means least, the project could not have run so smoothly without the contribution of Rick Tyrer and Lawrence McMinn of the Commission for the New Towns.

Richard Hayman, Wendy Horton, Shelley White
March 1999

Preface

Ironbridge is the physical embodiment of profound changes that took place in the Industrial Revolution of the 18th and 19th centuries. Spanning both banks of the River Severn for a distance of 3.6 km, the Ironbridge Gorge Conservation Area has been designated as a World Heritage Site since 1986 in recognition of its important role in the technological developments of the 18th century, principally the first use of coke for smelting iron ore in 1709 and the construction of the world's first significant cast-iron bridge in 1779.

This volume studies six of the key archaeological monuments in Ironbridge, which individually and in combination are of established national importance as examples of their type. Three of the ironworks – the Coalbrookdale Company's Upper Works and the Madeley Wood Company's Bedlam and Blists Hill furnaces – demonstrate technological developments in iron smelting from the early-18th to the early-20th centuries. The Coalbrookdale Company's Upper Forge is an important and rare survival of the industrial revolution in wrought iron manufacture, specifically the short period at the end of the 18th century before the widespread adoption of Cort's puddling process. Blists Hill Brick and Tile Works is one of the best surviving examples of the mechanisation of brick making in the late-19th century, and is part of an extensive 19th-century industrial landscape close to the former Shropshire Canal, which includes the nearby blast furnaces and Blists Hill Pit, where coal, ironstone, and clay were mined. The surviving length of canal, from Blists Hill to the Coalport Chinaworks, is in two sections separated by the Hay Inclined Plane, a notable triumph of 18th-century civil engineering.

The industrial monuments survive among the settlements that grew up to serve them, in a landscape whose topography has allowed significant areas of ancient and managed woodland to survive. The landscape is characterised by the River Severn, which flows through a gorge with steep wooded slopes. The local geology is dominated by coal measures and silurian limestone. Landslip and movement characteristic of a young and developing geomorphology have long been a phenomenon affecting the industrial landscape, and have now become important factors in the long-term sustainability of the monuments.

The Ironbridge district, encompassing Madeley and Broseley on opposite banks of the Severn, was the commercial and industrial focus of the East Shropshire (or Coalbrookdale) Coalfield from the 16th century onwards. Its industries were based on its mineral resources of coal, clay, ironstone, and limestone, beginning with large-scale coal mining in the 16th century. The River Severn, which until the railway age was the major trade route of western Britain, was the principal means of transporting finished goods and was an important factor in allowing the growth of industry in Ironbridge at a relatively early date. Until the 18th century, when industry expanded rapidly, the clay industries, principally potworks and tobacco pipe manufactories, were mainly established alongside coal mining and lime burning on the south side of the River Severn, while on the north side of the river coal and iron were the principal trades.

In the 18th century several technological and managerial innovations enabled the ironworks at Coalbrookdale to spearhead an unprecedented growth in the British iron trade. The ultimate symbol of 18th-century innovation was the Iron Bridge erected over the River Severn in 1779. The bridge was famous even before it was finished and the further development of iron in civil engineering and architecture followed in its wake. In the 19th century the iron trade declined and all but two of the ironworks in the Ironbridge Gorge closed, although one of them, at Coalbrookdale, remains in operation in a slightly modified form as a foundry casting domestic wares. Coal and clay mining remained relatively prosperous in the 19th century. The Coalport Chinaworks gained a reputation for high-quality porcelain, but by the end of the 19th century it was brick and tile manufacture that dominated the landscape, producing common bricks and tiles and specialist products such as terracotta. Another specialised branch of the trade was the manufacture of decorative tiles, two large factories for the production of which were erected at Jackfield in 1871 and 1883 respectively.

The economy of the area declined in the early-20th century as its industries found themselves with either depleted raw materials, outdated methods, or both. The proliferation of brick and tile works – large, dirty, and ugly – may have contributed to the grim image of the place struck up by contemporary authors. J E Auden, for example, described Ironbridge in 1912 as 'an uninteresting and somewhat squalid town . . . whose banks are here covered with slag and refuse' (Auden 1912, 138). A different mood was struck in the middle of the century, a change in perception which served as a prelude to the conservation movement. In 1939 John Betjeman and John Piper liked Ironbridge for the same reason Auden disliked it: it was 'attractively untidy', and the gorge was 'unforgettably beautiful and desolate' with its wooded hillsides 'stuck with chimneys and deserted brick kilns'. A few years later Tom Rolt was thrilled to see a horse gin still in use and to meet a coracle maker.

Active conservation in Ironbridge began in 1959 when Allied Ironfounders Ltd, owners of the surviving Coalbrookdale Foundry, excavated the old blast furnace at Coalbrookdale to celebrate the 250th anniversary of Abraham Darby's use of coke for smelting iron. The company opened a small museum there and in the 1960s the conservation movement made further strides with the founding of the Ironbridge Gorge Museum Trust (hereafter IGMT) in 1968. In the early 1970s IGMT embarked on restoration of the major monuments, most of which became Scheduled Ancient Monuments at that time, among the first industrial monuments to receive statutory protection in this way.

In 1963 a new town was designated in the East Shropshire Coalfield, later known as Telford. The Telford Development Corporation (TDC) was responsible for reclaiming large areas of derelict and previously industrial land for development. It also assumed ownership of many of the archaeological monuments and was active in ensuring that Ironbridge retained much of its historic integrity as it experienced an economic renaissance in the 1970s and 1980s. The TDC was disbanded in 1991 as its objectives were nearing completion. Residual duties included transferring much of its property to new owners and it was decided that a substantial number of the historic monuments and buildings should be given to a charitable trust set up to hold properties for the Ironbridge Gorge Museum Trust – the Ironbridge (Telford) Heritage Foundation – along with an endowment for their future maintenance. It was repairs to the monuments accompanying this property transfer which formed the basis of the archaeological work described in this volume.

The earliest voices calling for conservation in Ironbridge were enthusiasts rather than professional archaeologists (eg Rix 1955). Understanding of the area's industrial history has, however, always been underpinned by scholarship, led initially by historians of metallurgy, economic and social history, and the Quaker movement. The first major work on the subject was Arthur Raistrick's *Dynasty of Ironfounders* of 1953, a study of the Darby family by a fellow Quaker, followed by several studies of the local iron trade by Reginald Mott (1958, 1961). A full economic and social history of the East Shropshire Coalfield came in 1973 with Barrie Trinder's *Industrial Revolution in Shropshire* (2nd edition 1981), which was followed by studies of the art of industrial Ironbridge and the buildings of the district (Smith 1979a, Muter 1979). In the early 1980s IGMT established an archaeology unit to meet a growing requirement to treat archaeology of the industrial period in the same manner as that of any other period (Trueman 1988), while the Ironbridge Institute instigated the Nuffield Survey, a study of the historical geography and buildings of Ironbridge (Alfrey and Clark 1993). Despite the increasing scope of archaeological work, the present volume is the first sustained and comprehensive archaeological enquiry of the core industrial monuments of Ironbridge.

Préface

Ironbridge est l'incarnation physique des profonds changements qui ont eu lieu pendant la Révolution Industrielle du 18ème et du 19ème siècle. Chevauchant les deux rives de la rivière Severn sur une distance de 3,6km, le secteur sauvegardé d'Ironbridge Gorge a été désigné Site du Patrimoine Mondial depuis 1986, en reconnaissance de son important rôle dans les développements technologiques du 18ème siècle, principalement la première utilisation du coke pour la fonte du fer en 1709 et la construction en 1779 du premier pont mondial en fonte de grande importance.

Ce volume étudie six des monuments archéologiques clés d'Ironbridge, lesquels sont, séparément et collectivement, les témoins types d'importance nationale reconnue. Trois des fonderies, Upper Works de Coalbrookdale Company et les fourneaux de Bedlam et Blists Hill de Madeley Wood Company, démontrent les développements technologiques dans la fonte du fer du début du 18ème siècle au début du 20ème siècle. Upper Forge de Coalbrookdale Company est un important et rare témoignage de la révolution industrielle dans la fabrication du fer forgé, surtout essentiellement la courte période à la fin du 18ème siècle avant l'adoption générale du procédé de puddlage de Cort. Blists Hill Brick and Tile Works [Fabrique de Briques et de Tuiles] est l'un des meilleurs vestiges de la mécanisation de la fabrication des briques à la fin du 19ème siècle, et fait partie du vaste paysage industriel du 19ème siècle, près du canal du Shropshire, qui comprend également les hauts fourneaux à proximité et Blists Hill Pit, où étaient exploités le charbon, le minerai de fer et l'argile. La longueur de canal qui reste encore, de Blists Hill à Coalport Chinaworks [Fabrique de porcelaine], est en deux sections, séparées par le Hay Inclined Plane, un remarquable triomphe du génie civil du 18ème siècle.

Les monuments industriels subsistent parmi les populations qui s'installèrent à leur proximité pour les faire tourner dans un paysage dont la topographie a permis à d'importantes zones d'ancienne forêt et forêt exploitée de subsister. Le paysage est caractérisé par la rivière Severn, qui coule du fond d'une gorge aux pentes boisées raides. La géologie locale est dominée par les gisements houillers et le calcaire silurien. Des glissements de terrains et des éboulements caractéristiques d'une géomorphologie jeune et en développement ont longtemps été un phénomène, ils ont bouleversé le paysage industriel et sont maintenant devenus d'importants facteurs dans la viabilité à long terme des monuments.

La région d'Ironbridge, englobant Madeley et Broseley sur les rives opposées de la Severn, a été le foyer commercial et industriel du bassin houiller du East Shropshire (ou Coalbrookdale) depuis le 16ème siècle. Ses industries étaient basées sur ses ressources minérales de charbon, argile, minerai de fer et calcaire, commençant avec les charbonnages à grande échelle du 16ème siècle. La rivière Severn qui, jusqu'à l'âge du chemin de fer, était la plus importante voie de communication commerciale de l'Ouest de la Grande-Bretagne pour le transport des biens manufacturés et était un important facteur de la croissance de l'industrie d'Ironbridge à une date relativement avancée. Jusqu'au 18ème siècle, lorsque l'industrie s'est rapidement développée, les industries de l'argile, particulièrement les usines de poteries et les manufactures de pipes, étaient principalement établies le long des charbonnages et des chaufours sur la rive sud de la rivière Severn, alors que sur la rive nord de la rivière, le charbon et le fer étaient les principales industries.

Au 18ème siècle, plusieurs innovations technologiques et administratives permirent à la fonderie de Coalbrookdale de maintenir une croissance sans précédent dans l'industrie du fer britannique. Le Pont de Fer érigé sur la rivière Severn représente le symbole fondamental de l'innovation au 18ème siècle. Le pont devint célèbre avant même son achèvement et un développement ultérieur du fer dans le génie civil et l'architecture marcha sur ses pas. Au 19ème siècle, l'industrie du fer subit un déclin et, en dehors de deux fonderies d'Ironbridge Gorge, elles fermèrent toutes, bien que l'une d'entre elle, à Coalbrookdale, resta ouverte mais sous une forme quelque peu modifiée, celle de la fonderie propre aux articles ménagers. L'extraction du charbon et de l'argile restèrent relativement prospères au 19ème siècle. Coalport Chinaworks se fit remarquer pour la haute qualité de sa porcelaine mais, à la fin du 19ème siècle, ce fut la fabrication de briques et de tuiles qui domina le paysage, en produisant des tuiles et briques ordinaires ainsi que des produits spécialisés comme la terre cuite. La fabrication de tuiles décoratives fut une autre branche spécialisée de l'industrie et deux grandes usines furent établies pour leur production à Jackfield, respectivement en 1871 et en 1883.

L'économie de la région déclina au début du 20ème siècle, lorsque ses industries se retrouvèrent soit avec des matières premières épuisées, soit avec des méthodes surannées ou les deux. La prolifération d'usines de briques et de tuiles, grandes, sales et laides, a peut-être contribué à la sinistre image de cet endroit révélée par les auteurs contemporains. J E Auden, par exemple, décrivit Ironbridge en 1912 comme 'une ville sans intérêt et quelque peu sordide... dont les remblais sont couverts de scories et d'ordures' (Auden 1912, 138). Au milieu du siècle, un esprit différent se manifesta, un changement de perceptions qui servit de prélude au mouvement de sauvegarde. C'est dans un esprit totalement opposé à celui d'Auden qu'en 1939, John Betjeman et John Piper apprécièrent Ironbridge: c'était un 'désordre attrayant' et la gorge était 'd'une sombre beauté inoubliable' avec ses versants boisés 'couverts de cheminées et de fours à briques abandonnés'. Quelques années plus tard, Tom Rolt s'émerveilla de voir un treuil à cheval encore en utilisation et de rencontrer un canneur de canots en osier.

La sauvegarde active d'Ironbridge commença en 1959, date à laquelle Allied Ironfounder Ltd, propriétaires de la Fonderie de Coalbrookdale existant encore, firent des fouilles du vieux haut fourneau de Coalbrookdale pour célébrer le 250ème anniversaire de l'utilisation du coke par Abraham Darby pour la fonte du fer. La société ouvrit un petit musée sur place et, durant les années 1960, le mouvement de sauvegarde fit d'autres progrès avec la fondation du Ironbridge Gorge Museum Trust (désigné IGMT par la suite) en 1968. Au début des années 1970, IGMT commença à restaurer les plus importants monuments, dont la plupart devinrent des Anciens Monuments Classés à cette époque, parmi les premiers monuments industriels à recevoir une protection brevetée de la sorte.

En 1963, une nouvelle ville fut fondée dans le East Shropshire Coalfields, connue par la suite sous le nom de Telford. La corporation de développement de Telford (TDC) était responsable de la récupération de grandes zones d'anciens terrains industriels abandonnés afin de les redévelopper. Elle prit également possession de nombreux monuments archéologiques et se mobilisa tout particulièrement pour Ironbridge afin que son intégrité historique soit respectée lors de sa une renaissance économique au cours des années 1970 et 1980. La TDC fut dissoute en 1991, alors que ses objectifs étaient presque achevés. Parmi les tâches qui lui restaient, se trouvaient le transfert de la plus grande partie de ses propriétés à de nouveaux propriétaires et la décision fut prise de donner un grand nombre des bâtiments et monuments historiques à une fondation à but non lucratif créée pour garder les propriétés pour le Ironbridge Gorge Museum Trust — Ironbridge (Telford) Heritage Foundation — ainsi qu'une dotation pour leur entretien futur. Ce sont les réparations effectuées sur les monuments qui accompagnèrent ce transfert de propriétés qui ont formé la base du travail archéologique décrit dans ce volume.

Les voix les plus anciennes ayant plaidé pour la sauvegarde d'Ironbridge étaient celles d'enthousiastes plutôt que d'archéologues professionnels (par exemple Rix 1955). La compréhension de l'histoire industrielle de la région a toutefois toujours été étayée par le savoir, mené au départ par les historiens de la métallurgie, de l'histoire économique et sociale, et du mouvement Quaker. La première grande œuvre sur ce sujet fut *Dynasty of Ironfounders* de Arthur Raistrick, en 1953, une étude de la famille Darby par un autre Quaker, suivie de plusieurs études de l'industrie locale du fer par Reginald Mott (1958, 1961). Une histoire économique et sociale complète des charbonnages du East Shropshire parut en 1973 avec *Industrial Revolution in Shropshire* de Barrie Tinder (2ème édition 1981), qui fut suivie d'études de l'art du Ironbridge industriel et des bâtiments de la région (Smith 1979a), Muter 1979). Au début des années 1980, IGMT établit une unité archéologique afin de répondre à la nécessité croissante de traiter l'archéologie de la période industrielle de la même manière que celle de toute autre période (Trueman 1988), alors que l'Institut d'Ironbridge fut à l'origine du Nuffield Survey, une étude de la géographie historique et des bâtiments d'Ironbridge (Alfrey et Clark 1993). Malgré le niveau croissant du travail archéologique, ce volume est la première enquête archéologique soutenue et vaste des principaux monuments industriels d'Ironbridge.

Zusammenfassung

Ironbridge ist die Verkörperung der fundamentalen Veränderungen, die in der industriellen Revolution des 18. und 19. Jahrhunderts stattfanden. Die *Ironbridge Gorge Conservation Area* erstreckt sich auf eine Länge von 3,6km über beide Ufer des Severn und ist für ihre wichtige Rolle, die sie zur technischen Entwicklung im 18. Jahrhundert beigetragen hatte, seit 1986 als *World Heritage Site* anerkannt. Die erstmalige Verwendung von Koks zur Eisenverhüttung im Jahre 1709 und die Erstkonstruktion einer bedeutenden gusseisernen Brücke im Jahre 1779 wurden dabei als besonders hervorstechend angesehen.

Dieser Beitrag befasst sich mit den sechs wichtigsten archäologischen Denkmälern in Ironbridge, die für sich und als Komplex als wichtigstes Beispiels ihres Typus gesehen werden. Drei der Eisenwerke – die *Coalbrookdale Company's Upper Works* und die Schmelzöfen der *Madley Wood Company* und *Blists Hill* – veranschaulichen die technologischen Entwicklungen der Eisenverhüttung vom 18. bis zum frühen 20. Jahrhundert. Die *Coalbrookdale Company's Upper Forge* ist ein wichtiges und seltenes Relikt der Schmiedeeisen Manufaktur, besonders für die kurze Zeitspanne gegen Ende des 18. Jahrhunderts vor der Anwendung des Puddelverfahrens von Cort. Backstein- und Dachziegelwerke von *Blists Hill* sind die besterhaltensten Beispiele der Mechanisierung der Ziegelbrennerei aus dem späten 19. Jahrhundert und sind Teil einer ausgedehnten industriellen Landschaft des 19. Jahrhunderts in der Nähe des Shropshire Kanals, zur der auch die nahegelegenen Hochöfen und die *Blists Hill* Grube gehörten, in der Kohle, Eisenstein und Ton abgebaut wurden. Die bestehende Länge des Kanals, von *Blists Hill* bis zu den *Coalport* Porzellanwerken, ist von der *Hay Inclined Plain* durchlaufen, ein beachtlicher Triumph für den Tiefbau des 18. Jahrhunderts.

Die industriellen Denkmäler haben zwischen den Siedlungen, die durch ihre Versorgung entstanden sind, überlebt und liegen in einer Landschaft deren Topographie zur Erhaltung von ursprünglichen Waldgebieten und Forst beitrug. Die Landschaft ist durch den Fluss Severn geprägt, der durch eine Schlucht mit steilen, bewaldeten Hängen fliesst. Kohlenflöze und Silurischer Kalkstein bestimmen die heimische Geologie. Die, für diese junge, sich noch entwickelnde Geomorphologie charakteristischen Erdrutsche und tektonischen Verwerfungen, sind schon lange ein Phänomen, dass die industrielle Landschaft beeinflusst hat, und sind nun zu wichtigen Faktoren geworden, die zur langfristigen Erhaltung dieser Denkmäler beitragen.

Die Region von Ironbridge, die auch Madeley und Broseley am Gegenufer des Severn umfasst, war seit dem 16. Jahrhundert der Brennpunkt des Handels und der Industrie im Kohlegebiet von *East Shropshire* (auch *Coalbrookdale* genannt). Ihre Gewerbe beruhten auf Bodenschätzen wie Kohle, Ton, Eisenstein und Kalk, und begannen mit grossangelegtem Kohleabbau im 16. Jahrhundert. Der Severn, der bis zum Zeitalter der Eisenbahn die Hauptverkehrsroute für das westliche Grossbritannien war, wurde nun das wichtigste Transportmittel für Fertiggüter und spielte eine wichtige Rolle in der frühen Entwicklung der Industrie in Ironbridge. Bis zum 18. Jahrhundert, als sich die Industrie rapide entwickelte, wurden die Tongewerbe, zum grössten Teil Töpfereien und die Herstellung von Tonpfeifen, hauptsächlich entlang der Kohlezechen und Kalkbrennereien am südlichem Ufer des Severns gegründet, wogegen am Nordufer Kohle und Eisen die Hauptgeschäftszweige waren.

Im 18. Jahrhundert ermöglichten es verschiedene technologische und organisatorische Neuerungen, dass die Eisenwerke in *Coalbrookdale* an der Spitze eines beispiellosen Wachstums im Britischem Eisenhandel standen. Das bedeutendste Symbol der Neuerungen im 18. Jahrhundert war die im Jahre 1779 errichtete Iron Bridge, eine Eisenbrücke über den Severn. Die Brücke war schon vor ihrer Fertigstellung berühmt und weitere technische Errungenschaften im Tiefbauwesen und Architektur folgen ihr auf den Fersen. Der Rückgang des Eisenhandels zur Mitte es 19. Jahrhunderts führte zur Schliessung aller Eisenwerke in der *Ironbridge Gorge*. Nur zwei blieben von der Schliessung verschont, wobei eine in *Coalbrookdale* in eine Giesserei umgewandelt wurde, die Haushaltswaren formte. Kohle und Tonabbau blieb im 19. Jahrhundert verhältnismässig wohlhabend. Die *Coalport Chinaworks* gewann einen guten Ruf in der Herstellung von hochwertigem Porzellan, aber schon am Ende des 19. Jahrhunderts wurde die Landschaft von der Ziegelproduktion geprägt, die vor allem Backsteine und Dachziegel produzierte, sowie spezielle Produkte wie Terrakotta. Für eine Spezialbranche, die Produktion von dekorativen Dachziegeln, wurden in Jackfield in den Jahren 1871 und 1883 zwei grosse Fabriken errichtet.

Im frühen 20. Jahrhundert erlitt die Wirtschaft in der Region einen Rückgang und die Industrien fanden sich vor erschöpften Rohmaterialien, veralteten Methoden oder beidem. Die sich ausbreitenden Backstein- und Dachziegelwerke – gross, schmutzig und hässlich – mögen zu dem grimmigen Image beigetragen haben, das von zeitgenössigen Schriftstellern wiedergegeben wurde. J E Auden, zum Beispiel, beschrieb Ironbridge im Jahre 1912 als eine 'uninteressante und irgendwie verwahrloste Stadt..deren Ufer mit Schlacke und Müll bedeckt waren' (Auden 1912, 138). Mitte dieses Jahrhunderts wurde eine andere Stimmung angeschlagen, eine tiefgreifende Änderung in der Wahrnehmung diente als Vorreiter zur Denkmalschutzbewegung. Audens Abneigung zu Ironbridge wurde für John Betjeman und John Piper zum Wohlgefallen: es Bestand aus 'attraktiver Unordnung' und die Schlucht wurde als 'unvergesslich trostlose Schönheit' beschrieben, deren bewaldete Hänge 'mit Schornsteinen und verlassenen Ziegelbrennereien bestückt' waren. Einige Jahre später war Tom Rolt begeistert noch eine Pferdewinde in Betrieb zu sehen und einem Coracle*-Bauer (*leichtes, nusschalenförmiges Boot aus mit Häuten überzogenem Weidegeflecht) zu begegnen.

Der aktive Denkmalschutz in Ironbridge begann im Jahre 1959, als die *Allied Ironfounders Ltd*, die Eigentümer der noch vorhandenen Coalbrookdale Giesserei, den alten Gebläseofen in Coalbrookdale ausgruben, um das 250. Jubiläum der Verwendung von Koks zur Eisenverhüttung durch Abraham Darby zu feiern. Die Firma eröffnete an der Stelle ein kleines Museum und in den 60er Jahren machte die Denkmalschutzbewegung weitere Fortschritte, indem sie 1968 eine wohltätige Stiftung gründete: den *Ironbridge Gorge Museum Trust* (IGMT). In den frühen 70er Jahren übernahm die IGMT die Restauration der wichtigsten Baudenkmäler und die meisten der Gebäude wurden während dieser Zeit unter Denkmalschutz gestellt. Sie waren damit unter den ersten industriellen Denkmälern, die auf diese Weise gesetzlichen Schutz erhielten.

Im Jahre 1963 wurde eine neue Planstadt im *East Shropshire Coalfield* gegründet, die später Telford getauft wurde. Die *Telford Development Corporation* (TDC) war für die Wiederentwicklung von brachliegendem, ehemaligem Industrieland verantwortlich. Sie übernahm ausserdem den Besitz vieler archäologischer Denkmäler und hat aktiv daran mitgewirkt, dass Ironbridge während seiner wirtschaftlichen Wiederbelebung in den 70er und 80er Jahren seine historische Integrität behielt. Die TDC wurde 1991 aufgelöst, da seine Ziele fast erfüllt waren. Eine seiner letzten Aufgaben bestand darin, den Besitz auf neue Eigentümer zu übertragen und es wurde entschieden, dass eine grosse Anzahl der historischen Baudenkmäler einer Wohltätigen Stiftung übergeben werden sollten, die ausschliesslich zur Verwaltung der Eigentümer des IGMT gegründet wurde und Stiftungsgelder für deren zukünftige Instandhaltung erhielt: die *Ironbridge (Telford) Heritage Foundation*. Die Reparaturen der von dieser Übereignung betroffenen Baudenkmäler, und die damit verbundenen archäologischen Untersuchungen sind der Inhalt dieser Studie.

Die ersten Stimmen, die zum Denkmalschutz aufriefen, waren eher Liebhaber als Berufsarchäologen (z.B Rix 1955). Das Verständnis der industriellen Geschichte war allerdings schon immer durch geisteswissenschaftliche Forschung untermauert, allen voran die Geschichtsforscher der Metallurgie, der Wirtschafts- und Sozialgeschichte und die Quakerbewegung. Das erste bedeutende Werk zu diesem Thema war das 1953 herausgegebene Buch von Arthur Rainstrick: *Dynasty of Ironfounders*, eine Studie der Darby Familie durch einen Quakergenossen, dies war gefolgt von Reginald Motts diversen Studien des örtlichem Eisenhandels. Mit Barrie Trinders *Industrial Revolution in Shropshire* (2. Auflage 1981) kam 1973 eine vollständige wirtschaftliche und soziale Geschichte des East Shropshire Coalfield, gefolgt von ästhetischen Studien des industriellen Ironbridge und seiner regionalen Fabrikgebäude (Smith 1979a, Muter 1979). In den frühen 80er Jahren gründete die IGMT einen Archäologieverband um der wachsenden Anforderung entgegenzukommen, der Archäologie des Industriezeitalters dieselbe Stellung zu geben, wie die anderer Epochen (Trueman 1988). Zur selben Zeit wurde die *Nuffield Survey* vom *Ironbridge Institute* in die Wege geleitet, ein Gutachten der historischen Geographie und der Gebäude in Ironbridge (Alfrey und Clark 1993). Trotz des wachsendem Aussmasses archäologischer Studien, ist der vorliegende Bericht die erste kontinuierliche und vollständige Untersuchung der wichtigsten industriellen Baudenkmäler von Ironbridge.

1 Introduction: Archaeology and the Severn Gorge Repairs Project

The Severn Gorge Repairs Project accompanied the transfer in ownership of several of the most important archaeological remains in the Severn Gorge from the Telford Development Corporation to the Ironbridge (Telford) Heritage Foundation, a property holding company for the Ironbridge Gorge Museum Trust. Twenty sites and buildings were to be repaired and consolidated, ranging from complete buildings in full use, such as IGMT's Wharfage office in the centre of Ironbridge, to crumbling ruins like Bedlam furnaces or the lime kilns at Bower Yard. Six of the sites either were, or formed part of, a Scheduled Ancient Monument, whilst twelve others were listed buildings, one at grade I and four at grade II* (Table 1). Six of the sites are studied in this volume, grouped according to industry and proprietorship: the Coalbrookdale Company's Upper Works and Upper Forge, the Madeley Wood Company's Bedlam and Blists Hill blast furnaces and its Blists Hill Brick and Tile Works, and the Shropshire Canal (Fig 1). The study of the canal is focused upon the Hay Inclined Plane and also includes work on the extant sections of the canal, which are linked to the upper and lower ends respectively of the incline and are known as the Blists Hill Canal and Coalport Canal (Fig 1).

The project was the result of several years' planning, beginning with negotiations for the ownership transfer in the late 1980s. A working group was established in 1990 to develop a strategy and agree costs for the repair and consolidation of the monuments and buildings, the purpose of which was to ensure their long-term survival and structural stability. The project was initially managed by the Telford Development Corporation and subsequently by IGMT. The consultant architects were Stainburn Wheatley Lines (now Wheatley Taylor Stainburn Lines). Ian Stainburn was appointed project coordinator with particular responsibility for liaison with the other consultants: Barnsley and Associates (civil engineers); Bond Foster and Partners (quantity surveyors); John Neal (structural engineer); Scott Wilson Kirkpatrick (civil engineers). The archaeological component of the project was undertaken in house by IGMT, making full use of the available expertise and documentation. The contractual building work for each phase was let out to competitive tender in accordance with the guidelines of

Table 1: The buildings and sites covered by the Severn Gorge Repairs Project

Name	Grid ref	Listing/scheduling status	Archaeological input
Long Warehouse, Coalbrookdale	SJ 668 047	II (spot list 1997)	
Museum of Iron, Coalbrookdale	SJ 667 047	II*	Part
Coalbrookdale Chapel	SJ 669 046	II	Part
Coalport China Museum	SJ 695 024	II*	Part
The Wharfage, Ironbridge	SJ 672 034	II	
17 High Street, Coalport	SJ 694 026	II	Part
Warehouse, Blists Hill Open Air Museum (former brickworks drying shed)	SJ 695 036		
Upper Forge, Coalbrookdale	SJ 669 042	II	Full
Blists Hill Brick and Tile Works	SJ 695 035	II	Full
Blists Hill blast furnaces	SJ 695 034	SA 339, Grade II	Full
Lime kilns, Bower Yard	SJ 667 036		
Bedlam Furnaces, Ironbridge	SJ 678 033	SA 340, Grade II*	Full
Upper Furnace and associated structures, Coalbrookdale	SJ 668 049	SA 345, Upper Furnace Grade I, Snapper Furnace Grade II*, Turning Mill Grade II	Full
Tar Tunnel, Coalport	SJ 694 026		Part
Railway Tunnel, Silkin Way	SJ 693 033		
Coalport Canal	SJ 694 026	SA 342	Part
Hay Inclined Plane	SJ 695 028	SA 342	Full
Blists Hill Canal	SJ 695 033	SA 342	Full
Shropshire Canal Culvert	SJ 695 028		Part
Blists Hill mine shafts	SJ 695 035		Part

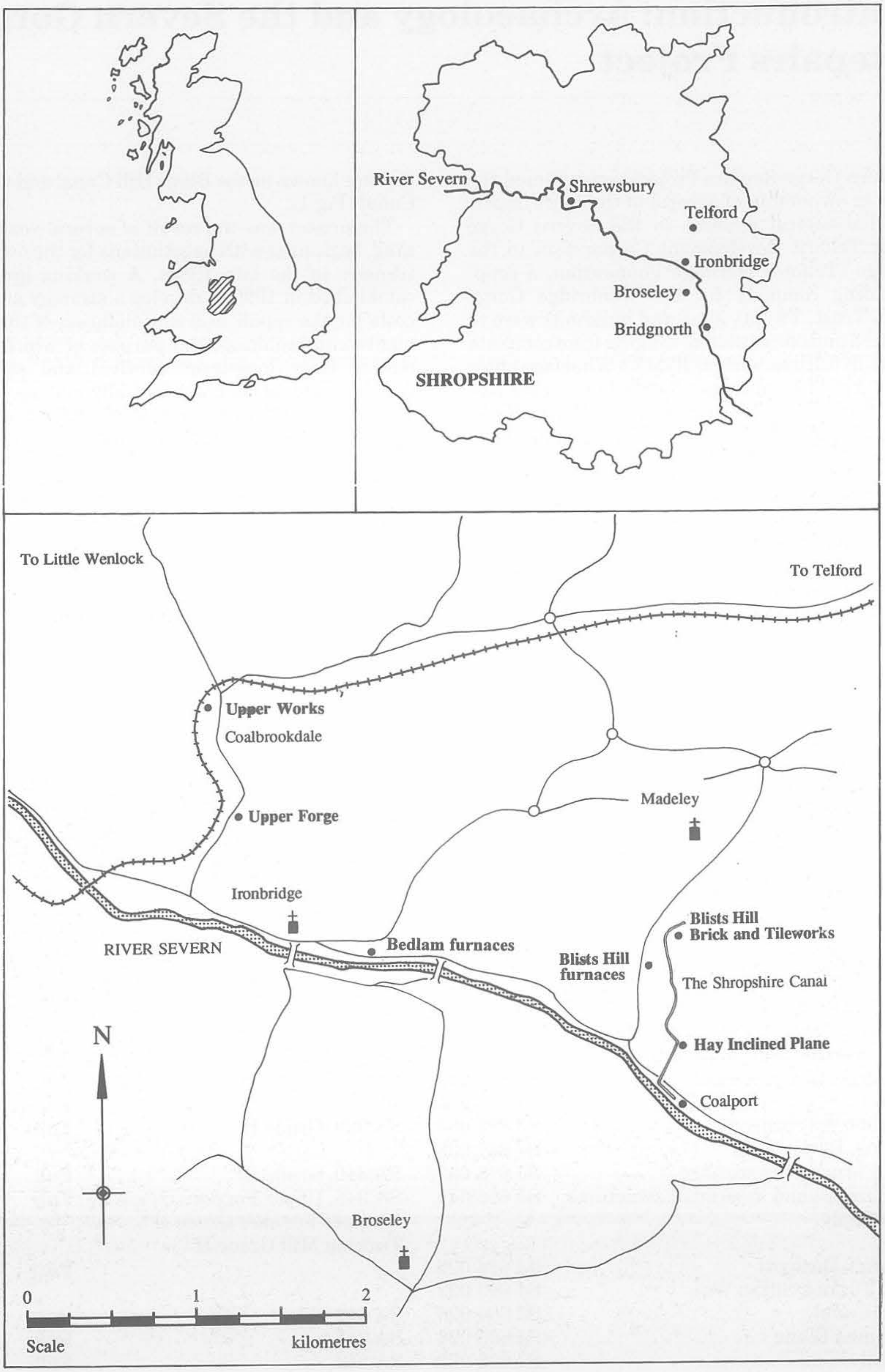


Figure 1 Location plan of the case-study sites.

the Telford Development Corporation, subsequently the Commission for the New Towns (CNT).

Many of the sites required several phases of work. The first phase in most cases was investigative, the results from which were necessary before the detailed repair specifications could be designed. Large sites such as Blists Hill blast furnaces required successive phases of work, each of which had to be complete before the next stage could be finalised. The main types of work are listed below, but the most common were the need to shed water from the structures and overcome structural destabilisation by inserting anchors and ties. The latter requirement was partly the result of geological movement and slip within the Gorge, but also a consequence of preserving buildings well beyond their intended working lives. Other work included the consolidation of brickwork and masonry; insertion of structural steelwork; underpinning foundations; vegetation removal; repair or replacement of openings; flaunching and capping; stabilising ground surfaces; and drainage works. The approach to conservation work is described more fully in Appendix 1. Alteration, conversion, reconstruction, and the provision of new services did not form part of the remit, but some such works were undertaken simultaneously by IGMT. Enhancement of structures only occurred in a few cases where there were underlying structural problems and generally involved the removal of unsympathetic modern building materials. In some cases, notably the Museum of Iron in Coalbrookdale, it was necessary to remove the contents of the building before the repair work could proceed (Fig 2). This was taken as an ideal opportunity to redesign the museum and its exhibits. The new Museum of Iron was opened in 1995.

The objectives of the archaeological work were to produce an archive and site narrative reports as defined in The Management of Archaeological Projects (hereafter MAP) (English Heritage 1989) and the work was to concentrate upon the areas of specified repairs and consolidation. Thus, the detailed specifications provided by the architects and engineering consultants were used as the basis for the archaeological briefs throughout the project. The repairs and associated archaeological recording were undertaken between 1991 and 1995. Towards the end of the recording phase and before the production of final reports, the aims and objectives of the archaeological work were amended to try to bring them closer into line with the developments arising from the 1991 revision of MAP (MAPII) and Planning Policy Guidance Note 16 (hereafter PPG16). The project was primarily concerned with building recording (see Appendix 2), but

Figure 2 The Museum of Iron is housed in a warehouse built in 1838, standing at the south end of the Coalbrookdale Upper Works. After repairs the museum was refurbished and reopened in 1995.

the monitoring of excavations and boreholes, and documentary research were also undertaken.

The repairs were funded by the Commission for the New Towns, part of the Department of Environment. English Heritage provided full grant aid for the archaeological programme under Section 24 of the Ancient Monuments and Archaeological Areas Act. The fullest archaeological briefs applied to the Scheduled Ancient Monuments – the Coalbrookdale Upper Works, Bedlam furnaces, Blists Hill furnaces, and the Hay Inclined Plane. Work on listed buildings was predominantly connected with groundworks, with building recording relating to selected areas where intervention was to be the greatest. In most cases, with the notable exceptions of the Upper Forge and the Blists Hill Brick and Tile Works, the archaeological work on listed buildings was minor and results were not substantial enough to justify presentation here as individual case studies. Buildings like the Coalbrookdale Museum of Iron have nevertheless been incorporated where appropriate into discussions of the broader context of the monuments and their conservation.

Only one site has been omitted from the present study. Excavations for renewing drains at the Coalport China Works revealed substantial assemblages of porcelain and earthenware, the results of which have been published separately as they required specialist analysis (Barker and Horton 1999).

A discussion below of the approach to the archaeological work precedes detailed case studies. Full unpublished reports have previously been written for each of the sites, allowing the information to be presented here in a condensed form. Where new information has emerged since the completion of the reports this has been incorporated. This is especially relevant to the study of the Upper Forge. The case studies conclude by reviewing the archaeological evidence in a broader local and national context. In the case of the ironworking sites their context is considered collectively. A retrospective consideration of the techniques and approaches employed in what has been one of the largest recording projects to be undertaken in industrial archaeology assesses the constraints and benefits of particular approaches and makes recommendations for future projects of this type. (Further consideration of the management of archaeological projects and recommendations for achieving the long-term sustainability of archaeological monuments are intended to reach a wider disciplinary audience and are given in Appendices 3 and 4.) The study concludes by assessing the achievements of the project in terms of the aims set out in this chapter and suggests areas for future research.

One of the aims of the present study is to argue that archaeological sites, even those less than a century old, benefit from more intensive recording than is often realised (*pace* Palmer and Neaverson 1998, 92–5). Archaeology can have a decisive role to play in our knowledge of the Industrial Revolution and what follows is intended to demonstrate how it can proceed from the drawing board to the analysis of technological change. Documentary sources alone are inadequate to show how plant and machinery was used and modified over its lifetime, but archaeology is well-placed to contribute to this issue. The study also acknowledges that the research of individual sites is constrained without adequate resources and can best flourish when it is an integral part of a curatorial or management strategy. The role of the buildings or industrial archaeologist is therefore to combine research with an active role in preservation.

Aims and scope of initial recording work

Although most of the monuments were undergoing their second generation of repairs, little documentation was available from the previous works and in effect the sites were all approached as if they were being repaired for the first time. With minor exceptions, no existing archaeological records were relevant to the archaeological fieldwork, which consequently could also make a fresh start. Because the project was conceived before PPG16 and in line with MAP there was no preliminary evaluation phase, which was subsequently to become standard practice in English archaeology.

Much of the initial archaeological work consisted of monitoring site investigations, which took the form of shell and auger boreholes, rotary boreholes, horizontal coreholes, and test excavations. Monitoring devices were installed concurrently by the engineers, including inclinometers and piezometers in boreholes and tell-tales on walls.

The scope of investigations at each site varied considerably. Sometimes the archaeological project manager was asked to comment on the locations of the boreholes or excavations and was able to move them to positions more likely to yield useful archaeological information. This was the case, for example, at Blists Hill blast furnaces and along the Shropshire Canal to the Coalport China Museum where a major programme of investigations was undertaken. On other sites there were very few if any investigations, resulting in a lack of advance information about the survival and potential of archaeological deposits. At the Upper Forge, three boreholes were drilled to the rear of the building, but it became quite clear that the scope of this investigation had not been extensive enough to characterise the ground conditions, as deep deposits of archaeological importance were subsequently found. No boreholes were undertaken at the Blists Hill Brick and Tile Works but some trial pits were excavated, mainly in connection with the east wall of the clay preparation block which was retaining a bank and was not adequately tied in with the rest of the structure. Investigation at the Coalbrookdale Upper

Works was limited but interesting, and consisted of two boreholes through the charging platform and an auger hole in the snapper furnace (Fig 3). It was thought that the charging platform might be a solid rubble structure, but this proved not to be the case, as confirmed during the later stages of the project, when vaulted chambers were found beneath the charging level (see below, Chapter 2).

Originally it was proposed to undertake the repairs in phases, carrying out urgent works first. In some cases, this involved making good the roofs and upper parts of the structures to make them weatherproof. However, the bases of the buildings were sometimes in too poor a condition for this to be a success, so this system of phasing was abandoned. Instead, a programme was devised on a site by site basis, with the project coordinator in consultation with the other team members. A system of phasing had to be retained for the archaeological work as English Heritage receives funding from central government annually, as opposed to the Commission for the New Towns which receives funding on a project basis. Thus, the archaeological programme was divided into three consecutive phases which were intended to trigger grant payments for each site project. All the site investigation works were undertaken as a clearly defined block in phase 1. The repairs were allocated to phases 2 and 3 (and sometimes phase 1), but in the event much of it was undertaken simultaneously.

The initial brief for building recording was to analyse the structures by annotating drawings provided by the architects and engineers. For the more complex monuments requiring extensive repair, namely the scheduled sites, the brief allowed for a full interpretation. For the remaining buildings and monuments, key elevations and plans of areas to be repaired were to be assessed. The architects' drawings proved to be unsuitable for the archaeological analysis of complex structures simply because the needs of architects and archaeologists are so different – the critical importance of dimensionally accurate drawings for archaeologists, in contrast to the requirement of architects to convey more practical information.

In the case of listed buildings, confining recording and analysis to those parts of the structures which were to be repaired proved in the end to be a hindrance to the interpretation. However, as a result of PPG16 and MAPII, the approach to building recording was modified during the course of the project to suit its particular needs and extra resources were provided later for work on some of the listed buildings.

In practice, much of the building recording was undertaken during the main repairs phase, not only because of amendments to the methodology, but because of problems with access: The erection of scaffolding and provision of safe working conditions were essential, especially the furnace sites which are on two levels separated by tall structures (Fig 4). Full scaffolding was never erected inside the clay preparation block at the Blists Hill Brick and Tile Works, limiting the amount of recording and thus analysis that could be done. Problems of access meant that much of the recording work had to be undertaken simultaneously with monitoring repairs, leading to some intense periods on site. At Bedlam, the archaeologists were commissioned by the architects to produce survey drawings for all the consultants. This proved to be the best solution, except that the front elevation of the monument was

Figure 3 The snapper furnace at the Upper Works, photographed in 1991 and looking north, showing one of the arched openings at the base of the furnace. Although it had previously undergone minor repairs it was treated as virgin archaeological territory.

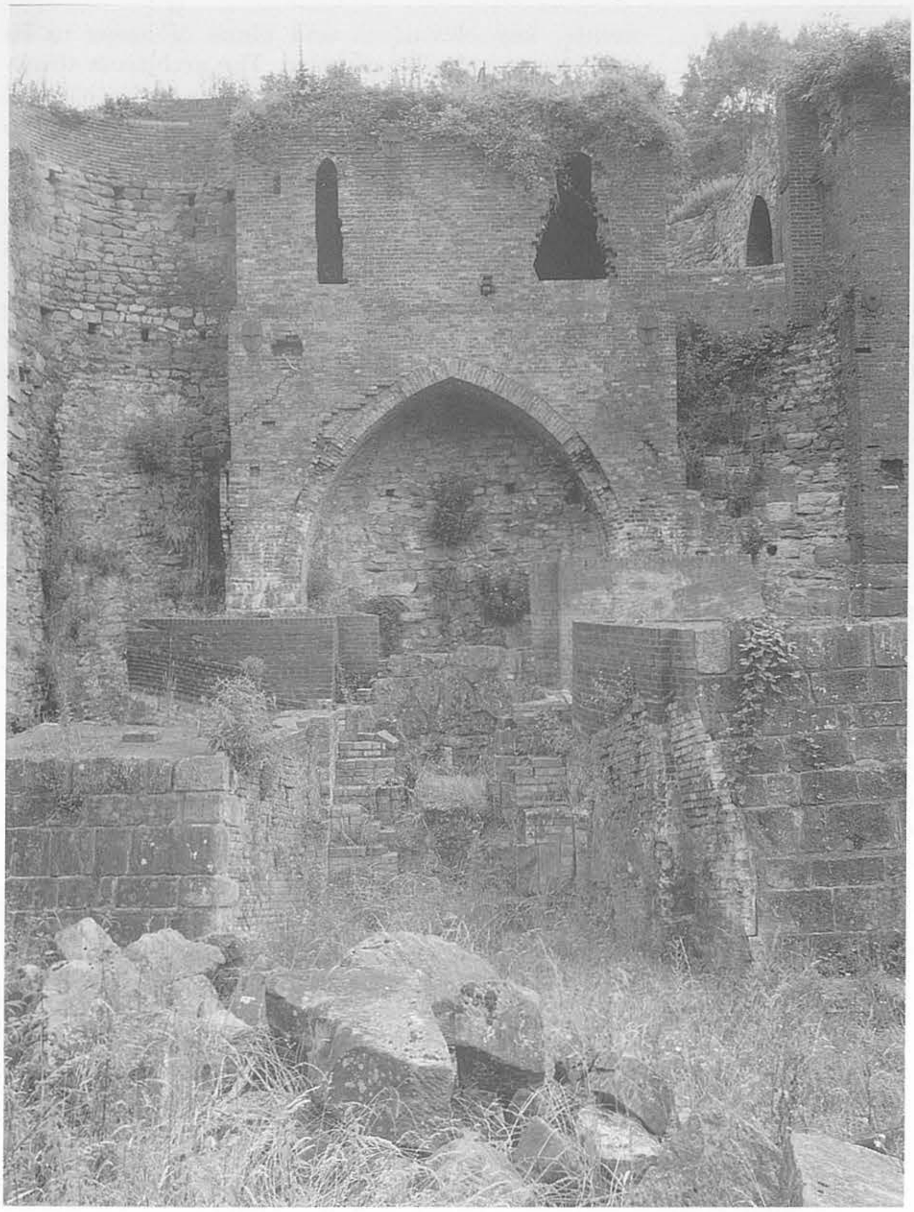


Figure 4 Furnace I and the north charging house at Blists Hill, photographed in 1991. Full recording of the charging house was not undertaken until scaffolding was erected. The stone rubble in the foreground was excavated in 1973 with the furnaces and probably formed part of the furnace bases. The bases were substantially repaired with brick following their excavation.

omitted as it was to undergo relatively few repairs. English Heritage provided additional funds to complete the record.

IGMT has a considerable body of historical and archaeological information on the East Shropshire Coalfield, including an archaeology archive dating back to the early 1980s and primary documentary material transferred from the Telford Development Corporation. Its library holds primary and the major secondary sources relating to industrial Shropshire as well as specialist technical literature. Documentary research was not itemised in the archaeological specifications as such, but allowed for research of secondary sources only (see below). This was amended in 1994 to include consultation of known primary sources, which meant that much historical work was done after the fieldwork.

The archaeological briefs made an allowance for the processing and archiving of finds. Finds were generally few because of the nature of the work and because many of the sites such as Bedlam had already been excavated and repaired. The major exception was at the Coalport China Museum, already mentioned (Barker and Horton 1999). The funding allowed for an assessment of the finds from Coalport, and also of a smaller assemblage of mid to late-19th century material found during the investigative phase on the site.

Interim reports were produced at the end of the first phase to trigger grant payments. These consisted primarily of the results of the site investigations, along with selected building recording and documentary research. The situation was more complicated for phases 2 and 3, because they were undertaken concurrently. During 1995, a second series of interim reports was produced to trigger grant payments. These included a review of documentary sources, brief site descriptions, a sample of finished drawings, a discussion of working hypotheses, and a list of the work required to complete the projects. The final reports, the full and definitive accounts of the work, were produced between 1995 and 1997.

Approach to fieldwork

From the outset the archaeological recording was intended to perform two functions: to acquire data for interpretation and to document interventions. The first criterion should ideally have been fulfilled before design briefs were prepared and scheduled monument consent (SMC) applications were submitted. The second criterion determined much of what was drawn, with several important consequences. In many cases both the exterior and interior walls of a building were drawn in detail, which many buildings historians might regard as excessive. Certainly a different strategy would have been adopted if research or preservation by record were the only criteria. Most of the drawings required were elevations, since these are self-evidently the most useful for documenting repairs. Fewer plans were therefore surveyed than was ideal from an archaeological perspective. As a result there is no plan of the whole Coalbrookdale Upper Works surveyed for archaeological purposes. The best solution was found at Bedlam, where the architects commissioned upper- and lower-level plans from the archaeologists.

Documentation of interventions required the elevations to be drawn in detail, the standardised conventions for which are explained in Appendix 2. A variety of survey methods were used. A theodolite was used to survey Bedlam. The important elevations were all drawn by hand using level datum lines in the same way as an excavated section would be drawn. The dam walls at the Coalbrookdale Upper Works were drawn from a photogrammetric survey conducted for the Telford Development Corporation. An EDM was acquired mid-way through the project and was used for some of the plans and elevations, both for the initial recording and the surveying of interventions such as new fences.

In addition, mainly black and white photographs were taken to document strategic phases of the repairs, crudely speaking before, during, and after. Large numbers of colour photographs were also taken as a form of note taking supplementary to the usual notebooks. Colour photographs were particularly helpful in distinguishing different areas of fabric. Context sheets were not used. Although they might have been relevant to groundworks, the recording of excavations was performed rapidly as they were machine-dug by contractors, and it would have introduced an inconsistency if different recording techniques were used for features below ground and those above. The use of contexts in building recording is discussed below in Chapter 11.

Boreholes and anchor drilling were monitored and recorded, and samples were taken. The engineer's or driller's logs were obtained afterwards to supplement the archaeological record. Sampling of soils and waste products from the ironworking sites rarely proved helpful, although material from the groundworks was systematically recovered. Samples of slag from the 18th- and 19th-century ironworking sites did not contribute to the understanding of any of the sites. At the beginning of the project it was hoped that samples of slag from the Upper Forge would enable the exact techniques of ironworking there to be discovered, but in the event new historical information eliminated the need for it. Likewise, an unsuccessful attempt was made to date the Upper Forge by dendrochronology using samples taken from the roof trusses, but again new historical information has rendered it unnecessary.

The case of mortars is different, however. These were systematically recovered with the intention of constructing a typological sequence which could be used as an aid to interpretation in addition to the normal structural analysis. It was found preferable not to select mortars from the surface if it could be avoided and all mortars needed to be dried out before they could be compared, since moisture affects their colour, texture, and hardness. The value of mortar samples will be reassessed in the review of techniques below (see Chapter 11).

Approach to interpretation

At the beginning of the project, the definitive accounts of the sites had in each case been provided by documentary evidence rather than archaeological analysis. The one partial exception is the Blists Hill Brick and Tile works whose buildings were interpreted as part of an 1870s brick manufactory (Dawes 1979), not of *c* 1851 as previous historical work had implied. Where archaeological work had previously been undertaken, as at the Hay Inclined Plane, Bedlam, the Upper Forge, and the Upper Works, it was constrained in its scope. John Malam's work at the Upper Works was essentially rescue recording when foundation trenches for a cover building over the upper furnace were dug (Malam 1982). Stuart Smith's account of Bedlam was based on the restoration of the site in the 1970s and the use of pictorial evidence (Smith 1979b). Previous excavation at the Upper Forge was occasioned by the need for training excavations at the Ironbridge Institute (Hanks 1988). Roger Tonkinson's study of the Hay Inclined Plane was part of a general study of the Shropshire Canal inclines, although it is a valuable document of the site before its first phase of restoration in the 1970s (Tonkinson 1964). The Nuffield Survey in the 1980s gave general accounts of the sites and was reliant on previously established historical material, but did not have an opportunity to undertake detailed fieldwork (Alfrey and Clark 1993). The obvious advantage of this from the perspective of the present authors was a comparatively clean slate.

At the beginning of the project, documentary evidence seemed to be the least promising avenue for furthering our knowledge of the sites. Documentary material relating to the Ironbridge area has been extensively researched (Trinder 1981), to the point that the principal sources are well known and many of them have warranted publication in their own right (Trinder 1979, 1988). It should also be remembered that the archaeologist studying Coalbrookdale is blessed with a remarkable series of maps which document the development of the area in stages from the mid-18th to the 20th centuries (Fig 5).

When the briefs for each site were drafted, documentary research was given a low priority for another, but related, reason. Documentary research is difficult to quantify and a research brief which does justice to the potential of the subject may take up a substantial amount of time with no guarantee of success. The problem of controlling documentary research in the real world of archaeology funding is both serious and difficult. The initial intention of using secondary sources only was partly determined by the obvious fact that the area had been extensively researched. It was also determined by funding constraints and the fact that MAP and MAPII take no account of it in their recommendations. In the event it became apparent that using second-hand history in conjunction with first-hand archaeology was inadequate, and the brief was later modified to allow known primary sources to be consulted. However this was limited to local sources held by IGMT, the Shropshire Records and Research Centre, the National Coal Board Collection in the Staffordshire Record Office, and the Boulton and Watt Collection in Birmingham Central Library. The final reports were careful to claim that the historical work was rigorous but not exhaustive.

In addition to the usual historical sources, it was hoped that a substantial archive of oral testimonies compiled by IGMT would be useful in elucidating the latter-day uses of sites such as the Coalbrookdale Upper Works and Upper Forge, whose histories in the 20th century have never attracted much interest. The greatest potential for oral history, however, was in the interpretation of the Blists Hill Brick and Tile Works, which continued in production until the 1930s.

The primary purpose of the archaeological investigations was to explain the sites in chronological and functional terms and to integrate the archaeological with the documentary evidence. This is the basis on which historic archaeology is founded and yet it had never been achieved satisfactorily for the Ironbridge sites. Site narratives could then be used to tackle more specialised themes. The primary theme was that of technology. The nature of archaeological evidence is particularly suitable for technological evaluation and archaeology can in theory often provide more definitive information than historical sources. For example, it has long been established that Ironbridge was the place where, at the end of the 18th century, steam power was more widely

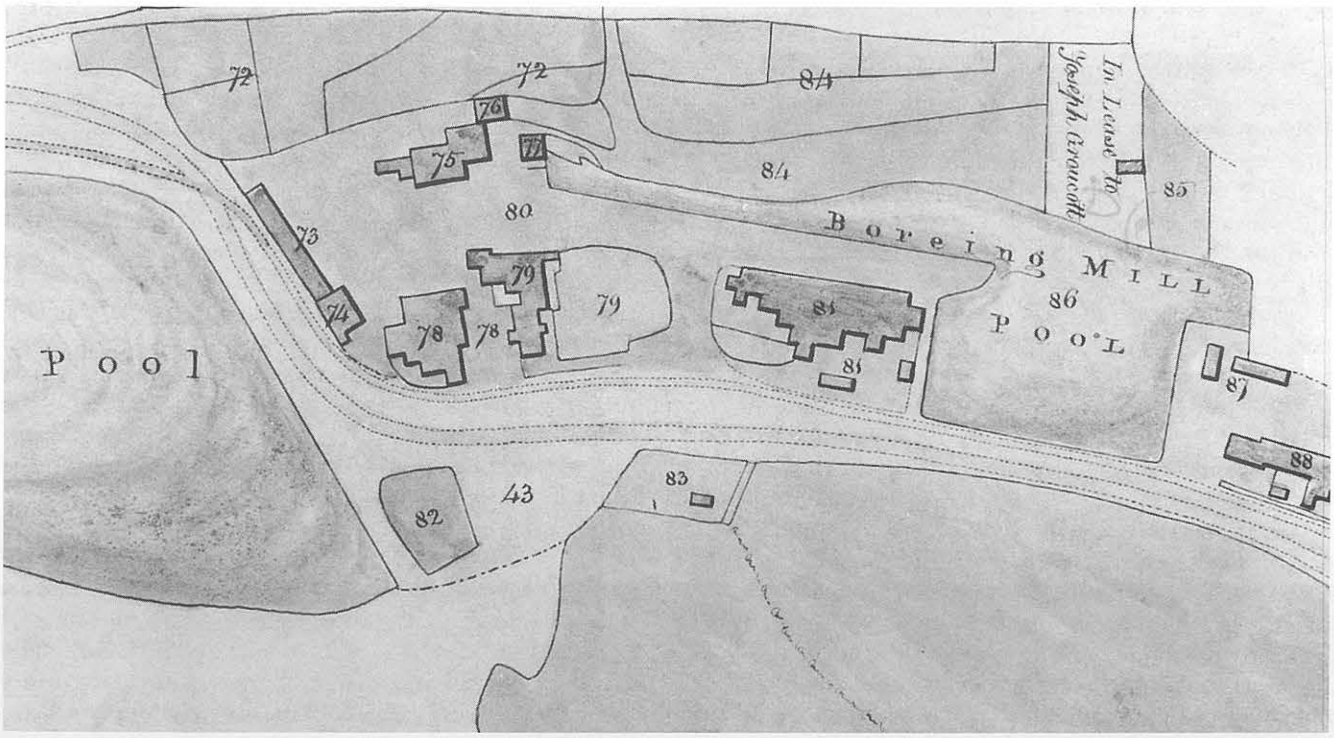


Figure 5 The Upper Forge and boring mill from a detailed lease plan dated 1838. North is to the left of the picture. Industrial Coalbrookdale is unusually well endowed with cartographic sources. (Shropshire Records and Research Centre)

used than almost anywhere else in Britain. There was also considerable experimentation into new types of engine, such as those designed by Adam Heslop on the Shropshire Canal. Do the Ironbridge sites therefore document a steady progression to technological complexity?

The greatest opportunity for assessing the technological context through time would be offered by the three sites where iron was smelted: the Coalbrookdale Upper Works, Bedlam, and Blists Hill. It has previously been argued of Bedlam that 'any archaeological investigation of the site needs . . . to aim at presenting a dynamic rather than a static picture of the works', Bedlam being 'a process which was constantly being improved through the industrial revolution period' (Smith 1979b, 23). This is a significant statement in its own right, given that it assumes that the ironworks would have kept pace with technological developments. However the three blast furnace sites span the mid-17th to the early-20th century, during which time many innovations were introduced into the trade: the introduction of coke smelting; the replacement of bellows by blowing cylinders powered by waterwheels, requiring a blast regulator; steam-powered blowing engines, also requiring a regulator; furnaces blown with tuyères on two or three sides of the furnace; and furnaces blown with hot blast. Only the latter does not concern us here as its absence in the local ironworks is well documented.

A consideration of the principal themes was intended to contribute to a more general understanding of the sites within the context of the Shropshire and British iron industries, allowing them to be understood as part of general trends in the iron trade. In this context the local iron industry has been characterised as innovative in the 18th century and increasingly old-fashioned as the 19th century progressed (Trinder 1981, 239). Blists Hill is the classic example of this, its persistence with cold-blast iron into the 20th century giving the impression that it has little to say about the contemporary iron trade (Clark 1993, 50). But Blists Hill has not previously been the subject of a detailed archaeological enquiry and the technological context of the site therefore needed careful consideration.

Where an initial phase of work was undertaken, as at the Upper Works, Bedlam, Blists Hill blast furnaces, and the Hay Inclined Plane, the process of recording and analysis helped to produce a more focused research agenda. The interpretive emphasis also shifted as new historical information became available. For example, the statistics of British blast furnace production which were published just after the fieldwork had been completed blew away some of the myths about the later years of the Blists Hill blast furnaces which the output figures for the works had already cast doubt upon (Riden and Owen 1995). Much of the historical research was done after the fieldwork was completed, for reasons explained above, although this was not quite the handicap that it could be imagined to have been. For example, the late date of the Blists Hill Brick and Tile Works buildings was proved long after the fieldwork, but analysis of the building had already rejected an argument for the mid-19th century that had been put forward on the grounds of historical evidence.

Report structure

The structure of the final reports was established before any of them were written, partly to standardise the reports as a coherent series, but also as a valuable exercise in thinking through the problems of presenting a diverse range of information. In addition to interpreting the monuments in accordance with the procedures outlined in MAPII, the archaeological reports were also intended for the future management of the monuments and information had to be tailored to that need.

The reports were divided into two main sections, describing firstly the sites as previously known and then detailing the interventions and the interpretation. The documentary evidence was described first, followed by detailed descriptions of each site as existing at the beginning of the project. Subsequently, previous works were to be described in detail and divided into two parts: previous interventions and previous archaeological work. Previous archaeological work was also taken to include the investigations in the first phase of the repairs project as these also informed the research agenda for the main phase of repairs. The conclusion of the first main section was to write a research agenda geared towards what was most likely to be resolved in the proposed recording works and interventions. Although in all cases the extent of the archaeological work was far greater than had previously been attempted, it was recognised from the beginning that the archaeological researches were not exhaustive. For example the Coalbrookdale Upper Works was known to have had a working life in the iron industry from the mid-17th century to the 20th, but the archaeological interpretation would be confined to the upstanding remains, leaving no possibility at present for investigation by excavation of the likely earliest features at the site, in particular the search for air furnaces, casting pits, and an early brass works.

The second main section began by documenting the interventions to the sites, providing all the necessary information for the reports to be treated as management documents. This included all previous excavations and structural repairs, the latter being identified on the repairs drawings described in Appendix 2. Groundworks undertaken during the course of the repairs project necessarily preceded the interpretation and were expected to provide important new information about the sites. Given that the reports were intended to be working documents rather than merely isolated statements, it was important to include alternative arguments in the discourse of interpretation. This openness is of course expected of an archaeological enquiry, but was additionally important because the reports were designed to form the basis of future work. Interpretation was followed by a statement of significance, allowing sites to be evaluated within a local and a national context. The final chapter made recommendations for the future management of the sites. In the case of the non-scheduled sites like the Upper Forge the statement of significance was a mechanism for establishing areas of national archaeological importance, a non-statutory but interim stage in advance of consideration for scheduling. This was one of the key management recommendations at the Upper Forge, while consideration was also given to the boundaries of the existing scheduled sites. The management recommendations were intended to provide an evaluation for future interventions. These identified research agendas, both in terms of archaeological and documentary research, identified the areas of archaeological sensitivity and suggested in broad terms the minimum archaeological specification which might be necessary in the event of any interventions.

In summary, the reports were designed to document all previous and current interventions at each site before taking our understanding of the sites further. Equally important, the reports were also conceived to combine research and management of the sites into an integrated whole, to assess their importance and to be an important document for future interventions and research.

2 The Upper Works, Coalbrookdale

Introduction

The place of Coalbrookdale in the history of the Industrial Revolution hardly needs introduction. The preservation of its major buildings as one of the key monuments of the period has not always been a foregone conclusion, however. In a prescient comment published in 1958 Nikolaus Pevsner described the older buildings at the Upper Works as 'shockingly sordid', and suggested that 'a little money could put it right and create a monument to early English industry' (Pevsner 1958, 156) (Fig 6). Efforts to save the site from clearance had been underway since the early 1950s, a campaign which triumphed in 1959 when the owners of the site, Allied Ironfounders Ltd, decided to create a small museum marking the 250th anniversary of Abraham Darby's adoption of coke for smelting iron. In archaeological terms the principal aim of the 1959 project was to remove the spoil that had been dumped on the site in the 1930s, an act which inadvertently saved the structures there from further deterioration by protecting them from the weather.

For archaeologists and historians intent on interpreting the site, one significant change was made during the campaign to save the furnace: A date of 1658 on two of the cast-iron lintels of the blast furnace was changed to 1638 (Fig 7). This alteration has never been acknowledged or explained in print and slipped unnoticed into the official history of the site, to the extent that it has only recently been questioned.

In 1970 the whole Coalbrookdale Upper Works became part of the Ironbridge Gorge Museum Trust, which created a museum of the iron industry in a warehouse of 1838, while a late 19th-century warehouse was converted for use as a library, gallery, offices, and institute. As for the blast furnace, a pyramidal cap had been erected over the top of the furnace in 1959 to protect its inner lining, which was superseded in 1982 by the erection of a cover building over the whole furnace (but not over the remaining structures on the site) (Fig 8). Subsequently the blast furnace has sometimes been referred to as the 'Darby furnace', but the term is not historically valid and is not used here.

Considering its significance as one of the landmarks of the Industrial Revolution, it is surprising how little archaeological work has previously been undertaken at the site. A limited amount of recording accompanied the erection of the cover building in 1982, excavations for which were undertaken by mechanical digger (Malam 1982). Further recording accompanied interventions to the wall of the pool dam, following its partial collapse in 1987. The consequence of this is that the definitive accounts of the site and its context in the history of technology have hitherto been provided by historians rather than archaeologists (Raistrick 1953; Trinder 1981; Cox 1990).

Figure 6 The Upper Works in the early 1950s, viewed from the east side, showing the upper furnace in the centre and the former turning mill in the background beneath the viaduct. The spoil around the site was cleared in 1959. The gabled truss on the right of the picture was taken down during the clearance works but was not reinstated. (Ironbridge Gorge Museum Trust)

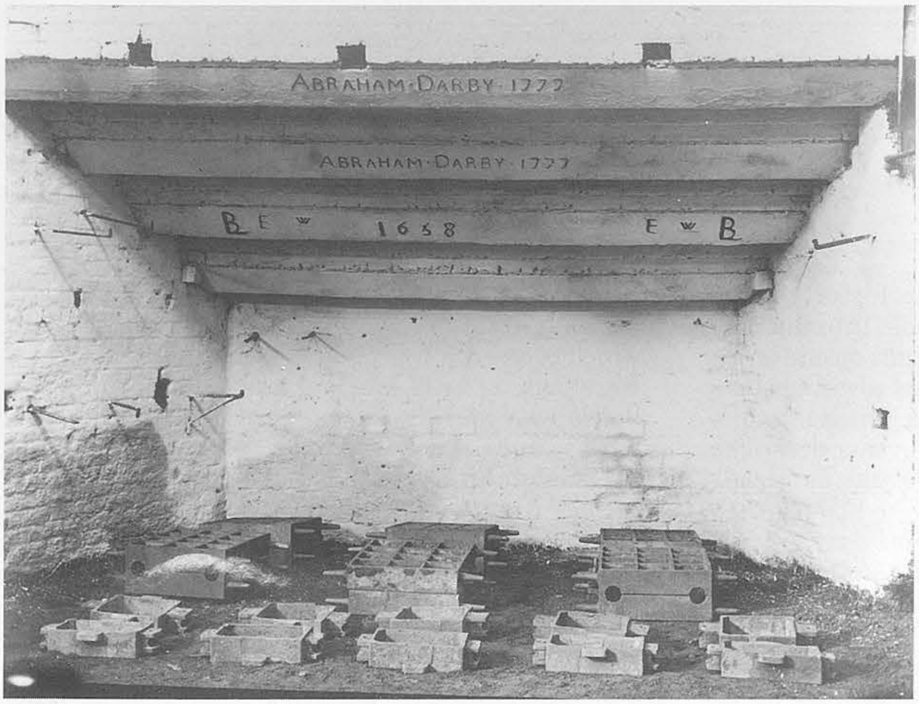


Figure 7 The forehearth of the upper furnace, photographed in the late-19th century when foundry buildings were attached to it. The lintel bears the date 1658, which was changed to 1638 at some time in the 1950s. (Ironbridge Gorge Museum Trust)

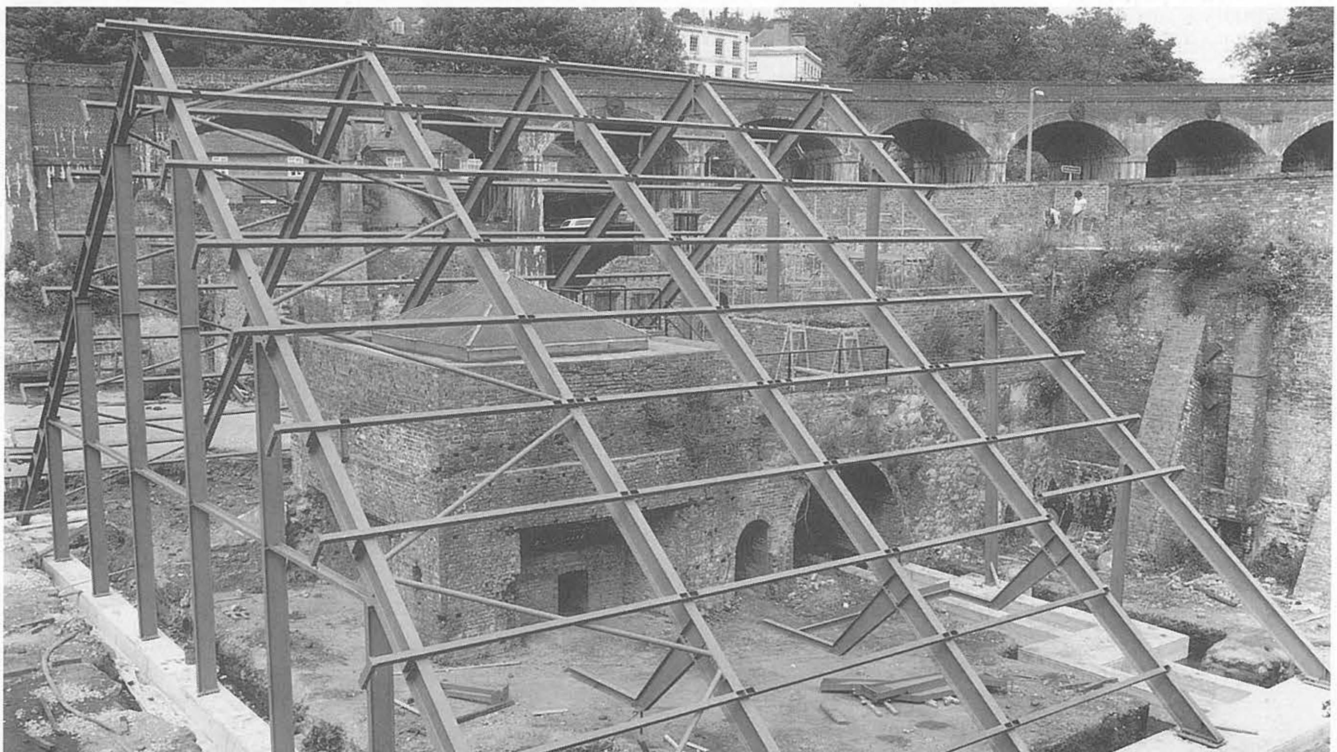


Figure 8 Erection of the cover building over the upper furnace in 1982. Only a minimum level of archaeological recording accompanied the work, despite its deep foundations. (Ironbridge Gorge Museum Trust)

The archaeological work proposed for the site was comprehensive with regard to the upstanding remains, but it was always acknowledged that a great deal of information remains buried. The principal aim of the work was therefore to provide a definitive account of the upstanding remains and to identify the potential for recovering further information about the site from excavations. Hitherto, a tendency has prevailed to interpret the Upper Works in terms of a single event, namely the first use of coke for smelting iron, giving a limited appreciation of the site as a whole. The erection of a cover building solely to cover the furnace is the physical embodiment of this view. The resulting rather one-dimensional appraisal of Abraham Darby I has recently been redressed by a historical study (Cox 1990) and it was hoped that the archaeological research would correspondingly provide a more rounded appreciation of the Upper Works and its broader significance in the archaeology of the iron industry.

Historical background – the Coalbrookdale Company

Before considering the Upper Works in detail it is worth sketching the general history of ironworking in Coalbrookdale and drawing attention to the wider context of other sites associated with the Coalbrookdale Company, generally known as the Dale Company before 1796. Within the East Shropshire Coalfield, the valley of the River Severn, especially the district which later became Ironbridge, was well-placed for industrial exploitation. It had sufficient sustainable woodland for making charcoal, its reserves of ironstone and coal were relatively easy to exploit, it had streams which could be harnessed for water power, and proximity to the River Severn, the major trading route of western Britain before the canal and railway ages.

The earliest direct evidence for ironworking in Coalbrookdale occurs in 1536 when 'le Newhouse and Calbroke Smithy' was let to Hugh Morrall for 63 years (Baugh 1985, 48). The 'new house called Calbroke Smethe' is mentioned again in 1544 when the manor of Madeley was sold to Robert Brooke, following its seizure by the crown from the dissolved Wenlock Priory (SRRC 245/1). The 'Calbroke Smithy' is most likely to have been a water-powered bloomery rather than a mere blacksmith's forge. Historians have located it at the site of the later Lower Forge on the basis of its proximity to the river and that several cast-iron plates, the earliest with the legend 'IH 1602', are said to have been extant there in the late-19th century (Randall 1880, 278; 1883, 56–7). John Randall understood them to have been 'hearth plates'. Unfortunately, recent historical studies have not been able to provide any further evidence of activity on the site of the Lower Forge at this time.

Further developments took place in the 17th and early-18th centuries, when Middle, Upper, and Great Forges and a blast furnace were added, but precise dates are again elusive. A steel house was established to make steel by the cementation process patented by Sir Basil Brooke, the lord of the manor of Madeley. Shipments of steel from Coalbrookdale are recorded in the Gloucester Port Books from 1615 until *c* 1680 (Wanklyn 1982, 5). The steel house stood between the Middle and Upper Forges, adjacent to a row of timber-framed workmen's cottages dated 1642. Frying pans were made at the Lower Forge by 1660, while the Upper Forge is said to have borne a lintel dated 1668 (*ibid*; Trinder 1979, 8). Upstream of the Upper Forge were the later blast furnaces of what became known as the Upper and Lower Works, which were also the site of early forges. The date of the upper furnace is discussed below; the lower furnace was built in 1715 by Abraham Darby I, the first furnace to be designed specifically for coke smelting (Trinder 1981, 13–16).

The geography of these separate enterprises was determined by the Dale Brook (Fig 9). The need to

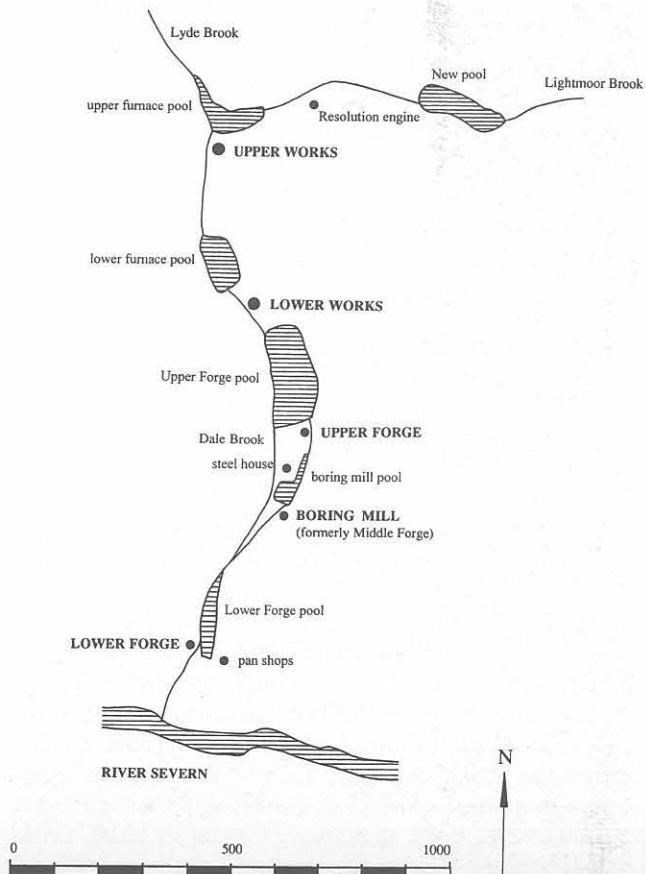


Figure 9 The Coalbrookdale watercourses, showing the reservoirs and works. The reservoirs were created in the 17th and early-18th centuries. The latest feature shown is the Resolution engine of 1781. Only the new pool (of c *1698) and upper furnace pool have survived.*

harness a natural water supply produced a linear development where the successive small works were separated from each other by reservoirs. By the early-18th century, iron was smelted at the upper end of the dale, was converted to wrought iron lower down at the Upper Forge, and was worked into nails and frying pans at the bottom of the Dale close to the river. The integration of processes implied by this sequence is, however, misleading. Coalbrookdale was not the world's first production line. As late as the 18th century pig iron was traded over large geographical areas for refining into wrought iron and there is no justification for assuming that pig iron from the upper or lower furnace was refined at the Upper Forge. Account books for the period show that pig iron was purchased from numerous sources and from as far afield as North America (*ibid*, 18–19). Similarly the steel house did not necessarily use locally produced wrought iron. Nor were the separate works under single management until the mid-18th century.

In the 18th century the iron trade in Coalbrookdale was developed by a partnership known as the Dale or Coalbrookdale Company, led by successive members of the Darby family and their Quaker associates, the Ford, Reynolds, Goldney, and Rathbone families, who became interrelated by marriage. In 1733 the partners took a lease of the nearby Willey blast furnace on the south side of the River Severn and retained the use of the blast furnace there until 1757, while a blast furnace at Bersham near Wrexham was controlled by the partnership between 1731 and 1753 (*ibid*; Grenter 1992, 177).

The great expansion of Dale Company interests, however, occurred in the mid-18th century, in conjunction with its leasing of large minerals reserves. In addition to the upper and lower furnaces in Coalbrookdale, blast furnaces were built on new sites at Horsehay in 1755 and at Ketley in 1757 (Fig 10). In 1760 a lease was taken on a forge at Bridgnorth on the River Severn, representing an expansion in wrought iron production precipitated by the improved quality of pig iron from coke-fired Shropshire furnaces and the need to find a new site to compensate for the insufficient water supply at Coalbrookdale. In 1776 the company also acquired the Madeley Wood or Bedlam furnaces, which were sold off in 1794, followed by Ketley in 1796. By the end of the 18th century, Horsehay was the company's principal works, in addition to which blast furnaces were built at Dawley Castle in 1810, while the Lightmoor Ironworks was acquired in 1839–40 (Trinder 1981, 141). The Horsehay furnaces were in blast until 1858 (although the works continued wrought iron production), Lightmoor until 1882 and Dawley Castle until 1883 (Riden and Owen 1995, 40–3). Throughout this period the company retained mines and limestone workings and in the latter half of the 19th century diversified into brick and tile manufacture.

The Darby family no longer led the Coalbrookdale Company by the mid-19th century, but became the principal shareholders in a partnership which purchased the Ebbw Vale and Sirhowy ironworks in Monmouthshire in 1844, and which later acquired the neighbouring Victoria, Abersychan, Pentwyn, and Pontypool ironworks (Ince 1993, 106–8). Blast furnaces at Ebbw Vale remained in blast until 1913 (Riden and Owen 1995, 15). The Coalbrookdale ironworks were therefore the nucleus of ironworking concerns spanning two centuries and spreading out to encompass two distinct ironworking regions.

Documentary evidence – the Upper Works, Coalbrookdale

The earliest reference to the building of the Coalbrookdale upper furnace is an ambiguous one. The lintels of the tuyère recess and forehearth formerly bore the date 1658, but they are part of a later rebuilding of the furnace, so it is not certain that they belong to the original structure. There are indirect references to a blast furnace in the 1660s, but the first unequivocal reference to the upper furnace is in 1688 when it was operated by Lawrence Wellington I, who supplied pig iron to Wytheford Forge near Shawbury in Shropshire (Baugh 1985, 48–9). By 1695 the furnace was operated by Shadrach Fox, who abandoned it *c* 1705 after it was damaged by flood water.

Abraham Darby I (1678–1717), a Bristol ironfounder, leased the derelict upper furnace in 1708, then rebuilt it ready for blowing-in by January 1709. The business of repairing the structure, furnishing it with bellows, and, crucially, the purchase of coke with which to fuel it, is documented in a sales book (SRRC 6001/328). Darby's initial success with coke smelting was probably not sustained, however, as shipments of pig iron to his foundry in Bristol declined in the period 1710–12, although in 1713 there was an upturn as both cast wares as well as pig iron were despatched from Coalbrookdale (Cox 1990, 131–3). Two years later, in 1715, Darby built a second coke-fired blast furnace (the lower or new furnace), a clear sign that a major technological breakthrough had been achieved.

Darby's achievements in Shropshire were founded upon his earlier enterprises in Bristol. For example, coke was used in the malting industry, where Darby had learned his first trade. Before acquiring a foundry at Cheese Lane in Bristol in 1703, he had also been a brass founder. Here he had become familiar with the use of sand moulds and air furnaces, both of which were subsequently introduced into the iron industry. In an air, or reverberatory furnace, the metal was placed in a separate chamber from the firebox, the heat from which was drawn across the metal by the draught of a tall chimney. Separating the iron from the fuel prevented sulphur contaminating the iron. Unlike blast furnaces, or the fineries for making wrought iron, air furnaces did not require blowing with bellows. The air furnace had a profound effect on the subsequent development of the iron industry, as did the sand mould, which Darby used for casting iron bellied pots, a technique he patented in 1707. Previously, loam moulding had required the mould to be made each time a casting was made. In Darby's method, wooden or brass patterns were pressed into boxes of sand. The moulds could therefore be used again and again to mass produce wares.

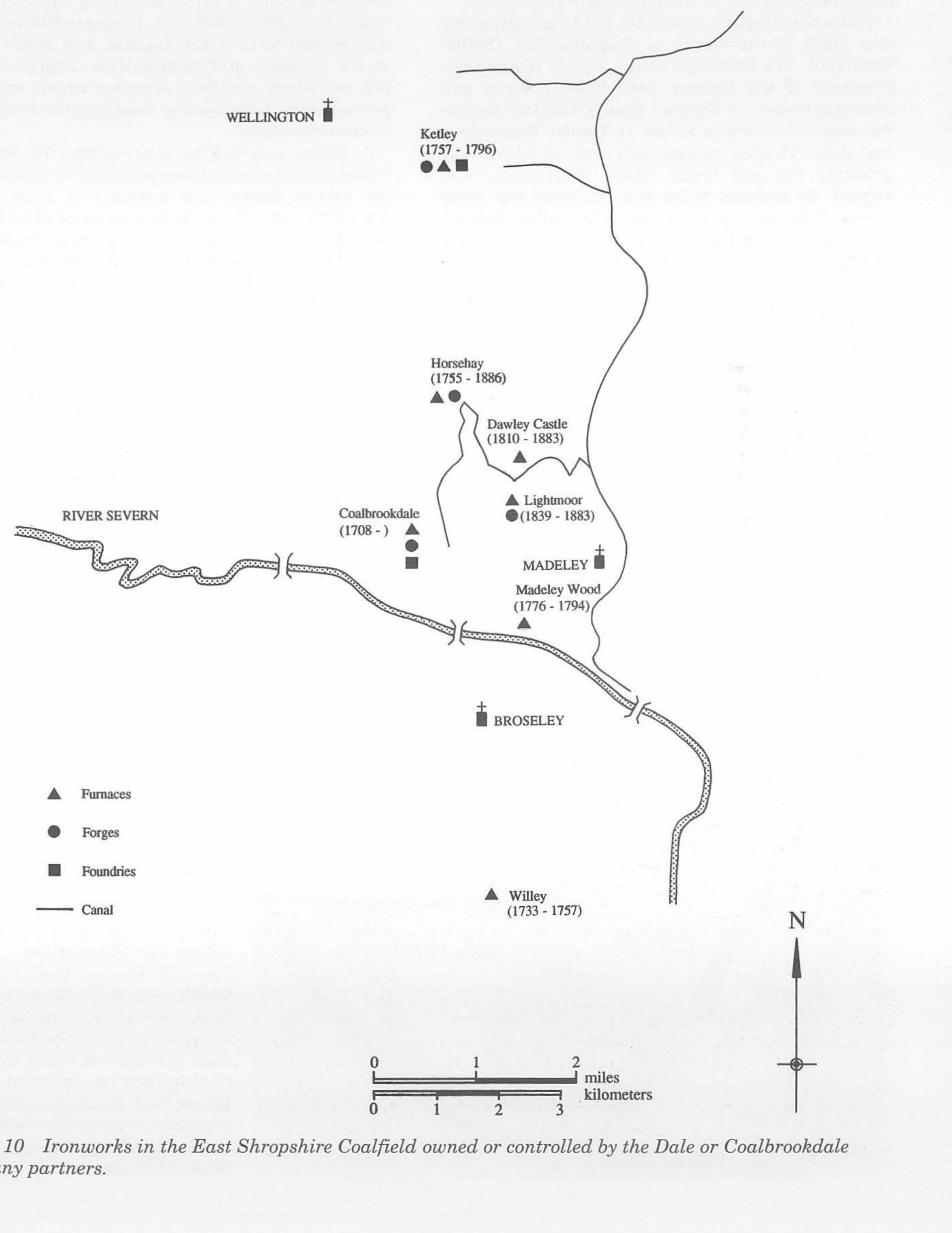


Figure 10 Ironworks in the East Shropshire Coalfield owned or controlled by the Dale or Coalbrookdale Company partners.

Darby was also a partner in a brassworks at Coalbrookdale, although it does not appear to have been a success as in 1714 a substantial amount of brass-working equipment was shipped to Bristol (*ibid*, 130). The precise location of the brass works and its associated callamy mine is not known, but there was a copper house and copper warehouse at Coalbrookdale, perhaps at the Upper Works, in 1718.

Following Darby's death in 1717, an inventory was made of the works at Coalbrookdale (SRRC 6001/300). The buildings at the Upper Works then consisted of the furnace with bellows room and charging house (or 'Tunnell Head'), and two moulding rooms seemingly sublet to Daniel Richardson and John Thomas respectively, one of which was probably the cast house where the furnace was tapped. In addition there was an office and store rooms. Like the upper furnace, the lower furnace was able to produce pig iron or cast wares, while Darby had also taken over the operation of the Upper Forge.

In 1717 control of the Coalbrookdale works passed to the fellow Quakers, Thomas Goldney and Richard Ford. Darby's son, Abraham Darby II, entered the management of the works in 1728 and became a full partner in 1738 (Trinder 1981, 17). Darby and Richard Ford were responsible for substantial new developments in Coalbrookdale. Parts for Newcomen steam engines were made there from at least 1718, with complete engines being supplied from 1722 onwards (Trinder 1981, 17–18). Of necessity, there must therefore have been a boring mill at Coalbrookdale as early as 1722. The earliest specific reference to one is in 1734, but this may have been for a new boring mill on the site of the old Middle Forge, designed to capitalise on the expected increase in demand for steam engines following the expiry of Thomas Savery's patent in 1733 (SRRC 6001/3190, 9, 52, 56). In the same year the lease of the works was renewed, another determining factor in their expansion, and which seems to have occasioned the development of the water-recycling system discussed below, as well as the renewal of the waterwheels at both blast furnaces (*ibid*, 54, 57). From 1739 cannon were cast at Coalbrookdale which would have required either another boring mill, or at least a different boring mechanism or 'spindle' (SRRC 6001/331). Boring mills needed a waterwheel to turn the spindle, and water was a scarce resource at Coalbrookdale, which explains the ambitious recycling schemes which were pioneered in the 18th century, adapting the techniques of mine drainage.

A pump, powered by a horse gin, for recycling water to the lower furnace pool from downstream of the Lower Works was installed in 1735 (SRRC 6001/3190, 40, 54, 55). This was superseded when a Newcomen-type engine began pumping water to the upper furnace pool from downstream of the Lower Works in 1743 (Trinder 1981, 18). Ten years later, a map of the Coalbrookdale Ironworks was surveyed by Thomas Slaughter, allowing an assessment to be made of the buildings then at the Upper Works and its development since the time of Abraham Darby I (Fig 11).

The style of Slaughter's cartography gives an impression that it is unreliable, but careful analysis will show that this is not so. The map is drawn with the principal components in elevation, which is initially confusing, but to make sense of the Upper Works the buildings need to be moved round clockwise in relation to the pool and the road across the dam (Fig 12). Once this is done, Slaughter's plan can be shown to be tolerably accurate in relation to later views of the works by Vivares in 1758 and the 1805 lease plan (Figs 13 and 15).

A valuable inventory of the buildings is given with a key. The blast furnace (20) has a charging house,

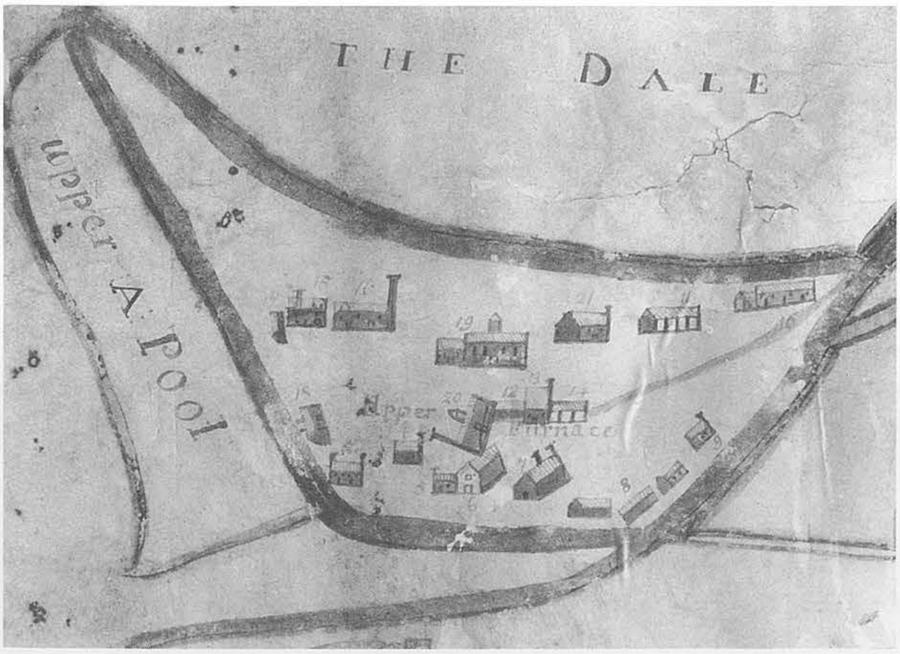


Figure 11 Detail of the Upper Works from a plan of Coalbrookdale by Thomas Slaughter, 1753. North is to the left of the picture. The buildings need to be turned round clockwise to show their true relation to the Upper Pool, the dam of which provided access to the charging house. (Ironbridge Gorge Museum Trust)

Figure 12 Thomas Slaughter's plan corrected by moving the buildings round clockwise so that the charging house backs on to the pool dam. The plan shows the office (3), two blacksmiths shops (4, 9), 'Allen the Baker's House' (5), charging house (6), joiners and smiths shop (7), '3 boreing mills' (8), stables (10), loam house (11), blast furnace and casting house (12, 20), waggoners house (13), loam house (14), moulding house and tenement (15), a foundry building with air furnace (16), brewhouse (17), the 'Old Forge' (18), Great Warehouse (19), and a warehouse and dwelling (21).

or 'bridge house' (6), a loam house and moulding house (14 and 15), and one air furnace (16), all of which were mentioned in the 1718 inventory. Three boring mills (8) indicate an additional waterwheel to the wheel powering the furnace bellows, while the warehouses, smith shops, and other ancillary buildings show considerable expansion from the inventory of 1718. Where the inventory described an integrated furnace and foundry complex, the Slaughter plan documents its extension into an integrated furnace, foundry, and engineering works. In addition to the boring mill at the Upper Works, Slaughter shows a second boring mill south of the Upper Forge, probably the new boring mill mentioned in 1734, which was subsequently described by several visitors, the earliest of whom was Charles Wood in 1754 (Hyde 1973, 40).

An engraving made by Thomas Vivares in 1758 after a drawing by George Perry, from north-east of the Upper Works, puts most of the works out of view, but it does show the proximity of the pool and furnace, buildings on the charging platform (effectively the pool dam), and coke hearths on the pool banks (Fig 13). The wide stack of the blast furnace is visible and the two tall stacks near it must be those of the air furnaces. On the left of the picture is a large cylinder for a steam engine which was being brought from the boring mill further down the Dale.

Abraham Darby II died in 1763, when his son, Abraham III, was only thirteen. Management of the company was continued by Richard Reynolds, son-in-law of Abraham II and father of William Reynolds (1759–1803), later a partner in the Dale Company and ironmaster at Ketley and Bedlam. Abraham Darby III took over management of the works in 1773 at the age of only 23 and there followed an eventful period when the Coalbrookdale ironworks were at the height of their fame. In large part this was due to the erection of the Iron Bridge in 1779, a fitting tribute to the enterprise and self-confidence of its chief progenitor. In 1781 Darby built an engine, known as the Resolution and designed by Boulton and Watt, which recycled water between the Upper Works and the Upper Forge, the most ambitious of many such recycling schemes in the East Shropshire Coalfield. In 1774 he purchased a half share in the manor of Madeley, intending to buy the whole, and in 1776 he purchased Bedlam

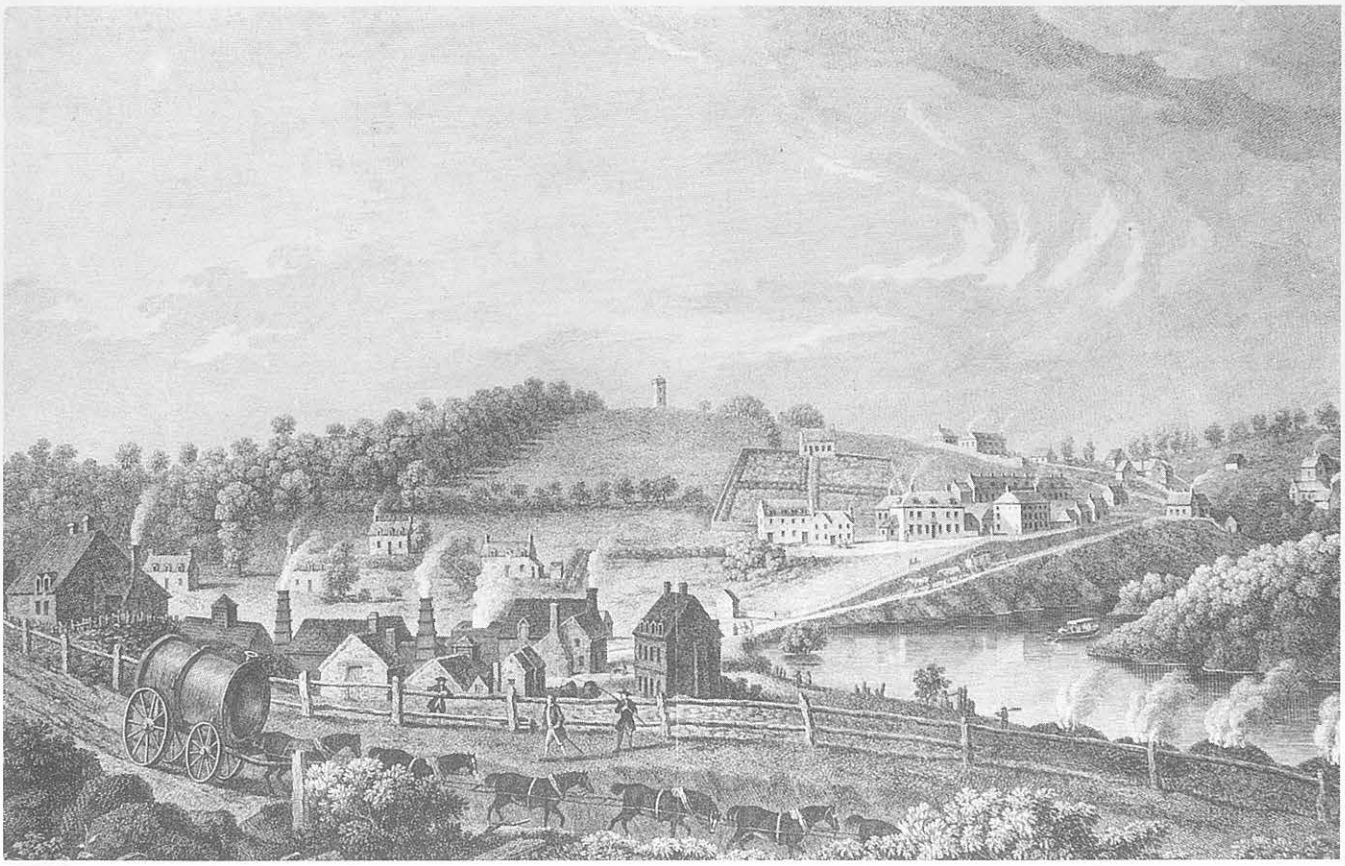


Figure 13 'A View of the Upper Works at Coalbrookdale', engraved in 1758 by Thomas Vivares. The view looks south-west over the Upper Works with an engine cylinder in the foreground brought from the Boring Mill further down the Dale. To the right is the upper furnace pool with coke hearths on its bank. The tunnel head of the blast furnace is square with smoke billowing from it and with an L-shaped range behind it, which are the charging house and a dwelling shown by Slaughter. The other two tall stacks probably denote air furnaces. (Ironbridge Gorge Museum Trust)

furnaces and the valuable mineral reserves associated with it, known as the Madeley Field. Unfortunately Darby's business acumen did not match his ambition. He sold his share of the manor to Richard Reynolds in 1781, while the profitability of the company declined markedly before his death in 1789.

The most informative sources for the site in the late-18th century are provided by visitors, some of whom were tourists, while others were connected with the iron trade or were Quakers. The image they portray of smelting, casting, and the interconnected workshops and fitting shops demonstrate that the Upper and Lower Works were both at this period self-contained smelting and engineering works. Unfortunately witnesses did not always agree on the details of what they saw, but over time they do document significant technological improvements.

For example, in 1754 Charles Wood saw bellows 20 feet (6.1m) long at the upper furnace, but according to Marchant de la Houlière, a Frenchman despatched across the Channel to report on English methods, by 1775 the bellows had been replaced by a pair of cast-iron blowing cylinders, and the waterwheel was partly built of cast iron (Hyde 1973, 40; Chaloner 1949, 213). This was confirmed a year later by Jabez Maud Fisher, who claimed that the cylinders were 6 feet 6 inches (1.98m) in diameter, had a stroke of 4 feet (1.22m), and fed air into a cast-iron 'funnel' 20 feet (6.1m) long to the tuyère (Morgan 1992, 265). A rough sketch of these cylinders was made in 1796 by Joshua Gilpin, which shows them to have worked in an almost identical way to the earlier bellows, the cams on the axle-tree depressing the piston rod, which was raised again by counterweights at the end of a beam (Fig 14). Gilpin's figures for the cylinders are close to Fisher's, except that the diameter was given as 7 feet (2.13m) (BUL Gilpin XXXIII). The replacement of the bellows with cylinders was a precondition of blowing the furnace on more than one side to increase the volume and distribution of the blast. Indeed the upper furnace is said to have been blown from two sides by 1790 (Trinder 1988, 43). According to Fisher in 1776 the waterwheel was 25 feet (7.62m) in diameter; in 1784 Charles Rennie claimed it was 30 feet (9.14m) in diameter and 4 feet 6 inches (1.37m) wide; while a visitor *c* 1801 claimed the diameter was 28 feet (8.53m) (Morgan 1992, 265; Matkin 1986, 26; Trinder 1979, 12).

Visitors were especially interested in the techniques of casting at Coalbrookdale, especially after 1779 when they wanted to see the place where

A

B

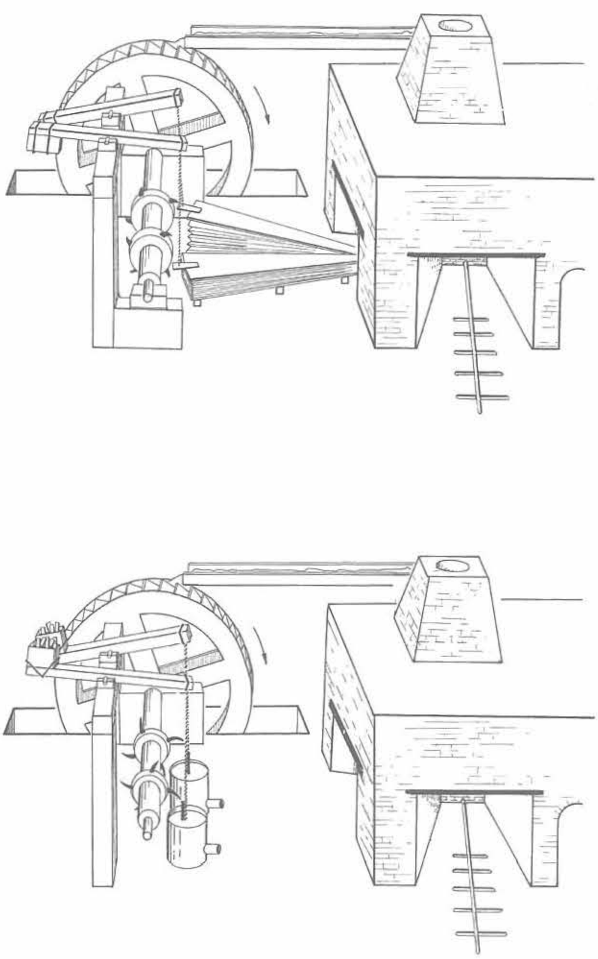


Figure 14 Reconstruction showing the operation of the blowing cylinders (B) described by Joshua Gilpin in 1796 in comparison with the earlier bellows (A). Gilpin described the counterweights at the back ends of the beams as boxes of pig iron.

the Iron Bridge had been cast. Fisher was impressed with the range of goods they produced: chimney tops, window frames, doors, palisades, ploughshares, domestic utensils, as well as boilers, cylinders, and pipes (Morgan 1992, 265). This range of wares increased steadily and by the turn of the century chests, bookcases, and gates could be added to the list (Trinder 1979).

By 1800, iron was cast at Coalbrookdale from three types of furnace: direct from the blast furnace, by air furnaces, and from a cupola furnace. In 1790 Samuel Ireland saw casting direct from the furnace, whereby the molten iron was directed into a large tub, into which the founders dipped their ladles to fill their sand moulds (Trinder 1988, 43). According to Joshua Gilpin the large tub was hoisted by a crane and carried to the larger moulds in the casting room floor (BUL Gilpin XXXIII). In 1802–3 the Swedish 'spy' Svedenstierna saw air furnaces used for making fine castings such as fire grates and screws for cider presses, and also described the cupola furnace at Coalbrookdale (Flinn 1973, 69). The cupola furnace had been patented by William Wilkinson in 1794. The early example at Coalbrookdale, at the Lower not the Upper Works, was first mentioned in a survey of 1797–8 and was used for melting scrap iron (Evans 1993, 93; Trinder 1979, 9; Dickinson 1923, 139). Svedenstierna described it as 'no more than a few feet high', its outside 'clad with pig-iron plates and the inside with refractory bricks'.

In 1780 one of the Coalbrookdale boring mills was apparently rebuilt in order to cast cylinders using John Wilkinson's boring mechanism, patented in 1774 (B&W, 2R, 24/1/1780). Later sources confirm that this must have been at the mill lower down the Dale, and does not refer to the Upper Works. The Upper Works mill was known as a turning mill by 1794 (SRRC 1681/138/4) and was subsequently mentioned in at least four accounts of the works. In addition to turning, ie smoothing and polishing the exterior and interior surfaces of cylinders and pipes, short pipes were bored with vertical boring mechanisms, and screws were turned on a lathe, all powered by a waterwheel concealed between two of the buildings (BUL Gilpin XXXIII; SML Goodrich E2, ff 42–3; Scarfe 1995, 100; Trinder 1979, 12). An account written *c* 1801 described the mill as 'the most complete for the purpose to which it is intended, of any in the Nation' (Trinder 1979, 12). The existence of upright drills discounts any argument that cylinders for steam engines could have been bored here at that time. Indeed a horizontal drill for cylinder boring was described by Goodrich at the other boring mill, where the revolving cutters made approximately one revolution per minute in the boring of a cylinder 78 inches (1.98m) in diameter (SML Goodrich E2, f 38).

The development of the Upper Works from the mid-18th to the early-19th century can be gauged by comparing Slaughter's plan with a lease plan of the works dated 1805, which shows the Upper Works at its peak as a combined smelting, founding, and engineering works (Fig 15) (SRRC 1681/138/7). The itemisation of the buildings in 1805 is identical to that of an earlier lease of 1794, which does not provide a detailed map, so the buildings shown in 1805 can confidently be assumed to have all existed by 1794 at the earliest (SRRC 1681/138/4). This is significant in one respect, as a flood of 1801 was said by many sources to have wrought devastation to the Upper Works, a claim which the lease plan suggests is exaggerated (SRRC 245/14; Randall 1880, 288–90).

By the late-18th century the Upper Works had expanded considerably, extending southwards across the road which originally formed the boundary of the works (Fig 15). A number of workshops had been added since 1753 (29–32), including a two-storey building (27) against the dam wall. The original office had been converted to a pattern store (20), and a small warehouse (24) had been built. In addition, further moulding rooms with air furnaces

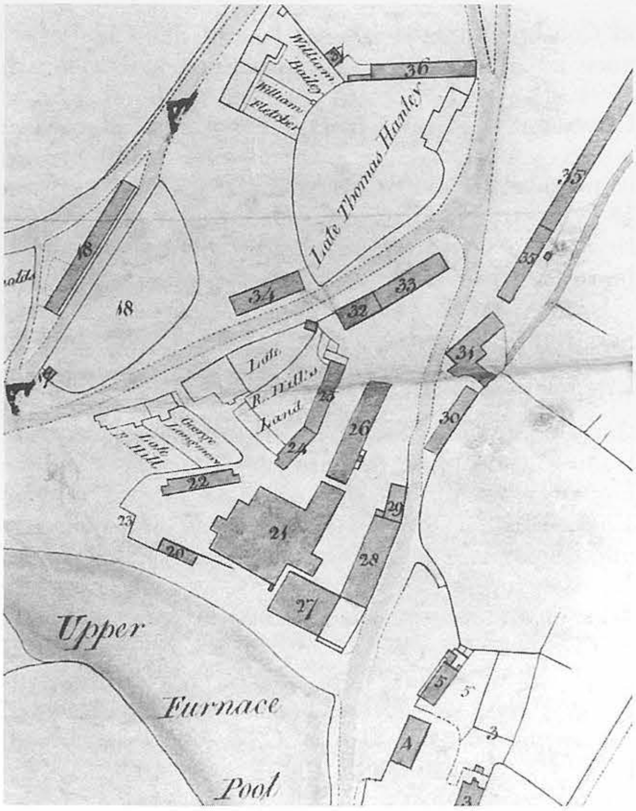


Figure 15 Detail of the Upper Works from a lease plan, 1805. North is towards the bottom of the picture. The plan shows the blast furnace with bellows house and casting room (21), unfinished snapper furnace (23), joiners and blacksmiths (27), pattern store in an old office (20), turning mill (28) with attached smithy (29) and two moulding rooms with air furnaces (22, 26). Workshops (30, 31) and a fitting shop (35) had been built on the south side of the road, showing the expansion of the works from the time of the Slaughter plan. (Shropshire Records and Research Centre)

(22, 25, and 26) had been added, making a total of four air furnaces at the Upper Works. The '3 boring mills' shown by Slaughter were now shown as a single large range known as the turning mill (28), while the long range south of the road (35) included a fitting shop.

In the north-east corner of the site was a 'new furnace unfinished' (23). This was a snapper furnace, a small blast furnace intended for smelting additional iron in times of high demand, and which in the early-19th century would be expected to make 10–15 tons of pig iron per week when the average Shropshire blast furnace made 25–30 tons. The Coalbrookdale snapper is first described as such in an 1804 inventory of Shropshire ironworks, which listed five snapper furnaces in the county, all of which were idle (SRRC 1781/6/28). There is no evidence that the Coalbrookdale snapper furnace was ever blown-in. In fact there is evidence to the contrary, as in 1843 the company negotiated with the lessor of the site to demolish the 'unfinished furnace' adjoining the blast furnace (SRRC 1681/153/11).

Smelting at the Upper Works declined in the early-19th century as Horsehay and Dawley Castle became the focus of investment. In 1815 the Yorkshire ironmaster Thomas Butler found the Upper and Lower Works 'very old and clumsy', although both furnaces were in blast, the upper furnace averaging 28 tons per week (Birch 1952, 232). In 1817 only one of the two furnaces was in blast, while in 1821, according to Joshua Field, neither of them were working and the Resolution engine was being taken down (Elsas 1960, 3; Hall 1927, 30). The blast furnaces are not known to have been in blast again. Field also mentioned 'some castings and a little bad mill work', specifically parts for a sugar mill bound for the West Indies (*ibid*).

The 1820s and 1830s were a nadir for ironworking in Coalbrookdale, but the business was revived by concentrating on the foundry trade. The low point is documented in a lease plan of 1838 (Fig 16), made just before substantial investment saw the renewal of the Coalbrookdale works (SRRC 1681/138/8). The lease mentions no air furnaces at the Upper Works and only three at the Lower Works. Other than that, the buildings are those shown on the 1805 lease, with the exception of a small engine (27), the purpose of which is not known. It may have transmitted power to the turning mill, although other evidence suggests the mill was water-powered.

In 1838 the company began to cast decorative ironwork, some of which was showcased at the Great Exhibition of 1851 (Trinder 1996, 129–30). Changes made to the works at that time are shown on the 1847 tithe map (Fig 17). The tithe apportionment describes the Upper Works as 'Moulding, Fitting, Bronzing, Turning, Modelling, Japanning, Engine Fitting, Carpenters' Workshops, Offices and Yard'. No foundry is mentioned, the cupolas all being located at the Lower Works and all obviously having been built since 1838. At the Upper Works, new workshops had been erected adjacent to the pool dam, while the south end was now defined by a large warehouse. The Great Western Railway, completed in 1864, had a major impact on the Upper Works as a viaduct was built over the north-west side of it, and across the upper furnace pool.

The first edition of the Ordnance Survey, dated 1883, records the erection of further workshops at the Upper Works (Fig 18). By 1912 these buildings were primarily moulding shops, pattern stores, an ornamental iron workshop, a dressing and grinding shop, and a large new fitting shop (Fig 19). Two cupolas had also been erected in the yard in the centre of the Upper Works (IGMT 1986.7002). In the late-19th century, however, the northern end of the Upper Works declined as new engineering shops were built elsewhere at the Lower and Upper Works, replacing the smaller, cramped workshops. In 1922 the Coalbrookdale Company became part of Allied Ironfounders Ltd, who concentrated upon

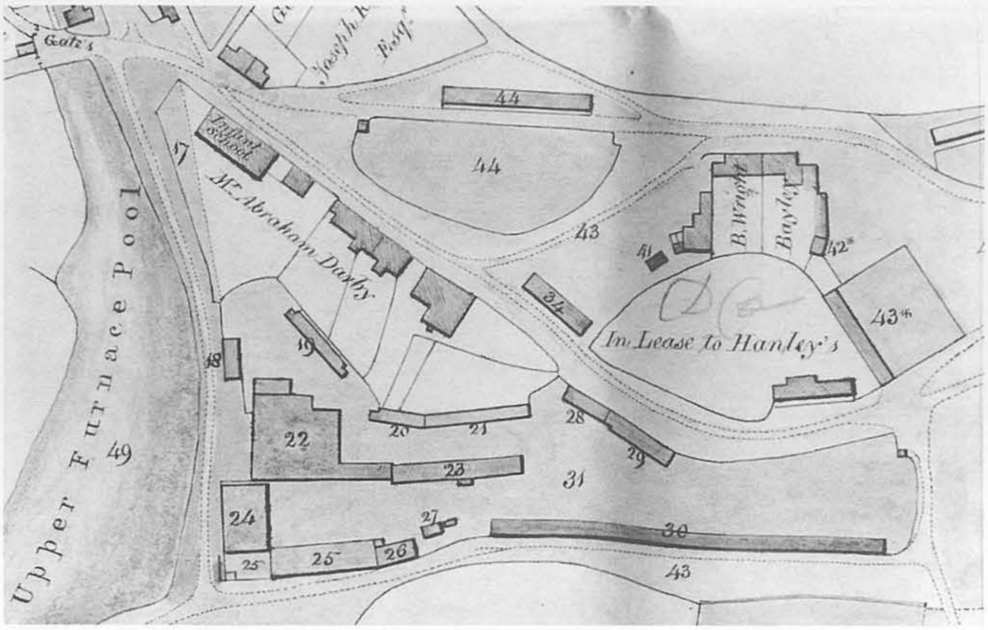


Figure 16 Detail of the Upper Works from a lease plan, 1838. North is to the left of the picture. The blast furnace (22), turning mill (25), smithies (24, 26), pattern store (18), moulding rooms (19, 23) and workshops (30) are the same as in 1805. Only the steam engine (27) is an addition. The snapper furnace is no longer shown and no air furnaces are listed. (Shropshire Records and Research Centre)

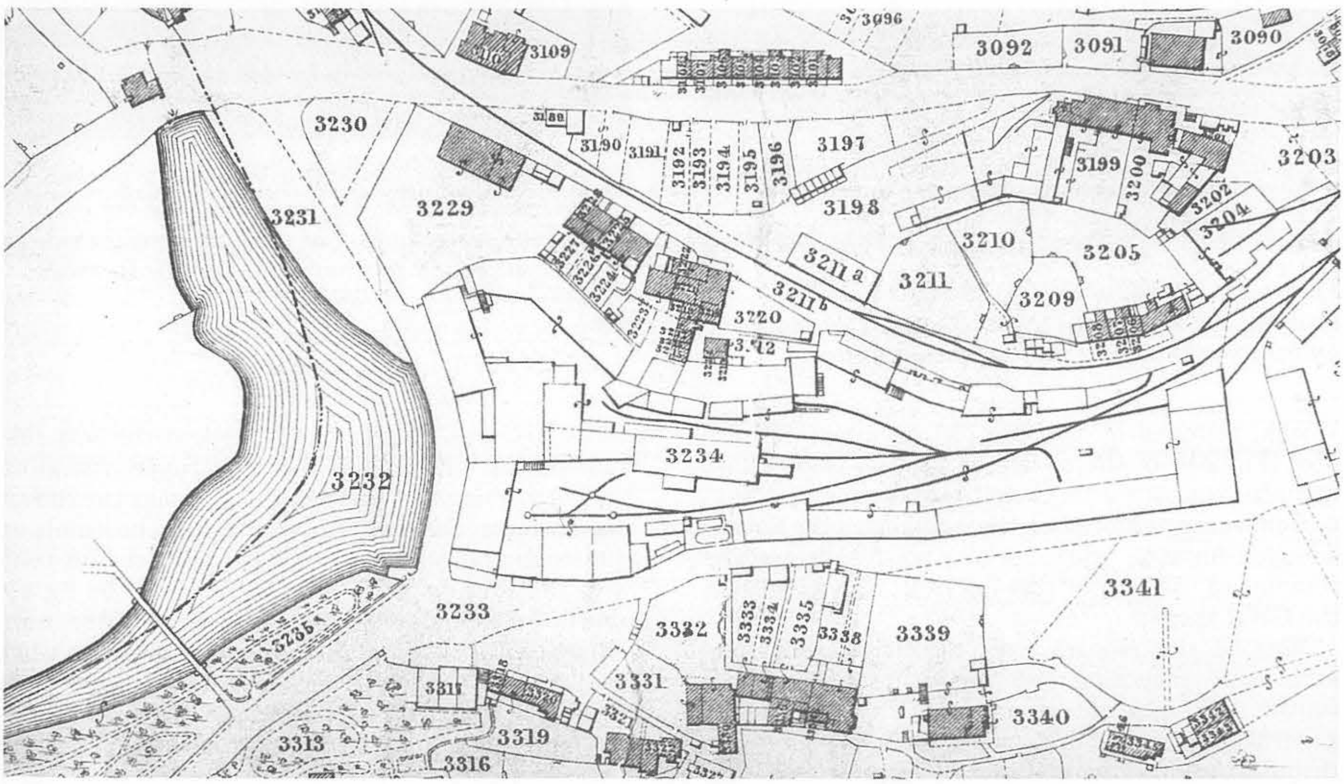


Figure 17 Madeley tithe plan, 1847. North is to the left of the picture. The apportionment describes plot 3234 as 'Upper Dale Works, consisting of Moulding, Fitting, Bronzing, Turning, Painting, Modelling, Japanning, Engine Fitting, Carpenters Workshops, Offices and Yard'. (Ironbridge Gorge Museum Trust)

developing the Lower Works. The waterwheel and blowing cylinder for the upper furnace had probably been removed after the furnace was given up, but the wheel at the turning mill remained *in situ* until it was removed in 1926, although the pipes which fed it from the pool were removed in 1910 (Peskin nd). The mill was latterly used for grinding sand, while by 1912 it was part of the pattern store, as were the buildings against the pool dam (IGMT 1986.7002). The moulding shops on the south side of the upper furnace were vacated in 1932, after which they were cleared and the area became an ideal place for dumping foundry waste (Raistrick 1980, 123).

The site

Archaeological recording was concentrated upon the early structures at the north end of the Upper

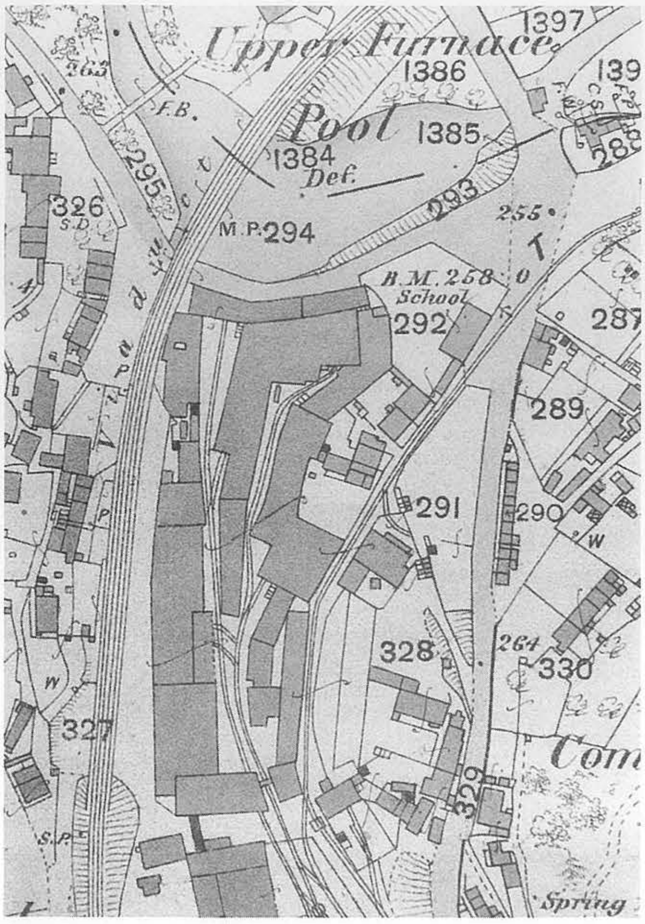


Figure 18 Detail of Ordnance Survey, 1883, showing the viaduct on the west side of the works and the yards largely infilled with buildings.

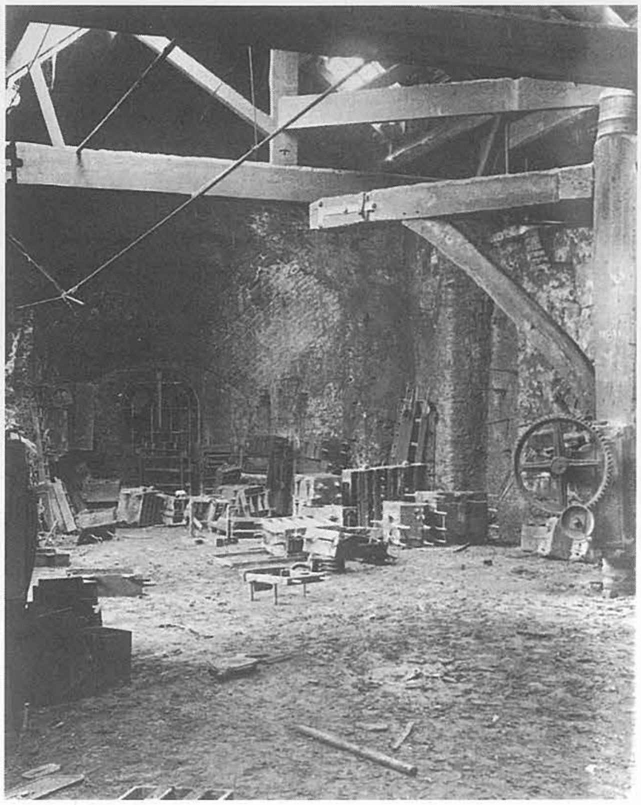


Figure 19 A late 19th-century view of a workshop on the east side of the Upper Works, looking north to the snapper furnace. The wall on the right side is the retaining wall in front of the snapper furnace. (Ironbridge Gorge Museum Trust)

Works, bounded by the dam of the upper furnace pool (Fig 20). In the centre of the site is the blast furnace (beneath a steel and glass cover building) and charging platform; on the east side is the former snapper furnace; while on the west side are the remains of the former turning mill, above which is the GWR viaduct.

Most of the repairs were superficial, allowing large-scale recording but producing little visual impact. Structural interventions were minor, generally consisting of anchors and short coreholes through the charging platform, which revealed little of significance to the archaeological interpretation. Groundworks were confined to drainage trenches between the upper furnace and snapper furnace charging platforms and are discussed with the upstanding remains of those structures.

Upper furnace and charging platform

The blast furnace is encased in brick, with substantial traces of rubble stonework beneath it (Fig 21). On the west side the stone wall extends beyond the furnace to form the wall of a wheelpit, on which there are score marks from a waterwheel (Fig 21A). The furnace has a tuyère recess on the south side under cast-iron lintels, a forehearth on the east side with similar lintels, and a smaller tuyère recess on the north side in a ramped passage below the charging platform (Figs 21B, 22C, and 22B). The lintels on the south and east sides bear the altered date 1638 with the initials EWB and BEW, while the lintels above the forehearth are also inscribed 'Abraham Darby 1777' (Fig 23). Inside the furnace, the boshes and stack are brick-lined, while the well is of sandstone. The furnace stack is partially cut down, leaving an upper surface of exposed core brick and stone (Fig 22A).

The charging platform abuts the dam wall and generally has rubble-stone walls with substantial areas of brick (Figs 21 and 22). The brickwork in the walls is partly integral with the furnace brickwork. At ground level on the east side is a large brick-vaulted chamber opening to the former cast house (Figs 21C and 22C). The chamber extends the full width of the charging platform and the vault obscures a blocked doorway in the west wall (Fig 21A). The charging platform is extended to the east along the line of the dam, its walls being a similar combination of rubble stone below brick (Fig 24). The brickwork in the south face of this extension incorporates the gable end of a former building, in which are two blocked attic windows behind an

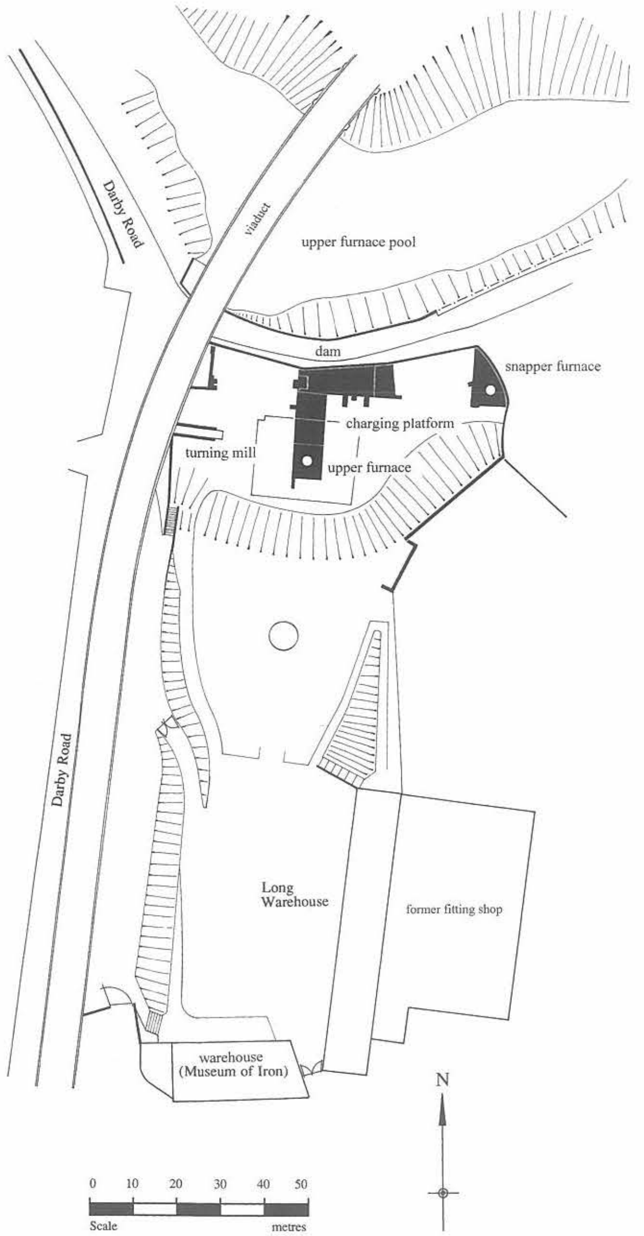


Figure 20 Upper Works site plan.

added flue and one of two raked brick buttresses. The upper surface of the charging platform is partly capped with concrete, but survives on two levels. The upper level formerly led directly to the road across the dam through a now blocked opening in the parapet of the dam wall. Brick steps led down to a lower level at the back of the furnace, where the floor is modern concrete. The extension to the charging platform on the east side also has a concrete top surface (Fig 24).

Although two of the lintels are dated 1658 they are not in their original positions. Consequently there is a question mark over their provenance, a factor made more significant by John Randall's claim that they were brought from a blast furnace at Leighton 5.7km to the west (Randall 1880, 278–9). Whether Randall was using documents which are no longer available or repeating a local myth, we do not know. For the practical purposes of interpreting the site, however, the lintels should be taken to refer to the building of the upper furnace in 1658 until evidence is forthcoming to demonstrate otherwise. The monogram is even less comprehensible, despite efforts to link it with Basil Brooke and the opportunity to solve an 'enigma' (Höltgen 1982) (Fig 23). The initials BEW or EWB, or even BE or EB (on the dubious basis that the W is a crown) do not correspond to any known individual involved in either the ownership or management of the furnace. The legend might have referred to the foundry men, just as a lintel at the Upper Forge bore a legend referring to the forgemen, but there is no proof. In the late-19th century John Randall could cite many 17th-century so-called 'hearth plates' at the Lower Forge which were said to have belonged to an earlier furnace, but none of them bore the names of individuals known to have been connected with the early Coalbrookdale iron trade (Randall 1880, 278; 1883, 56–7).

Whatever its date, the crucial question is what survives of the structures that Abraham Darby would have found when he came here in 1708. For the blast furnace to have operated it would have required a reservoir, a wheelpit and bellows room, a charging level above the furnace, and a casting house in front of it.

Beneath the extant brick fabric of the furnace are rubble-stone walls or fragments of wall on the east, west, and north sides (Figs 22C, 21A, and 22B). These are considered to belong to the original furnace. The substantial wall on the west side is obscured behind projecting modern stonework; it also continues south to form one wall of the wheelpit, which is also contemporary (Fig 21A). Given the necessity of providing a level for charging the furnace from the top there is no reason to doubt that the rubble-stone parts of the charging platform are also of this date, excepting the extension on the east side which is discussed below. The ramped passage on the north side of the furnace is defined by rubble stonework at low level on both sides and was therefore probably also an original feature (Figs 21C and 22B). The charging platform also incorporated a passage further back which, although it was later rebuilt in brick, has earlier rubble stonework at its entrance on the west side (Figs 21C and 21A). This evidence is important because the width of the charging platform, together with the position of the wheelpit wall and the passage behind the furnace, demonstrate that when the furnace was subsequently rebuilt it was no larger than the previous furnace, except presumably in its internal capacity.

Although the wheelpit wall bears the scar of a waterwheel, it was not necessarily made by the first wheel to have been housed in the pit. There is good documentary evidence for the replacement of the waterwheel in 1734 and again before 1775.

The original charging platform was probably as high as the dam, but its height, and that of the furnace, cannot be proven because the present upper

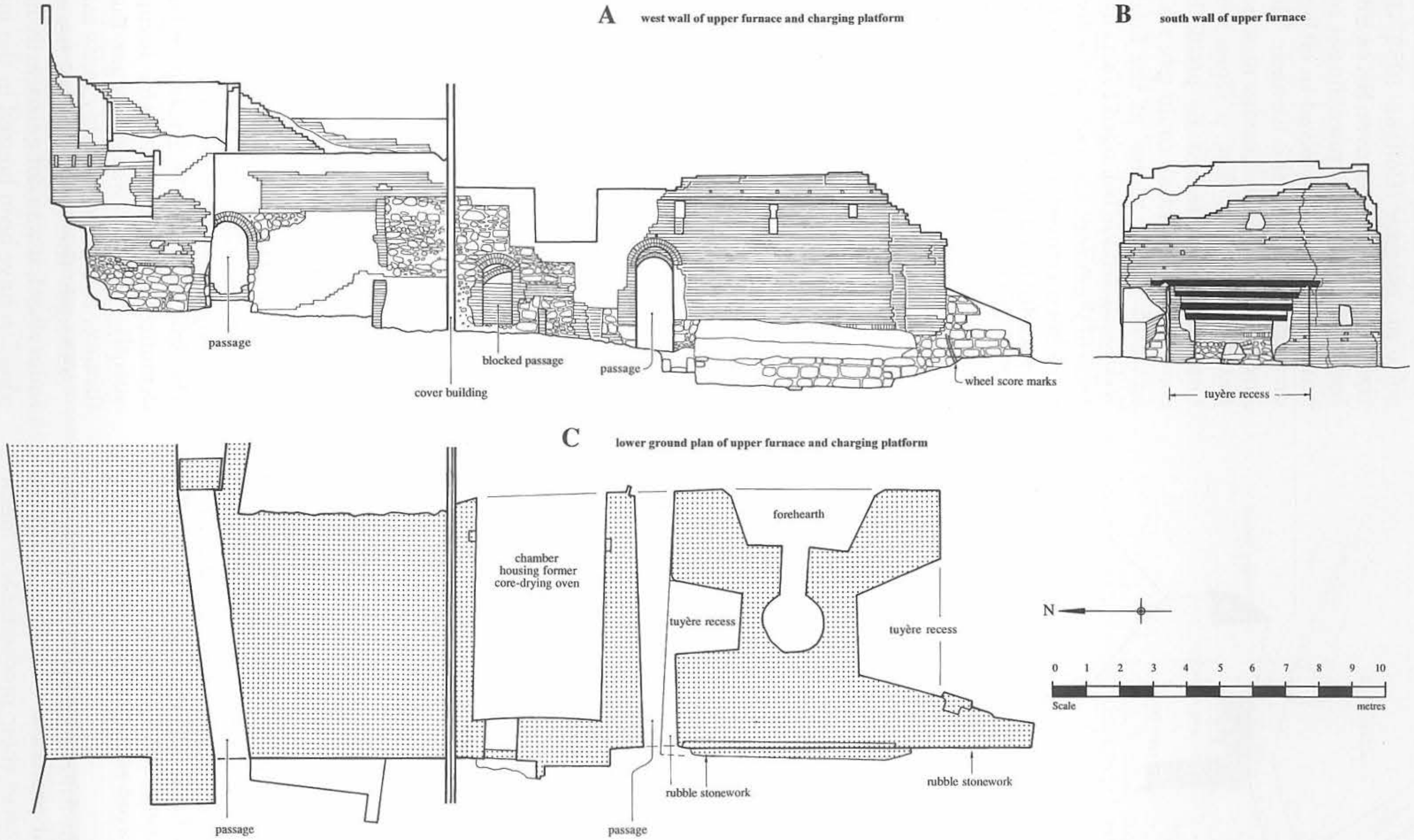


Figure 21 Ground plan of the upper furnace and charging platform (C), with the west (A) and south (B) elevations. The west elevation shows the rubble stone of the original furnace and part of the wheelpit wall.

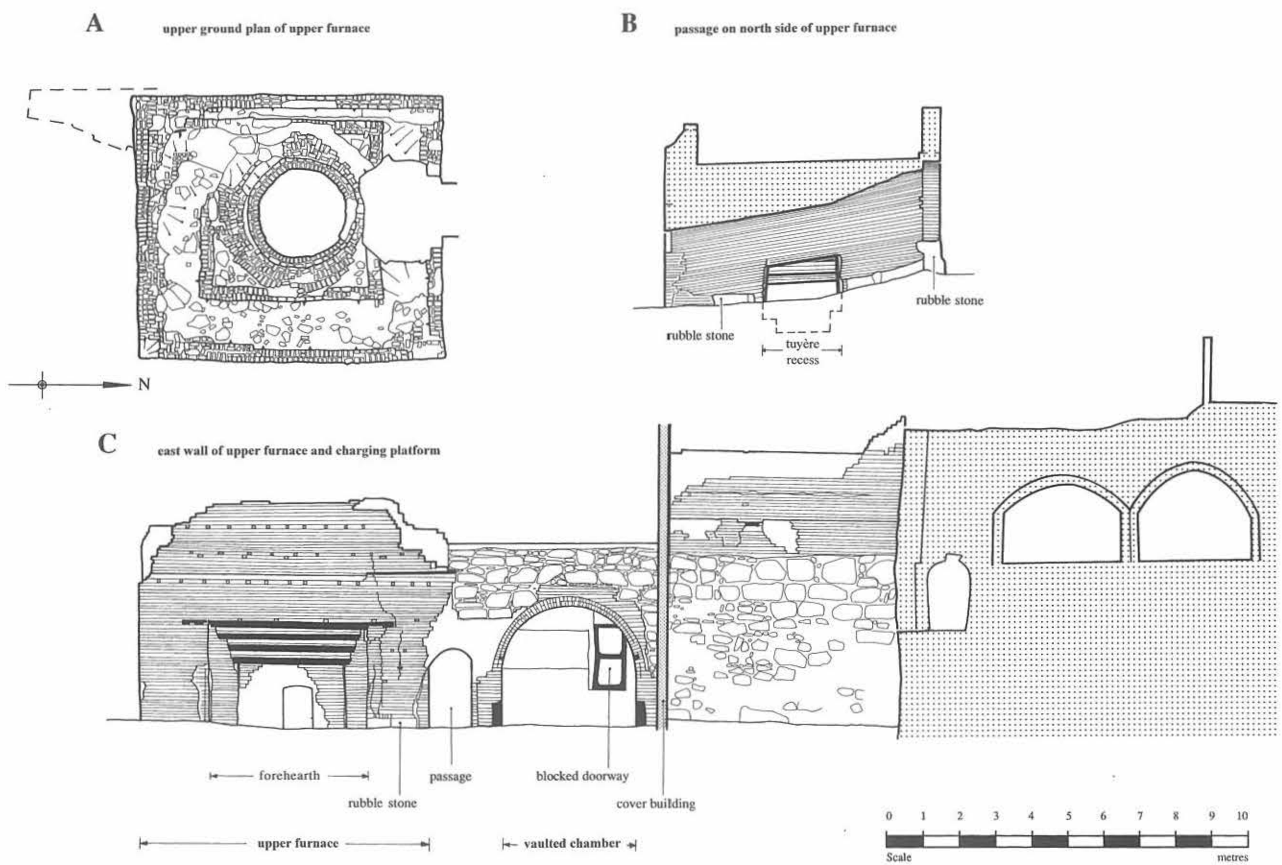


Figure 22 The upper ground plan of the upper furnace (A), shows exposed core work. The east elevation (C) of the upper furnace and charging platform shows the furnace forehearth and the vaulted chambers below the charging level. The north elevation (B) of the upper furnace, inside the passage behind the furnace, shows the inserted tuyère recess and rubble stonework of the original furnace.

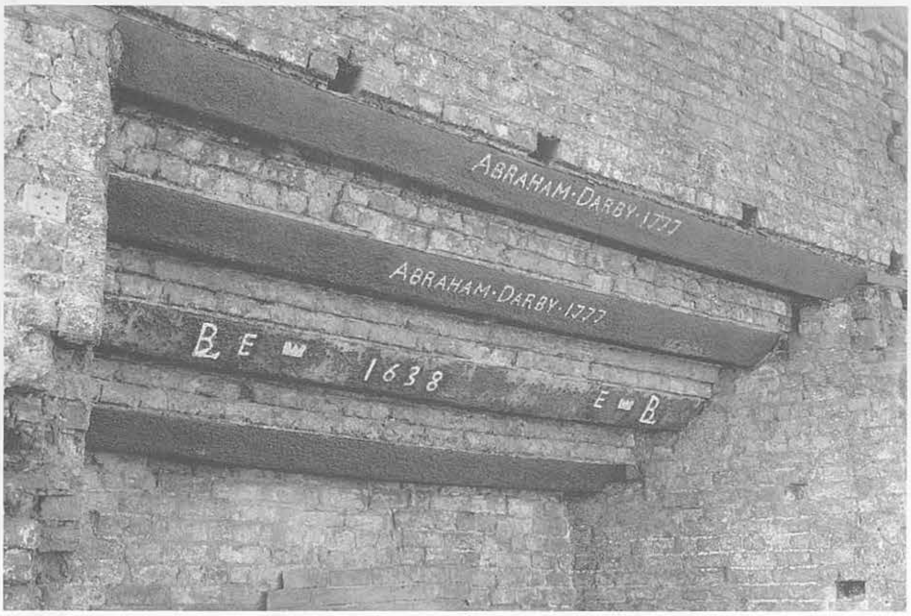


Figure 23 Lintels above the forehearth of the upper furnace. The date 1638 was introduced in the 1950s when the legends were renewed in white paint.

Figure 24 The extension on the east side of the charging platform, photographed looking north-west in 1998 after the completion of repairs. The raked buttresses are built against the gable end of the moulding and casting rooms of 1777, behind which is a vaulted passage.

surface of the charging platform is determined by buildings erected on it in the 19th century. Necessarily the dam would have existed when the furnace was built, but the faces of the wall are considered to be later, for reasons given below (see Fig 26). However, the rubble-stone wall behind the brick skin on the west side of the furnace might well be the original face of the dam. Unfortunately there is no structural link between the wall and the charging platform.

These fragmentary rubble-stone structures appear to be all that survives of the works when Abraham Darby I leased it in 1708. Darby's account book for the period 1708–10 gives us an indication of the work he undertook to bring the furnace back into blast and they are exactly the sort of measures one would expect at a furnace which had stood idle for three or four years (SRRC 6001/328): The hearth was rebuilt and the bellows were repaired. There is no evidence that he had to rebuild the exterior casing of the furnace (there is no record, for example, of purchasing the quantity of bricks that would have been required to build the furnace in its present form), and claims that the furnace had been 'wrecked by an explosion' in the flood *c* 1705 seem to be exaggerated (Raistrick 1980, 126). Darby's furnace was therefore probably the original stone-encased furnace of the 17th century. Other additions that Darby must have made, such as the building of an air furnace in the casting house, have not yet been found.

The furnace was rebuilt in 1777. Its external walls can be seen on the east and south sides, where the tuyère recess and forehearth are situated (Figs 22C and 21B). The west side of the furnace is defined at low level by rubble stonework, above which is a 19th-century brick skin which clearly abuts the 1777 brickwork at the south-west angle (Fig 21A).

The skin incorporates an arched opening to the passage on the north side of the furnace. Behind the arch at a lower level is the earlier brick tunnel vault of the passage. The brickwork of this passage is earlier than 1777 as it abuts the 1777 brickwork at the north-east angle of the furnace, but is obviously later than 1658 because the stonework beneath it is earlier and aligned slightly differently (Fig 22B). The brickwork of the passage is the only evidence of changes after 1658 and before 1777. The passage wall has a tuyère recess cut into it (Fig 22B). The date of this recess is highly significant because it denotes the blowing of the furnace on two sides. The technology for achieving this was facilitated by the replacement of the bellows with blowing cylinders. Marchant de la Houlière saw blowing cylinders here in 1775 before the rebuilding of the furnace, but that does not mean that the furnace was blown from two sides at this early date (Chaloner 1949, 213). The lintels used in the recess differ considerably from those of the larger tuyère recess and forehearth, suggesting that the second tuyère was inserted post 1777, but it must have been inserted before 1790 when blowing the furnace on two sides was mentioned by Samuel Ireland (Trinder 1988, 43).

Previously it has been argued that the furnace was blown on three sides, on the basis of a small aperture in the boshes, above the forehearth (Malam 1982). This opening clearly exists as an integral part of the furnace lining, but the argument that it was used for blowing cannot be sustained. Its position is far too inaccessible to install a tuyère and supply it from a blast main, for which there is in any case no evidence. An alternative argument is that it forms part of the annular ducts in the furnace lining for the escape of hot gases in the brickwork, as has been observed at Bedlam.

The wheelpit wall bears score marks caused by the shroud of the waterwheel, suggesting an approximate diameter of 7.3m (24 feet) (Fig 21A). This was the size of the wheel mentioned by Charles Wood in 1754 and is close to the 25 feet (7.62m) diameter cast-iron wheel mentioned by Fisher in 1776 (Hyde 1973, 40; Morgan 1992, 265). However, it is smaller than the 8.5–9.15m sizes mentioned after the 1777 rebuilding (Matkin 1986, 26; Trinder 1979, 12). The score marks cannot be linked definitely with any particular phase of use, although they are more likely to have been caused by a cast-iron rather than a wooden waterwheel.

As for the charging platform, the passage immediately north of the furnace has been discussed. Behind it is the vaulted chamber facing the former cast house to the east (Figs 21C and 22C). This chamber is also part of the 1777 rebuild, although it seems likely that an earlier chamber existed here, otherwise the charging platform would have to have been quarried out to create it. The chamber was originally accessible from the west side of the charging platform, where there is a blocked doorway (Figs 21C and 21A). However the chamber was subsequently deepened to extend the full width of the charging platform, as defined by a clear break in the brickwork half way along the chamber, the vault of which cut off the earlier doorway in the west wall (Fig 21A). It was in this chamber in 1982 that the base of a core-drying oven was located and the remains of brick benches were found against the back wall (Malam 1982). At the rear of the charging platform at ground level is another passage (Figs 21A and 21C), whose brick-vaulting would also appear to date it to the 1777 rebuilding, although a passage clearly already existed here because there is earlier stonework at a low level. The passage is now blocked but, beyond the blocking, the passage was found to continue beneath the eastern extension of the charging platform. It originally continued as an open passage behind the casting rooms, leading to the former office shown against the dam wall on Slaughter's map and the 1805 lease plan (Figs 11, 12, and 15). It was not vaulted until the charging platform was extended southwards over it, first shown on the 1883 Ordnance Survey (Fig 18).

Slaughter's 1753 map shows the bridge house (6) and the dwelling (5) attached to it forming an L-shaped range, which is clearly visible in Vivares' engraving and is similar to the plan form of the extant charging platform (Figs 11, 12, and 13). The extension on the east side must therefore have been built by 1753 and originally had a dwelling on top of it. The 1805 and 1838 lease plans show that, at a lower level against the dam wall, an office was attached to its east side which was mentioned in the inventory of 1718 (Figs 15 and 16). This renders it likely that the extension had been built by 1718 and might, therefore, have been added by Abraham Darby I. No evidence of the office can be seen in the east wall of the extension because the east wall was rebuilt in the period 1838–47 (see below in the discussion of the dam wall). The gable end of a brick building with attic windows, which is visible in the south face of the extension, was the north wall of the moulding and casting rooms that must have been rebuilt with the blast furnace in 1777 (Fig 24). Directly behind it is the passage to the former office referred to above. The infilling of the attic windows occurred simultaneously with the vaulting of the passage, which is first shown in 1883 (Fig 18). The passage was later blocked by cross walls (Fig 21C).

Two small excavations on the charging platform in advance of underpinning revealed the upper surfaces of a pair of vaulted chambers beneath the charging level and extending into the pool dam (Fig 22C). It was possible to see inside the southernmost chamber sufficient to establish its salient dimensions. The dimensions of the northernmost chamber were established by the insertion of an endoscope through a hole drilled in the crown of the vault.

The upper brick levels of the charging platform are related to the erection of a new building on top of the charging platform when the site became a foundry in the 19th century. This is not shown in the

1838 lease plan and must therefore belong to the period immediately after it when the foundries were reorganised (Fig 16). According to the 1847 tithe map, access to it was gained by means of steps on the west side of the blast furnace (Fig 17). Also related to the cessation of smelting are the brick infill of the tuyère opening and forehearth (Fig 7) and backfill in the recess on the north side.

Dam wall

The faces of the pool dam flanking the upper furnace are aligned differently and should therefore be treated as separate entities. Subsequent to the Severn Gorge Repairs Project there have been two campaigns of borehole drilling at the Upper Works (undertaken to establish why the dam leaks) and it is worth summarising the results here as they are relevant to the interpretation of the upstanding remains. In 1995 test pits were dug and vertical bore holes were drilled into the top of the dam (C, D, and E in Fig 25), which revealed the core of the dam to include a significant proportion of industrial waste (IGMTAU 1996a). No evidence was found that the pool might have been a natural feature, and it was therefore interpreted as having been created by constructing a dam at the confluence of two streams. The industrial waste also demonstrated that the dam is the result of enlargement and/or repair.

In 1997, boreholes were drilled at an angle into the base of the dam wall (F, G, and H in Fig 25) (IGMTAU 1998a). West of the blast furnace discrete areas of rubble stone are visible behind the present brick face (Fig 26). The rubble stone was found to continue at least 2.5m below the present ground level of the site, while behind the wall the core consisted of redeposited shale and clay. This might have been the original core of the dam and thus the wall may well belong to the mid-17th century. The preindustrial ground level is estimated at 68.8m AOD from borehole evidence (Fig 25). Allowing for a furnace approximately 25 feet high (7.6m), the top of the dam would therefore be a maximum of 75.4m AOD, the approximate height of the present dam, to allow a level upper surface from which to bring the raw materials to the charging platform and high enough for water to be drawn off to feed an overshot wheel. Where it is visible the stonework rises to approximately 72m AOD (Fig 26). The brickwork above it is offset from the stone wall below and is not parallel with it. Given this fact and taking into account the quantity of industrial waste recovered from borehole investigations, the upper section appears to be a rebuilding, which accounts for the fact that no evidence has been found for a watercourse from the dam to the upper furnace waterwheel.

Slaughter showed a two-storey joinery and smithy against the west side of the pool dam ('7' in Figs 11 and 12). This was enlarged as part of the fitting shop (later the pattern store) built between 1838 and 1847 (Figs 16 and 17), and survives as a brick skin against the wall (Fig 26). Other remains of this building have survived: First-floor beam sockets are visible at the level of the offset, above which are the grates of two fireplaces with projecting flues, and recesses suggesting work benches. The pattern store has a pronounced offset at the level of the first-floor beam sockets and blocked fireplaces with external flues (Fig 26). Above is a brick parapet, which continues over the charging platform, where it contains a blocked opening, to the east side of the dam wall. A boiler feed pipe is also inserted into the wall. The west end of the building has also survived, of which the upper level was rebuilt at a later date. A boiler was added outside the south-west angle of the building (Fig 27). This particular model first appeared in the Coalbrookdale Company Catalogue in 1875.

The rubble-stone wall of the east section of the dam abuts the snapper furnace charging platform and blocks an opening within it, making it later than 1794 (Fig 28). It also continues behind the east wall of the extension to the upper furnace charging platform (Fig 24). However, this end wall of the extension to the charging platform can be seen to be an addition and reveals no evidence of the office that Slaughter and the lease maps show butting against it and the dam wall until 1838 (Figs 11, 12, 15, 16, and 24). This office must therefore have been demolished after 1838, which dates the east section of the dam wall to between 1838 and 1847, when it is shown on the tithe plan as the wall of a single new large building. The boreholes drilled at an angle into the base of the dam wall in 1997 confirmed this interpretation (IGMTAU 1998a). In front of the dam, cast-iron floor plates and part of a brick floor were revealed by a preliminary test pit, belonging to one of the foundry buildings erected in the 1840s. Beneath them were deep demolition layers, suggesting wholesale demolition of the earlier buildings here.

The east section of the dam wall has two distinct sections (Fig 28). The lower, stone section abuts the snapper furnace charging platform. The upper, brick section was added later as the upper storey of the three-storey building, constructed against the dam by 1847 and a pattern store by 1912 (Fig 17) (IGMT 1986.7002). Beam sockets and inserted flues survive, while the upper-storey windows are infilled with brick. The brick floor of the building was possibly found in a small excavation in 1987, although the excavators argued that it belonged to the office referred to by Slaughter (IGMTAU 1988a, 16–17). This floor was also revealed in the 1997 boreholes. During groundworks, a trench on the south-east side of the upper furnace charging platform revealed a long iron flask, of the kind used for moulding in a foundry, laid east-west on top of a brick wall oriented north–south (Fig 29). To the south, three abutting brick walls at right angles to each other

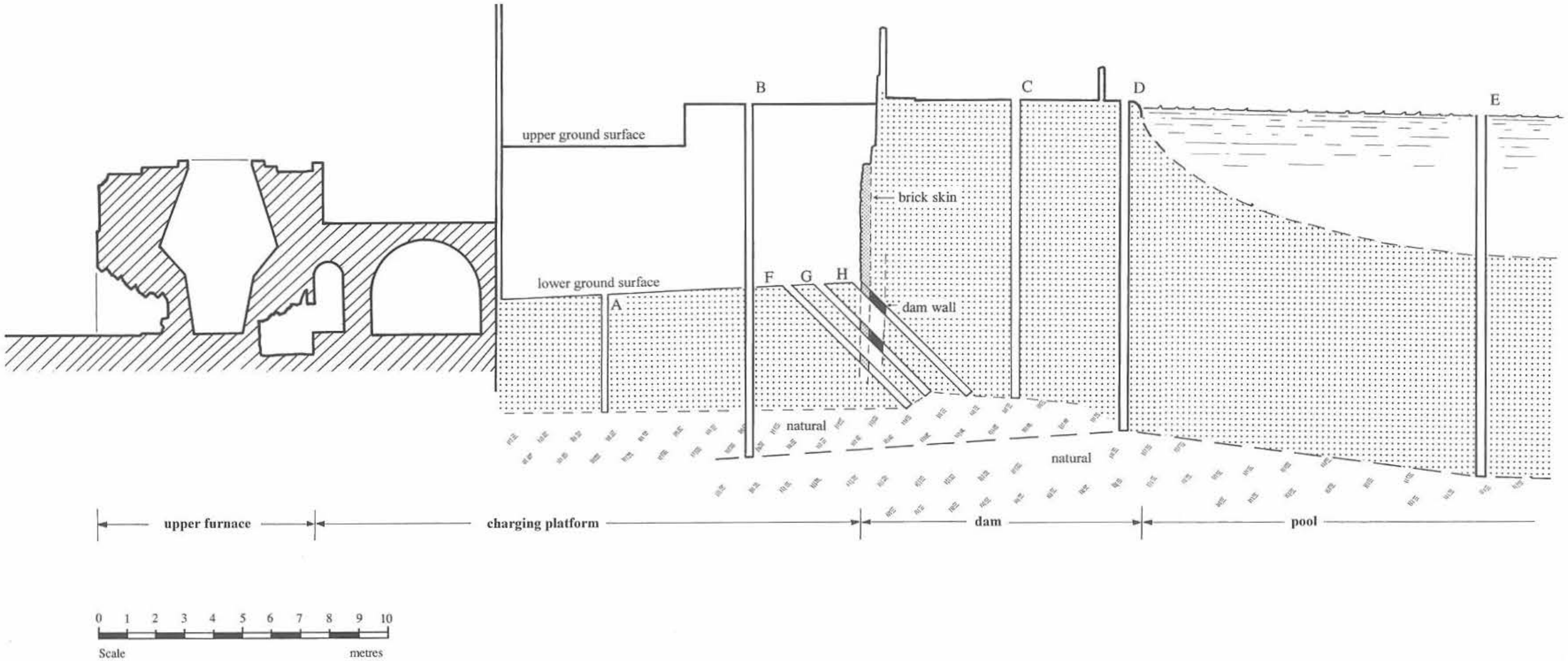


Figure 25 A cross section through the upper furnace, charging platform and pool dam to show the profile of boreholes in the dam. Borehole B was drilled in 1992, C, D, and E in 1995 and A, F, G, and H in 1997.

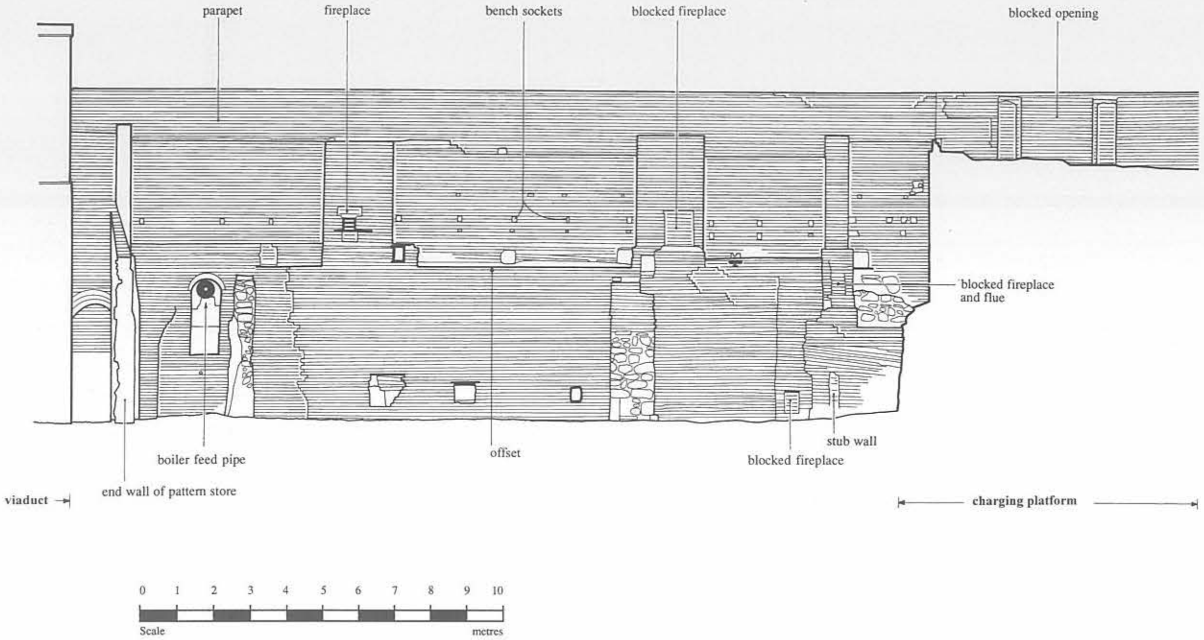


Figure 26 South face of the dam wall on the west side of the charging platform. Discrete areas of early rubble-stone wall can be seen behind the brick skin, which forms the side wall of a fitting shop built between 1838 and 1847.

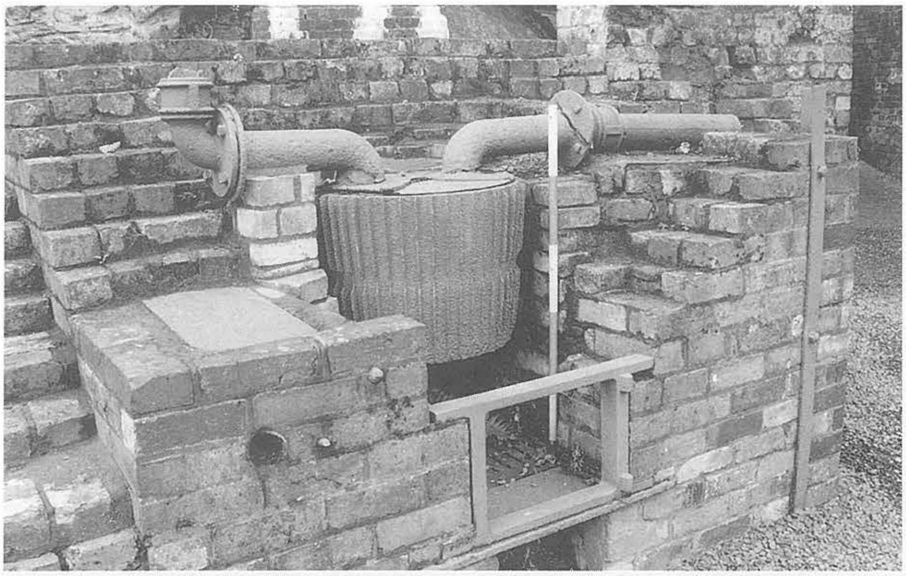


Figure 27 A cast-iron ribbed boiler, of a type which appears in the Coalbrookdale Company Catalogue in 1875, photographed in 1998 after the completion of repairs.

were also uncovered, two of which probably belonged to the 19th-century pattern store although they are clearly not coeval. The other foundation wall was of the casting house rebuilt *c* 1777. The walls were not removed to ascertain what they had been laid on. The roof of the 19th-century building was supported on cast-iron piers, two of which have survived, although subsequent to 1959 they were turned around 90° in order to accommodate exhibits placed on the site. At parapet level a rubble-stone wall continues around the north-east corner of the site above the snapper furnace (Fig 20). This wall is first shown in a lease plan of 1827 and again in 1838 (Fig 16).

Snapper furnace

The snapper furnace was under construction in 1794 (SRRC 1681/138/4). Slaughter's 1753 plan suggested that a brewhouse and a moulding house and tenement (labelled 17 and 15) had previously occupied the site but no evidence of them is visible above ground (Figs 11 and 12). The snapper furnace is brick, with a charging platform to its north, principally of rubble stone (Fig 30). The charging platform retains brick-vaulted chambers at ground level, one of which continues as a brick-vaulted passage on the east side of the furnace below a rubble-stone wall, against which the furnace was built, and emerges

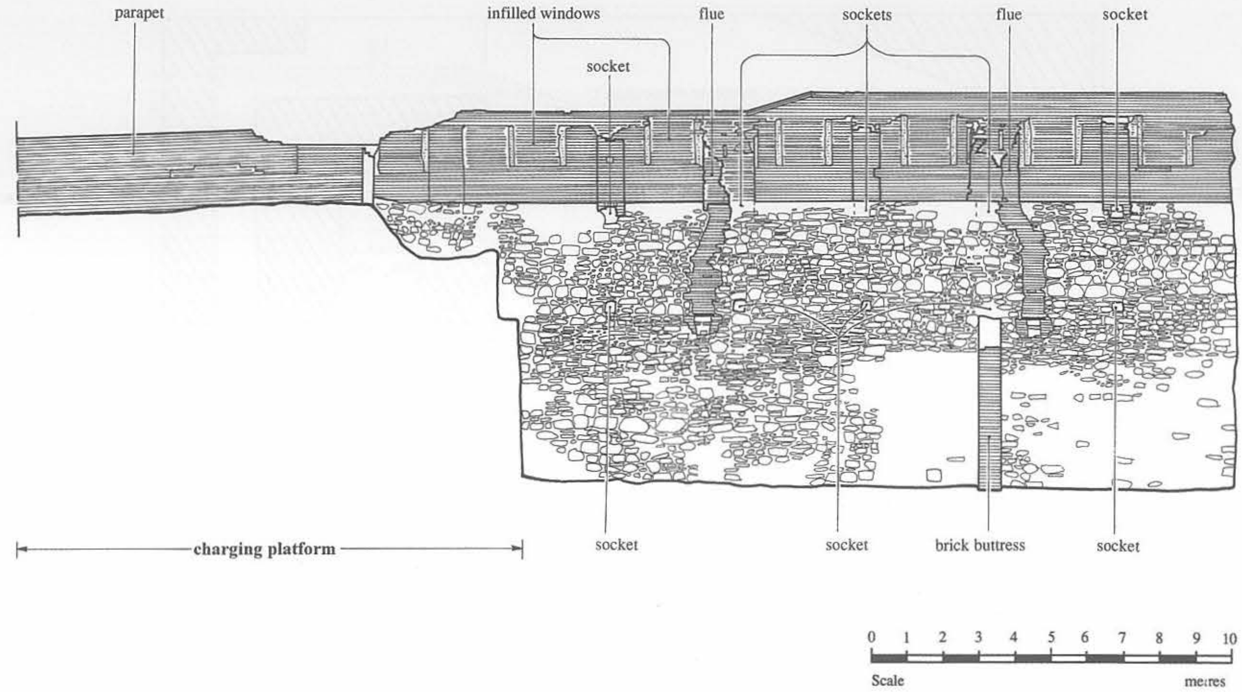


Figure 28 South face of the dam wall on the east side of the charging platform.

on the south side of the furnace (Fig 31). Another high-level brick-vaulted chamber was partially exposed behind the east end of the dam wall, adjacent to the snapper furnace charging platform. The opening made in the dam wall during repairs was unfortunately too small for the chamber to be accessible. Neither the chambers nor the passage reveal evidence of an opening for a tuyère (Fig 31). The furnace must therefore have been designed for blowing on one side only. Of the two extant arched openings on the south and west sides, it is not obvious which was for the tuyère and which was the forehearth, except that the south recess (Fig 30B) is wider and is therefore more likely to have been the forehearth where the furnace was tapped. Presumably the blast would have been provided by the blowing cylinders for the upper furnace. Investigations behind the retaining wall on the east side of the snapper did not find evidence of a wheelpit (IGMTAU 1997b).

Neither the snapper furnace nor its charging platform survive to their original intended height (Fig 30A). Significant changes appear not to have occurred until after 1843, after the Coalbrookdale Company proposed to demolish it. It probably survived only because it acted as a buttress to the pool dam behind it. The fact that a small building was erected on top of it demonstrates the degree to which space was at a premium in the Upper Works.

The most important question regarding the snapper furnace is whether it was ever blown-in. The documentary evidence suggested strongly that it was not and no archaeological evidence emerged to challenge that view because the inner lining of the furnace is wholly missing. Internally the lower part of the furnace is square (Fig 31), of a wider span than the circular stack brickwork above it, which is supported on cast-iron plates at the corners. It was intended that the boshes and well should be built inside this square shell, as can be seen at numerous other 18th-century blast furnaces, such as Bonawe and Craleckan in Argyll and Duddon in Cumbria. Oral evidence claims that firebricks were reclaimed from the furnace during the 1939–45 war (Trinder pers comm), but the furnace is unlikely to have retained its lining at so late a date.

On the west side of the furnace are brick steps leading up to the charging platform, beyond which is a short return wall or buttress (Fig 30A). The stair rises to a small brick floor on top of the furnace, on which a building had been erected by 1847 (Fig 17).

Turning mill

Remains of the turning mill are focused upon a wheelpit flanked by the high brick walls of the former north and south ranges (Figs 32 and 33). The ranges were evidently single-storey with attics. Their rear gable ends survive partly against the viaduct piers and are constructed of brick above rubble stone (Fig 34). The rubble-stone wall projects beyond the gable ends of both ranges and on the south side incorporates the brick wall of a further range at this end.

The boring mills shown by Slaughter consisted of three detached buildings ('8' in Figs 11 and 12) and were probably the buildings where the first cylinders were bored *c* 1722. The extant turning mill is built partly on to the earlier rubble-stone wall, in which three recesses have been infilled (Fig 34). This rubble-stone wall is probably all that survives above ground of the 1720s boring mill. The origin of

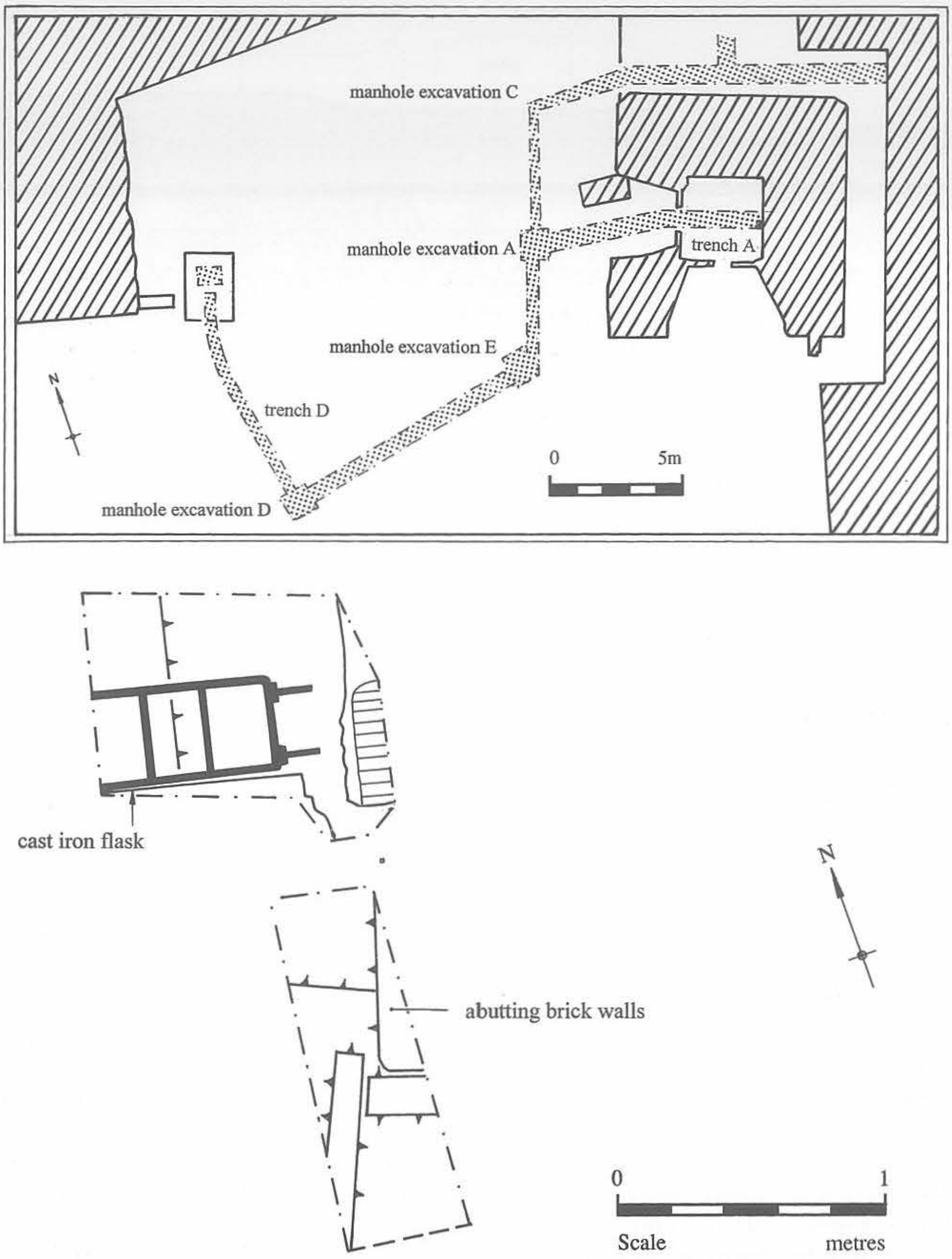


Figure 29 Drainage trenches excavated between the charging platform and the snapper furnace, revealing abutting walls of the foundry buildings and a cast-iron flask from the foundry.

these earlier buildings is intriguing, as they may have been related to the brassworks operated by Abraham Darby I, although there is as yet no archaeological evidence to substantiate this.

The extant turning mill must belong to the late-18th century. The walls facing the wheelpit both have dentilled eaves courses, a commonplace embellishment in all kinds of late 18th-century Coalbrookdale buildings (Fig 33A) (Muter 1979, 55). A late 19th-century photograph of the buildings also shows them to have had crow-stepped gables, which again precludes an early date (Fig 35). Slaughter shows the original boring-mill buildings as single-storey without attics (Figs 11 and 12). One of Slaughter's buildings has a gabled end bay but otherwise the gable ends are oriented north to south, while the extant mill ranges have gable ends east to west. Since early boring mechanisms for both cylinders and cannon worked horizontally, early boring mills would be expected to be single storey. However, Goodrich in 1803 saw vertical drills, which could only have been used in a building with a second storey or attic.

Further confirmation of the date is found in the wheelpit. Its west wall is steeply ramped and at the base are two cast-iron rails set into the brickwork (Fig 33A). This type of rail was first cast at Coalbrookdale in 1767 (Fig 36) (Broadbridge 1971, 9). The extant mill is therefore likely to belong to the late-18th century, which is perhaps why a visitor *c* 1801 commented upon its modernity, describing it as 'generally allow'd to be the most complete [mill]

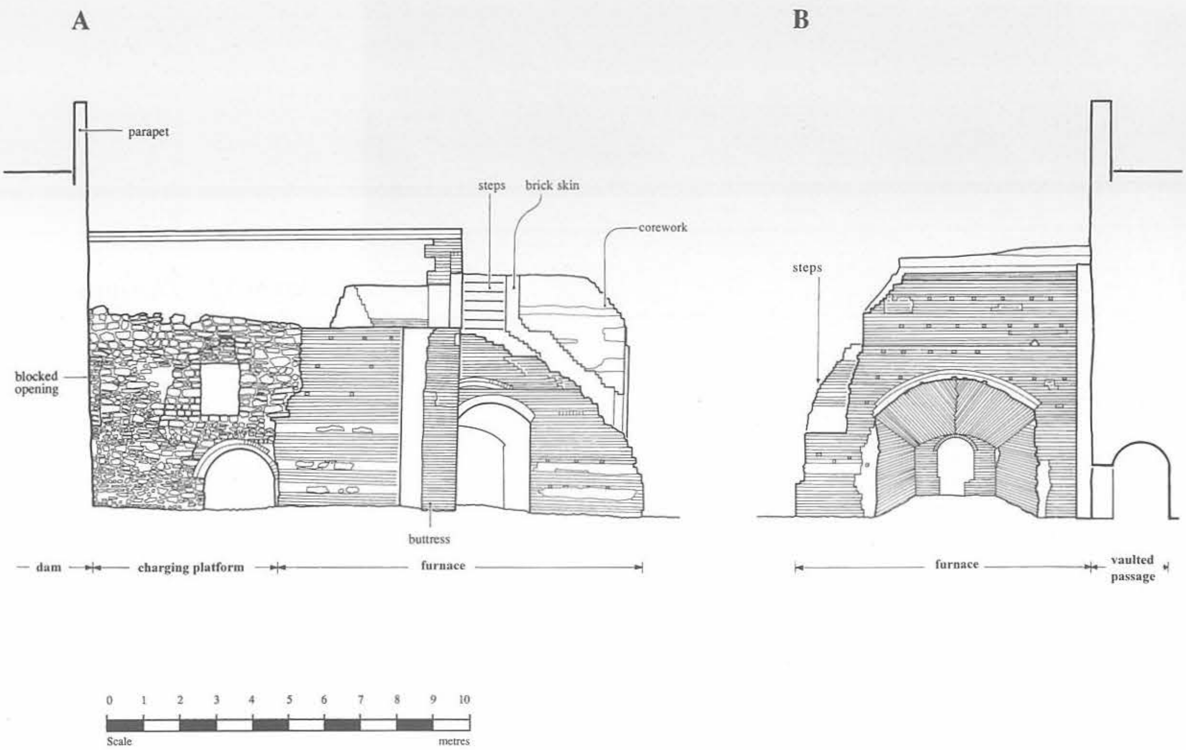


Figure 30 West (A) and south (B) elevations of the snapper furnace. The west elevation shows the charging platform and steps leading up to the former building erected on the charging platform by 1847.

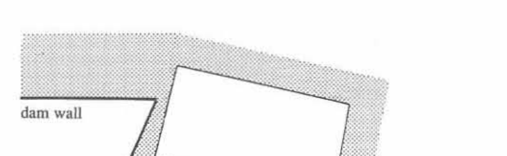


Figure 31 Ground plan of the snapper furnace showing the splayed recesses in its south and west walls, the vaulted chambers on its north side and the passage on its east side.

for the purpose to which it is intended, of any in the Nation' (Trinder 1979, 12). The earliest mention of this range as turning mills occurs in 1794 (SRRC 1681/138/4). A broad date range can therefore be established of 1767–94. However, the main Coalbrookdale boring mill was rebuilt in 1780 and perhaps the turning mill was a part of the same reorganisation. Certainly its architectural details suggest that it was part of the major rebuilding of the 1770s.

The wheelpit is 1.7m wide and has opposing score marks left by the shrouds of the waterwheel in its walls (Fig 33A). This enables its diameter to be estimated at 8.5m (28 feet). In the west wall, at a higher level, is a cast-iron pipe (Fig 34). This is set in later brickwork and can hardly have remained *in situ* while the viaduct was being built, even though Jabez Maud Fisher in 1776 commented specifically on the use of pipes instead of launders to feed the wheels (Morgan 1992, 265). However, its level may be at the level of the earlier pipe and, if so, the waterwheel would have been a high-breastshot type. The extant pipe is directly above an infilled square shaft, which appears to have been a dump shaft whereby the wheel could be stopped by diverting the water directly into the shaft.

The wheelpit floor is compacted soil where the absence of a tail race is puzzling (Fig 33A). The structure of the end walls of the pit – ramped to the west and stepped to the east – appears to preclude the possibility that the tail race was infilled. Far

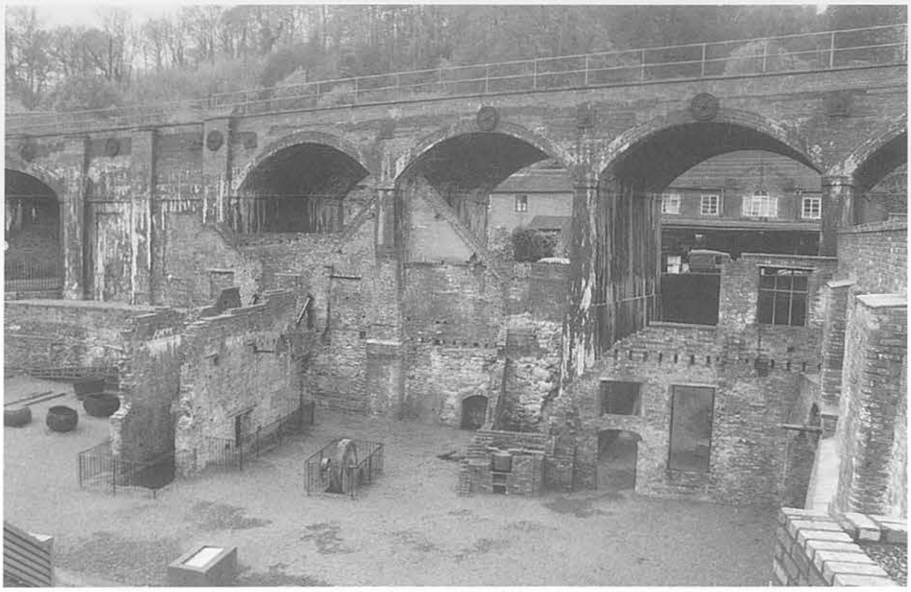


Figure 32 The turning mill and viaduct, photographed from the west side in 1991 prior to the commencement of repairs. The two free-standing walls to the left enclose the turning mill wheelpit. The structure on the right is part of the fitting shop built against the dam wall between 1838 and 1847.

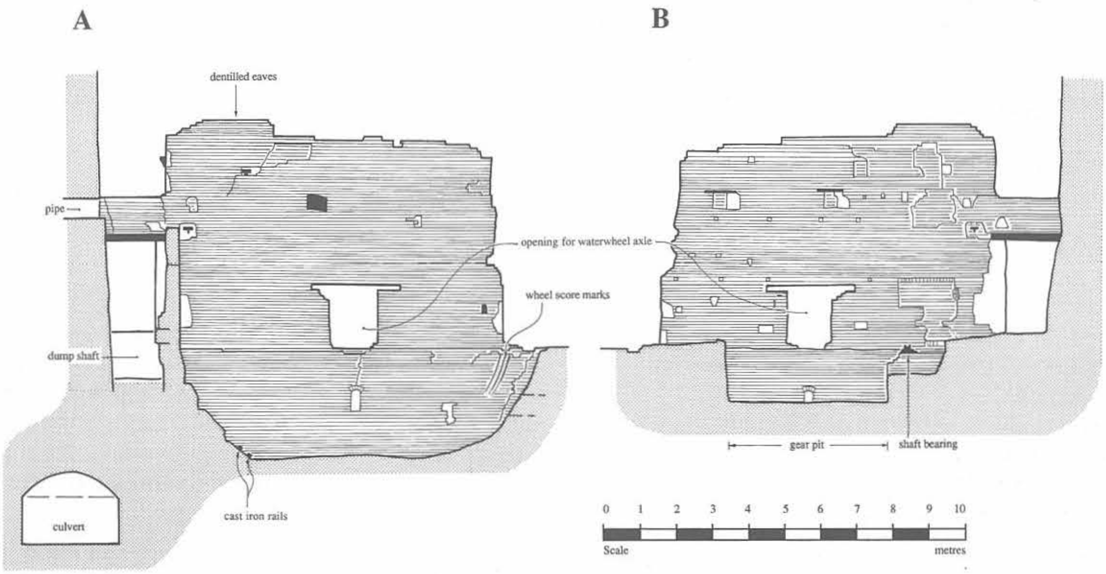


Figure 33 External (A) and internal (B) elevations of the turning mill north wing. The external elevation shows the integral wheelpit and its position in relation to the culvert below ground linking the upper furnace pool to the former lower furnace pool.

more likely, given the known proximity of a culvert beneath the boring mill leading from the upper furnace pool to the Lower Works, is that the water was drained away through a shaft which is now infilled. This matter cannot be resolved until the wheelpit and dump shaft are investigated further or a detailed survey is undertaken of the culvert.

There are openings for the waterwheel axle in the flanking walls, but nothing has survived above ground of the settings for the bearings. On the north side of the wheelpit is a pit either for a flywheel and/or a large gear wheel (Fig 33B). At the back of the pit is a shaft bearing for a secondary gear wheel. Turning and boring mechanisms would leave few archaeological traces in the mill walls. Power for the vertical shafts seen by Simon Goodrich in 1803 was probably transmitted by means of bevel gears, which would have been fixed to the ground. Clearer evidence on the layout of the mills is therefore most likely to come from future investigations below ground.

The north lateral wall of the north range survives at a low level and is mostly a modern rebuild. Attached to it is a boiler in a brick setting which is attached to the end of the pattern store discussed above with the dam wall (Fig 27). When the viaduct was built in 1864 a pier was constructed against the gable end of the north range and round openings were made in the piers to allow the pipe to the wheelpit to pass through, which probably provides a date for the extant pipe and its surrounding brick-work. Contemporary with the viaduct was a brick

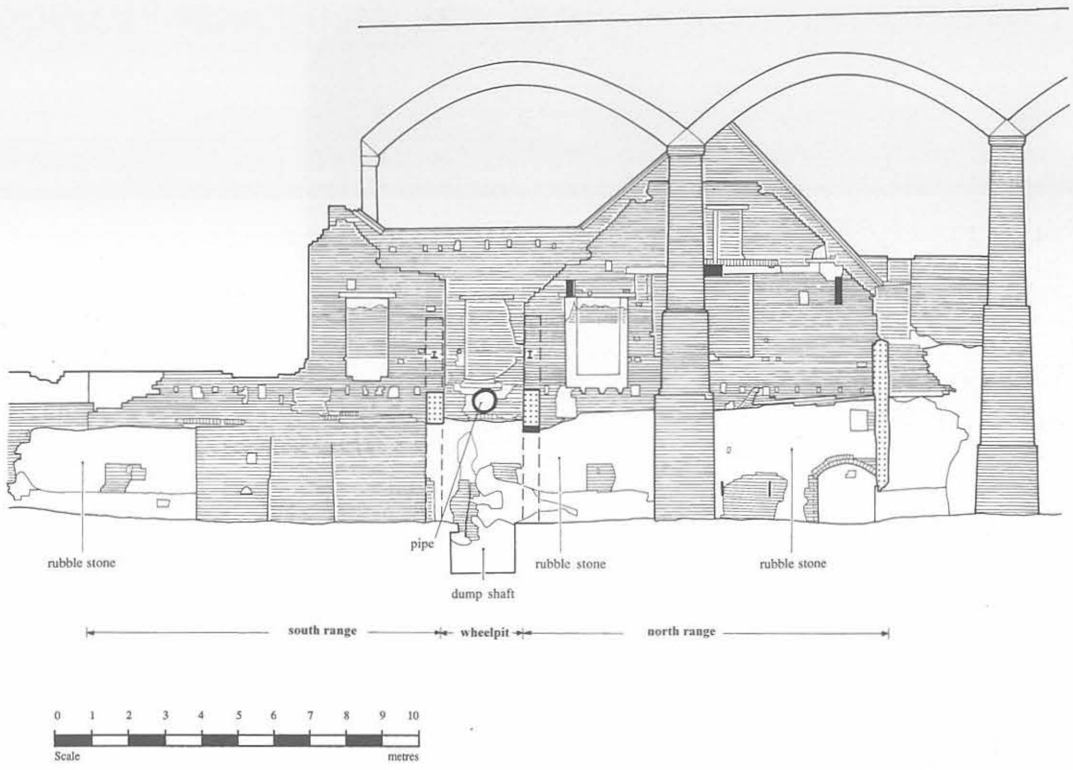


Figure 34 Gable ends of the turning mill beneath the viaduct, showing earlier rubble-stone walls and blocked openings in the brickwork. The cast-iron pipe above the dump shaft supplied the waterwheel.

skin against the early rubble-stone wall and sometime after the viaduct was built the gable end windows were infilled (Fig 34). At some time in the 19th century the wheelpit must have been roofed over, as a photograph of the late-19th century shows it as such (Fig 35). The lease plans also suggest it was roofed, although the description *c* 1801 suggests it was then an open space, as do the dentilled eaves.

Information on the later use of the turning mill is reliant principally upon oral testimony. In the late-19th century the wheel continued to provide power, distributed by means of belt drives, for what became engineering shops, and later on polishing and sand-grinding shops. In 1906 electric power was introduced and the wheel was apparently stopped. From 1912 the buildings became part of the pattern store, until cleared *c* 1930.

Cast-iron rails

Cast-iron rails were found reused as lintels in the turning mill wheelpit and in one of the openings in the snapper furnace charging platform (Fig 36). Given their importance in the early history of railways their discovery is worth noting. (Two similar rails have been recovered from the basin at the bottom of the Hay Inclined Plane and are now displayed in the Coalbrookdale Museum of Iron.) The rails are the type first introduced in 1767, when Richard Reynolds was the manager of the Dale Company works, and were laid for the pre-existing railways between the River Severn and the Upper Works, extending north to Horsehay and Ketley. Production of these rails at Horsehay is well authenticated and 16,067 rails had been cast by 1774, enough for 8 miles of track (Lewis 1970, 261–2, citing SRRC 6001/333). These early examples were 3.25 inches (83mm) wide and 1.25 inches (32mm) deep, and were either 6 or 7 feet (1.83m or 2.13m) long. As castings they were simple, although they appear to have been superseded relatively quickly and individual rails were mostly melted down as scrap.

Simon Goodrich saw some examples of cast-iron rails during his visit in 1803 (SML Goodrich E2, f 36). The rails were nailed to wooden buffers on which wagons weighing 1.5 tons could carry a load of 4.5 tons. Both rails seen by Goodrich were 6 feet (1.83m) long, except that one had three lugs incorporating peg sockets, the other four (Fig 37). Of the examples at the Upper Works, insufficient of the rail in the snapper furnace charging platform is visible to ascertain its length or number of lugs. The rails in the turning mill wheelpit both have three lugs visible, but both are longer than the 1.7m width of the wheelpit and probably therefore had four lugs.

Summary interpretation

Documentary and archaeological evidence enable the Upper Works to be interpreted in a number

Figure 35 A cast-iron fountain in the yard at the Upper Works, with the turning mill in the background, photographed in the late-19th century. It shows the pitched roof added to the wheelpit, the tall attic storey of the north wing and its crow-stepped gable. (Ironbridge Gorge Museum Trust)

of phases, not all of which have archaeological evidence.

Phase I (1658–1708): Evidence for the building of the first furnace at the Upper Works is ambiguous. Two cast-iron lintels bearing the date 1658 should be considered the most likely date of its erection until new evidence proves otherwise. Of this first furnace the stonework beneath the later furnace survives above ground, as do the rubble-stone walls of the charging platform, and part of the wheelpit (Figs 21 and 22). No evidence survives above ground of the cast house or of any of the other buildings which were listed in the inventory of 1718, such as the office, old forge, or copper house, buildings which may have belonged to the previous century. The height of the original pool dam was probably little different from its present level. The rubble-stone part of the dam wall on the west side of the furnace (Fig 26) may well belong to this phase because the arrangement of buildings that Abraham Darby leased in 1708, such as the office, old forge, and a brewhouse which stood close to the dam, implied a vertical face to the south side of the dam.

Phase II (1709–17): For all the innovatory genius of Abraham Darby I, there are no structures on the site which can be specifically ascribed to his tenure of the works, although such evidence probably survives below ground. Alteration to the upper furnace, specifically the brickwork of the passage on its north side (Fig 22B), might be associated with Darby I, but the date range of this alteration is a broad one. The extension of the charging platform on its east side (Fig 24) is earlier than 1753 and also might be associated with phase II. There is no evidence that Abraham Darby I rebuilt, rather than repaired, the upper furnace when he prepared it for blowing-in in 1709 for smelting with coke. No evidence survives above ground of the air furnaces that Darby introduced. Darby briefly operated a copper and brass works at Coalbrookdale, most likely to have been at the Upper Works, although no archaeological evidence for it has yet been found.

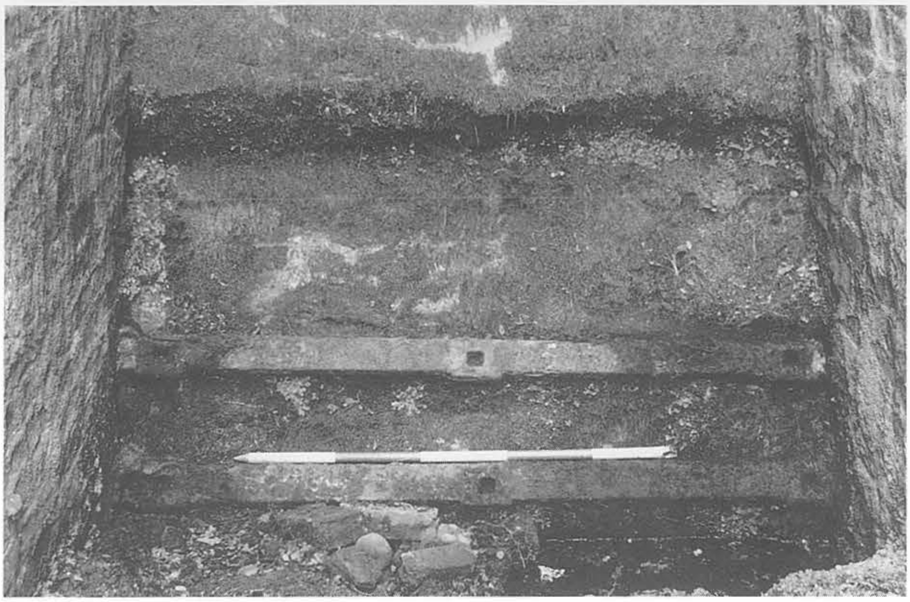


Figure 36 Two cast-iron rails embedded in the west wall of the turning mill wheelpit, of a type first cast at Horsehay in 1767.

Phase III (1718–1753): During the period that Richard Ford and Abraham Darby II managed the works it was expanded to become an integrated furnace, foundry, and engineering works. A boring mill was built *c* 1722, although when a new boring mill was erected elsewhere in Coalbrookdale in 1734, the Upper Works mill appears to have become secondary to it. The original boring mill is shown as three detached structures on the 1753 plan of the works by Thomas Slaughter ('8' on Figs 11 and 12). Archaeological confirmation is provided by the rubble-stone wall beneath the west gable ends of the later turning mill ranges (Fig 34). During the 1750s, expansion at Coalbrookdale may have been temporarily curtailed by the establishment of the Horsehay and Ketley Works.

Phase IV (1773–1794): The substantial archaeological remains at the Upper Works appear to belong mainly to the late-18th century. This coincides with the period when the works was managed by Abraham Darby III (from 1773 to 1789), a period of great activity that saw the construction of the Iron Bridge in 1779, the renewal of the boring mill near the Upper Forge in 1780, and substantial development at the Upper Forge itself later in the decade. This may have been one reason why the Dale Company's finances were in such a parlous state by the 1790s. Darby renewed the Upper Works on a large scale. The only datable feature is of course the blast furnace, which is dated 1777, which was blown from cylinders rather than the old-fashioned bellows. It was soon modified to be blown from two sides, which had been achieved by 1790. (Previously it had been argued that the furnace had been blown on three sides but this is now discounted.) Concurrent with the renewal of the blast furnace in 1777 was the probable rebuilding of the cast house.

Darby probably also constructed the surviving turning mill, on the site of the earlier boring mill,

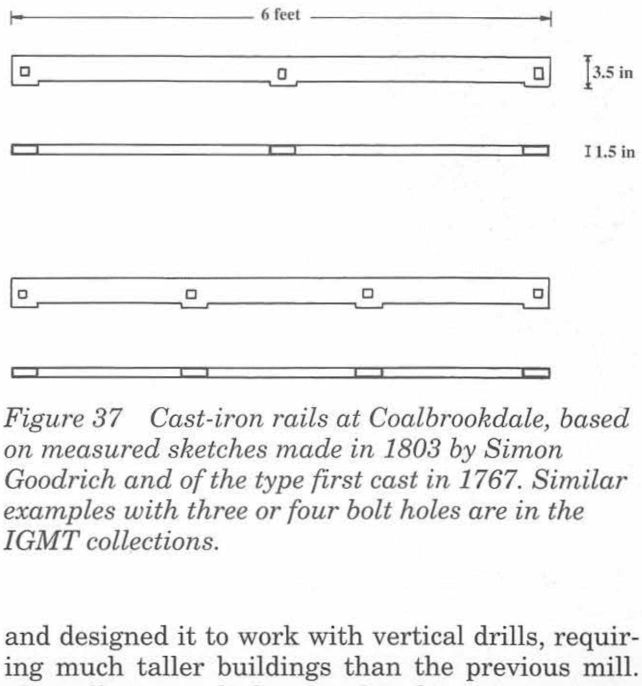


Figure 37 Cast-iron rails at Coalbrookdale, based on measured sketches made in 1803 by Simon Goodrich and of the type first cast in 1767. Similar examples with three or four bolt holes are in the IGMT collections.

and designed it to work with vertical drills, requiring much taller buildings than the previous mill. The mill is securely dated within the range 1767–94, but its crow-stepped gables and dentilled eaves seem to fit comfortably with the redevelopment of the upper furnace and the boring mill in the period 1777–80. It is not known whether Darby had begun to build the snapper furnace before his death in 1789. It was certainly under construction by 1794, although there is no evidence that it was ever finished. During this period the Upper Works was also extended beyond its original boundary – the road on the south-west side – with workshops and an engine-fitting shop, the clock tower upon which is visible in a sketch of Coalbrookdale drawn in 1789 (IGMT CBD 59.130.1). The extent of the expansion is also shown on the 1805 lease plan (Fig 15).

Phase V (1794–1838): During this phase the Upper Works suffered a period of decline, although there were no major physical changes to the works: Accounts of a flood which occurred in 1801 implied devastation, but archaeological evidence suggests that the accounts of damage to the works have been exaggerated. The upper furnace remained in blast until at least the end of the Napoleonic war in 1815. During this time the snapper furnace appears not to have been blown-in. The likelihood is that it had never been built up to its full height and if it had been, it was reduced in height by 1827 when a retaining wall passed over the top of its charging platform. The end of smelting was followed by the end of casting at the Upper Works. Although dates are elusive, the lease of 1838 documents the nadir in the fortunes of the Upper Works, where none of its former air furnaces were in use and no cupolas had been built to replace them.

Phase VI (1838–1930): With the renewal of the lease in 1838 the Upper and Lower Works were rationalised into a combined operation, with cupola furnaces erected at the Lower Works and a new warehouse constructed at the south end of the Upper Works, today housing the Museum of Iron (Fig 2). In addition to the turning mill which continued in operation, the Upper Works buildings became fitting shops, workshops, and stores. In conjunction with this, new buildings were erected against the pool dam on either side of the upper furnace and charging platform, evidence for both of which survives (Figs 26 and 28). In addition, a new building was erected on the upper furnace charging platform and a small building was built above the snapper furnace. New buildings were also erected on the south side of the snapper furnace, against the retaining wall on the east side of the site (Fig 19). The turning mill continued in operation, becoming a polishing shop in the early-20th century, until which time its waterwheel is said to have remained in operation.

The largest physical impact on the Upper Works occurred in 1864 when the Great Western Railway branch line to Coalbrookdale was completed, the line of which required a viaduct passing over the upper furnace pool and the turning mill (Figs 32 and 34). The decline of the Upper Works relative to the Lower Works continued throughout the 19th century. Its small workshops were replaced in the 1870s by a new large erecting shop built at the Lower Works, and at the end of the 19th century with another large fitting shop at the south end of the Upper Works, leaving the older, smaller buildings at the north end of the Upper Works of little use except for storage and other such desultory uses. It is little surprise therefore, that the final use to which these buildings were put was a pattern store. In the early 1930s the patterns were destroyed and the main buildings were cleared in order to level the ground.

3 The Upper Forge, Coalbrookdale

Introduction

Of all the major ironworking sites in Ironbridge, the Upper Forge offers the most potential for furthering knowledge about the early Coalbrookdale iron trade. It is the sole survivor of a complex of industrial and domestic buildings which evolved in the 17th and 18th centuries. Of these other buildings only Rose Cottages, dated 1642 and built for workers at an adjacent forge or steelworks, survive above ground. Between Rose Cottages and the Upper Forge were an 18th-century boring mill with pool and a 17th-century steel house. The name 'Upper Forge' encompasses two separate buildings, the old Upper Forge which was demolished when the road was widened, and which stood at right angles to the new Upper Forge. The new Upper Forge remained occupied until 1993, latterly as offices.

Prior work has been minimal. The surviving building has not previously been the subject of a detailed documentary search and a resistivity survey and two trial trenches conducted in 1986–7 revealed little of significance largely because, as will be shown, they were conducted in the wrong place (Hanks 1988). Earlier accounts of the site have therefore been drawn from general enquiries and have argued that the building was erected in the 1760s, that an engine was added in 1787, and that it was converted to a stable by 1847 (Clark 1993, 43–4). Interest in the building and its date has been heightened by its possible connection with the Cranage brothers, two Dale Company forgemen who obtained a patent in 1766 for making wrought iron in an air furnace using coal.

The present project allowed detailed recording of the building. Before repairs to the building began, three small exploratory trenches were excavated inside the building in areas thought to be of archaeological sensitivity. During the repairs, extensive external groundworks were undertaken primarily to investigate the structural instability of the building. The evidence most germane to the Upper Forge was found on the east side of the building, where excavations (by machine) lowered the ground level adjacent to the building by approximately 2m to reduce the level of spoil against the forge wall, and to facilitate the insertion of gabions in an attempt to stabilise the steep bank behind.

Although this work did not exhaust the archaeological potential of the site, with the additional element of new historical evidence, a fresh interpretation of the Upper Forge was made possible using information that had not previously been available.

Documentary evidence

The Upper Forge was in existence by 1668, since a visitor *c* 1801 saw a cast-iron pillar with the date inscribed on it by two of the forgemen (Trinder 1979, 8). The forge was leased to Shadrach Fox in 1696, and appears in the inventory of the Coalbrookdale Works made in 1718 following the death of Abraham Darby I (Baugh 1985, 49; SRRC 6001/300). Thomas Slaughter's 1753 map of Coalbrookdale with its table of references shows the buildings on the site in some detail (Fig 38). In addition to the Upper Forge itself (32) there was a charcoal house (34), and close

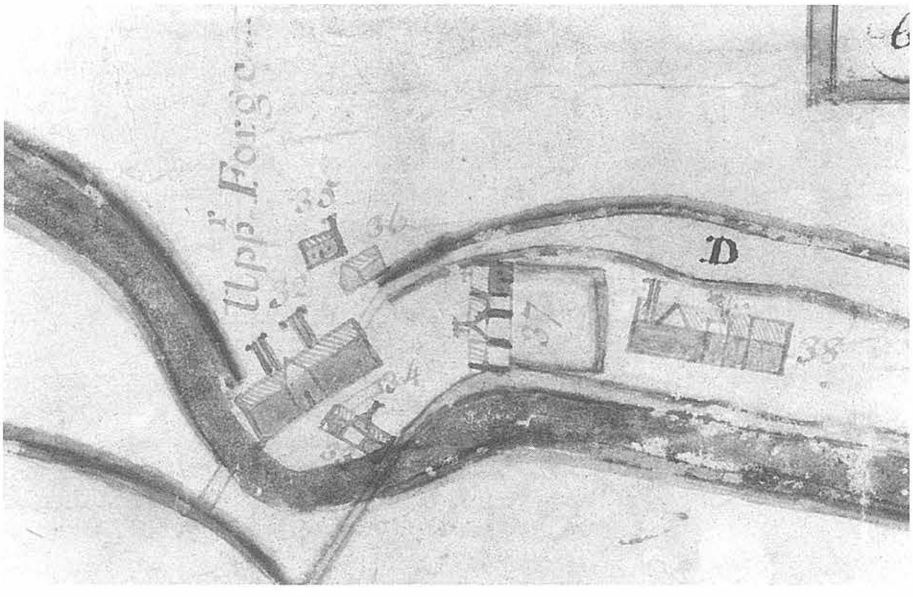


Figure 38 Detail of the Upper Forge from Thomas Slaughter's plan of Coalbrookdale, 1753. North is to the left of the picture. It shows the forge with finery and chafery stacks (32), a stamper mill (36), smithy (35), charcoal store (34), two houses (33, 37), and a malthouse (38) that was formerly a steel house. Downstream from the forge is the boring mill pool (D). (Ironbridge Gorge Museum Trust)

to an open watercourse were a stamper mill (36) and a smithy (35). The stamper mill was referred to in 1754 when Charles Wood noted that the company made stamper heads and shanks for the Cornish tin mines (Hyde 1973, 40). This trade was first referred to by Richard Ford in 1734 and the stamper mill may well therefore date from at least that time (SRRC 6001/3190, 4). Slaughter's map suggests that the stamper mill was south-east of the old Upper Forge, adjacent to the brook, in the general location of what would become the new Upper Forge. Wood also noted that the forge had two fineries and a chafery for making bar iron. One of the fineries used coke rather than charcoal. Indeed the adaptation of the fineries at Coalbrookdale for coke fuelling has previously been studied by Charles Hyde (1977, 38–40). However, the output of bar iron from the Upper Forge was not substantial. National surveys made in 1717, 1736, and 1750 show the forge to have produced well below the national average (King 1996, superseding Hulme 1930).

In 1766 Thomas and George Cranage, two local forgemen, obtained a patent for making wrought iron in an air furnace using coal. They were encouraged to do so by Richard Reynolds, who was then manager of the Dale Company concerns (Mott 1983, 8–10). The company evidently invested money in making the process viable and a detailed account of it was written in 1768 by William Lewis and Alexander Chrisholm (Wedgwood 39-28405, ff 69–70). There were two air furnaces at the Upper Forge, where pig and scrap iron were heated three times. The first heat was moderate and the iron was seldom if at all stirred. The second heat was stronger and the iron was stirred in a similar manner to the later puddling process, but the blooms were shingled manually with sledgehammers rather than a water-powered hammer. The third heat was similar to the earlier chafery and later balling furnaces, whereby the iron was brought to a welding heat sufficient to be beaten under the main forge hammer. Semi-finished iron was also sent downstream to the company's forge at Bridgnorth for drawing out into merchant bar, there being insufficient water at Coalbrookdale. The quality of the iron was variable, however, and the method was given up shortly afterwards. The patent was subsequently acquired by the Dale Company for £30.

The Cranage trials occurred at the old Upper Forge nearly a decade before the new Upper Forge was built. The erection and early development of the new Upper Forge is uncommonly well documented, having been the subject of a dispute between the Dale Company and its neighbour, John Powis Stanley, who in 1786 claimed the building had been unlawfully erected on his land (PRO C12/1693/97). Stanley lost his case, but the proceedings left an account of when and why the building was erected, and an accompanying plan of Coalbrookdale showing the site in considerable detail (*ibid*; SRRC 1681/179/1) (Fig 39).

According to the Dale Company the 'New Upper Forge' had been erected at a cost of £20,000 on the site of an earlier building, presumably the stamper mill shown by Slaughter. Stanley claimed no knowledge of this earlier building, although he did remember a bridge across the watercourse which was removed in 1768, so perhaps the stamper mill had been taken down before then. Stanley claimed that the new building was intended at first to be a slitting mill, but was soon converted to a forge, after which an engine and boiler were added to the building. Stanley was vague about dates but other accounts fill in the missing details.

The slitting mill was under construction in 1776 when it was seen by two visitors. Jabez Maud Fisher noted that the waterwheel was entirely of cast iron, was 12 feet (3.65m) in diameter and turned two 'flywheels' 20 feet (6.1m) in diameter, suggesting two banks of rollers (Morgan 1992, 266). In June of the same year the agricultural journalist Arthur Young noted also that the slitting mill was unfinished but saw 'immense wheels 20 feet diameter of cast iron', presumably the same two flywheels (Trinder 1988, 34). However, these wheels were probably not flywheels in the modern sense of the term, but gear wheels.

According to Stanley, the slitting mill was not a success and the building was converted to forge use *c* 1783. By 1785 the extant building had certainly become an integral part of wrought iron making at the Upper Forge site. At this point it is worth digressing to establish the broader context of wrought iron manufacture in the late-18th century because it is crucial to the significance of the Upper Forge and other contemporary forges. The 1780s was a key period in the iron industry because developments in the refining of pig to wrought iron precipitated a new phase in the industry where the mass production of wrought iron became the index of commercial success.

The traditional finery and chafery had been charcoal fuelled, with water power required to work the bellows and hammer. It was a time consuming, highly skilled, and consequently an expensive operation. In the finery, the pig or scrap iron was heated and stirred using a long bar to bring it into contact with the blast of air. Once it had formed a spongy mass, known as a bloom, it was removed and shingled under a hammer to remove the slag trapped in the interstices of the coagulated metal. The bloom was returned to the hearth for a second heating, whence it was removed for a second hammering. An 'ancony' was created which was shaped rather like a dog's bone: the middle of the bloom was drawn into a bar, leaving the ends, still containing slag, as amorphous lumps. In this state the ancony was heated in the second hearth, the chafery, after which the iron was drawn out into bars under a hammer. Although coal was used with some success in the chafery at Coalbrookdale in the 1730s and at the Stour Valley forges in the 1750s, the wrought iron trade remained dependant upon charcoal (Ince 1991, 34). The problem was therefore to find a quicker, cheaper way of making wrought iron using mineral fuel. The Cranage method referred to above was one of numerous competing processes. The crucial breakthrough was puddling and rolling, based on patents granted to Henry Cort in 1783 and 1784, but in Shropshire the earlier technique of stamping and potting was already established before puddling became commercially viable.

Stamping and potting was patented in 1773 by John Wright and Richard Jesson of West Bromwich, and was a slight variation of a method patented by Charles Wood in 1761 and 1763. The pig iron was refined in four stages. The iron, mixed with scale or cinder, was first heated in a normal blast-operated finery, but using coal instead of charcoal. It was then removed and beaten into plates by one hammer and once it had cooled it was broken into small pieces by a second hammer (stamping). The 'granulated' iron was then washed in a rolling barrel to remove sulphurous material, and in the final stage was put into a reverberatory furnace inside clay pots (potting). Eventually, the clay pots would have broken and the iron particles would have coalesced into one amorphous mass, which could then be removed and drawn into the requisite shape under the hammer.

A survey of the wrought iron trade compiled in 1794 showed that stamping and potting was most commonly employed in Staffordshire (B&W MII/5/10). It had also been adopted at a number of works in the East Shropshire Coalfield. In 1785 two Frenchmen, the La Rochefoucauld brothers, described stamping and potting at the Upper Forge, giving one of the few detailed descriptions of the process. After the iron was removed from the finery and shingled:

> it is thrown 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 made in the neighbourhood [at Horsehay] . . . they 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 (Scarfe 1995, 98–9).

The description suggests that the bulk of the process was undertaken at the old Upper Forge, while the new Upper Forge merely contained a hammer where the bars were finished off. Therefore the process had probably been established at the old Upper Forge irrespective of the building of the new Upper Forge. However, later in 1785 major changes were begun which integrated the buildings into the process in a different way. The earliest mention of a steam engine for the Upper Forge occurs in April 1785, before the la Rochefoucauld brothers' visit. It refers ambiguously to a proposed 'forge' engine, implying that it was intended to work a hammer, although later sources establish that it was in fact a blowing engine (B&W letterbook 9, f 133). The erection of this engine in 1785–6 irritated John Powis Stanley, who claimed that its smoke, sulphur, and steam were polluting his trees and underwood (PRO C12/1693/17).

It was after the addition of an engine house to the building that the plan of the Upper Forge complex was surveyed by George Young in 1786 (Fig 39). A description made *c* 1801 makes it clear that the fineries were contained within the new Upper Forge, which therefore had a steam-powered blowing cylinder and a water-powered shingling hammer, while the air furnaces were housed in the old Upper Forge (Trinder 1979, 8). This is also confirmed in a lease plan of 1805 (see Fig 41) (SRRC 1681/138/7).

The plan of the site drawn in 1786 shows the two forges facing a yard, of which the old Upper Forge with its accompanying air furnaces is on the north side, with the new Upper Forge on the east side (Fig 39). The half-round projection on the east side of the new Upper Forge is the boiler, while around it are dashed lines representing the watercourses. A watercourse leads around the east side of the boiler, beyond which it divides, one branch leading to the tail of the boring mill pool, the other continuing along the side of the pool, which was evidently culverted as it is mentioned as such by Stanley, and because the key to the map refers comically to 'the wheel thro' the arch goes'.

The site appears in a pencil sketch of Coalbrookdale drawn by Joseph Farington in 1789 (Fig 40). The viewpoint, from the hillside to the south-west, allowed many buildings at the site to be shown, although they cannot be reconciled with earlier and later maps without some difficulty. The new Upper Forge is on the right of the picture, with two cowls on the ridge, two tall stacks, probably of the finery hearths, to their left, and the engine house with a tall stack behind. At the south end a new wing

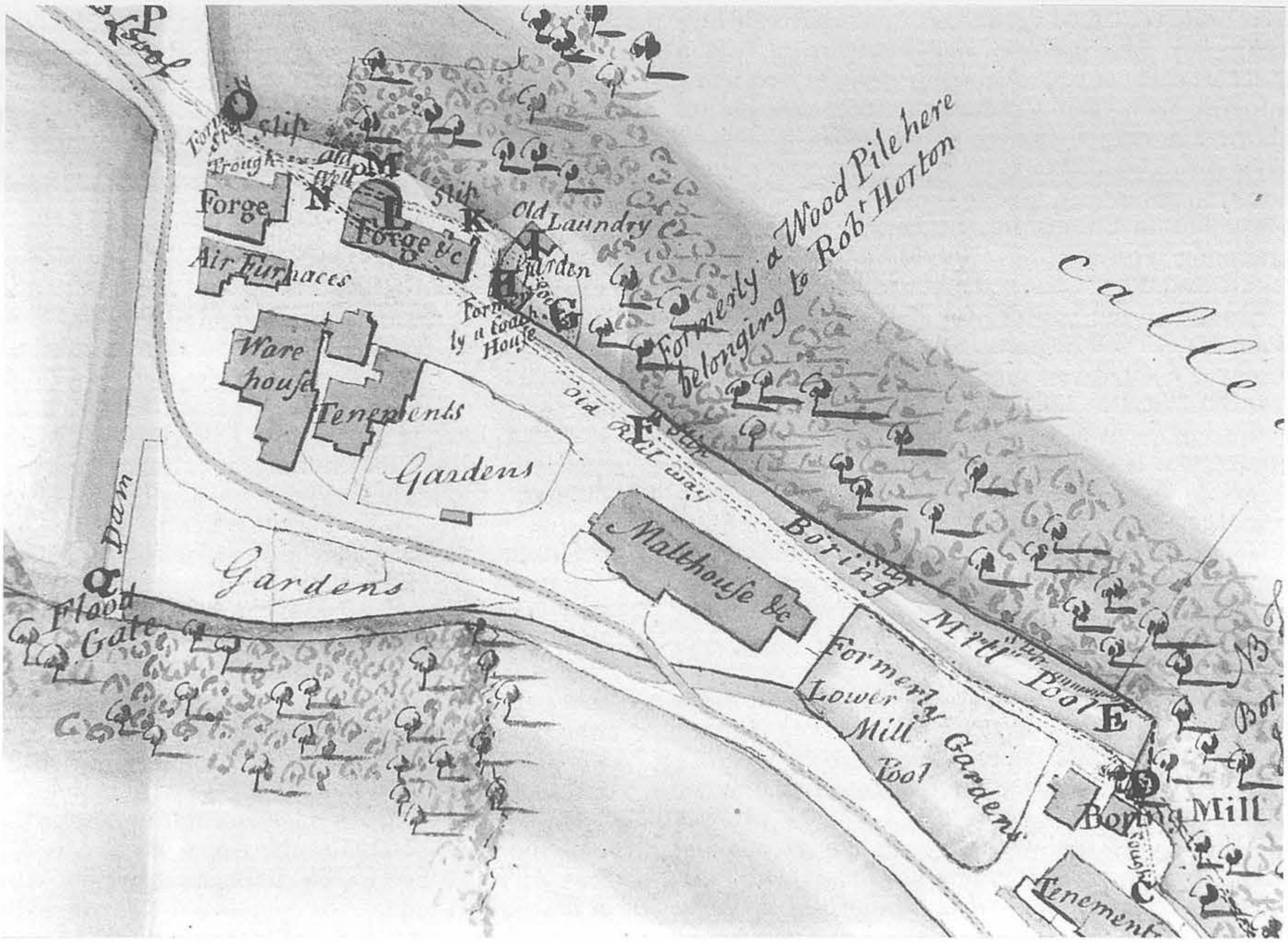


Figure 39 Detail of the Upper Forge from a plan of Coalbrookdale by George Young, 1786. North is to the left of the picture. The old Upper Forge is shown in two parts as forge and air furnaces. On the east side of the new Upper Forge (L or 'Forge &c') is a haystack boiler, while the dashed lines represent watercourses. South of the malthouse is the lower mill pool, not shown by Slaughter but used for recycling water to the Upper and Lower Works by means of a culvert to the pump shaft of the Resolution engine. (Shropshire Records and Research Centre)

has been added to the building, which has a pair of stacks and a gabled dormer.

The old Upper Forge was at right angles to the new building, but Farington does not show it, instead showing a building with three cowls parallel with the new Upper Forge. Behind this, however, is an engine house with the beam protruding from the building. The engine house was built in 1787 for a Boulton and Watt hammer engine, but worked only until 1793 (B&W Catalogue, f 40). The buildings to the left of the picture are the warehouse and tenements shown on the 1786 and 1805 maps (Figs 39 and 41), while the Upper Forge pool behind has two sluices from where water was channelled to the forge waterwheels.

The lease plan of 1805 identifies the buildings on the site by means of a key (Fig 41), and shows the wing added on the south side of the new Upper Forge (57 and 58), which is attached to a cottage (63) behind it, which was shown in 1786 as a laundry with a cellar (SRRC 1681/179/1). The old Upper Forge (55) is considerably larger than the building shown by Slaughter, while the hammer engine house (56) had been converted to a tenement by this time. The warehouse (59) and tenements (60) are also shown, as is the former steel house (65) which had been converted into a malthouse by 1734 (SRRC 1987/35/2). The plan shows fourteen dwellings at 'Upper Forge' and there is little doubt that by the early-19th century more people lived there than worked there.

The stamping and potting works, using the technology of the early Industrial Revolution, had an output considerably higher than the previous finery and chafery. For example in 1800–1, 395 tons of bar iron were sent to Stourport, and 376 tons to Worcester. In addition 859 small bars were sent to Horsehay for faggoting, ie the welding of small bars together to make a larger forging (IGMT CBD.59.82.4, ff 126, 136). In 1754 Charles Wood was told that the finery and chafery at the Upper Forge was producing a mere one and a half tons per week

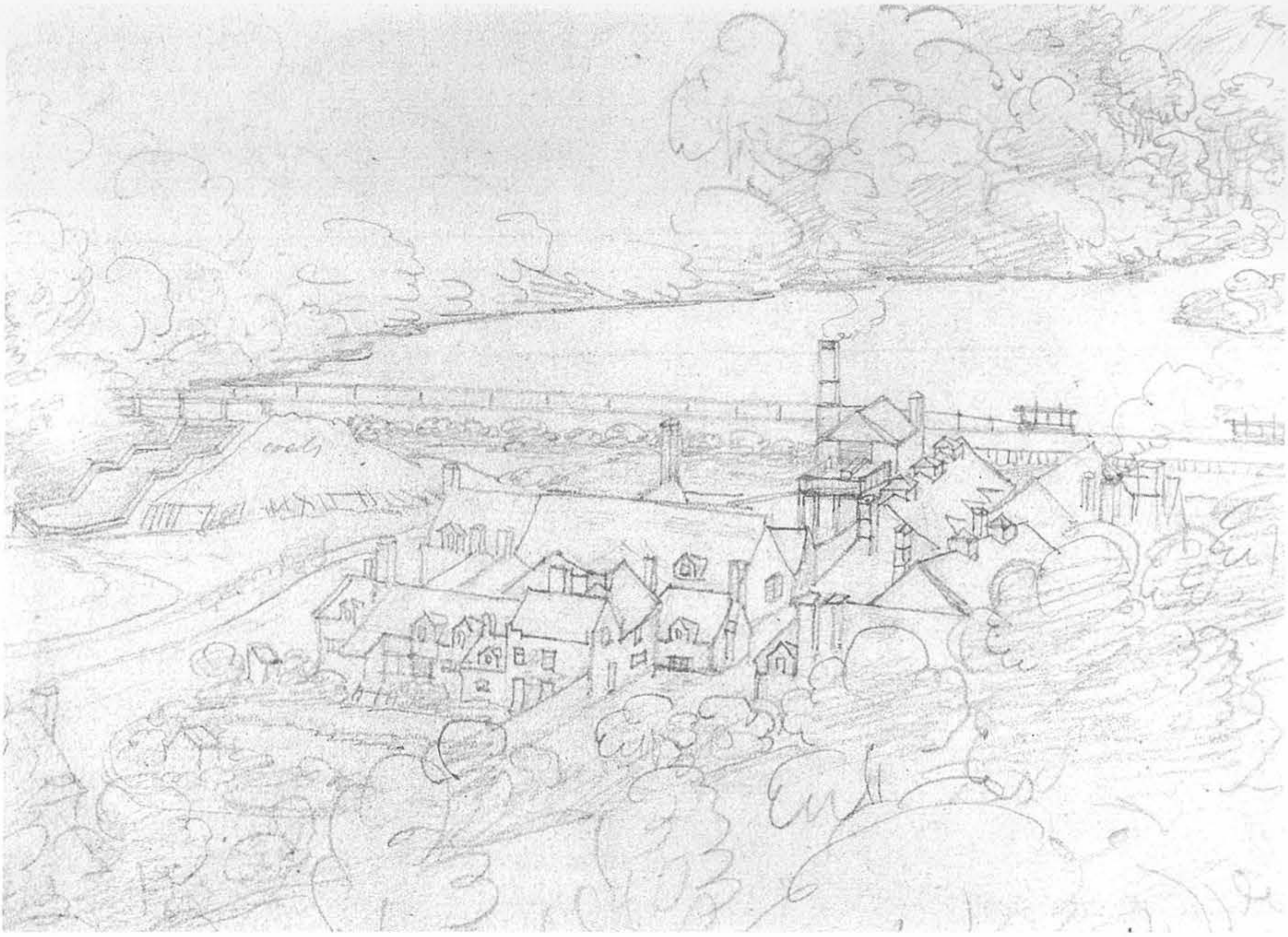


Figure 40 Detail of the Upper Forge from a pencil sketch of Coalbrookdale, drawn in 1789 by Joseph Farington and looking north-west over the Upper Forge pool. The new Upper Forge is to the right. Its central range has two cowls on the ridge. Attached to its north is the higher engine house with boiler stack on the right. On the west side of the central range are two finery stacks. On the south side the south wing is shown with two stacks and a dormer. The old Upper Forge is probably the building to the left of the new Upper Forge, with three ridge cowls. To its left (west) is a forge engine with the beam projecting from the building and a boiler stack behind; it was built in 1787 but stopped in 1793. The ranges on the west side of the site are the warehouses and tenements shown in 1786. (Ironbridge Gorge Museum Trust)

(Hyde 1973, 40). Although neither of these figures can be said to account for the entire production, the difference in scale is striking.

The successful adoption of puddling at the end of the 18th century profoundly altered the relative fortunes of the various iron making concerns in Britain. In 1802–3 the Swedish 'spy' Svedenstierna devoted considerable attention to the puddling process, but passed over stamping and potting very briefly (Flinn 1973, 52–5, 69–70). By the early-19th century South Wales had become the nation's leading producer of bar iron. As early as 1804 Gilbert Gilpin, of the Old Park works in Shropshire, was complaining of the 'trade of South Wales undercutting the trade of this country', and predicted that soon 'South Wales will command *all* the coasting (together with a great part of the local) iron trade of this kingdom' (SRRC 1781/6/28). The works in Coalbrookdale, laid out on a hillside to suit the requirements of the 17th century, could not, or at least did not, compete and their subsequent history was to reflect this changing situation.

There are no direct references to the Upper Forge producing wrought iron after 1803, when Simon Goodrich witnessed the stamping and potting process and was told that stamped iron was considered superior to but more costly than puddled iron (SML Goodrich E2, f 43). There is no reason to suppose that the Upper Forge was not still in operation when Thomas Butler, of Kirkstall Forge in Yorkshire, visited Coalbrookdale in 1815 and commented on the outdated appearance of the works (Birch 1952, 232). Butler also visited Horsehay, where stamped iron was still made, although it had probably been puddled first, the stamping and potting being utilised in place of the balling furnace and rolling mill (*ibid*). In 1821 Joshua Field found that the Coalbrookdale works 'are in a great measure deserted, the lease

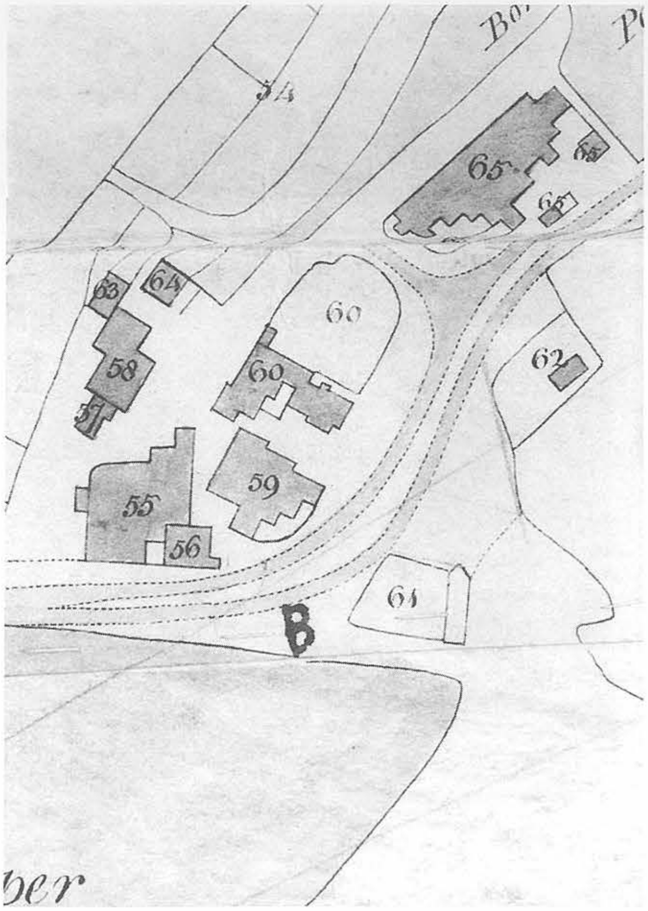


Figure 41 Detail of the Upper Forge from a lease plan of the Coalbrookdale works, 1805. North is towards the bottom of the picture. It shows the old Upper Forge (55), with the former forge engine house adjacent but converted to a tenement (56), new Upper Forge (58), 'blast engine' (57), 'Old Laundry, now a tenement' (63) and 'House over the Brook' (64), formerly a coach house, and the warehouse and tenements (59, 60). (Shropshire Records and Research Centre)

being nearly out, the Company are at little pains to keep them up' (Hall 1927, 30). Despite the moribund state of the iron trade in Coalbrookdale he did notice that 'a small forge or 2 is working from the stream of water which originally led to iron works being established here'. One of these forges might have been the Upper Forge, although there is no mention of a steam engine. From 1810 the Coalbrookdale forges were considered as part of the Horsehay forges for the purposes of accounting, a factor which obscures their later history, but it is possible that, as with the rest of the Coalbrookdale works, production at the Upper Forge endured a prolonged decline.

The old Upper Forge had been converted to a stables by 1827 (IGMT 1986.6999). By 1838 the new Upper Forge had been converted to a 'mill and hay-bay' (SRRC 1681/138/8). In the tithe apportionment of 1847 the mill is listed as a kibbling mill. The accompanying plan shows a watercourse leading from the Upper Forge pool to what is represented as a waterwheel on the north-east side of the building, therefore locating the kibbling mill in the earlier engine house (Fig 42).

The Upper Forge complex was evidently used to stable the company's horses and to grind their feed. Its later history is known primarily from oral testimony, the earliest account being written in 1948 by Charles Peskin, who was born in 1862. According to Peskin there was a smithy nearby (Peskin nd, 14). Another local resident, Jack Jarvis, claimed that the mill worked until the 1920s, latterly grinding feed for the horses at Lightmoor brickworks (IGMT T46).

In 1938 the road through Coalbrookdale was widened, and all the buildings on the site were demolished, with the exception of the extant Upper Forge and the former Malthouse, which stood until 1967 (Raistrick 1975, 18). Photographs taken in the early 1950s show the extant Upper Forge in a poor condition. During the later 1950s the site was occupied by a plant hire business and in the 1970s it was used by the Telford Development Corporation as a store, during which time the upper storey of the former mill was taken down and a large opening, wide enough to allow vehicular access, was cut into the west wall facing the yard (Fig 43).

The site

The building

The Upper Forge is an isolated building below the level of the main road through Coalbrookdale, with a car park and picnic site next to it (Fig 44). It is aligned north–south with its front facing a yard on the west side, while on its east side is a steep bank. The building comprises a gabled single-storey central range, which has a two-bay former engine house attached on its north side, of two storeys under a pent corrugated iron roof and the end bay narrower, and a south wing built as a lean-to against the gable end of the central range and projecting behind with a gabled roof. The fabric is brick throughout, but exhibiting numerous additions and alterations. The central range and south wing have tile roofs.

The central range represents the earliest phase of the building, built in 1776. Its dentilled eaves continue to the south bay of the engine house, the lower storey of which is integral and was also part of the original building. The present four-window front to the west wall is a later addition and is discussed below (Fig 45). An original brick arch probably formed a lunette opening at the north end, now the lower storey of the engine house and cut down to make a doorway. To the right of the wide doorway in the central range the wall is thicker and incorporates the responds and haunches of a pair of former arched openings. The crown of one of these is shown clearly in a photograph taken in the 1950s, with a later arch beneath it (Fig 46). The earlier arch must

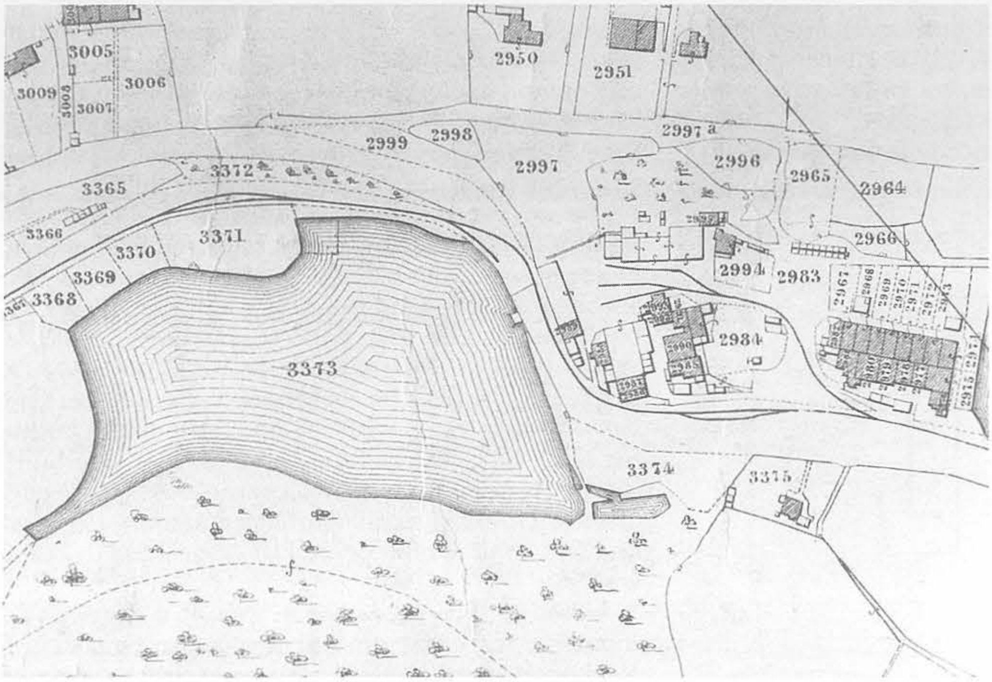


Figure 42 Detail of the Upper Forge from the Madeley tithe map, 1847. North is to the left of the picture. The domestic buildings are shaded. The new and old Upper Forges are included in Plot 2983, which the apportionment describes as 'Kibbling Mills, Stables, Buildings, Yard, Tramford'. On the north-east side of the new Upper Forge is a waterwheel with a pipe leading to it. (Ironbridge Gorge Museum Trust)

Figure 43 The Upper Forge looking north east in 1985, after the upper storey of the engine house had been taken down and with a lean-to added to the front. Most of the openings associated with its use as a stable have survived. (Ironbridge Gorge Museum Trust)

have formed a round-headed opening approximately 4.3m wide. Of the second arch at the south end, an opposing arch spring is discernible by corbelled brickwork left after the arch bricks were removed. The west wall therefore originally had two wide round-headed doorways and a smaller lunette opening.

The original south wall, now mostly enclosed within the south wing, had a wide round-headed doorway, now infilled, similar to those of the west wall (Fig 47A). In the gable is a round vent. The north wall of the original building was mostly demolished in a later phase. It might have had a similar doorway to the south wall but this is not known.

On the east side, the south bay of the engine house is again integral with the central range up to eaves level (Fig 47B). The south end is enclosed within the south wing. At the north and south ends are infilled lunettes, similar to those in the west wall. The remainder of the east wall was much rebuilt in subsequent phases, but must have had one opening for the shaft of the waterwheel for the slitting mill and later a forge hammer. The wheel has left score marks on part of the wall, and was said by Fisher in 1776 to have been 12 feet (3.65m) in diameter (Fig 48). The wheelpit did not survive alterations made in 1785 when the engine house was built.

Below the concrete and tile floor in the central range a trial excavation uncovered an earlier brick floor that could have been contemporary with the first phase of the building, since it formed the threshold of the large doorway in the south wall but did not extend into the south wing. The floor was

0.72m lower than the present floor level. However, the early floor was not extensively revealed and no evidence of the fixtures inside the building has yet been found. If Jabez Maud Fisher and Arthur Young were correct, the interior contained two stands of rolling mills, each with a gearwheel which must have been inside the building. At least one of the mill stands had been replaced by 1785 when the La Rochefoucauld brothers saw a forge hammer inside the building. The central range has a three-bay roof with king posts and raking struts (Fig 49B).

The engine house was added in 1785–6 for a Boulton & Watt engine, which later sources confirm powered a blowing cylinder. The northernmost bay of the original central range was raised in height to become the south bay of the engine house, and the original north wall was demolished to allow a thicker bob wall to be constructed in its place. The bob wall is integral with the north bay of the building (Fig 49A). In addition, a cross wall was built inside the central range to form the south gable end of the engine house, which butted against the east and west walls and obscured the lunette in the east wall.

Access to the engine house was by a doorway in the north wall. The interior layout can be deduced from limited internal excavations and the logic of housing an engine in the building. In the north bay, beneath a brick floor laid on casting sand, the core of the engine bed was uncovered, together with the brick face of the corresponding condenser pit. The excavation was not conducted in the centre of the bay, so no evidence was found of the holding-down bolts which would have enabled the dimensions of the cylinder to have been estimated. Furthermore, the top of the engine bed had been removed, presumably for the insertion of a later floor, leaving an

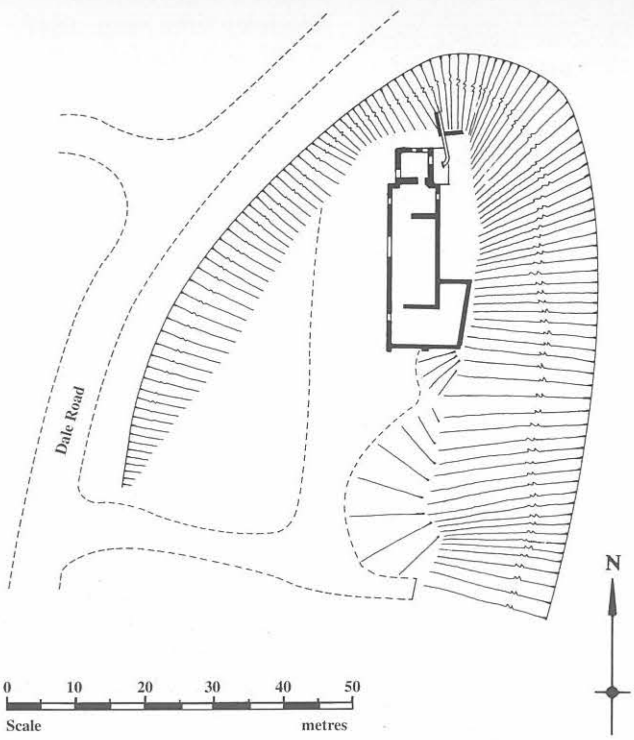


Figure 44 Upper Forge site plan.

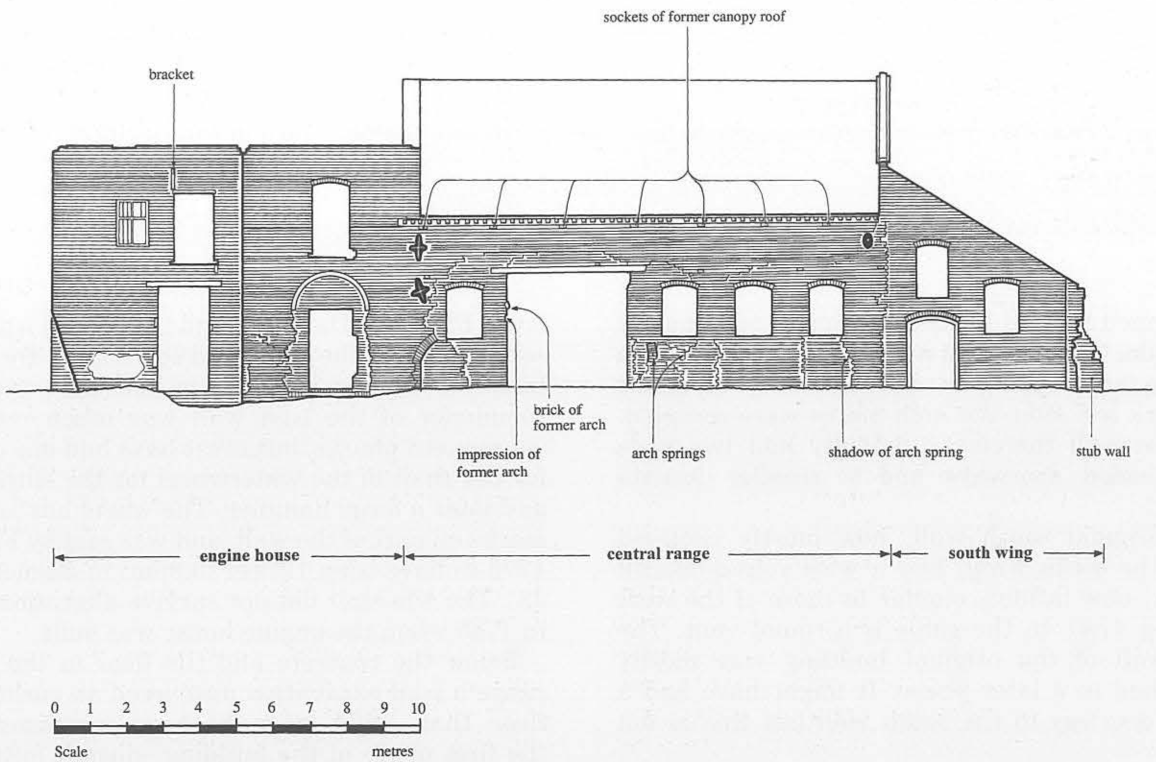


Figure 45 The west elevation of the Upper Forge, facing the yard.

Figure 46 The former mill and stables photographed in the 1950s looking east. The mill occupies the former engine house, in which the upper gabled bay with hoist and door is clearly added as there is a change in the shade of the brickwork. To the right, above the stable door of the central range, are fragments of two former arches belonging to the first two phases of the building. (Ironbridge Gorge Museum Trust)

exposed surface of core bricks. The excavation was not deep enough to ascertain the depth of the condenser pit and nor was any evidence revealed of a condenser feed pipe. In the south bay a floor of worn bricks was found, but no holding-down bolts associated with the blowing cylinder which must have been installed here. Therefore the date of the floor, or at least its chronological relationship with the rest of the building, remains unclear.

The bob wall contained an integral fireplace and flue on the north side of the wall, which matches the chimney shown on Farington's sketch of 1789 (Fig 40). The first floor in the north bay was supported on two spine beams, while at the top of the extant bob wall are two spring beams, which must also be integral with the building. On the south side of the bob wall five spine beams define the level of the first floor (Fig 49A), although the central beam could not originally have spanned the entire room because it would have interfered with the connecting rod from the engine beam. A doorway connected the two sides of the bob wall at first-floor level.

Three separate sections of a boiler base were revealed in and flanking the floor of wheelpit 2 on the east side of the engine house (Fig 50). One of them is set into the wheelpit floor, while another continues beneath the north bay of the engine house and is integral with it. The boiler's location agrees with the plan of the building shown on the 1786 map (Fig 39). No evidence of the boiler stack, which Farington showed against the east wall of the engine house (Fig 40), was found, probably because it was removed when a later waterwheel was inserted.

Changes are apparent to the central range concurrent with the erection of the engine house. In the west wall a large arch was inserted, the respond of which is directly aligned with the south wall of the engine house (Fig 45). This arch is clearly visible in the 1950s photograph of the building (Fig 46). In the

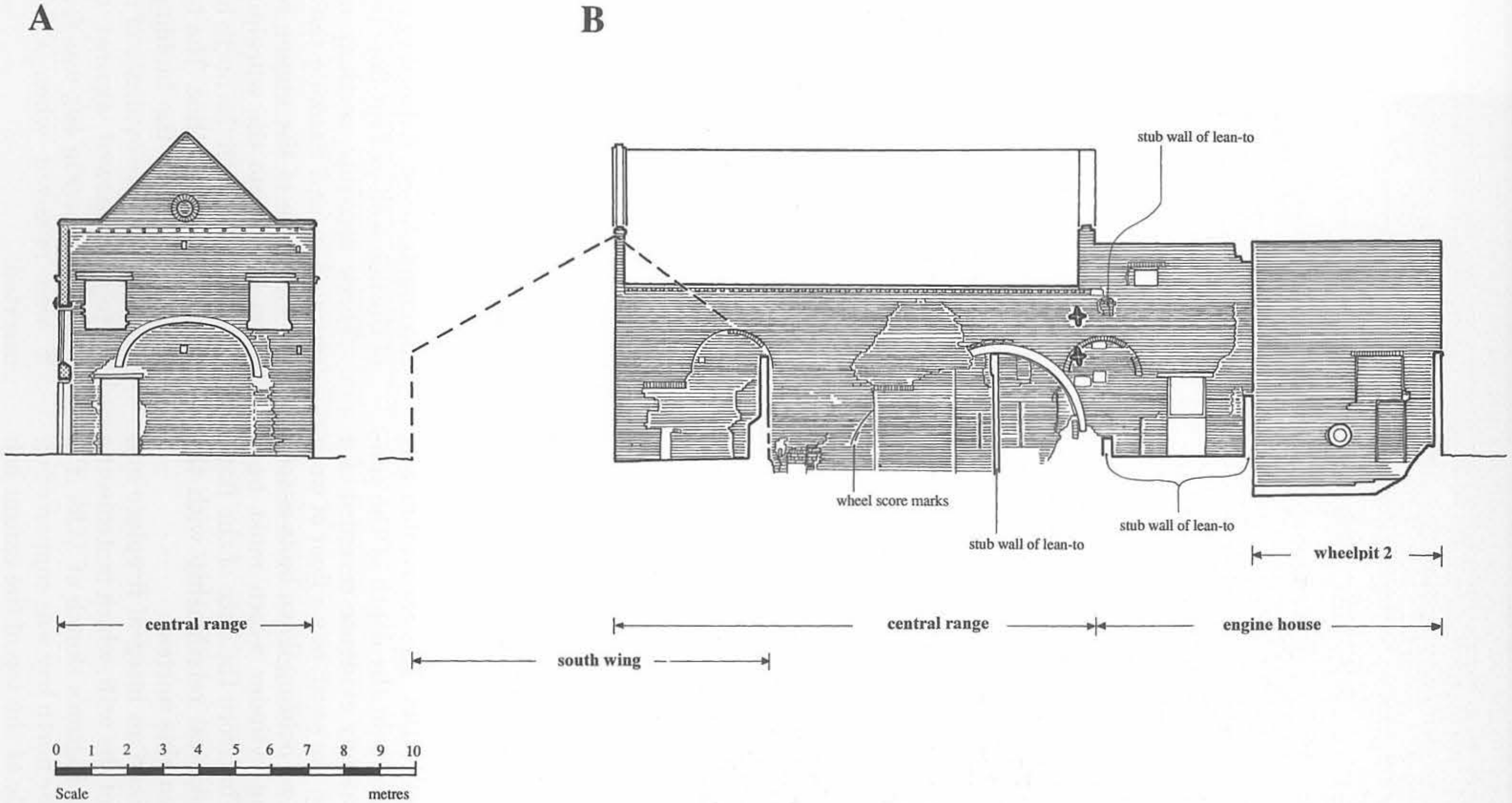


Figure 47 The south elevation of the central range (A) and east elevation of the central range and engine house (B), showing evidence of former waterwheels.

jamb of the wide central range doorway a solitary brick has survived of the inserted arch, with the impression of the arch of a later doorway beneath it (Fig 45). A corresponding arched opening was also made in the east wall, partially cutting the earlier lunette (Fig 47B). The axle of the waterwheel was mostly likely spanned by the arched opening, but could not have been central to it. A new waterwheel accompanied the erection of the engine house and was installed in wheelpit 1, exposed during the groundworks (Fig 50).

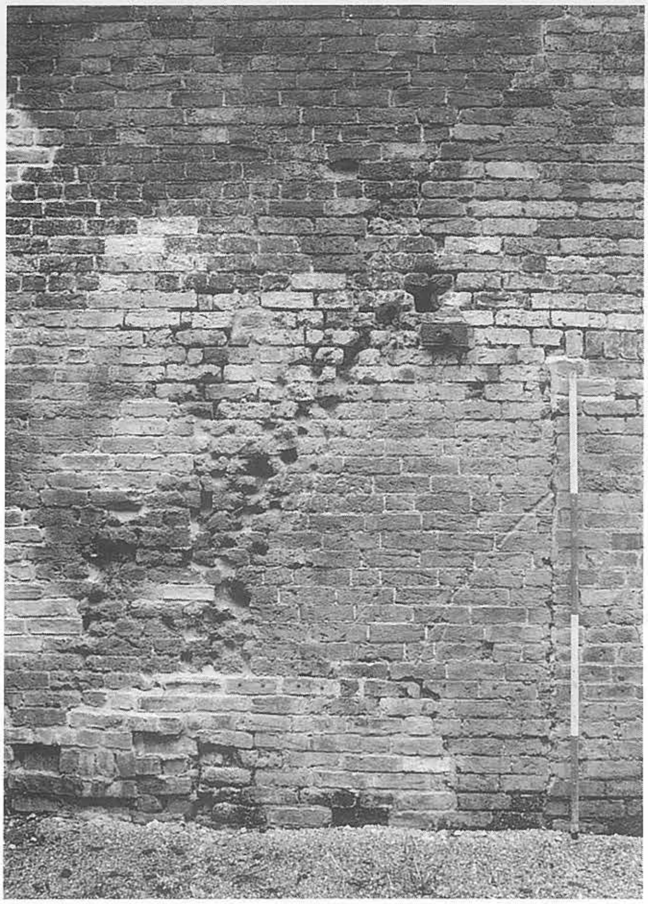


Figure 48 Waterwheel score marks on the central range east wall.

Substantial portions of the brick walls of wheelpit 1 were found, a massive structure 7.7m long and 3.7m wide (Fig 50). In its east wall were score marks left by the waterwheel (Fig 51). The south wall incorporates an arched tailrace entrance directly beneath but not integral with either the north wall of the south wing or the east wall of the wheelpit. On the west side of the wheelpit was a brick skin one course thick, offset approximately 50mm from the east wall of the central range (Fig 52). The brick skin was demolished after it had been recorded to allow repairs to the central range wall. A mortared surface, within which was the impression of a timber baulk, was found on the east side.

The wheelpit is far larger than would have been necessary to house a wheel working a hammer, so the wheel must have occupied only part of the pit. The tailrace entrance is offset from the central range wall and it would be expected that the tailrace would be in line with the wheel. It is 2.2m wide and the wheel may be estimated as having a similar width.

The argument that the wheel in this phase was mounted away from the central-range wall is supported by the fact that the boiler was positioned against the engine-house wall, where the original water launder or pipe must have passed in order to

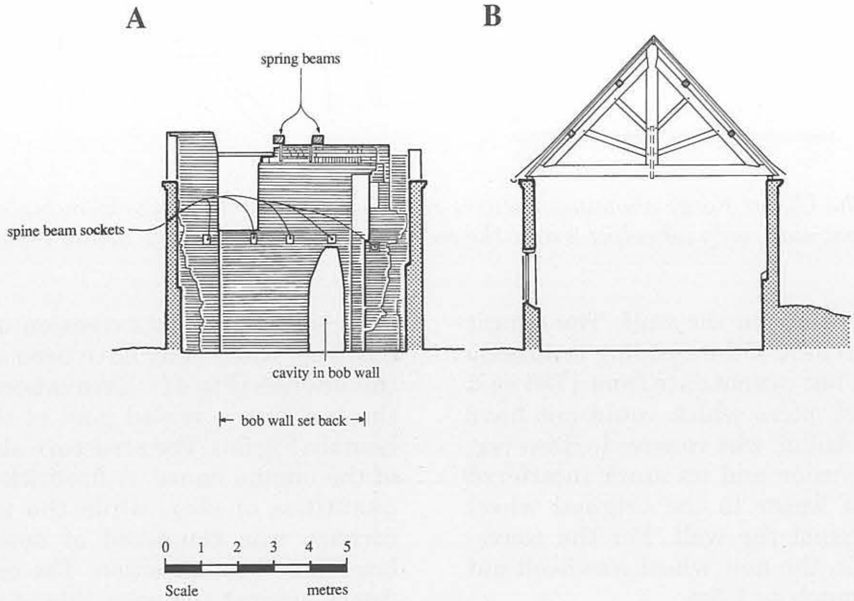


Figure 49 The south elevation of the engine house bob wall (A) and a cross-section of the central range showing a typical roof truss (B). The original upper floor levels in the engine house are denoted by the levels of the spine beams and spring beams.

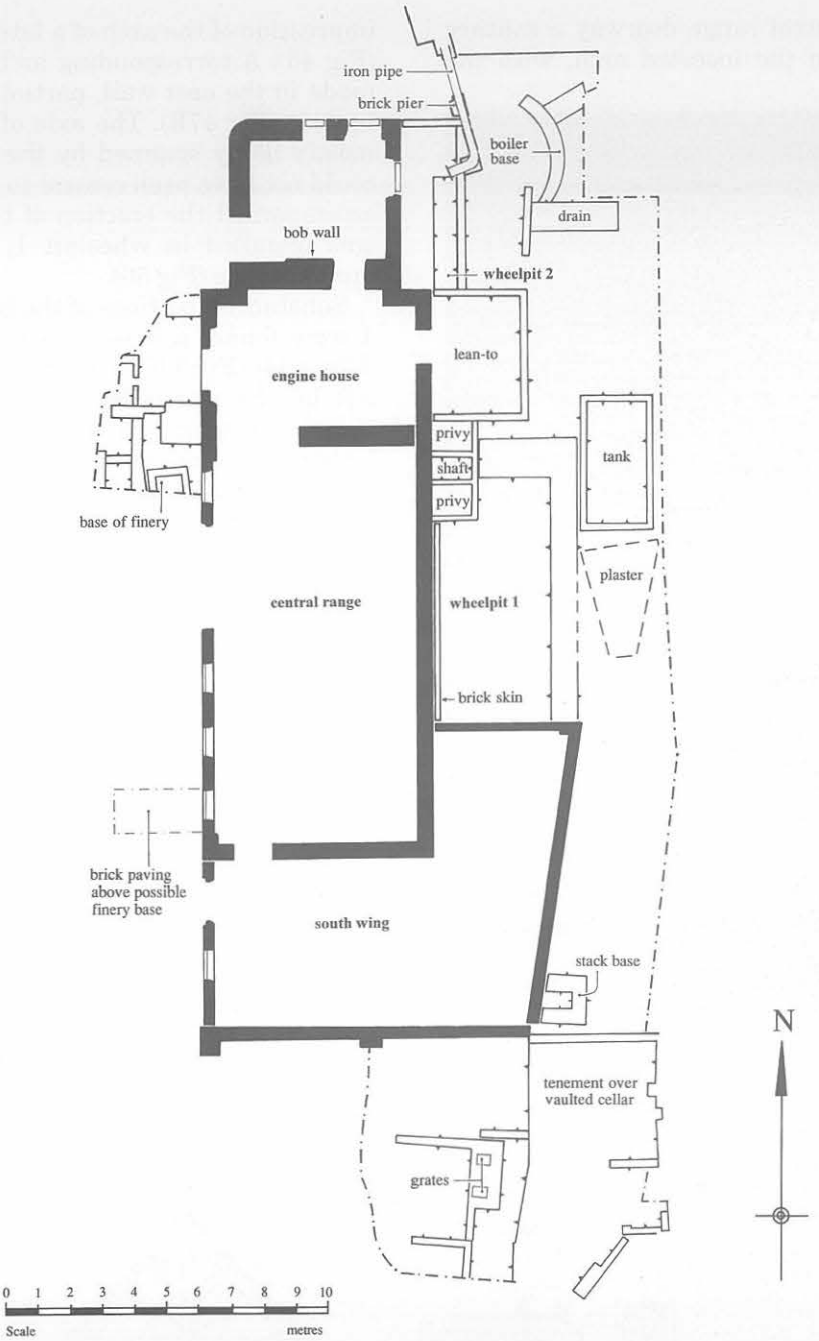


Figure 50 Plan of the Upper Forge showing features revealed in the groundworks outside the building. Of the features on the east side, only wheelpit 2 and the cast-iron pipe were visible before excavation began.

supply a waterwheel close to the wall. The extant pipe on the north-east side of the building is directly aligned to wheelpit 1 but cannot date from 1785 as it is supported on brick piers which could not have been built until the boiler was removed. However, the presence of the boiler and its stack interfered with the delivery of water to the original wheel which was flush against the wall. For the convenience of supplying it, the new wheel was built out from the wall by as much as 1.5m.

Fineries were built in 1785 and were blown from the engine. Farington's sketch shows two stacks on the west side of the building, suggesting a pair of hearths (Fig 40). Later maps, such as the 1805 lease plan, show a roofed extension over this side of the building, which may have been an open canopy over the fineries (Fig 41). Excavation on the west side of the building revealed part of the base of a finery hearth (Fig 50). The structure abutted the south bay of the engine house. A firebrick-lined pit contained quantities of slag, while the internal core of the furnace was composed of cross walls forming a box-framed construction. The existence of a second finery against the west side of the central range is probable, but a second excavation further south revealed only a pavement of white bricks with industrial waste below, the core of a brick structure only appearing at the base of the excavation. This

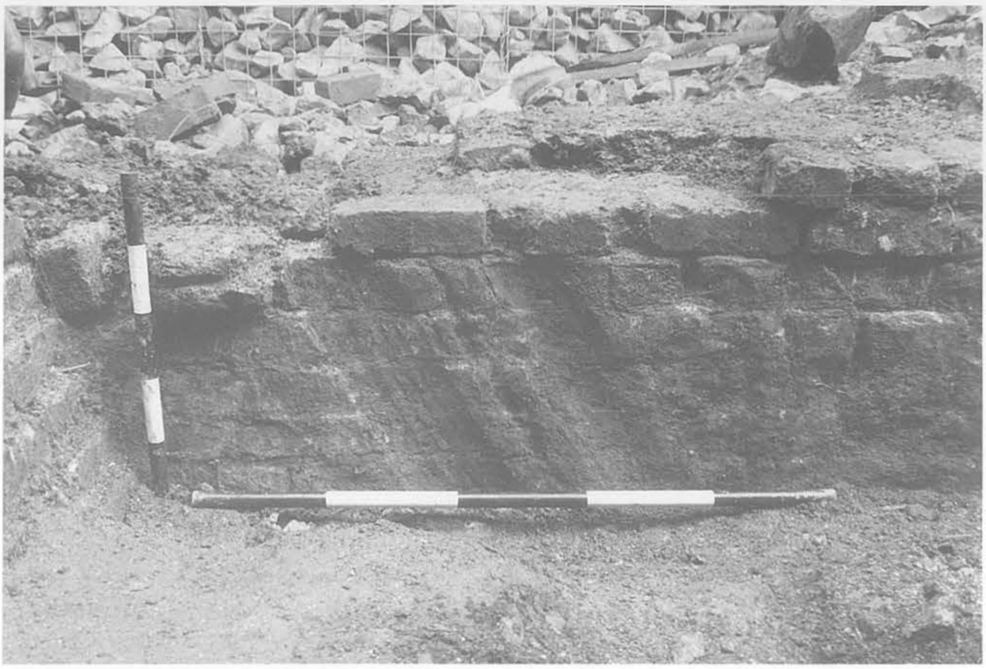


Figure 51 Waterwheel score marks in the east wall of wheelpit 1, photographed during excavation in 1994.

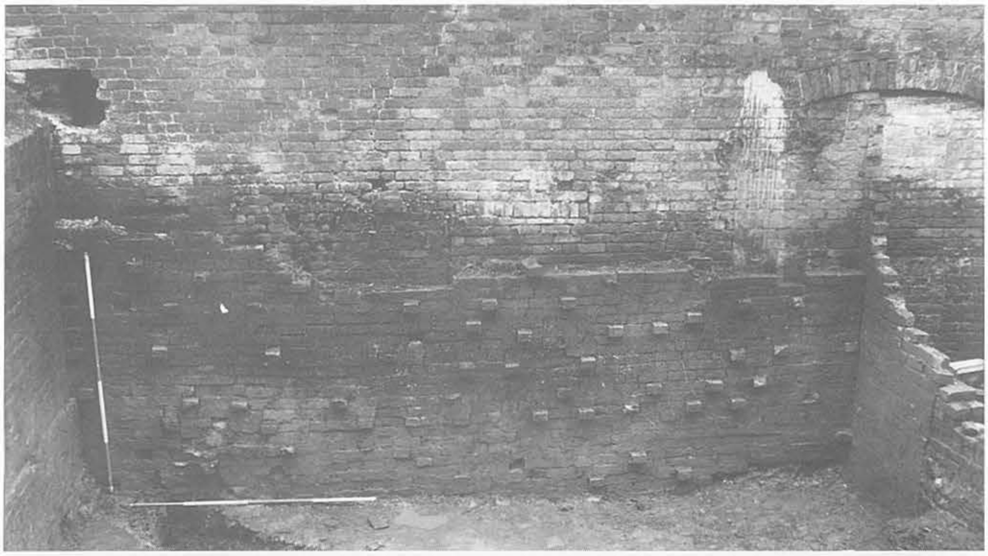


Figure 52 The skin wall exposed against the central range east wall inside wheelpit 1, photographed in 1994 during excavations. The skin wall was demolished after it was recorded to allow repairs to the central range wall.

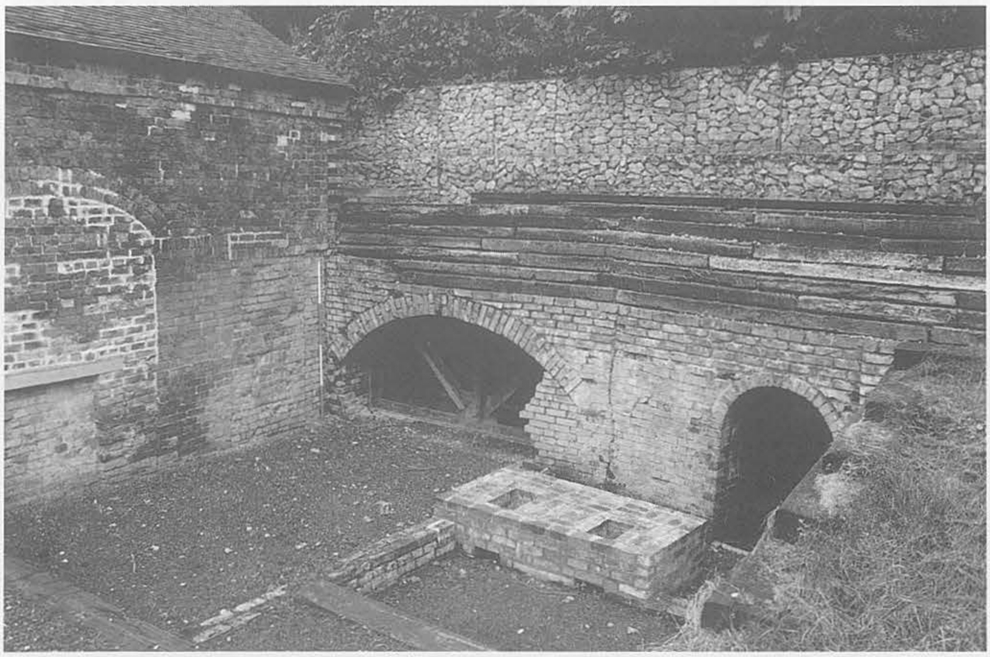


Figure 53 Cellar walls beneath the former laundry, later a tenement, exposed in excavations outside the south wing, photographed looking east in 1998 after the completion of repairs and groundworks. A butt joint clearly separates the two cellar openings. At the upper level, later covered with sleepers, were the foundations of a single-unit dwelling.

might have been the base of a second hearth, but excavation was not extensive enough to confirm this.

The blowing engine and finery hearth demonstrate the major changes that were undertaken and the increase in scale of the stamping and potting process at Coalbrookdale. The archaeology confirms the historical evidence that the fineries were situated at the new Upper Forge while the air furnaces for the potting process were at the old building. According to the La Rochefoucauld brothers stamping was carried out manually using a sledgehammer, but there is no evidence where this was carried out. The absence of hammer scale from excavations inside the building may at first seem conspicuous, except that adequate means of retaining the iron fragments would have been devised, otherwise the process would hardly have been efficient.

The south wing is first shown in Farington's sketch of 1789, and must have been added since 1786 (Fig 40). Although the walls are of different dates the plan form of the building has not changed (Fig 50). The only original wall to have survived is the east wall, which abuts the old laundry on the south-east side. The short north wall, facing wheelpit 1, was originally open above the tail race. The tail race itself may well have been an open watercourse until the south wing was built. The present south and west walls of the wing are later rebuilds. The purpose of the south wing is less clear than its phasing and the interpretation is conjectural pending further information. Logically it should have been used for washing and granulating the iron, as space for the other processes has already been defined. However, no archaeological evidence has been found to support this and the culverts directly beneath the wing (see below) bore no evidence for vertical shafts which might have been associated with waste water from the washing process. Farington's sketch shows two stacks in the original south wall, suggesting a smithy, although there was a smiths shop at the old Upper Forge by 1794 (SRRC 1681/138/4) (Fig 40). Alternatively the stacks might represent small air furnaces used for working scrap iron. It is unfortunate that the south wall was rebuilt later in the 19th century, but interesting from an archaeological perspective, as excavation could contribute to this problem in the future. In the east wall is a blocked fireplace, but its external stack, uncovered during excavations, was clearly an addition to the building and so does not define its primary purpose (Fig 50).

Further changes were made to the east wall of the central range, although they cannot be related to the addition of the south wing and may therefore be later (Fig 47B). The large arch was infilled, the infill incorporating a smaller arched opening, possibly to allow control of the sluice for the waterwheel by means of a lever. In the centre of the wall a new opening was cut for the shaft of the waterwheel, subsequently also infilled.

There is some archaeological evidence that the waterwheel in wheelpit 1 remained in use after the engine was stopped. The large cast-iron pipe on the north-east side of the building is aligned directly towards wheelpit 1, and continues to a point above the position of the haystack boiler (Fig 50). The brick pier supporting the pipe could only have been built after the boiler had been removed. The pier also appears to be earlier than the wall of wheelpit 2 (discussed below).

Excavations on the south side of the south wing exposed vaulted cellars with brick paving outside of them (Fig 53). When they were built is not clear. The two bays of the cellar are aligned at different angles with a butt joint between them, suggesting they are not contemporary. However, they must both be dated within the broad range of 1753–1786 as they are not shown on Slaughter's plan but are mentioned in Young's survey of the latter date. Above the cellars the walls of a former cottage were revealed, the west wall being continuous with the front wall of the larger bay of the cellar (Fig 50). This was the building described in 1786 as 'Cellar and Laundry over', and in 1805 as 'Old Laundry, now a Tenement' (SRRC 1681/138/7). The laundry was presumably sited there to take advantage of the water in the brook, which must therefore have occurred before the brook was culverted. The internal dimensions of the single-unit dwelling were approximately 3.7m square, with a fireplace in the east wall, while the bay of the cellar beneath it is 4.15m by 3.25m.

The mill was in existence by 1838 and was installed in the former engine house (SRRC 1681/138/8). An opening, later converted to a window, was made in the north wall of the engine house which could have facilitated the removal of the power cylinder (Fig 50). The blowing cylinder was probably removed through the west wall of the engine house: The irregular butt joints beneath the original lunette suggest that the wall was knocked out here for removal of the machinery (Fig 45). This opening was then made into a doorway, with doorways above it in the upper storeys under segmental heads (Fig 45). In the north bay were also doorways in the upper storeys, possibly converted from earlier windows as they have wooden lintels instead of segmental heads.

On the east side of the building wheelpit 2 was visible before the excavations began (Fig 50). It has brick walls and floor, while the east wall was built around a pillar that carries a cast-iron pipe through which water was evidently fed to the wheel (Fig 54). A circular opening was made in the east wall for the wheel shaft (Fig 47B). The wheelpit is offset from the engine house wall in order that its tailrace is aligned to the side of the central range (see Fig 55). The wheelpit was built in the position of the former haystack boiler, the line of the brick boiler setting being partially visible in the wheelpit floor.

The interior of the engine house, with its engine bed and condenser pit, was obviously unsuitable for mill use. Internal excavation showed that the condenser pit was infilled and the engine bed was lowered, after which a new brick floor was laid on a layer of casting sand. An irregular opening was knocked through the bob wall, exposing the brick core, allowing access between the two bays of the building at ground-floor level (Fig 49A). In the south bay a fireplace was inserted across the angle between the bob wall and the east wall.

The upper floor levels of the original building were maintained and on the first floor a circular cut in the floor boards appeared to be related to the laying of a bed-stone, one of probably two pairs of stones in use at the mill. Half of one of the stones was uncovered during excavations on the west side of the building, where it had been used as the threshold of a doorway.

The remainder of the building was probably converted to a stables simultaneously with the conversion of the engine house. Although there is no direct evidence for this, the mill was producing feed for the works' horses and so there is a logical connection between them. The finery hearths had been removed and the west wall of the central range was partly rebuilt with new windows and doorway, as was the west wall of the south wing (Fig 45). Inside, a new brick floor was laid 0.72m above the earlier forge floor. A similar brick floor inside the south wing contained a drain consistent with its use as a stable. Within the central range a straw loft was added at the south end supported on a brick cross wall (removed at the beginning of the repairs project), and two openings were cut into the south wall at loft level for pitching straw into the wing below (Fig 47A). The original wide doorway in the south wall was infilled by this time, if not earlier, and a narrower doorway inserted in its place.

The openings in the east wall were blocked (Fig 47B) and wheelpit 1 was infilled by 1847, when the tithe map shows that a lean-to and privies had been added to the rear of the building (Fig 42). These had not been shown on the 1838 lease plan (Fig 5). The base of a brick water tank with rendered internal surfaces unearthed on the east side of the pit probably also belongs to this period (Fig 50). Later, the south wall of the south wing was rebuilt. The wall abuts the east and west walls and has several infilled openings, including two centrally-placed segmental arches between which is a brick buttress (Fig 43). The mill is said to have remained in use until *c* 1930 and to have been ruinous by 1938. Of later interventions, the floor was laid with concrete and a large doorway was cut into the central range wide enough for vehicular access (Fig 45).

Culverts

A complex system of brick-lined culverts was found on the east and south sides of the building (Fig 55). These document each phase of the extant Upper Forge, and also incorporate evidence most likely to have been associated with the old Upper Forge and the stamper mill shown on the site in 1753 by Slaughter (Figs 38 and 55).

Culvert I links wheelpits 1 and 2 and is aligned against the east wall of the central range. Culvert II crossed wheelpit 1 diagonally, linking I and VIII, and was constructed of white and red brick above the wheelpit floor. (It was removed after it had been recorded.) Culverts I and II are therefore clearly associated with wheelpit 2 and belong to the 19th century. The remainder are earlier and more complicated.

Culvert VIII, at 1.85m the widest of the watercourses, follows a diagonal course from wheelpit 1

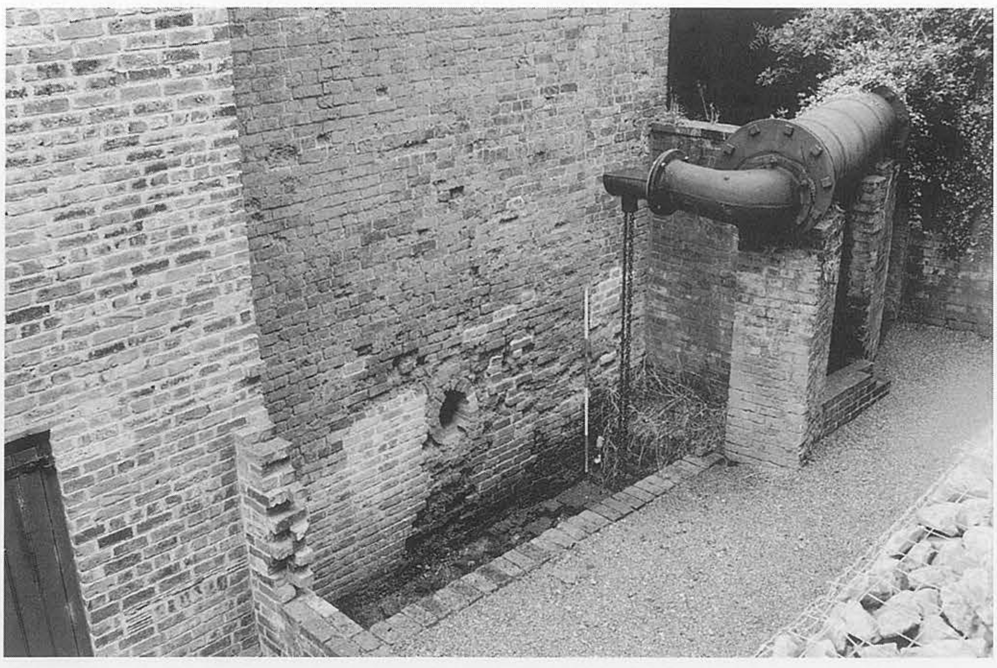


Figure 54 Wheelpit 2 and cast-iron pipe, photographed looking north west in 1998 after the completion of repairs. The opening for the waterwheel's axle is clearly visible. The direction of the pipe suggests it originally supplied the wheel in wheelpit 1. The brick piers supporting it are built above the former boiler base.

beneath the south wing, where it divides. The bricks in the floor of culvert VIII respect the line of the central range and not the direction of the culvert. Culvert III, separated from VIII by a butt joint and a step down in the floor, is directly aligned with the central range wall. Built into the floor are a series of timber cross members. It appears, therefore, that III originally ran adjacent to the central range wall and that VIII superseded it. When VIII was built the bricks in the floor followed the orientation of bricks in the earlier floor of III.

Culvert IV is a short section linking VIII and V, and was revealed only after a brick skin blocking it off from VIII was removed. Culvert V is beneath the south wing; it originally continued northwards and may still extend beneath the central range, but it is blocked with brickwork on the south side of the central range wall. Since culvert III is aligned exactly with the east wall of the central range, it is therefore probably later than V. In culvert V the floor and vault were found to have been cut away to insert IV. Culvert V is cut into VI, the south end of

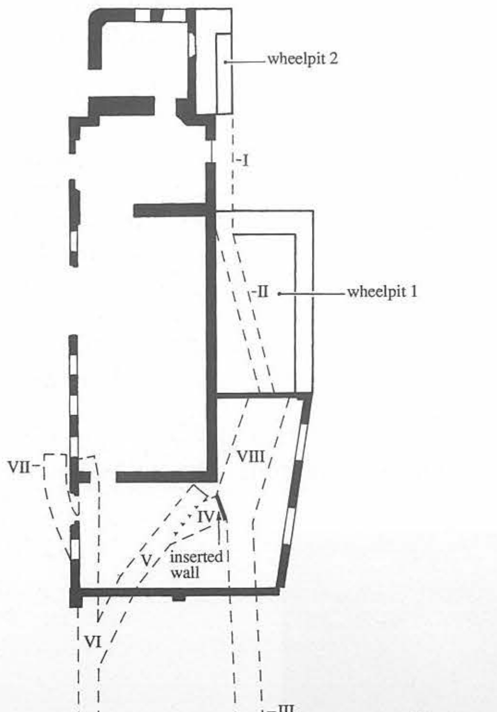


Figure 55 Plan of the culverts beneath the Upper Forge in relation to the extant wheelpits.

which was discovered, but the north end of which was blocked with silt. Culvert VI is cut by VII directly beneath the south wing, with an inserted cast-iron lintel to support the vault in VI. However, the floor of VII is lower than VI, the only fall from south to north in the whole system.

Culvert VI is the earliest and must be earlier than the extant building because it is located directly beneath the west wall of the central range. It evidently drained into the tail of the boring mill pool. Indeed at the south end of the culvert stepped brickwork was found which is considered to define the pool itself. It is also earlier than the central range because, although it was subsequently blocked, it originally continued beneath the south-west angle of the building.

Excluding VII, which cannot be fitted into the chronology, the sequence of culverts is: VI–V–III–IV–VIII–I–II.

Culverts VI, V, IV, II and perhaps VIII are all shown on the plan of the works made by Young in 1786 (Fig 39). However, VI and V predate the extant building. Culvert VI must either be a tailrace from the old Upper Forge, or possibly a by-pass channel from the Upper Forge pool to the boring mill pool. It may be the open channel shown on Slaughter's plan. Structurally there are two phases to the vaulting of the culvert, suggesting the watercourse may have been partly open at one time, but that it had been culverted before culvert V was cut into it.

The functional relationship between VI and VII is unclear. Although the floor is stepped, suggesting that water flowed from south to north, a later brick drain inserted into the north end of VII shows that it must in reality have flowed from north to south, however inefficiently. Possibly VII was built in 1776 to replace that part of VI which was directly beneath the central range wall, and which could have been exposed when foundations for the central range were dug. Culvert V was cut into VI, but its north end was blocked before the central range was built. It could have been related to the old Upper Forge, but was more likely related to the stamper mill mentioned by Slaughter and Wood in the 1750s, and on the foundations of which the central range was said to have been built in 1776 (Hyde 1973, 40; PRO C12/1693/97).

Originally, the central range had a waterwheel against the east wall, score marks from which are visible in the wall. Its tailrace survives in part as culvert III, which had a separate outfall into the boring mill pool and was not originally connected with the remaining culverts in the system. This was achieved when IV was cut between III and V, which might have been when VIII was inserted. Culvert VIII was built as the tailrace serving wheelpit 1 in 1785, and was made necessary when a new waterwheel was built away from the wall of the building.

The later phases are connected with the conversion to a mill. Wheelpit 2 and culvert I had been added by 1838 when the mill was in use. Two privies were uncovered against the south wall of the central range (Fig 50). One was directly above culvert I, the other above wheelpit 1. They are both shown on the 1847 tithe map (Fig 42). Culvert II was added when wheelpit 1 was infilled, possibly also by 1847. The blocking of the northern end of VI may have occurred in 1776 when the central range was built and the northern end of VII when the old Upper Forge ceased operation, possibly as early as 1821 when Joshua Field noted the absence of activity at Coalbrookdale (Hall 1927, 30).

Summary interpretation (Fig 56)

An Upper Forge was in existence by 1668, although only indirect evidence for this was found during the ground investigations, namely culverts VI and VII leading to the boring mill pool. Culvert VI is probably the open channel shown by Slaughter in 1753, which was culverted by 1776. As early as 1734 and as late as 1754 there was a stamper mill on the site of the extant building. Culvert V is probably the tailrace of its waterwheel and so far is the only archaeological evidence which can be assigned to the mill. The mill was engaged in producing shanks and parts for stamper heads for ore crushing in Cornwall. Of the smithy shown close to the stamper mill in 1753 no evidence has been found.

Phase I (1776–85): The extant building was erected in 1776 as a slitting mill. There is, however, no documentary evidence that the mill ever operated as such before it was converted for forge use *c* 1783 and no archaeological evidence has yet been found to contribute to this particular problem. Wright and Jesson's stamping and potting process for refining pig into wrought iron was patented in 1773 and was soon adopted at Coalbrookdale. The extant building was used initially to draw the iron into bars and was thus the last stage of the process which was carried out at the old Upper Forge. In this first phase the building comprised the central range, which had large openings in the west and south walls, and a brick floor. A waterwheel was built against the east wall, evidence for which is provided by abrasions on the wall of the building (Fig 48). The tailrace of this wheelpit is culvert III, which flowed into the boring mill pool (Fig 55). The wheel originally powered two banks of rollers with 20-feet diameter gear wheels, but was soon converted to work a forge hammer.

Phase II (1785–6): A blowing engine was added in 1785–6. The northernmost bay of the central range was raised in height; the original north wall was mostly demolished to be replaced by a thicker bob wall; and the engine was housed inside a completely new structure (Figs 45, 47B, and 50). The core of the engine bed and the corresponding wall of the condenser pit were uncovered during excavations in 1993. This structure confirms the indirect historical evidence that it was a Boulton and Watt engine with a separate condenser. The brick base of a haystack boiler was found on the east side of the engine house (Fig 50).

Concurrent with the installation of the blowing engine was at least one, but probably two, fineries on the west side of the building (Fig 50). The installation of a blowing engine also necessitated changes to the waterwheel of the original building, because the haystack boiler and its stack were built in the position of the original watercourse supplying the wheel. A new waterwheel was positioned away from the wall of the central range and was housed in a new pit, wheelpit 1. It powered a shingling hammer. The tailrace was formed by culvert VIII, which fed the water to culvert III and/or culvert IV (Fig 55). Therefore by 1786, when Young surveyed the site (Fig 39), the extant culvert system was already in place. A house over culvert VI and the laundry, with cellars beneath (Fig 53), had also been built by 1786.

Phase III (1786–1789): The south wing was added between 1786 and 1789. It might have been used for granulating and washing the iron, but Farington's sketch of 1789 shows two tall stacks in the south wall, suggesting blacksmiths' hearths or air furnaces (Fig 40).

The south wing was the final development of the 1780s, representing a substantial investment in stamping and potting. By 1785 the technique had already been introduced, but the erection of a blowing engine and fineries in that year was a considerable expansion in the scale of operations. The fineries at the new Upper Forge were the first phase of the process. The blooms were shingled into flat plates inside the building and were then granulated and washed. Although no evidence has been found for the granulating or washing of the iron, it is not clear how much, nor what form of evidence this would leave behind. The extant building operated in tandem with the old Upper Forge, where the 'potting' was carried out, which required the granulated iron to be heated inside clay pots in an air furnace, followed by drawing of the iron into bars. A Boulton and Watt forge engine at the old Upper Forge, erected in 1787, was stopped in 1793, but the descriptions of the works in 1801 and 1802–3, and the production figures for 1800–1, do not suggest a decline in output. The drawing into bars was probably done with a water-powered hammer in the old Upper Forge.

There are no direct references to the new Upper Forge as a working forge after 1803, but there is no reason to suppose that it was not working in 1815 when Thomas Butler made a vague reference to the forges, and when stamped iron was still made at Horsehay (Birch 1952, 232). By 1821 neither of the two Coalbrookdale blast furnaces was in blast, although Joshua Field noticed that 'a small forge or 2 is working', which may again refer to the extant

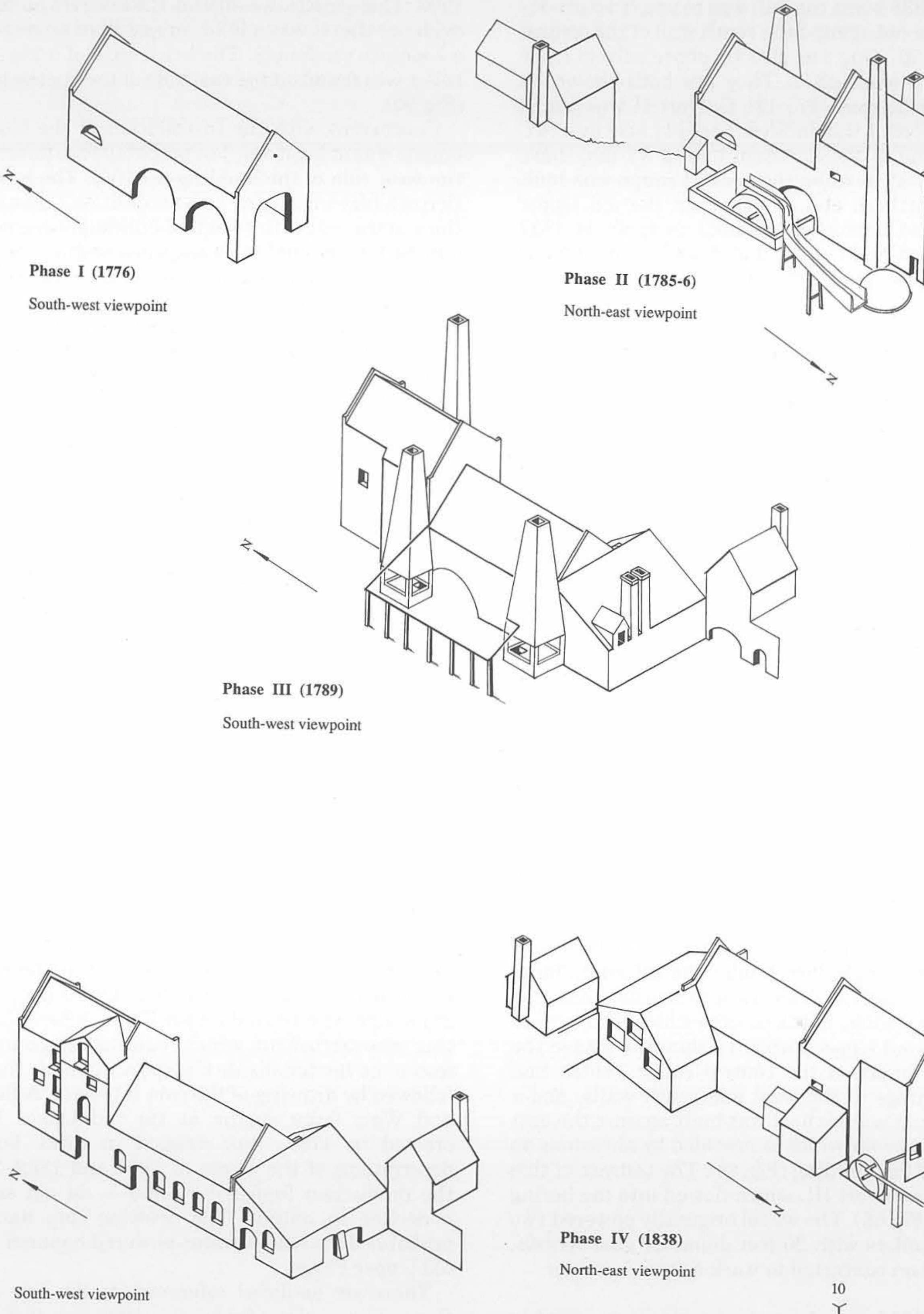


Figure 56 Reconstruction of the Upper Forge in phases I, II, III and IV.

building. By 1827 the old Upper Forge had been converted to a stables but, although the new Upper Forge was still referred to as a forge, it was not necessarily working. There is evidence, however, in the form of the cast-iron pipe which fed wheelpit 1, that some work continued at the Upper Forge after the boiler was removed and therefore after the blowing engine was stopped (Fig 50). No evidence has been found to suggest that the Upper Forge was ever converted to the more modern puddling process, but it might have been involved in what Butler implied was the specialist and limited production of stamped iron.

Phase IV (1827–38): By 1838 the new Upper Forge had been converted to a mill and stable. The mill ground feed for the works' horses, some of which were also stabled within the building. The engine was taken out (unless it had been removed when the boiler was taken out) and the engine house was converted to a mill. New doorways were built in the west wall for the raising and lowering of sacks (Fig 45); on the east side a waterwheel of approximately 3.0m diameter was housed in wheelpit 2, where the haystack boiler and stack had previously stood (Fig 47B). Inside the building, a new brick floor was laid above the core of the engine bed, although the original upper floor levels were maintained. The mill comprised at least one, but probably two pairs of stones.

The west walls of the central range and south wing were partly rebuilt with iron-framed windows and stable doors (Fig 45). In the east wall of the central range, the waterwheel in wheelpit 1 was removed and the opening from here into the building was infilled (Fig 47B). Before 1847 a lean-to and privies were added at the back of the building, necessitating the infilling of wheelpit 1 and the insertion of culvert II to drain water from wheelpit 2 to culvert VIII (Figs 50 and 55).

Inside, a loft was inserted in the central range for storing hay and straw, and two corresponding openings were cut into the south wall (Fig 47A). A new brick floor was laid above the earlier forge floor, with a tiled floor beneath the loft, perhaps indicating a harness room. Evidence for the use of the building as a stables was provided by a central gully in the brick floor of the south wing. The mill continued in use until at least the 1920s, but by the 1950s was in a poor condition (Fig 46). It was subsequently used for a variety of less than glamorous purposes – principally vehicle storage and offices – and in the 1970s the upper storey of the former mill was taken down (Fig 43).

4 Bedlam furnaces

Introduction

Bedlam furnaces is the only site covered in the present volume which can claim to have been previously 'written up' (Fig 57). It is the most ruinous looking of the surviving ironworking sites, but is prominently located near the River Severn and has attracted interest from historians since the late-19th century, initially in the work of the local historian John Randall. At the onset of the present project the definitive accounts of Bedlam were written following the restoration of the site in the 1970s and the discovery of important new documentary evidence (Smith 1979b, 1981).

Until 1971, when excavation began, the lower level of the site was partially buried by spoil and debris, and the structures were obscured by vegetation (Fig 58). Major repairs were undertaken in the period 1974–5 and between 1975 and 1979, to the extent that nearly half of the visible structure is modern (Fig 59). The excavations, undertaken by volunteers primarily to expose features for consolidation and display, were not conducted for archaeological research purposes. For example, south of the engine house two circular brick boiler bases were exposed but were not recorded before they were covered over again. Other observations were made of features which were not accessible in the present project. In a collapsed passage behind the blast furnaces a cast-iron blast main was found *in situ* and has apparently remained so. At the front of furnace I, iron plates survived around the tap hole, which led to a suggestion that the furnace was of the open-dam type.

Stuart Smith's interest in the site lay principally in the furnaces and their blowing arrangements. He argued that furnace I was built in 1757 and that the original furnace II was later 'taken down and moved east to accommodate a further tuyère' (Smith 1979b, 26). He also postulated the existence of a blowing engine on the east side of the site, an argument based on the discovery of a portfolio of drawings by George Potts of Norwich, made in the period 1798–1801. One of these drawings, dated 1800, is of a blowing engine at 'New Bedlam' (IGMT 1994.527). However, it has since been demonstrated that this

Figure 57 Bedlam furnaces photographed looking north from Waterloo Street in 1993, before repairs, showing the brick stack of furnace II on the right and the masonry encased furnace I on the left.

Figure 58 A void in the charging platform photographed looking west c *1972 before the site was restored. The north side of furnace I is to the left, with the west wall of the charging houses in the centre. The arched opening indicates the existence of a passage at the back of the furnace and into the wheel chamber. The roofless wheel chamber is in the background with only part of its vault surviving.*

engine was at Barnetts Leasow on the opposite bank of the Severn, for which detailed design drawings exist (B&W portfolio 681; Ince 1992, 88). Smith also argued that, subsequent to the cessation of smelting in the 1840s, furnace II was converted to a brick kiln, part of a Madeley Wood Company brickworks on the north side of the ironworks.

Subsequent archaeological work has been modest. In 1985, recording of the charging house walls and the infill inside them yielded evidence broadly in agreement with Smith's thesis, except that it was argued that furnace II was the earlier and that furnace I was a later addition, the reverse of Stuart Smith's argument (Higgins 1988a). In 1986 a wooden waggonway was discovered south-west of the site in a small excavation for the installation of a gas main (N W Jones 1987). With oak sleepers and rails, it was dated 1750–60 and is consistent with a plan of Bedlam made by George Perry before 1771 (Fig 60).

Documentary evidence

Bedlam was a colloquial name for the Madeley Wood ironworks, which operated under four periods of ownership as follows:

Madeley Wood Furnace Company 1757–1776
Dale Company 1776–1794
William Reynolds & Company 1794–1803
Madeley Wood Company 1803–1843

From the outset, Bedlam was part of an integrated mining and ironworking concern, one of a number of such concerns which emerged in the East Shropshire Coalfield in the 1750s. In 1756 Thomas Brooke obtained a 21 year lease to dig for coal in Madeley Wood, lay rails, and construct wharves on the River Severn (SRRC 1681/183/14). In the following year Henry Rainsford, Edmund Ford, and George Goodwin obtained a 21 year lease to dig ironstone and coal, and to erect an ironworks in Madeley Wood (*ibid*). Brooke then joined forces with Rainsford, Ford, and Goodwin, and set up a partnership of twelve equal shares in order to raise capital to develop the mines and railways, and build furnaces.

The agreement made in 1757 refers to work 'then begun'. In a chancery action against the Dale Company, dated September 1758, mention is made of the Madeley Wood ironworks having been erected 'about a year ago' and that it was to be completed 'this winter', suggesting that iron was not produced until 1759 (IGMT 1986.5331.4, f 207). By June 1760 two blast furnaces and an engine had been built (SRRC 1681/132/24).

A plan of the works was drawn by George Perry (British Museum K Top xxxvi 16-1). Its purpose is unknown, but it presumably shows the layout of the Bedlam works at some time between 1757 and his death in 1771 (Fig 60). A pair of blast furnaces is shown with a single casting house and two charging houses (labelled 'Bridgehouse'). The furnaces are blown by pairs of bellows on one side of each furnace. A 'Fire Engine', or Newcomen-type pumping engine, is supplied with steam by two boilers, and is used to pump water from the engine pit which appears to be an unroofed structure. The shaded areas adjacent to each boiler would appear to be stacks. The two 'Air Furnaces', 'Loam Houses', and 'Moulding Rooms' indicate that the works operated as a foundry. The furnaces also made pig iron for sale. In 1776 an agreement was made for the supply of 'grey melting Pig Iron of as good Quality as hath hitherto been

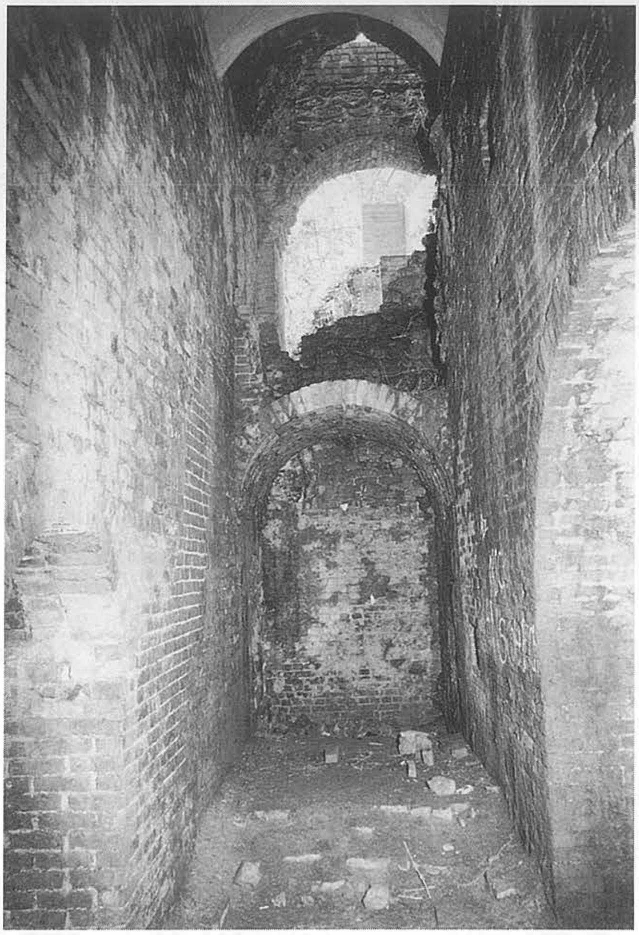


Figure 59 The wheel chamber photographed in 1993 before repairs were undertaken, looking west towards the engine pit. On the right is an opening where the waterwheel's bearing was fixed, while on the left is an opening to the bellows room. Above the lower of the arches in the background was a small reservoir feeding the water launders. The wheelpit is in the foreground, hidden beneath a later brick floor.

usually made at Madeley Wood Furnace' and 'such small Sized Pigs as hath been usually made there' (SRRC 1987/60/4).

The plan has some puzzling aspects. The bellows on the right (east) look too far away from the furnace and thus the position of its waterwheel is also odd. In addition, there is no indication of how the water was fed to this wheel, a problem which will surface again in the archaeological interpretation. A network of railways shows how the raw materials were brought to the works, the railway to the west being the one found during excavations in 1986.

In 1774 John Smitheman sold his share of the Manor of Madeley to Abraham Darby III of Coalbrookdale (Baugh 1985, 36). Darby also purchased Bedlam for the Dale Company in 1776 for £4600 (SRRC 1987/60/5). There are a number of documents associated with these purchases and herein a contradiction occurs in the description of the Bedlam works. Two undated notes of buildings belonging to the Madeley Wood Furnace Company could be associated with either sale. A 'List of buildings etc. at Madeley Wood' mentions 'Fire Engines' in the plural (SRRC 1987/60/1). The other list mentions two engines, although one of the lists could have been copied from the other (SRRC 1987/60/2). This second list appears to have been drawn up after the sale of the works in 1776 because it refers elsewhere to a stables and a house 'occupied by the old M Wood Co', but it is possibly related to the sale of the manor because elsewhere a parcel of land held by lease 'will be assigned to Abm Darby with the Freehold'.

Additions to the works not shown on Perry's plan included coal tar buildings and ovens, which are discussed below. The most interesting aspect of the lists, however, is the mention of two engines, given that only one was shown by Perry. In addition, in one of the lists a pool is mentioned on the site of John Jones' house, also shown on Perry's plan, while in the other list ground formerly in the occupation of Jones was used as coke hearths. However, there is a good case for questioning the existence of a second engine. Perry showed only one engine. The formal agreement conveying the Madeley Wood works to the Dale Company in 1776 lists only one engine (SRRC 1987/60/5). Five years later the Dale Company discussed the possibility of converting this one pumping engine to a direct blowing engine (B&W Letter book 5, f 175). All subsequent references, as will be shown, also refer to a single engine.

There is still the problem of the pool to resolve, although this might have had nothing to do with the supply to the waterwheels. Water was also used in the distillation of tar, in large enough quantities to demand a reservoir. Experiments with coke ovens were an attempt to find a more economical way of producing coke than the usual open heaps and tar was a by-product of this method. This was achieved by cooling the smoke from the smouldering coal, possibly by drawing the smoke through pipes suspended in a pool of water. This may explain the pool referred to above. Several alterations and/or repairs to the Madeley Wood ovens are recorded in Darby's personal ledger between 1777 and 1779 (IGMT 1993.3374, f 43), when the operations apparently ceased (Trinder 1981, 55).

The appearance of Bedlam in the later-18th century can be judged from a wash drawing by Edward Dayes (1763–1804), one of a number of works by the artist purchased by J M W Turner in 1833 (Fig 61). It is not dated but it was probably drawn before 1789 because it does not show the coke ovens discussed below and is in general agreement with Perry's plan (Fig 60). Viewed from the south-west, Perry's smith's shop and loam house are on the left of the picture, with the engine house next to it. The engine house has a chimney in its gable end. Perry shows this stack as one of a pair built in the angles of the engine house, but this is obscured in the Dayes drawing by the large chimney adjacent to the loam house. At the back of the engine house the engine

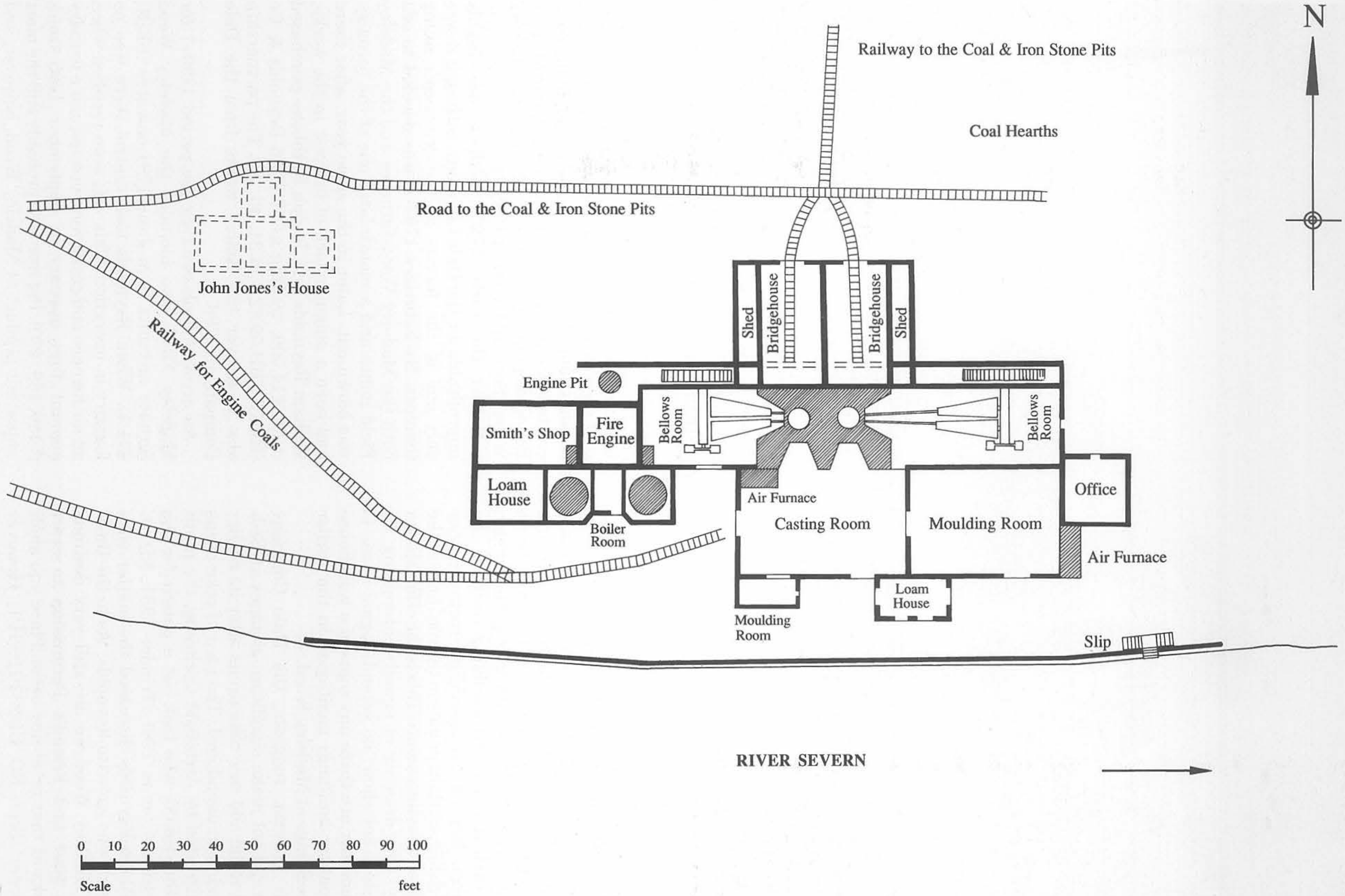


Figure 60 'A Plan of the Iron Works at Madeley Wood in Shropshire', surveyed by George Perry before 1771. (Tracing of the original map in the British Museum, K Top xxxvi 16/1.) The engine house with its shaded stacks, western wheelpit and bellows room, and the charging house (or 'Bridgehouse') walls have survived. Part of the wooden railway closest to the river, south-west of the smith's shop, was found in 1986.

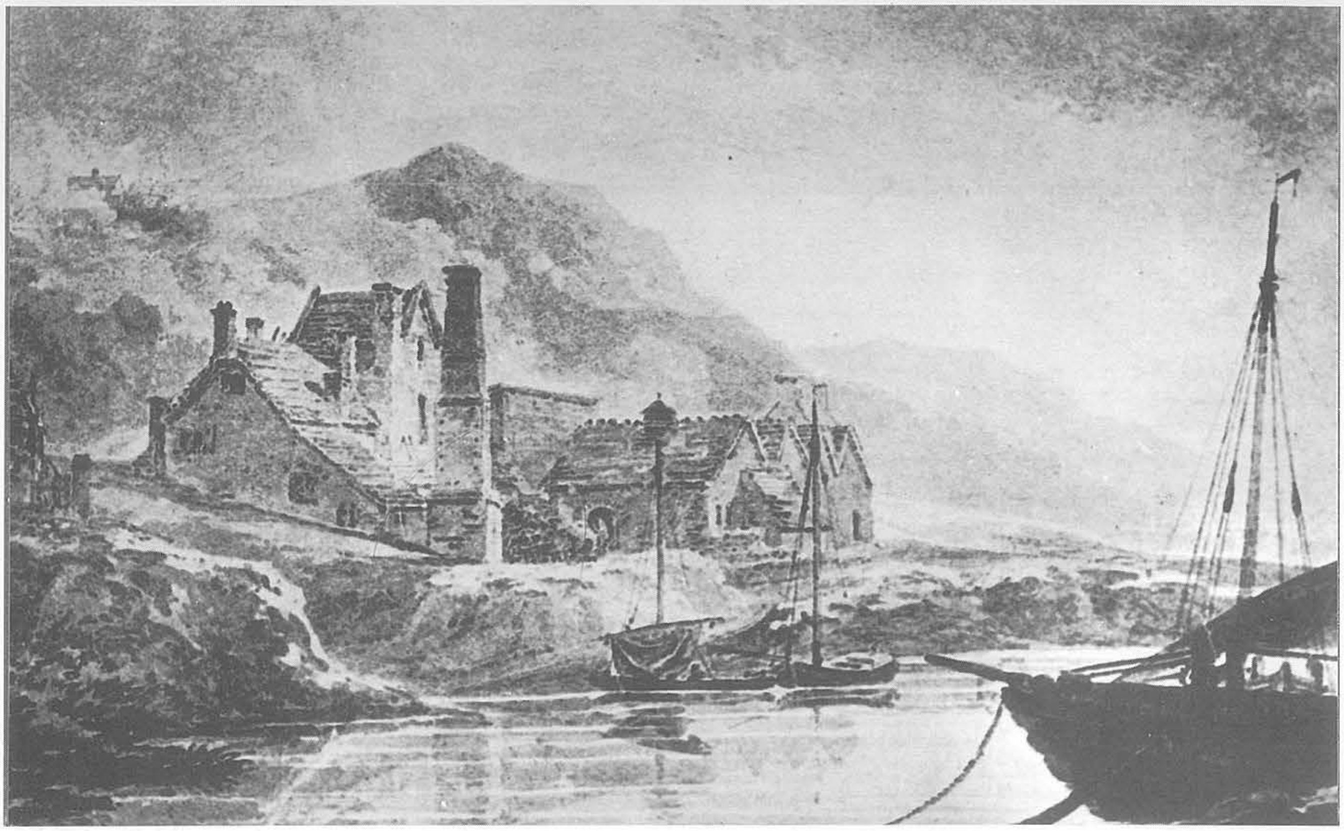


Figure 61 Wash drawing of Bedlam furnaces attributed to Edward Dayes. Undated but probably before 1789. The viewpoint is from the south west: on the left is the smithy with the taller engine house adjacent. The furnaces are to the right of the tall boiler stack; the four-span roof in front indicates the casting and moulding rooms, with the gable of the office at right angles beyond it. (Tate Gallery)

beam can be seen projecting from the building, indicating that the engine pit was not a roofed structure. Adjacent to the engine house is the furnace structure, presumably housing both furnaces in a stone outer casing. The building at the front has a ridge and furrow roof line with four gables, which are the casting room and moulding room on the Perry plan. Beyond the moulding room another gable is visible, at right angles to the roof lines of the moulding and casting rooms. This is the office shown by Perry. The drawing is equally interesting for what it does not show: no second engine house is visible, and nor are there any signs of a warehouse or the coal tar buildings mentioned in the earlier lists of buildings at Madeley Wood.

As the drawing suggests, the Dale Company probably did not make significant changes at Bedlam, but it did add new coke ovens after its earlier ovens had been abandoned. The idea of coke ovens was resurrected by Archibald Cochrane, the ninth Earl of Dundonald, who took out a patent for the manufacture of tar in 1781 (Trinder 1981, 55). In 1787 William Reynolds discussed the matter with Dundonald, who wrote to Reynolds: 'As to the Business at Madeley Wood we are still very desirous to have your and Friend's Permission to erect Tar Works at that or at any other Place you shall think proper' (Scots RO, GD233/109/H/1). However Reynolds' partner, William Rathbone, had refused to grant a building lease, one of the reasons being that the ovens might be objected to by neighbouring tenants (*ibid*). It appears that ovens had finally been erected by early 1789, as Dundonald again wrote to Reynolds enquiring of 'the Cokes made at Madeley Wood' (Scots RO, GD233/109/H/4).

During the early 1790s Bedlam was highly unprofitable for the Dale Company, although it was only one of the factors in the company's ailing finances. By February 1794 it was decided to sell both the Madeley Wood furnaces and the Madeley Field mines and a month later one of the furnaces was blown out. Later in the same year, after there had been a singular lack of interest in the works, William Reynolds and Joseph Rathbone purchased it for £14,000, trading as William Reynolds & Co (IGMT CBD.59.82.3, ff 31, 40, 73). The partnership also took over the Ketley works from the Dale Company in 1796.

An account book covering the period 1790–7 for Madeley Field also includes the Madeley Wood furnace accounts from June 1794 onwards (SRRC 271/1). When Reynolds took control there was no foundry in operation. This was soon rectified when an air furnace and crane were erected and a foundry account first appears in September 1795 (*ibid*, ff 156, 159, 170). Pig iron was probably still the most important product at Madeley Wood, however, and on which its reputation chiefly rested. For example in 1798 William Reynolds charged Boulton and Watt 10 shillings per ton more for Madeley Wood than for Ketley pig iron (B&W 3/10/25). A description of Coalbrookdale made *c* 1801 also refers to the high quality of Madeley Wood iron: 'The cast iron made here is of a superior quality to any other in the nation for melting into goods particularly for the Birmingham manufactory of small wares' (Trinder 1979, 14).

In 1796 Reynolds was also preparing to bring the 'lower furnace' back into blast although when it was blown-in is not known (SRRC 271/1, ff 181, 183). In the national survey of 1796, William Reynolds listed only one blast furnace at Madeley Wood (Riden and Owen 1995, 45). The production figures in the account book to 1797 do not help because there is no sudden rise in output at the works which would suggest that two furnaces were in blast, as they certainly were by 1801 (SRRC 271/1; Cossons 1972, 172).

In 1802–3 Bedlam was visited by the Swedish metallurgist Eric Svedenstierna, who wrote:

> Exactly opposite to Broseley, below the iron bridge, lay two blast furnaces and a remelting furnace, which belonged to a Mr Raynolds [sic]. A cylinder blower of 7 feet diameter provided the air for both blast furnaces, and had a regulator which consisted of a cylinder inverted in water, into which the air came close to the floor, and went through an opening set opposite into the blast furnaces. The water, which, before the blast commenced, stood all the time at a given height in the cylinder, served here as the counterweight, and worked in the same way as the movable lid on an upright cylinder, as is generally used in England to regulate the blast. (Flinn 1973, 70)

The most significant evidence provided by this account is that both furnaces were blown from a single cylinder, replacing the earlier bellows. In theory this cylinder could have been powered by a blowing engine or a waterwheel. However, no evidence has emerged for the installation of a blowing engine at Bedlam during this period. Only a single engine is mentioned in the accounts for Madeley Wood between 1794 and 1797 and although it is therein referred to as a blast engine it was evidently still used for pumping water as it was periodically necessary to clear the culvert between the river and the engine pit (SRRC 271/1, f 171). Even if the blowing cylinder was water-powered, one of the waterwheels shown by Perry would have been disused by this time, probably the eastern waterwheel given that it was further away from the engine pit.

There are two important sources for reconstructing the appearance of Bedlam in the early-19th century. One is pictorial; the other is a lease plan (IGMT 1970.66.5). The plan has previously been dated 1840 because it belonged to a bundle of documents which included an 1840 lease of Bedlam. However, it was clearly surveyed for an earlier lease (Fig 62). On the north-west side of the works is Bedlam Hall, a 17th-century coalmaster's house let to Elizabeth Cox and the late William Reynolds. The house had certainly been demolished by 1839 when a gas works was erected on the site (Bagshaw 1851, 569). It must

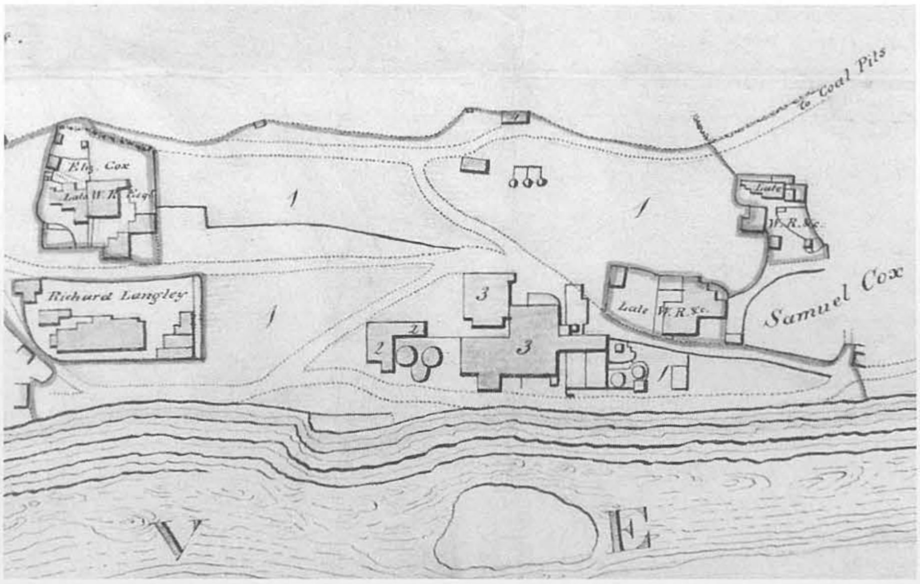


Figure 62 Detail of a lease plan showing Bedlam and its surroundings, undated but probably surveyed in the early-19th century. North is at the top of the picture. It shows the engine house and smithy (2) with adjacent round boilers, and the furnaces with attached foundry buildings and charging houses (3). On the east side are two round coking ovens with attached square stacks (1); further coke hearths are north and west of the works (1). Around the site are workers cottages, but outside the area of the works lease. To the north-west is Bedlam Hall, which is let to Elizabeth Cox and William Reynolds. (Ironbridge Gorge Museum Trust)

also be earlier than 1828, by which time one of the cottages west of the furnace was let to Benjamin Bennet, not Richard Langley as denoted on the plan (Pigot 1828, 675). The plan may have been drawn in 1816 when Joseph Reynolds inherited the manor, since he is named on the map as lord of the manor. However, it might well have been copied from an earlier survey: A later lease of 1858 shows exactly the same configuration of buildings at the works, even though the accompanying schedule makes clear that they had been mostly demolished by that time (SRRC 1681/184/2). The configuration of buildings on the site suggests that no more than two furnaces could have existed at the site at that time, which places the survey before the addition of a third furnace in the period 1806–10 (see below).

The plan agrees tolerably well with Perry's plan, even if the surveyors disagreed in their measurements, and a key identifies the main features (Figs 60 and 62). The lease plan shows the same L-shaped block containing the smith's shop and engine house (2), which is supplied with steam by two round boilers. The block containing the furnaces and the charging, blowing, and casting houses (3), is of a similar extent and plan to the Perry survey, except that the office appears to have been extended, perhaps as a warehouse. A warehouse is mentioned at Madeley Wood in the 1770s (SRRC 1987/60/1 and 2), and one was still in use in 1803 (Staffs RO D876/155, f 41). On the north side of this is a square feature, possibly a stack, which might reflect the rebuilding of the foundry by William Reynolds. On the east side of the site are two circular coke ovens (1) with associated stacks, presumably those erected in 1789. The main coke hearths, however, are to be found on the north and west sides of the works.

The plan is obviously important for locating Lord Dundonald's coke ovens, and also provides evidence regarding the engine. The engine was almost certainly still used for pumping water, as the engine house is no larger than that shown by Perry and did not have the elongated rectangular plan form characteristic of a beam blowing engine. The engine pit is not denoted on the plan, but that is not significant: Another part of the same plan, showing the pumping engine at the Lloyds, again shows the engine house and boilers, but not the pump shaft. Power for the blowing cylinder described by Svedenstierna therefore appears to have come from a waterwheel.

Of the pictorial evidence for Bedlam in the early-19th century, it is only necessary to discuss the painting by Paul Sandby Munn for the purposes of the archaeological interpretation (Fig 63). The other images will be considered later in discussions of contemporary portrayals of industrial scenes and the relationship between pictorial evidence and archaeological interpretation (see Chapters 10 and 11). Munn's painting was made in 1802 and views

Figure 63 'Bedlam Furnace, Madeley Dale, Shropshire' by Paul Sandby Munn, 1803. Bedlam Hall is on the left. The ironworks is in the middle distance, denoted by the two stacks, with the taller stack of the coke ovens behind. No charging houses are shown, contradicting the archaeological evidence. (Ironbridge Gorge Museum Trust) the site from the west side. On the left of the picture is Bedlam Hall, in the right foreground the cottages shown on the lease plan let to Richard Langley. Behind the cottages are the two stacks of the engine house and in the background is a tall stack associated with the Dundonald coke ovens. To this extent it agrees tolerably well with the lease plan, but it will be argued later that asking more of a work such as this is stretching the evidence too far. What both the lease plan and Munn suggest is that the original works of the 1750s survived largely unaltered to the early-19th century, whereas previous archaeological interpretations have argued for substantial changes by this time (Smith 1979b; Higgins 1988a).

William Reynolds died in 1803. His nephew, William Anstice, now assumed the control of the works and a new Madeley Wood Company was formed (Staffs RO D876/155, ff 1, 43). The foundry closed immediately, one of its last pieces of work being a waterwheel destined for a mill in Shrewsbury (*ibid*, f 66). There is no evidence to suggest that Anstice made any immediate significant additions at the works, although there are references to the purchase of bricks from the Coalport brickworks in 1806 and 1808 (*ibid*, ff 134, 135). According to Gilbert Gilpin, of the Old Park ironworks in Shropshire, only one of the Madeley Wood furnaces was in blast in May 1804 and the weekly make was 28 tons (SRRC 1781/6/28). In 1806 both furnaces were again in blast (B&W MII/15/2) and within four years a new furnace had been built (Riden and Owen 1995, 45). The precise date of the third furnace is unknown, although it may have been erected 1808–9 when large losses appear in the accounts (Staffs RO D876/155, ff 158–9). A fourth furnace is mentioned in a survey of 1813, which may be an error, as all subsequent references record three furnaces (Riden and Owen 1995, 45). Unfortunately no cartographic evidence has been found for this crucial period of expansion at Bedlam.

By 1815 the iron trade was secondary to coal for the Madeley Wood Company, in spite of the high price that the Madeley Wood iron commanded. When the Yorkshire ironmaster Thomas Butler visited Shropshire in 1815, two of three furnaces were in blast: 'The furnaces are not so large generally 32 to 36 feet high and 10 to 11½ feet wide and some have been 12 feet in diameter. One furnace in which they make the common melting and forge pig blown on both sides with two holes, generally about 2 inches each' (Birch 1952, 232).

Neither of the furnaces shown by Perry could have been blown on two sides because they stood too close together. If one of them had been rebuilt in a different position that would have allowed two of the furnaces to be blown from two sides. If Butler's description that only one furnace was blown on two sides is accepted, then this furnace was probably the new furnace built after 1806. It also implies that the two 1750s furnaces were still in blast in 1815 and were blown on one side, a problem that archaeology is well placed to solve. There is an undated and unattributed watercolour that may show Butler's third furnace. It is a view of both the Barnetts Leasow and Bedlam works, from a south-easterly viewpoint (Fig 64). Although not dated, it must be before 1830, the latest date that Barnetts Leasow is known to have been working (Riden and Owen 1995, 38), and after the demolition of Bedlam Hall. Bedlam is necessarily in the distance, but the watercolour appears to show two blast furnaces, one of which has a distinctive bottle-shaped stack (as does the Barnetts Leasow furnace). To the right (east) of it is what appears to be a furnace encased in a masonry insulating core. The walls of this core are battered and have a series of arched openings, similar in appearance to the blast furnace at Moira in Leicestershire built in 1806 (Cranstone 1985).

In 1817 all three furnaces were idle during the depression in the iron trade which followed the end of the war with France in 1815 (Elsas 1960, 3). When the price of iron fell so low that it was not profitable to make it, many Shropshire ironmasters simply stopped their furnaces rather than accumulate a large stockpile (Trinder 1981, 137–8). The market price recovered slightly in 1818–19 and in 1821 Joshua Field saw Bedlam with two furnaces in blast (Hall 1927, 31). Subsequent surveys of the industry record three furnaces at Bedlam (Riden and Owen 1995, 45), but it is doubtful whether they were all simultaneously in blast following the depression in 1817. In 1825 only two of the furnaces were in blast and the yearly output was estimated at 4160 tons, a suspiciously high figure given the evidence of actual recorded output in subsequent years (B&W MII/17/2). A reliable and consistent set of production figures exists from 1826 onwards and suggests a gradual decline of the works, no doubt partly influenced by the building of new furnaces at Blists Hill in 1832 and 1840 (Staffs RO D876/ADD/3/1). In 1826 the Bedlam furnaces produced only 2867 tons of pig iron, rising to 3853 tons in 1831, which probably denotes two furnaces. This is the highest recorded output figure for Bedlam, but a year later it fell to 3303 tons even though the figure included the make at the new Blists Hill furnace. Output rose steadily throughout the 1830s to 7766 tons in 1839. This would suggest that two furnaces remained in blast at Bedlam until the end of the 1830s.

From 1826 onwards Bedlam had a single 'blast engine', which was fitted with a new cylinder in 1832 and a new boiler in 1835 (*ibid*, ff 70, 100). The last furnace at Bedlam was blown out in 1843 (Riden and Owen 1995, 45). The engine probably continued pumping water to the end, as direct historical evidence for a blowing engine is nil. There is also circumstantial evidence for the continued use of a waterwheel. In 1880 John Randall described the ruins at Bedlam: 'The race in which the old wheel worked is still observable, as also are the arches which supported the reservoir into which water was pumped from the Severn' (Randall 1880, 179). The

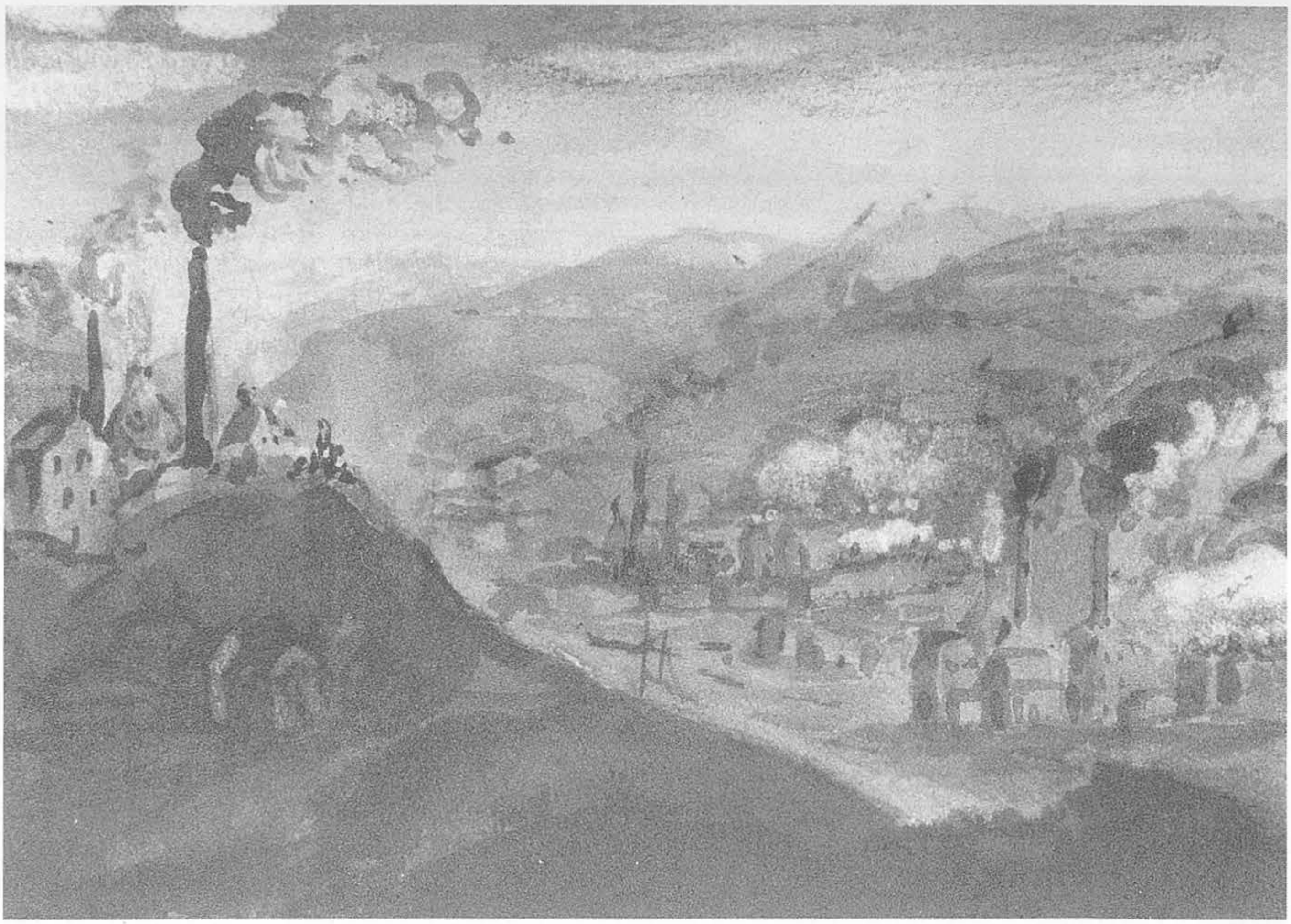


Figure 64 'Barnetts lizzar and Bedlam Furnaces near the River Severn'. Undated and unattributed. Bedlam is in the distance to the right, with at least two furnaces and the coke hearths behind. Bedlam Hall is not shown and may have been demolished. Barnetts Leasow is on the left. Note the furnaces shaped like pottery kilns at both works. (Private collection)

fact that Randall was able to describe the water power system at Bedlam suggests that until its closure, the blast was provided from a waterwheel, which was supplied from a pumping engine.

The 1840s saw the establishment of a brickworks in Madeley Wood, the documentary evidence for which will be considered here because an argument that one of the furnaces at Bedlam was converted for use as a brick kiln has become common currency (Smith 1979b, 24; Clark 1993, 69; Alfrey and Clark 1993, 52, 108). This possible reuse has to be seen in conjunction with the ruination and/or dismantling of the ironworks. In 1841 a lease for digging fireclay was obtained and the manufacture of firebricks must have started in that year, for a 'White Brick-work' is mentioned in the accounts as having made a profit over three months to July 1841 (IGMT 1970.66.3; Staffs RO D876/ADD/3/1, f 172).

Both Bedlam furnaces and the brickworks are depicted on the tithe map of Madeley parish, dated 1847, where Bedlam is described as 'Brick & Tile Works, Ruins of Old Furnaces & Waste at Bedlam' (SRRC 2280/2/45). The brick and tile works is shown as a substantial group of structures, with what appear to be three circular kilns at the western end (Fig 65). The plan implies that the 'Brick and Tile Works' and 'Bedlam Furnaces' are distinct entities. One of the furnaces at Bedlam is depicted in a solid rather than a broken line and has a rectangular structure on the side of it that looks like a bridge for charging a blast furnace. The remainder of the ironworks, however, had been mostly demolished. The smith's shop, casting shed, charging houses, coke ovens, and other associated buildings shown on the early 19th-century lease plan have all gone. This is confirmed in a lease of 1858 where the works was described as 'lately taken down' (SRRC 1681/184/2). The third furnace is not shown

The brickworks closed in 1889 when the veins of nearby fireclay had been exhausted (SRRC 1681/184/6). If a brick kiln or kilns had been built at the Bedlam works, then Randall did not mention it in 1880 when he implied the site was ruinous. In 1908 Randall again described the site with no hint that a kiln had been built here: 'The massive arches and other portions of the dismantled buildings remain, whilst the funnels which formerly belched forth smoke and flame, illuminating the district for miles,

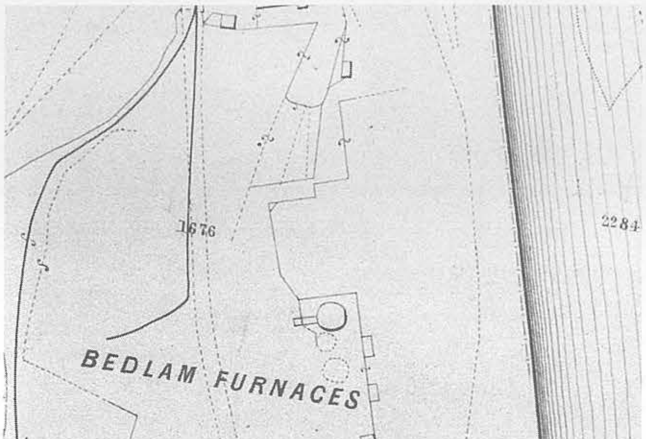


Figure 65 Detail of Bedlam furnaces and brickworks from the Madeley tithe map, 1847. North is to the left of the picture. Plot 1676 is described as 'Brick & Tile Works, Ruins of Old Furnaces & Waste at Bedlam'. Only two furnaces are shown, one represented by a dashed circle, the other a solid line with a bridge to it, and with the dashed tuyère chamber between them. The engine house and engine pit stand on the west side but the other structures had mostly been demolished. A wall is shown leading from the cottage west of the works and continuing to the north-west corner of the engine pit. This was not shown in the earlier lease plan (see Fig 62). (Shropshire Records and Research Centre)

stand like the keep and towers of some old feudal fortress' (Randall 1908, 471).

The first edition Ordnance Survey of 1883 shows two blast furnaces (Fig 66), one of which is on the eastern side of the site and does not appear on the tithe map (Fig 65). It can hardly have been a kiln, being far too small and in an awkward location at the bottom of a slope with rough ground in front of it. This must be the elusive third furnace which was mysteriously omitted from the tithe map.

After 1889, the site must be considered to have been abandoned for industrial purposes. An early 20th-century photograph shows a helter-skelter and a big wheel in front of the furnaces, one of which looks, at least superficially, like a kiln, while behind are buildings of the former brickworks (Fig 67). In 1929 the site was described as 'a derelict pile of buildings, now in course of demolition', during which time, in an apparently unrelated incident, a trespasser was killed by a fall of debris (*Shrewsbury Chronicle* 27/12/1929, 7). Between 1900 and the early 1970s there was a build up of soil, spoil, and rubble over the site.

The site

The remains of Bedlam furnaces are set back from the north bank of the River Severn and stand against a steep bank. The structures are in a ruinous condition with substantial areas of modern restoration (Fig 68). The site existed and still exists on two levels: an upper level for charging the furnaces and a lower level for tapping them. The extant structures are mostly of brick, with some masonry. The centrepiece of the site are furnaces I and II, separated by an open tuyère chamber (Figs 69 and 70). At the west end is an engine house with the engine pit behind it. The engine pit connects with the wheel chamber which in turn has an opening into the bellows room. Between the bellows room and engine house are vaulted passages in a cruciform plan. On the north side of the furnaces, at the upper level, are the walls of the former charging houses. Rubble-stone retaining walls are on the east side of the site.

Some perspective on the original topography of the site was provided by borehole investigations undertaken in 1993 (Fig 71). A useful if not infallible device, borehole evidence at Bedlam can be interpreted in conjunction with Perry's plan and the drawing by Edward Dayes (Figs 60 and 61). The important point to consider is whether the works was built against a steep natural bank, thereby utilising the natural topography to create charging and tapping levels, or whether it was built on a sloping hillside.

The boreholes, drilled on the north and north-west sides of the site (A, B, and C in Fig 71), showed that the natural is considerably lower than the present ground level. Natural was encountered on the north side of the site, beyond the limit of the charging houses, 8m below the present ground level, with brick rubble at a depth of 5.5m (A in Fig 71). This justifies an argument that the site was built on a slope rather than against a bank. Perry's plan also suggests a gradient far less steep than it presently is. The railways on the west side of the works ascend

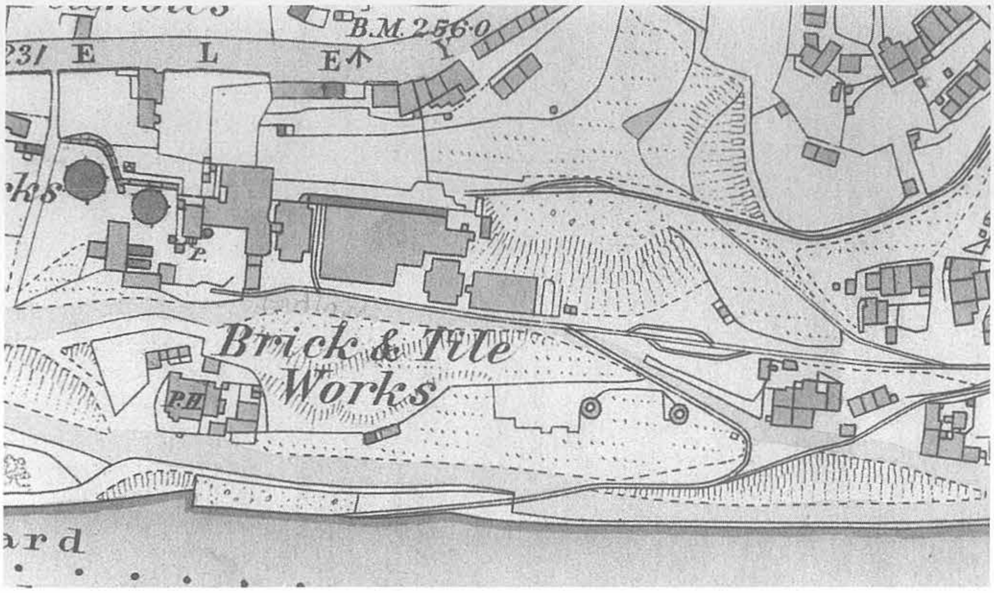


Figure 66 Detail of Bedlam from the Ordnance Survey, 1883. The map shows two shaded furnaces, one of which is on the east side of the site and was not shown on the tithe map and may be the otherwise elusive third furnace. The other blast furnace is within the main block of the works that includes the engine house.

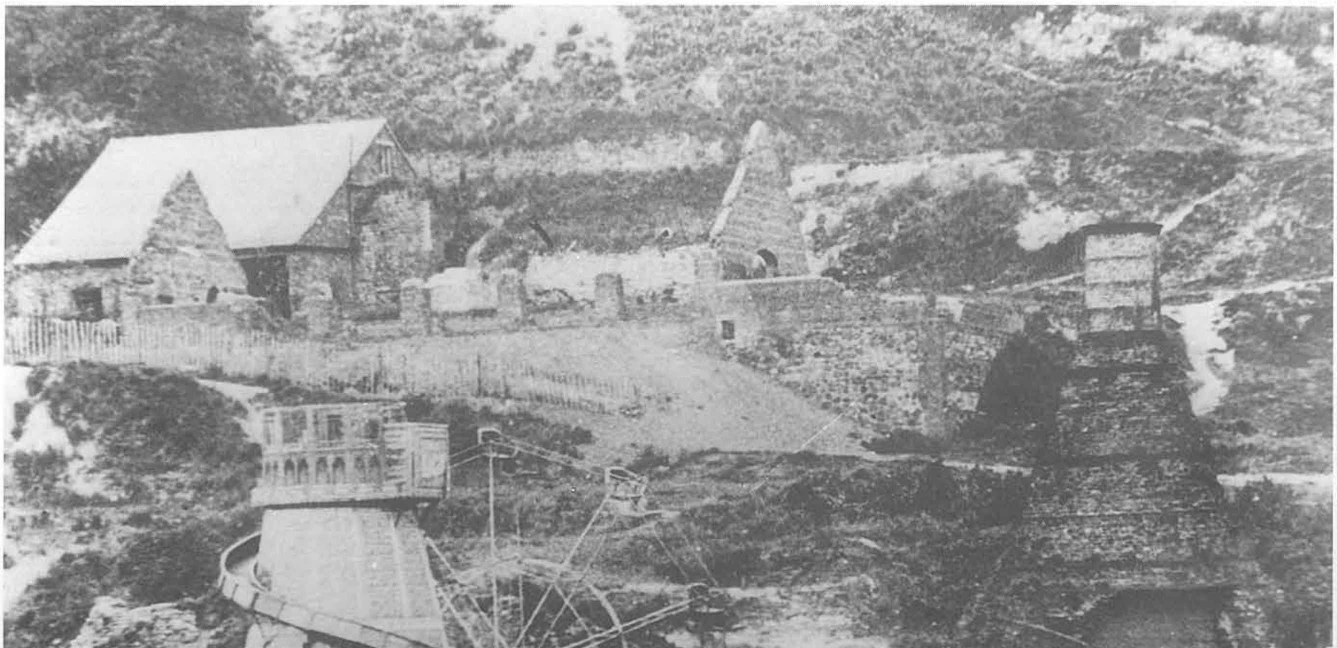


Figure 67 Bedlam photographed 1900–10, looking north from the opposite bank of the river, while it was the site of a temporary fairground, and with ruined brickworks buildings in the background. The masonry encased furnace I is in the centre of the picture, the tall brick stack of furnace II to the right. (Ironbridge Gorge Museum Trust)

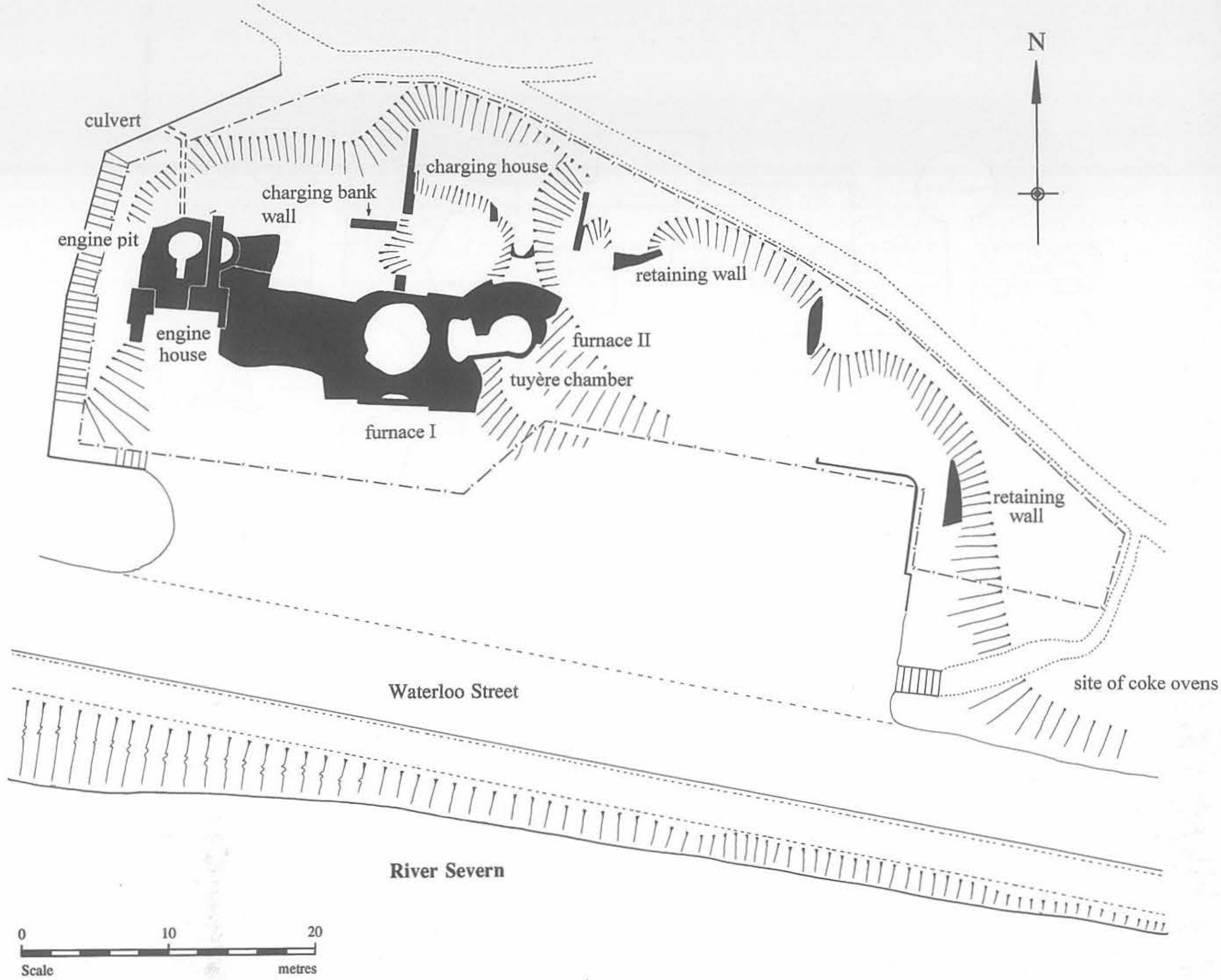


Figure 68 Bedlam site plan. Neither blast furnace, nor the charging houses behind them, survives to its original full height, but the path on the north side of the site is shown on the early 19th-century lease plan (see Fig 62).

the hillside from the river without the aid of inclined planes, while Perry shows the engine pit with only a wall on the north side but not the west side, surely an impossibility if the terrain was as steep as it presently is. In Edward Dayes' drawing there is a bank in front of the smith's shop which may well have been the natural profile of the site, suggesting that the site was partly levelled to build the works. The engine beam can be seen protruding from the building with no hint of a wall around the engine pit as high as it presently is. In summary, therefore, there is ample evidence that the present topography of the site differs significantly from its profile in 1757, which constituted a sloping hillside with the buildings cut into it.

Historical evidence suggests that the original works was little altered until the early-19th century, approximately half the working life of Bedlam. Several structures can be assigned to the original phase of the works by reference to Perry and Dayes (Figs 60 and 61). These are the engine house, wheel chamber, cross passages, bellows room, and the charging houses. A structural interrelationship demonstrates that the above structures are contemporary, with the exception of the charging houses, which cannot be physically linked with the other structures. The brick charging house walls are considered to belong to the first phase for two reasons. Firstly, two charging houses are shown by Perry. Secondly, the lower section of the west wall is of hand-moulded brick in a buff-coloured mortar, as are the central and east walls, similar to the other original structures.

It is worth comparing in more detail Perry's plan with the archaeological evidence for the first phase (Figs 60 and 69). Perry shows the engine house and bellows room with a common dividing wall and a chimney stack, which is still extant and is integral with the engine house. He does not, however, show the cross passages, although there can be no disputing their integrity with the bellows room, engine house, and wheel chamber. Similarly the plan does

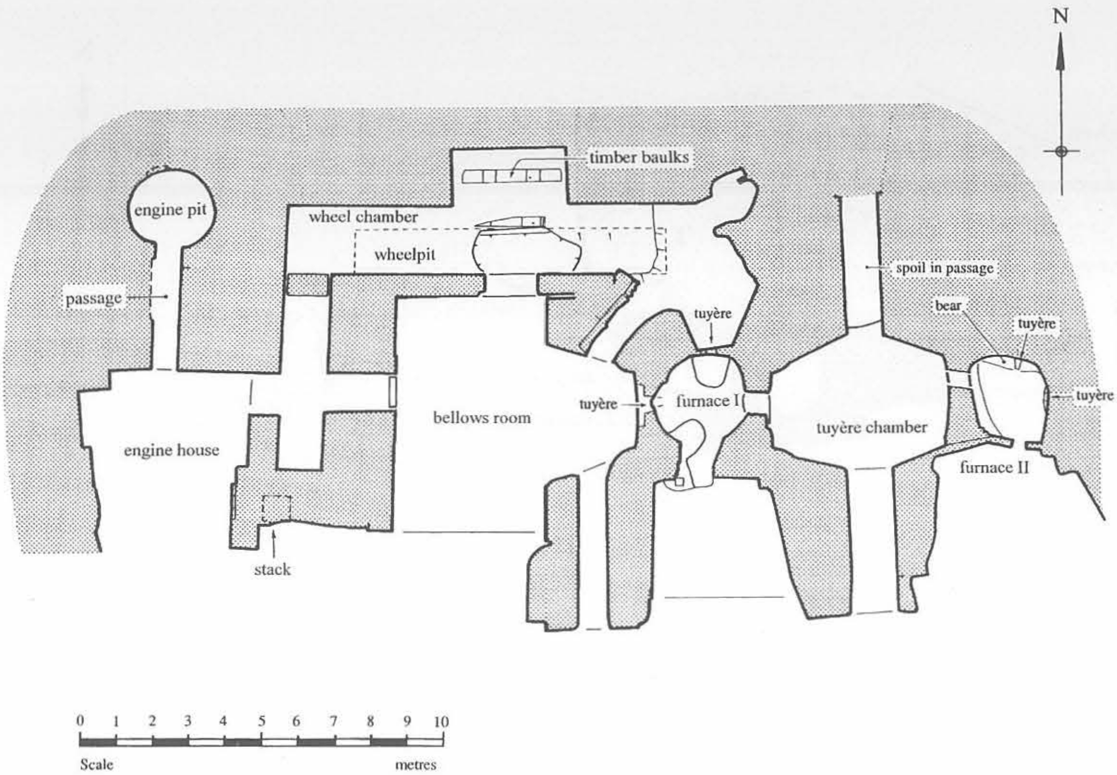


Figure 69 Bedlam lower ground plan.

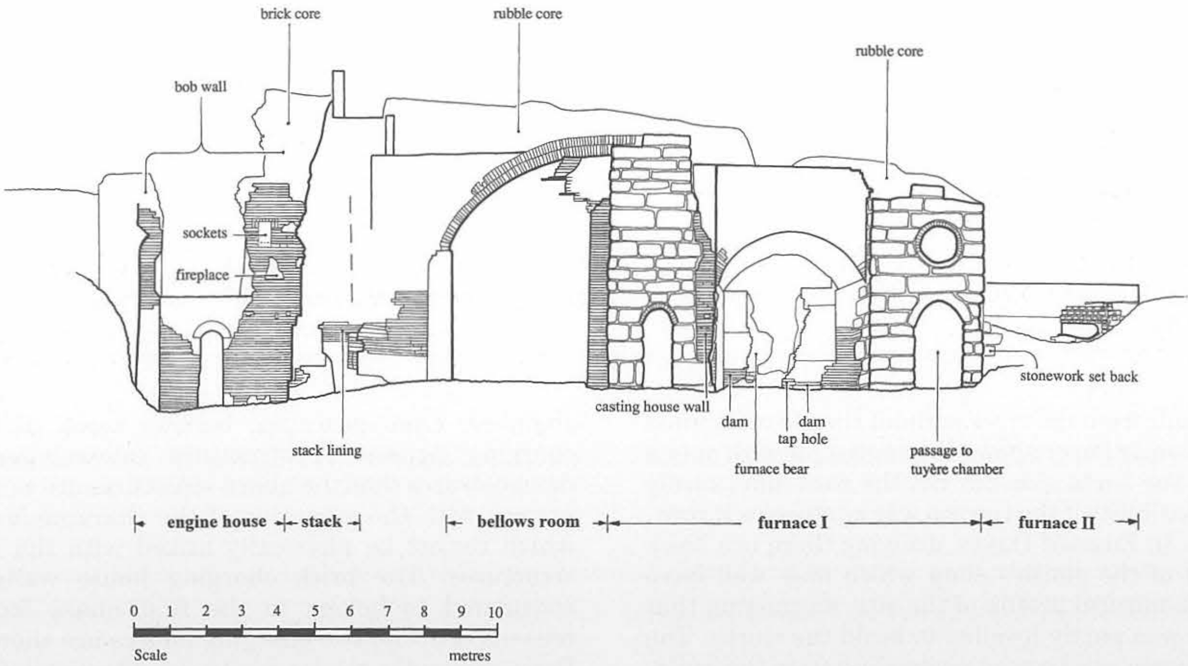


Figure 70 The south elevation of the furnaces, bellows room, and engine house.

not show the vaulted recess on the north side of the wheel chamber, although it is clearly integral. Perry shows the engine pit in line with the wheel chamber, as logic would dictate. The present engine pit is noticeably out of alignment with it and will be shown to be later.

The position of furnace I, butted by the west charging house wall (Fig 68), demonstrates that it cannot belong to the earliest phase as Stuart Smith had suggested. Logically the two furnaces should have been spanned by the charging house walls, as shown by Perry (Fig 60). Furthermore, the opening between the wheel chamber and bellows room defines the position of the waterwheel's axle tree (Fig 69). From the axle tree the top boards of the bellows were depressed by means of cams. Contemporary accounts of blast furnace bellows suggest that the Bedlam bellows would have been at least

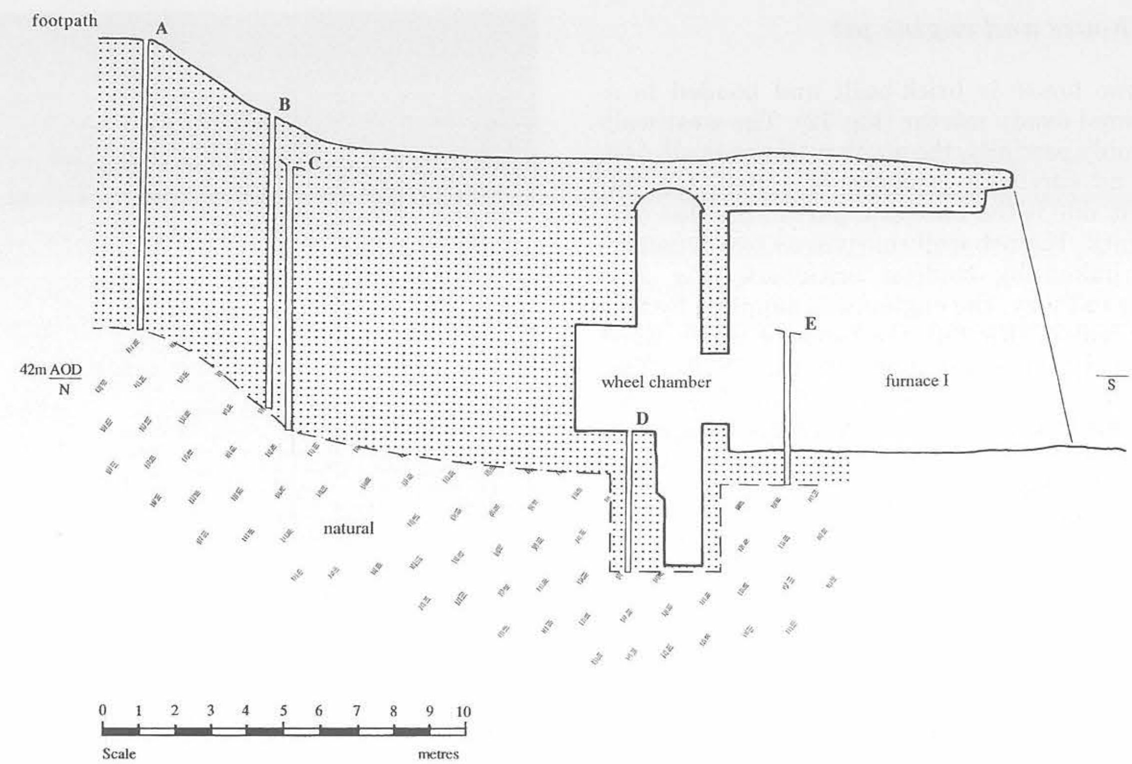


Figure 71 Cross-section through the site showing the level of natural ground, as revealed by the borehole investigations in 1992.

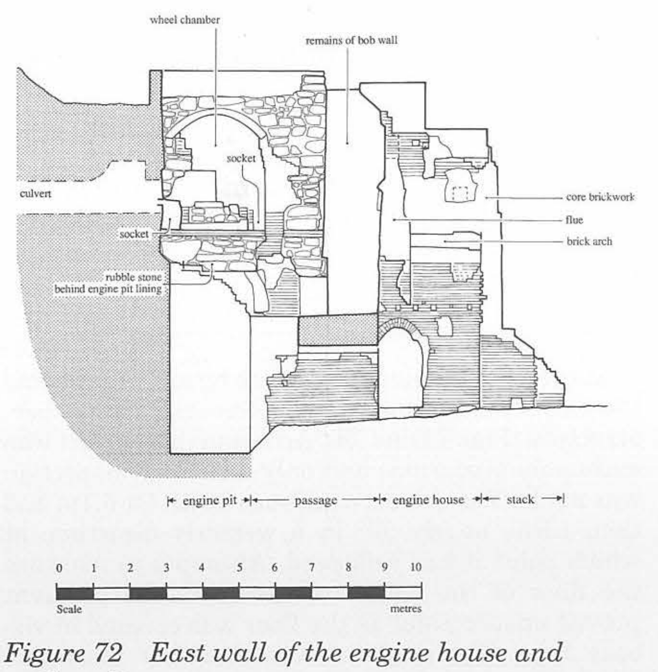


Figure 72 East wall of the engine house and engine pit.

6m (20 feet) long. The position of the opening from the wheel chamber marks the rear of the bellows, which could only have been 3.5m long if furnace I was an original structure. Clearly furnace I was blown by another method and is later, while the original furnace was positioned at least 2.5m further east.

The tuyère chamber can be discounted as an original feature because it existed to blow the furnaces from a second side, the technology for which was not available in 1757. Furnace II is in the position of the original east furnace to judge from its relationship with the charging house walls, but the relining and rebuilding of this furnace precludes an argument that it could be the original furnace (Figs 60, 67, and 68).

Some ambiguities in the documentary evidence have not been positively resolved by the archaeology. The existence of a second engine has already been doubted and no archaeological evidence for it was encountered. This raises a further question, namely how was the waterwheel on the east side of the site, as shown by Perry, supplied with water? Could water have been fed to it from the pool mentioned in the 1770s? The presence of the waterwheel and absence of the pool on the Perry plan suggests not (Fig 60). There is no archaeological evidence for a pool and the evidence for the original topography of the site, as discussed above, would require a pool to be some distance from the works in order to be higher than the waterwheel. The most likely source of water for both wheels was surely the engine pit, the water for the eastern wheel being channelled through the western wheel chamber. It seems clear that the engine pumped water to be channelled directly into the wheel chamber and not into a separate holding pond – the engine pit was located next to the western wheel chamber precisely because water was channelled from one to the other (Fig 60).

Engine house and engine pit

The engine house is brick-built and bonded in a buff-coloured sandy mortar (Fig 72). The west wall survives only partially, the south wall not at all, and there is no surviving evidence of a roof. On the south-east side is the base and part of the flue of a former stack. The bob wall survives as two detached sections linked by modern brickwork (Fig 70). According to Perry, the engine was supplied by two haystack boilers (Fig 60), the bases of which were uncovered during excavations in the 1970s. The engine house has a first-floor level defined by a line of joist holes in the side walls which are integral to the building (Fig 72). The cylinder was probably housed on this floor. It was positioned between the large beam socket and the partial survival of another for spine beams in the bob wall (Fig 70). In the side walls are what appear to be the haunches of brick vaults (Fig 72). These appear to have acted as corbels supporting either another working floor or cross beams further holding the cylinder in place.

The brick-lined engine pit is enclosed by a superstructure principally of rubble stone, but much repaired and heightened in modern brick (Fig 73). The east wall has an arched opening into the wheel chamber (Fig 72). Perry shows the original engine pit in line with the wheel chamber, but the present engine pit is out of alignment with it (Figs 60 and 69). Of equal significance is the fact that Perry showed no wall on the west side of the engine pit, while Dayes gave no hint that a high superstructure was built above it. The present brick shaft is bonded in a buff-coloured mortar, similar to the other phase I mortars, but the brickwork can be seen, at the top of the shaft on the east side, to have been laid in front of a stone core (Fig 72). This core is bonded in a distinctly different, dark grey mortar with coal fragments. None of the other original structures showed this grey mortar and the use of industrial waste (ie coal dust) in the mix strongly suggests that such mortars are secondary. Therefore the engine pit cannot be the original shown by Perry (Fig 60). It will be argued below that changes in the engine house relate to the replacement of the original engine and are contemporary with the enlargement of the engine pit to increase its yield of water.

Grey mortars characterise the remainder of the superstructure above the engine pit, except on the north side where rubble stone in a light-coloured mortar appears to be earlier and may be the north wall shown by Perry (Figs 64 and 74). On the east and west sides the rubble-stone walls clearly butt against the earlier bob wall (Fig 72). Furthermore, the arched opening into the wheel chamber is wider than the chamber itself but is positioned directly above the engine pit. Within the east and west walls of the engine pit superstructure are brick bands defining the bases of two sockets in each wall, suggesting the presence of two cross beams spanning the engine pit as part of a head frame.

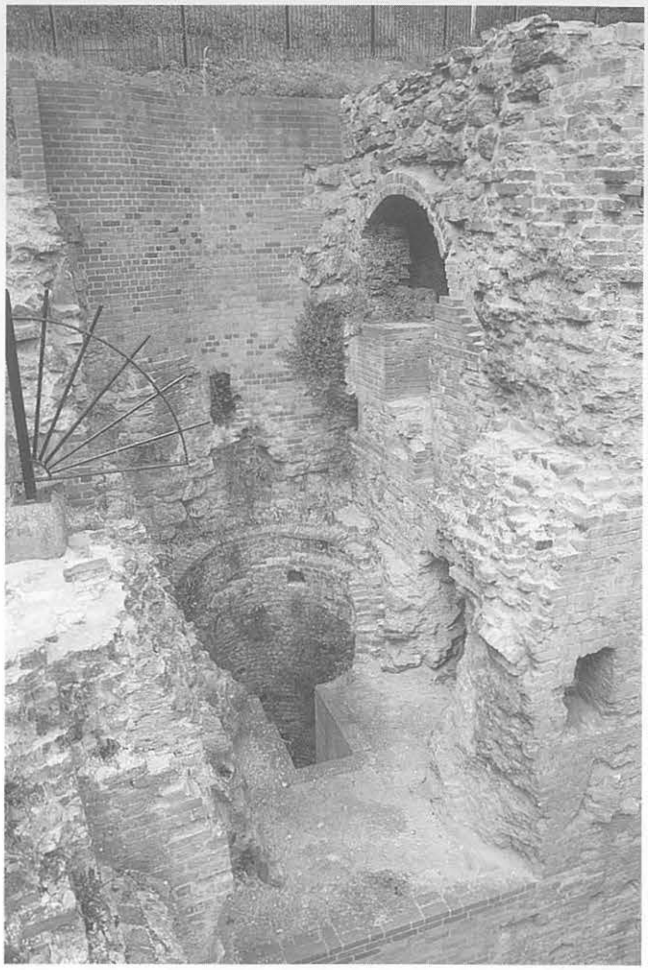


Figure 73 The engine pit, looking north and photographed in 1997 after the completion of repairs. In the back wall, immediately above the pit, is a small culvert opening while the opening to the wheel chamber is the higher brick arch in a rubble-stone wall.

At the approximate level of the head-frame beams is a culvert in the north wall of the engine pit superstructure (Figs 73 and 74). Access to this culvert was extremely precarious and only a cursory inspection was made. The culvert continues north for 5.1m and then turns nearly 90° in a westerly direction, at which point it has collapsed. Attempts to measure the floor of the culvert to ascertain its gradient proved unsuccessful as the floor was covered in viscous lime. The gradient was therefore measured from the roof, which appeared to suggest that it sloped down from the entrance. The extant opening is in a brick surround, but there is a clear break between this and the culvert itself, not to mention the fact that the narrow opening gives a false impression of the wide culvert behind it (Fig 72). The opening is clearly therefore later than the culvert itself.

What was the purpose of the culvert? The evidence is inconclusive because the gradient could not be reliably determined to establish in what direction

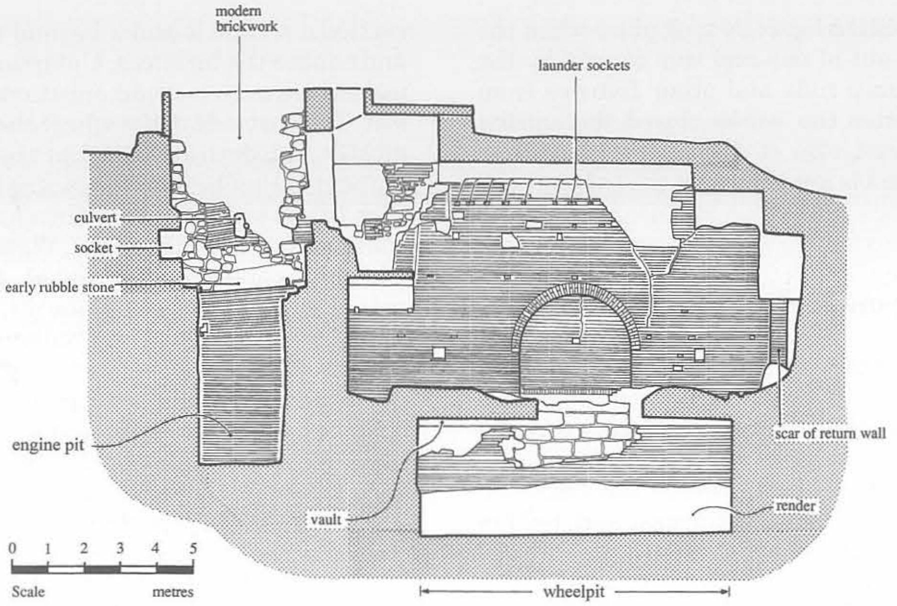


Figure 74 North wall of the engine pit and the wheel chamber and wheelpit

the water flowed. A culvert 0.9m wide would have enough capacity to supply the waterwheel without the need of a pumping engine, so it is inherently more likely that water flowed away from the engine pit and that the culvert is an overflow channel. However, if this is the correct explanation it would make little sense to narrow the culvert opening to its present width (Figs 73 and 74).

There are two remaining important questions regarding the engine pit: why was the superstructure built above it and when was it carried out? The 'why' is perhaps easier to resolve. As a retaining structure, it was self-evidently built to retain a heightened ground level behind it. The boreholes revealed evidence of made ground above the natural clay which suggested that the area north of the works was raised considerably, perhaps in order to create a level working platform for preparing the materials for charging, but this could not have occurred to the present extent when the furnaces were built in 1757, as discussed above in relation to the topography of the site (Fig 71). It is argued below that the superstructure is contemporary with the building of furnace I and associated changes to the whole upper level of the site.

The argument that the changes to the engine pit are contemporary with the changes in the engine house is based on the similarity of mortars. In the engine house, joists supporting the first floor were removed and at least one of the joist holes on the east side was infilled with brick in a grey mortar (Fig 72). Two potential sockets for cross beams are visible in the east wall, which belong to this secondary, grey mortar phase. The lower is matched by a corresponding cavity in the west wall. Both cavities are insertions because there are substantial traces of grey mortar at the back of each cavity and they probably housed a cross beam. A rectilinear impression in core stonework at high level might be connected with another beam, but not one which was inserted into the wall, nor which could have spanned the building, as its position would have interfered with the connecting rod between the cylinder and engine beam.

The apparent lowering of the level of the first floor should logically be interpreted as evidence for a new engine. Lowering the original cylinder would have required its connecting rod to the engine beam to have been lengthened. A more likely interpretation is that a new cylinder was inserted which had a longer stroke, which effectively means a new engine, which might have been installed in 1832 when a new cylinder appears in the accounts (Staffs RO D876/ADD/3/1, f 70). However, there are problems with this interpretation if it is accepted that the changes in the engine house are contemporary with the enlargement of the engine pit and that this enlargement was carried out in the early-19th century. Engines of this date were mounted on a bed plate fixed to a solid bed of brick or stone by holding-down bolts. This kind of engine bed would not collapse of its own accord and removing it would have involved substantial demolition work, making the chance of its survival very high indeed. No evidence of the existence, or even the former existence of an engine bed has been discovered, presumably because the engine was a simple atmospheric engine. Such an engine may have seemed antiquated after 1800, but it should be remembered that it was not required to raise water from anything like the depth of contemporary collieries.

The final evidence for changes to the engine house is of demolition. The ground-level doorway in the east wall was widened by knocking out one of the imposts, leaving core brickwork exposed (Fig 72). In addition, the bob wall was substantially demolished (Figs 70 and 73). The exposed cores of the wall are such that it cannot have fallen down of its own accord. This demolition logically took place when the waterwheel went out of use and was caused by the removal of the pump rods and other fixtures from the engine pit. After the works closed the smithy attached to the west side of the engine house was also demolished and is not shown on the tithe map of 1847 (Fig 65).

Wheel chamber and bellows room

The wheel chamber is a tall narrow structure with a modern concrete barrel vault (Figs 59 and 74). Most of the south wall, the dividing wall between the wheel chamber and bellows room, is also modern. The chamber is wider at high level at the west end, next to the engine pit, while at the east end, behind furnace I, is the scar of a former return wall. In the north wheel chamber wall is a large vaulted recess above the wheelpit (Fig 69). Embedded into the floor of the recess are two timber baulks.

Given the argument that water was channelled directly from the engine pit to the wheel chamber, some control over the flow of water should be expected in the form of a small penstock. There is evidence for such a reservoir immediately inside the west entrance to the wheel chamber, next to the engine pit. A brick vault at the west end was most likely built to support a substantial structure above it or a substantial weight of water (Fig 59). Above the vault a scar of brickwork can be seen in both wheel chamber walls (Fig 74), which are arguably all that survives of a substantial brick core on which the penstock was fitted. The height of this proposed penstock depends upon the height of the wheel, which is discussed below. Beneath the vault was a doorway into the cross passages which provided access from the engine house to the wheel chamber.

The wheelpit walls are of large blocks of coursed, hammer-dressed sandstone (Fig 74). The depth of the wheelpit was not established until the infill, principally clay, was excavated. The addition of a brick skin (discussed below) has meant that no tail race opening is now visible, but the floor is brick and slopes down from east to west, ie drains back towards the engine pit.

The only possible evidence for the level of the timber launder is a row of eight sockets in the north wall of the chamber (Fig 74). The substantial rebuilding of the south wall has meant that any evidence on this side has been lost. If they do define the level of the launder then the maximum diameter of the waterwheel was 8.6m (28 feet 3 inches), while its width was approximately 1.35m (4 feet 5 inches). The original wheel was probably overshot, turning it in the right direction to depress the top boards of the bellows (see Fig 14A for the probable arrangement of bellows and axle tree).

If the engine pit supplied water to the waterwheel on the eastern side of the site it would be expected that the launder supports in the wheel chamber carried a second launder beyond the wheel chamber and behind the furnaces. Unfortunately, archaeological evidence that could substantiate this is mostly lost. The east side of the wheel chamber north wall is mostly a modern rebuild, but there is arguably one launder socket beyond the centre line of the wheelpit (Fig 74). A lower vault at the east end of the wheel chamber is a later insertion. Water from the eastern wheelpit could have drained back through the extant wheelpit to the engine pit, but the sealing up of the extant pit has obscured any possible evidence for this.

Substantial changes at the west end of the wheel chamber are directly related to the enlargement of the engine pit described above. The upper level of the wheel chamber was widened at this end under a brick vault in grey mortar distinct from the vaulting over the rest of the chamber. It may be these two vaults that Randall meant when he referred to 'the arches which supported the reservoir' (Randall 1880, 179).

There are several other features in the wheel chamber which have not thus far been interpreted. The east return wall of the wheel chamber was demolished, probably when furnace I was built, leaving only a scar in the north wall (Fig 74). Significant alterations were made to the wheelpit after the waterwheel had been removed. Brick walls were added at the east and west ends of the wheelpit, thereby blocking up the tail race and perhaps also a culvert leading from the original eastern wheelpit. A brick skin was also added to the north wall, and brick vaults were added at both ends leaving a gap in the centre. Finally a render was applied to the surfaces in the form of the same grey mortar used to bond this phase of brickwork. Above the vaults a new brick floor was laid, demonstrating the adaptation and reuse of the wheelpit and wheel chamber after the waterwheel had been removed.

When and why was this done? The obvious explanation might be that a blowing engine rendered the waterwheel obsolete, and therefore the wheel chamber was converted for a different purpose. In conjunction with this, Stuart Smith previously suggested that the wheelpit might have been used as a blast regulator (Smith 1979b, 26). However, water regulators required the use of an inverted cast-iron cylinder lowered into the water, confirmed by Svedenstierna's visit to the site in 1802–3. Such a cylinder could not have been removed once the vaults had been built and the regulator for a 7-foot (2.1m) diameter blowing cylinder would have been far larger than the dimensions of the wheelpit.

It will be argued below that when furnace I was built the waterwheel was still in use. Furthermore there is no documentary evidence for the installation of a blowing engine at Bedlam and, until evidence demonstrates the contrary, any argument that the waterwheel was disused before the closure of the works in 1843 is unjustified. This dates the sealing of the wheelpit to later than 1843. The sealing up and rendering of the wheelpit suggests that it was used as a water tank (a similar phenomenon was observed at the Blists Hill Brick and Tile Works). The clay inside the pit might have been dumped there to act as a lining.

Structurally, the open-fronted bellows room consists of north and west walls and a half vault of brick (Figs 69 and 70). The half vault was originally a whole vault but was truncated when the present furnace I was built to the west of the original furnace. This was proved when a void above the vaulted tuyère recess on the west side of furnace I was examined and the bellows room vault could be seen continuing on a downward arc to butt against the furnace brickwork.

The long axle-tree which operated the bellows was supported on a bearing, or gudgeon, at each end. On the north side of the wheelpit this is represented by the timber baulks in the vaulted recess (Fig 69), but there is no evidence for the opposite bearing in the bellows room. A wooden frame would have been built above the bellows, on which wooden beams with counterweights pivoted. In the west wall of the bellows room is a vaulted recess which must have housed one of the counterweights. A second counterweight recess is now infilled.

Svedenstierna gave a good account of the replacement of the original bellows by the blowing cylinder by 1802–3. Given the convincing evidence that the waterwheel remained in use after the bellows were discontinued, the bellows room is the most likely location of the regulator witnessed by Svedenstierna. As yet no archaeological evidence has been found to support this, but the evidence would be below ground, possibly partly beneath the present furnace I which had probably not been built by this time.

Furnace I and tuyère chamber

Furnace I is the largest structure on the site. Its lining is circular in plan and stands in an almost square casing with splayed openings for tuyères on the east, west, and north sides, and the forehearth on the south side. The furnace casing consists of battered, hammer-dressed stone walls to the front (Fig 70) and straight-sided walls to the side and rear. The west side of the furnace was built beneath the east side of the bellows room vault and effectively supports it. The front wall incorporates a vaulted passage to the tuyère chamber between the furnaces (Fig 70). The tuyère chamber is faced in brick, polygonal in its ground plan, has recesses for tuyères to both furnaces, and has a brick-vaulted tunnel at the rear, the end of which is blocked with spoil (Fig 75).

In the tuyère recess on the west side of furnace I is a short passage leading to the rear of the furnace (Fig 69). The passage is partly a modern rebuild, but the floor and walls clearly indicate that it was cut through the original masonry core of the furnace casing. This leads to the east end of the wheel chamber and the tuyère opening on the north side of the furnace. The opening is beneath cast-iron lintels, rather than raked brick vaulting, and appears to be an addition (Fig 76), as does the passage at the back of the furnace not investigated in the present project, where a blast main survives *in situ* (Smith 1979b, 24–5). Furnace I was therefore originally blown on only two sides. Given that the furnace did not originally have a continuous passage around the back of it, the original conveyance of blast from one side to the other is mostly likely to have been achieved by means of a blast main below ground (cf Blists Hill furnaces, see Chapter 5).

In the south wall of furnace I is an attached brick wall which is considered to be all that survives, above ground, of a casting house (Fig 70). The battered masonry walls flanking the forehearth are not contemporary, at least not in their present form, because the batter of the walls differs, being markedly steeper on the east side. Integral with the stonework on the east side is the brick wall of the forehearth which can be seen to have been built in front of an earlier brick wall, probably the original forehearth wall. Therefore the present east side is later than the west side and represents a partial rebuilding of furnace I. Integral with the masonry wall on the east side is the passage from the front to the tuyère chamber. The present tuyère chamber must therefore represent a modification, for it can hardly be doubted that a tuyère chamber previously existed, furnace I having been built to the west of the original furnace specifically to allow blowing from two sides. The earlier chamber is represented by the passage on its north side (Fig 69), the present tuyère chamber brickwork being integral with the entrance to this passage. However, butt joints inside the entrance show that the passage belongs to an earlier phase. The passage is evidently related to a wall at the back of the furnaces, which may include the wall discovered in 1993 when a test pit was excavated behind furnace II (see below). The passage was probably built to provide access to the back of the furnaces to facilitate maintenance.

When was furnace I built? Here Butler's description of the works in 1815 is relevant (Birch 1952, 232). According to Butler, the furnaces were between 32 feet and 36 feet high (9.85m–10.98m). He obviously did not measure them himself, so his information was either furnished by the manager or was an educated guess. Furnace I is now 8.80m from the tap hole to the top of the furnace lining on the north side, but this defines neither the top nor the bottom of the furnace. The hearth could be expected to be as much as 1m below the tap hole, while the top of the stack (excluding the tunnel head which was often omitted in the vital statistics of furnaces) was evidently higher than survives today, because the diameter at the top is approximately 4.6m, far too wide for the tunnel head. Bearing these considerations in mind, furnace I is likely to have been at least 11m high, minus the tunnel head. Although this is higher than the figure offered by Butler, if it is accepted that his figure was an estimate, then furnace I *could* have been one of the furnaces he was describing. The alternative view is that the furnace that Butler saw blown on two sides was the unlocated third furnace built after 1806 and that in 1815, the two 1757 furnaces were still in blast and blown on one side only. This seems more likely, especially as the building of furnace I with a tuyère chamber on its east side logically means that two furnaces rather than one were blown from two sides. This would date furnace I later than 1815.

The interior of furnace I is half filled with the residue of the last charge, but behind this the sandstone lining of the boshes can be seen. The existence of sandstone must be considered as unusual for a 19th-century blast furnace. Regarding the residue of the last charge, an account of blowing out a blast furnace given in 1842 is quoted in full here because it provides the necessary interpretation:

> When it is intended to discontinue a furnace they must blow it out, as it is called. It would not do merely to cease blowing the blast, for then the melted and half-melted materials would all vitrify into one solid mass, and would also adhere to the sides of the furnace, so that it would be impossible ever to clear the furnace, and the whole must come down (British Parliamentary Papers 1842, 48).

Furnace I was therefore not blown-out; it was abandoned.

Furnace II

Furnace II is composed of two distinct structural elements. The interior lining of the well and boshes rises 2.55m high; above it are the substantial remains of a brick furnace stack, of which the inner lining is missing (Fig 77). The lining of the well is sandstone and gauged firebricks, behind which is a layer of red sand. Two tuyères are visible, at different levels, on the north and east sides (Fig 69), while on the north side the position of a higher tuyère is infilled with modern brick. There is no longer evidence of a tuyère on the west side, facing the tuyère chamber, because the lining has collapsed here. A western tuyère is suggested, however, in a photograph of 1972 (IGMT 1986.13474). The brick stack is cone-shaped and is built into the bank (Fig 77). The upper section is freestanding, of stepped brickwork with wrought-iron straps (Fig 78).

Figure 75 The tuyère chamber, looking west towards the tuyère recess of furnace I. The impression of a former tuyère can be seen in the furnace bear. On the right is the passage to the rear of the furnaces, now inaccessible, while on the left is the passage to the south side of the furnaces.

Figure 76 The tuyère recess on the north side of furnace I, at the east end of the wheel chamber. The recess is supported by cast-iron lintels instead of the brick arches used for the other tuyère recesses, and the remains of two superimposed tuyères can be seen.

In 1993 a test pit was dug in the charging platform at the back of furnace II to a depth of 3.5m (Fig 79). This revealed a vertical, straight brick wall at the back of the furnace, beneath which was a wall of rubble sandstone. The stone wall was considered to belong to the original furnace structure, ie of 1757, while the brick wall was interpreted as the outer casing of the extant furnace stack. The pointed brick and stone faces of these walls suggest that there was a chamber, or at least a passage, beneath the charging platform at the back of the furnace.

An interpretation of furnace II cannot proceed until the problem of the supposed brick kiln is resolved. The argument that the brick superstructure is a kiln is not based on any convincing historical evidence. Superficially the shape of the superstructure resembles a pottery or brick kiln, but there the similarity ends. If it was a kiln then access would be required to load it with bricks. There is no evidence of any such access from ground level, or even at a higher level, as the furnace is shown largely intact in an early 20th-century photograph (Fig 67). Another problem is how the kiln could have been fired. There is no evidence of fireboxes, nor of a flue from a firebox into the base of the furnace. Nor is there any evidence of an internal floor on which the bricks could have been stacked. During the 1970s, repair works at the front of the furnace were undertaken to support a wrought-iron bar on the assumption that this was a 'fire bar' spanning a flue into the kiln (Fig 70). However, the bar is integral with the blast furnace lining and a similar bar is visible at a much higher level on the west side of the boshes. The bars were most likely tension bars in the furnace structure.

Taking these considerations into account, the kiln theory for furnace II cannot be sustained. In fact the interpretation of the brick superstructure as a blast furnace is far more compelling, particularly since the same bottle-shaped profile was painted in 1847 at the Madeley Wood Company's other iron-works at Blists Hill (see Fig 82). The watercolour by Warington Smyth shows wrought-iron straps around the furnaces, one of which has survived on furnace II. If the furnace was similar to the Blists Hill furnaces then it possibly had a square stone base on which the brick stack was built. The tithe plan suggests that this was so (Fig 65). Evidence from the test pit excavated behind the furnace might also support this, although the stone wall was probably built for an earlier furnace. Archaeological evidence for a base at the front of the furnace is presently restricted to part of a masonry wall set back from the front wall of furnace I (Fig 70).

In the photograph of the fairground at Bedlam, the stack of furnace II dwarfs the remains of furnace I (Fig 67). In 1867 one of the Blists Hill furnaces was said to be 45 feet (13.7m) high (see Chapter 5 below). Furnace II presently stands 8.2m high above the internal ground level, although the hearth stone may be as much as 1m below the furnace bear, the residue left in the hearth after the furnace had blown out. Even so, the charging platform can be estimated to be in the region of 3–5m above the present ground level on the upper level of the site, while the furnace could have been 14m high.

Furnaces II and I are similar insofar as the well, but not the boshes, are primarily of sandstone, but the stacks of the furnaces are markedly dissimilar. In its present form the tuyère chamber is associated with a remodelling of furnace I, but is integral with the stack of furnace II. Furnace I was partly encased within a masonry shell, while furnace II is of a later design. Furnace I was originally blown from two sides, while furnace II was surely always blown from three sides. Two tuyères are *in situ* (Fig 69), but it cannot be doubted that there were originally two tuyères at the back (cf Smith 1979b, 25) and a fourth on the west side, fed from a blast main in the tuyère chamber.

To return to Butler, if the interpretation here is correct then furnace II, like furnace I, is later than 1815 in its present form. The tithe plan shows a bridge from the charging platform to furnace II, but

Figure 77 The brick stack of furnace II, photographed looking north during repairs in 1994. The lower part of the furnace in the foreground is mostly restoration work of the 1970s.

no such bridge connecting with furnace I, whose stack is delineated with a broken line (Fig 65). It is therefore possible to argue that furnace II was the last furnace at Bedlam to remain in blast and that furnace I had been given up some years previously.

Charging platform

The upper level of the site does not survive to its original full height behind the furnaces. Evidence of the charging platform is principally the three parallel walls of the charging houses (Figs 68 and 78). Between the central and western walls is a deep depression, at the base of which is an opening lined with concrete, leading to the passage at the back of furnace I and into the east end of the wheel chamber via a half arch. Figure 58 shows the arch to the wheel chamber before restoration in the 1970s, while to its right the arch of a recess or doorway is shown, possibly leading to the 'shed' shown by Perry (Fig 60). The wall on the west side is in two detached sections, the southern section of which abuts the centre of furnace I.

Changes within the charging houses have previously been recorded and interpreted by David Higgins and it is worth reviewing his findings here. He assumed that the charging houses were originally freestanding and were infilled with waste at the same time as being raised in height. Subsequently they were further infilled and a sandstone retaining wall was built east of the charging houses by cutting away some of the earlier tipped material (Higgins 1988a, 150).

Higgins' conclusions amplify, and at the same time partly contradict, the interpretation given here. The charging house walls are considered to belong to the earliest phase of ironworking. However, two phases are discernible, the earlier phase consisting of brickwork in a buff-coloured mortar, the later of brick in a grey mortar. The earlier phase at least was associated with two roofed buildings

Figure 78 The upper level of the site, photographed looking west in 1991 before repairs began. The curved brickwork of the furnace II stack is clearly visible on the left. The charging house walls are obscured by vegetation cover.

that were a standard feature of the mid-18th century and are shown by Perry (Fig 60). The charging level would have been roughly level with the tops of the furnaces, but there is no indication in the surviving original walls of beams for an upper floor level. Higgins' second phase was the infilling of the charging houses and the raising or rebuilding of its walls. The infilling was probably connected with the raising of the charging level, which must have encompassed the whole western area of the site and is confirmed by borehole evidence (Fig 71). The result was a considerable extension to the materials preparation area, perhaps where roofed charging houses had been dispensed with. The infilling occurred at the same time as the engine pit was enlarged and the superstructure was built above it. It therefore took place during the active life of the waterwheel.

In Higgins' third phase was the construction of the rubble-stone retaining wall on the east side of the charging platform. The wall is first shown on the 1847 tithe map; it does not appear on the early 19th-century lease plan, where the area east of the charging houses is occupied by a range of buildings, implying a gentler topography (Figs 62 and 65). The interpretation preferred here is that the retaining wall should belong to the initial heightening of the charging platform, since the wall is bonded in grey mortar characteristic of the rebuilding of the charging house walls and engine pit superstructure.

David Higgins also argued for the excavation and backfilling of the spoil behind furnace II, which agrees well with the argument that the fill was removed in order to build furnace II, which is later than furnace I. This suggests that the raised charging platform was originally necessitated by the increased furnace capacity represented by furnace I. The new position of furnace I to the west of the original furnace meant that the charging house became misaligned with it and may therefore have been dispensed with, being replaced by an open charging platform. Unfortunately, the rear of the furnaces has yet to be fully investigated, so the interpretation is necessarily tentative.

As neither furnace survives to its full height the charging platform must have been at a considerably higher level than survives today. However, the upper level of the site must have existed on two levels: the high-level vault at the west end of the wheel chamber incorporates a half-round vent which could never have been covered with spoil. Similarly there are features above the bellows room, well below the tops of the furnaces, including steps down to the upper storey of the engine house.

The 1883 Ordnance Survey shows a wall extending from the north-east corner of the engine pit

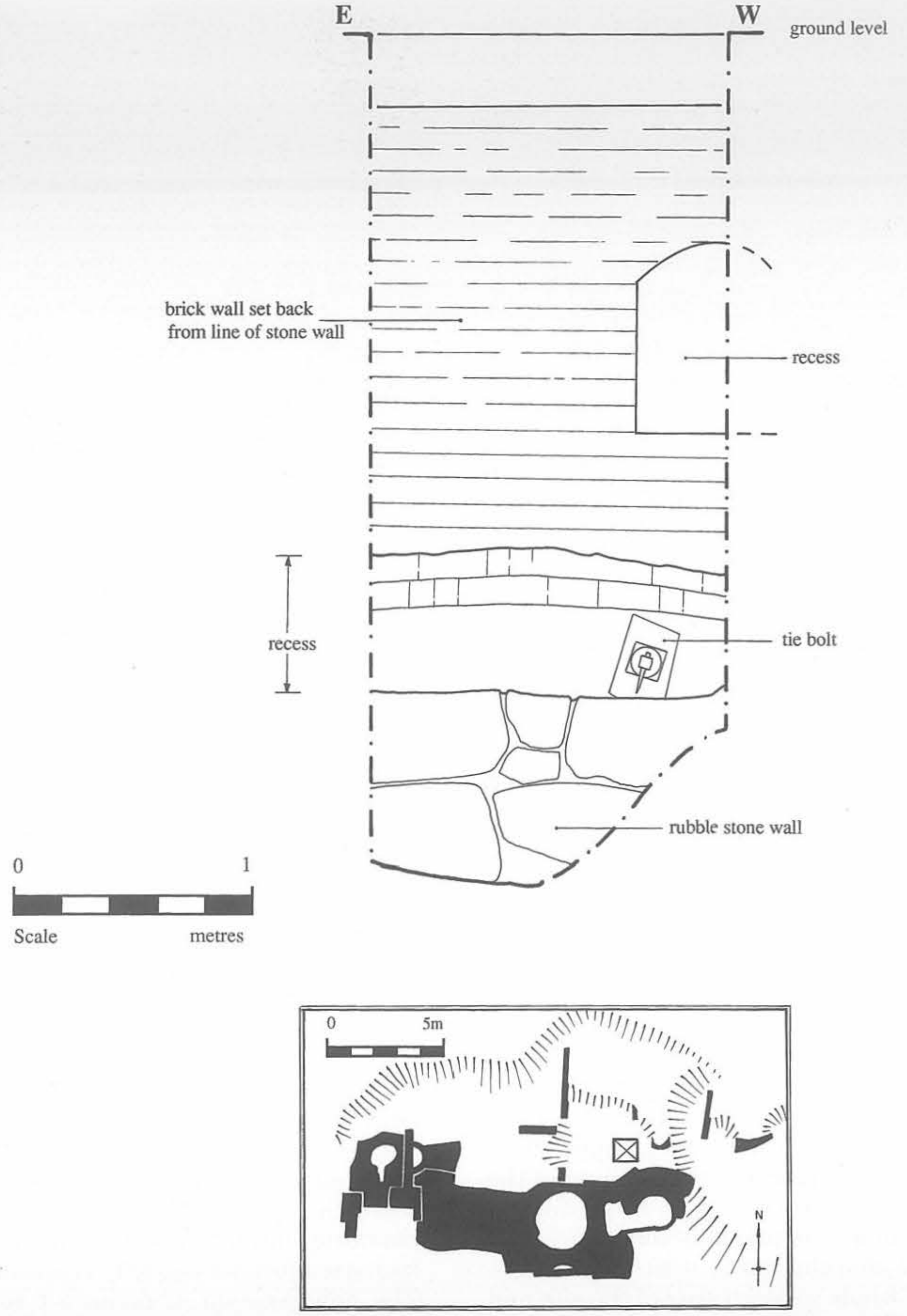


Figure 79 A test pit excavated through the charging platform on the north side of furnace II, revealing the rear walls of the structure.

across the charging platform and to the north of the retaining wall on the east side of the charging houses (Fig 66). The omission of this wall from the tithe map does not preclude its existence. Instead the tithe map shows another wall from which a bridge was built to furnace II. The wall retaining this higher charging bank was revealed in drainage trenches on the upper level of the site. These revealed two parallel brick walls oriented east to west and to the west of the charging house walls, the northernmost of which was 3m long and bonded in a light grey mortar, the southernmost in a similar grey mortar, and with rubble stone between them bonded in a buff coloured mortar (Figs 68 and 80).

According to the tithe plan the rubble-stone wall east of the charging houses was part of a longer retaining wall enclosing a roughly rectangular space east of furnace II. Another section of this wall survives on the east side of the site and the 1883 Ordnance Survey suggests that the third furnace was adjacent to it (Fig 68). Archaeologically, the eastern side of the site remains *terra incognita*, largely due to the build up of spoil and because there has never been a need for any ground stabilisation. This is where future investigations may answer some of the unresolved problems of Bedlam, although the survival of the structures on the west side is a strong argument that the principal components of the works were here when it ceased production in 1843.

Summary interpretation

Phase I (1757–9): Bedlam furnaces were begun in 1757, but were not completed until 1759 at the earliest. The works had two blast furnaces and a pumping engine and its layout is shown with tolerable accuracy in a plan by George Perry and a wash drawing by Edward Dayes (Figs 60 and 61). Of the structures shown on the plan only the engine house, wheel chamber, and part of the bellows room have survived to any meaningful extent (Fig 69). The position of the charging houses is still discernible (Fig 68), but the original charging level has been lost in substantial later changes. The eastern waterwheel and bellows room were east of the present furnace II, an area which remains to be investigated.

Further development of the works in the 18th century was minimal. Coke ovens were built somewhere near the coke hearths before 1776, followed by a second range of ovens on the east side of the works, erected in 1789 and shown on an early 19th-century lease plan (Fig 62). In 1794 one of the furnaces had been blown out; it was relined in 1796 and was in blast again by 1801. In 1795 the foundry was also rebuilt. According to Svedenstierna, by 1802–3 the bellows had been replaced by a blowing cylinder and water regulator, probably housed in the extant bellows room and powered by a waterwheel in the surviving wheelpit. This suggests that the wheelpit and bellows room on the east side of the furnaces were disused by this time. There is, however, no direct archaeological evidence for any of these changes.

Phase II (1806–10): A third furnace was added between 1806 and 1810, which was probably designed to be blown on two sides. This is the elusive third furnace, for which no archaeological evidence has yet been found. Its most likely location is on the eastern side of the site, in the position of the furnace-like structure shown on the 1883 Ordnance Survey (Fig 66).

Phase III (post-1815): Substantial changes are apparent in the archaeology of the site which must belong to the 19th century, but there are no specific dates. The two original furnaces are considered to have remained in blast until at least 1815. Later, probably during or after the trade depression of 1816–18, the present furnaces I and II were built. Furnace I is the earlier and concurrent with its erection the charging platform was heightened and extended, while modifications were made to the supply of water, proving that the power for the blowing cylinders continued to be provided by the waterwheel. The engine pit was enlarged and realigned with the wheel chamber (Fig 69) and there are contemporary changes in the engine house which might indicate a new engine, such as the replacement of the first floor by a floor at a lower level, as indicated by the cavity left by an inserted beam socket at a lower level than the original joists (Fig 72). The engine certainly had a new cylinder in 1832. A superstructure was built above the engine pit to retain the substantial artificial platform built on the north side of the site (Figs 73 and 74). At the same time the original charging houses were infilled and a retaining wall was built across the eastern side of the site, thus creating a raised platform across the entire area north of the furnaces (Fig 68).

Furnace I is located to the west of the original west furnace, encroaching upon the original bellows room and charging houses, but not the wheel chamber. The lower half of furnace I was encased within a core defined by masonry walls (Fig 70), but above

Figure 80 The 19th-century charging bank wall partially revealed during groundworks on the upper level of the site. It consists of two brick walls with rubble fill between them.

this it rose in the form of a brick stack, possibly with a bottle-shaped profile. It was designed to be blown on two sides. The tuyère chamber does not survive in its original form, except for a passage which led from it to the rear, which either allowed access to the rear of the furnaces or housed a blast main (Fig 69). Later, two superimposed tuyères were added at the back of furnace I, probably when a passage was cut from the bellows room to the eastern end of the wheel chamber through the insulating core of the furnace (Figs 69 and 76). Until this time there was no passage around the rear of the furnace in which a pipe could have conveyed air from one side of the furnace to the other. This suggests that tunnels were originally built underground, although the rear tuyères of furnace I were later supplied with air from a pipe which remains *in situ* in the passage behind the furnace.

Phase IV (post-1815): The only major alteration to furnace I was the subsequent rebuilding of the front wall on the east side, integral with which is the present tuyère chamber (Figs 70 and 69). Probably integral with the renewed tuyère chamber is the brick stack of furnace II (Fig 77). This structure is not, as was previously argued, a brick kiln, but the only survival of a specific type of 19th-century blast furnace design, a design that was later used at Blists Hill.

Throughout the 1820s Bedlam is listed as having three furnaces, but corresponding production figures cast doubt as to whether all three furnaces remained in blast. The interpretation preferred here is that two furnaces were in blast during the 1820s and remained so during the 1830s, although one furnace may have been temporarily blown out in 1832 when output fell and the engine was modified. The blowing in of the second Blists Hill furnace in 1840 may have precipitated the permanent blowing out of one of the Bedlam furnaces, leaving only one furnace in blast. Ironworking ceased at Bedlam in 1843. Four years later the tithe plan shows the bridge of furnace II intact, suggesting that only furnace II was in use by the 1840s (Fig 65).

Phase V (1843): After the closure of the works the buildings were mostly dismantled. The bob wall of the engine house was partly demolished for the removal of pump rods (Figs 70 and 73). The casting houses and ancillary structures, like the smithy attached to the engine house, had completely disappeared by the time of the tithe map of 1847 (Fig 65). The remaining structures survived largely because they are either wholly or partly retaining the bank on the north side of the site. There is no evidence that the site was later reused for brick making, although the rendering of the wheelpit walls suggest that it was used for water storage after the removal of the waterwheel (Fig 74).

Some problems of interpretation remain, such as the slim possibility of a blowing engine on the site, the location and survival of the third furnace and the second waterwheel, and evidence for the distribution of air to the furnaces, which appears at some stage to have been achieved by means of tunnels underground. The probable survival of water power throughout the working life of the furnaces is one of the least-expected conclusions of the work. The other is that the Madeley Wood Company appears to have invested heavily in modernising the works on the eve of its decline. This might have been difficult to explain were it not for the fact that precisely the same phenomenon was observed at the Madeley Wood Company's other ironworks, at Blists Hill.

5 Blists Hill blast furnaces

Introduction

Blists Hill is the least studied of the upstanding ironworking sites in the Ironbridge Gorge and has not previously been the subject of a detailed archaeological enquiry. Beyond the necessity of providing a definitive chronological and functional account, the technological context of the site needs careful consideration. Blists Hill belongs to the 19th-century generation of ironworks in the East Shropshire Coalfield, a period when Shropshire was no longer in the vanguard of technological change. The consensus view of Blists Hill has been that it was something of an antique curiosity by the early-20th century, continuing to smelt cold-blast iron long after hot-blast became standard (Clark 1993, 50), a view which will be reassessed in the light of the new interpretation.

The ironworking remains formed part of the initial exhibits of the open-air museum at Blists Hill and were substantially repaired in the 1970s. In 1971 a blowing engine, thought to have been similar to the engine which had originally been housed in the north engine house, was donated by the Lilleshall Company and lowered into the building from above, the roof having collapsed some years previously. The blast furnaces were excavated in 1973, requiring the removal of approximately 3.5m of overburden, and were extensively repaired using new and reclaimed materials (Fig 81). The south engine house was restored during the period 1978–80, when the building was completely reroofed.

Figure 81 Blists Hill blast furnaces looking north and photographed in 1978, after restoration of the furnace bases and north engine house. The north engine house is in the background with stack and a modern boiler house attached on its left-hand side. Subsequent clearance around the furnace bases has meant that the brick pit in the right foreground is no longer visible. (Ironbridge Gorge Museum Trust)

Documentary evidence

The Blists Hill works was built and operated by the Madeley Wood Company. At first it was an addition to their ironworks at Bedlam, but after 1843 it replaced the older site. The advantage of Blists Hill over Bedlam was twofold: it was better located with regard to ironstone and coal reserves, and on a more accessible site adjacent to the Shropshire Canal; it was also built on freehold land, unlike Bedlam which was erected on leasehold land where royalties were payable on every ton of iron produced.

Production at Blists Hill started with a single blast furnace and blowing engine in 1832 (Staffs RO, D876/ADD/3/1, f 70; B&W MII/17/1). In 1838 a second engine was under construction and by 1840 a second furnace had been constructed and blown-in (*ibid* ff 138, 147, 167; Randall 1880, 174). In 1844 a third furnace was blown-in, by which time only one engine was in use (Riden and Owen 1995, 38; Staffs RO, D876/ADD/3/1, f 205).

The layout of the Blists Hill works is depicted in a watercolour of 1847 (Fig 82). Warington Smyth, a mining geologist, painted the works from a north-west viewpoint. Three blast furnaces have brick stacks strengthened by wrought-iron straps and behind each of them are the charging houses, with the casting houses in front. In 1864 these furnaces were described as 45 feet (13.7m) high and 11 feet 6 inches (3.5m) wide at the boshes (Percy 1864, 560). The casting house to the left is set back from the other two; this and its corresponding furnace are also larger than the other two which appear to have been constructed as a pair. To the left (north) is the smaller and earlier of the two engine houses, its dimensions suggesting that it housed a beam blowing engine. To the right of the furnaces is a second, larger engine house, housing the engine erected in 1838–40. Adjacent to it the boilers are clearly visible. To the left of the picture coal is being converted to coke in open heaps, the traditional Shropshire method.

Smyth's drawing conveys well the upper level for charging the furnaces and the lower level for tapping them. The gradient of the hillside suggests that it was partly quarried out to exploit the natural topography to better effect when building the furnaces. Two plans of the works show the retaining walls linking the charging houses with the engine houses: a survey of the proposed Shropshire Union Railway made in 1846 and the Madeley tithe map of 1847 (SRRC 6008/35; 2280/2/45).

Both plans agree broadly with Smyth's watercolour. On the tithe map, plateways are shown which illustrate how raw materials and finished goods were conveyed around the site (Fig 83). From the canal, a plateway runs to one of the charging houses, while another continues along the canal past the works and may therefore be an extension of the coke yard or was perhaps where the ironstone was calcined. Another plateway leads from the top of the site to the bottom by means of an inclined plane.

A different method of charging the furnaces is shown in a photograph of the works which must have been taken before *c* 1871 for reasons given below (Fig 84). A continuous gantry is shown at the charging level which links all three furnaces and continues behind the original north engine house. The gantry allowed all three furnaces to be charged from a single point on the charging platform.

Substantial alterations were made at Blists Hill in the early 1870s, which were principally concerned with heightening the blast furnaces. The date of these changes, with the exception of a new engine house, is not entirely clear, however. In theory, the date when the blast furnaces were rebuilt should be discernible in the output figures, since major structural work would be expected to have temporarily reduced the make of iron. In practice this is not so. A 'new furnace account' first appears in the company's annual statements for the year 1870–1 (Staffs RO D876/ADD/3/2, ff 232, 237). In this same year 11,497 tons of pig iron were made, the highest output the works would ever achieve. Since 1868 the output had been above 10,000 tons and it did not fall below that figure until 1872–3, when 9771 tons were made. Not until 1878–9, when the make was a mere 4891 tons and only one furnace was in blast, was there a substantial fall in output, although it should be remembered that the 1870s were a difficult period for the iron trade during which time the market, and thus the output of individual works, was volatile.

In 1873 a new blowing engine was purchased (Staffs RO D876/ADD/3/2, f 254). This was a single-cylinder, twin-flywheel engine, and although there is no mention of the maker's name in the accounts it was said to have been built by J C Stevenson of Preston (Brown 1969, 40). The Madeley Wood Company contracted Stevenson to build other engines in the 1870s and Stevenson was a regular purchaser of Blists Hill pig iron (Staffs RO D876/ADD/3/2; D876/ADD/3/4).

An late 19th- or early 20th-century photograph, viewing the site from the west, shows all the major changes of the 1870s (Fig 85). In front of the furnaces, the original casting houses were retained, a significant fact because it will be used to date the blast furnace bases. The furnaces themselves are larger than before: the charging gantry for the previous furnaces can still be seen in the picture, well below the new charging level. In 1908 Randall described the furnaces as 50 feet (15.24m) high and 13 feet (3.96m) wide across the boshes, a rise of only 5 feet (1.52m) above the earlier furnaces, if either of the figures are accurate (Randall 1908, 472; Percy 1864, 560). At charging level is a continuous gantry.

The photograph also shows that the upper storeys of the earlier charging houses had been demolished. Behind the furnaces is the lift which was evidently used to raise the raw materials from the old to the new, higher charging level. It consists of a cast-iron

Figure 82 Blists Hill blast furnaces by Warington Smyth, 1847. The site is viewed from the north west. The original north engine house is on the left, the taller south engine house with boiler stack is on the right. The northern casting shed and corresponding blast furnace are set back from the line of the other two and are larger. Note the resemblance of the blast furnaces to pottery kilns. (Ironbridge Gorge Museum Trust)

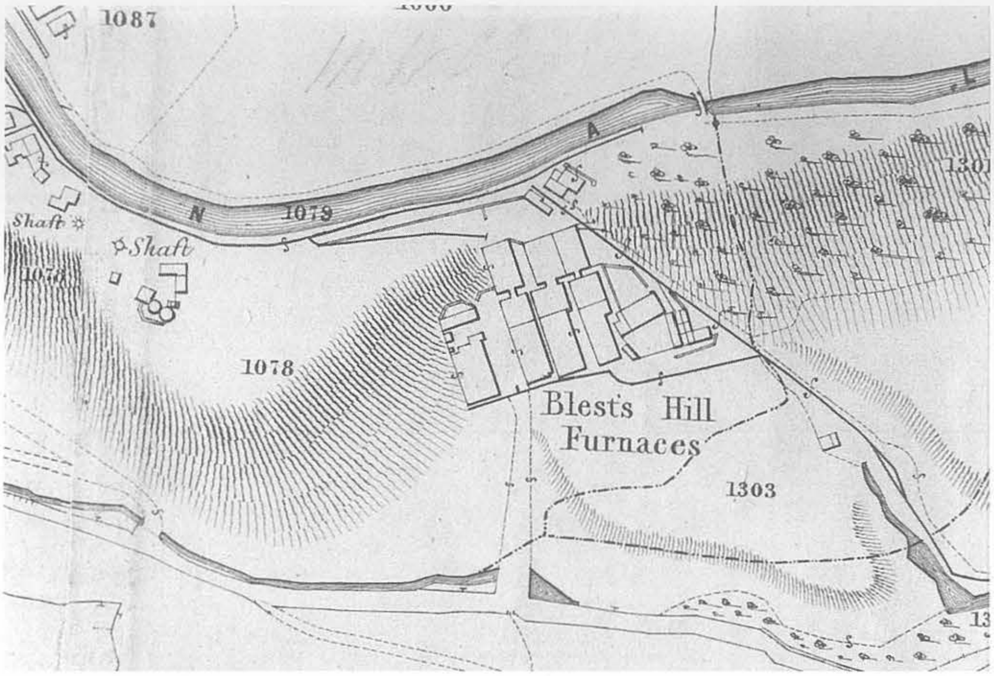


Figure 83 Detail of Blists Hill from the Madeley tithe map, 1847. North is to the left of the picture. Plot 1078 is the coke yard and the mine depicted is Blists Hill Pit. The furnaces with charging and casting houses, and with engine houses on their north and south sides, agrees well with the Smyth drawing. The north engine house is considerably smaller than the south engine house. On the south side is an inclined plane with an engine at the top on the canal side. (Ironbridge Gorge Museum Trust)

gantry with pulleys at either end. Further behind, a large calcining kiln had been built with an iron-girder ramp on its north side. This was powered from a small engine shown on the south side of the charging platform and the inclined plane on the 1902 Ordnance Survey (Fig 86).

The 1902 Ordnance Survey also shows a single building having replaced the earlier charging houses. On the north side of the site was a substantial coke yard, which had grown over time to the extent that by 1902 it had completely surrounded Blists Hill Pit. The Ordnance Survey shows small circular features in between the network of plateways, which denote brick flues, known as 'tunnels', around which the coal was heaped up and which provided a draught of air during the coking process. On the west side of the site is the Coalport branch of the London and North Western Railway, which opened in 1860. Initially the Madeley Wood Company continued to use the canal (owned by LNWR since 1857) for the conveyance of pig iron (Trinder 1981, 153). The incline on the south side of the works, with its engine at the top and a corresponding network of plateways, show that it was still taking pig iron from the casting houses to the canal side at this time. The first edition of the Ordnance Survey, dated 1883, shows plateways from the casting houses leading directly to a railway siding, indicating that the railway received some business from the Madeley Wood Company by this time. The Shropshire Canal remained open for traffic until *c* 1894 but a dispute arose in 1905 between the LNWR, who wanted to abandon the canal, and the Madeley Wood Company, who claimed that when the LNWR purchased it they agreed to maintain it. The Madeley Wood Company appear not to have been interested in keeping the canal navigable, since they agreed in 1907 to keep the Blists Hill section open as a reservoir (SRRC 1681/185/8).

John Randall claimed that in 1908 each of the three furnaces was in blast, producing 4000 tons of pig iron per year (Randall 1908, 472). Knowing that only one furnace was in blast in the final years of the works, Ivor Brown suggested that the other two furnaces must therefore have been blown out in 1908 (Brown 1969, 40). However, this is contradicted by documentary evidence which has not hitherto been easily available (Staffs RO D876/ADD/2 and 3; Riden and Owen 1995, 38–9). The company's output figures to 1902 and the government-compiled official statistics for the iron industry document the slow decline of the works. As noted above, the highest output was achieved as early as 1871, either immediately before or after the enlarging of the blast furnaces, and ironically two years before the new blowing engine was installed. After a peak of 11,230 tons in 1882, when all three furnaces were in blast, output steadily diminished and never reached 10,000 tons again. Until 1901 there were two furnaces in blast almost continuously, but after 1901 only one. In 1902, the last date for which output figures are available, output had fallen to 5713 tons. The works closed in 1912, ostensibly due to a nation-wide coal strike called by the Miners Federation of Great Britain, which shut down all of the collieries in Madeley (*Shrewsbury Chronicle* 15/3/1912, 5).

Deeper reasons for the closure of the works are not hard to find (see Trinder 1981, 240–1). Management could and evidently did use trades unions as a convenient scapegoat. However, the profit and loss figures given in the accounts show clearly that the Blists Hill ironworks could never have been a highly profitable operation – between 1874 and 1902 the works is recorded as making a loss in all but three years (Staffs RO D876/ADD/3). The Madeley Wood Company's primary business was its collieries, not its blast furnaces. Nevertheless the company suffered

Figure 84 Blists Hill blast furnaces photographed before 1871 from the west side. The south engine house and boilers are on the right, the north engine house and stack on the left. Note the continuous gantry at charging level, in front of the charging houses, linking the same blast furnaces shown by Smyth. In the foreground is the Madeley Wood Company timber yard. (Ironbridge Gorge Museum Trust)

in the same way as other ironmaking concerns in the East Shropshire Coalfield: it had a dwindling supply of native raw materials (especially ironstone) and it was unfavourably situated with regard to importing raw materials in the quantity and quality necessary for a profitable business. The steady decline in output from the 1870s onwards is a graphical demonstration of this.

The company's accounts indicate that local ores were used for smelting, although tiny quantities of imported hematite were being used in 1875, perhaps only for experimentation (Staffs RO D876/ADD/3/2, f 279). Other than hematite, the ores were Crawstone, Pinneystone, and Blackstone, the same combination that had been used at Bedlam and on which the company built its reputation for high quality grey-melting pig iron. By 1886 supplies of Crawstone, the best of the ores, appear to have been worked out because subsequently only Pinneystone and much smaller quantities of Blackstone were used (Staffs RO D876/ADD/3/2).

In 1920 the Madeley Wood Cold Blast Slag Company began crushing slag at the site for use as ballast, probably to the west of the furnaces near the railway (Baugh 1985, 55). In 1943 the company was sold to Coalmoor Basalt Ltd who continued operations (IGMT 1989/3436, ff 166–7). As to the works itself, its history after closure is known largely from photographs. Two photographs taken in 1918 show the removal of a large boiler by Screen Brothers of Oldbury in Worcestershire, and it is tempting to suggest that they purchased the engines as well (Fig 87). By 1918 the furnaces had also been dismantled to the level of their bases and most of the buildings had been demolished, the wrought- and cast-iron fixtures having been salvaged for scrap. It is possible that the site was not cleared until near the end of the 1914–18 war because it could have been needed to renew operations for the war effort.

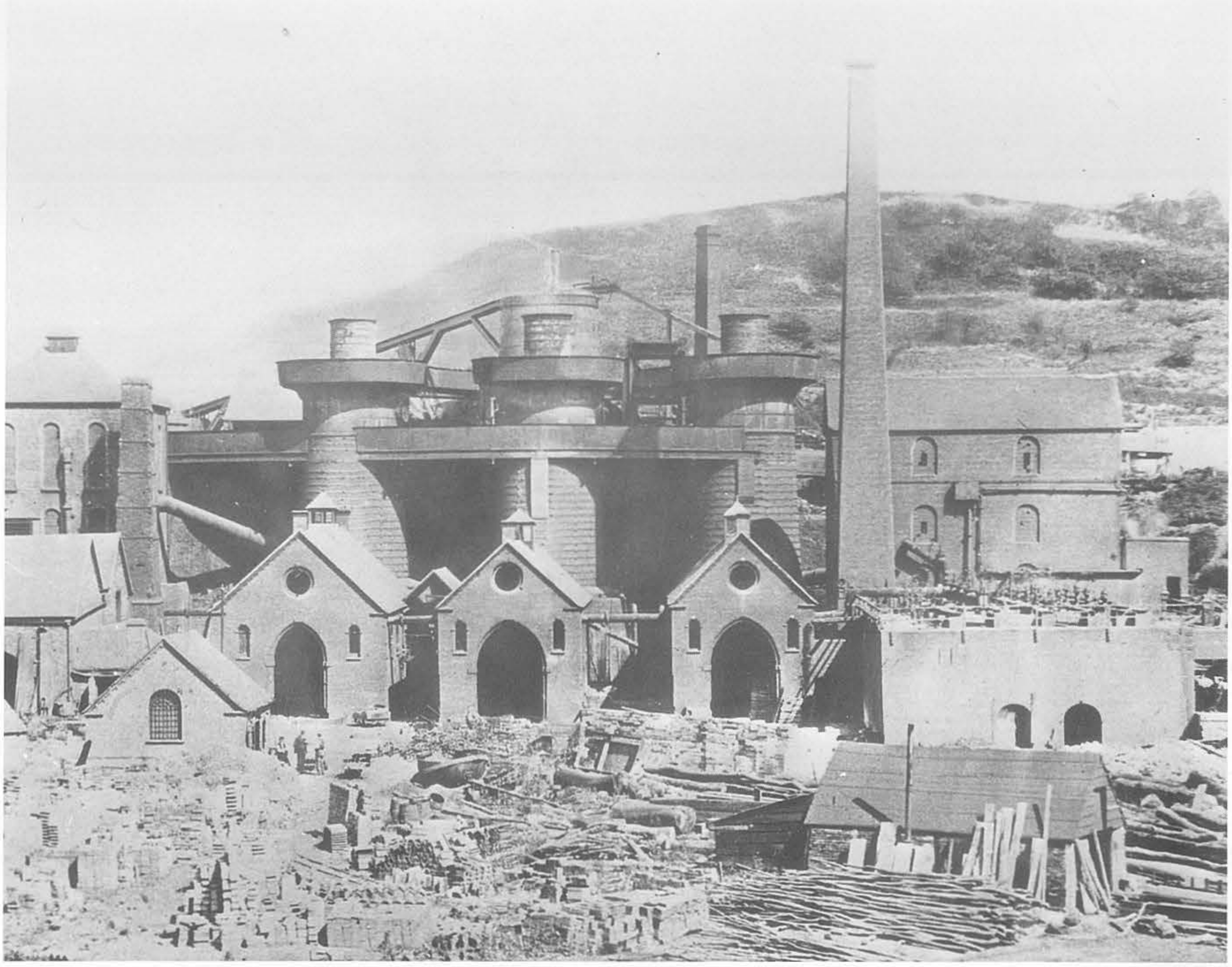


Figure 85 Blists Hill blast furnaces in the late-19th or early-20th century, photographed from the west side. The south engine house is on the right, the new north engine house on the left. The furnaces have been rebuilt and are higher than previously, as shown by the gantry at the earlier charging level. The original charging houses have gone. Between the centre and right furnaces is the superstructure of a lift to the new charging level. Behind the central furnace is a calcining kiln with ramp on the north side and winding cable on the south side. In the background is the stack of the incline engine. (Ironbridge Gorge Museum Trust)

After its clearance, the site quickly became overgrown and the ground level around the furnaces became considerably raised. The stack beside the south engine house was demolished sometime between 1957 and 1959. During the 1960s Blists Hill was used as a landfill site by the Telford Development Corporation, causing considerable damage to the western part of the site. Photographs of that period show the blast furnaces buried and the engine houses ruinous (Fig 88). In 1969 Blists Hill was chosen as the site for an open-air museum and restoration at the site began in 1971.

The site

The ironworks is structured around the three blast furnaces, which stand together in a line with the north and south engine houses at either end (Fig 89). On the east side the ground is higher and consists of charging houses with retaining walls linking them to the engine houses, thus forming a curtain around the furnaces. The site is bounded to the east by the Shropshire Canal and to the south by an inclined plane.

The natural topography of the site can be examined in some detail and is relevant to the siting of the ironworks because hitherto Shropshire blast furnaces had traditionally exploited natural contours, providing a convenient charging level. The canal was operational by 1792 and follows the natural contour of the hillside. Smyth's watercolour suggested that the furnaces had been built into the hillside and that the charging level was above the pre-industrial ground level. Evidence of the groundworks supports this interpretation. Borehole investigations suggested that the natural ground forms a near vertical plane behind the charging houses, which is unlikely

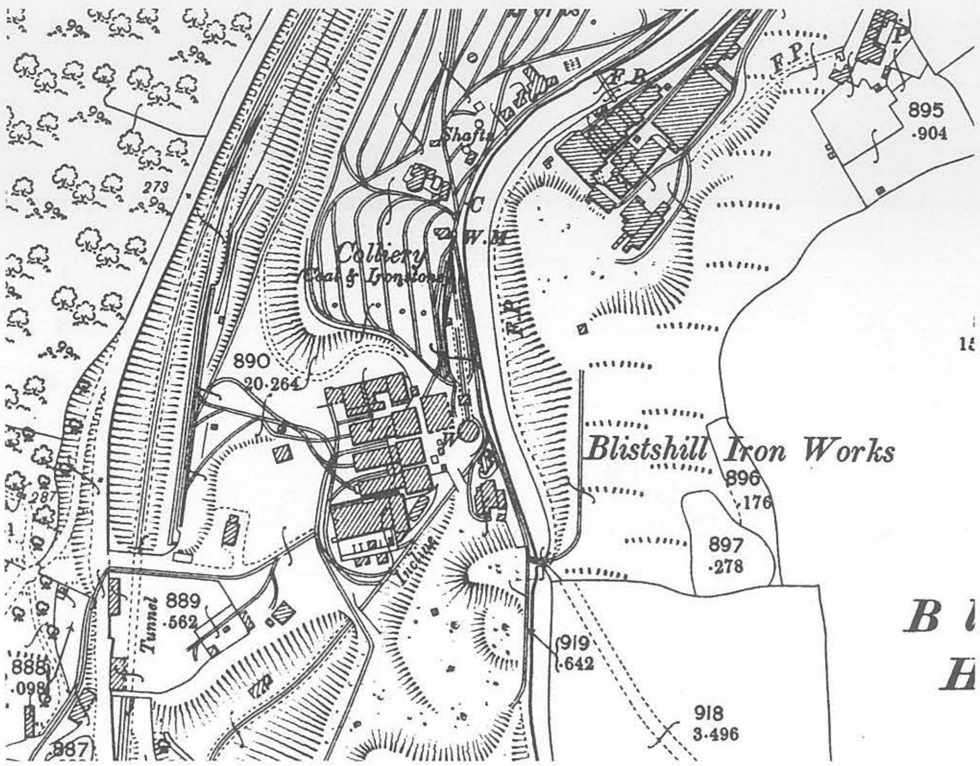


Figure 86 Detail of Blists Hill from the Ordnance Survey, 1902. The charging houses have gone, to be replaced by a building on the north side and the round calcining kiln. Structures on the south side of the incline represent the winding engine for the kiln ramp.

to have been a stable natural profile, strongly suggesting that the hillside was partly excavated to make a convenient charging platform (Fig 90). This information was confirmed when anchor holes were drilled into the retaining walls linking the charging houses with the engine houses and revealed natural clay and mudstone at 3–5m behind the face of the wall, even near the bottom, with possible colliery waste dumped as a backfill immediately behind the wall. The materials preparation area was probably originally focused on the north side of the site, as it was in later years (Fig 86). The inclined plane south of the engine house is bounded on the south side by a rubble-stone wall and cubical blocks of cold-blast slag. Whether the incline existed in its present from as early as 1832 is uncertain.

Blast furnaces

The blast furnace bases are square in plan, with battered walls of hammer-dressed sandstone and splayed openings in each face – on the west side to the forehearths, on the remaining sides to the tuyères (Fig 91). Beyond the openings for the tuyères each furnace has brick shafts leading to a network of tunnels beneath the furnaces (Fig 92). Brick paving largely surrounds the furnaces, although there are discrete areas of compacted soil. Furnace I is the largest of the three furnaces and is set back from the line of furnaces II and III, which share the same plan dimensions.

The main axis of the tunnels runs directly beneath the centre of furnaces II and III, then continues under furnace I after a short link (Fig 92). Three shorter tunnels are at right angles to the main section, running eastwards beyond the tuyère openings on the east side of each furnace. The tunnels are brick-built and barrel-vaulted. At the base of the shaft on the east side of furnace II is a short length of blast main 3.7m long between the shaft and the centre of the furnace. The tunnels are self draining: At the junction of the tunnels beneath furnace I is an integral brick-vaulted culvert leading westwards for approximately 5.0m, at which point it has collapsed. The tunnels pass directly beneath the furnace hearths and served the important function of preventing water seeping from the ground into the hearth. Cast-iron plates below the hearths are not integral with the vaults of the tunnels and were probably renewed whenever the furnaces were relined.

Furnace I is clearly the earliest as it stood adjacent to the earlier north engine house and is therefore dated 1832 (Figs 82 and 84). The main doorway of its casting shed is said to have had the date 1832 on the keystone (Randall 1908, 471). Furnaces II and III were built as a pair but documentary evidence suggests they were blown-in in 1840 and 1844. An alternative argument, that the bases were built in the 1870s when the later furnace stacks were erected, has little to recommend it: The original casting houses survived into the 20th century and would most likely have been demolished if the

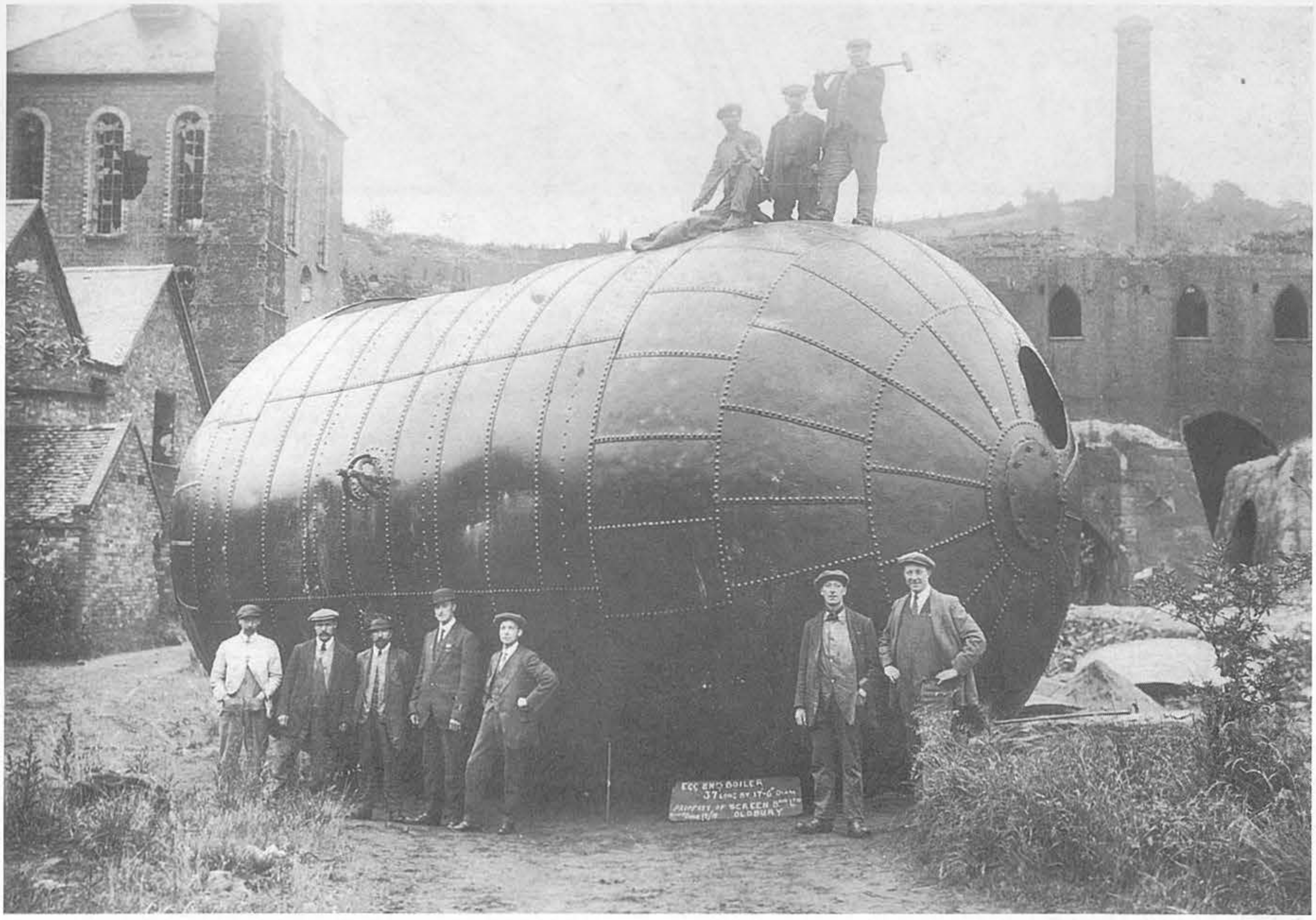


Figure 87 Removal of a boiler in 1918 by Screen Brothers of Oldbury. Note the arched forehearth and tuyère recess to the blast furnaces, partially obscured by the boiler end. The north engine house on the left shows part of a window jamb taken out when the steam pipe was removed. The building on the left with the two-span roof remained in use as a workshop. In the background is the stack of the incline engine. (Ironbridge Gorge Museum Trust)

original furnace bases had also been demolished. The tunnels are integral with the furnaces above them and show how air was distributed to the tuyères. Of the distribution of air from the earlier north engine house to furnace I little can be known except the obvious point that the blast main is most likely to have descended into the tunnels through the shaft on the north or east side of the furnace. From 1840 the source of the blast main was on top of the retaining wall east of the south engine house (see below). The blast main then probably entered the tunnels through the shaft on the south or east side of furnace III.

Each of the blast furnaces was blown on three sides. The openings to the furnaces were originally arched (although the 1970s restoration has rendered this far from obvious), as can be seen in a photograph showing the removal of a boiler (Fig 87). In its final phase furnace II was blown by a pair of tuyères on the east (rear) side, probably with single tuyères on the other sides. The corresponding double aperture to furnace I is modern, although it appears to replicate its final form when the furnace was in blast. The linings of each furnace contain firebricks made in Stourbridge, a well-known centre of fire-brick manufacture in the 19th century. They cannot be earlier than the 1870s because the furnaces must have been completely relined when they were heightened. An account published in America in 1912 claimed that one of the furnace linings was then 27 years old, although it was not necessarily a furnace in blast (Leese 1912, 108).

Only fragmentary evidence of the casting houses survives above ground. Although no tap holes are now extant, furnaces I and II each have walls which bisect their respective forehearths. A similar feature was illustrated by William Truran in 1855 in his description of blast-furnace design: on one side of the wall was a plateway on which the cinder tubs for the conveyance of slag would run; on the other side were the pig beds (Truran 1855, plate 36).

Charging houses

The north charging house is built of brick on two piers of coursed sandstone spanning a shallow blind arch of rubble sandstone (Fig 93). There are two

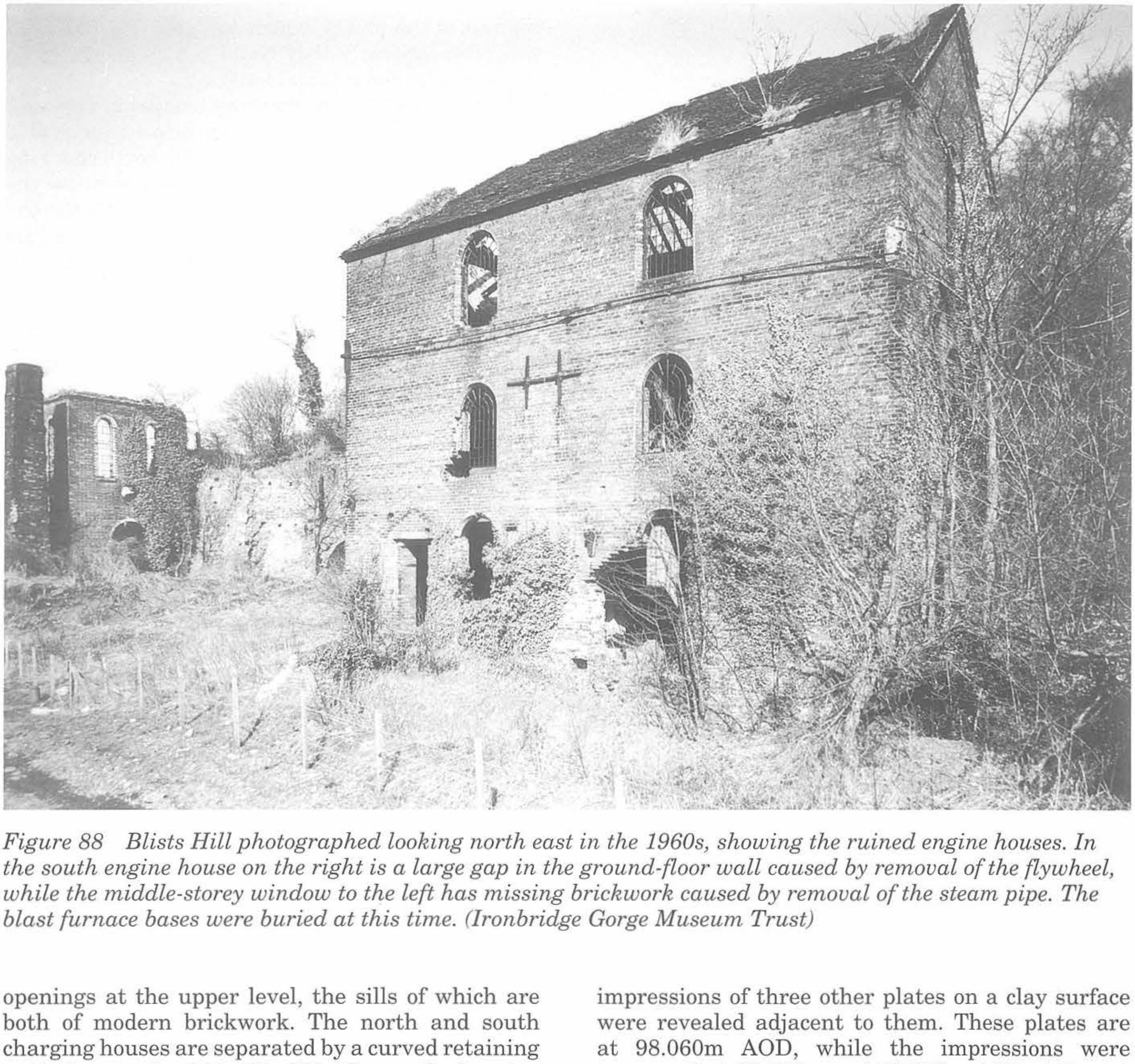


Figure 88 Blists Hill photographed looking north east in the 1960s, showing the ruined engine houses. In the south engine house on the right is a large gap in the ground-floor wall caused by removal of the flywheel, while the middle-storey window to the left has missing brickwork caused by removal of the steam pipe. The blast furnace bases were buried at this time. (Ironbridge Gorge Museum Trust)

openings at the upper level, the sills of which are both of modern brickwork. The north and south charging houses are separated by a curved retaining wall of coursed rubble (Fig 89). The north charging house is butted by a curved retaining wall which continues beneath the north engine house. Like the north charging house, the south charging house is of brick on piers of coursed sandstone which span two recessed bays under keeled brick tunnel vaults. The right-hand bay has a U-shaped brick counterweight pit inside it (Fig 93).

The purpose of the charging houses was to assemble the raw materials and keep them dry. The chambers below the charging level contained blacksmiths' hearths and other workshops for maintenance. The outlines of the charging houses became clearly discernible on the charging platform once it had been cleared of soil and vegetation (Fig 94). The charging house walls are of rubble stone below the former ground level, brick above. The north charging house has brick flues in the north and east walls. Enclosed by the charging house walls are several cast-iron plates. Two of the plates appeared to be *in situ*, as they respect the walls of the building and the impressions of three other plates on a clay surface were revealed adjacent to them. These plates are at 98.060m AOD, while the impressions were measured at 98.110m and 98.070m AOD. Adjacent to them the jambs of a doorway, with their possible pintle, were revealed at approximately 97.9m AOD. The plates could therefore plausibly have been integral with the north charging house, dating them to 1832.

The south charging house is divided into two units of roughly equal size by a central wall and contains small brick structures inside it (Fig 94). Within the south bay is an exposed jack arch in a grey mortar, within which there is a large rectangular cavity above the shaft to the counterweight pit. Several cast-iron floor plates, or fragments of plates, were found. The southernmost of the openings in the east wall revealed core stonework at 97.91m AOD. The charging level, and the cast-iron plates, must have been above this level since the opening probably had some form of threshold, probably brick or cast iron. Although the extant plates were discovered at levels between 98.35 and 98.73m, none of them could be related to the walls of the building, except the

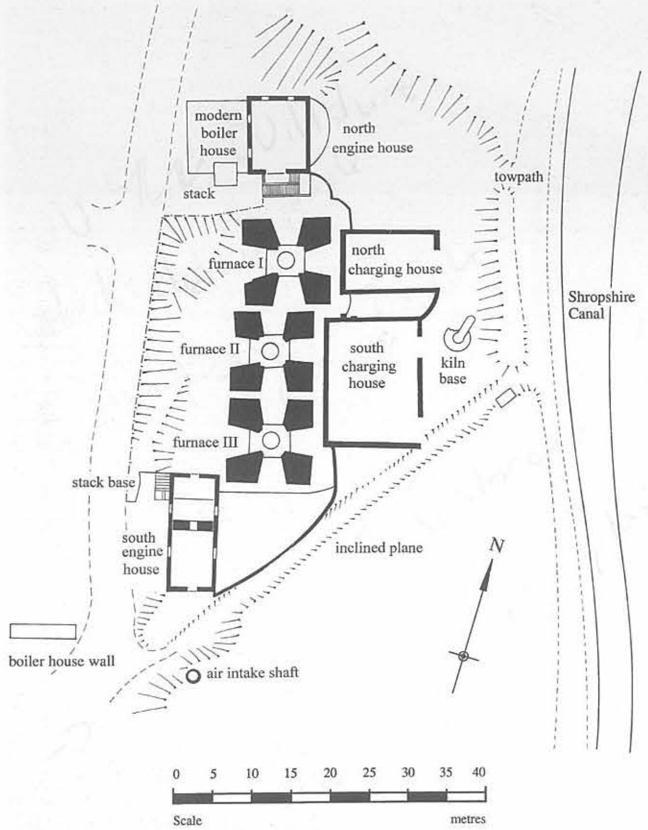


Figure 89 Blists Hill blast furnaces site plan. The charging houses and engine houses are all linked by retaining walls. West of the south engine house are vaulted chambers below ground and beneath the former boiler settings.

highest of the plates, which was laid over the east wall. Consequently they could not be shown to be integral with the original building.

The openings to the charging bridges in the west walls were not discovered due to the poor survival of the wall (Fig 93). The west wall of the north charging house rose to 97.78m AOD, compared with the suggested height of approximately 98.1m for the charging level. The west face of the south charging house rose to a height of 97.7m AOD compared with a suggested height of above 98.0m.

North of the north charging house is a small structure with a brick wall bonded in a pink lime mortar, roughly parallel with the charging house walls, and enclosing a small area of brick paving (Fig 94). Further north, and adjacent to the pit on the east side of the north engine house, is another small structure paved principally with worn refractory bricks. These structures do not appear on the tithe map but were built before the 1870s as they are shown in the early photograph of the works (Figs 83 and 84). They are probably contemporary with the heightening of the retaining walls here, discussed below in relation to the north engine house.

Superimposed on the north charging house was evidence of a later building, comprising two brick piers on the east side and a north wall beyond the north wall of the charging house. Evidence of the south or west walls was not found. This building belongs with the demolition of the charging houses and heightening of the blast furnaces in the 1870s. The new open-sided building is shown on the Ordnance Surveys of 1883 and 1902 (Fig 86). According to the 1883 Ordnance Survey a plateway entered the east side of the building and then emerged from the

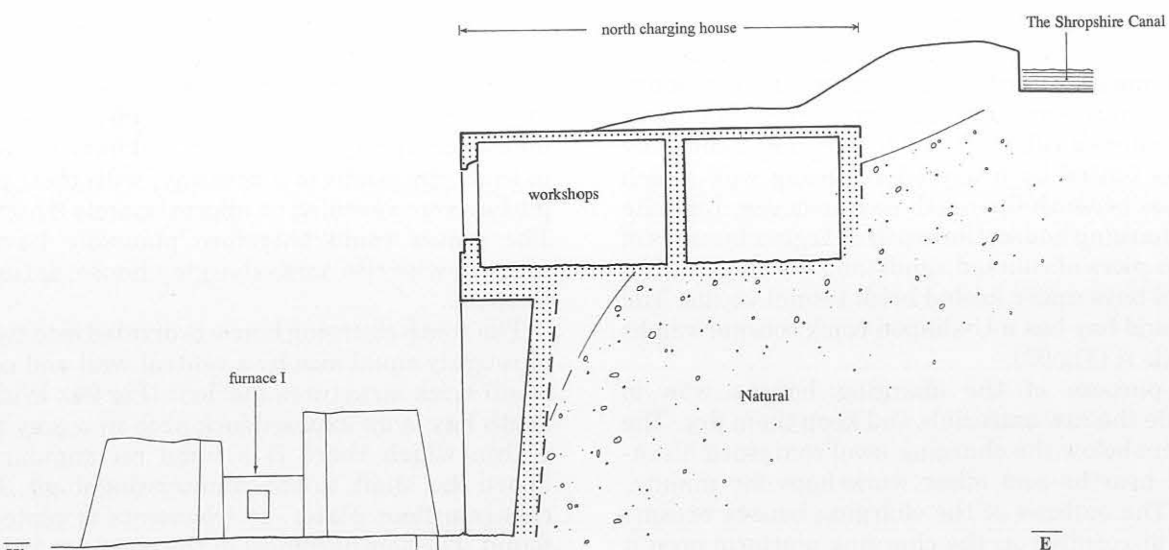


Figure 90 Profile of the natural ground in relation to the north charging house and furnace I, after a drawing by Wheatley Taylor Stainburn Lines architects. The drawing is based on evidence provided by borehole investigations in 1992 and was confirmed during drilling for anchors in 1994.

Figure 91 The blast furnace bases with the charging houses behind, photographed looking east in 1997 after repairs to the charging houses.

south side, passing over the unroofed space between the two former charging houses, continuing southwards over the inclined plane. The bridge over the inclined plane is shown on the 1902 Ordnance Survey (Fig 86). No evidence of the plateway is now visible, but some evidence of where the bridge crossed the inclined plane survives (Fig 94): In the south wall of the south charging house are four courses of bullnose bricks, bonded in a buff-coloured mortar distinct from the otherwise grey mortar of the coursed stone wall. The bullnose bricks must define the west side of the bridge over the inclined plane, which must therefore have passed directly over the entrance to the easternmost of the chambers beneath the charging platform (Fig 95). The consequence of this was that when the bridge was demolished so too was the arch or lintel over the entrance to the chamber.

After the earlier buildings were demolished a new floor must have been laid across the charging platform, almost certainly of cast-iron plates. The north wall of the original north charging house was exposed at between 98.27m and 98.49m AOD. The new floor level must therefore have been higher than this, although there were no archaeological deposits *in situ* at this level. In the former south charging house the core of the dividing wall was exposed at 98.70. Only one of the plates, above the east wall of the original building, can therefore be ascribed to this phase, although even this could have been redeposited. The remainder therefore belong to the debris of abandonment in 1918.

Absence of evidence for plateways on the charging platform demonstrates the extent of clearance that followed the closure of the works, a factor which has a considerable bearing on the interpretation (or apparent lack of it) of the charging platform lift. The photographic evidence for the lift has been discussed (Fig 85); the archaeological evidence is equally slim. The lift was located above the void in the charging platform. The shaft descends through to ground level, where it is defined by the U-shaped counterweight pit (Figs 93, 94, and 95). Above this feature are butt joints in the vaulted ground-level bay, indicating its partial rebuilding in the form of a circular opening, integral with which are sockets in the wall below the vault, suggesting a platform above and around the pit. A shaft from the charging platform down to the lower ground level probably allowed a counterweight for the lift to ascend and descend. If this is correct, the platform above the counterweight pit could have allowed access to the weights for maintenance.

The photograph of the lift suggested that it comprised a gantry with pulleys at either end, in which case there could have been two counterweights (Fig 85). The lift would have been a small one. Its purpose was to take the charging barrows,

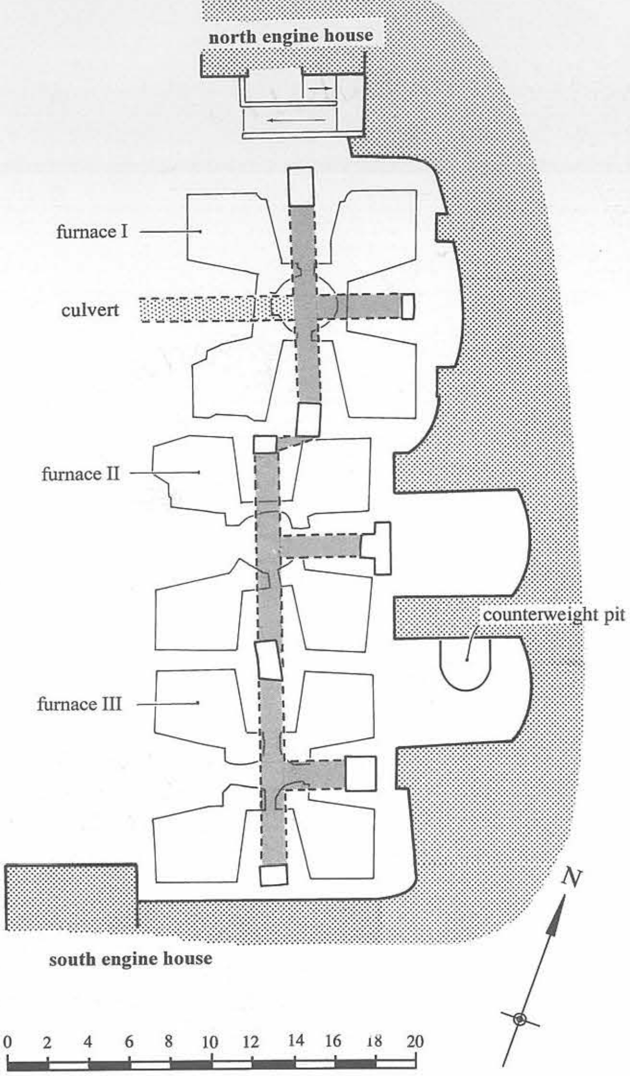


Figure 92 Plan of the blast furnaces showing the blast-main tunnels in relation to shafts at ground level. Note the awkward junction between furnaces I and II.

perhaps only one at a time, up to the new charging level where the barrows were wheeled across separate gantries for each furnace. The lift would not necessarily have needed motive power. It could just as easily have been worked manually with a crank handle. Alternative power sources might have been hydraulic or pneumatic, but unfortunately the evidence for these is nil. Near the shaft, several displaced sections of brickwork were found, which were probably originally part of the footings of the gantry that served the heightened furnaces.

In the south wall of the charging house is a doorway into the chambers below the charging platform (Fig 95). The chambers are constructed of random rubble walls. In the south charging house, the passage on the east side has a keeled brick tunnel vault; otherwise the chambers all have brick jack-arches supported on cast-iron T-section beams.

The hearths in the chambers below the charging platform are not all of the same phase (Fig 95). Of the two hearths in the north charging house, the hearth in the north-east corner of the west chamber is probably integral because its stack is integral with the north wall of the north charging house (Figs 94–96). The larger hearth in the west wall must be later because its flue ascends in the middle of the west wall of the building, exactly where the bridge originally crossed from the charging house to the furnace. The hearth and flue must therefore have been inserted after the open charging platform was created by demolishing the original buildings in the early 1870s. A hearth in the south charging house is integral to the building.

A small fireplace in the east chamber of the north charging house is probably not integral with the original build, since its flue, as visible on the charging platform, is not integral with the charging house wall (Figs 94 and 95). However, its position would also have interfered with the open-sided building added in the 1870s, as suggested by the position of the pier on its north side. Perhaps the fireplace enjoyed only a short period of use.

North engine house

The north engine house was built in 1873 almost exactly on the site of the original 1832 engine house (Fig 97). Several features earlier than 1873 have survived. The extant square brick boiler stack is shown by Warington Smyth and is 17.5m high (Fig 97A). It must have been built in 1832 to serve the original boilers. The engine house stands on a high plinth, which is of brick except on the south side where it is rubble stone continuous with the retaining wall between the engine house and the north charging house, and probably therefore of 1832. The east wall of the present building faces a semi-elliptical pit bounded by a random rubble retaining wall. It was found to contain loose fill, primarily brick and tile debris from the 1971 rebuilding of the engine house roof (Fig 97C). Excavation revealed that the retaining wall consists of two builds separated by a ledge. The tithe map shows, on the east side of the original north engine house, the semi-elliptical shape of the pit, suggesting that the east wall of the extant north engine house was built above the foundation of the earlier building (Fig 83). The lower stage of the retaining wall would therefore appear to be contemporary with the original north engine house. A brick floor continues beneath the engine house wall. A brick plinth is built on this floor directly beneath a shallow buttress in the engine house wall and has four holding-down bolts (Fig 97B). The purpose of the plinth was probably to support the gantry shown in the pre-1871 photograph (Fig 84), which passed directly over it and was secured by the holding-down bolts. If so, it is probably contemporary with the heightening of the

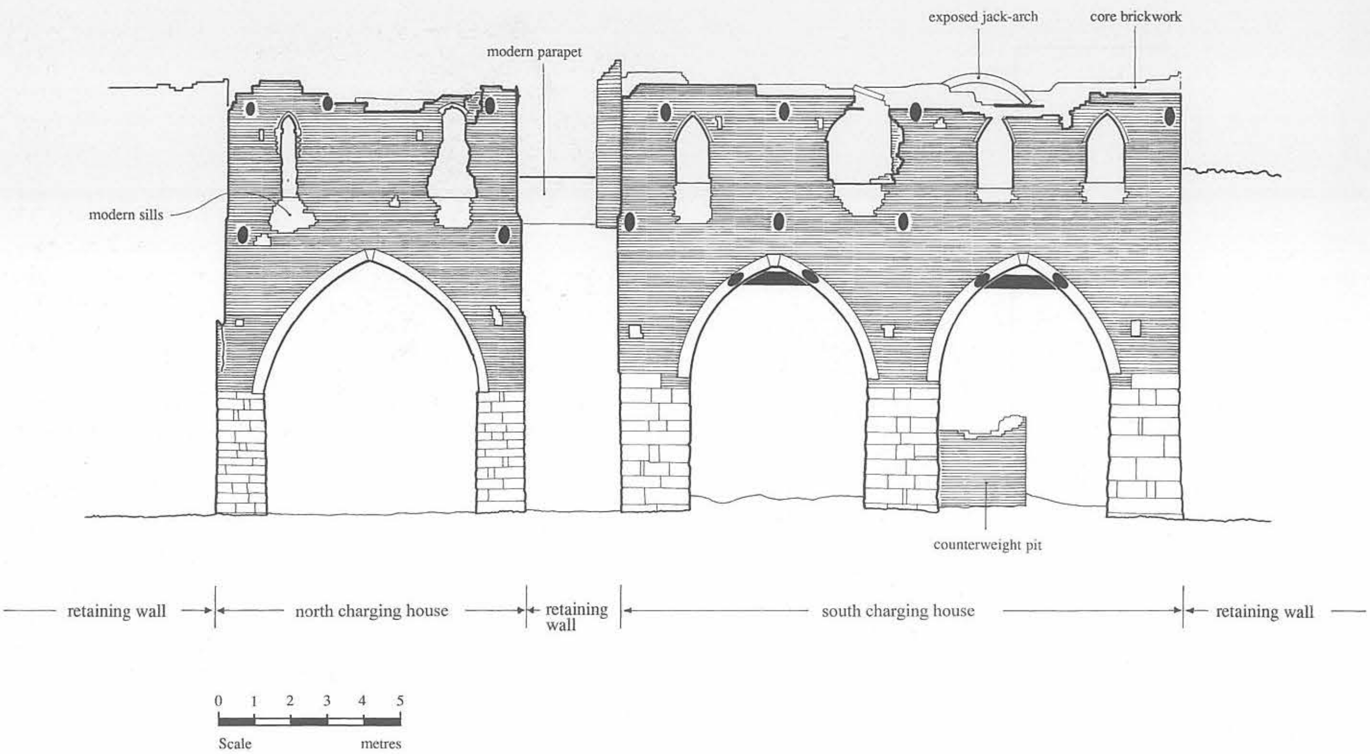


Figure 93 West elevation of the charging houses facing the blast furnaces. The large opening in the north charging house is a shallow blind arch with recessed rubble-stone infill. By contrast, the south charging house has tunnel-vaulted chambers, the vaults strengthened by cast-iron beams. The position of the lift installed in the 1870s is denoted by the counterweight pit and the exposed jack arch above caused by the removal of the lift.

retaining wall defining the pit and the heightening in brick of the retaining wall between the north engine house and north charging house (Fig 97A).

The north engine house is a tall single-storey building of red brick with white-brick dressings (Fig 97). It has a modern hipped tile roof (added after the engine was inserted in 1971) and round-headed windows with small-pane glazing in iron frames. In the front wall, facing south, is a cavity with a modern cast-iron pipe inserted into it (Fig 98). At ground level is a round-headed doorway reached by a dog-leg stair of brick, most of which was rebuilt in the early 1970s. The stairway butts against the engine house plinth. On the west side is a modern boiler house abutting the plinth, and partly enclosing the stack (Fig 97A). In the two-window north wall of the engine house the openings are boarded and not glazed and a retaining wall abuts the north-east angle.

The interior is of white brick with bands of red brick. The vertical engine installed in 1971 stands on a modern concrete floor. On the north side is an integral brick partition wall one brick thick, behind which is a narrow passage 0.8m wide. The partition wall is faced in white brick with red brick bands and has a large cavity at a high level.

The north engine house exhibits few alterations from its original build. It is unfortunate, from an archaeological perspective, that a new concrete floor was laid in 1971 before the engine from Priorslee was installed, since valuable evidence lies (or lay) beneath it in the form of engine mountings and flywheel pits. However, there are minor features which can be interpreted to explain something of how the engine worked (Figs 97 and 98).

The steam pipe formerly entered the building on the west side, adjacent to a window jamb. Its removal *c* 1918 necessitated rebuilding part of the wall in the 1970s (Fig 87). Air was taken into the building on the north side, where there is no evidence that the two openings, now boarded up, were ever glazed. The internal partition wall is integral with the original build and its purpose was probably to help control the flow of air to the engine. Air was probably drawn in through the windows and was sucked up to a high-level opening in the centre of the partition wall, in which the engine's air intake pipe was inserted. It has been suggested that cloth was hung over the openings in the north wall to prevent objects entering the intake pipe and fouling the engine (Winkworth 1990, 10). The air outlet is better understood: the blast main was inserted through the south wall, where a modern pipe has been reinstated (Fig 98).

Pictorial evidence and the extant stack demonstrate that boilers were located on the west side of the original engine house (Fig 82). However, steam for the new engine was probably raised from the boilers beside the south engine house. The photograph taken in the late-19th century shows a steam pipe from the boilers passing through the casting houses to the north engine house (Fig 85). By 1873,

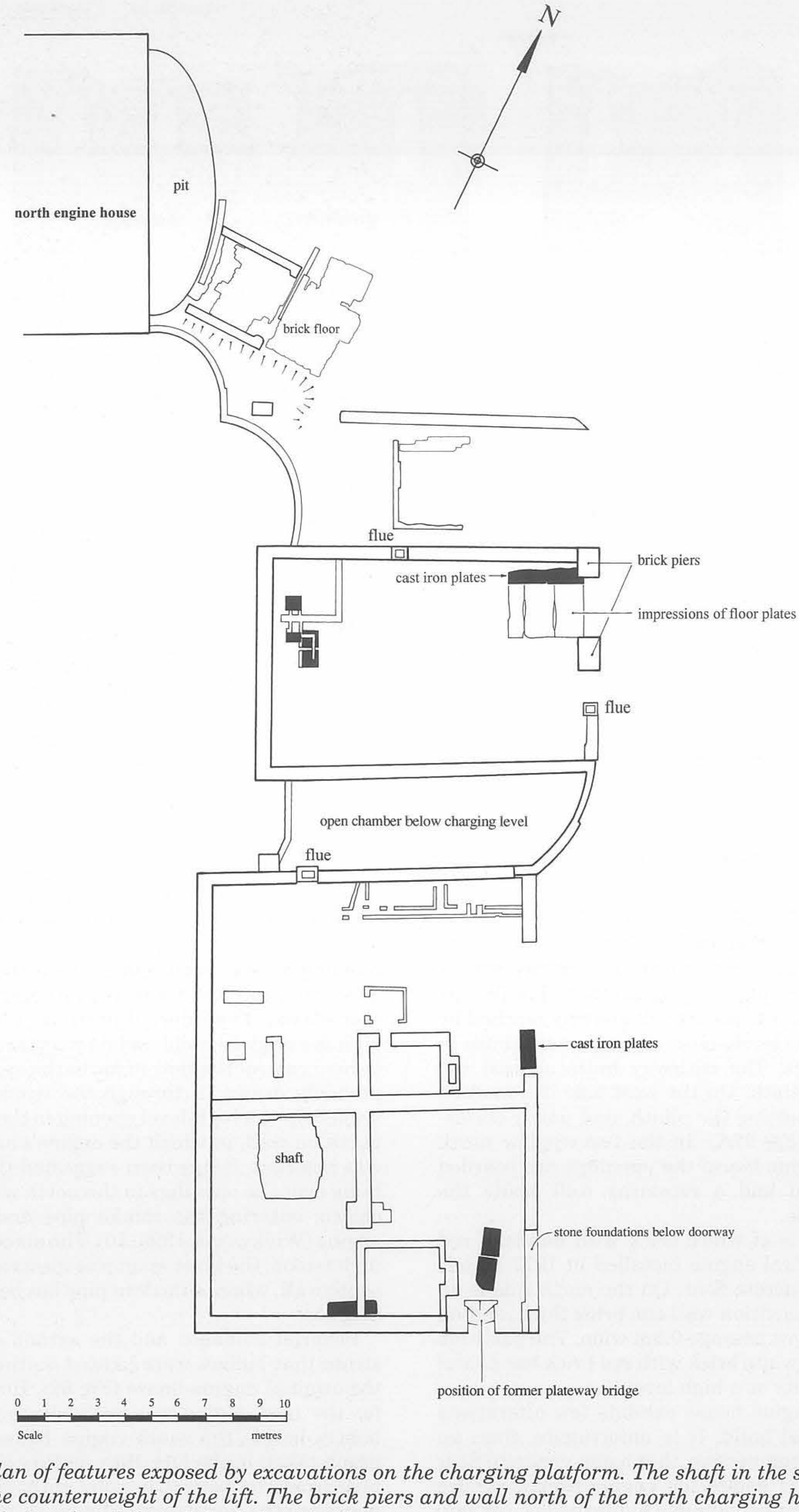


Figure 94 Plan of features exposed by excavations on the charging platform. The shaft in the south charging house is for the counterweight of the lift. The brick piers and wall north of the north charging house belong to the building that replaced the original charging houses.

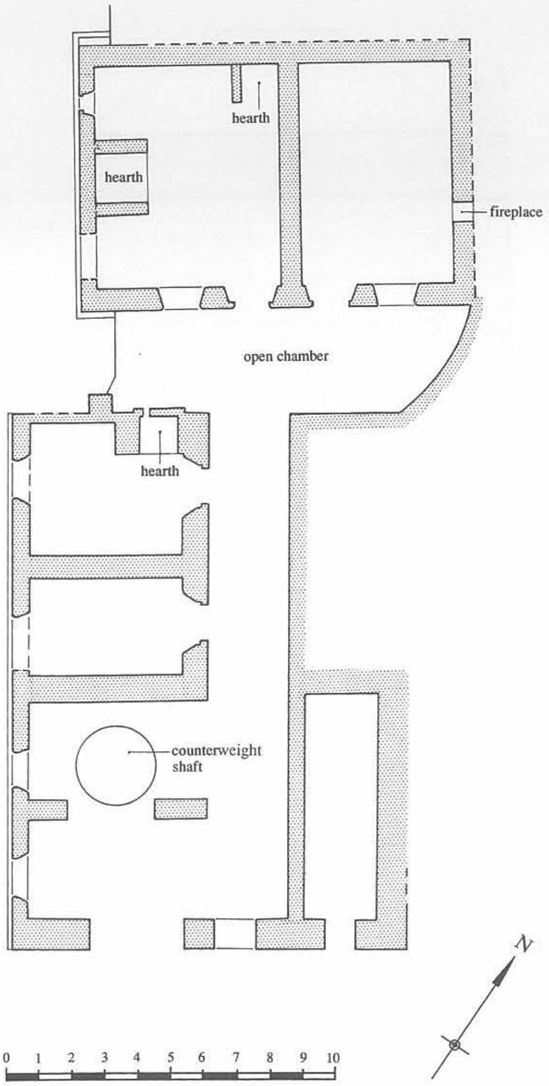


Figure 95 Plan of the chambers below charging level in the north and south charging houses.

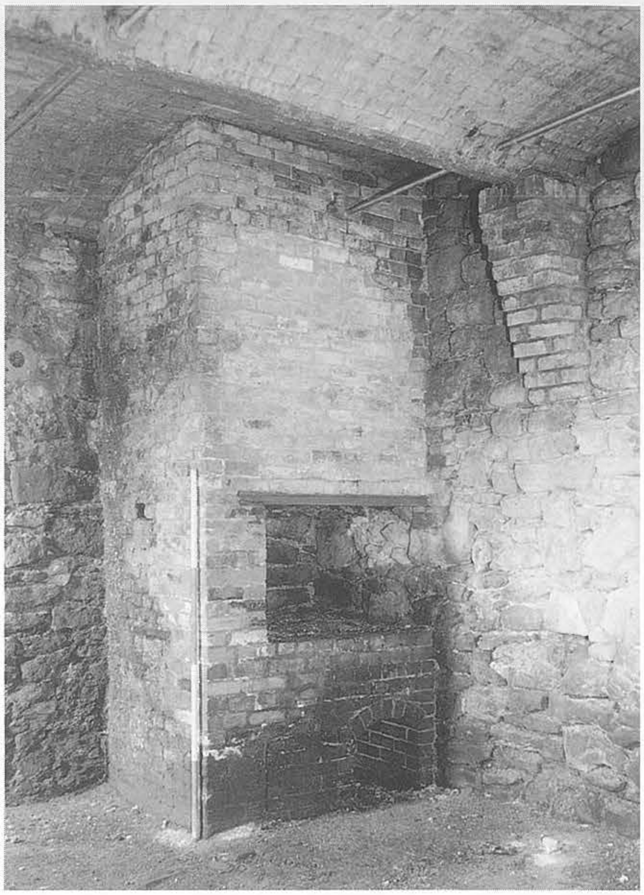


Figure 96 Blacksmith's hearth below the charging level in the north charging house, with brick jack arch above.

the old boilers would have been idle for some thirty years and are unlikely to have been reused. There is no mention of new boilers in or after 1873 in the Madeley Wood Company's annual accounts (Staffs RO D876/ADD/3/2 and 3). It is important to point out, however, that oral testimony contradicts this argument, claiming that a boiler was situated in the original boiler house (IGMT T42). The same source also adds that the original boiler house was also used as a brass-moulding shop where bearings were made for the machinery used at the works and Madeley Wood Company collieries and brick and tile works, a practice that continued after smelting at the works had ceased. There has been no archaeological investigation of this area, however, which is now occupied by the modern boiler house.

South engine house

The tall south engine house is of three storeys and two bays on a high plinth (Fig 99). The fabric is brick, with a roof of modern tiles. Some round-headed windows retain small-pane, iron-framed glazing. Against the west wall are brick steps to the main doorway, which are in turn butted by the base of a boiler stack (Fig 99B). In the south wall is a large doorway under a pointed arch with a keystone dated 1840 (Fig 99A). The east wall has a doorway under a round head and with modern jambs (Fig 100A). Flanking the doorway are round openings for blast pipes in the plinth, of which the opening to the south is considerably larger, of 1.45m diameter. Beneath the ground-floor window is a cast-iron condenser feed pipe.

The interior is divided into two bays by the bob wall of coursed masonry (Figs 100 and 101). The power cylinder was located on the north side of the bob wall and was mounted on a cast-iron bed plate which was secured to the engine bed by means of four holding-down bolts, of which two survive (Fig 100B). The steam pipe entered the building on the west side, where the boilers were situated, and adjacent to the northernmost window in the middle storey (Fig 99B). The condensing cylinder and an adjacent air and water pump were positioned below the power cylinder in the condenser pit, which is 4.5m deep (Fig 100A). The condenser pit would have been covered with a floor (possibly of cast-iron

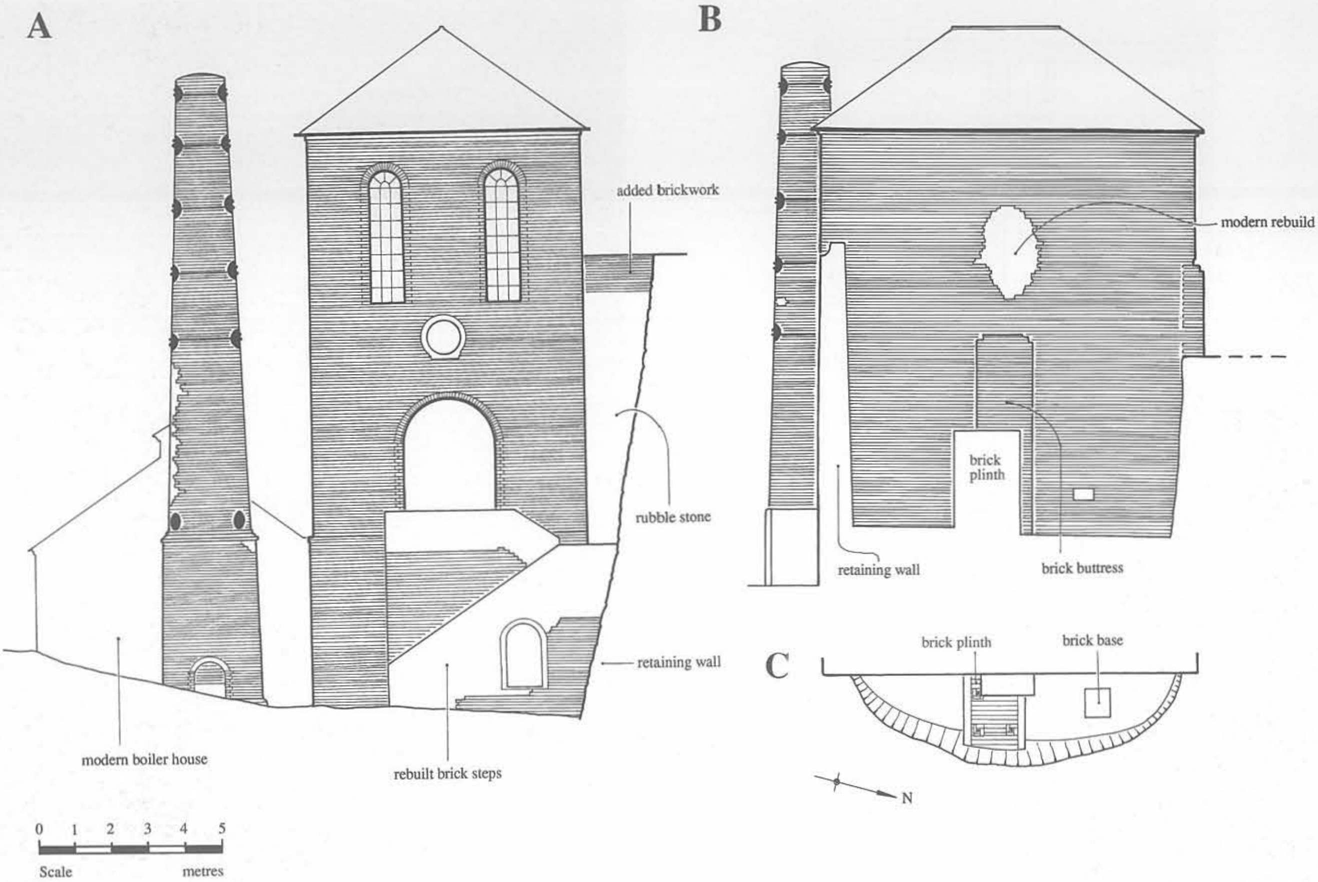


Figure 97 South (A) and east (B) elevations of the north engine house and stack, and plan (C) of the pit on the east side of the engine house. The south side incorporates the opening for the blast main. The pit on the east side predates the present building and its brick plinth supported the end of a charging gantry.

plates) so that the condensing cylinder and the water pump were concealed. The cylinder and pump were supported on three beams, the broken-off, cast-iron sockets of which are visible in the bob wall (Fig 101). The condenser feed pipe is in the east wall and can be followed across the paved area east of the engine house, where it emerges from the retaining wall. The source of the water must therefore have been the Shropshire Canal, for which there is also some indirect historical evidence, the Madeley Wood Company having insisted that the Shropshire Canal here be maintained as a reservoir (SRRC 1681/185/8).

The archaeology on the south side of the bob wall indicates that a flywheel and two blowing cylinders were installed there (Fig 100B). The flywheel pit is on the west side. It has a tunnel beneath it, access to which is from the condenser pit on the opposite side of the bob wall (Fig 101). The position of the blowing cylinders, which would have been mounted on a cast-iron bed plate, is defined by four holding-down bolts with a deep pit between them (Fig 100B). These blowing cylinders were probably double-acting and worked thus: air was drawn in on the south side of the building through a pipe in the large circular opening which was housed in the deep pit below the cylinders (Fig 100A). A brick air intake shaft has survived on the south side of the building (Fig 89). From the blowing cylinders it was conveyed in a large and a small cast-iron pipe in the east wall of the building (Fig 100A). The different diameters of the blast main openings corresponded to the different diameters of the cylinders. By having two blowing cylinders it is possible that the need for a blast regulator, obligatory in early blowing engines of the late-18th and early-19th centuries, was obviated. There is certainly no evidence for a blast regulator and there is no obvious space which it could have occupied, there being little space between the south engine house and furnace III.

At second-floor level the pivot for the beam is missing but the spring beams are *in situ*. The two spring beams are each made up of two dovetailed sections. At eaves level are two timber beams, carried on the collar beams, which have hooks in the centre (Fig 101). The position of these hooks is exactly above the ends of the engine beam. Chains would have been attached to these to lift the beam when maintenance work was required or when parts of the engine were replaced.

The south engine house shows no major changes which would suggest that the engine was ever substantially modified or replaced. A new flywheel was installed in 1863–4 (Staffs RO D876/ADD/3/2,

Figure 98 The north engine house, photographed looking north across the blast furnace bases in 1995, after the completion of repairs.

ff 135, 147). Although there is strictly speaking no archaeological evidence which can be unequivocally assigned to this, the cutting out of part of the bob wall on the south side may have been the result of inserting the new, or removing the old flywheel. The other evidence within the building is for the removal of the engine, which probably took place in 1918 when Screen Brothers removed the boilers. The power and condensing cylinders were removed through the window in the north wall of the building, necessitating some removal of its sill brickwork, which was reinstated in the 1970s. The beams supporting the condensing cylinder were also removed and the sockets were broken off (Fig 101). The largest area where brickwork was removed was in the west lateral wall, seen clearest in a photograph taken during the 1960s (Fig 88). This allowed the removal of the flywheel and was again infilled in the 1970s. The blowing cylinders were probably removed through the east wall by knocking out one of the window sills, which was then repaired as a doorway in the 1970s (Fig 100A).

Outside the building, clearance of vegetation revealed, in the area of the former boilers to the west, a large, cast-iron plate which gives access to a brick lined tunnel. This was found to be barrel-vaulted, with soot-blackened walls and a small brick shaft in the vault. It is oriented east to west, butts against the west wall of the south engine house and has the remains of two cross-tunnels on its south side. The ends of the tunnels are all defined by collapsed brickwork and a build up of soil.

A paved area east of the engine house is retained by a wall between it and the blast furnaces and is enclosed by a high wall linking the south charging house to the south-east angle of the south engine house (Fig 89). The brick paving exhibits two phases. The earliest phase is represented by brick paving and the brick-lined channel for the condenser feed pipe described above. By 1902 a small building had been erected here (Fig 86), the archaeological evidence for which is the three parallel brick walls and corresponding paving. This building probably had no more than an ancillary function, such as a shed for storage, and there is no archaeological evidence to suggest otherwise.

A substantial part of the area east of the engine house is earth covered, probably a result of removing the brick paving when the blast main was salvaged after closure. The blast main emerged from the east side of the south engine house below the level of the paved surface, but it must then have been carried above the surface, above the retaining wall at the south end of the furnaces, and above the level of the condenser feed pipe (Fig 100A).

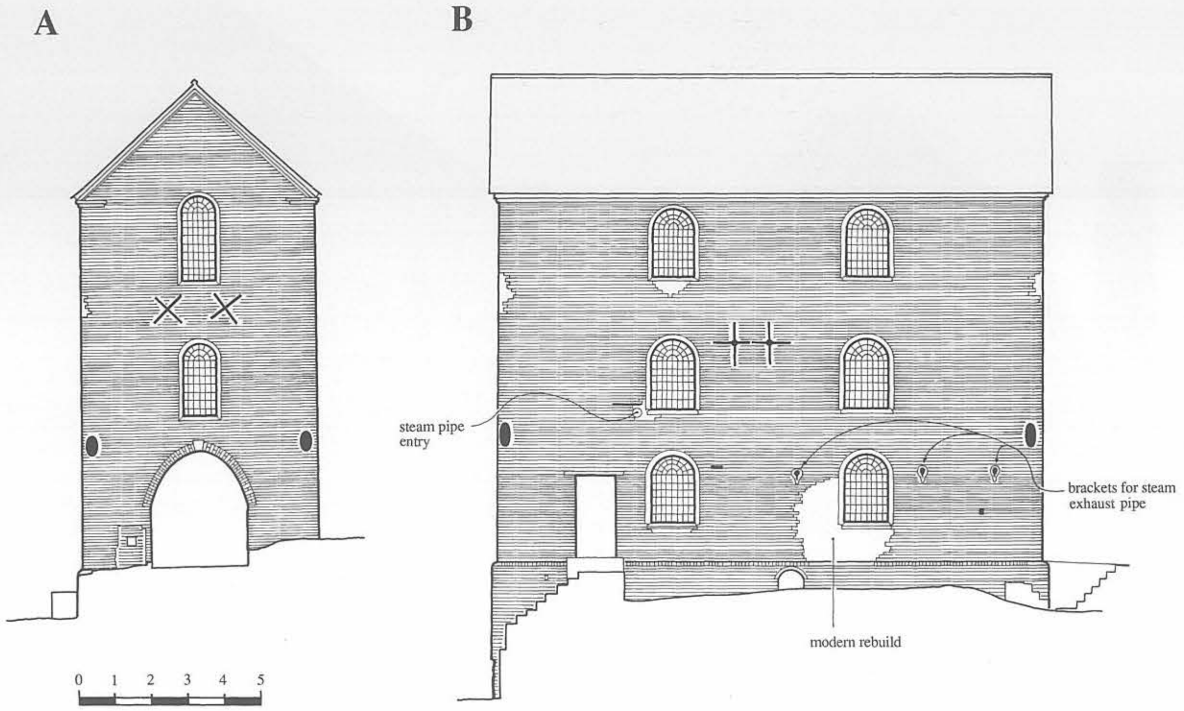


Figure 99 South (A) and west (B) elevations of the south engine house. The steps to the doorway in the west wall denote the difference in the level between the casting floors and engine. The base of the boiler stack is in front of the steps (see Fig 89).

Calcining kiln

East of the charging houses, below the level of the canal towpath, is the calcining kiln base, a configuration of eight sheared holding-down bolts with an associated brick-lined access pit (Fig 89). This can be interpreted with reference to contemporary technical literature. The holding-down bolts evidently secured a base plate, above which was probably a circular configuration of pillars which supported an entablature. The entablature carried the lining of the kiln, which was a single brick thick, and was clad in wrought-iron sheets. Traditionally, calcining kilns were constructed on similar lines to lime kilns, having a single draw hole at the bottom. This alternative design effectively provided access around the entire bottom of the structure for drawing the charge. The design was in use in the north of England in the 1860s (Fig 102), while columns with entablatures were also adopted for blast furnaces during the same period (Kohn 1869, 42–3). Three similar calcining kilns were in use in Shropshire at the Lilleshall Company's Lodge blast furnaces by 1873 and, like the Blists Hill kiln, they were charged from the top of a steep ramp (Griffiths 1873, 107) (see Fig 152).

The Blists Hill kiln charging ramp is clearly seen in photographs and on the Ordnance Survey (Figs 85 and 86). The base of the ramp is a brick structure to the north of the kiln, although it was not investigated in the present project. Power was derived from a small engine to the south of the kiln and beyond the inclined plane, not to be confused with the small inclined plane engine on the canal side. No evidence of the engine for the kiln ramp has been found, although the area has not been investigated in detail.

Summary interpretation

Phase I (1832): Ironworking at Blists Hill began in 1832 with a single furnace and blowing engine. Warington Smyth's watercolour of 1847 shows that this earliest furnace is furnace I (together with the tunnels beneath it) because it stood adjacent to the earlier, smaller engine house (Fig 82). It follows that the north charging house also belongs to this phase, as does the original boiler stack. The works was constructed by cutting into a natural hillside and then backfilling to create a level platform on top of the north charging house.

Phase II (1840–1844): A new beam blowing engine was under construction, together with two new furnaces, by 1838. The south engine house became fully operational in 1840 (the date is on a keystone), and the boiler settings and paved areas associated with the south engine house must also be of that date. The second and third furnaces were blown-in in 1840 and 1844 respectively (Riden and Owen 1995, 38; Randall 1880, 174). However, the south charging house was constructed to serve two blast furnaces, as was the integral network of tunnels

A

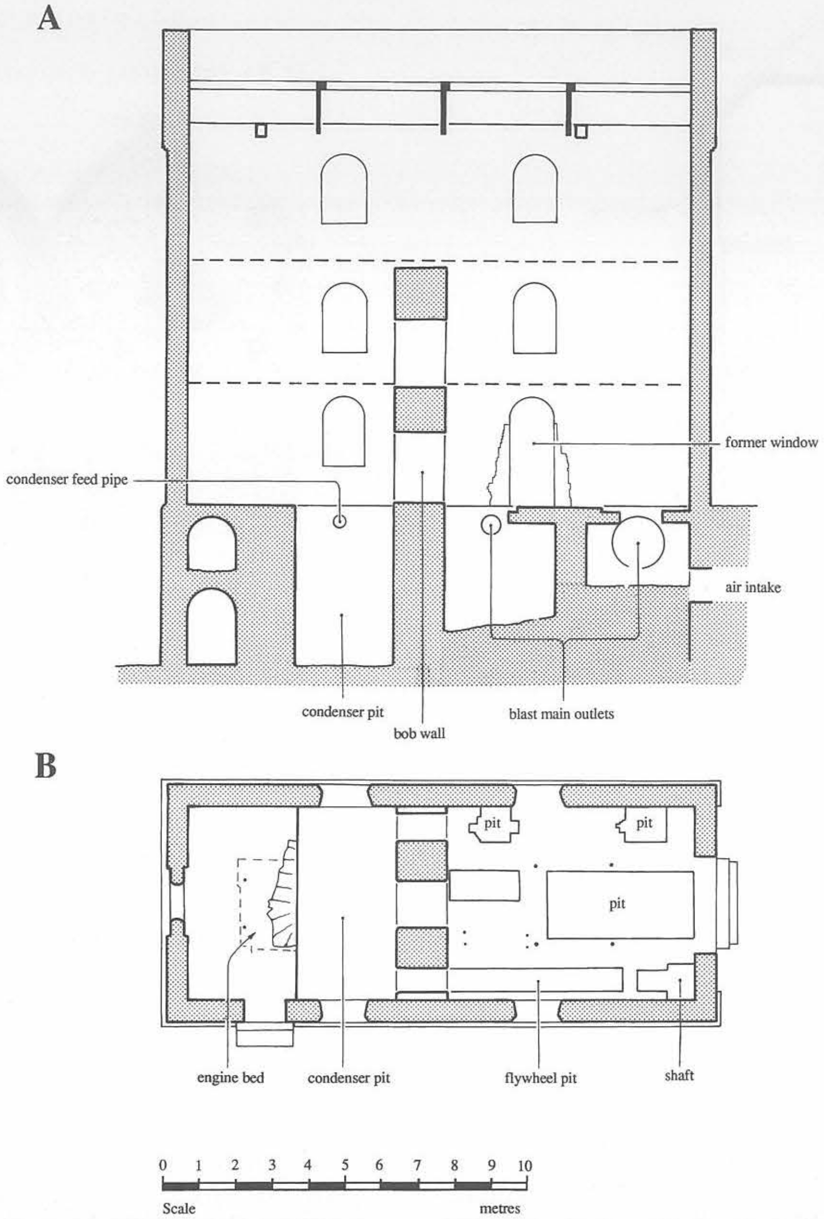


Figure 100 Internal east elevation (A) and plan (B) of the south engine house. The elevation shows, on the north side of the bob wall the engine bed and condenser pit with condenser feed pipe. On the south side of the bob wall are two blast main outlets, denoting two blowing cylinders. The plan shows the engine bed and condenser pit, and the flywheel pit and the central pit that housed the air intake pipe.

beneath furnaces II and III. Also the position of the south engine house in relation to the earlier furnace I is such as to suggest that the space between was earmarked for two furnaces. It is therefore argued that furnaces II and III were conceived as pair, despite the fact that four years separate their blowing-in. By 1844 the earlier engine had become disused, or was perhaps retained as a standby. There is evidence, however, that the engine did not work perfectly and certainly caused serious problems during trials in 1831 (Staffs RO D876/ADD/3/1, f 60).

The watercolour by Warington Smyth, together with the tithe map, both dated 1847, provide accurate portrayals of the works which can be reconciled with the archaeological evidence (Figs 82 and 83). Apart from the features described above, they confirm that the coke yard was on the north side of the charging platform, adjacent to the canal, and that an inclined plane had been constructed immediately south of the works, although the date of its construction is not known.

The blast furnaces at Blists Hill had a distinct bottle-shaped profile (Figs 82 and 84), similar to furnaces which the Madeley Wood Company had erected at Bedlam where production ceased in 1843. Furnaces of a similar profile are not known outside the East Shropshire Coalfield and are an important example of a local preference in blast furnace technology. It is typical, however, that when these

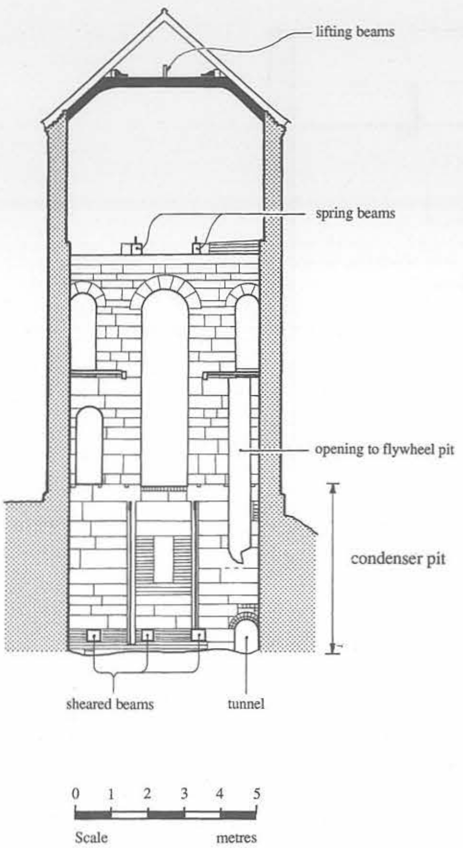


Figure 101 The north elevation of the bob wall, facing the condenser pit, in the south engine house. The sheared cast-iron beams supported the condensing cylinder and pump. The tunnel continues beneath the flywheel pit, providing access to its holding-down bolts.

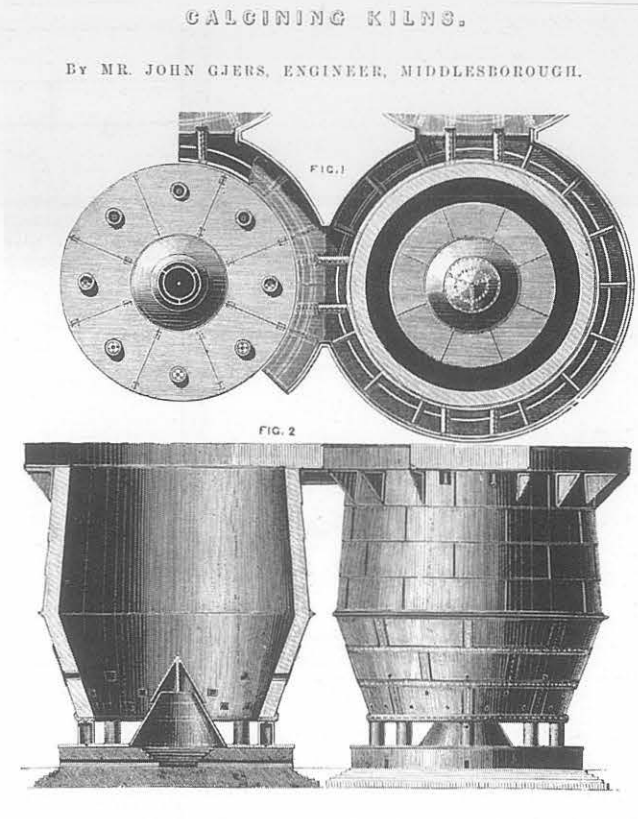


Figure 102 A calcining kiln built at Middlesborough in the 1860s, of a type later erected at Blists Hill. It is constructed of bricks on a cast-iron base plate bolted to the ground and clad in iron sheets. At Blists Hill, the bolts and their associated access pit have survived. (From Frederick Kohn's Iron and Steel Manufacture, *1869)*

furnaces were superseded, the new, larger furnaces built on the original bases were of a standard design seen throughout England, Wales and Scotland, consisting of cylindrical stacks clad in iron sheets (Fig 85).

Phase IIa (1847–71): In Phases I and II the furnaces were charged by means of bridges from the charging houses but at some stage between 1847 and 1873 this arrangement was modified (and modernised) by means of a continuous gantry across the furnaces at charging level (Fig 84). This gantry continued northward to the east side of the original north engine house, terminating over the pit on its east side (Fig 97C). Within the pit the gantry was secured by holding-down bolts in a brick plinth.

There was some heightening of the ground north of the charging houses to create a level charging platform. The retaining wall between the north engine house and the charging house was heightened in brick and the pit on the east side of the engine house was heightened in rubble stone (Fig 97A).

Phase III (1871–3): In the early 1870s, perhaps as early as 1871, major changes to the charging platform were made when the blast furnaces were heightened. A higher charging level required the installation of a lift, which in turn required the demolition of the upper storeys of the north and south charging houses, such buildings having become outmoded by the mid-19th century. A new building, open on its east and south sides and identifiable as a line of brick pier bases on the east side, was erected on the site of the earlier north charging house (Figs 86 and 94). Its appearance must, ironically, have been similar to the storage areas used when charcoal was the fuel used in iron smelting. Nothing survives of the lift apart from a shaft in the charging house and a counterweight pit. The shaft, which descends through the south charging house from the charging platform to the ground level beside the furnaces, allowed counterweights to ascend and descend (Figs 93 and 94). The lift could have been hydraulic or pneumatic powered, or perhaps manually operated, but no evidence has been found to clarify this point.

At the rear of the charging platform a calcining kiln was erected, constructed of a thin skin of firebricks clad in wrought-iron sheets above a cast-iron base plate (Fig 89). Although it was completely dismantled after closure of the works, the holding-down bolts, with associated access pit, are visible below the canal towpath. It was charged from the top by means of a ramp, probably powered by a small engine on the south side of the site.

In 1873 the north engine house was built for a single cylinder, vertical blowing engine made by J C Stevenson of Preston. It was erected almost exactly in the position of the earlier north engine house, which was therefore demolished, although the old boiler house and stack were retained (Fig 97A). The new building was erected partly on a rubble plinth, which had been the plinth of the earlier engine house, and with a retaining wall on its north side. On the east side, it may have been built partly over the top of the brick plinth inside the pit. The new engine did not, however, necessarily signal the demise of the beam engine in the south engine house, which could have been retained as a standby. Steam for the new engine was raised from the boilers beside the south engine house. Whether the old boilers of 1832 were retained is doubtful, although the original stack survived, possibly serving as a flue to a small furnace said to have been housed in an adjacent brass-moulding shop. The blast to the furnaces was distributed through blast pipes in the tunnels below each furnace (Fig 92).

The 1870s saw a considerable investment by the Madeley Wood Company at Blists Hill, amounting almost to a wholesale renewal of the works. The irony of this investment is that it was never exploited to the full. Production never again equalled its 1871 peak of 11,497 tons, and 1882 was the last year in which all three furnaces were simultaneously in blast. Certainly national trends were a factor in the variation of output and in the long-term decline. Exhaustion of local ores was another reason, particularly when the Crawstone ores had been worked out by the mid 1880s. But none of these reasons can deflect from the obvious fact that the Madeley Wood Company invested heavily in ironworking when its core and most profitable business was its collieries and could never have reaped the rewards of that investment. This same irony was equally apparent at Bedlam and will merit further discussion below in relation to the Shropshire iron trade of the late-19th century, and in relation to the history of the Madeley Wood Company. Equally worthy of discussion is the fact that this investment was made in cold-blast technology long after hot-blast smelting had become the norm (see Chapter 8).

Phase IV (1918): From 1899 only one of the furnaces was in blast, probably furnace I as it was nearest to the engine house. Smelting ceased in 1912 after a colliers' strike, but it was probably not until 1918 that its plant and machinery were salvaged (Fig 87). The casting houses and the sheds on the charging platform were taken down. Most of the cast-iron floor plates on the charging platform appear to have been salvaged, as was the charging platform lift. The furnaces were demolished to the level of their bases and the calcining kiln was probably likewise dismantled, each of them again having large quantities of ironwork to be salvaged. The boilers were removed in 1918 by Screen Brothers of Oldbury, who probably also removed the blowing engines. The archaeology of this demolition is clearly visible in the buildings, especially the south engine house where cavities in the walls show how the engine was ripped out (Fig 88).

6 Blists Hill Brick and Tile Works

Introduction

Blists Hill Brick and Tile Works became part of the new open-air museum at Blists Hill in 1969 (Fig 103). As a survivor of a once important local industry, ambitious plans were soon put forward for its restoration and incorporation into the museum displays, but in the event they were not carried out (Hammond 1979). The site is extensive, spanning both banks of the canal. The later buildings to the west of the canal were outside the scope of this project, but include large drying sheds which have been requisitioned for museum storage, whilst one houses the museum's foundry. The site of the corresponding kilns has since been built upon, but the remains have been recorded during excavations (Higgins 1988b; IGMTAU 1998b). The older works on the east side of the canal, meanwhile, has had to wait patiently for its share of the limited resources available for conservation. It is one of the more extensive major industrial monuments in Ironbridge, covering about 1.2 ha, and its fragile structures make it one of the most difficult to manage. Previous repairs have been piecemeal, while other interventions, especially drainage works connected with a local housing estate, have been undertaken without any archaeological contribution.

The archaeological interpretation of the site has, to date, been based on the work of Nicholas Dawes (1979) and Martin Hammond (1979), whose primary

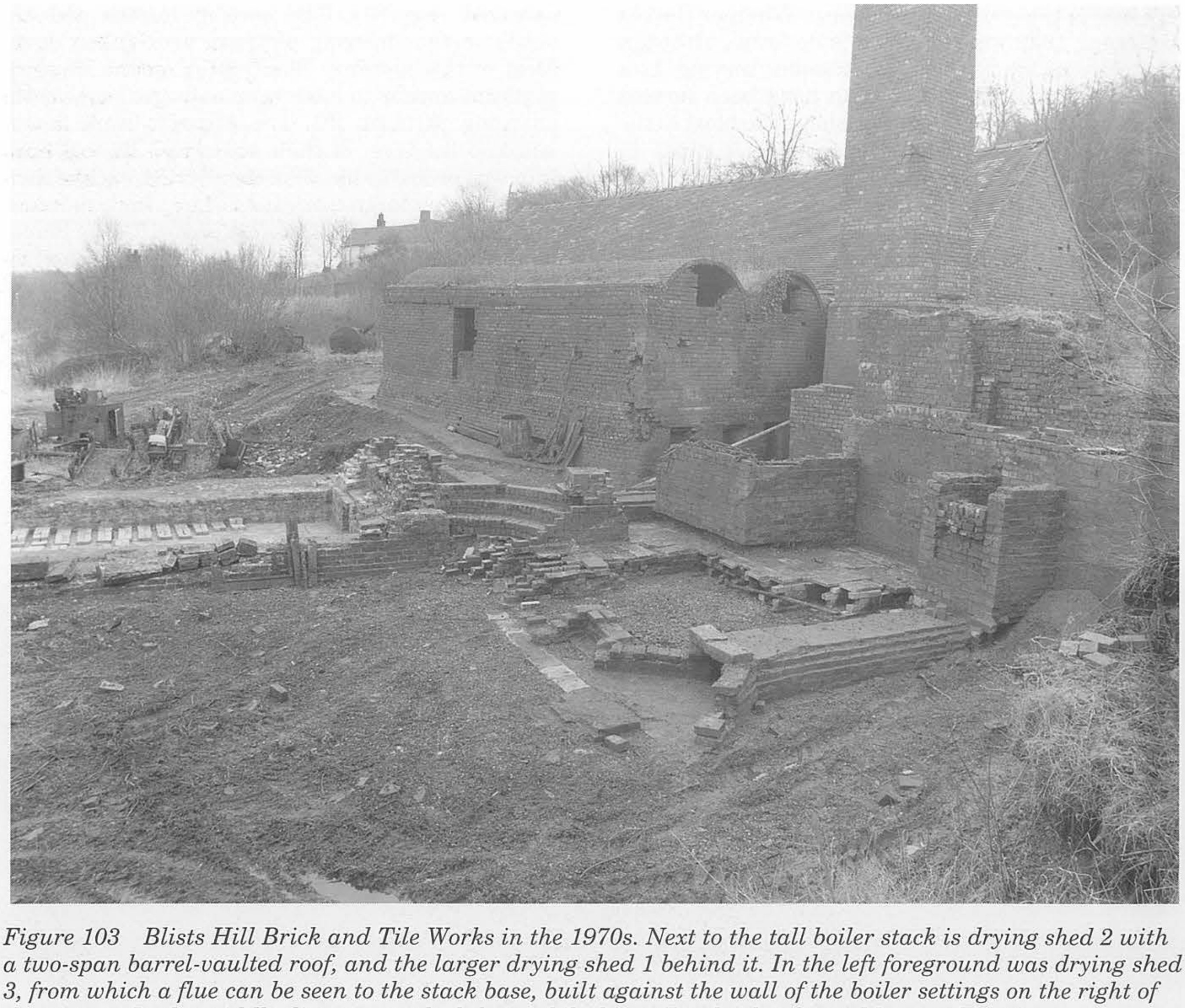


Figure 103 Blists Hill Brick and Tile Works in the 1970s. Next to the tall boiler stack is drying shed 2 with a two-span barrel-vaulted roof, and the larger drying shed 1 behind it. In the left foreground was drying shed 3, from which a flue can be seen to the stack base, built against the wall of the boiler settings on the right of the picture. In the middle distance, to the left, is a kiln base. (Ironbridge Gorge Museum Trust)

sources were derived from Trinder. Whilst acknowledging evidence for the early use of the site, these previous studies have interpreted it as a typical works of the 1870s, which remained in use until the 1920s, and specialised in producing hand-moulded bricks and tiles. In addition to the usual historical sources, an archive of oral histories was assembled by Ian Brown in 1980. It was used in conjunction with the analysis of the buildings in the hope that it would assist in the detailed interpretation of the site, especially since advertisements by the company were for both machine- and hand-moulded products.

Documentary evidence

The Madeley Wood Company has a long history of brick and tile manufacture. Clay was a by product of mining, so brick making became a subsidiary to the company's core activities of coal mining and ironworking. For example, a brick kiln had been established in the Lloyds by 1796, while large-scale manufacture started in 1841 when a brickworks was established close to the furnaces at Bedlam (SRRC 271/1, f 188; Staffs RO D876/ADD/3/1, f 172). A small brickworks at Blists Hill is shown on the Madeley tithe map of 1847, when it consisted of two buildings at right angles to the canal, with a smaller building further north (Fig 104). The large plot (1080) south of the brickworks is described as 'Brickwork, Clampits, etc.' and evidently comprised clay pits, suggesting that the location of the raw material rather then the proximity to the canal was the principal determining factor in the siting of the works. This is also likely to have been the case with the earlier Lloyds brickworks.

A major expansion of the Madeley Wood Company's brick making at Blists Hill occurred in the 1870s. A new 'Kiln Account' first appears in the annual statements in 1871 (Staffs RO D876/ADD /3/2, ff 232, 237). A year later an engine had been constructed and clay was brought from Styches Pit in Madeley Wood (*ibid*, ff 242, 244). Clay from Styches Pit was also supplied at this time to the Bedlam Brickworks where white bricks were made. The establishment of the extant brickworks therefore appears to belong to 1871–2. The nearby Blists Hill Pit was mined for clay from 1879 onwards and subsequently clay was also mined from the company's Hill's Lane Pit (Staffs RO D876/ADD/3/3, ff 28, 94, 201).

The extent of the brick and tile works is shown on the Ordnance Surveys of 1883 and 1902, and the function of individual buildings has been ascertained by oral history (Brown 1980) (Fig 105). On the south side of the works was the bank where the clay was weathered. The clay preparation block occupied the south-east side of the works, with a yard and drying sheds on its north side. A range of kilns was built along the east side of the canal and west of the drying sheds. The works is said to have had a large engine to drive the machinery in the clay preparation block and a small engine for pumping water to the boilers (*ibid*). The 1902 Ordnance Survey shows several additions to the works, in particular an extension to the clay preparation block and expansion west of the canal, on land which was formerly part of the coke yard for Blists Hill ironworks. Later a small inclined plane was built across the canal from Blists Hill Pit to the clay preparation block and clay bank. It is first shown on the Ordnance Survey of 1925.

By contemporary standards the brick and tile works was not large. It was obviously designed for mechanised production but by the early-20th century it advertised itself as a specialist producer of hand-made bricks and tiles in a variety of colours (Fig 106). In 1912 George Legge and Sons took over

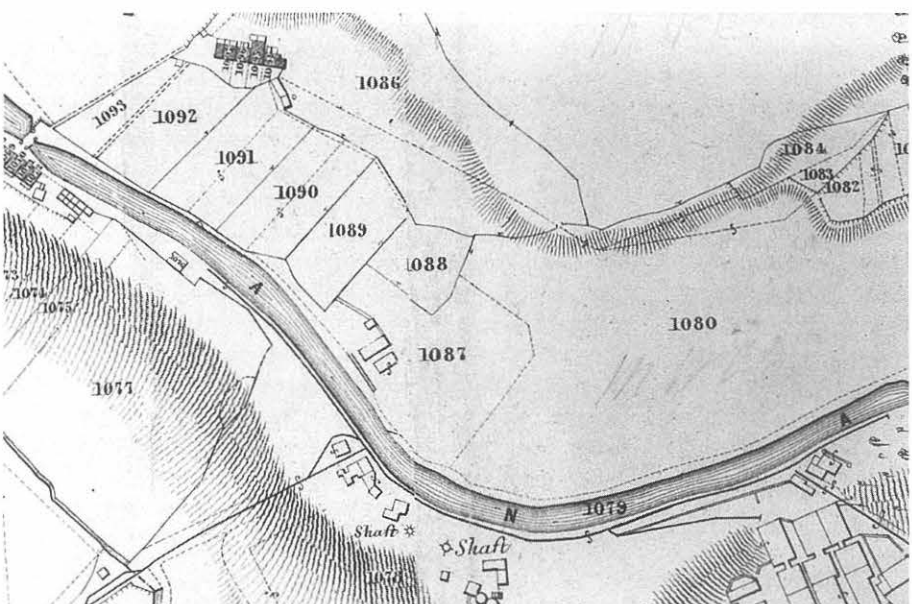


Figure 104 Detail of Blists Hill from the Madeley tithe map of 1847. North is to the left of the picture. Plot 1087 is described in the apportionment as 'Brickworks', plot 1080 as 'Brickwork, Clampits etc'. Blists Hill Pit is on the west side of the canal. (Ironbridge Gorge Museum Trust)

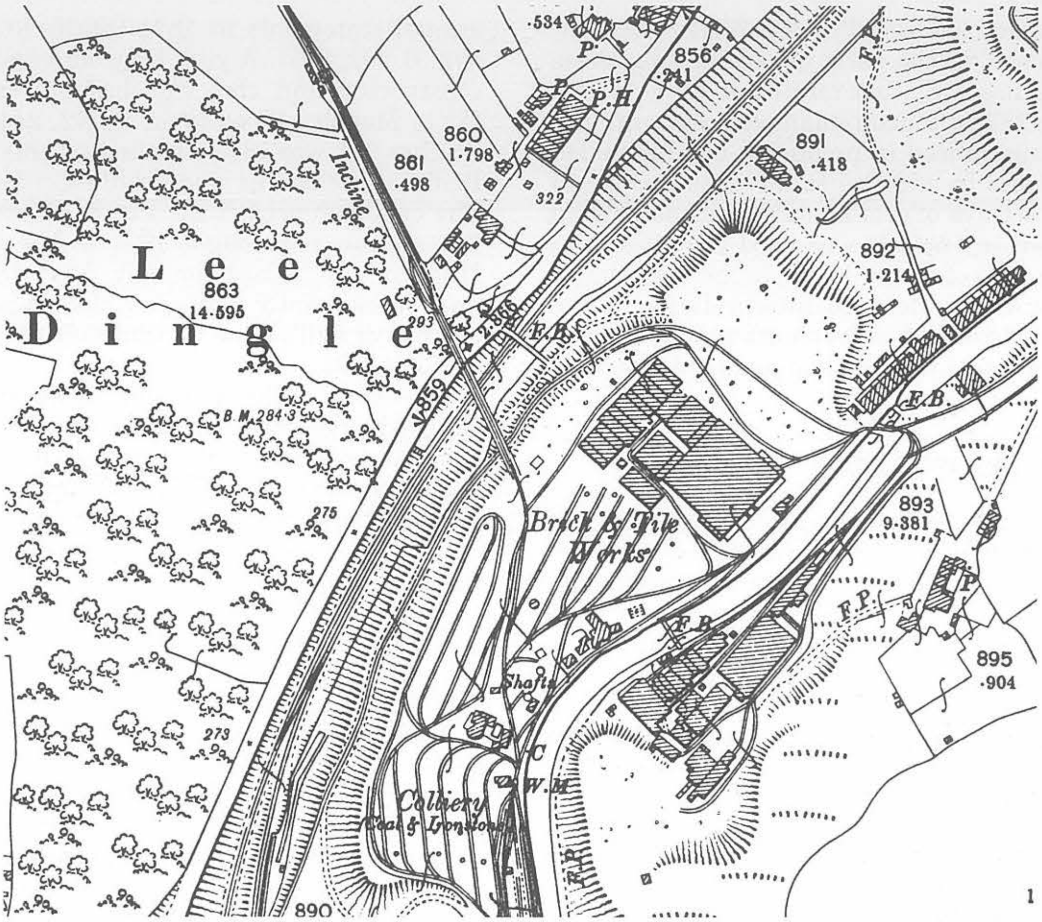


Figure 105 Detail of Blists Hill from the Ordnance Survey of 1902. On the east side of the canal, the clay preparation block and engine house are at the south-east corner of the works; the large buildings are drying sheds while a row of kilns is situated next to the canal. On the west side of the canal is the extension of the works on land shown as the coke yard for the furnaces in 1883. It consists of large drying sheds, and kilns on the north-west side.

the works and apparently purchased it outright from the Madeley Wood Company for £3000 in 1916 (Baugh 1985, 53; Brown 1969, 42). The kilns on the east side of the canal are said to have remained in use until the mid 1920s, after which only a small number of hand-made bricks were made in the drying sheds (Brown 1980). The clay preparation block, however, remained an integral part of the works. In 1938 Legge's was liquidated (Baugh 1985, 53). After 1945 sanitary pipes were made at Blists Hill by the firm of John Raleigh, who also operated the Benthall Pipeworks on the south side of the River Severn. It is not known the extent to which the buildings on the east side of the canal at Blists Hill were used during this period. Pipe manufacture ceased in 1956 and a year later the site was occupied by a haulage contractor, who demolished the tallest of the chimney stacks on the east side of the canal (Brown 1980).

The site

The buildings on the east side of the canal form a complete brick and tile works (Figs 107 and 108). The clay preparation block comprises two ranges and an adjoining engine house (Fig 109). To their north is a yard, with the former boilers to the west. North of the boiler settings are two extant drying sheds. A third drying shed with an integral stack base survives at ground level west of the boiler settings and a fourth stood on the north side of the yard, beyond which is the former office, now used by IGMT as a store. Set back from the canal bank are the bases of three kilns. The site is bound to the south by a former inclined plane on a retaining wall.

The present project is the first archaeological programme to have been instigated at the brick and tile works, although its scope was limited to those parts of the site undergoing repair, principally the clay preparation ranges and adjoining engine house; the boiler settings; and the two upstanding drying sheds. A range of groundworks was undertaken during the project for structural investigations, drainage works, and the reduction of ground levels. During 1995, a second project was carried out at the brick and tile works to provide access for visitors. These are discussed where features of interest were found.

The tithe plan of 1847 indicates that the earliest structures making up works were close to the canal

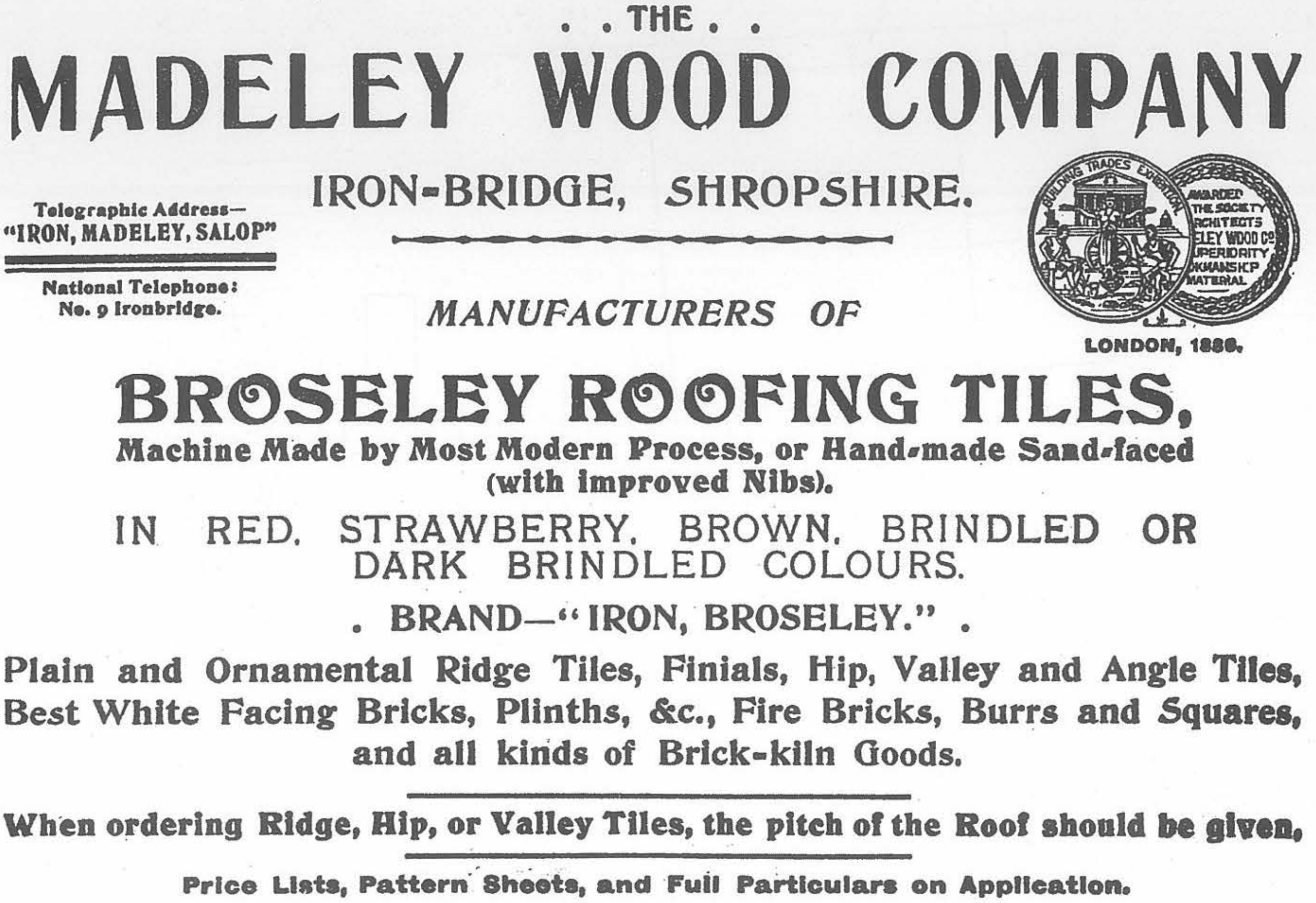


Figure 106 Advertisement for the Madeley Wood Company Brick and Tile Works published in The British Clay Worker *in 1900. Both machine- and hand-made tiles were produced at that time.*

and approximately in the position of the present northernmost kiln (Figs 104 and 107). No investigations were undertaken here during the current project, but a loose rubble retaining wall behind the kiln may relate to this phase.

The engine house and the western clay preparation range belong to the new works that was built in 1871–2 on the east bank of the canal. The eastern clay preparation range was added later (Fig 110). The small, single-storey, three-window engine house is integral with the western clay preparation range, which is three storeys to the front and two to the rear (Fig 111). The engine house interior is dominated by a rectangular brick engine plinth with timber sills, designed as the bed for a horizontal engine (Fig 110). The flywheel was situated between the engine bed and the east wall. The engine tender worked from the high ground-floor level, which is level with the top of the engine bed. The lower level allowed the flywheel to turn and provided access to the holding-down bolts (Fig 112B). Two large bearing boxes are built into the dividing wall between the engine house and clay preparation range (Fig 112A).

The western clay preparation range has ground- and first-floor doorways facing the yard (Figs 109 and 112B), and a second-floor doorway in the south gable end, providing access from the former clay bank (Fig 113B). From this doorway is a ramped wooden floor, with part of a plateway *in situ*, leading to a hopper (Fig 114). Against the east wall of this floor is the base of a former pair of rollers. Beneath the hopper, at first floor level, are four large timber spine beams, which span the ground floor (Fig 110). Two of them bear the scar of a circular pan base. A trench excavated in the ground floor revealed a brick plinth on the east side, and the base for a pillar or column in the centre. The south end of the first floor is a raised clay-covered platform, containing the bases of former clay bins (Figs 110 and 112A). A doorway from this level opens into the engine house while a steep wooden stair leads to the upper storey.

Evidence for the incline plateway bringing clay to the building was found in excavations to the south of the western clay preparation range, which revealed a timber beam bolted to a brick plinth aligned with the upper level doorway (Fig 110). This was probably the base of the incline up which the wagons were drawn. At right angles to it were two nearly parallel timber baulks, laid on brickwork with a timber cross beam between them. At the southern end of these timbers was brick paving and a short length of plateway aligned north–south (Fig 110). The clay may have been brought from the weathering heap on this plateway, and then loaded from here onto the incline.

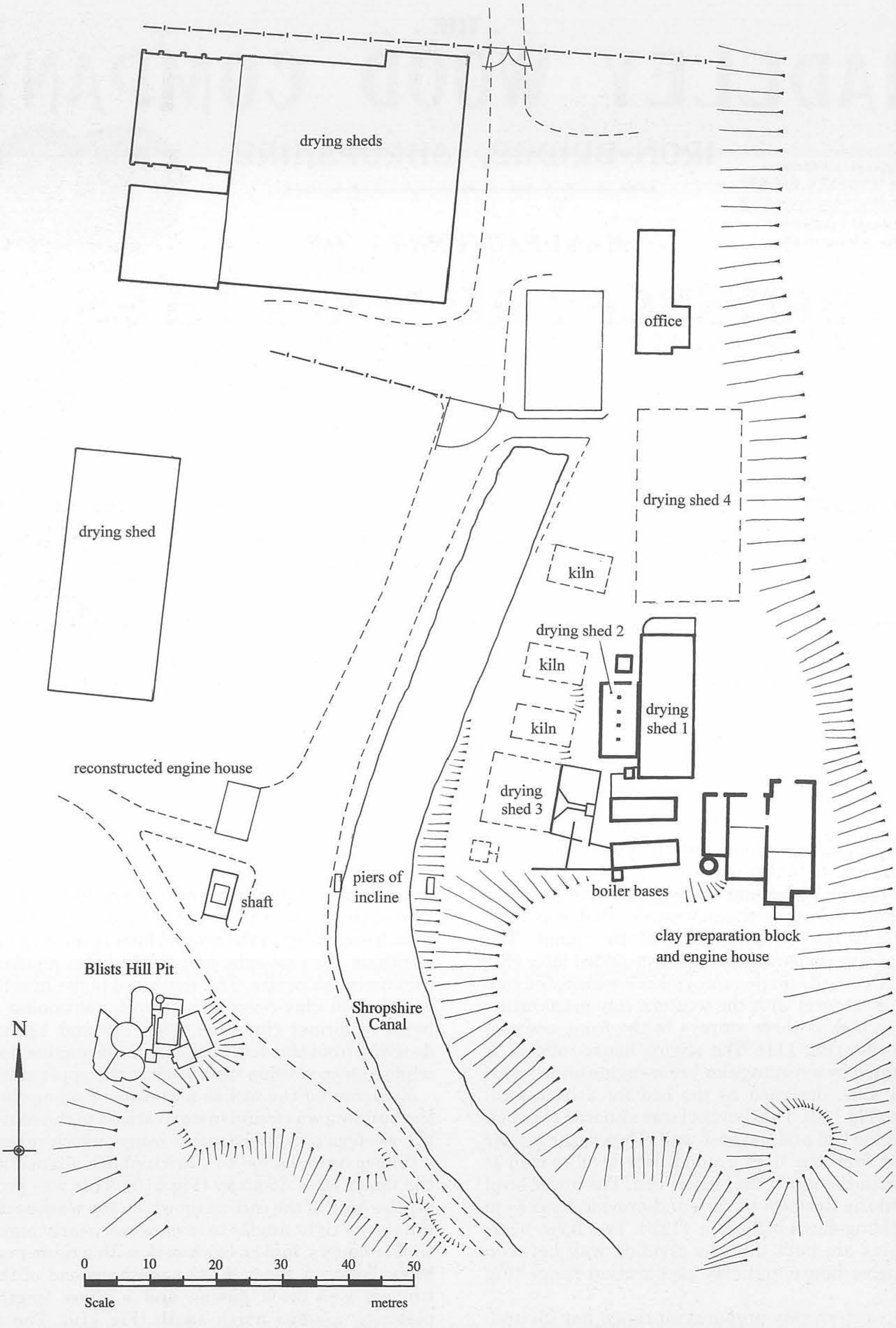


Figure 107 Brick and tile works site plan. Standing structures are the clay preparation block and engine house, drying sheds 1 and 2, the former offices, and the boiler bases and stacks. Ruined structures are depicted in a dashed line.

Figure 108 The brick and tile works, looking east across the Shropshire Canal. The engine house and roofs of the clay preparation block can be seen between the boiler stacks. Drying sheds 1 and 2 are to the left.

Figure 109 The north side of the clay preparation block and engine house with the yard in the foreground. The east range of the clay preparation block, to the left, was added later. Photographed in 1993 before the start of the repairs.

Originally, the engine was served by a single boiler, represented by the northernmost of the two extant boiler bases, which are not quite aligned with each other (Fig 107). The southern boiler is later and is first shown on the Ordnance Survey of 1902 (Figs 105 and 115). They are both rectangular, indicating Cornish (with one firebox) or Lancashire (with two fireboxes) boilers. Each base has a flue to its own stack. The stacks are square and survive to their full height with corbelled caps (Fig 108). On the north side of the northernmost boiler are two brick piers which formerly supported a cylindrical tank. On the east side, against the south gable end of the engine house, is the shell of a haystack boiler.

Drying sheds 1 and 2 stand parallel with each other on the west side of the yard. Shed 1 is earlier because its western openings were blocked by the construction of shed 2. Drying shed 1 is a seven-bay, open-sided brick shed under a pitched tile roof (Fig 116). The north gable end has a battered plinth containing five stoke holes in a stoking pit (Fig 117). The south gable end contains two lancet openings, one to each side and with pintles in the jambs. The interior is partly floored in brick, but also retains brick heating ducts on the west side (Fig 118). It appears that drying shed 1 was constructed in 1872. The flues beneath it are attached to the original north boiler stack, which belonged to this original phase. Of the structures which were not investigated in the present project, drying shed 3 was probably an integral part of the original 1870s works and was served by its own flue, as were the pair of kilns on its north side (Fig 107). This would have created a compact site where the earlier buildings shown on the tithe map could have remained standing.

Drying shed 2 appears to belong to a second phase of building, *c* 1872–83. Originally it had a two-span, tunnel-vaulted roof (Fig 103), but only a few fragments of the springers and haunches were left at the beginning of the project (Fig 119). In the south end wall are the former stoke holes, now blocked, whilst there were two doorways in the north wall. The flues

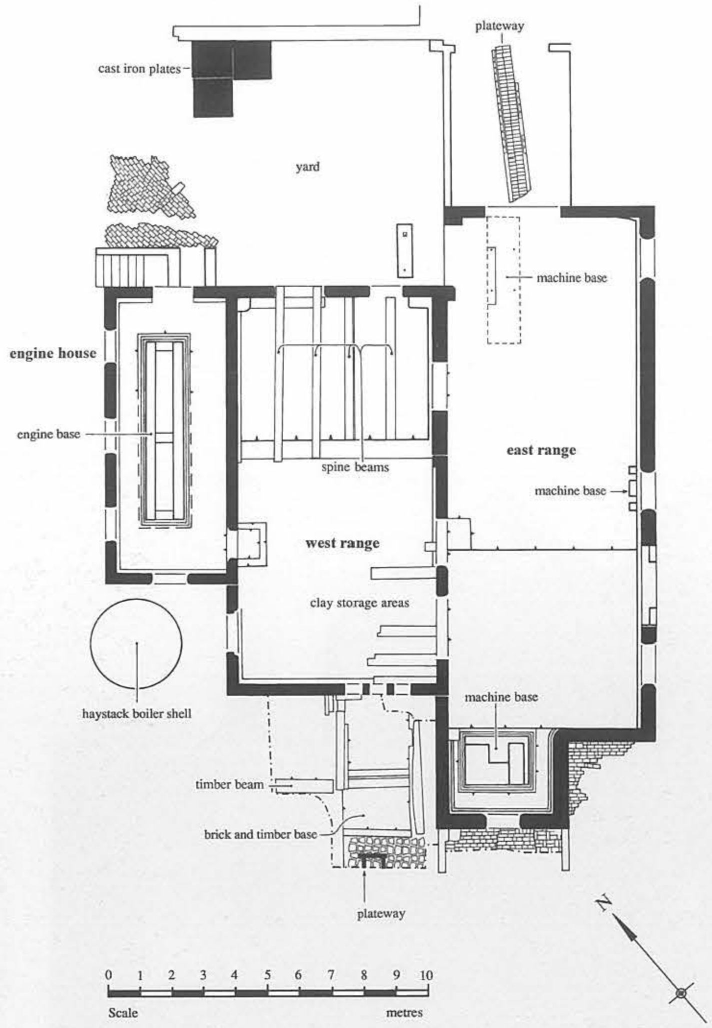


Figure 110 Plan of the clay preparation block. The weathered clay arrived via the plateway to the south of the building and was then loaded onto an adjacent incline, the position of which is marked by a timber beam. In general terms, the clay moved from the top to the bottom of the western range, into the eastern range, and out via the plateway at the north end.

would have run into a stack base to its north, which is surrounded by brick paving. Below ground, its walls contain flue openings and cast-iron damper plates (Fig 119).

During groundworks in 1995, the south end of drying shed 4 was revealed. It was found to be served by two axial flues which evidently continued to the large stack base north of drying shed 2. The stoking pits of drying shed 4 must therefore have been at the north end. Inside the building was a tile-laid floor, probably defining the area where the tiles were pressed before being laid out to dry. A further small excavation west of this drying shed revealed two parallel flues running between the northernmost kiln and the former stack base (Fig 120). Drying shed 4 was certainly erected by 1883 and is probably contemporary with drying shed 2 and the north kiln, as they all shared the same stack. The north kiln is the best preserved of the three kilns and is on the site of the small brickworks shown in 1847 (Fig 104). It is rectangular, formerly with a vaulted roof, the flue leading out of the east end. It is therefore of the downdraught, intermittent type (Fig 121).

By 1902, the east range of the clay preparation block had been added, along with the south boiler base and south stack (Fig 105). This indicates an increase in the capacity for clay preparation and probably corresponds with the construction of new drying sheds and kilns on the west side of the canal. Probably at the same time, drying shed 2 was converted to a water tank: The stoke holes at the south end were infilled with brickwork, whilst the two doorways in the north wall were blocked with brick at their lower levels. The interior walls were rendered to approximately 1.2m above floor level, corresponding to the level of the infilling of the doorways. The floor was also rendered and a raised platform in the north-west corner may be contemporary.

The east range is cut into a bank and was added to the west range, the external eaves cornice of which is now visible inside (Figs 110 and 112C). It is also of three-storey height and its roof intersects with that of the west range (Fig 112B). Two large openings were formed between the two ranges. The east range has a wide ground-floor doorway to the yard and a partly infilled doorway above it (Fig 112B). Inside the doorway are four holding-down bolts and the rectangular scar of a former machine. The position of another fixture is defined by rebates in the east wall above a cast-iron base plate (Figs 110 and 113A). Test pits against the internal east wall revealed earlier floors of brick or tile and a possible drainage channel. This suggests changes in the arrangement of machinery. A raised platform at the south end has a brick floor, while the projecting bay in the south wall houses a large brick machine base (Fig 113). Joist sockets at the north end of the range

Figure 111 The west side of the engine house. A bearing box can be seen at a high level in the wall of the clay preparation block behind. The boilers stood in front.

define stairs and platforms to a high-level gantry, where the bearing boxes are situated (Figs 112C and 113A).

The Ordnance Survey maps show the importance of railways in moving materials to and from the brick and tile works (Fig 105). A short length of plateway, 2.3m long and laid on brick paving, was found in the yard during ground clearance. Its orientation suggested that it continued around the east side of the east range (Fig 122). Immediately north of the east range, within the outline walls of a former projection, was the brick bed of a plateway, but there were no surviving rails (Fig 110). At the north-west corner of this projection was the remains of a wall

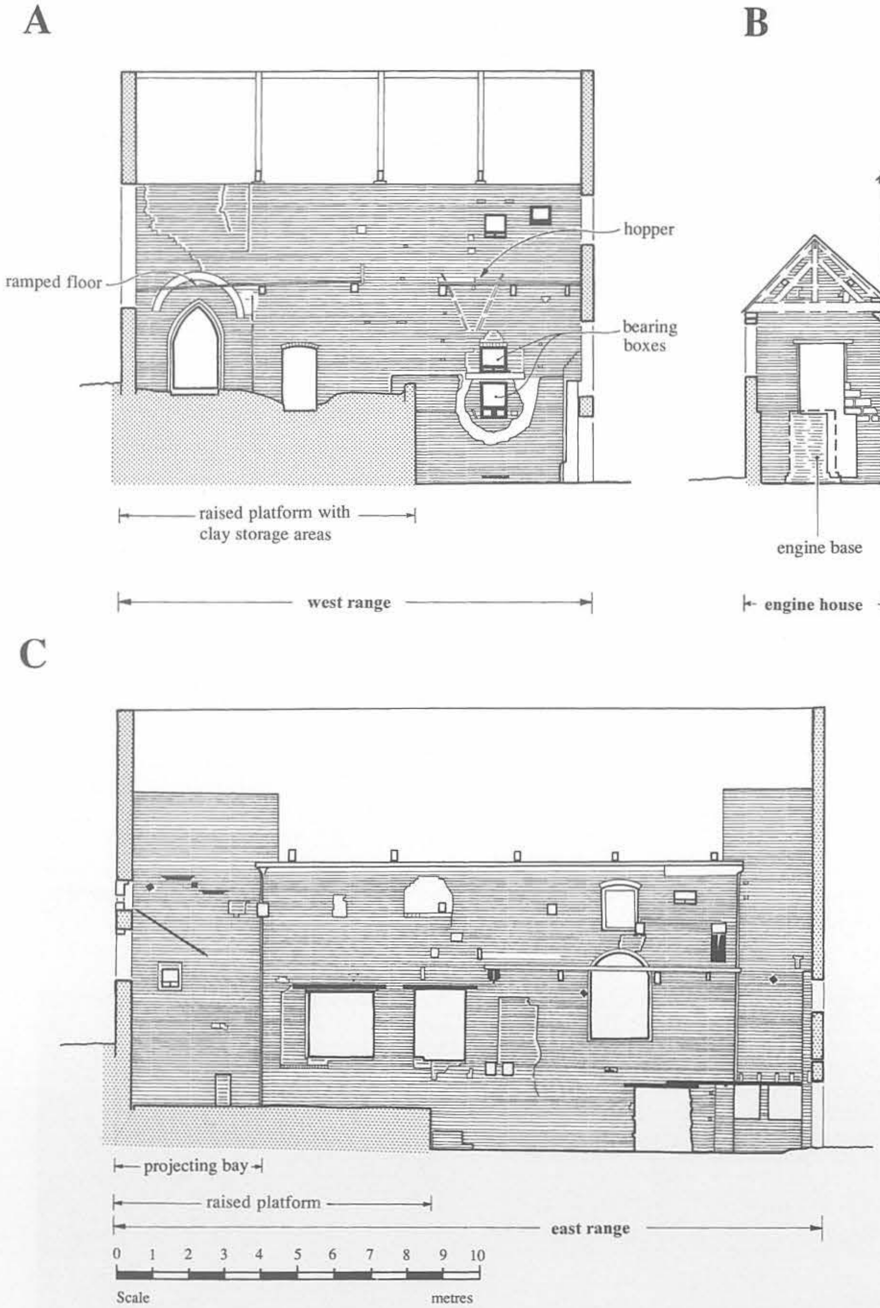


Figure 112 Internal elevations of the clay preparation block. (A) is the west wall of the west range, showing the ramped floor along which the clay was brought before being passed through rollers and then into the hopper. A pan mill was located below, from which the plastic clay was moved onto the raised platform towards the rear. Several bearing boxes are visible towards the north of the wall, behind which is the engine. (B) is the north wall of the block. The flywheel for the horizontal engine was to the right of the engine base. Two of the spine beams in the west range supported a pan mill, whilst a bat machine was in front of the altered ground-floor doorway of the east range. (C) is the west wall of the east range, which is also the former external wall of the west range. The two square-headed openings to the left are contemporary with the east range.

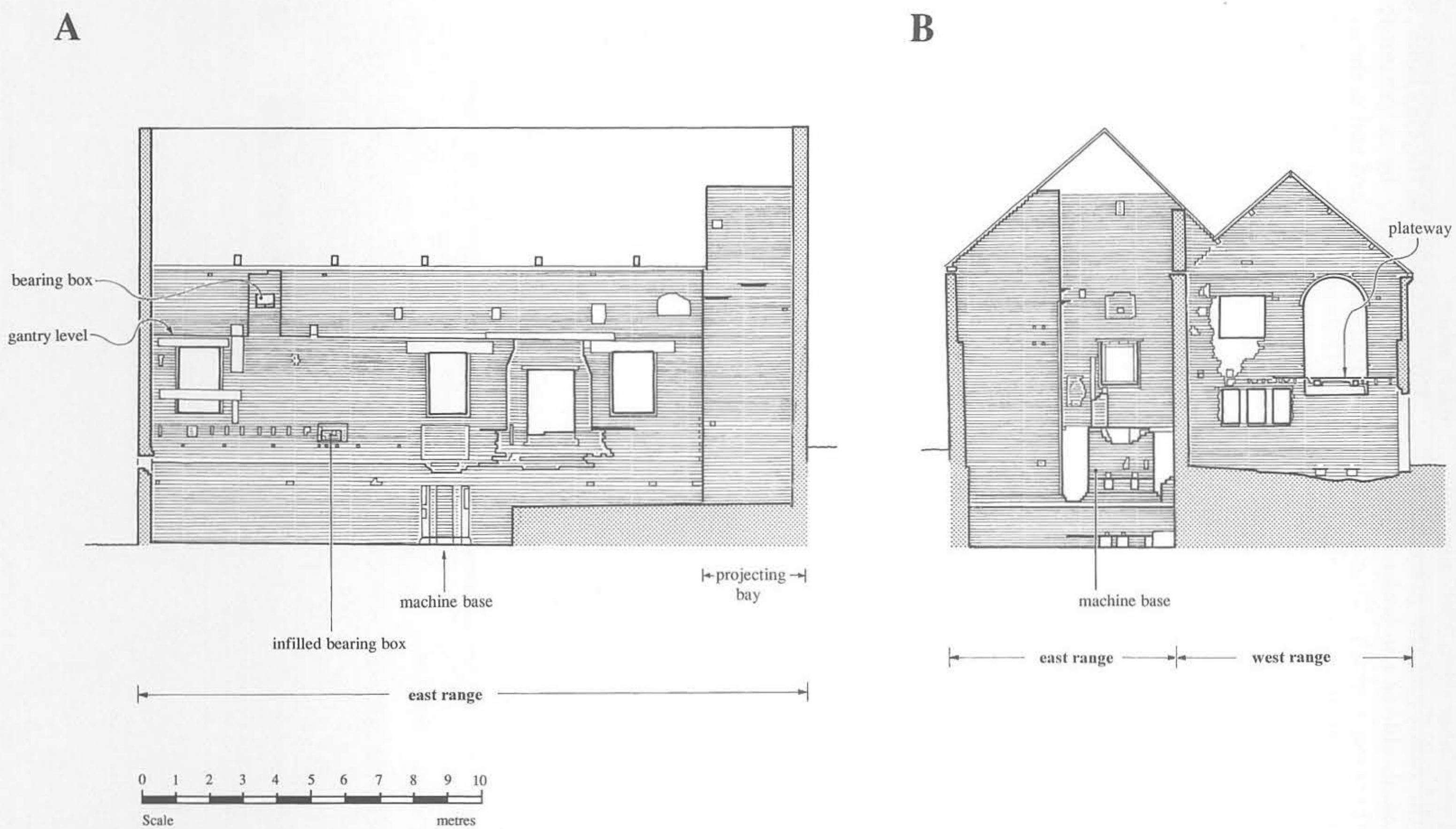


Figure 113 Internal elevations of the clay preparation block. (A) is the east wall of the east range, showing a machine base against the wall, possibly for a mixing machine. The high-level gantry was for decoupling the belt drives. (B) is the south wall of the block, showing the plateway entering the building at upper-storey level. The projecting bay in the east range was built for a large machine base, the purpose of which is unclear.

bounding the north part of the yard (Fig 110). A drainage trench across the north doorway of the east range exposed two sections of iron plateway below the present brick floor, one section consisting of two iron rails with curved ends.

The only extant features later than 1902 are the inclined plane across the canal and the associated retaining wall on the south side of the boiler bases which abuts the southernmost stack. These had been built by 1925 and are shown on the Ordnance Survey of that date.

Discussion

In this section, the manufacturing processes at the Blists Hill Brick and Tile Works are analysed by combining physical evidence with the oral testimonies collected in 1980 (Brown 1980). Invariably these accounts cover the 20th century when the works specialised in hand-made products and specials, whereas the structure and scale of the site indicate that it was originally intended for machine-made bricks and tiles. There are no first-hand accounts by Madeley Wood Company employees who could have described the earlier use of the clay preparation block, let alone any evidence of milling and mixing in the building before the east range was added at the end of the 19th century. The oldest employee interviewed went to work at the brickworks after being demobbed in 1919, by which time it was owned by George Legge and Sons. The accounts also occasionally contradict each other.

Clay was taken to the clay bank, south of the clay preparation block, by a plateway which passed through the main yard and is shown on the 1883 and 1902 Ordnance Surveys (Fig 105). A fragment of this plateway was found during ground clearance in the yard (Fig 122). Clay was weathered for several months during which time it was periodically wetted and turned over by casual labour. Frost accelerated the process by breaking up the clay.

Oral accounts state that there was a pan mill on the south side of the clay preparation block during the 1920s and 1930s. No trace of this mill was found during the groundworks on the south side of the building and there is no evidence that it was powered from the steam engine. It may have been powered by its own motor. Water and clay were mixed together in the pan mill, which was used to temper the clay, improve its plasticity and isolate any stones (Fig 123). Making bricks by such a method was known as the semi-plastic process because very little water was required, much increasing efficiency. From the pan mill, some of the

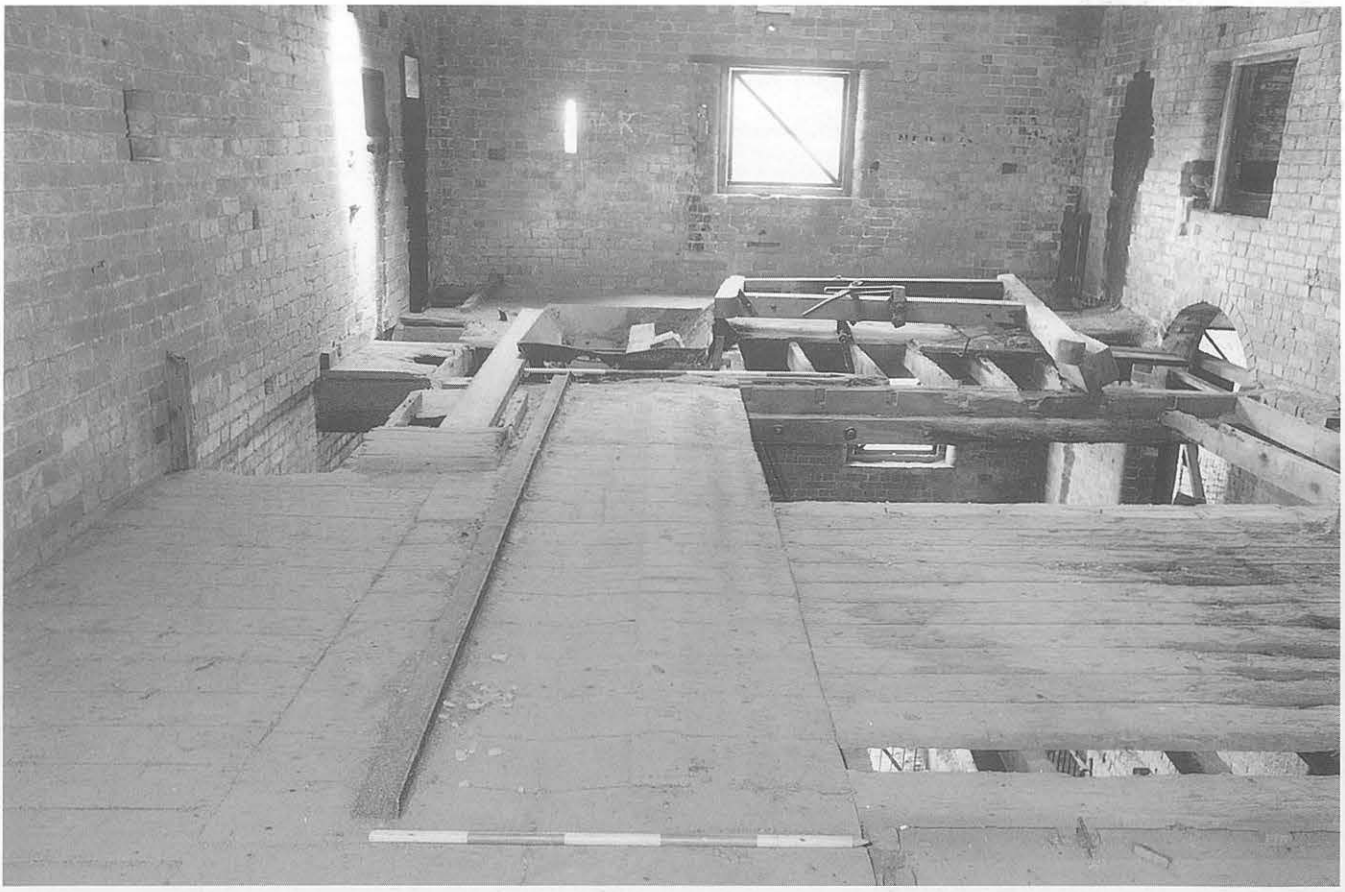


Figure 114 The ramped floor and plateway in the upper storey of the west range. The hopper is at the end of the plateway.

ready clay appears to have been taken straight to the drying sheds for moulding.

The original layout of the clay preparation block and its operation can be reconstructed in general terms. The logic of the original range is self-evident: clay entered the upper storey at the south end and went through the milling and mixing processes with the aid of gravity, machine-moulded bricks emerging into the yard on the north side of the building for distribution to the drying sheds. The use of gravity is illustrated in a number of contemporary illustrations of brick making (Fig 124). Power for the process came from the steam engine which transmitted power by means of line shafts and belt drives.

Most of the clay was brought directly from the clay bank into the clay preparation block by means of the inclined ramp on the south side of the western range. Part of the base of this ramp, a timber beam bolted to a brick plinth, was found during excavations (Fig 110). A chain was attached to a tub on plateway rails which was then hauled up by means of a belt drive operated by a clutch mechanism linked to the engine. Once inside the building the clay is said to have been tipped out onto the floor,

Figure 115 The base of the southern boiler with flue running into the stack. The boiler was of the Cornish or Lancashire type.

Figure 116 The east side of drying shed 1 viewed from the yard. The flue of the drying shed led to the stack on the left, which also served the northern boiler.

from where it was passed through a pair of rollers (primary crushers) and then on to the hopper. The east side wall of the upper storey retains the base of what appears to have been a pair of rollers. Beneath the hopper, a pan mill was mounted on the large spine beams. The circular scar of the pan base is still visible. Beneath the pan mill a pug mill would be expected, the whole arrangement being a conventional one for the period. Unfortunately, excavations in the lower storey did not reveal evidence of a mill base. However the existence of a ceramic pipe below ground level here suggests that the original mill was removed while the clay preparation block was still working, perhaps when the east range was added. This was certainly the case by the 1920s when clay was distributed from the hopper to the raised platform on the middle storey where it was wetted and turned. The floor was laid with solid steel plates to prevent the clay sticking to it.

The rear of the middle storey must always have been for clay storage because, although the steel plates previously laid there have been taken up, the brick walls of narrow clay bins have survived at a lower level. A drum fixed to the ceiling directly beneath the plateway on the upper floor could have been associated with a conveyor for moving the clay from the hopper to the middle floor. Alternatively, clay could have been drawn into the building through a large doorway in the west wall. Another possible route for the clay is that it passed through the rollers and the hopper and then by-passed the pan mill by being directed out of the building

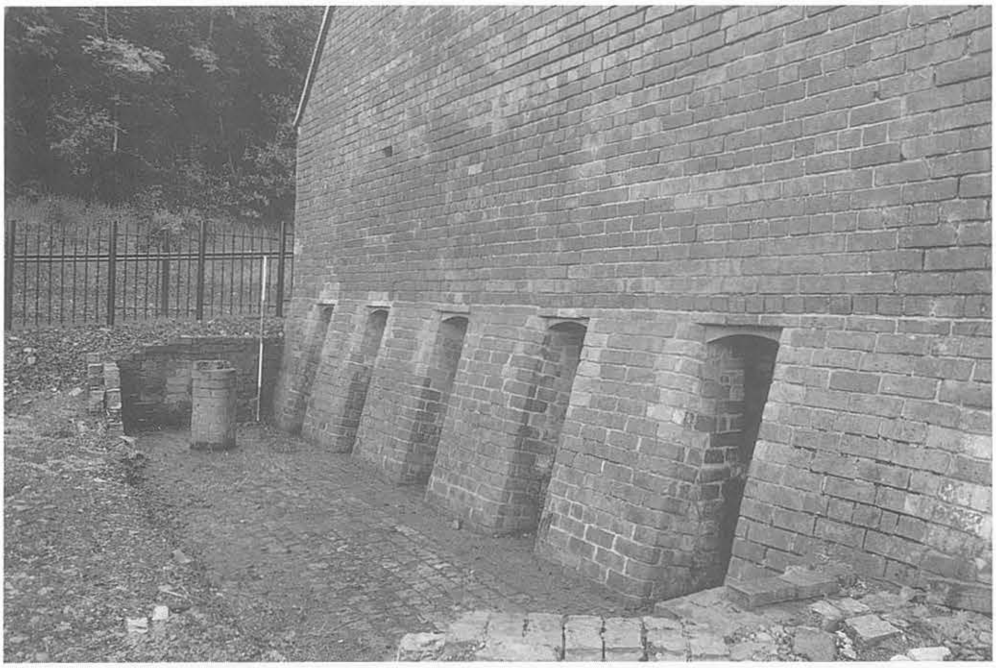


Figure 117 The stoke holes at the north end of drying shed 1, photographed in 1998 after completion of repairs.

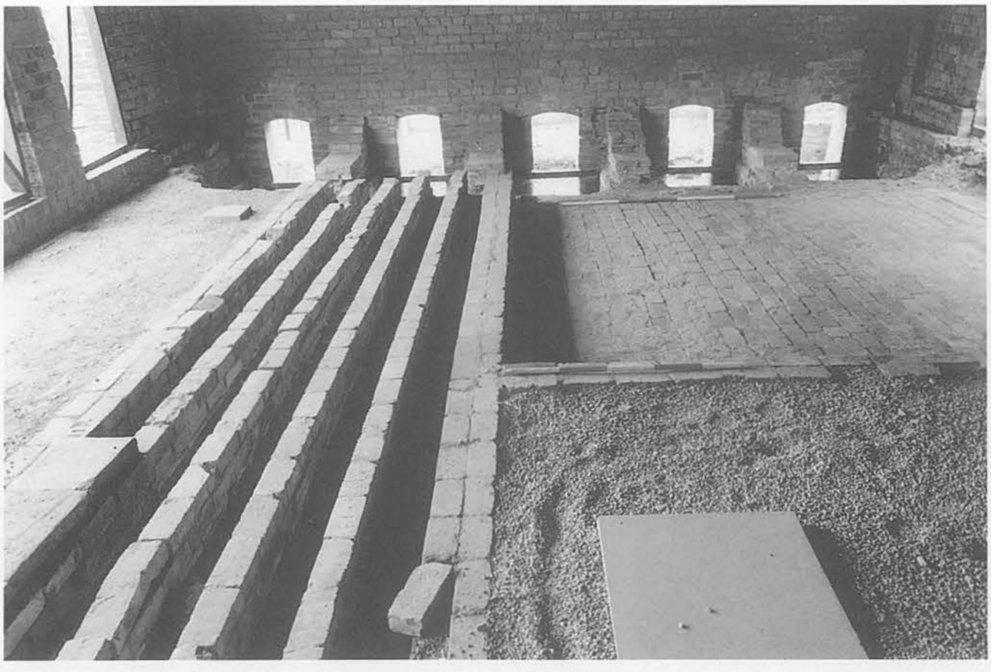


Figure 118 The interior of drying shed 1, looking north, photographed in 1998 after the completion of repairs. The hot air ducts are on the left and the working floor is on the right where the tiles were pressed into moulds on benches.

Figure 119 The north end of drying shed 2, with the large stack base in the foreground, and drying shed 1 on the left, photographed in 1998 after the completion of repairs. The ends of the barrel-vaults were reconstructed from fragments during the course of the project.

through the first-floor doorway in the north wall (Fig 112B). Just north of the building, three cast-iron plates built against a brick wall (Fig 110) must be considered as the remains of a 20th-century clay store since the wall is not shown on any of the Ordnance Surveys (Fig 105). At the northern angle between the west and east ranges are two parallel brick walls, one of which has two holding-down bolts within it. These walls could have supported a small crane.

Alterations were evidently made to the west range when the east range was added. From the clay storage area on the first floor, where the steel plates were laid, openings were made (or enlarged) in the wall in order to pass clay through to the east range. In the upper floor, a window in the east wall was blocked and against the wall a base was constructed comprising brick plinths and timber baulks, almost certainly for supporting the rollers.

Inside the east range were mixers or pug mills and a bat machine. Against the east wall are the rebates of a former machine base, possibly relating to rollers (Fig 113A). Compound clay preparation machines were introduced in the late-19th century and were a significant advance in mechanised production: The mixed clay was fed into one end, extruded into a continuous stream, and then cut by wires into rough shapes (Fig 125). It was said by former employees that the elaborate milling was primarily necessary for tiles rather than bricks. Unfortunately, archaeological evidence for these processes is slight. By 1902 an added projection had been built on the north side of the east range, in the yard, the outline walls of which are still visible (Figs 105 and 110). Contemporary with this was the widening of the main doorway and presumably also the infilling of an opening above. Inside the widened entrance to the range a new machine base, possibly for the bat machine, was built into the floor (Figs 110 and 125). The latter is said to have become disused in the early 1920s when a new bat machine was erected on the west side of the canal.

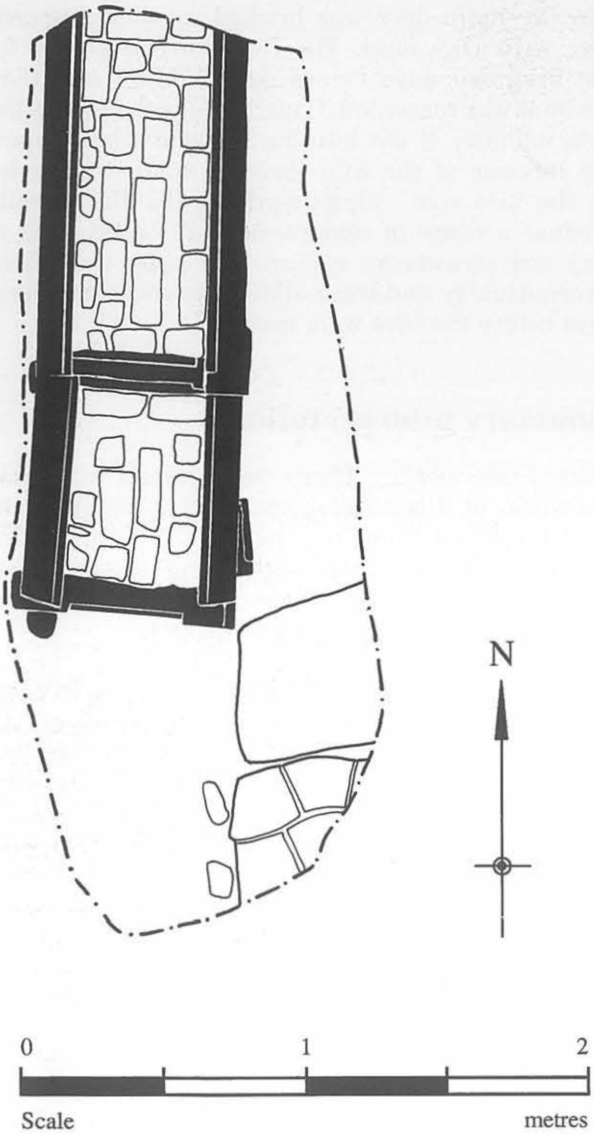
Figure 120 Two parallel flues excavated during access works in 1995, linking the northern kiln with the stack base adjacent to drying shed 2. This arrangement shows that the kiln was of the downdraught type. The photograph looks north.

Figure 121 Base of the north kiln, erected on the site of the brickworks buildings shown on the Madeley tithe map of 1847. The rectangular kiln, viewed from the south west, had a vaulted roof with flue leading out to the east.

The machines in the east range could not be used when the rollers and pan mill in the western range were working. The power for the machinery was taken by means of belt drives from line shafting at a high level, the position of which is defined by bearing boxes in the walls, reached by a narrow gantry supported on two pairs of cross-beams. A stairway at the north end of the east range provided access to the gantry for uncoupling the belts.

Oral history has implied that power was transmitted from the north end of the building to the south for the operation of the incline across the canal, although the evidence is rather vague. Against the external, west wall of the east range there was said to have been a wooden platform from where the incline was operated. The timber beams revealed here during excavations may have been the sills of its framework (Fig 110), but are more likely to be connected with the ramped incline leading up to the south doorway of the west range. A winding drum was said to have been installed at a high level inside the east range, possibly on the high brick machine base in the projecting bay (Fig 113B). Here, however, the oral and the archaeological evidence part company. The projecting bay is certainly in alignment with the incline, but appears in the 1902 Ordnance Survey when the incline does not and is part of the original construction of the east range. Possibly the incline was planned or even under construction at the time of the survey. However, there are no openings in the walls of the east range which would be consistent with a winding drum associated with the incline, for example at a high level in the west or south walls. The argument, therefore, that the two are connected is not sustainable without further corroborative evidence. It is perhaps more likely that the incline was powered from a separate motor or small steam engine. However, it is difficult to imagine an alternative use for the high machine base at the south end of the building, as it is not at all clear why power would otherwise be required here.

The increase in the capacity of the clay preparation block is likely to explain the addition of a second boiler. J C Stevenson is the most likely maker of the engine at the works. One of the company's horizontal, non-condensing engines, of 10 horse-power and with a cast-iron bed plate bolted to a concrete plinth, was constructed at the Army and Navy Stores in Westminster in 1886 and is similar, if a little smaller to what would be expected at Blists Hill (Clark 1890, 143–9). This had a flywheel with a diameter of 7 feet (2.13m) and a cylinder with a diameter of 10 inches (254mm) and stroke of 20 inches (508mm). The engine stood on a foundation bed 3.05m by 0.84m in plan. This compares with plan



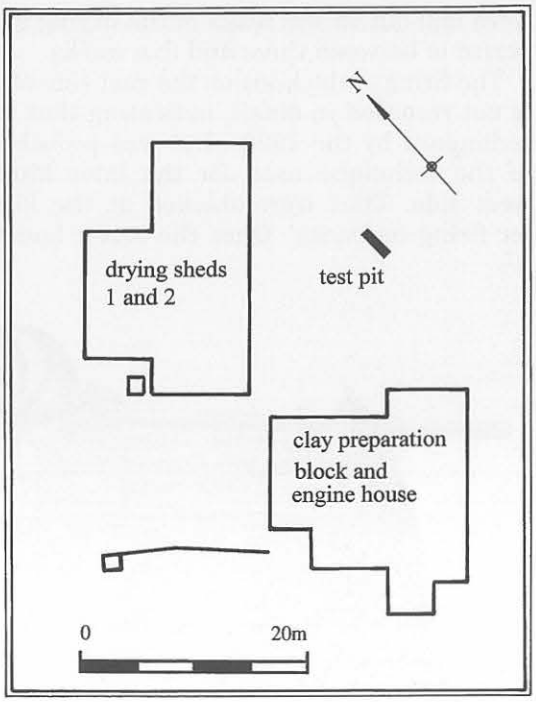


Figure 122 A fragment of plateway discovered during ground clearance in the yard. The cast-iron rails are surrounded by brick paving. The plateway led round the east side of the buildings to the clay weathering heaps on the south side, as shown in the Ordnance Survey of 1902.

dimensions of 5.6m by 1.15m for the engine bed at the brick and tile works (Fig 110), suggesting an engine somewhat larger than 10 horse-power and a flywheel correspondingly larger than 7 feet (2.13m).

The extant remains of a haystack boiler survive beside the engine house, but the boiler could not have raised steam for the engine because such boilers were used solely for low pressure engines. It could, nevertheless, have been a cylinder for condensing the steam, or alternatively a water tank.

From the clay preparation block the clay was taken either to the drying sheds across the yard, or to the works on the west side of the canal, by means of horse-drawn wagons known as 'dans'. The drying sheds on the east side were used for hand moulding both bricks and tiles. Drying shed 1 was used for bricks, the clay being collected in barrows wheeled across the yard. The narrow flues do not occupy the whole of the floor area and there is, at least in the north-east quadrant, a brick floor, which is consistent with the oral evidence that bricks were pressed into moulds on benches inside the building (Fig 118). There is no record of what, if anything, was made in drying shed 2 by the 1920s, probably because it was already in use as a water tank, as the render applied to the interior walls demonstrates. (A similar feature was encountered at Bedlam where the wheelpit was also sealed with render, seemingly to hold water.) A pipe inserted through the stoke hole blocking is above a small sump, which perhaps defines the position of the small pump for raising water from the canal. In drying shed 4, hand-made tiles, including crested ridge tiles and finials ('specials'), were shaped by hand. Otherwise the tile makers used small presses, from which the tiles were turned out and left to dry before they were stamped with the maker's number and pressed over a 'stamping horse' to give them a camber. The moulded bricks and tiles were laid out on the floors of the drying sheds for a period of between three and five weeks.

The firing of the kilns on the east side of the canal is not recorded in detail, indicating that they were redundant by the 1920s, but was probably similar to the technique used for the later kilns on the west side. Tiles were stacked at the kilns ready for firing in 'hacks'. Once the setter had filled the kiln the main door was bricked up and plastered over with clay mud. The fires burned gently for the first two days ('smoking the kiln') and then the heat was increased. Control of the firing was the responsibility of the kiln burner who could inspect the interior of the kiln through small trial holes on the kiln roof. Adjustments in the firing could produce a range of colours, normally a brindled or very red strawberry colour. The kilns were fired intermittently and were allowed to cool for several days before the tiles were removed.

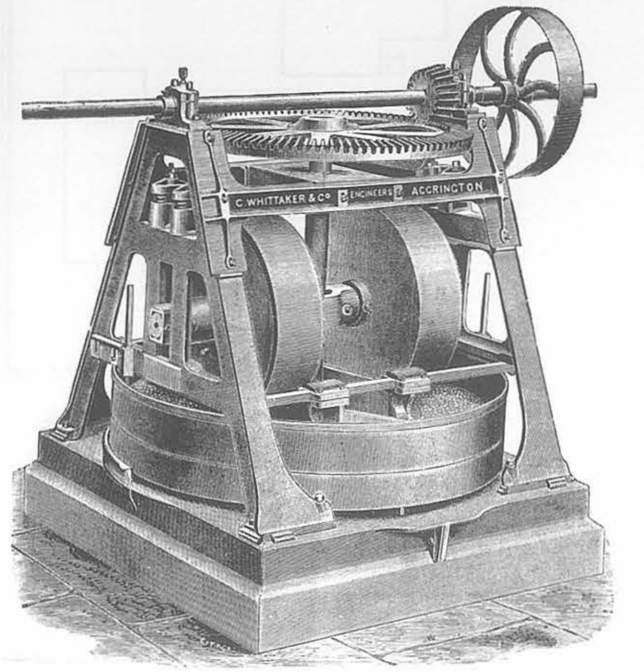


Figure 123 A belt-driven pan mill, as illustrated in The British Clay Worker *in 1900. The line shaft and belt drive is attached to the top of the machine. The clay was crushed and mixed in the circular pan by the two large edge runners.*

Summary interpretation

Phase I (pre-1847): There was a small brick and tile works at Blists Hill, owned and operated by the Madeley Wood Company, by 1847 (Fig 104). Clay was dug from pits on the south side of the site. Sheds and a kiln were built near the canal bank in an area not investigated in the present project.

Phase II (1871–2): In the 1870s a new works came into operation which incorporated many of the features of mechanisation that characterised the brick and tile industry in the latter half of the 19th century. It is this later works to which the extant buildings belong. Clay was originally brought from Styches Pit in Madeley Wood, from where clay was also mined for the Madeley Wood Company's other brickworks at Bedlam, where white bricks were made until 1889. From 1879 clay also came from across the Shropshire Canal at Blists Hill Pit and from Hill's Lane Pit.

At the south end of the works was a clay bank. The western range of the present clay preparation block and its adjacent engine house were working by 1872 (Fig 110). The engine was probably a horizontal, non-condensing steam engine made by Stevenson of

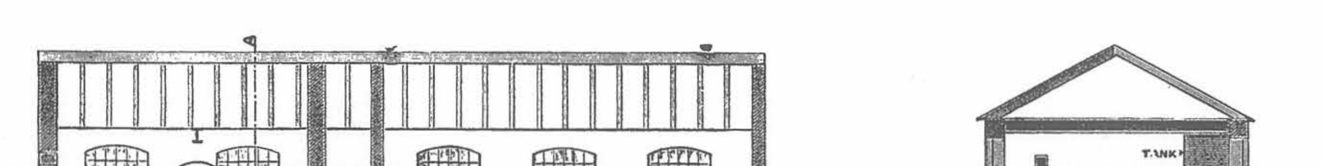


Figure 124 A typical clay-preparation building from The British Clay Worker, *published in 1900. The arrangement at the Blists Hill Brick and Tile Works was similar, with the clay entering the building at a high level, passing through a pan mill, and down into a pug mill.*

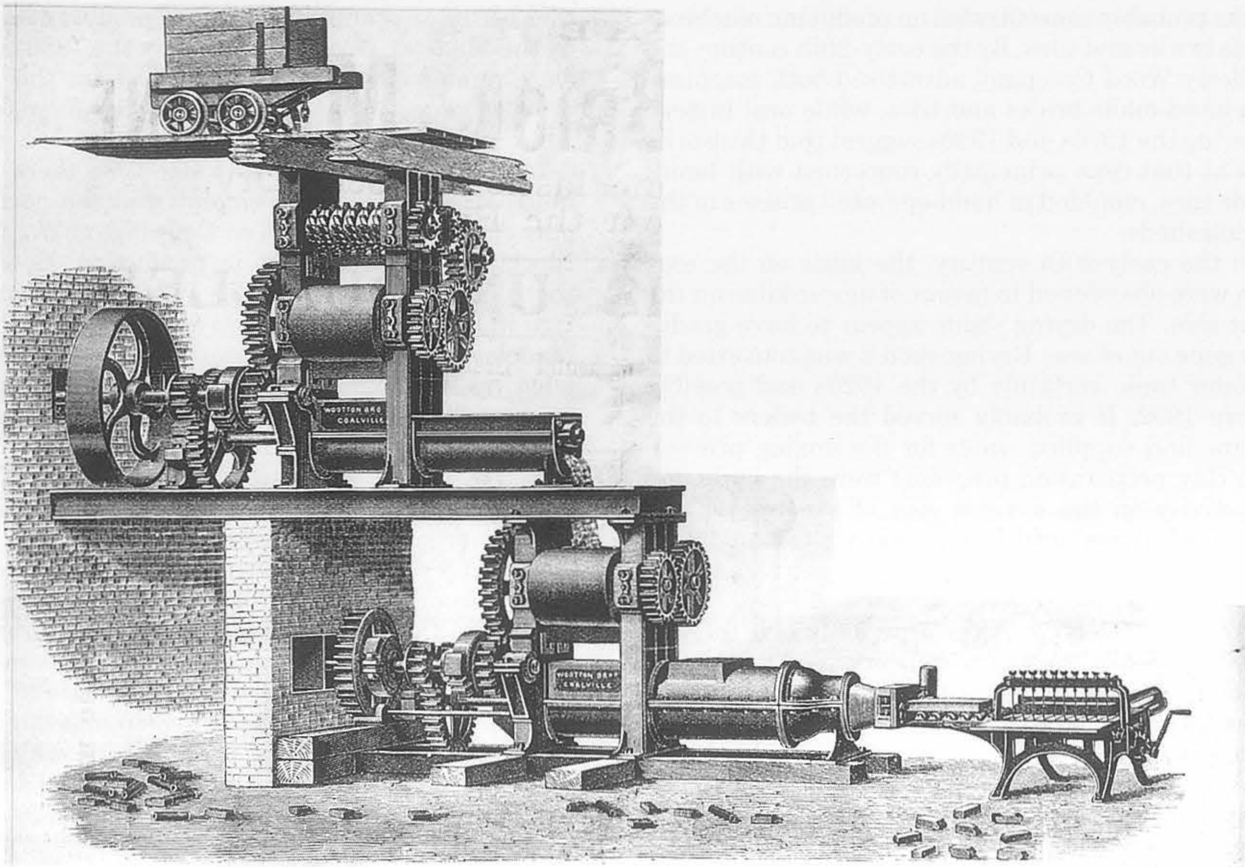


Figure 125 A typical compound clay preparation machine, as illustrated in The British Clay Worker *in 1900. These multi-function machines were developed in the late-19th century. The clay was passed down through crushers and rollers into a horizontal mixer. From here, it was extruded into a continuous stream which finally passed through the wire cutter. The rough shapes were then taken to the drying sheds.*

Preston. The engine provided the power for a ramp whereby clay was brought into the building in wagons from the clay bank. It also powered rollers, a pan mill, and a pug mill inside the western range. Steam was raised from a Cornish or Lancashire boiler represented by the northern boiler base, integral with which was the north stack. Clay was brought to the upper storey of the western range and was fed downwards through various processes: rollers (or 'primary crushers') in the upper storey, a pan mill in the middle storey, which was located directly above a pug mill.

Drying sheds 1 and 3 are probably contemporary with the clay preparation block (Fig 107). Although they were not investigated directly, the two intermittent downdraught kilns on the west side of the drying sheds also appear to have been constructed as a pair in this phase. The result was a compact works immediately south of the earlier brickworks buildings, which may have remained in use.

Phase III (1872–1883): Shortly after the new brickworks had been built, it was extended on its north side, replacing the earlier buildings shown on the tithe map (Fig 104). Drying sheds 2 and 4 were added as well as an additional kiln, all of which were served by the same large stack on the north side of drying shed 2. All of these structures are shown on the 1883 Ordnance Survey.

Phase IV (1883–1902): A major expansion took place before 1902 when the east range was added to the clay preparation block (Figs 105 and 107). A second boiler with associated stack was added to the south of the earlier boiler and stack. During this phase the only other addition on the east side of the canal was the works office. However, new drying sheds and kilns were erected on the west side of the canal on what had previously been the coke yard for the blast furnaces at Blists Hill. As iron production declined at the end of the 19th century the coke yard could be reduced in size.

Phase V (1902–25): The other major addition to the works was an inclined plane across the canal, the earliest datable evidence for which is 1925. During this period the works came under the control of George Legge and Sons from 1912, who purchased it outright in 1916 and continued in production until 1938.

The expansion of the brick and tile works on the west side of the canal signalled the slow decline of the works on the east side. When it was built, the works probably concentrated on producing machine-made bricks and tiles. By the early-20th century the Madeley Wood Company advertised both machine- and hand-made bricks and tiles, while oral history covering the 1920s and 1930s suggest that the works was at that time principally concerned with hand-made tiles, moulded in hand-operated presses in the drying sheds.

In the early-20th century, the kilns on the east side were abandoned in favour of newer kilns on the west side. The drying sheds appear to have gradually gone out of use. Drying shed 2 was converted to a water tank, certainly by the 1920s and possibly before 1902. It probably served the boilers to the engine and supplied water for the mixing process. The clay preparation processes were the mainstay of activity on the eastern side of the works, and remained active until Legge's went into liquidation in 1938.

Phase VI (1957–69): After a period when the site was technically part of a sanitary pipe works but probably disused, it was leased to a haulage contractor, who promptly demolished the tall stack adjacent to the drying sheds. It is possible, although not certain, that drying sheds 3 and 4 were also demolished at this time. The site remained disused until 1969 when it became part of a new open-air museum, now known as Blists Hill Victorian Town.

The brick and tile industry in the East Shropshire Coalfield

The growth of the local brick trade in the latter half of the 19th century reflected a national trend. In the south east of England the brick industry grew dramatically after 1850 to serve London, giving rise to large-scale brickworks in the Medway valley in Kent and the area of Oxford clay to the north, such as Bedfordshire and Peterborough (Trinder 1982, 241–3; Preston 1977, 91–8). As a consequence of the improved communications provided by railways, changing fashions in architecture, a growth in population, and new uses for ceramic materials, bricks, tiles, and sanitary pipes from the East Shropshire Coalfield were able to exploit a regional demand for cheap materials. The Blists Hill Brick and Tile Works is characteristic of the latter half of the 19th century when there was a proliferation of new brickworks in the district, all making bricks and tiles by the semi-plastic or semi-dry process, and occasionally making terracotta and other specialist products (Fig 126). The 20th century saw the move into 'specials', part of a strategy to sustain production when the mass market was no longer viable.

Within the Ironbridge Gorge, the manufacture of bricks and tiles was concentrated more heavily on the south side of the river, where the iron industry declined in the early-19th century. Here, Broseley tiles became a standard product, a product also used by the Madeley Wood Company. By the 1880s there were numerous brick and tile works in the Ironbridge Gorge, on both sides of the river, many of which were small and specialised in hand-made, decorative products. At the same time there were much larger brickworks emerging in the northern part of the coalfield, such as Donnington Wood and Blockleys, which remains in production. However, the Blists Hill Brick and Tile Works is also important in the context of the iron and coal trades of the Madeley Wood Company. In this sense it is paralleled by the Coalbrookdale Company's Lightmoor brickworks and the Lilleshall Company's Donnington Wood Brickworks built in 1875 (Trinder 1996, 113). Blists Hill was therefore typical of a coalfield brickworks. Such works usually had permanent kilns, mechanised clay preparation processes, and exploited a regional rather than a national market. Bricks from the Ironbridge Gorge, for example, were used almost universally in the 19th century for buildings in Bridgnorth, ten miles downstream from Ironbridge on the River Severn (Trinder 1996, 66).

Archaeologists have devoted comparatively little attention to the brick and tile industry, which has been a poor relation of the iron industry in spite of the fact that in the late-19th century there were more brick and tile works in the Ironbridge Gorge than there had been ironworks in the 18th century. One of the mitigating factors has been the drastic clearance of brickwork sites. A survey of the brick industry in Scotland, conducted between 1977 and 1985, is to date the only comprehensive survey of its type (Douglas and Oglethorpe 1993).

Of other local brickworks, traces of a stack and several retaining walls survive above ground at Bedlam, although the site later became part of a gas works. More substantial remains are at Lightmoor, a site that was used for brick making as early as 1779 and was later owned by the Coalbrookdale Company (IGMTAU 1988b). The surviving structures date principally from the early-20th century and include remains of continuous kilns. Production continued there on a reduced scale until 1993. The site is clearly an important one and its kilns are of a later type than the remains of the intermittent kilns at Blists Hill. At the Woodland Brick and Tile Works in Ironbridge, the office, with decorative ridge tiles, has been converted to a house. Two stack bases can be seen at the Rock Brick and Tile Works near Calcutts. In addition, machinery has been salvaged by IGMT from the Lightmoor Brickworks and the Milburgh Tileries at Jackfield.

Looking further afield, there are few readily comparable examples. In Hampshire, there are circular downdraught kilns at Baileys Hard on the Beaulieu Estate, which closed in 1934, and at Northwood, on the Isle of Wight, a kiln of 1856 survives, having remained in use until the 1960s (Moore 1988, 38). At the Bursledon Brickworks near Southampton, built in 1897, is a Hoffman kiln and

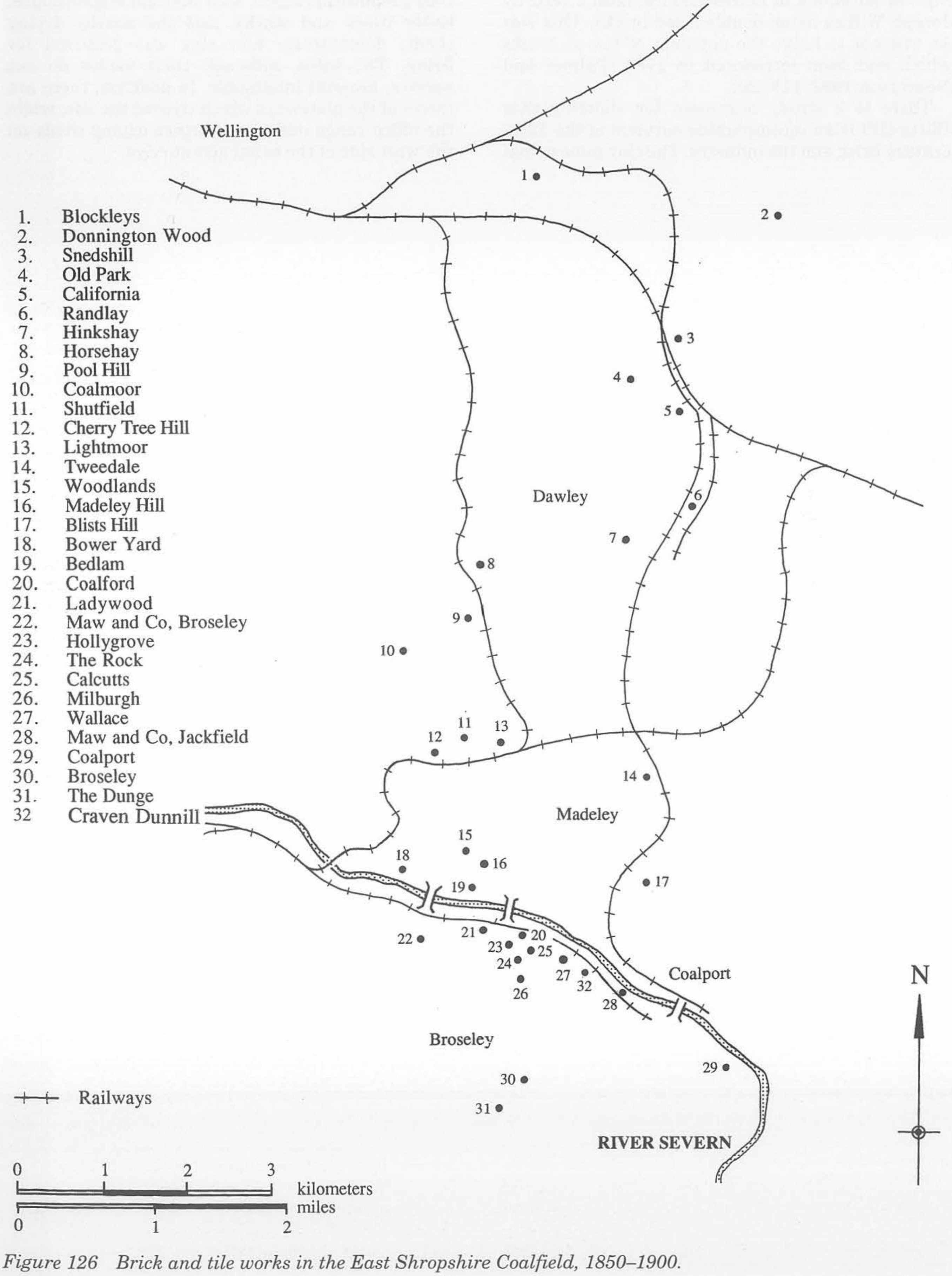


Figure 126 Brick and tile works in the East Shropshire Coalfield, 1850–1900.

drying shed, with imported machinery (*ibid*). There is a former drying shed, now converted into dwellings, at Measham in Leicestershire, built *c* 1802 by Joseph Wilkes using double-sized bricks. This was an attempt to halve the payment of tax on bricks which had been introduced in 1784 (Palmer and Neaverson 1992, 119–20).

There is a strong argument for claiming that Blists Hill is an incomparable survival of the 19th-century brick and tile industry. The clay mine across the canal is still discernible, as is the incline by which the clay was brought to the weathering heap. Clay preparation sheds, with adjacent engine house, boiler bases and stacks, and the nearby drying sheds, demonstrate how clay was prepared for firing. The kilns, although their vaults do not survive, are still intelligible. In addition, there are traces of the plateways which crossed the site, while the office range and some further drying sheds on the west side of the canal also survive.

7 The Hay Inclined Plane and Shropshire Canal

Introduction

The Hay Inclined Plane was one of the most technologically ingenious structures in the East Shropshire Coalfield in the late-18th century. Bold and ambitious, it attracted the admiration of strangers from far and wide. It was part of the Shropshire Canal which provided an important link between the East Shropshire Coalfield and the River Severn, particularly the concerns in the northern part of the coalfield. The surviving section of the canal, including the Hay Inclined Plane, is at the southern end (Fig 127).

Having fallen into dereliction during the early part of the 20th century, the Hay Inclined Plane and the canal were cleared and restored by IGMT from 1969. These works were not accompanied by archaeological recording, so some archaeological information has been lost. A survey of the inclined planes of the Shropshire Canal was undertaken in the early 1960s (Tonkinson 1964). Roger Tonkinson's drawings reveal that up to sixteen courses of brickwork have been lost from the engine house at the Hay Inclined Plane during the last thirty years, which has implications for other fragile ruined brick structures of this type. Whilst Tonkinson's study is of considerable importance, a detailed archaeological explanation has not been produced to date. A definitive chronology is required to explain the early years of the site and the subsequent changes, whilst evidence for the engine type has yet to be investigated. These questions form the subject matter of this study. The development of steam-powered canal inclined planes in Shropshire was a significant innovation, at a time when there was a major expansion in the general use of engines in the coalfield and an increased demand for effective transportation systems for manufactured goods and raw materials.

Restoration of the Hay Inclined Plane began when the slope of the incline was regraded by a detachment of the Territorial Army Royal Engineers by adding a layer of clinker from Ironbridge Power Station. The last generation of standard gauge rails at the incline were identified by a British Railways civil engineer as LNWR B190 type, and rails of a similar type were laid by volunteers in 1975 (Trinder 1978, 10; Trinder pers comm 1996). The rails which had remained *in situ* were lifted and laid on new timber sleepers, and the beds on the counterplane were paved with rubble stone. The basin at the foot of the incline was excavated in 1974, and the section of the canal between the incline and the Coalport China Museum was restored in 1976 (Trinder 1978, 10). The loading bays, boiler bases, and stack were repaired using cement mortars after 1974, whilst minimal works were undertaken to the engine house.

Documentary evidence

The Hay Inclined Plane was one of three inclined planes built on the Shropshire Canal and one of six in the East Shropshire Coalfield. The Shropshire Canal Company was formed in 1788 to construct and operate an eleven-mile long canal from Oakengates to the River Severn (Plymley 1803, 296; Trinder 1981, 77) (Fig 128). The idea of a canal crossing uneven terrain, where sharp changes in level could be overcome by the use of inclined planes, is said to have come from the inclined plane which had recently been constructed on the nearby Ketley Canal by William Reynolds to serve his ironworks (Trinder 1981, 292).

In broad terms, the Shropshire Canal was to run from the south end of the Donnington Wood Canal, which had been completed by 1767 (*ibid*, 75). It would continue south through Oakengates and Hollinswood, where it formed a junction with the existing Ketley Canal, and then through to Southall Bank where it would split into two branches. The eastern branch would pass through Windmill Farm, Madeley, and to the Hay Farm, from where it would continue to the place later known as Coalport, adjacent to the River Severn. The western branch would pass through Horsehay to Brierly Hill. From here, a section was proposed through Coalbrookdale to Styches Weir on the River Severn but this last section was never constructed (*ibid*, 77). The Shrewsbury Canal was built shortly afterwards to link the coalfield with the county town (*ibid*, 84). The Shropshire and Shrewsbury canals joined at Donnington Wood.

Five inclined planes were proposed for the canal; three on the eastern branch and two on the western branch, but the latter were on the section which was never built (*ibid*). At Brierly Hill, a different system was attempted for lowering and raising goods: a lift system using two parallel shafts which was later replaced by a railway incline (Plymley 1803, 295). The most northerly inclined plane on the eastern branch would be at Donnington Wood, close to the northern terminus of the canal. The second was proposed for Windmill Farm, to the south of Southall Bank, and the third, near the south terminus of the canal, would be at the Hay Farm.

The Committee of the Shropshire Canal Navigation included landowners, coalmasters, ironmasters, and entrepreneurs of the East Shropshire Coalfield. Well-known names included Richard

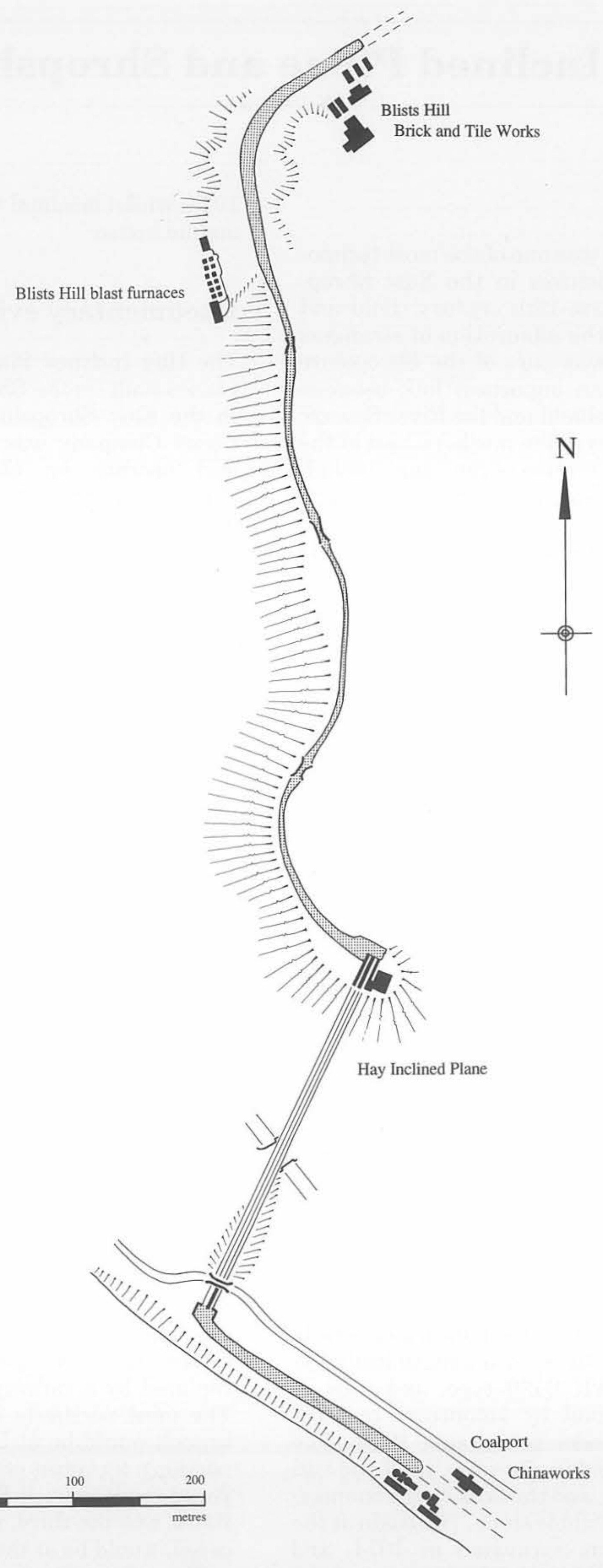


Figure 127 Plan of the surviving section of the Shropshire Canal between Blists Hill and Coalport. Industrial concerns such as Blists Hill blast furnaces, the brick and tile works and the Coalport Chinaworks were built alongside the canal. The purpose of the Hay Inclined Plane was to lower, or raise, goods from one level to another.

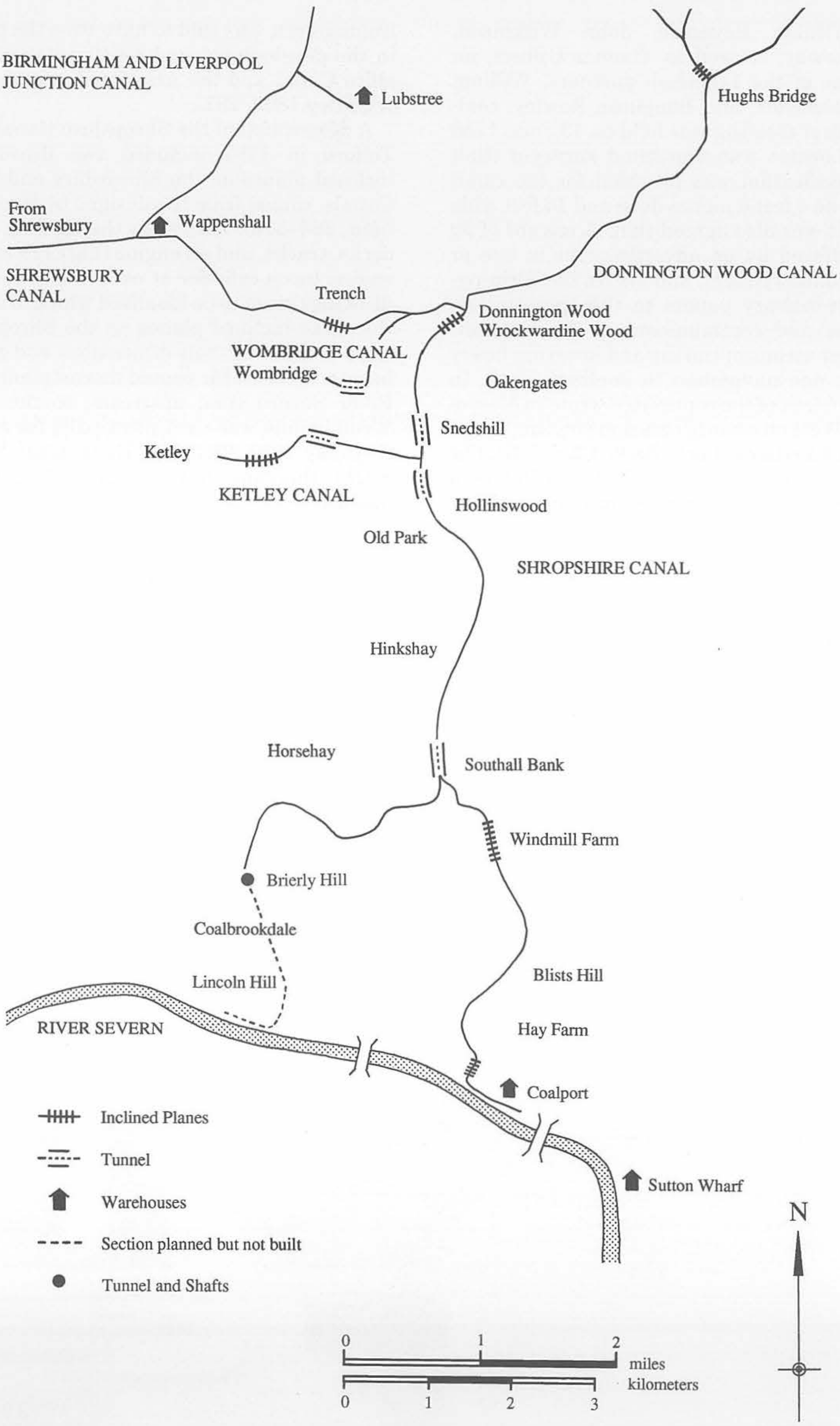


Figure 128 Canals of the East Shropshire Coalfield. The canals were linked with the national network, providing access to the River Mersey and the major ports of the North West. A variety of engineering solutions was required to cope with the upland terrain of the coalfield, such as inclined planes, tunnels, and shafts. (After Trinder 1981)

Reynolds, William Reynolds, John Wilkinson, Edward Blakeway, as well as Thomas Gilbert, an agent and one of the Lilleshall partners, William Ferriday, ironmaster, and Benjamin Rowley, coalmaster. The first meeting was held on 13 June 1788 when John Lowdon was appointed surveyor (Rail 869/1). A specification was provided for the canal which was to be 4 feet 6 inches deep and 16 feet wide at the base. It was also agreed that 'A reward of 50 guineas be offered by an advertisement in one or more of the London papers, and also in the Birmingham and Shrewsbury papers to that person who shall discover and communicate to the Committee . . . the best means of raising and lowering heavy weights from one navigation to another' (*ibid*). In addition, the Clerk of the committee wrote to Messrs Boulton and Watt on several occasions inviting them to put forward a scheme (*ibid*; B&W 4/3/6, 7, 8). The competition was won jointly by Henry Williams of Ketley and John Lowdon of Snedshill. James Watt and John Wilkinson acted as judges (Rail 869/1).

Henry Williams became the principal engineer and manager of the Shropshire Canal, a post he held for over fifty years. He began his career erecting engines for the Coalbrookdale Company and became a well known local figure, building the section of the Holyhead road which ran through the coalfield and becoming a partner in the Ketley Ironworks (Trinder 1981, 79, 123). However, William Reynolds, perhaps the most outstanding of the Shropshire ironmasters, was said to have been the prime mover in the development and construction of the Shropshire Canal and the associated engineering works (Plymley 1803, 291).

A description of the Shropshire Canal by Thomas Telford in 1797 included two drawings of the inclined planes on the Shropshire and Shrewsbury Canals, copied from the designs by Henry Williams (*ibid*, 284–316). They show the winding mechanism, docks, tracks, and an engine (Figs 129 and 130). The engine has a cylinder at each end of the beam. The drawings seem to be idealised which is important as the three inclined planes on the Shropshire Canal were to differ in their dimensions and gradient (see below). More traffic passed downstream towards the River Severn than upstream, so the Donnington Wood incline was used principally for raising goods (Plymley 1803, 293). The Donnington Wood incline might therefore have required larger boilers to operate.

The canal was constructed in sections beginning at the north end. By February 1790, the line of the canal was approaching the Hay, whilst in June 1790, the last section of the canal, now known as the Coalport Canal, was built. Three pumping engines were ordered for the canal between May 1789 and May 1790, one of which was erected near Windmill Farm (Rail 869/1). The engines were removed when the canal was fully operational, in retrospect a mistake given the ensuing water shortage problems.

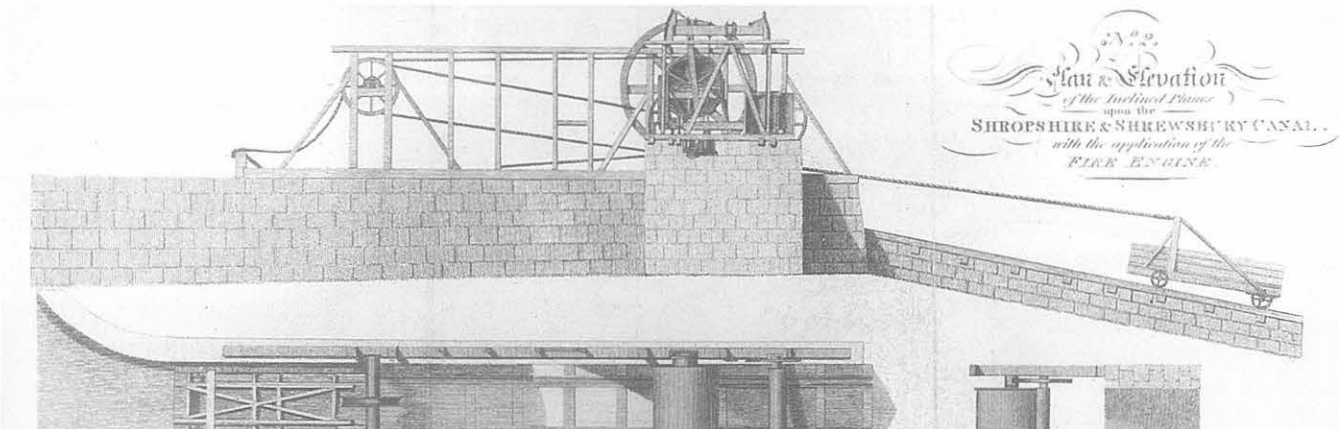


Figure 129 Plan and elevations of the inclined planes on the Shropshire and Shrewsbury Canals, drawn for Thomas Telford. They are thought to be copies of the design models for the inclines. (From Joseph Plymley's General View of the Agriculture of Shropshire, *1803)*

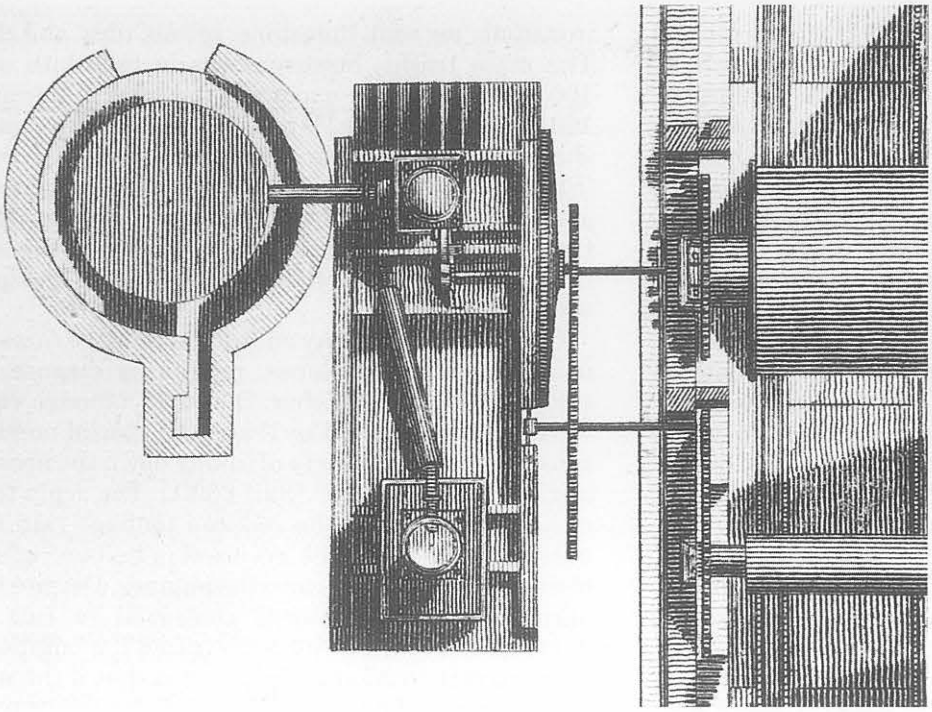


Figure 130 Detail from the plan of the inclined planes on the Shropshire and Shrewsbury Canals. The engine has a cylinder at each end of the beam, characteristic of those made by Adam Heslop. A single haystack boiler is behind the engine and the winding mechanism is in front. The drawing is a mirror image (on a vertical axis) of the arrangement at the Hay Inclined Plane. (From Joseph Plymley's General View of the Agriculture of Shropshire, *1803)*

First reference is made to one of the inclined planes in December 1789, when timber and iron rails were to be provided at Windmill Farm (Rail 869/1). In October 1790 it was 'ordered that a machine be erected and railways formed upon the line of the Canal near Southall Bank [Windmill Farm] and the Hay' (*ibid*). Timber sleepers were to be 7 feet long and 6 by 12 inches, whilst the iron rails were 6 feet long, 8 inches wide and 2 inches thick, with a flange 3 inches high. There were to be four holes in each rail. Boats were ordered for the canal, each 20 feet long, 6 feet 2 inches wide and 3 feet deep (*ibid*).

The first winding engine was erected at the Donnington Wood Inclined Plane (also known as Wrockwardine Wood) after January 1791. The engine was provided by agents Thomas and John Gilbert (Rail 869/1; Trinder 1981, 75, 100). It was on approval but was accepted by the company a year later (Rail 869/1). Unfortunately, the maker of the engine is not known.

During 1791 work was continuing at the Hay Inclined Plane, particularly to the rails and pavements. It was noted in October 1791 that 'Mr Wilkinson and Mr Reynolds having requested that men and horses should be kept at the Inclined Planes at the Hay and Windmill Farm to draw the boats up the same' (*ibid*). The request was agreed to. A horse gin may have been used for raising boats, but it is also possible that horses simply dragged the boats up the rails (Trinder 1981, 80). Wilkinson and Reynolds had to indemnify the Company against any expenses which might arise, possibly because the incline was still under construction. This is further suggested because Henry Williams was paid for directing the making of the incline nine months later (Rail 869/1).

In October 1792, the company agreed to erect an engine at the Windmill Farm incline. Finally, on 19 December 1792, it was ordered 'that an engine be erected at the top of the Inclined Plane at the Hay under the direction of Mr William Reynolds' (*ibid*). This was probably undertaken in early 1793. As the inclined plane itself was probably finished in the first half of 1792, it may well have been powered by a horse gin for the intervening period. A winding mechanism operated by a brake would have been essential for downward movement. Power would have been needed for dragging boats up the counterplane and for any upward traffic.

The Shropshire Canal Company minutes do not record the types of engines which were erected at the inclines, but two contemporary accounts have been found which show that at least two out of the three inclines were powered by Heslop engines. Adam Heslop worked for William Reynolds and his engines were manufactured at the Ketley Ironworks (Trinder 1981, 97, 101). In 1790 he obtained a patent for a 'New invented engine for lessening the consumption of steam and fuel in fire or steam engines' (Dickinson and Jenkins 1927, 316). It was similar in many ways to James Watt's engine because it had a separate condensing cylinder, but differed in having a cylinder at each end of the beam. This arrangement is shown in the drawings produced for Thomas Telford in 1797 (Plymley 1803, 294–5). Heslop was one of many engine designers working in East Shropshire, including James Sadler and James Glazebrook (Trinder, 1981, 97), and it was easy to have engine parts made in the local ironworking concerns.

In 1795, James Watt junior received a letter from his assistant, John Southern, describing the engines he had seen in Coalbrookdale: 'We saw at the inclined planes two engines of Heslop's *invention*, but they have improved upon the construction since Mr Boulton and I were at the Bank, by adding what they call an air pump . . . and putting a valve in the piston of what they call the cylinder, but which is now a very large air pump (& very unmanageable too we learnt) . . . We did not see either of them work' (Dickinson and Jenkins 1927, 316).

If Southern reported seeing two Heslop engines, Simon Goodrich in his visit to Shropshire in 1799, saw three: 'I proceeded about 2 miles farther along the bank of the canal and arrived at another Inclined Plane at Coalport . . . These two Inclined Planes as well as the one I saw yesterday were exactly upon the same plan & the same Machinery was used in all . . . A Heslops Steam Engine of 10 or 12 Horses power is . . . used to work the machinery' (Trinder 1988, 65). Later correspondence, said to have been written in 1879 by William Reynolds Anstice of the Madeley Wood Company to the Keeper of the Science Museum, also noted the use of Heslop engines, at the Hay and Windmill inclines (Williams 1965, 100; Tonkinson 1964). Thus, if one of the original engines was not a Heslop, it is most likely to have been the one at Donnington Wood. However, a drawing of the Donnington Wood engine from William Reynolds' sketchbook shows the engine partially hidden behind timber cladding, but it does in fact look much like a Heslop engine (Fig 131). It is quite possible, of course, that this engine was changed later.

By 1793, the minute book shows that the Shropshire Canal and Hay Inclined Plane were fully functioning. The goods transported on the canal included ironstone, pig iron, limestone, bricks, tiles, and clay. The main traffic, however, was in coal with over 100,000 tons being exported annually (Tonkinson 1964). The Horsehay Day Book of the Dale Company shows the range of goods transported in 1794–6 (SRRC 6001/334). These included consignments of ground clay and firebricks sent to the John Rose China Manufactory at Coalport, but most of the traffic was bound for the River Severn via the Coalport wharves.

Customers had to pay additional tonnage rates for using the inclined planes, prompting disputes as early as 1794. In October, the extra tonnage rates were reduced from 3d to 1½d but a special meeting considered 'the propriety of taking down the present engines on the planes' (Rail 869/1). The reply from customers was that the reduced tonnage rate was acceptable and that the proprietors had no right to charge more, nor to remove the engines. Despite this agreement, the argument continued to run. In September 1795, the company raised the additional tonnage rate to 2d and it was noted that if the mining companies did not agree, it might be necessary to remove the engines (*ibid*). A further increase in rates in October 1796 was disputed and in November, Henry Williams was directed to remove the Windmill Farm engine. In May 1797 the committee resolved that the ropes and carriages at Windmill Farm, and the engines, ropes, and carriages at the other two inclined planes should be refused to anyone not paying 2d extra tonnage (*ibid*).

Disputes over tonnage rates led iron and coal masters in the northern part of the coalfield to build their own railway to the River Severn. It was

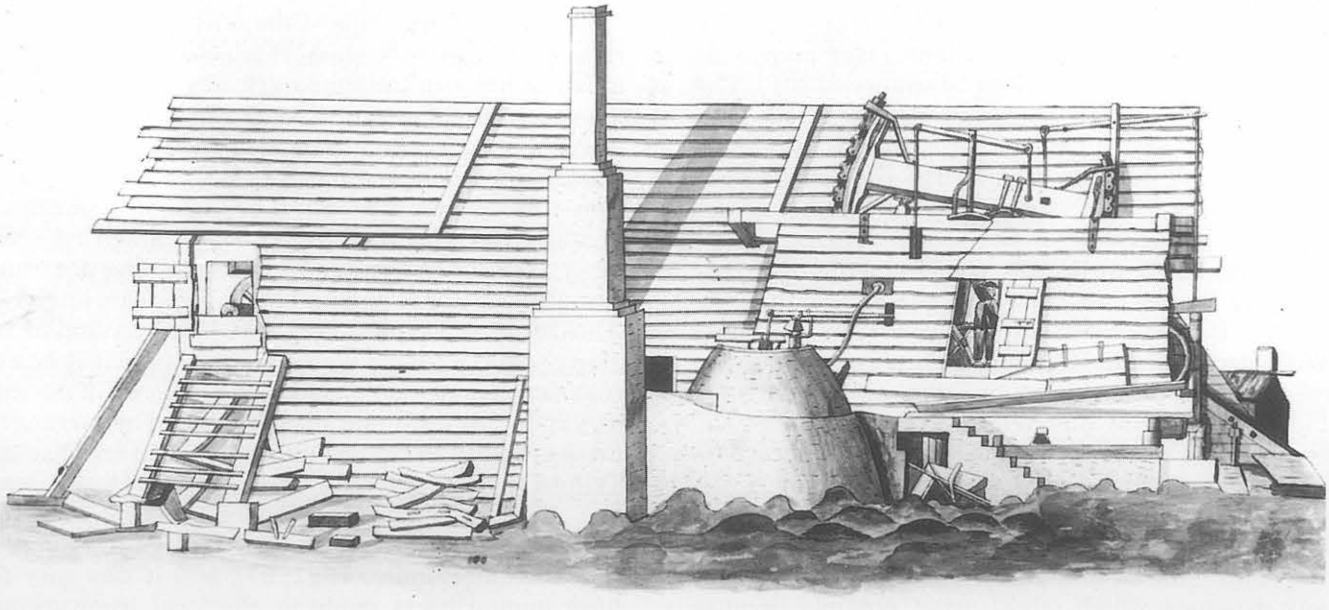


Figure 131 The Donnington Wood engine, sketched by William Reynolds. Though hidden behind timber cladding, the beam is seen projecting above the cladding. The arrangement of rods suggests that this might be a Heslop engine, but firmer evidence is required. A single haystack boiler and stack stand in front of the engine house. (Science Museum)

constructed in 1799 from Hollinswood to Sutton Wharf, east of Coalport, at a tenth of the cost of the canal (Trinder 1981, 84). In June 1812 the Lilleshall Company came to an agreement with the Shropshire Canal Navigation that they would take up their rails and convey their goods by canal in exchange for £500 (Rail 869/1; Trinder 1981, 84).

From 1795 to 1800, William Reynolds was allowed to use the Hay Inclined Plane free of charge or at a reduced rate as part of an exchange. In 1800, he wanted to use the engine in return for repairing it and supplying it with slack coal (Rail 869/1). Clearly, this was for his own purposes not connected with the business of the Canal Company. Whether this was purely for transportation, or whether he wished to use the engine for a different purpose is not known. Reynolds was planning a large chemical works at Coalport with Lord Dundonald in 1799, to be located between the Hay Inclined Plane and Coalport Bridge to the east. The manufacture of alkali, soap, glass, alum, white lead, dyes, and fertilisers was proposed (Trinder 1981, 134). The engine could have been used in connection with these plans, which never came to fruition, probably because of Reynolds' death in 1803.

In September 1800, the ropes at the Windmill Farm and Hay Inclined Planes were replaced by chains. This early use of wrought-iron chain was a significant development, but it may not have been a complete success: in March 1801, payment was ordered for 'the repairs of four boats damaged by a chain breaking upon the Hay Inclined Plane' (*ibid*). John Randall also reported melodramatically 'on a chain snapping we have known a canal boat with five tons of iron pigs on board gain such velocity that on coming in contact with the water in the lower canal it . . . lighted in the Severn, close to the ferry-boat, into which it pitched some of the iron pigs' (Randall 1880, 94).

Almost from the beginning, the Shropshire Canal was prone to major breaches and slippages along its length, requiring not only costly repairs, but payment of damages to land owners. In April 1799, a large slip at Blists Hill required the construction of a pool and dam, while in June 1810, it was agreed that Francis Darby of the Hay Farm should receive compensation due to sustained damage being caused by large slips in the canal (Rail 869/1).

The first cartographic depiction of the Hay Inclined Plane, a plan of 1803, shows lands belonging to the Hay Farm (SRRC 1681/181/20). It shows two parallel tracks from the top to the bottom of the inclined plane, and an annotation for an engine house in the position of the present engine house (Fig 132). The accompanying statement does not provide a specific description for these features because they do not form part of the Hay Farm (SRRC 1681/181/21). A scaled plan of the inclined plane was produced by Jean Dutens in 1818–19. The drawing of the winding mechanism is very detailed although it does not show an engine. The position of the drive shaft suggests that it was on the west side of the head of the incline (as in Telford's drawing), but the map of 1803 shows that the engine was always on the east side. Two Prussian engineers, Carl von Oeyenhausen and Heinrich von Dechen, visited the Hay Inclined Plane in 1826–7 during a tour of England and Wales (Lee and Gilbert 1971, 73–4). They wrote a detailed report noting that the plane had an engine with a 16 inch diameter cylinder and a 36 inch stroke and that it only had three rails, the central one being common. There is no evidence that the incline ever had three rails, so this description has to be treated as unreliable. This is further supported by the fact that von Oeyenhausen and von Dechen gave the wrong length (793 feet) for the inclined plane (*ibid*), so they may have

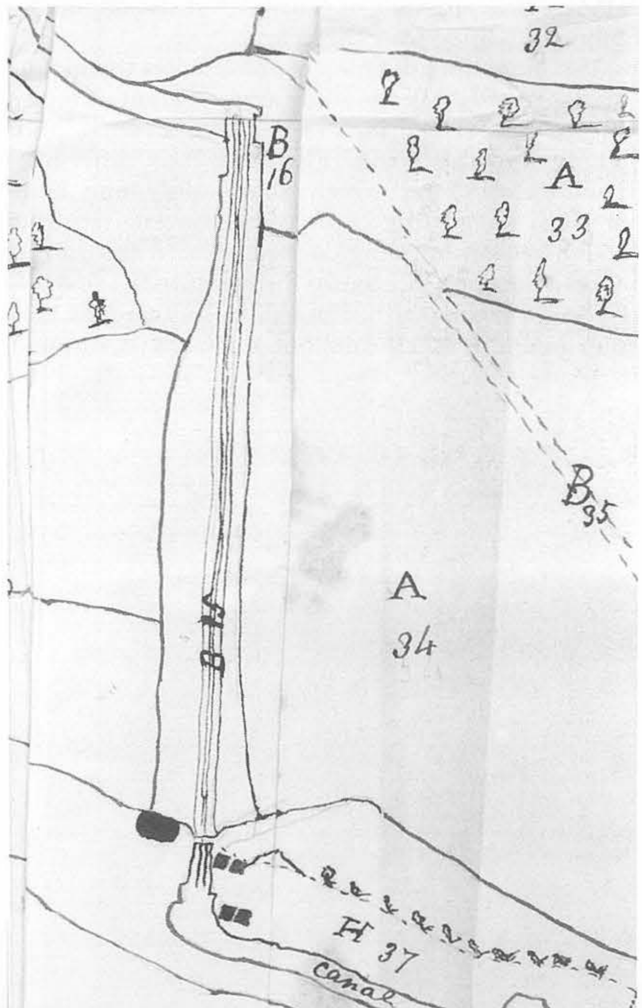


Figure 132 Excerpt of a map showing lands belonging to the Hay Farm, 1803–4. This is the earliest depiction of the Hay Inclined Plane, clearly showing the double tracks. Unfortunately there is no key for annotations B15 and B16 as the incline belonged to the Shropshire Canal Company, and not to the Hay Farm. (Shropshire Records and Research Centre)

confused it with another structure they had seen on their tour.

From 1830, it was necessary to let tenders for repairing the engines at the inclined planes, implying that the original engines were still present. The contracts were renewed in 1835 for a further five years (Rail 869/1). That the engines and machinery were in a poor state was suggested by Joshua Field in his diary of his tour of the Midlands in 1821. Of the Hay Inclined Plane he noted, 'The machinery is very rude, the Whimsey a very bad one, the railway strong but very much out of line, the rope barrels & c well contrived' (Hall 1927, 31).

According to William Reynolds Anstice in 1879, the engine at the Hay was changed for a Boulton and Watt engine in the 1840s (Williams 1965, 100). The Shropshire Canal Company minutes do not mention new engines being installed at any of the inclined planes. It is possible, of course, that the engine was simply modified over the years.

The Madeley tithe map of 1847 shows the inclined plane with exactly the same arrangement as today – engine house, two boilers flanking a stack, and a building to the north (Fig 133). It is different to Telford's drawing which shows only one boiler, perhaps suggesting changes to the engine. There was a second building connected with the running of the operation located on the towpath to the west of the head of the inclined plane. It is a two-unit building, but the apportionment does not mention its function; it was simply part of the 'Inclined Plane, Engine House & C' and may have been an office for a toll keeper; the disputes about tonnage rates suggests that payment had to be collected at each inclined plane. In a subsequent photograph of 1870–80, the building is shown with an arched opening facing east towards the incline, and a chimney in the south-east corner (Fig 134).

Railways became serious competition from 1845 when various companies were negotiating the purchase of the Shropshire Canal. In 1857, the London and North Western Railway purchased the canal for £62,500, by which time the canal and its inclined planes were in poor condition. In 1856, a (perhaps biased) report for the Shropshire Canal Conversion Bill claimed that 'the inclines and engines are dropping together into ruin, almost unserviceable' (Tonkinson 1964). Water shortage and mining subsidence were serious problems. After the Shropshire Canal was bought by LNWR, it was superseded by a railway except for the section which ran from the foot of the Windmill Farm incline to Coalport (*ibid*). Thus, the only surviving inclined plane was at the Hay. This short section was used to transport goods to and from the Madeley Wood Company's ironworks and mines at Blists Hill.

After its purchase by the LNWR, little is known of the Hay Inclined Plane until it is shown in the photograph of 1870–80 (Fig 134). Randall's description of the Hay Inclined Plane in 1880 noted 'another

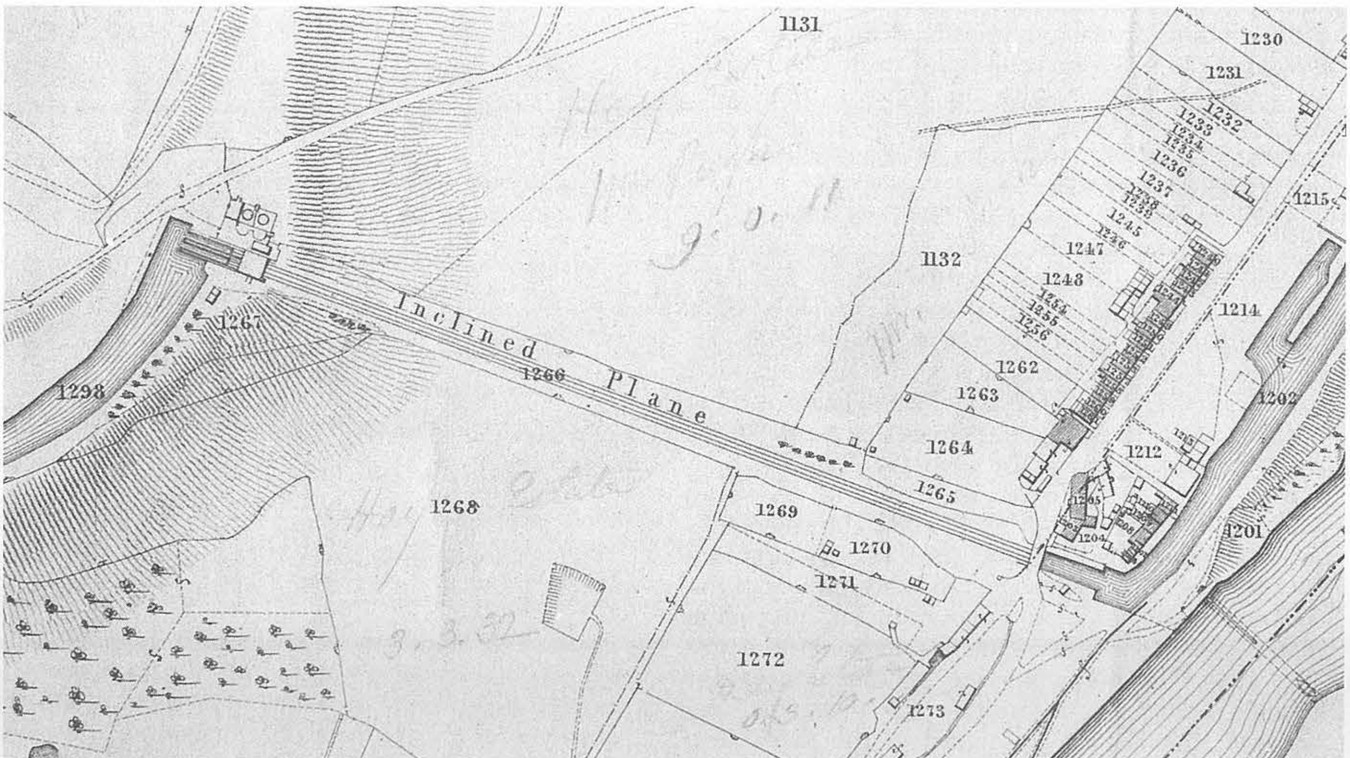


Figure 133 The Hay Inclined Plane and Shropshire Canal shown on the Madeley tithe map of 1847. North is to the left of the picture. The arrangement of the boilers and engine house are exactly as they are today. The small building at the end of the tow-path may have been for a toll keeper. (Ironbridge Gorge Museum Trust)

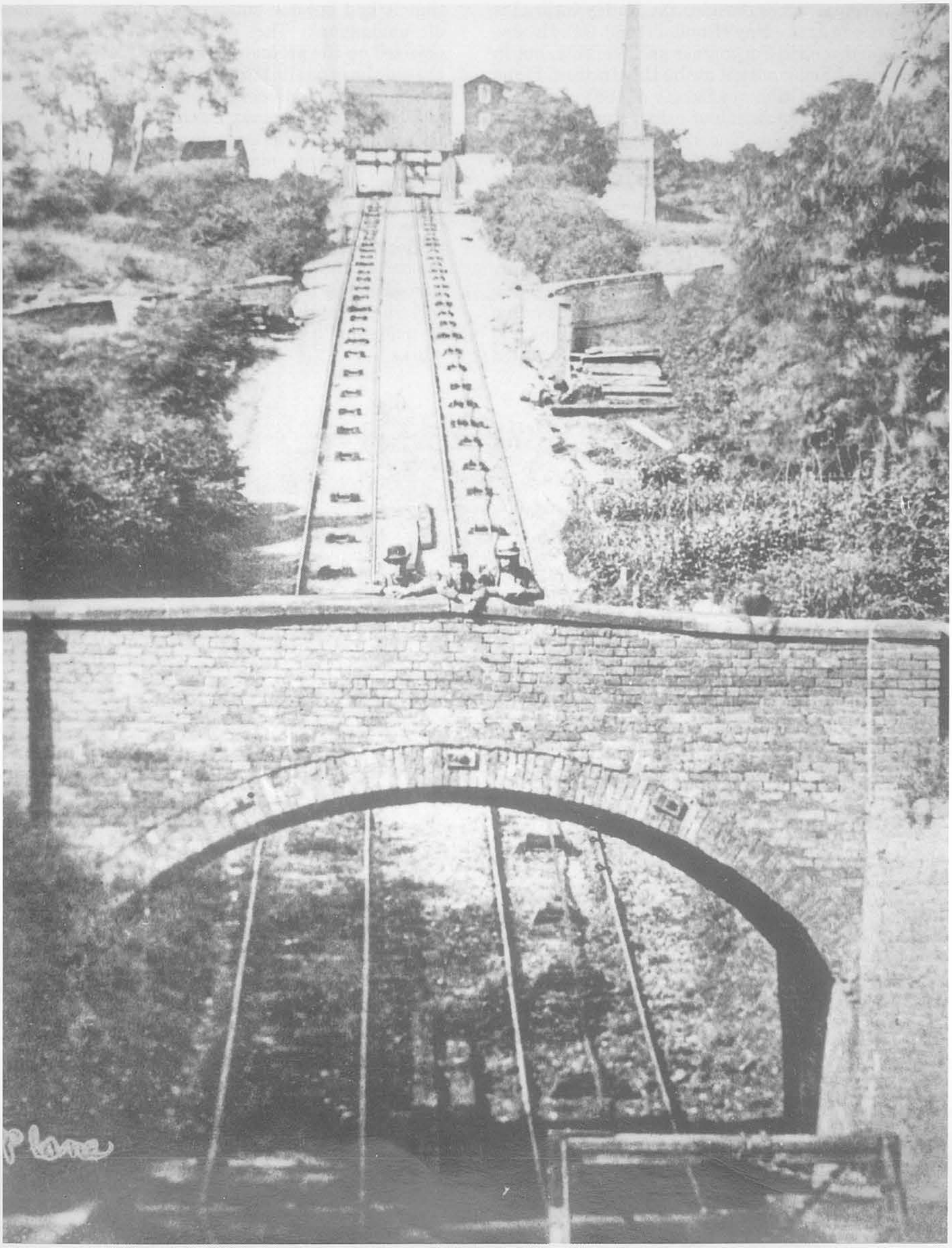


Figure 134 Photograph of 1870–80, showing the Hay Inclined Plane. Note the heights of the winding house, engine house, and stack. A wheel can just be seen on the west side of the engine house. (Ironbridge Gorge Museum Trust)

of these contrivances [besides the Ketley incline] is still in use near the Hay' (Randall 1880, 94). He also mentions three Heslop engines still working, but in the Madeley Field and not at the Hay Inclined Plane (*ibid*, 363). The Ordnance Survey of 1883 shows the incline, and a photograph of c1890 shows it in use but in poor condition. The 1902 Ordnance Survey, however, marks it as disused (Fig 135). An article of 1899 in a magazine called *Good Words* stated that the Hay Inclined Plane had been out of use for five years (Tonkinson 1964). Thus it seems likely that it fell out of use in 1894.

The Inclined Plane, however, was not officially abandoned. In 1905 a dispute arose between the Madeley Wood Company and LNWR regarding the proposed closure of the Hay Inclined Plane and Coalport Canal (SRRC 1681/185/8). LNWR stated that it had become 'unnecessary for the purposes of navigation'. The Madeley Wood Company objected on the grounds that when LNWR had purchased the canal in 1857 it had agreed to 'keep open and in condition proper . . . and with all proper and sufficient steam engines, machinery . . . and to work the said Inclined Plane steam engines'. The Madeley Wood Company maintained that LNWR had reneged on their original agreement and that they were unable to use the inclined plane and the lower section of the canal because LNWR had neglected them. A settlement was finally reached on 8 October 1907, when the Madeley Wood Company agreed to the abandonment on various conditions, including that the section through Blists Hill should be made into a reservoir with a dam near the ironworks.

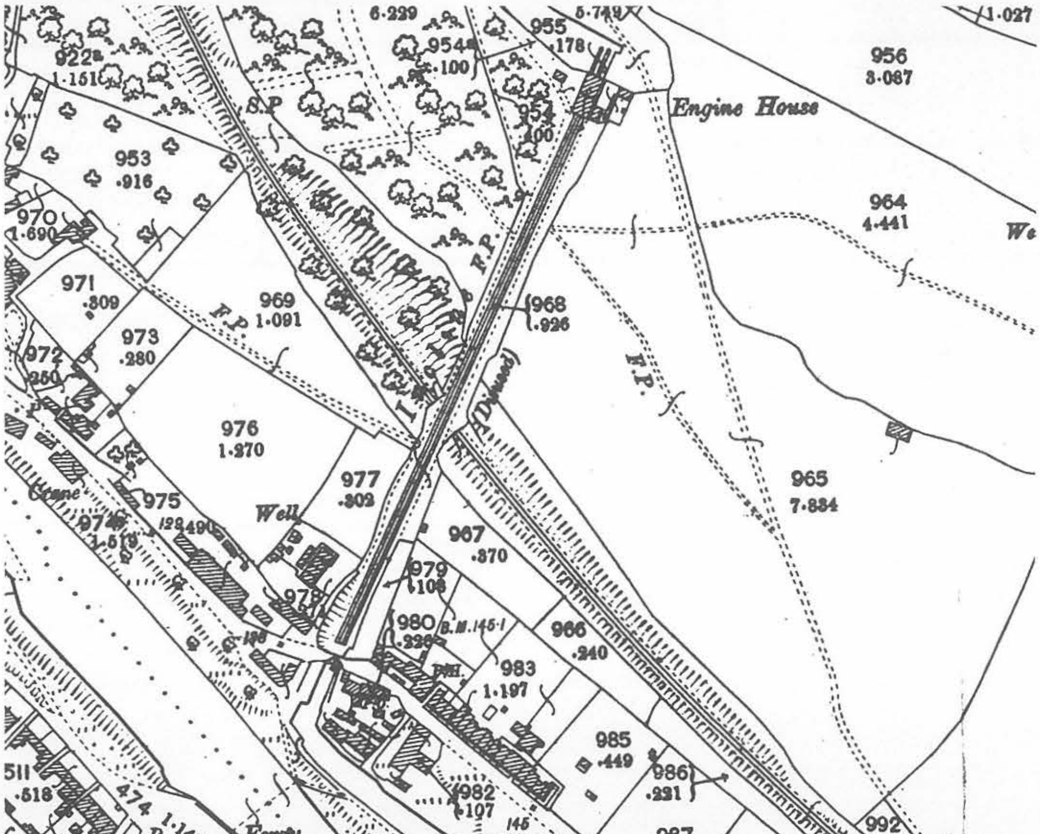


Figure 135 Detail of the Hay Inclined Plane from the Ordnance Survey of 1902. The incline is marked as disused, although a structure had been built over the north end of the loading bay walls since 1883.

The agreement resulted in the official demise of the Hay Inclined Plane and Shropshire Canal leading to a long period of dereliction: The rails on the incline are said to have been taken up in 1910 (Trinder 1996, pers comm). In 1935 the site was derelict and Watkins-Pitchford reported that the handles of the brakes could be seen sticking out of the weeds (1935, 17). Photographs from the 1950s show that the engine house and winding house had been taken down and the boilers and machinery removed. The lower canal basin had become infilled and everything was overgrown.

The site

The Hay Inclined Plane has a horizontal length of 275m and a slope length of 282m, from the apex to the lower canal basin. The fall is 63m resulting in a gradient of 23% (Fig 136). It is laid with double-tracked rails on modern sleepers. At the top of the incline are two loading bays (one for each track) incorporating a short counter-plane of 15m length. To the east of the loading bays is a small ruined engine house, boiler settings, and stack, bound by stone and brick retaining walls (Fig 137). Canal basins are sited at the top and bottom of the incline. From the top basin, the canal runs north-west for 600m through thick woodland, with a sharp drop to the south-west. It is furnished with three stop locks, which originally had safety gates which pivoted from the west side, but which were later replaced by stop planks. The canal survives as far as the Blists Hill Brick and Tile Works (Fig 127). In the visitors' car park beyond, the canal is infilled, but a short section is open further north. The lower canal runs east, parallel with the River Severn, and has only been excavated as far as a stop-lock at the west end of the Coalport China Museum. A grassed area between the canal and the High Street covers a second, lower canal basin.

From October 1791, when the canal was still under construction, the Hay Inclined Plane was worked by horses who dragged boats up the slope. The canal was completed in the first half of 1792, but this was before the engine was erected in early 1793. Movement of goods would have been predominantly downwards, so some type of winding mechanism and brake must have been required. Additional power would have been needed to raise goods up the counter-plane and up the main slope. There are two alternatives; a horse gin installed at the top to operate the winding mechanism for both upward and downward movements, or horses pulling full boats up the slope and counter-plane while a brake mechanism controlled downward movements.

The archaeology of the site shows that the loading bays and some type of winding mechanism were in use before the engine was erected. The earliest sections of the masonry loading bays incorporate the counter-plane and terminate just south of the sill, short of the engine house (Figs 138 and 139). The bays were later extended to the south. The walls contain a series of recesses for holding-down bolts, narrow rebates with cast-iron plates at their bases, some infilled. Across the north end is a low masonry dam (Fig 139). The holding-down bolts towards the centre of the counter-plane appear to be integral with the walls and probably held down the sill beam or frame for a winding mechanism. A horse gin could have been located on the east or west side of the inclined plane, but the east side is more likely because the west side was the towpath. It is most likely to have been north of the extant engine house, which must have been under construction when the horse gin was in use. No evidence of a horse gin has been found to date.

The upper canal basin was built after the loading bays but the two are probably roughly contemporary (Fig 140). The basin is rectangular in plan and bounded by masonry walls to the north and east, repaired and altered in the 1970s. On the south side is a graded earth bank to the west of the loading bays, while the canal runs off from the west side. The basin was originally lined with red clay. Map evidence from 1803–4 until 1902 suggests that the basin was never remodelled (Figs 132, 133, and 135). Alterations did occur, most notably the insertion of an overflow culvert into the east wall, which fed the lower (Coalport) Canal. The Shropshire Canal

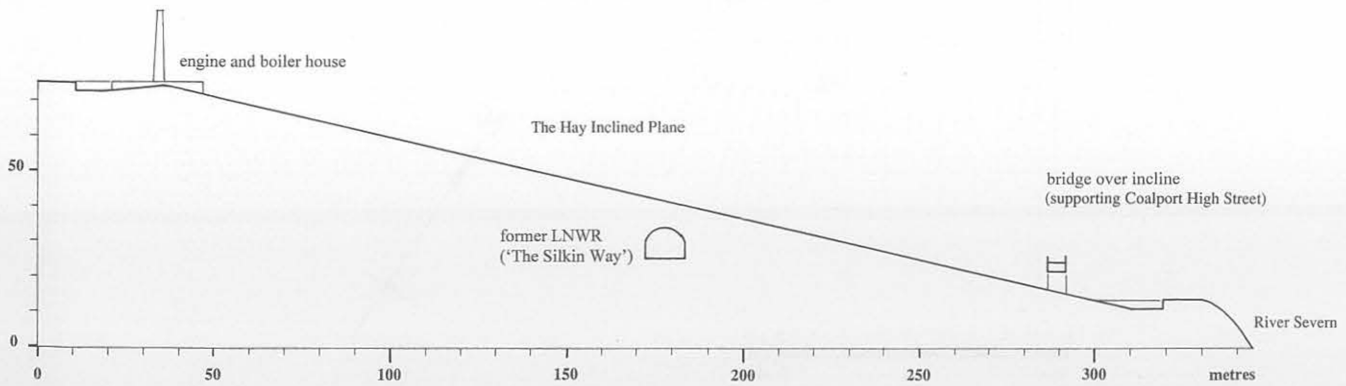


Figure 136 Profile of the Hay Inclined Plane. It has a gradient of 23% and a short counter-plane at the top. A bridge was made underneath for the London and North Western Railway (Coalport branch) in 1857.

Company Minute Book reveals that in 1790 the lower canal was fed by a different source, water from a spring running by the side of the Sheepwash Meadow (Rail 869/1). This was before the canal was complete.

The loading bays at the bottom of the incline are similar to those at the top, but there is little sign of alteration. Each has four pairs of recesses for holding-down bolts and there is a masonry dam at the lower end. Early rails survive in these bays, though they are normally below water. When the canal was recently drained for repairs, a wear mark was seen on the paving between one set of rails caused by the friction of the ropes or chains. The canal basin walls are also of dressed masonry but they were extensively repaired in the 1970s with areas of brick and concrete.

The upper loading bays were extended when the engine house was built in 1793, the eastern loading bay wall forming the west side of the flywheel pit (Fig 139). Bolts inserted between the old wall ends and the extensions, and within the extensions, held the sill for the new winding frame. The winding house superstructure, which survives as a low brick wall surmounting the east and west loading bay walls, was extended southwards at the same time as the loading bays.

Possibly at the same time, there were alterations to the original dock walls to the north (Fig 139). New stop gates with cast-iron rebates were inserted at the north end, above the dam. An outflow culvert approximately 0.6m above ground level was inserted next to the gates in the east loading bay wall, but its purpose is unclear. There is

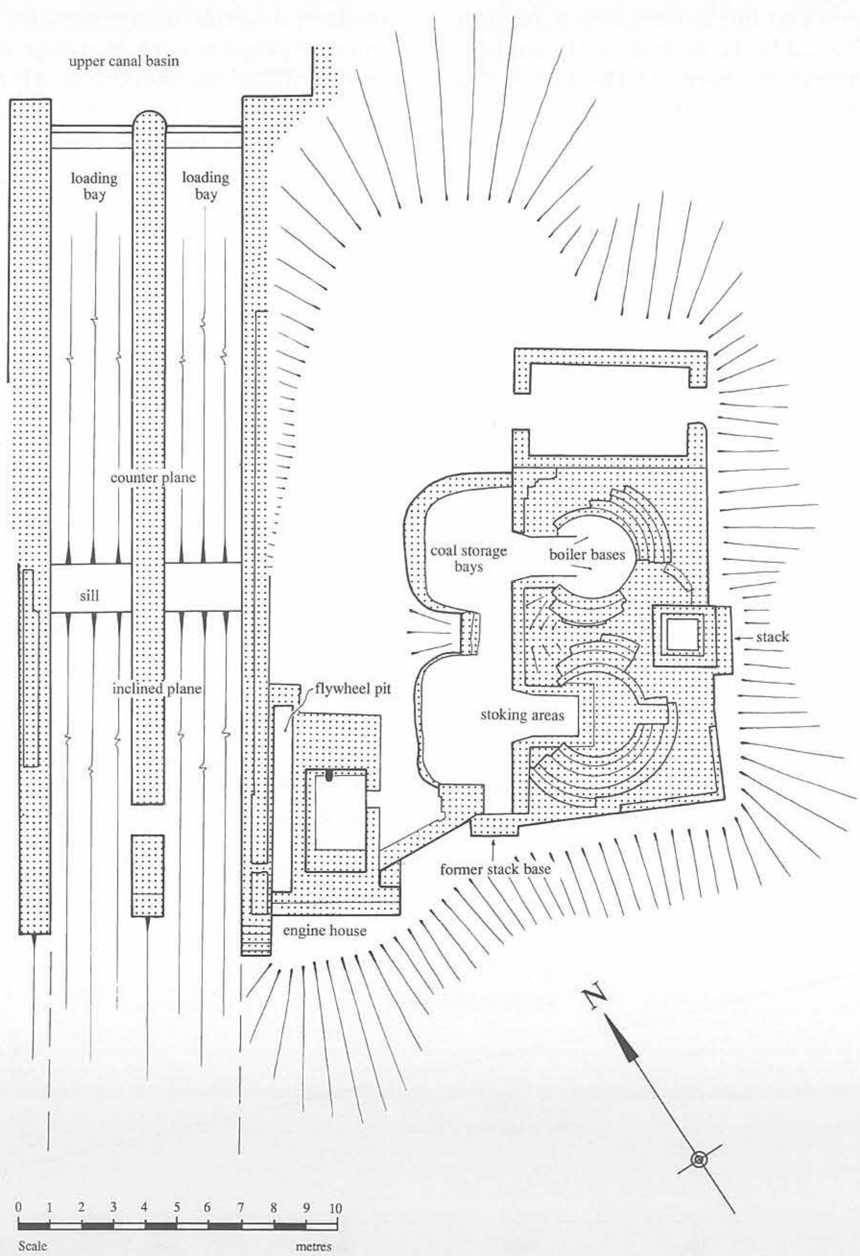


Figure 137 Plan of the head of the Hay Inclined Plane, showing the loading bays, engine house, boiler house, and coal storage areas.

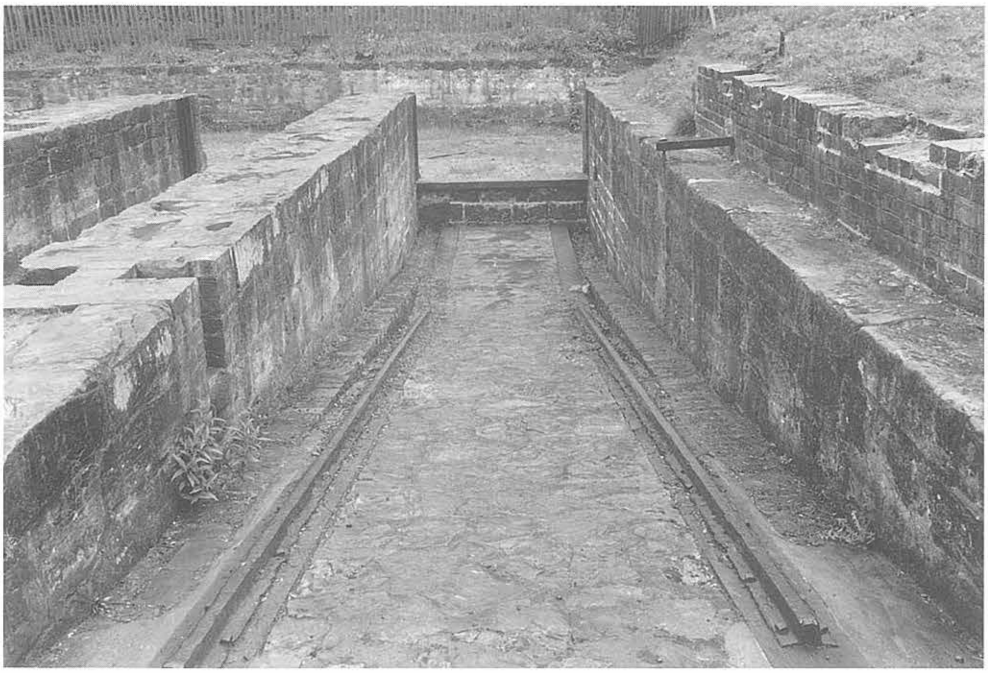


Figure 138 Iron rails laid on the counter-plane in the eastern loading bay, photographed in 1993. These are original to the structure but were relaid on modern paving in the 1970s.

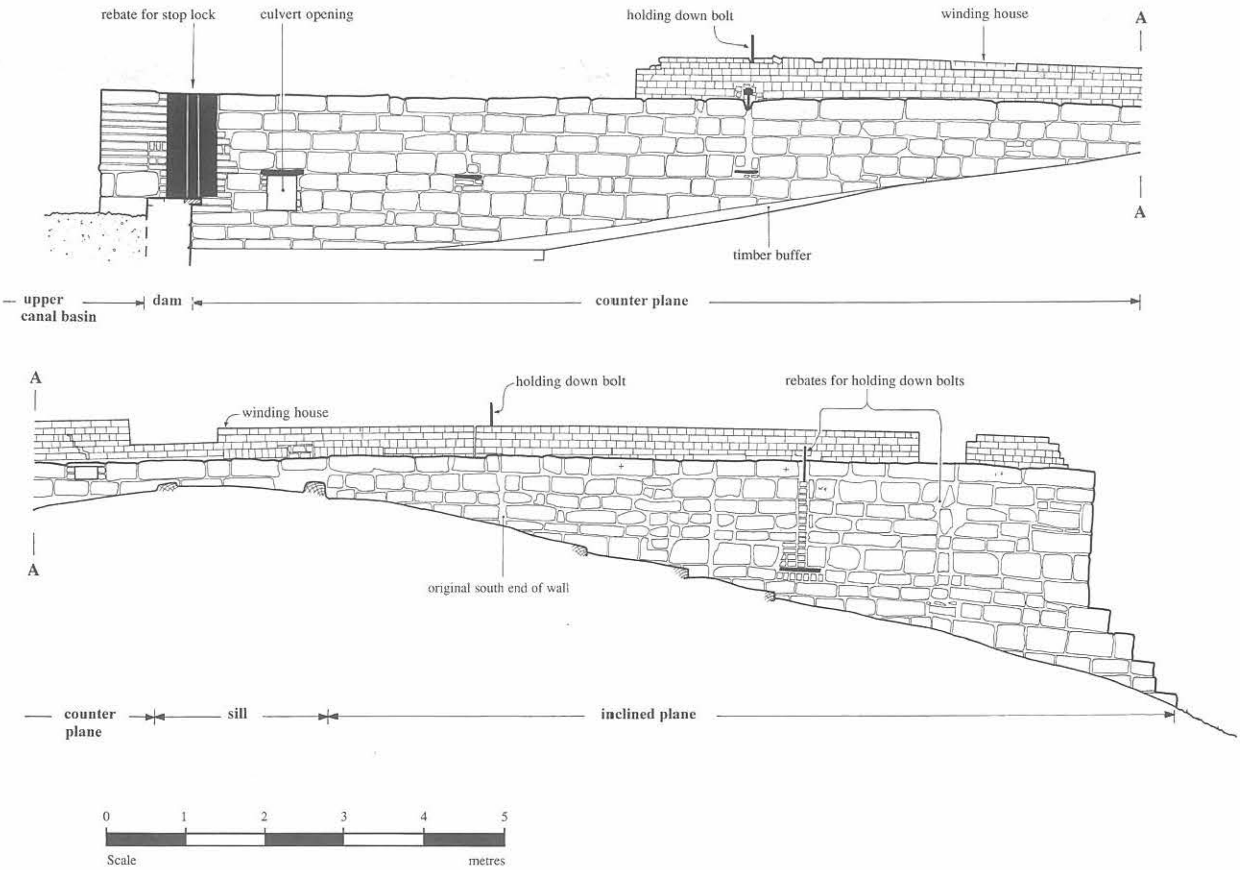


Figure 139 Elevation of the east wall of the eastern loading bay. Before the engine was erected, the wall terminated just south of the sill. The masonry wall is surmounted by the base of a brick winding house, which was also extended southwards when the engine was built. The recessed bolts held down the frame for the winding mechanism.

Figure 140 The upper canal basin at the Hay Inclined Plane, photographed looking north in 1998 after it had been refilled with water. The rails in the loading bays run down into the water, so that tub-boats could be easily attached to the cradles on the incline.

no matching overflow culvert in the western loading bay, so it cannot be connected with settling boats on cradles as formerly suggested (Watkins-Pitchford 1935, 16). It may have been associated with the other culvert opening in the east wall of the canal basin.

The design for the inclined planes on the Shropshire Canal reproduced by Telford shows an engine house with one boiler and a chimney (Plymley 1803, 295) (Figs 129 and 130). This closely matches the Donnington Wood incline as depicted in William Reynolds' sketchbook (Fig 131). Whether the engines were constructed on the left or right sides of the inclines was probably determined by geology, topography, and other practicalities. The map of 1803 has an annotation for the engine in its current position suggesting that it was always on the east side at the Hay (Fig 132).

The engine house superstructure has changed little since its original construction in early 1793. It is a small rectangular structure of dark red/brown bricks on a rubble sandstone plinth standing nearly 2m high to the south, where the ground falls away (Figs 137 and 141). The walls enclose a cylinder bed to the north and a condenser pit to the south (Fig 142). The flywheel pit, between the engine house and loading bays, is 0.6m wide. Although small in plan, the engine house formerly stood to a considerable height, as seen in a late 19th-century photograph (Fig 134). Two visitors to the site, John Southern in 1795 and Simon Goodrich in 1799, said that the engine was by Heslop (Fig 143). The most distinctive characteristic of a Heslop engine is that it has two cylinders, one at each end of the beam and this arrangement is shown in the Telford drawing (Fig 130).

Before interpreting the remains of the engine house, it is worth considering how a Heslop engine would have worked (Fig 143): The steam entered the receiving cylinder, mounted high, from where it was educted to a lower working cylinder, located at the other end of the beam in a water tank. When the steam in this lower cylinder was condensed, a vacuum was created and the piston would fall, creating the working stroke. The connecting rod and crank would therefore have to be at the other end of the beam, next to the receiving cylinder. A drive shaft running from the crank would work the flywheel and the winding mechanism, and gears could be taken off it to work subsidiary shafts.

The receiving cylinder would have been mounted on the surviving cylinder bed (Fig 142). A narrow central shaft was for the holding-down bolt, with access provided at the base of the plinth. Two pairs of sockets in the pit probably held the beams which supported the water tank in which the working cylinder was immersed. At the base of the north side of the pit is a large irregular cavity, an outflow for water (Fig 142). The beam fulcrum was probably supported by a wooden frame, but no evidence remains. With this arrangement, the connecting rod must have been located immediately south of the receiving cylinder on the north side of the beam. The flywheel would then be expected to occupy the northern half of the flywheel pit.

Archaeological evidence supports the argument that the original layout of the boiler and chimney at the Hay was similar to that in Telford's drawing (Figs 129 and 130) but had changed by 1847 (Fig 133). The extant boiler bases are enclosed within retaining walls to the south and east (Figs 137 and 141). At the west end of the south side is a projecting stone plinth 1.4m wide. This supports a vertical column of hand-made red brickwork, with offsets, which survived to a much greater height in the 1960s (Tonkinson 1964) (Figs 137, 141, and 144) and appears to have been a chimney stack. Physical evidence shows that the structure is earlier than the

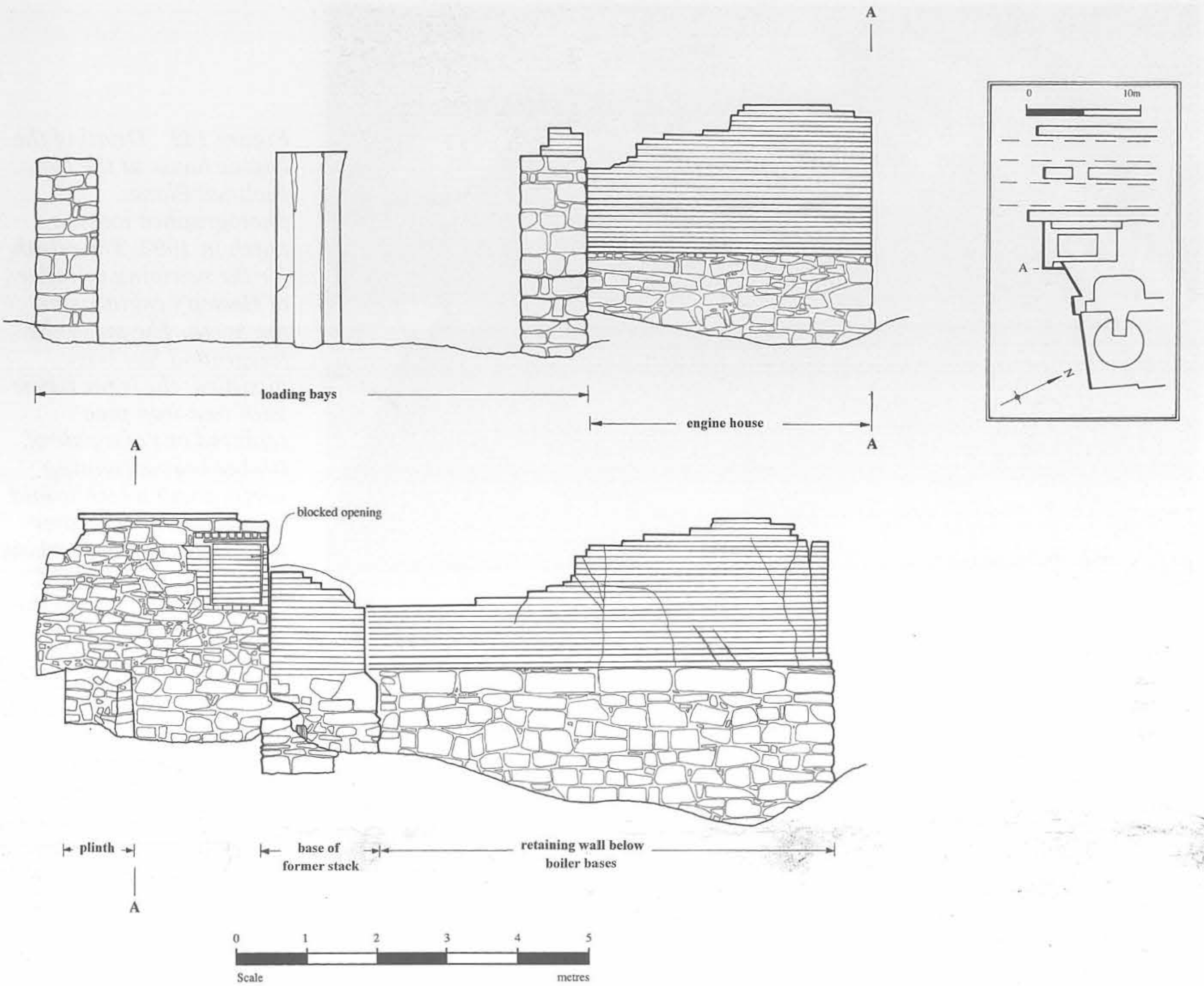


Figure 141 South elevation of the engine house and boilers at the Hay Inclined Plane. The projecting base of the former stack is linked to the engine house by an angled wall which is probably contemporary. A plinth beneath and to the left of the wall may be earlier. New boilers were added before 1847 and the retaining wall on the right is of that period.

boiler retaining wall to its east and is roughly contemporary with an early, misaligned, rubble wall to its west. Beneath this west wall is another rubble wall which also runs beneath the engine house (Fig 141). Its purpose is uncertain, but it is clearly earlier than the engine.

The interior of the former chimney stack was converted to a recess when the new boilers and stack were built. Some of the internal brickwork on the south and west sides was altered, whilst the east side was replaced by the west retaining wall of the new boilers. The interior was whitewashed (removing any evidence for smoke blackening) and there is a small iron pintle suggesting a former gate. A later half arch has collapsed into the recess (Fig 145), but was visible in its original position in a photograph of the 1970s. Originally it sprung from a pier which had been inserted into the south coal storage area of the new boilers (Fig 137). The south end of the coal storage retaining wall contains much disturbed brickwork. This may have formed part of the original boiler setting, which one would expect, from Telford's drawing, to be in this position, north of the stack and east of the engine house (Figs 129 and 130).

The winding mechanism at the Hay Inclined Plane does not survive, although there is evidence for the attachment of the frame to the dock walls (Fig 139). A hypothesis for the working of the winding mechanism is as follows, based partly upon the drawings by Telford and Dutens, and a token showing the self-acting Ketley Inclined Plane (Figs 146 and 147). The main winding drum was aligned with the connecting rod of the engine although the drive shaft was not continuous, but linked by gear wheels so that the engine could be disengaged from the drum. A smaller winding drum for the counter-plane was positioned to the south. Both these were linked by gear wheels and would have operated simultaneously. Brake wheels for both winding drums were

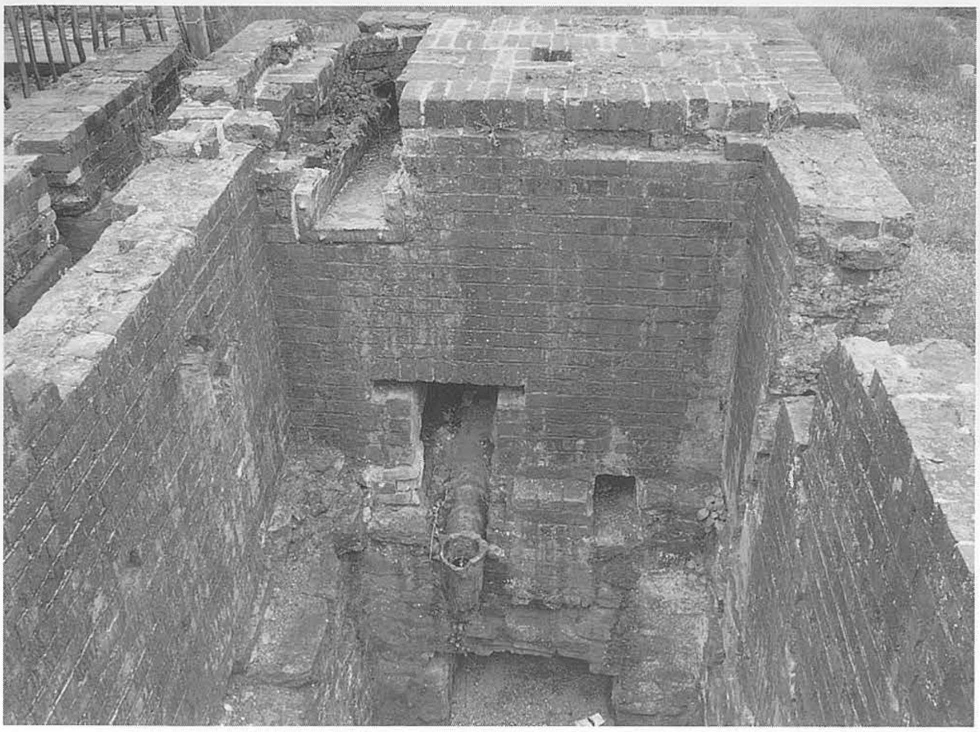


Figure 142 Detail of the engine house at the Hay Inclined Plane, photographed looking north in 1993. The plinth for the receiving cylinder of Heslop's engine is to the north. The pit in the foreground has been modified: the large recess with cast-iron pipe replaced one of a pair of timber beams running north–south which would have supported a water tank in which the working cylinder was immersed. The flywheel pit is on the left.

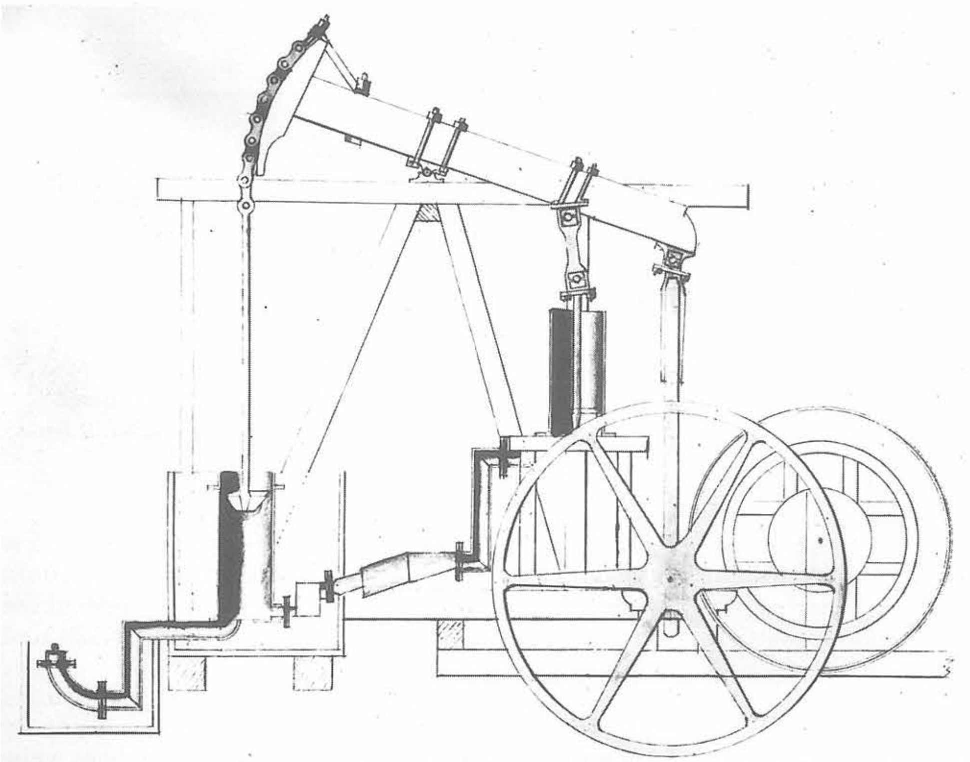


Figure 143 A Heslop engine from William Reynolds' sketchbook. Note the water tank on the left containing the working cylinder. The beam is longer on the right side of the fulcrum and supports the receiving cylinder, mounted high, and the connecting rod. (Science Museum)

located upon the central loading bay wall, worked by hand-operated levers. Pulleys were located to the north. The ropes or chains for each set of rails were independent of each other, but were wound round the drums in opposite directions so that one boat went up whilst the other went down. After a boat had been hauled up the counter-plane to the sill, it had to be disconnected from the smaller winding drum. The engine began the movement of the boat down the inclined plane and again when the full boat reached the bottom, so that the empty boat could be pulled up to the sill. In between, the inclined plane was self-acting except when a full boat was rising (Tew 1984, 18–20; Trinder 1978, 8–9). When the empty boat reached the upper canal, it was replaced by a full boat, so that each set of rails was used for upward and downward movement. The boats moved up and down on cradles which had large wheels to the rear and smaller wheels to the front. This helped to keep the boats level but posed a

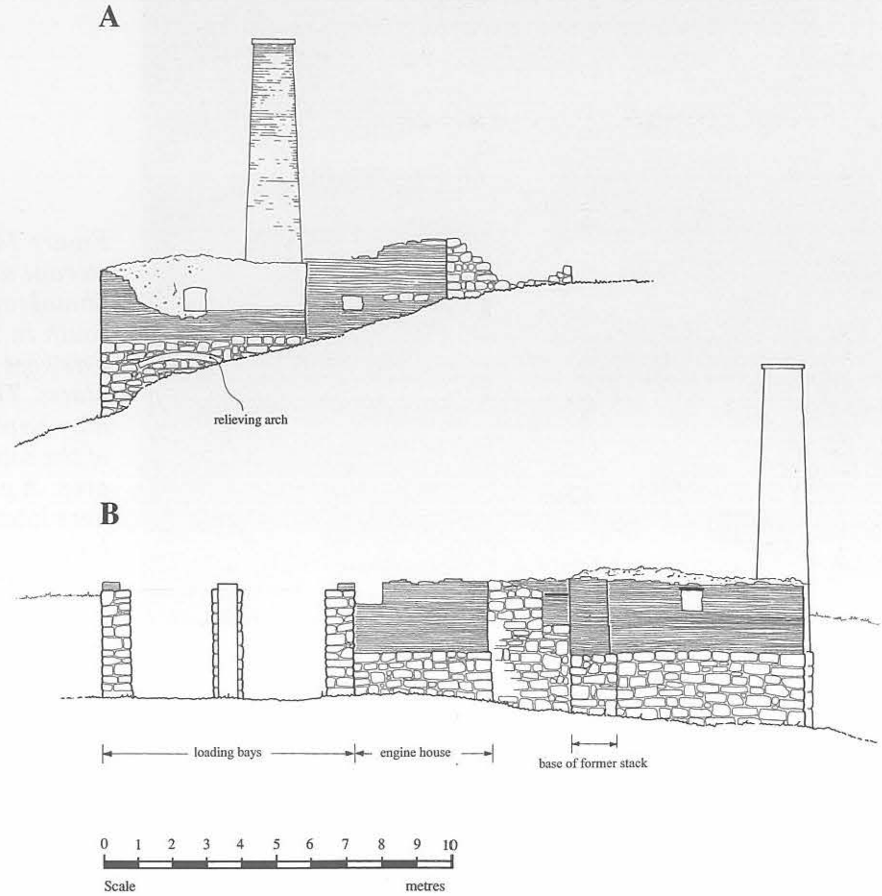


Figure 144 Elevations of the Hay Inclined Plane engine house and boiler settings in the early 1960s. Up to sixteen courses of brickwork have been lost since that time, so the drawings are useful for showing features which no longer exist. (A) is the east retaining wall of the boiler settings, showing a now buried relieving arch. (B) is the south elevation of the structure showing the earlier stack standing much higher. The flue opening to the right was barely visible in the early 1990s. (After Tonkinson 1964)

problem on the counter-plane, where they would be tipped at an unacceptable angle. To solve this problem, the cradles had an extra set of wheels fitted on the outside to run along raised buffers.

It was recorded in the Shropshire Canal Company Minute Book that William Reynolds was using the engine for his own purpose from 1795–1800 (Rail 869/1). Whether the engine was used for winding or some other function is not known. It is possible that it was connected with a proposed chemical works at Coalport, but a brief search of fields to the east of the Hay inclined has revealed no evidence of any relevant features.

The current configuration of two boilers and a chimney stack was laid out to the east of the original structure some time before 1847 (Figs 133, 137, and 141). A sherd of porcelain and a saggar fragment found in the fill in the south-east corner of the structure show that it dates to after the foundation of the John Rose china manufactory at Coalport in 1795–6. This proves that the boilers are not original to the site. The two new boiler bases are aligned north to south, with the new stack between them (Fig 148). They are formed of three concentric rings of machine-made firebrick which surround and stand above brick platforms (Fig 149). The white bricks of the concentric rings were laid dry, but those to the north in particular have modern cement pointing. Some of the bricks are stamped 'Hall Stourbridge'. Dissimilar curved flues run from each boiler base to the stack. Further flues run to the exterior walls of the structure. The north boiler base flue runs east to a square headed opening which is now blocked. The parallel flue from the south boiler base is under a segmental brick vault. A second flue, fragmentary in nature, leads to the exterior south wall. The tapering stack is on a square base and random rubble plinth, with arched openings for flues to the north and south. The stack rises 7m but the top has been truncated (Fig 148). Its base is advanced beyond the face of the east wall.

Each boiler base has a corresponding area for stoking and coal storage (Figs 137 and 145). The coal storage areas are defined by sloping brick retaining walls with rounded angles. As noted above, the south end of the south coal store retaining wall is very disturbed. In front is the passage from where the boilers were stoked. All these areas are paved with brick and three large cast-iron plates have been laid over the top.

Figure 145 The coal storage and stoking areas, photographed looking south in 1993. The coal was kept on cast-iron plates. The original boiler may have been in the area of the south coal storage area. A pier was inserted here later, supporting a half arch which has now fallen into the former stack base.

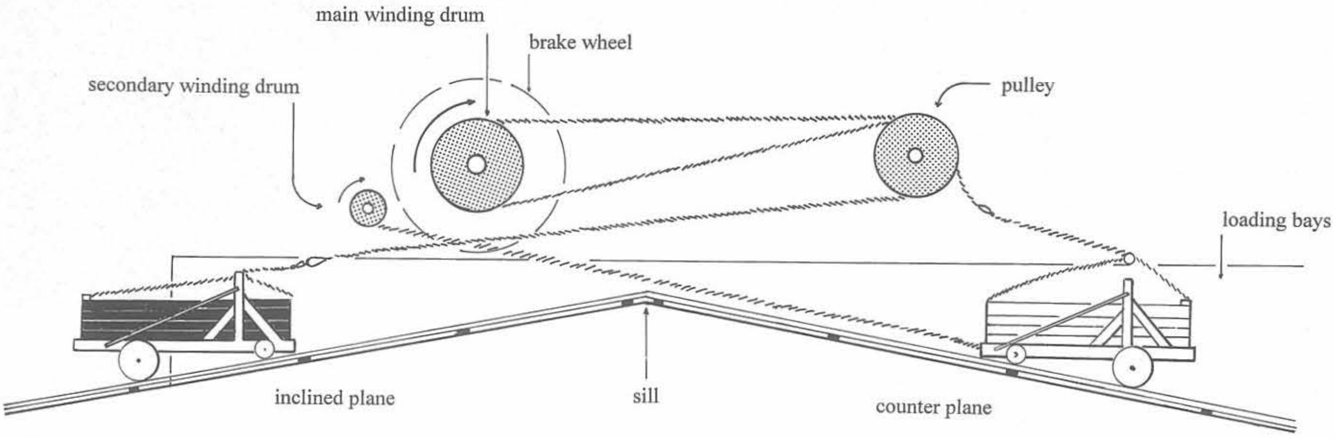


Figure 146 A reconstruction of the winding mechanism at the Hay Inclined Plane. The engine was connected to the main winding drum but when a boat was hauled up the counter-plane, it had to be disconnected and attached to the secondary winding drum.

The structure of the new boiler settings and chimney underwent no significant alterations during their lifetime, but there were minor changes. The concentric rings of the settings consist of machine-made firebricks which can be dated to the later-19th century. They are therefore not original and it is likely that they needed to be replaced on a regular basis. The exterior flue to the north boiler was an original feature, but it was blocked by the concentric rings of the settings so it cannot have been essential. The east exterior flue to the south boiler was partially rebuilt with a new segmental-arched opening. It was set back from the wall face, possibly due to structural destabilisation; there is also a wide misaligned crack at the south end of this wall. Tonkinson's drawing of 1964 shows a wide arch within the masonry plinth, more or less below this flue opening, which is now below ground level (Fig 144). It had masonry fill below, so was probably a relieving arch built to support the new flue. In 1964, the flue to the south wall was shown to have a square opening with an iron lintel, similar to the north boiler flue.

It is likely that the boilers worked as follows: after the fires were lit, smoke and hot gases would pass around the boiler shell in a 'wheel draft', a flue within the concentric rings of brickwork, and then escape up the chimney. The flues to the exterior walls could have allowed air in when the fires had just been lit, as this apparently helped to get rid of smoke, as well as providing more oxygen (Dickinson and Jenkins 1927, 241–2). Alternatively, they could have been cleaning holes, but they are rather too low when compared to the position of the wheel drafts (*ibid*, 238).

A small rectangular building is attached to the north side of the boiler bases. The walls survive to less than 1m height and are of random rubble. It has a brick floor with doorways into the east and west ends, and had steps leading up to the east door (Fig

Figure 147 The Ketley inclined plane, shown on the reverse of a trade token of 1789. The incline was operated by counter-balancing, so that the weight of a full boat descending would raise an empty boat. A simple brake mechanism was operated by hand. Trade tokens were a form of currency which compelled the work force to buy provisions at company shops, often at inflated prices. (Ironbridge Gorge Museum Trust)

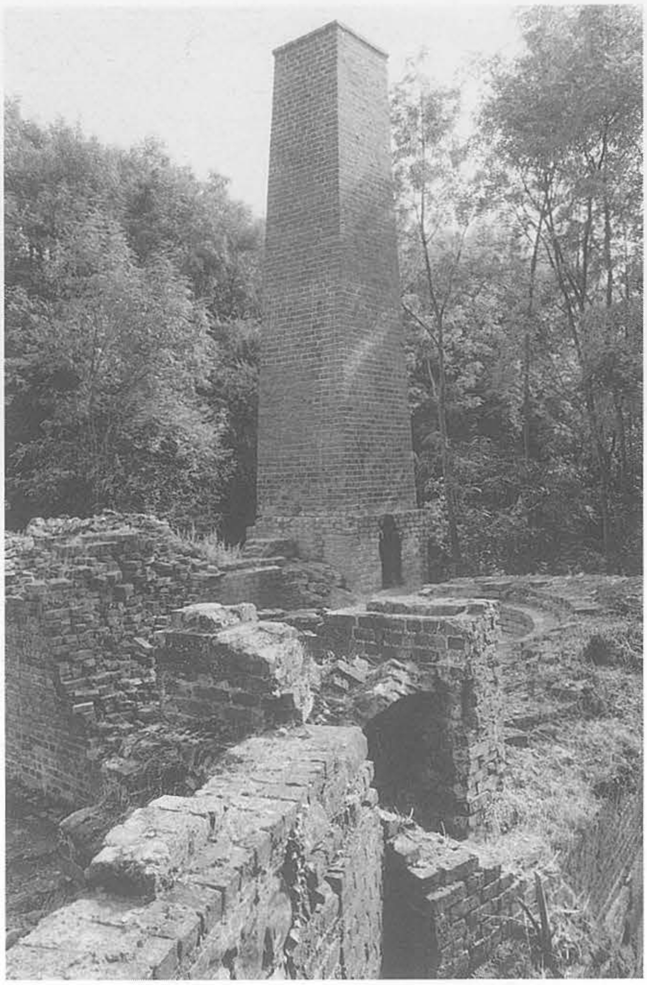


Figure 148 The stack at the Hay Inclined Plane, photographed looking north-east in 1993. Constructed before 1847, the stack originally stood higher. The remains of the older stack base can just be seen in the foreground.

137). It is first shown on the Madeley tithe map of 1847 (Fig 133) and appears to have been built at the same time as the boilers. It may have been for the engine- or boiler-man. The map of 1847 also shows an extension of the north wall of this building westwards until it reaches the docks which includes a doorway which would have been the only obvious entrance into the structure. This wall no longer survives above ground.

Although the structure of the engine house was not altered during its life, changes to the machinery clearly occurred. A recess for one of the beams which supported the water tank for the working cylinder was blocked, suggesting that the tank was either moved or removed. This recess, on the west side of the north face of the pit, was blocked on the insertion of a much larger opening from which a cast-iron pipe emerges (Fig 142). Its function is not clear but it could have supplied steam to the bottom of a double-acting cylinder, or been linked to an eduction valve. A shallow, iron-lined gully inclined towards the north was inserted along the west side of the cylinder plinth and then passed below ground. It may have been an overflow culvert from a tank, perhaps even feeding water back to the boilers.

The engine was probably changed to a Watt-type arrangement of power cylinder with separate condenser supplied with steam at atmospheric pressure. The bottom of a small wheel mark is located on the east face of the flywheel pit at its north end, probably denoting a gear wheel, and associated with the large flywheel shown in a photograph of 1870–80 (Fig 134). It is therefore likely that the connecting rod must have been moved to the south end of the beam with the power cylinder and condensing cylinder at the north end. It is not known when these changes were made to the engine, but it may have coincided with the construction of the new boilers and stack. The Shropshire Canal Company Minute Book states that repairs were undertaken to the engines from 1830 and 1835, suggesting that they were not new at that time. Thus, changes may have occurred after 1835 and before 1847 when the new boilers and stack are shown on the Madeley tithe map. This agrees with the comment by Anstice that the engine was changed before 1849 (Williams 1965, 100). There is no evidence that the engine was actually made by Boulton and Watt; it was probably either of this type or amended to this type.

Alterations to the engine led to changes in the loading bay walls and thus the winding mechanism. The south extensions of the loading bay walls contain later recesses for holding-down bolts (Fig

Figure 149 The south boiler setting, photographed looking north-east in 1993 in advance of repairs. Note the concentric rings of firebricks, which were originally laid dry to allow for expansion. A flue can be seen leading to the stack and another to the exterior east wall.

139) and an opening was cut through the central loading bay wall. This would correlate with the movement of the flywheel towards the south. There were also changes to the earlier walls to the north, when new holding-down bolts were inserted. However, these appear to relate to a very late phase: a structure is shown in this location in the Ordnance Survey of 1902 (Fig 135), but not in the earlier edition of 1883.

Summary interpretation

The Shropshire Canal Company was formed in 1788 to allow the movement of goods from the East Shropshire Coalfield to the River Severn. The upland nature of the proposed route resulted in a competition to design the best method of raising and lowering goods from one level of the canal to another. It was won jointly by Henry Williams, who became the canal engineer, and John Lowdon, the surveyor. Some drawings of the successful model were produced by Thomas Telford and included a depiction of a Heslop engine (Fig 129). Construction of the Shropshire Canal began at the north end in December 1788 and it was open for traffic in the first half of 1792.

Phase I (1791–2): Horses were used to pull boats up the Hay Inclined Plane in October 1791 when the canal was still being built. In 1792 the inclined plane was working without a steam engine. The archaeological evidence shows that the loading bays were built before the engine was erected (Fig 139). They contain the remains of holding-down bolts, which would have supported the frame of a winding mechanism. The mechanism was probably operated by a horse gin, although no evidence for one has yet been found. The upper canal basin was constructed after the loading bays, but is essentially of the same phase. The lower loading bays at Coalport are similar; the side walls contain holding-down bolts, probably for a frame.

Phase II (1792–3): William Reynolds erected the engine at the Hay Inclined Plane in early 1793. The archaeological evidence shows that this was a Heslop engine, in accordance with Thomas Telford's drawing in 1797 and the observations of two visitors in 1795 and 1799 (Figs 130 and 143). A single boiler was located to the east of the engine with a stack to the south, the general arrangement shown by Telford. Remains of this stack can still be discerned as a column of brickwork on a masonry plinth projecting from the south retaining wall of the structure (Fig 141).

The loading bays were extended down the main slope to support a new winding mechanism, the holding-down bolts for which are still visible (Fig 139). The brick superstructure of the winding house was also extended to the south. At the north end of the loading bays, stop gates with cast-iron rebates were inserted above the dam. An overflow culvert was built in the eastern loading bay wall, although it is not clear when. The canal basin overflow culvert may have also been inserted at this time.

In 1800 the ropes at the Hay Inclined Plane were replaced by wrought-iron chains, a recent innovation. In 1830–5 repairs were undertaken to the engine but there is no evidence of any major changes by this time.

Phase III (1835–47): The structure was remodelled between 1835 and 1847. Two new boilers with a stack on the east side were constructed, along with a small building to the north (Fig 133). The engine appears to have been altered within the existing engine house superstructure. Although insufficient fieldwork was undertaken in this area for a full analysis, it is likely that a power cylinder with separate condenser was located at the north end of the beam, while the connecting rod was moved to the south end of the beam. A small building with stack was constructed on the west side of the head of the incline plane by 1847, possibly for the collection of tolls (Fig 133).

The Shropshire Canal was purchased by LNWR in 1857. It was superseded by the railway except for a short section between the foot of the Windmill Farm incline and Coalport Station. The Hay Inclined Plane was by now the only surviving incline on the Shropshire Canal. The canal and the three inclined planes had been reported to be in a poor state of repair. Amendments were made to the flue system of the boilers.

Phase IV (1894–): In 1894 the Hay Inclined Plane fell into disuse. An extension to the winding house was erected above the north end of the docks after 1883, for which holding-down bolts are visible (Fig 135). In 1907 the Hay Inclined Plane was formally closed following an agreement between LNWR and the Madeley Wood Company. The rails were removed in 1910 and a period of dereliction followed.

Restoration work began at the Hay Inclined Plane in 1969. The site was taken over and managed by IGMT and the Hay Inclined Plane began a new life as an ancient monument and, for the second time, a tourist attraction.

The Shropshire Canal in context

The Shropshire Canal was part of the expanding canal network in Britain in the 18th century, but can also be seen in the context of transport facilities in the East Shropshire Coalfield. Industrialists had always been dependent on the River Severn, the second longest navigable river in Britain. The river, used in conjunction with the new canal network, allowed a far greater range of destinations to be reached. Coalport was a port for the transhipment of goods from the Shropshire Canal to the River Severn, whilst Stourport, further downstream, provided access to the Staffordshire and Worcestershire Canal and hence Birmingham and the Black Country. Direct links could also be made to the cities of Northern England, such as Liverpool, and North Wales, via the Shropshire, Shrewsbury, and Ellesmere Canals (Randall 1908, 425; Trinder 1981, 67). This was especially important at a time when industrial activity was growing at an almost exponential rate (Trinder 1981, 61). Roads were never much of an alternative, although Thomas Telford's Holyhead Road, completed in East Shropshire by 1835, did take some freight traffic (*ibid*, 148). This was short-lived, however, with the coming of standard-gauge railways to Shropshire in the mid-19th century. The railways were the new way forward: Heavy loads could be easily transported to almost limitless destinations. The River Severn was also unreliable to the extent that sometimes it was not navigable for several months of the year (Plymley 1803, 82). It soon became redundant and the associated canal network was used mainly for local traffic.

Expansion of the canal network in the late-18th century meant more canals in upland locations. Telford had described the Shropshire Canal in 1797 as passing though unusually hilly and waterless terrain (Plymley 1803, 290). Traditionally, goods were raised from one level to another by locks, but these needed a lot of water and were slow to use. The alternative was to invest in heavy engineering works such as inclined planes, lifts, tunnels, and aqueducts. The most common solution in East Shropshire was the inclined plane. This solution had its origins in the inclined railways associated with the mining of coal and ironstone, which descended steeply to the River Severn. One of the earliest recorded inclines was in use at Broseley by 1607 (Lewis 1970, 258–9). The wagons were generally controlled by ropes, and the winding mechanisms operated by horses or men, but sometimes wagons had individual brakes. Counter-balanced or self-acting inclines developed in Shropshire from the mid-18th century (*ibid*).

The earliest canal inclined plane in Shropshire was at Ketley, constructed in 1788 by William Reynolds. It was self-acting, with a vertical rise of 22m, and was designed to move goods from the Ketley Ironworks to the Ketley Canal. With a working life of thirty years it was relatively short-lived. It closed in 1818 when the Ketley furnaces were blown-out and it became immediately derelict (Tonkinson 1964). The canal inclined plane was a progression of the railway incline in Shropshire, but Reynolds appears to have been aware of developments elsewhere in Britain. His sketchbook contains a drawing of an inclined plane at the Cyfarthfa ironworks in South Wales (Dickinson 1923), whilst he almost certainly knew of Ducart's Canal in County Tyrone, Northern Ireland (Lewis 1970, 289). This canal was cut from Coalisland to nearby collieries and required three inclined planes each with a maximum rise of 21.5m. At first, the inclines were to be water-powered and the boats were designed to pass over rollers. Finally, the boats ran over rails, and ascended by means of counter-balancing and a horse gin. The inclines were never a great success and were only used intermittently from 1777 until 1787 (Tew 1984, 6; McCutcheon 1965, 174).

The Ketley Inclined Plane was the model for the five inclined planes which followed in East Shropshire (Figs 128 and 147). They were built within a few years of each other; the Hugh's Bridge incline on the Donnington Wood Canal was ordered around 1790 and was operating by 1794, the three inclines on the Shropshire Canal were complete by 1793 and the Trench incline on the Shrewsbury Canal was authorised in 1793 (Tew 1984, 21) and working by 1797 (Hadfield 1966, 333). They were the first canal inclined planes in Britain to be powered by steam.

By 1800, there are said to have been about 200 steam engines in the East Shropshire Coalfield, the densest concentration in Britain (Trinder 1981, 93). Most of them were atmospheric engines employed at the collieries, where pumping engines preceded and outnumbered winding engines. High premiums were payable to Boulton and Watt before the expiry of Watt's patent in 1800, a situation which probably encouraged industrialists to experiment with different forms of engines from a variety of lesser-known inventors (Trinder 1981, 98).

Adam Heslop, whose engine had a cylinder at each end of the beam, is the best known of these rivals to Boulton and Watt, mainly because he was patronised by William Reynolds (Fig 143). Apart from the remains at the Hay, the base of a Heslop engine survives at the Blists Hill Pit (now backfilled for its long-term preservation). The only known complete Heslop engine is from Kell's Pit, Cumbria, erected in 1795, which is now exhibited at the Brighton Engineerium. Adam Heslop and his brother Crosby made engines primarily for collieries: Five engines were erected in the Madeley Field during the period 1794–7 while the Heslops were working there, although it is not clear whether they built them all (SRRC 271/1; Trinder 1981, 101). It was relatively easy to adapt colliery engines, whether for winding or pumping, for canal use. Heslop also experimented with 'beamless' engines, which transmitted power by means of a crankshaft. Other contemporary engine designers in the coalfield were the balloonist James Sadler who erected simple winding engines around Coalbrookdale in 1792–3 (Trinder 1981, 97), and James Glazebrook, who erected a blowing engine at Calcutts Ironworks around 1800 (SRRC 6001/2366). In 1803 Simon Goodrich saw an experimental, high-pressure, pumping engine erected under the supervision of Richard Trevithick at Coalbrookdale (SML Goodrich E2, f 42).

Another innovation associated with the Shropshire Canal inclines is wrought-iron chain which is first mentioned in the Shropshire Canal minutes in 1800, only a couple of years after its invention. By 1802 there were two chainworks at Coalport, one of which supplied the Shropshire Canal (Trinder 1981, 129).

The Hay Inclined Plane has survived much more completely than the other Shropshire canal inclines and this can be attributed to its late date of closure and its location. With a successful working life of over one hundred years, the Hay Inclined Plane is quite exceptional, outlived only by the Trench Inclined Plane. The Donnington Wood and Windmill Farm inclined planes closed in 1858 when that section of the canal was closed and replaced by railway (Tew 1984, 18). Little remained by the turn of the century and the Windmill Farm incline is now completely destroyed by a housing estate. The upper part of the Donnington Wood Inclined Plane survives as a rough track while the site of the engine house is still extant. A housing estate was built over the site of the Ketley Inclined Plane in the 1970s. The Hugh's Bridge incline went out of use *c* 1879, so also had a relatively long life. It survives as an embanked slope and the upper and lower canals are still visible. The Trench Inclined Plane on the Shrewsbury Canal was the last to be closed, in 1921. It has been completely destroyed by a road which is regrettable because the masonry docks survived until the 1970s (*ibid*, 21; Trinder 1996, 176–7). The Hay Inclined Plane is also exceptional because it is the steepest on the Shropshire Canal. Its gradient of 23% compares with approximately 7% for the Windmill Farm incline, and 12.5% for Donnington Wood (Hadfield 1966, 153, 333).

An alternative method of raising and lowering goods was attempted at Brierly Hill, the terminus of the western branch of the Shropshire Canal, which linked with Coalbrookdale. This was the tunnel and shaft system, which had also been used at Hugh's Bridge before the construction of the canal inclined plane. Samborne Palmer, a Somerset coal master, visited Brierly Hill in July 1791 and saw crates being raised and lowered inside two vertical shafts by counter-balancing. Between the two shafts above ground level, was a large winding drum and fly wheel, whilst above each shaft were cast-iron pulleys. At the bottom, crates were loaded into horse-drawn railway wagons in a tunnel approximately 300m long (Doughty 1979, 20). The system was replaced only two or three years later by a railway incline known as the 'Old Wind', possibly because the weight of goods ascending was too great to achieve successful counter-balancing (*ibid*; Lewis 1970, 290; Trinder 1981, 80–1).

The steam-powered canal inclined planes of Shropshire were both early and unusual. The only comparable incline was the High Wellisford Inclined Plane on the Grand Western Canal. In 1836 a steam engine was installed in place of the 'bucket in a well' method which had been a dismal failure. The engine was short-lived, however, as that section of the canal was closed in 1837 and the inclined plane machinery was dismantled (Tew 1984, 14–15).

Canal inclined planes could also be water powered and there is a concentration of these in south-west England dating to the early-19th century. In 1819 an Act was passed for the construction of the Bude Canal which had five inclined planes powered by waterwheels and a sixth operated by the 'bucket in a well' method with a steam engine in reserve. The Bude Canal Engineer, James Green, was responsible for several other water-powered canal inclined planes including one on the Rolle or Torrington Canal (*ibid*, 12–15; Hadfield 1967, 196). Four inclined planes were built on the Chard Canal by Sir William Cubbitt *c* 1834, two powered from the lower end, one by a turbine and one by an overshot wheel (Tew 1984, 16). There were also three inclined planes constructed on the Kidwelly and Llanelli Canal in South Wales in 1838. Two were water powered but the third was never used (Hadfield 1960, 258).

All the inclined planes so far discussed carried small tub-boats. Important new developments occurred in the late-19th and early-20th centuries when inclines were designed to handle medium-sized and full-sized boats (Tew 1984, 24). There were two inclined planes of this type in Britain, both steam powered. One was on the Monkland Canal in Scotland and the other was the Foxton Inclined Plane on the Grand Union Canal in Leicestershire. The Monkland Canal supplied coal and iron to Glasgow, but when traffic increased, the water supply proved insufficient for the locks. In 1850, an inclined plane was installed. Some counter-balancing was achieved by filling descending caissons with water, but it was mainly powered by a high-pressure engine driving two vertical drums on separate shafts in opposite directions, which were located in a pit under the top of the incline. The caissons were 21m long and each had 10 pairs of wheels. The incline closed down around 1887 when the coal pits were nearly worked out and there was competition from the Caledonian Railway (*ibid*, 35–6). The Foxton Inclined Plane was built in 1900 and its purpose was to bypass the Foxton Locks. The canal had been taken over by the Grand Junction Canal Company who wanted to encourage traffic between the Derbyshire Coalfield and London. Boats were carried transversely on two large caissons 24m long, which each had eight pairs of wheels running on four tracks. Counter-balancing was used to some extent and the slope at the top could be altered to counteract the effect of the descending caisson entering the water. Thus the need for extra power was limited, but there was a 25 horse-power engine which also provided hydraulic power for lock gates and rams. Unfortunately, the incline soon became a white elephant because the Canal Company agreed to install narrow locks at Watford, so that wide boats could not pass up the canal. It was closed in 1910 (*ibid*, 36–8) and thus had a very short working life. It is now a scheduled ancient monument. These technological developments, allowing a much greater volume of traffic to be carried, occurred between fifty and one hundred years after the construction of the inclined planes on the Shropshire Canal.

8 Iron in the East Shropshire Coalfield: a retrospective view

The intensive study of four major ironworking sites leads inevitably to a fresh review of the iron industry of the East Shropshire Coalfield. In this section the ironworks of Madeley Wood, Coalbrookdale, and other works in the Ironbridge Gorge are discussed in the context of the iron industry of both Shropshire and Britain. Several themes have emerged in the present study, either through a reassessment of documentary sources or as a direct result of archaeological interpretation. These include the technological and managerial factors in the development of the iron industry in the 18th century, the pre-eminence of the foundry over the forge in the local trade, and the influence which the ironworks of the East Shropshire Coalfield exerted on the development of the British iron industry in the 18th and 19th centuries.

The development of coke smelting and the integrated ironworks

The adoption of coke smelting was to have unforeseen consequences in the future management of iron production. The question of why there was a delayed reaction in the spread of the new method does not need a convoluted explanation. In fact, there is no special reason why coke smelting should have made an immediate impact. As will be discussed below, Darby did not publicise his discovery or attempt to gain financially from its use, but was interested in it principally for the development of his foundry. Nevertheless there was a sudden growth in the building of furnaces for coke smelting in the 1750s which does warrant a more detailed consideration.

The classic interpretation of this development is the 'quality of iron' theory, meaning that coke pig iron was initially inferior to charcoal pig for almost all conceivable uses, especially for the forge. Its adoption in the 1750s by the Stour valley forges in Worcestershire has been cited as the benchmark of its improved quality (Ashton 1951, 35–6). Here coke pig iron was first used in 1754–5 and subsequently coke pigs were purchased from all but one of the new generation of Shropshire works: Horsehay, Ketley, New Willey, and Lightmoor (Ince 1991, 37–41). Exactly what improvement was perfected in the 1750s has never been entirely clear, except that it was most likely connected with the quality of ironstone, given the absence of Bedlam and Coalbrookdale in the list of suppliers to the Stour forges. The ores exploited for the Coalbrookdale and Bedlam furnaces were more suited to the foundry than the forge. Nevertheless an improvement can hardly be denied and there was evidently a market for coke pigs. As will be discussed below, the new ironworks of South Wales also engaged in wrought iron manufacture from coke pigs at this time and the Dale Company increased its capacity for making wrought iron by leasing a forge at Bridgnorth in 1760.

The principal alternative to the quality of iron theory has been in the work of Charles Hyde, whose economic arguments have gained wide currency (Hyde 1977). Hyde has argued that, although in theory a delay in the spread of coke smelting might have been inevitable while ironmasters in different regions sought coal suitable for conversion to coke, the principal reason was the relative cost of coke and charcoal pig iron. Coke pig iron, it was calculated, became significantly cheaper in the 1750s, partly through decreased fuel costs, but also the increase in costs of producing charcoal (cf Harris 1988, 34–5). There is no doubt that price was an important determining factor in the spread of coke smelting, but it was more complex than the relative cost of coke and charcoal. The growth of coke smelting was also facilitated by significant technological and managerial developments, the latter having additional economic benefits which cannot be read directly from contemporary account books.

The first, most obvious benefit of using mineral fuel was that multiple furnaces could be built in one place, to be supplied with fuel from the same source, with long-term cost benefits. The addition of the lower furnace at Coalbrookdale in 1715 is the perfect demonstration of this. Where charcoal was used for smelting, ironmasters purchased fuel from neighbouring landowners, or else leased their own woodlands (Crossley 1995). In the early-18th century, Abraham Darby acquired fuel for his blast furnaces from local coalmasters, principal among whom was Richard Hartshorne who, in a minerals lease taken in 1710 in Dawley, north of Coalbrookdale, was given authority to convert the coal to coke close to the pits. Hartshorne was possibly responsible for trials with coke smelting at Kemberton blast furnace before 1714 (Trinder 1981, 15–16). In fact it is logical to suspect that he and fellow coalmasters had a greater interest than the ironmasters in seeing the spread of the new technique, seeing a potentially lucrative new market for coal.

A wholesale change in the supply of minerals to the blast furnaces occurred in the early 1750s. In 1754 Abraham Darby II leased mines to the north of Coalbrookdale in Dawley and Ketley, thereby gaining control of the raw materials for his works. The ironmaster had also become a coalmaster. In turn, coalmasters were major figures in the new iron-making partnerships which were established in the 1750s. The extreme view of this tendency is to argue that the new generation of ironworks were merely subsidiary to the mines (cf Smith 1979b, 22). Primary sources do not really support this view, however, but document the integration of the two trades. The two blast furnaces each at Horsehay and Ketley were blown-in between 1755 and 1758 by an established partnership of ironmasters. Of the nine original Madeley Wood partners, three described themselves as master colliers, while John Smitheman was lord of the manor and was already active in the coal trade. Two of the partners, William Ferriday and Edmund Ford, described themselves as ironmasters, the latter having been a partner in nearby Leighton blast furnace, which was charcoal fuelled. In 1758 two of the partners also became partners in the Lightmoor blast furnace, which was again dominated by master colliers and was formed after a partnership had been established for the digging of coal in the locality (SRRC 1681/183/8 and 10). A year earlier the New Willey Company was formed, which built a new blast furnace on the south side of the river and whose partners included John Wilkinson, an ironmaster from Bersham, and Edward Blakeway, who briefly became a partner in the Dowlais and Plymouth ironworks in South Wales (Ince 1993, 47, 53).

The integration of mining and ironworking was perhaps the most important factor in the unprecedented expansion of the coke-based iron trade in Shropshire in the 1750s. It signalled a change in both the management of the works and the structure of the industrial landscape. At Horsehay and Ketley, new mines and furnaces were linked by new Dale Company railways, a model of how industrial exploitation occupied an increasing proportion of the landscape while its control was concentrated into fewer hands. The Madeley Wood Furnace Company did not build its furnaces at Bedlam until the partners had secured a lease to mine ironstone and coal, and to transport them to the works by means of a railway (SRRC 1681/132/24). Subsequently the company expanded its interest in local mines, acquiring leases previously held by other parties. Its responsibility for the Lloyds pumping engine by 1776, and presumably the collieries the engine drained, is the best documented example of this. The original partners had interests in limestone workings at Lincoln Hill in Ironbridge (where the Coalbrookdale furnaces also acquired limestone) (SRRC 1987/60/1). By 1803 limestone for the blast furnaces came by railway and river from Wenlock Edge, three miles west of Madeley Wood (Staffs RO D876/155, ff 31–4). Several other quarries in Madeley and on Wenlock Edge were leased in the early-19th century (SRRC 1681/184/1; 1681/184/7; IGMT 1970.66.3).

There is less evidence that the Madeley Wood Company was a major owner of workers' dwellings in the area, in marked contrast to the Coalbrookdale Company. However there may be special historical reasons for this. Several cottages near Bedlam are shown on the early 19th-century lease plan as formerly belonging to William Reynolds, as was Bedlam Hall which appears to have seen its last days divided up into tenements (IGMT 1970.66.5). It is possible that these dwellings were simply not passed to the Madeley Wood Company when Reynolds' estate was divided up after his death. Nevertheless the Madeley Wood Company's operations represent an extensive landscape of economic integration.

The integration of mines with blast furnaces was not exclusively a Shropshire phenomenon. It was also a necessary precondition to the development of the new generation of ironworks on the northern edge of the South Wales Coalfield. In a remote district of South Wales, where there was no history of extensive mining, the partners in the ironworks at Hirwaun, Dowlais, Plymouth, and Cyfarthfa, all established between 1757 and 1765, each had an extensive lease to exploit minerals for their individual use (Atkinson and Baber 1987, 21–5). The Carron ironworks in Stirlingshire was founded in similar circumstances in 1759 (Campbell 1961, 21).

In a lease agreement of 1710 Richard Hartshorne was required to build his coke hearths not more than 30 yards from the pit mount at his collieries in Dawley. By the mid century, coke hearths were part of the expanded materials preparation areas at the ironworks. Vivares' 1758 engraving of the Coalbrookdale Upper Works clearly shows the coke hearths on the bank of the Upper Works pool (Fig 13), while Perry's plan of Bedlam denotes coke hearths on the north side of the charging houses (Fig 60). This was a trend which developed over later periods, encompassing the calcining of ironstone as well as coking, and is why it is no surprise to learn that the earliest coke ovens in the district were located at the Madeley Wood ironworks rather than the Madeley Field collieries or River Severn wharves (SRRC 1987/60/1). The dramatic impact on the landscape made by siting the coke hearths next to the furnaces can be seen in numerous paintings of industrial scenes, notably de Loutherbourg's 'Coalbrookdale by Night' of 1801 (Fig 156).

Perry's plan illustrates another key enabling factor in the expansion of the iron trade in the 1750s, namely the use of a pumping engine. The problem of water supply had vexed Richard Ford at Coalbrookdale in the 1730s. He even suggested developing a blowing mechanism for the furnaces worked by horses rather than a waterwheel, but eventually decided to adapt the pumping engines used in mine drainage (SRRC 6001/3190, 4). Of other ironworks erected in the 1750s there were engines for recycling water at Lightmoor, Horsehay, and Ketley, in addition to the engine at Bedlam. Bedlam differed from the others, however, since the ultimate source of its water was the River Severn, below the level of the furnaces, rather than a stream above the furnaces.

Of the related new works in Wales and Scotland, only the Dowlais ironworks required an engine for recycling water. At the Carron ironworks, the use of blowing cylinders instead of bellows was pioneered by John Smeaton from 1764 (Campbell 1961, 37). The use of blowing cylinders at Coalbrookdale by 1775 must therefore have been one of the earliest instances of such use, although those Joshua Gilpin saw at Coalbrookdale in 1796 were primitive compared with the four-cylinder blowing device designed by Smeaton for the Carron works in 1768 (Fig 14B) (Mott 1961b, 275–6). Isaac Wilkinson, one of the original partners in the Dowlais furnace, had obtained a patent for cylinder blowers in 1757, but whether they were successfully used there is not known (*ibid*). His son, John Wilkinson, is said to have used a similar version at New Willey before he erected a Boulton and Watt engine in 1776 to blow the furnaces direct, and introduced the water regulator to keep a constant pressure to the blast. Although blowing engines were adopted at some of the new Shropshire ironworks built in the last quarter of the 18th century, such as Barnetts Leasow, the combination of waterwheel and pumping engine was used at Benthall, Donnington Wood, Calcutts, and at a forge at Wrens Nest. At the Uffington slitting mill, just west of the East Shropshire Coalfield, a windmill was used to pump water to the mill pond in dry seasons (*Shrewsbury Chronicle* 18/4/1794).

The complete absence of evidence for a blowing engine at Bedlam was unexpected but instructive. At the contemporary Clydach ironworks it was also assumed that a blowing engine replaced an earlier waterwheel to blow three of the furnaces, 'but no trace of an engine house has come to light' (Wilson 1988, 33). An engine house is one of the ironworking structures least likely to have vanished without a trace and the absence of such evidence is particularly significant. It is clear that some earlier assumptions regarding technological progress in the iron industry need to be revised. In the 1970s, Bedlam could be described without controversy as 'not of an installation which once built was never altered, but of a process which was constantly being improved through the Industrial Revolution period' (Smith 1979b, 23). The archaeological interpretation of Bedlam has shown the comparative longevity of the installations and has helped to demonstrate the continued viability of water power in a period when the direct blowing engine was supposed to reign supreme. Bedlam is by no means an isolated example, however. Many of the large South Wales ironworks, such as the Cyfarthfa and Plymouth works in Merthyr Tydfil, continued to use water power on a large scale well into the 19th century. In many cases pumping engines were used to guarantee the water supply, but an engine working machinery directly had no immediate advantage over an adequately supplied waterwheel. Therefore, to contrast the waterwheel and blowing engine as antiquated and modern respectively is clearly too simplistic an assumption for the late-18th or early-19th century.

When it was first built, Bedlam was ambitious insofar as two blast furnaces stood side by side, a convenience denied to the Coalbrookdale, Horsehay, and Ketley furnaces by the need to recycle the water to work the waterwheels. The layout of the Bedlam works was otherwise a conventional one. The combination of blast furnaces and air furnaces was to be replicated at numerous other contemporary works whose business was in cast iron. When the Stour valley forges began refining coke pig iron there was also no longer a reason why the furnaces and forges should be geographically separated, as they had been when pig iron was traded over distances for refining. The trend for erecting integrated works for smelting and forging was begun at Carron and Cyfarthfa, which will be discussed below. In the second half of the 18th century, many of the East Shropshire Coalfield ironworks also had integral forges, but by 1800 cast iron was emerging as the principal product of the local iron trade (Fig 150). This is the context which is most useful to the discussion of the ironworks studied in this volume.

Local phosphoric ores were particularly suited to cast rather than wrought iron. Darby appears to have known this even before he leased the Coalbrookdale upper furnace, as its previous occupant, Shadrach Fox, specialised in casting ordnance. Shropshire coal with its low sulphur content was available in Bristol and Darby may also have seen it in use at the brassworks in Coalbrookdale, with which he was associated from as early as 1706 (Cox 1990, 131). The argument that Darby's arrival in Coalbrookdale and his adoption of mineral fuel was a happy coincidence is therefore not a convincing one. Cast iron remains the sole product of the Coalbrookdale Works at the end of the 20th century and Blists Hill, until its closure in 1912, produced only pig iron for the foundry. Several other factors also contributed to the culture of cast iron, in particular the arrival of Abraham Darby I in 1708. Darby had owned a foundry in Bristol since 1703 and had secured a patent for sand moulding in 1707. At Coalbrookdale he intended to and did develop the foundry by introducing air furnaces, and made a name for himself casting iron pots. There is also evidence that Darby attempted to keep secret his method of casting pots to increase his commercial advantage (SRRC 1987/58/13). Coke-smelted pig iron was at first unsuitable for conversion to wrought iron. Until the 1750s, the Upper Forge used and mixed pig iron from other Shropshire and British blast furnaces and sometimes pig iron from North America as well (Trinder 1981, 19).

The principal technological innovations of the 18th century with which Coalbrookdale was closely associated were based on cast rather than wrought iron. The Iron Bridge over the River Severn is the most spectacular of many examples and a fitting monument to the local iron trade. It should be remembered, however, that before the bridge was built, the foundries at Coalbrookdale were already casting iron waterwheels and the Upper Forge in 1776 had two 20-foot diameter cast-iron flywheels. The weight of these individual items is not known, but it is a reminder that the Coalbrookdale founders were not novices when they were asked to cast ribs for the bridge. Earlier than that, Coalbrookdale had established itself as one of a handful of foundries which had the expertise to cast and bore steam engine cylinders, a trade it had developed since 1722 and which increased after Thomas Savery's patent expired in 1733.

Slaughter's plan shows the Coalbrookdale Upper Works as an integrated works for smelting, casting, and engineering (Figs 11 and 12). Although the principal Coalbrookdale boring mill was sited further down the valley, and the Upper Works boring mill was converted to a turning mill in the latter half of the 18th century, the Upper Works pioneered the new integration of ironworking which had become commonplace in Shropshire and elsewhere by 1800. There were boring mills for manufacturing engine cylinders or cannon at the New Willey, Calcutts, and Benthall works on the south side of the River Severn. A similar trend also emerged in the newer ironworking areas, notably at Carron in Stirlingshire where a foundry and boring mill were built in addition to the blast furnaces (Campbell 1961, 21).

The wrought iron trade in the late-18th century

Nothing has so far been said of the wrought iron trade of the late-18th century, the period when the East Shropshire Coalfield was at the forefront of new technological developments. The second half of the century was a period of experimentation when various methods of manufacturing wrought iron with mineral fuel were tried. In 1766 two Dale Company workmen, Thomas and George Cranage, patented a new process which, despite encouraging early results, soon proved uneconomic and was given up. The stamping and potting techniques of Charles Wood and Wright and Jesson have already been discussed in the context of the Upper Forge. A survey of the trade produced in 1794, based on information gathered *c* 1789, lists sixteen forges in Shropshire where the old finery and chafery method was in use, compared with four – Ketley, Donnington Wood, Eardington, and Wrens Nest – where stamping and potting was in use (B&W MII/5/10). The list is obviously incomplete: Horsehay, Coalbrookdale, and possibly Lightmoor and Snedshill also had forges for stamping and potting in the last decade of the 18th century, making a total of up to eight works (Trinder 1981, 50; Ince 1992, 86–7; Baugh 1985, 121–2). Three other coalfield ironworks on the south side of the Severn also had integral forges in the late-18th century, although it is not known what processes were in use. In 1784 John Rennie described forge hammers at Benthall and New Willey, while a forge at the Calcutts ironworks was advertised in the sale of the works in 1786, but is absent from a plan of the works dated *c* 1800 (Matkin 1986, 23–5; *Shrewsbury Chronicle* 18/2/1786; SRRC 6001/2366). The Benthall and New Willey forges appear to have been shortlived and each of these three works subsequently specialised in boring cannon or engine cylinders.

Despite anomalies in the national statistics, a pattern of wrought iron manufacture emerges. Of the charcoal-fuelled forges, only Bringewood (now in Herefordshire) was integral with a blast furnace and all were outside the East Shropshire Coalfield. The reverse is true of stamping and potting. With the exception of Eardington near Bridgnorth, stamping and potting was confined to the coalfield, while only Eardington and Wrens Nest were forges not closely integrated with parent blast furnaces, if the relationship between the Horsehay blast furnaces and the Coalbrookdale Upper Forge can be so described.

The patentees of stamping and potting, John Wright and Richard Jesson, probably erected the first forge in Shropshire for the process at Wrens Nest, between Broseley and Bridgnorth, in 1777 (Trinder 1981, 40). The Coalbrookdale Upper Forge may well have been the next forge to adopt the process. Although the date of the conversion from the old finery and chafery method is not precisely known, stamping and potting was not adopted at Horsehay until after 1781, or at Ketley until 1785, while the Donnington Wood forge was erected after 1785 (*ibid*, 42–3). At Eardington, stamping and potting was in use side by side with the finery and chafery during the 1780s (Mutton 1970).

Between 1785 and 1787 the Dale Company's investment in stamping and potting was considerable and was matched only by a comparable investment in forge engines at John Wilkinson's Bradley works. By 1787 there were two Boulton and Watt engines at the Upper Forge complex in Coalbrookdale, five at the Ketley forge and slitting mill, and two at Horsehay (Ince 1992, 86–7). The dates are significant because at Ketley in 1784, both Peter Onions and Henry Cort had demonstrated similar rival methods to stamping and potting. William Reynolds appears to have been suitably encouraged by Cort's process, which according to Thomas Cranage made good marketable bar iron (Mott 1983, 47–9). Nevertheless the Dale Company did not adopt the process and nor did Reynolds take out a licence to use it at his new Donnington Wood works. The partners in the Dale Company could therefore claim to have been as well informed as anybody in the iron trade when they judged that stamping and potting was the future of wrought iron manufacture. It was after Cort's visit that the Ketley and Donnington Wood forges were built and that the investment was made in the expansion of stamping and potting at Coalbrookdale.

The Cranage brothers assigned their patent to the Dale Company for a mere £30. One of the reasons that the Dale Company did not adopt puddling in 1784 was their claim that Cort had copied the Cranage brothers. Like puddling, the Cranage patent also specified an air furnace, but the description of the process given in the patent was conveniently vague, to the extent that any future use of an air furnace could be construed as an infringement. This may have been why the Dale Company was interested in acquiring it. Reginald Mott has demonstrated that the significance of the Cranage method as a precursor of puddling has been exaggerated (Mott 1983, 9). In the long term the refusal to embrace puddling looks like a misjudgement, but from the perspective of 1784 this hardly seems fair: Puddling would not have been the first technological breakthrough to fall by the wayside after a promising start. In the event, Cort was bankrupted well before puddling became a commercial success, while Richard Crawshay of Cyfarthfa persisted with it for some five years before it began to pay dividends.

Nevertheless, the increase in the scale of production that stamping and potting achieved over the finery and chafery is well represented at the Coalbrookdale Upper Forge with the doubling of its plant and the purchase of two engines. Steam power was to eliminate the geographical constraint imposed by water power, allowing flatter and larger sites to be used in the future, which ironically sealed the fate of the Coalbrookdale site. The premium on space at the Upper Forge is also symbolised by the dispute in which the Dale Company and its neighbour, John Powis Stanley, became embroiled in 1786.

Stamping and potting was an important early phase of wrought iron manufacture during the Industrial Revolution. It was a commercially successful process that freed the industry from its dependency on charcoal and, in establishing coal-based technology, paved the way for the integrated ironworks of the 19th century. Pig iron was no longer traded over large geographical areas for refining to wrought iron. The fact that stamping and potting was one of a series of rival processes merely illustrates the potential reward of finding a cheap method of making wrought iron. The success of puddling over stamping and potting was not immediate, however. As late as 1799 the Coalbrookdale forges were profitable, at a time when puddling was establishing itself as the most commercially viable process. In 1803 Simon Goodrich visited the Upper Forge and was told that stamping and potting produced 'best hammered iron' which, although it was more expensive than puddled iron, nevertheless produced a superior quality product (SML Goodrich E2, f 43). The key element in the process appeared to be the stamping or granulating of the iron, not the kind of furnace in which it had been heated. In his early experiments with puddling Richard Crawshay used a combination of first, the puddling furnace, then stamping and potting to replace the shingling and balling furnaces (Evans 1990, 95–6). In fact Cort's specification also acknowledged that iron could be granulated after it had been puddled. When puddling was first introduced at Ketley the puddling furnace replaced the finery, after which the iron was granulated and heated in clay pots in the traditional way; the rolling mill was not a part of the process (BUL Gilpin XXXIII).

It is important to stress these qualitative aspects of ironmaking, otherwise progress is inevitably interpreted as a one-way street, glossing over the subtleties in the forgeman's craft. This qualitative model is a useful way of interpreting other sites where the experience was to be similar to that in the East Shropshire Coalfield. An example is the Mitton Upper and Lower Forges near Kidderminster, where stamping and potting was introduced in 1796 and was used in parallel with puddling from 1799, producing different qualities of iron, until the commercial advantages of puddling superseded the fineries and stamped iron was made from the puddling furnace (Ince 1991, 42–4). The opposite occurred at James Foster's forge at Hampton Loade on the River Severn, where stamping and potting was superseded by puddling and finally was replaced by the specialist production of charcoal iron after 1829 (Mutton 1970, 240). Into the 1830s stamped iron was still made at Horsehay for 'best iron' and was commonly used in the making of boiler plates (SRRC 245/140). This is the equivalent specialisation in wrought iron that the Coalbrookdale Company was to achieve in cast iron. Such diversity should be seen as an integral part of the 19th-century iron industry.

The impact of the puddling process

Investment in the shortlived technology of stamping and potting and specialisation in the foundry trade are two factors in the pre-eminence of the East Shropshire Coalfield in the 18th century. They are, however, among many factors in its relative decline during the 19th century. The impact of puddling altered the structure and management of iron-working sites in a radical way. Successful pioneers of the process such as Richard Crawshay of Cyfarthfa and Samuel Homfray of Penydarren, both in Merthyr Tydfil, integrated their operations to the extent that their forges refined the pig iron from their own blast furnaces on a far larger scale than had been possible with the earlier stamping and potting technique. In fact in the early years the demand for pig iron outstripped the capacity of their blast furnaces and they were required to purchase pig iron from neighbouring works. This was the fulfilment of the ambitions held by many of their predecessors, including the founding partners of the Carron Company and Abraham Darby I, who was ambitious to combine iron and brass production at Coalbrookdale. Puddling also saw the fulfilment of a trend towards the integration of blast furnace, foundry, and forge, which began when fossil fuel was used in the refining of pig iron. Stamping and potting was introduced at Cyfarthfa in 1767 and in the 1780s at Penydarren, just as the Wright and Jesson modification of the technique was introduced in Shropshire during the 1780s at Horsehay, Ketley, and Donnington Wood, all under the influence of William Reynolds. However, a sharp increase in the scale of production was the defining characteristic of puddling, a development which was reflected in the physical expansion of the new works. The rolling mills necessary for puddling required large flat sites, which in turn helped to encourage the development of increasingly large works.

None of the ironworks in Ironbridge adopted the puddling process, although it was in use at Horsehay, Ketley, Old Park, and perhaps Lightmoor, by the beginning of the 19th century (Fig 150). In the 19th century, the local ironworks were outside mainstream developments in the industry. This may have been partly due to conservative instincts, but it should be remembered that *c* 1800 Ironbridge was one of the most technologically advanced districts in Britain and encompassed an unsurpassed concentration of ironworks and other industrial enterprises. William Reynolds was widely respected as one of the most innovative men of his generation, but puddling was adopted only at his Ketley works, not at Bedlam where there was hardly scope for physical expansion at the foot of a hillside on the bank of the River Severn. The notion of local culture in the iron trade is the most difficult element to pin down, but it undoubtedly existed and was also a factor in the slow take up of new ideas compared with less established regions. By the early-19th century it had become a commonplace to describe the iron trade in terms of regional entities. As early as 1804 Gilbert Gilpin blamed the poor state of the Shropshire trade on 'South Wales' and in 1815 Thomas Butler compared the Coalbrookdale works unfavourably with Staffordshire and Wales (SRRC 1781/6/28; Birch 1952, 232). Both were well-informed comments on the drift of commercial significance in the iron trade.

Specialisation in the iron trade – the Coalbrookdale Company and the Madeley Wood Company in the 19th century

Taking the impact of puddling into account, it is customary to view the 19th-century iron trade of the Ironbridge Gorge in terms of decline. By the end of the 1820s none of the older ironworks on the south side of the River Severn were working, in spite of the fact that many of them were less than half a century old. Depletion of raw materials was one reason and the decline in the market for ordnance was perhaps another, but this does not entirely explain the collapse of the industry. The hitherto underestimated factor is the landscape, its uncompromising topography allowing little scope for expansion. But there were survivors who withstood economic and technological changes, and they did so by specialisation. These were the Coalbrookdale Company and the Madeley Wood Company.

The Coalbrookdale blast furnaces are not known to have been in blast after 1817 and, given that the company had other, larger furnaces at Horsehay and Dawley Castle, it is unlikely that they were ever blown-in again. The 1820s was the low point of ironworking in Coalbrookdale, but its renaissance came about by applying its traditional expertise to a find a niche in the growing market for cast iron.

Abraham Darby I had pioneered the integration of blast furnace and foundry at Coalbrookdale, superseding an older pattern of the separate foundry which he had operated at Cheese Lane in Bristol. Coalbrookdale remained in the vanguard of the new trend in integrated foundry and engineering works in the 18th century and by 1800 the Upper Works was among the most sophisticated ironworks in Britain with its blast furnace, foundry, and boring and turning mill. In the long term, however, the invention of the cupola furnace (by William Wilkinson in 1794), together with improved communications, was to undermine the advantage of siting the foundry and engineering works close to the blast furnace.

In the 19th century, the foundry and engineering trades migrated to towns and transport routes. Boulton and Watt's Soho Foundry, near Smethwick, was built close to the Birmingham Canal in 1795–7. It comprised air furnaces, cupolas, and a steam-powered boring mill. It is one of the earliest examples of a steam-powered engineering works free of the geographical constraints of water power, as was the Round Foundry in Leeds, of 1795. 19th-century Shropshire had two foundries of note in addition to the Coalbrookdale Company, whose reputations were built on the previous local expertise in the iron trade. John, Robert, and Thomas Hazeldine had established a foundry in Bridgnorth by 1795 and in the early-19th century made high-pressure steam engines designed by Richard Trevithick, as well as some of the earliest threshing machines. Their brother, William Hazeldine, established his own foundry at Longden Coleham in Shrewsbury in 1796 and is best known for casting bridges and canal installations for Thomas Telford (Trinder 1996, 57–9). Subsequent to the blowing out of the blast furnaces, the Coalbrookdale foundries should be seen as part of this development and from 1838 developed a reputation for decorative work.

The Madeley Wood Company should also be seen within the framework of cast iron, but in a different sense. In 1815 Thomas Butler made two significant comments on the Bedlam furnaces. Firstly he said that the raw materials 'cannot bear a large column of air to be poured into the furnace, neither will they

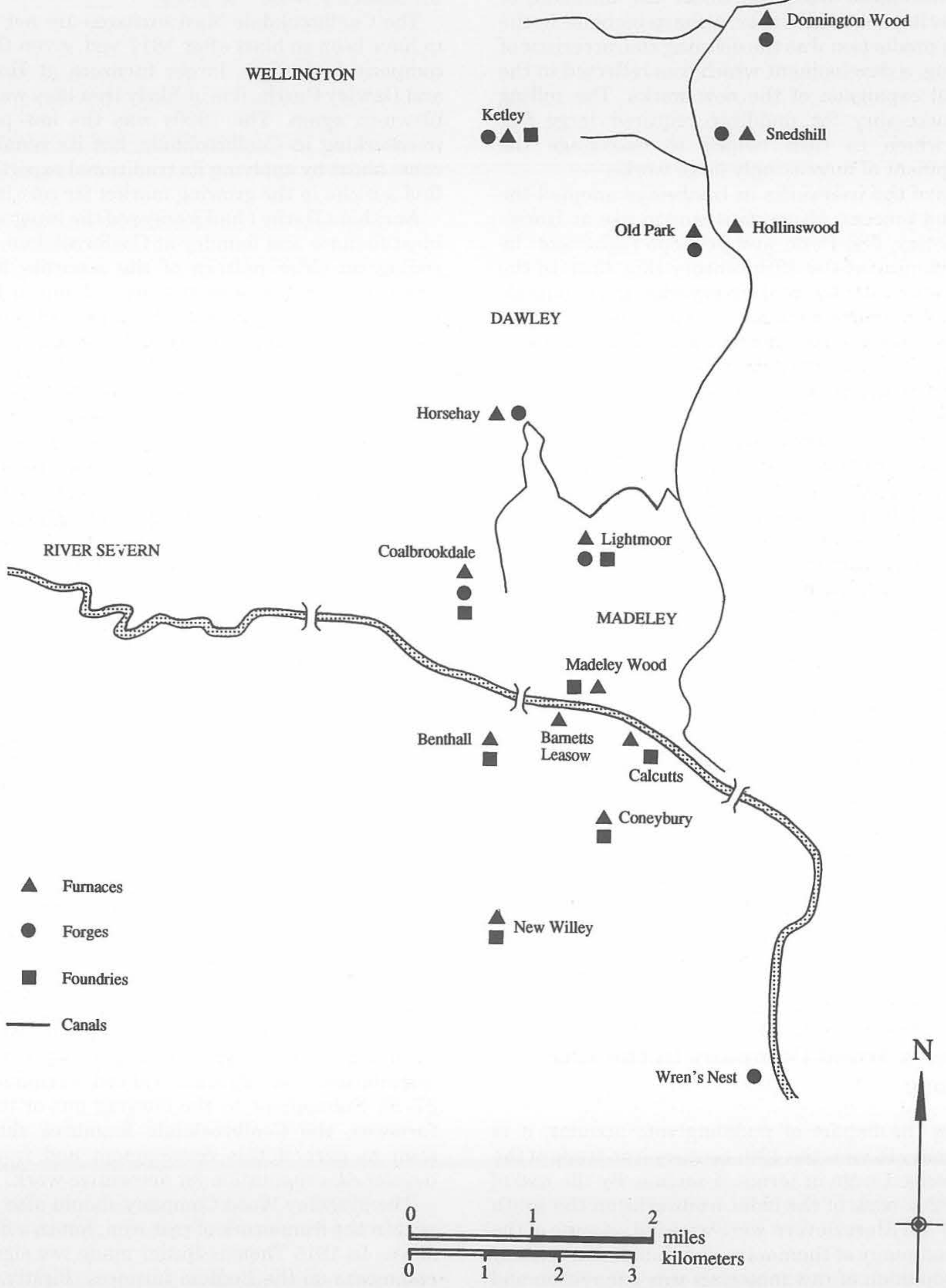


Figure 150 Ironworks in the East Shropshire Coalfield in 1801. Ketley, Horsehay, Old Park, and Lightmoor had adopted puddling by 1801. The remainder were forges for stamping and potting.

bear great velocity in the blast, when they wish to make fine smooth iron' (Birch 1952, 232). Secondly he noted the relatively modest output of Bedlam furnaces and that output depended on whether the furnaces were producing foundry or forge pig: 'They seldom exceed 25 tons No 1 good iron per week, but they can make 35 tons good grey strong forge' (*ibid*). This reminds us of the limitations of statistics and output figures and that not every ironworks can be judged in terms of its technology or size. Butler's qualitative analysis is crucial to understanding the context of Bedlam and Blists Hill in the British iron trade.

According to Butler, it was common knowledge that 'Madeley Wood pig iron is some of the very best in England'. Later, Samuel Timmins remarked that the Madeley Wood Company's iron was considered the most suitable for casting hollow-ware and commanded correspondingly high prices (Timmins 1866, 107). Numerous other examples from the mid-18th century to the end of the 19th century could be cited to demonstrate the high regard for Madeley Wood iron which, as Butler conceded, was in the first instance due to the high quality of the local Crawstone, Blackstone, and Pinneystone ores. Bedlam and Blists Hill can therefore legitimately be regarded as specialist producers.

The first furnace at Blists Hill was blown-in in 1832 at a time when the British iron industry was at an important juncture. The end of the 18th century had been a period of phenomenal growth in the trade, fuelled by unprecedented demands for iron during the French wars of 1793 to 1815. Post-war depression put an end to many unprofitable concerns, but the recovery of the 1820s, followed by a boom in the British iron industry during the railway mania years of the 1830s, saw a new wave of capital investment. In Shropshire, Blists Hill belongs to the 19th-century generation of ironworks located on the edge of the East Shropshire Coalfield, most of which belong to the period of post-war recovery (Fig 151). The other new Shropshire works were the furnaces for cold-blast iron at Lodge (1825), Hinkshay (1825–7), Stirchley (1825–7), Madeley Court (1843, replacing Wombridge furnaces of 1819–20), Dark Lane (1830s), Priorslee (1851), and Langley Field (1824–6). Here, more advanced mining methods made it possible to exploit previously unworked seams (Trinder 1981, 146).

Of other established ironworking districts, a similar wave of expansion took place in South Wales, notably in the western part of the region where anthracite fields were exploited for the first time (Ince 1993, 3). The 1830s also saw the rise to prominence of the Scottish iron trade, following Nielson's patent for hot blast, with which Blists Hill can be profitably contrasted. The received wisdom of blast furnace management had hitherto been that the colder the air the better, on the basis that the yield from blast furnaces was uniformly higher over winter than during the summer months. However, Nielson's experiments at the Clyde ironworks showed that by heating the air a substantial saving in the amount of coke required to smelt the iron could be achieved. Iron thus became cheaper to produce. The impact of the hot blast technique on Scottish output figures is clear: In 1830, 24 blast furnaces produced 37,500 tons of pig iron; in 1839 the figures had risen to 54 furnaces and 195,000 tons (Scrivenor 1854, 261).

Conservative resistance to the new method, based on the claim that hot-blast iron was inferior, helped to delay its widespread dissemination until the middle of the century. Hot blast was never introduced at Blists Hill, although it was patented in 1828 four years before the first furnace was built. Indeed the physical constraints of the site were such that it would have been difficult to introduce the necessary stoves once the three furnaces and the two engine houses had been erected. Hot-blast stoves were nearly as large in plan as blast furnaces and rose to a similar height. It is the Madeley Wood Company's persistence with cold-blast smelting, even after hot blast became the norm in Shropshire, that has been used to characterise Blists Hill as old fashioned. There is certainly substance to the claim that its methods were conservative, for example the continued manufacture of coke in open heaps, while its collieries at Blists Hill were notoriously antiquated (Trinder 1981, 139; Leese 1912). However, it is misleading to judge Blists Hill primarily in terms of technological progress.

Leaving aside the absence of hot blast and the continued manufacture of coke in open heaps, there was little plant in use at Blists Hill that could be deemed antiquated. Of the first engine, too little is known. The beam blowing engine of 1840 was typical of the period, as was the vertical blowing engine of 1873. The original furnaces had an unusual design, but the later, more cylindrical stacks were much like other blast furnaces of the later-19th century when regional variations in furnace design disappeared. The tops of the furnaces were never closed, however, contrary to common practice in the later-19th century, but cold-blast iron was smelted in open-topped furnaces into the 20th century. Its iron clad calcining kiln was typical of the period and three similar kilns were built at the Lilleshall Company's Lodge furnaces. Indeed the layout of the Blists Hill Works from the 1870s onwards is remarkably similar to Lodge, the only comparable 19th-century Shropshire works that also specialised in cold-blast pig iron (Fig 152) (Griffiths 1873, 106–7).

Hot and cold blast produced different qualities of iron, differences which became more distinct depending on the type of ore or ores which were being smelted and the capacity and internal profile of the blast furnace. Even as late as 1946 it was noted that cold-blast iron was still smelted in small open-topped furnaces and the smelting was a deliberately slow process using carefully-selected raw materials. Cold-blast pig produced a specialist foundry iron possessing distinct qualities: it could take a fine polish, it was resistant to shock, and possessed high tensile and transverse strength (Bashforth 1948, 11–12). In Britain, the iron was used largely for chilled and grain rolls, engine cylinders, hydraulic machinery, and other heavy engineering castings. In 1934 Charles Mitchell similarly specified that the best constructional cast iron was made from cold-blast pigs (Mitchell 1934, 174).

Cold-blast iron can therefore be seen as a specialist product for which there was evidently a market. Indeed, the Madeley Wood Company's accounts demonstrate that its customers at the end of the 19th century were largely engaged in heavy engineering, firms like Ruston Proctor and Co,

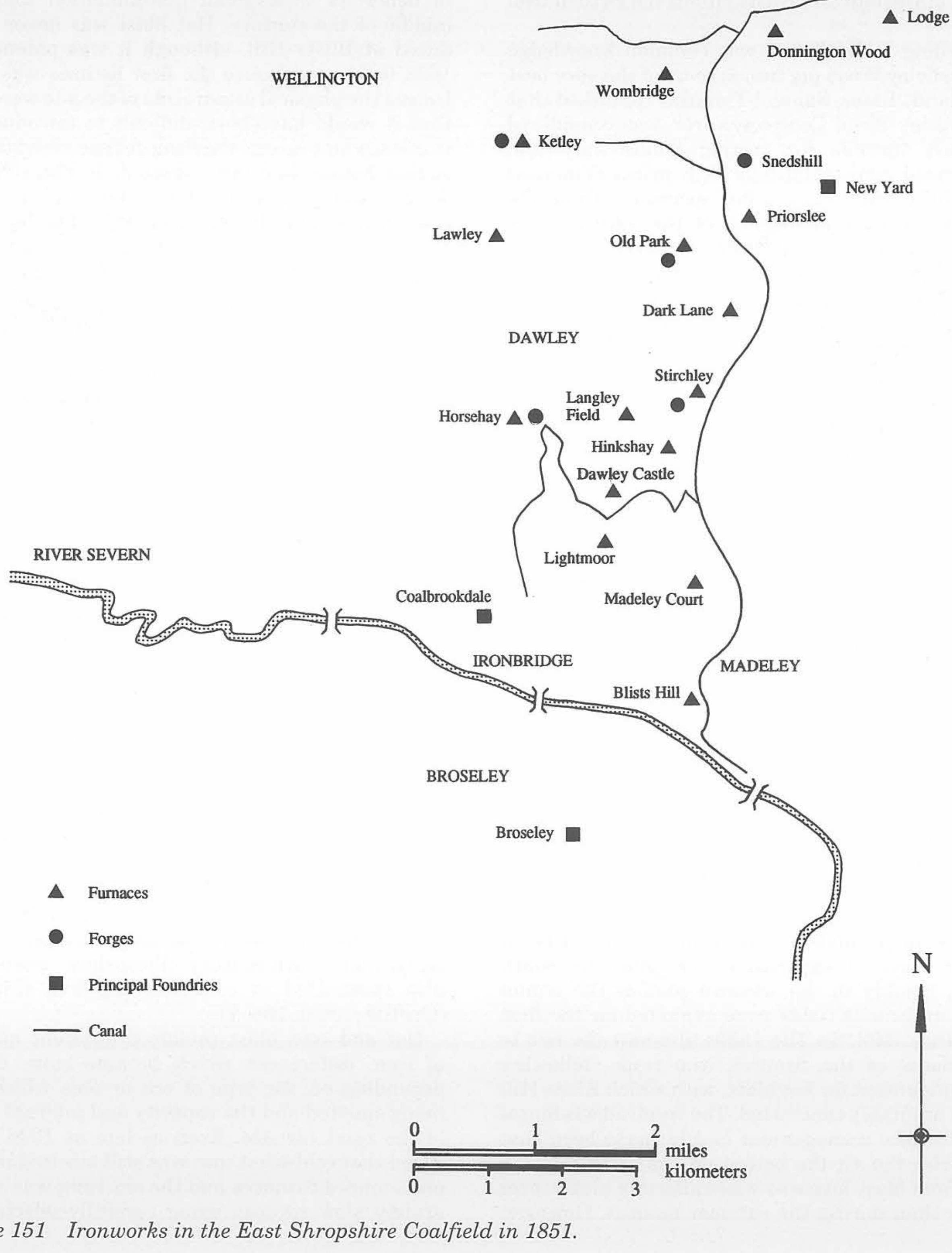


Figure 151 Ironworks in the East Shropshire Coalfield in 1851.

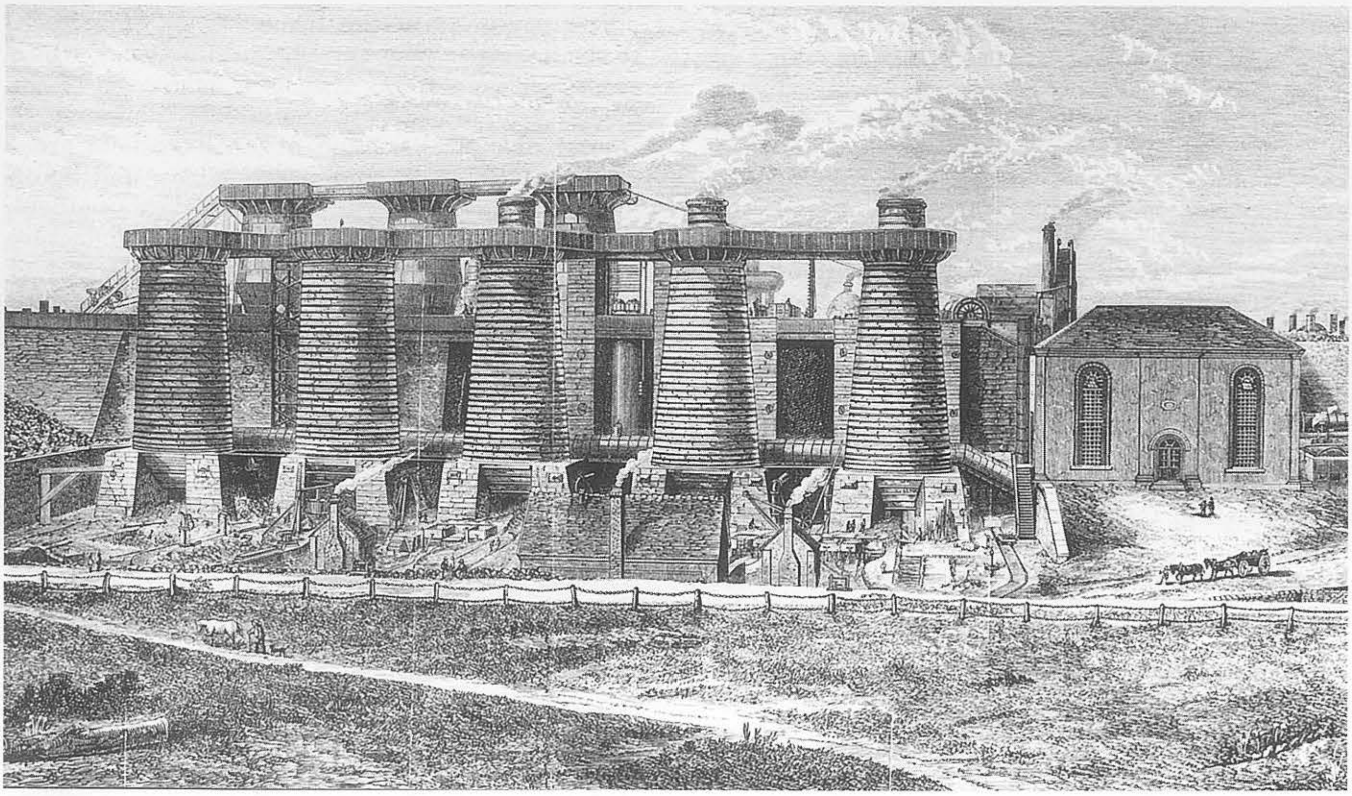


Figure 152 The Lilleshall Company's Lodge furnaces. Like Blists Hill, the works was known for smelting cold-blast pig iron. Its blast furnaces have cylindrical stacks on masonry bases, and a continuous gantry at charging level. Behind are three calcining kilns with associated ramp and winding cable. Both the layout and the details are very similar to Blists Hill. (From Samuel Griffiths' Guide to the Iron Trade, *1873)*

Hydraulic Engineering Co, Maudsley Sons and Field, LNWR, and GWR (Staffs RO D876/ADD/3/4).

The other Shropshire ironworks were principally concerned with wrought iron manufacture and consequently housed puddling furnaces and rolling mills. The wrought iron industry collapsed in the last quarter of the 19th century in the face of competition from better placed ironworks in Teesside and Northamptonshire and from the cheaper technology of steel. Of the Shropshire ironworks, only the Priorslee works converted to making Bessemer steel and was one of only two ironworks where smelting continued into the 20th century. The other was Blists Hill which survived precisely because it was untypical.

Diversification

The Madeley Wood Company is ideal for a case study in industrial diversification. As has already been discussed, its forerunner, the Madeley Wood Furnace Company was founded upon the integration of the coal and iron trades in the mid-18th century. Its other trade was in bricks and tiles, although not until the 19th century did it add large-scale brick and tile manufacture to its core business, as did the Coalbrookdale Company.

The extent of early brick making by the Madeley Wood Company and its forerunners is not clear because there is too little archaeological evidence, although it should be remembered that by the mid-18th century brick was a ubiquitous building material on both banks of the river Severn. All of the surviving phase I structures at Bedlam are of brick, as is Lloyds engine house of 1745. The existence of local brick kilns or temporary clamps therefore cannot be doubted and is demonstrated by the protests of local ironmasters against a proposed tax on bricks in 1784 (Trinder 1981, 59–60). There is good evidence for a brick kiln in the Lloyds at the turn of the 18th century, although no site has ever been identified (Staffs RO D876/155, f 188); and by 1796 there was a 'Brick Kiln Leasow' in Madeley Wood, which again is unidentified (SRRC 271/1, f 195). Minerals leases covering the Madeley Field routinely listed royalties payable on any bricks which were made at the pit banks, but it is unclear whether these were made in temporary clamps or kilns. Large-scale brick and tile manufacture began in 1841 at Bedlam.

The proximity of furnaces and mine at Blists Hill illustrates an enduring problem of interpreting the Madeley Wood Company's activities. As early as 1815, the company was said to have found the coal trade more profitable than the iron trade and this can only have increased throughout the 19th century (Birch 1952, 232). And yet considerable investment was made in the ironworks in the 1870s, while the collieries continued with obsolete equipment. Moreover the subsequent output figures for the ironworks suggest that the company could never have achieved a return on its investment since the ironworking side of the business appears to have declined almost as soon as the works was renewed. Precisely the same phenomenon was apparent at Bedlam, where investment was made after the end of the Napoleonic war at the same time as its output slowly declined. In neither case, however, do the surviving accounts declare the extent of the investment, nor a true figure of the profits and losses of the company's separate concerns.

The Madeley Wood Company has yet to attract the attention of a business historian, but it both needs and deserves one. For the present, it is the archaeological interpretation that has highlighted the complexities in the company's operations, demonstrating that the ironworking side of the business was related to the collieries in ways which are not at present satisfactorily understood. The place of brick manufacture in the Madeley Wood Company's strategy is less problematical. The Bedlam brickworks was built to exploit a suitable vein of fireclay from Styches Pit, but as soon as the vein was worked out the brickworks was closed down. Similarly, the Blists Hill Brick and Tile Works was dispensed with in 1912 in the wake of the colliers' strike and local pit and ironworks closures, but its colliery business as a whole remained viable until nationalisation in 1947.

The proximity of the furnaces, pit, and brickworks, together with the Shropshire Canal, which passes through Blists Hill, is a microcosm of the diversity of industry in a coalfield landscape. A similar diversity is found in other coalfield areas such as North-East and South Wales, and South Staffordshire. In the South Staffordshire Coalfield, brick making prospered alongside iron manufacture and coal mining in the 19th century, to a greater extent than the East Shropshire Coalfield, which was less well endowed with raw materials. On the south side of the River Severn, large-scale brick making followed the demise of ironworking. The situation in South Wales is dissimilar, however. The large iron companies built brickworks to meet their own requirements, but rubble stone remained the principal building material in the area throughout the 19th century. The accessibility of suitable building stone was the main reason for this but, in the second half of the 19th century, ironmasters diversified into sale coal rather than commercial brick making. For example, in 1859 the Dowlais Iron Company acquired the neighbouring Penydarren Ironworks principally for its large coal and iron reserves and promptly entered the sale-coal market (E Jones 1987, 249–51). Specific economic factors must therefore be cited to account for the diversification into brick making in East Shropshire during the 19th century and to have contributed with technological and geological factors to the particularity of the relict landscape.

9 Ironbridge and the archaeology of the British iron industry

A comparison of the Ironbridge sites with other ironworking sites in Britain will amplify the importance of what has survived and place it in a wider context. The survival rate of British ironworks is notoriously uneven and it is worth considering whether the survivors constitute a representative sample of what once existed, or whether they are merely freak examples. Published surveys of iron-industry remains have either been focused upon blast furnaces (Riden 1993, 1995), or are confined to smaller geographical areas, as in Stephen Hughes' survey of Glamorgan in *The Buildings of Wales* series (Newman 1995, 72–5).

Charcoal ironworks

From the era of charcoal smelting, the 18th and 19th centuries is the period to which most of the surviving sites belong. For earlier periods, the work of David Crossley and others in the Weald has identified relict landscapes and demonstrated the quantity and quality of evidence which can be recovered by excavation (Cleere and Crossley 1995). Charcoal-fuelled blast furnaces of the 18th century are over represented among surviving sites for a number of reasons and not simply because they are the most recent. Charcoal furnaces were generally constructed inside a substantial masonry casing, the kind of structure that will not quickly disappear if it is not purposely demolished. Some of these furnaces were built against natural hillsides and act as retaining walls. They were invariably constructed as single furnaces, often in remote locations where there has been little pressure to redevelop sites. Bonawe and Craleckan in Argyll, Dyfi and Dolgun in West Wales, Backbarrow, Duddon and Newland in Cumbria, Rockley in South Yorkshire, and Charlcott in Shropshire are all good examples of this, and it is hardly a coincidence that three of these remote furnaces (Dyfi, Duddon and Bonawe) are the best-preserved charcoal-fuelled blast furnace sites in Britain (Dinn 1988, Riden 1993, Hay and Stell 1986). A few furnaces are known to have been reused: Gun's Mill furnace in the Forest of Dean was converted as part of a paper mill in the 18th century, while the charcoal store at Newland has been reused as a barn (Riden 1993, 40–2, 119). The examples cited all belong to the final era of charcoal smelting and are contemporary with the coke-fired furnaces of the Coalbrookdale Upper Works and Bedlam. Backbarrow and Rockley are the only surviving furnaces that were converted from charcoal to coke firing, the Coalbrookdale furnace having been to all intents and purposes rebuilt. Bedlam offers the most instructive contrast with these sites because, despite some similarities in the layout, like the use of charging and bellows houses, it was built for two furnaces and a pumping engine, features that belong firmly in the coke era.

Evidence of water power, bellows houses, and casting houses are common surviving elements at charcoal ironworks. Bonawe, Duddon, and Newland are the only extant blast furnaces with surviving charcoal stores but the other sites all possessed them. Beyond that, evidence of materials preparation can be considered in terms of landscapes rather than sites. Bonawe was established in 1753 in the Scottish Highlands by Richard Ford and Co, builders of Newland furnace, to exploit the Caledonian Forest for charcoal. Elements of a landscape of extensive forests managed for charcoal production around Loch Awe can still be seen (Hay and Stell 1984). These are on a far more extensive scale than evidence of charcoal burning in the coppiced woodlands around Ironbridge.

Coke ironworks – materials preparation

Ironworks of the coke era were equally the focus of extensive landscapes, with their coal and ironstone pits and limestone quarries. As has already been discussed, ironworks of this period also required much larger materials preparation areas than charcoal ironworks (see Chapter 8), but features associated with them have rarely survived.

The Ironbridge district cannot claim to possess any of the coke ovens or calcining kilns of national significance. This can be explained partly by the local preference for calcining and coking in open heaps rather than kilns or ovens. At Coalbrookdale there was a small coke yard beside the upper furnace pool, and a larger one beside the lower furnace pool, later developed as the office range and a yard of the Coalbrookdale Foundry. The former coke yard at Bedlam was developed as the Bedlam brickworks from the 1840s, later taken over by the Ironbridge Gas Works. At Blists Hill, the former coke yard was occupied partly by the brickworks and is now almost wholly covered by the Blists Hill Victorian Town, an open-air museum. It has already been remarked that until the closure of the works, coal was converted to coke in open heaps, which is ironic given that the area had seen some of the earliest experiments in coke ovens.

The likelihood of finding evidence of the coke ovens erected at Bedlam in 1789 is high because their location is well documented and the ground has not been redeveloped. Of the whereabouts of the earlier coke ovens, in use during the 1770s, nothing is known. Regional preference is one factor determining the distribution of surviving examples. In the East Shropshire and Staffordshire ironworking areas, traditional open heaps remained in use in the 19th century in conjunction with coke ovens and their use continued to some extent at Cyfarthfa until a new coke works was built in 1905. The other major factor is the mode of construction. Like blast furnaces, kilns or ovens have survived when they are constructed with a brick or stone outer shell, especially when built into a bank. Later examples that were erected of large component parts could be easily dismantled and therefore do not survive, although Blists Hill provides a good example of the kind of archaeological evidence left behind by such structures.

Coke found wider applications than the iron industry and only those ovens connected with ironworking are considered here. At Bersham, a single coke oven has been identified and is dated post-1763. It was possibly an experimental oven roughly contemporary with the Bedlam ovens, which were surely also experimental in nature. The best examples of coke ovens and calcining kilns are to be found in South Wales, principally with the second generation of ironworks in the Bridgend district, erected in the mid-19th century. Tondu ironworks near Bridgend retains a substantial proportion of its large ranges of coke ovens, with a smaller range of similar ovens at the nearby Cefn Cwsk ironworks. Bryndu in Glamorgan and Abersychan in Monmouthshire also have ranges of coke ovens. In England there are a group of ovens at Vobster Breach Colliery in the North Somerset Coalfield, from where coke was supplied to the Seend and Westbury ironworks in Wiltshire in the 1870s (Gould 1994). Tondu ironworks retains the best and most complete group of calcining kilns, dating to the mid-19th century, although in South Wales there are other good examples at Blaenavon, Gadlys in Aberdare, and Stepaside in Pembrokeshire. Another group of kilns is at Rosedale in North Yorkshire, dating from the 1860s, but located at ironstone mines rather than an ironworks.

Water and steam power

Three ironworking sites in South Wales are comparable with Bedlam furnaces in their evidence for water power – Clydach, Cyfarthfa, and Neath Abbey. At the Clydach works, archaeological evidence for water power is well preserved, on a site where no blast engine house has been found (Wilson 1988). The masonry dam at Neath Abbey is considerably later than the furnaces, *c* 1840. The Cyfarthfa works in Merthyr Tydfil, established less than a decade after Bedlam, was in most ways the complete opposite of Bedlam, having been Britain's largest ironworks from the end of the 18th and through the first quarter of the 19th century. Nevertheless, a large waterwheel for blowing the furnaces was erected in 1796, while the extensive rolling mills remained water-powered throughout the 19th century, with steam power being introduced only gradually. Complementing its massive bank of blast furnaces, evidence of the use of water power at Cyfarthfa is extensive (IGMTAU 1995; Hayman 1996), lending further weight to the argument that the waterwheel remained a viable source of power even in the age of steam, its efficiency principally determined by the availability of water. The only extant water-power structure comparable with Cyfarthfa, in its engineering, is the Bont Fawr Aqueduct in Pontrhydyfen, near Port Talbot, built 1824–7 for the Oakwood Ironworks.

Engine houses are one of the most durable of buildings at an ironworks and numerous examples have survived. Blists Hill is the best surviving example of the development in blowing technology in the 19th century, with its 1840 beam engine superseded in 1873 by a single-cylinder vertical engine. The context of the Blists Hill engine houses is enhanced by the reconstruction opposite the blast furnaces of the pair of beam blowing engines built by Murdoch, Aitken and Co of Glasgow for the Lilleshall Company's Priorslee Works in 1851. Inside the north engine house, meanwhile, is a re-erected blowing engine built in 1886, also for the Priorslee Works. The only other site with two engine houses is Tondu.

Engine houses are also the buildings most likely to offer architectural display, an increasingly significant factor in the 19th century. This is particularly true of the generation of works roughly contemporary with Blists Hill, as at Tondu, Banwen, Venallt, and Gadlys, all on the western side of the South Wales coalfield. Abersychan works in Monmouthshire was designed with a well-conceived classical front to the casting sheds and engine house, but must have seemed bland compared to the extraordinary Bute Ironworks near Rhymney, designed in Egyptian style by James McCulloch in 1828. Neither architectural composition has survived (although there are substantial remains at Abersychan), but these were at the extreme end of a general trend. By the mid century, engine houses and other buildings would be expected to possess some architectural graces. Sober, sub-classical styles were the norm, exuding order and solidity, with only occasional, more frivolous touches, like the Italianate engine house of 1847 at Dalmellington in Ayrshire (Butler and Duckworth 1993). At Blists Hill, photographs show the casting houses to have had rebated openings with pointed arches (Figs 84 and 85), a Gothic style only in the most dilute form, while the engine houses are stylistically different.

They are comparable with many Welsh engine houses, like those at Ynysfach in Merthyr Tydfil or Llynfi near Maesteg, both of 1839, which use pennant sandstone with limestone dressings and round-headed openings, the overall effect strongly reminiscent of contemporary non-conformist architecture. At Blists Hill, the south engine house has round-headed windows with radial glazing, had a pedimented doorcase, and its gable ends have windows recessed within blind arches (Fig 99). Meanwhile the north engine house has taller, thinner, round-headed windows, prominent white-brick dressings, and a hipped roof (Figs 97 and 98). Two local Wesleyan chapels share a broad family resemblance to the south engine house, at Ironbridge (1837) and Madeley (1841). The sub-classical tradition persisted into the later-19th century at Dowlais where there is a large brick blast-engine hall, the only surviving building at the works.

Coke-fired blast furnaces

Numerous coke-fired blast furnaces have survived from the 18th and 19th centuries. Again, the durability of construction and the fact that many furnaces were built into banks has been an important factor in their survival. Indeed, a blast furnace can survive even if its facing stones have been robbed out, as at Blaenavon. There is, however, a glaring regional discrepancy in the survival of early 19th-century works. South Wales and Staffordshire vied with each other for importance in the trade during that period, but whereas there are numerous surviving blast furnaces in South Wales there are none in South Staffordshire, while only one outlying blast furnace survives in North Staffordshire, at Springwood, near Newcastle-under-Lyme. At Cyfarthfa, in Merthyr Tydfil, six of the seven early 19th-century furnaces remain standing, as well as the partial survival of four of the blast furnaces at its sister works at Ynysfach, but at the rival Dowlais works none of the 14 furnaces has survived. Blaenavon, Clydach, and Neath Abbey are the other South Wales ironworks where multiple blast furnaces have survived from late 18th-century sites, while the other notable furnace survivals in South Wales, like Gadlys, Cefn Cribwr, Banwen, and Venallt were the smaller second-generation works constructed in the first half of the 19th century. In England the best surviving furnaces are again the smaller works, like Morley Park in Derbyshire, Whitecliff in the Forest of Dean, and Moira in Leicestershire (Cranstone 1985).

The upper furnace at Coalbrookdale differs from the examples quoted because it has a brick casing, nor does it differ significantly in size from earlier charcoal furnaces. The surviving structures at Bedlam exhibit the classic symptoms of a disused ironworks. The structures stand against the steep bank and could not have been taken down without endangering the stability of the ground above it. The rest of the buildings were demolished very soon after the closure of the works – they are not shown on the 1847 tithe map (Fig 65) – a feature common to many sites and the reason why so few casting sheds have survived. This is also partly true of the Upper Works in Coalbrookdale where the snapper furnace became an integral component of the dam wall at the north end of the works. The comparatively late date of closure at Blists Hill may have been a factor in its survival, but the same may also be relevant at Bedlam where, although smelting ceased in 1843, the site remained part of the Madeley Wood Company's leasehold, where a brickworks was situated until 1889. The location of Bedlam, at the foot of a hillside set back from the river, was hardly a prime site for redevelopment.

The archaeological work at Bedlam and Blists Hill has established that their furnaces are a special type and this should be stressed. Furnace I, dating from the early-19th century, continues with the generous use of stone casing (Fig 70), although higher up it almost certainly had a brick stack with a profile shaped like a pottery kiln. As such it is an intermediate form between the masonry-cased type typical of the 18th century and later furnaces, which had brick stacks on stone bases.

Blast furnaces with the distinctive bottle-shaped profile are known to have been built at four ironworks in Shropshire. Of this unusual design, only furnace II at Bedlam survives above the level of the boshes (Fig 77). Its resemblance to a kiln has hitherto caused it to be misinterpreted as part of the nearby brickworks. Apart from Bedlam and the phase I and II furnaces at Blists Hill (Figs 82 and 84), the other examples are on the south side of the river. The furnaces at Barnetts Leasow appear in an undated watercolour of the early-19th century (Fig 64) and the circular design is suggested in a plan of the furnaces dated *c* 1801 (B&W Portfolio 703). The fourth and possibly the earliest example is depicted in a watercolour of a disused furnace near Broseley, dated 1821 (Fig 153). The furnace is probably Coneybury, built in 1786 but described by Thomas Butler in 1815 as ruinous (Riden and Owen 1995, 39; Birch 1952, 232). The preference for such a style is unlikely to have been the influence of a single engineer or proprietor, the difference in date between the Coneybury and Blists Hill furnaces being over fifty years. The answer may lie in the specialised production of high-quality foundry pig iron, but is equally likely to represent a local culture in ironworking.

For Scotland there is a notable dearth of surviving furnaces from the coke era, as there is in the remainder of Britain from the second half of the 19th century – the era of hot blast smelting. In fact the furnaces at Blists Hill are arguably the latest surviving furnaces in Britain. With Bedlam, they are the only surviving structures associated with the tall brick stacks that were typical of the later period.

Figure 153 'Old Furnace, Broseley' by Homes Smith, 1821. The site is probably the Coneybury furnace. The profile of the furnace, built in 1786, is similar to the furnaces at Madeley Wood and Barnetts Leasow with a tapering round stack. The artist appears to have added battlements to the tunnel head, and the charging house on the left is 'inaccurately' depicted at a lower level than the charging level of the furnace. (Shropshire Archaeological and Historical Society)

None of the more common cylindrical furnace stacks has survived. As with the later calcining kilns, such freestanding furnaces were liable to collapse or were susceptible to demolition after being blown out.

Wrought iron manufacture

The archaeology of the wrought iron trade is scarce. The two most important sites in Shropshire can be considered as outside the mainstream of contemporary developments. The Coalbrookdale Upper Forge, like Wren's Nest and the Mitton Forges in the Stour valley, was one of the few forges not directly connected with a blast furnace, as were the comparable forges at Ketley and Horsehay. The Upper Forge now stands somewhat isolated from its former related buildings and is also in a category of its own among the local ironworking sites. In the East Shropshire Coalfield it is the only surviving building where wrought iron was manufactured and one of only three extant sites where stamping and potting was practised. The others are at Wrens Nest and Eardington. Wrens Nest is the only site where pots from the potting process have been uncovered. The buildings no longer stand, but traces of the water-power system remain (Hurst 1968; Trinder 1996, 127). At the Eardington Upper and Lower Forges, on the right bank of the River Severn near Bridgnorth and built in the period 1782–9, stamping and potting was superseded by charcoal iron manufacture (Mutton 1970). Eardington and Wrens Nest are untypical in the sense that they belie the contemporary trend for siting the forge with the blast furnaces, as was the case at Horsehay, Ketley, and Donnington Wood. Elsewhere in Britain, Wortley Top Forge in Yorkshire was built as a finery and chafery in 1713 on the site of an earlier forge. Wrought-iron railway axles were made there in the 19th century using puddled iron from the Wortley Low Forge, where puddling was introduced in the early-19th century. The forge closed in the early-20th century. Two original tilt hammers survive with restored waterwheels and four original cranes (Crossley 1990, 167). As such it is comparable with the Coalbrookdale Upper Forge as a relatively small, water-powered building which was adapted over a long period of time.

Puddling heralded the introduction of large ironworking sheds, whose light construction and need for ventilation produced some distinctive designs and used some of the earliest iron roof trusses. Large-scale sites are vulnerable to clearance and redevelopment, however, and none of the forge and rolling mill sheds of the early-19th century have survived, with the exception of the Neath Abbey works, where the main forge and mill have been used as a clothing factory in the late-20th century. The other example is found in a slightly different context, at the Treforest Tinplate Works near Pontypridd, built by the Crawshays of Cyfarthfa in 1834–5. The site retains a former water-powered rolling mill 150m long, a tinning house with wrought-iron trusses, and a four-bay smithy that retains its cast-iron frame, the kind that was erected at Cyfarthfa and elsewhere in the early-19th century. But these two sites are a poor return given the widespread use of such buildings in the 19th century.

Integrated ironworks

The surviving ironworking sites are worth more than the sum of their component parts. Several of the most completely preserved blast furnace sites are untypical and this must be regarded as a factor in their survival. Blists Hill is an obvious example, a small ironworks whose production relied purely on cold-blast pigs, yet it is easily the best-preserved of the 19th-century generation of ironworks in the East Shropshire Coalfield. Elsewhere, Moira and Whitecliff are both monuments to failed investments. The surviving Welsh works are also biased towards the smaller or shortlived sites, the most obvious example of which must be Banwen, whose two furnaces, engine house, and ancillary buildings were built in 1847, but where there is no evidence for any sustained campaign of smelting.

The ironworking remains at Coalbrookdale are incomparable, not merely because of their association with Abraham Darby I, but because they span a long period from the 17th century into the 21st. The close proximity of pool and furnace at the Upper Works was unusual and hardly ideal (as was proved by flood damage *c* 1705 and in 1801) and inhibited the expansion of the materials preparation area when coke hearths were laid there in the mid-18th century. The interpretation of the Coalbrookdale Upper Works has emphasised the importance of its structures as a group, representing an early furnace, foundry, and engineering works in addition to the obvious significance it derives from its association with Abraham Darby I. Development of the foundry and engineering businesses over nearly three centuries can be followed by comparing the earliest structures with the later buildings at the Upper and Lower Works. The later and larger buildings at the south end of the Upper Works include a large warehouse (now housing the Museum of Iron) built in 1838 for the trade in ornamental castings, which had a clock tower added in 1843 giving a strong visual focus to the works buildings (Fig 2). Near to it stands a long warehouse with a former fitting shop behind it, erected at the end of the 19th century (Fig 20). At the Lower Works, the core of which is still used by the Coalbrookdale Company, is a long 16-bay erecting shop built in two phases between 1879 and 1886, which replaced smaller workshops at the Upper Works, and a large office range developed piecemeal in the second half of the 19th century. The site of the early 18th-century blast furnace and foundry at the Lower Works is occupied by 19th- and 20th-century foundry buildings.

At most works which were comparable to the Coalbrookdale Upper Works in terms of their combination of blast furnaces and boring mills, like New Willey and Calcutts in the Ironbridge Gorge, or Carron in Scotland, structures do not survive above ground. This heightens the archaeological significance of the Upper Works turning mill and the site of the boring mill lower down the Dale. In the Weald, one early 18th-century boring mill has been excavated at Pippingford (Crossley 1975). The closest parallel to the Coalbrookdale Upper Works is at Bersham near Wrexham where excavations have been ongoing since 1987 (Grenter 1992, 1993). The works was built in 1717 and the furnaces were coke-fuelled from 1721. From 1763 it was managed by John Wilkinson, who also owned the New Willey ironworks in Shropshire and Bradley in Staffordshire, and was one of the leading ironmasters of the late-18th century. Substantial remains of Wilkinson's octagonal foundry has survived at Bersham, along with a blast furnace, lime kiln, and coke ovens. Excavations have yielded some spectacular evidence, especially a wooden waggonway laid in 1758, as well as the bases of three air furnaces. This is an indication of the huge potential of the Coalbrookdale Upper Works and Bedlam if they are ever excavated. The other relevant example of an integrated furnace, foundry, and engineering works is at Neath Abbey, where the former engine manufactory has survived to a substantial degree close to two large blast furnaces. The Neath Abbey ironworks operated from 1792 until the 1840s.

The survival of ironworking sites within a broader industrial and cultural landscape is too wide a subject to be covered here and has been partially tackled in previous work on Ironbridge (Alfrey and Clark 1993). The Madeley Wood Company is ideal for a future case study of a corporate industrial landscape. At Blists Hill the ironworks, pit, and brick and tile works survive in close proximity. Further afield, the Bedlam brickworks survives fragmentarily, although the site has never been properly investigated. The landscape of Madeley Wood and the Lloyds also retains much evidence of the extensive network of plateways across the Madeley Field, roughly the area between Bedlam and Blists Hill (see Fig 1). Sites include the Lee Dingle Bridge, built over the LNWR in 1890 to replace an earlier viaduct, and across which coal was brought from Meadowpit Colliery. From the 20th century and further to the north east of Blists Hill stands the modernist pithead baths from Kemberton Pit, built by J H Bourne and opened in 1941 (Brown 1996). It is these peripheral features that must in future be drawn into the broader archaeological context of the Madeley Wood Company.

10 Industry in art: a case study of Ironbridge

Pictorial representations can be combined with contemporary written accounts to constitute an important body of evidence, revealing something of the attitude of outsiders to the world of industry. Fortunately Ironbridge attracted many such people at the turn of the 18th century, who have left valuable records of the place in words and pictures. The art of industrial Ironbridge has already been surveyed by Francis Klingender (1972) and Stuart Smith (1979a), and contributes another layer of meaning to the archaeological sites. Archaeology is expected to benefit from the accounts of witnesses, but it also has something to offer to the debate. In particular, the archaeological interpretation of Bedlam has enlarged our understanding of the images which portray it, although they were originally consulted for the opposite reason.

The contemporary context of industry is well expressed in written descriptions. The motives of the visitors to the district varied as much as the subjects they gave their attention to. The iron industry attracted insiders like Charles Wood and Thomas Butler who were well qualified to judge the technology they were describing, while the likes of Simon Goodrich and Joshua Gilpin had enough technical knowledge to match their curiosity for machines like Trevithick's engine or the waterwheel at the Benthall mill. Others came to the area specifically to learn about industrial processes, such as Eric Svedenstierna, Marchant de la Houlière, and the La Rochefoucauld brothers, for all of whom Ironbridge was merely one item on their itinerary. The majority of visitors, however, were educated men with no special knowledge and no special technological interests but with a natural curiosity and a penchant for descriptive prose. Common currency during this period was praise of British trade, the East Shropshire Coalfield giving the visitors much to feel satisfied about. In 1758 George Perry could state with approval that since Abraham Darby had come to Coalbrookdale 'its Trade and Buildings are so far increas'd that it contains at least Four Hundred and Fifty inhabitants, and finds employment for more than Five hundred People' (Trinder 1988, 24). In an engraving made after a drawing by Perry, the scene of human activity is one of the most striking elements of the picture (Fig 13). But Perry did not describe or portray the technology which had made the growth of trade possible.

An ambivalent attitude to industry characterised many descriptions of Ironbridge, varying between the extreme emotions of repulsion and exhilaration. Charles Dibdin complained that 'the day was insufferably hot, and the prodigious piles of coal burning to coke, the furnaces, the forges, and the other tremendous objects emitting fire and smoke to an immense extent, together with the intolerable stench of the sulphur, approached very nearly to an idea of being placed in an air pump' (*ibid*, 71). By contrast Henry Skrine found in 1798 that 'by night the numerous fires arising from the works on the opposite hills, and along the several channels of the two valleys, aided by the clangour of the forges in every direction, affect the mind of one unpractised in such scenes with an indescribable sensation of wonder' (*ibid*, 62). Like many of their contemporaries, the descriptions of Skrine and Dibdin are impressionistic, viewing the subject matter from a distance. Only a minority of visitors wrote more graphic accounts, describing waterwheel diameters and the like. But among these accounts it is not obvious that technological progress was the defining characteristic of the age, at least not in the manner it would be today. One of the principal objects of interest *c* 1800 was not the Heslop or Trevithick engines but the large corn-mill waterwheel at Benthall, first described in 1799 and situated a few yards uphill from the Iron Bridge (Fig 154). There are several images and numerous accounts of it. Even Simon Goodrich devoted as much attention to it as he did to the Trevithick engine and the cast-iron railways at Coalbrookdale or Lord Dundonald's coke ovens at Calcutts (SML Goodrich E2).

The contribution of these visitors is a useful preamble to the works of contemporary artists. Artists came here for much the same reason as many other tourists, principally to see the Iron Bridge. When they arrived, many were delighted with the dramatic and unusual scenery. It is important to remember, however, that industry was an occasional subject for these artists, whose work was governed largely by commercial considerations. It is also worth remembering that what an archaeologist would today call industrial is profoundly different from the 18th-century understanding of the term. Whereas a corn mill and a colliery would both qualify today as industrial subjects, in the 18th-century this was not so. Mining was a subject which could only be found in certain types of landscape. It had a jarring impact on the landscape with its spoil heaps, horse gins, and pumping engines; it was an employer of men, women, and children whose appearance and daily tasks set them apart from the norm, while coal was a commodity which could be traded for profit, contributing to the general well-being of the nation. A corn mill, on the other hand, was locked into a rural landscape often idealised as an unchanging world, part of an economy perfectly in tune with its surroundings.

In terms of what would now be regarded as industrial, what captured the artists' attention? Stuart

Figure 154 'Great Wheel at Broseley, Salop', a view of the corn mill at Benthall in 1802 by Paul Sandby Munn. (Ironbridge Gorge Museum Trust)

Smith's study of Ironbridge showed that the favourite subjects were furnaces, engine houses, the large waterwheel at Benthall (Fig 154) and another at Swinney downstream of Coalport, the Iron Bridge, and panoramic views contrasting the natural with the industrial. There are conspicuous omissions from this list: Numerous small potworks on the south bank of the River Severn, as well as the local brick kilns, never attracted the same pictorial interest as even the local collieries. In general, the artists of industry in Ironbridge enjoyed the novelty aspect of industry and used it to construct images that satisfied a market for the picturesque and curious.

It is odd that none of the industrial proprietors of the district, with one notable exception, commissioned artists to flatter their manufacturing empires, as William Crawshay did at Cyfarthfa in 1825 when he commissioned a series of views of his works and mansion from the native Merthyr artist Penry Williams. A portrait of William Reynolds painted *c* 1795 shows him as a pioneer of civil engineering, holding plans for the cast-iron aqueduct built at Longdon-on-Tern in Shropshire, with an inclined plane behind him. By contrast his father Richard Reynolds, perhaps the most astute of the Quaker businessmen, was portrayed holding a copy of the Bible.

The one ironmaster who did commission artists to produce works was Abraham Darby III. Darby commissioned two paintings of Coalbrookdale in 1777 from William Williams, engraved and published the following year, and which are within a picturesque tradition. Entitled morning and afternoon views of Coalbrookdale respectively, both are from high vantage points and place industry within a rural setting of overwhelming greenery (Fig 155). In 1780 Williams was also commissioned by Darby to paint the Iron Bridge, a highly successful publicity stunt for the Dale Company. Subsequently the Iron Bridge became one of the most widely-portrayed scenes in the British landscape.

The best known portrayal of the Ironbridge district at the height of its fame is P J de Loutherbourg's 'Coalbrookdale by Night', exhibited at the Royal Academy in 1801 and ostensibly a painting of Bedlam furnaces (Fig 156). De Loutherbourg (1740–1812) made his name as a scene painter and set designer for the London theatre, where he worked between 1773 and 1785. Later he pioneered the Eidophusikon, a series of moving pictures with sound effects, one of the antecedents of the cinema. Francis Klingender has described his landscape works as genre scenes by a painter who introduced a strong emotional content into the landscape.

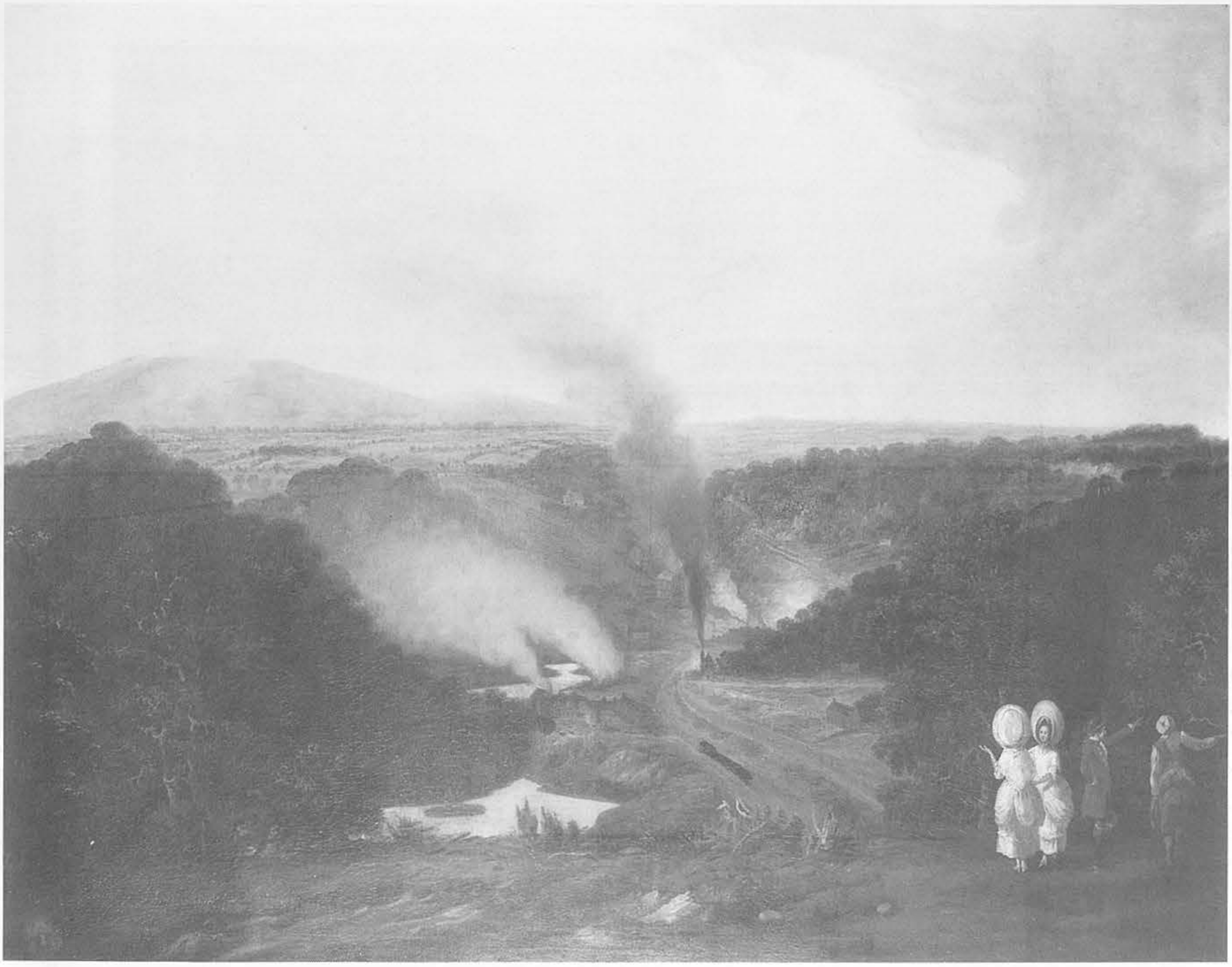


Figure 155 'An Afternoon View of Coalbrookdale', by William Williams, 1777. The view looks north west over Coalbrookdale and the Upper and Lower Works. (Shrewsbury Museums Service)

His work was a significant move away from the earlier taste for picturesque scenery and became an important influence on J M W Turner (Klingender 1972, 85–8). Recently Stephen Daniels has interpreted the picture as a spectacular patriotic image with apocalyptic overtones, placing it in the contemporary context of war with France (Daniels 1992).

'Coalbrookdale by Night' is vintage de Loutherbourg, strong and dramatic in its lighting effects. How much the image resembles what he saw when he visited Bedlam is another matter. Although there are no known sketches relating to the painting, a number of sketches exist from de Loutherbourg's studies of other industrial scenes in Ironbridge and elsewhere. Compared to his paintings, the sketches are surprisingly matter of fact (Figs 157, 158, and 159). His drawing of the Resolution steam engine in Coalbrookdale records in a kind of note form the boilers, pipes, head frame, and the rest, drawn much as they would have appeared and without imposing an artistic personality (Fig 157). The same is true of his wash drawing of boilers and a casting house, which has previously been interpreted as Bedlam (Fig 158) (Smith 1979a, 48). The wagon boiler and round stack cast doubt on this attribution, but the main point is that the features are again drawn in a detached manner. It is also interesting to note that none of his sketches contain people.

The authenticity of de Loutherbourg's sketched scenes is even more convincing when his other works are considered. His drawing of the Dyfi furnace in West Wales, made *c* 1800, proved an important tool in the consolidation and archaeological interpretation of the site in the 1980s. It agrees well with an etching made from a similar viewpoint by J G Wood over a decade later, and even shows a crack in the furnace casing which remains visible (Dinn 1988, 120–1).

Like most of his contemporaries, de Loutherbourg travelled the country producing sketches, in effect taking notes, from which he could fashion completed works in his studio. A comparison of his sketches with 'Coalbrookdale by Night' shows the resulting contrast most clearly. 'Coalbrookdale by Night' is highly charged with the artist's personality. There is a horse and cart in the foreground while assorted cast-iron objects are strewn impossibly about like flotsam. The figures, intentionally diminutive and

Figure 156 'Coalbrookdale by Night', by P J de Loutherbourg, 1801. Bedlam Hall is to the left, the ironworks in the middle distance to the right. The picture is largely a studio conception and is not intended to be a faithful representation of objects observed in the field. (Science Museum)

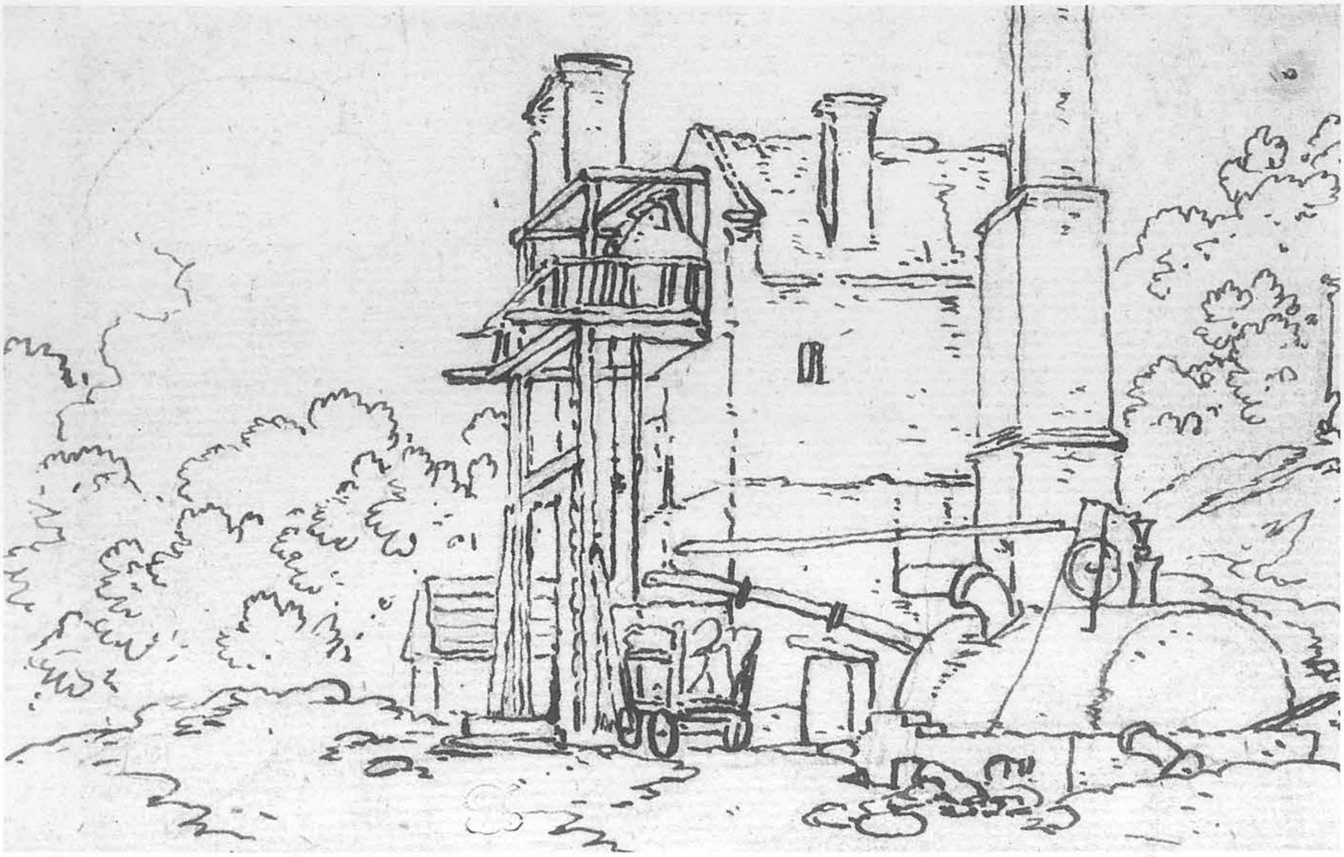


Figure 157 Pencil sketch of the Resolution engine in Coalbrookdale, by P J de Loutherbourg, c *1800. (Tate Gallery)*

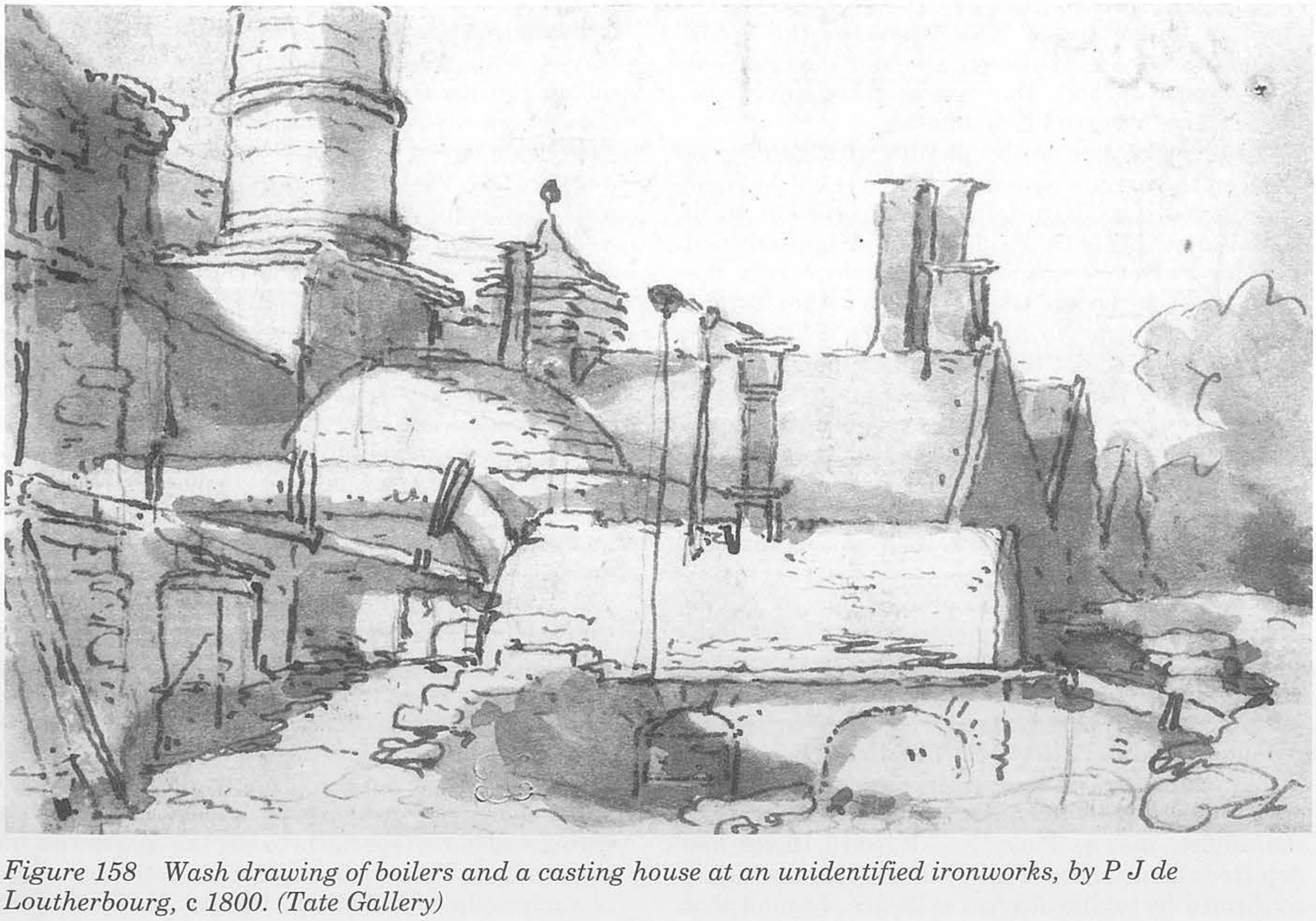


Figure 158 Wash drawing of boilers and a casting house at an unidentified ironworks, by P J de Loutherbourg, c *1800. (Tate Gallery)*

Figure 159 Wash drawing of a foundry in Madeley Wood, by P J de Loutherbourg, c 1800. (Tate Gallery)

shadowy to emphasise the drama of the scene behind them, are rustic in the most hackneyed sense, genre figures that make no claim to be portrayals of observed individuals.

The identification of the picture with Bedlam is based on the conjunction of the furnaces on the right and a large house on the left, known as Bedlam Hall. A similar painting by Paul Sandby Munn entitled 'Bedlam Furnace' was discussed above with the archaeology of the site (Fig 63) (see Chapter 4). The buildings are also shown on the early 19th-century lease plan of Bedlam (Fig 62), which demonstrates the extent to which de Loutherbourg reinvented the landscape when he worked on the picture in his studio. De Loutherbourg suggests that the furnaces were built on a flat site and that Bedlam Hall was sited on a craggy eminence. In fact both were built on a sloping hillside and the road passed directly adjacent to Bedlam Hall above two cottages (Fig 62). The level foreground of 'Coalbrookdale by Night' is therefore invented. In pictorial terms, the foreground is essential to the structure of the image despite its detachment from the main scene behind it (the line of a plateway could easily have acted as a stronger visual link between the two but in practice is not shown). The ironworks on the right has an engine house with chimney stacks rising from the angles, just as Perry and Edward Dayes had depicted them earlier (Figs 60 and 61), and which is confirmed by archaeological evidence. Beyond that is a casting house with cowl, again familiar from Dayes' watercolour, together with a silhouetted hill in the background. These are features drawn from observation, presumably utilising one of the sketches he must have made at the works. But it is unlikely that the whole picture was worked up from a single sketch. Whereas the engine house is shown in some detail the charging houses that should be above the blast furnaces, and which the lease plan suggests were standing into the early-19th century, are not shown. It is tempting to suggest that de Loutherbourg sketched the engine house and casting houses only, ie the lower level of the works, and amalgamated this with a sketch of Bedlam Hall – perhaps the conjunction of Bedlam Hall and the coke hearths gave him the idea for the picture in the first place. The inhabited foreground could then be added in front of the scene to provide depth, movement, and human drama, the sum of which is an artistically convincing painting but portraying a landscape that never existed outside the artist's imagination. This makes him an unreliable witness but enhances our appreciation of him as a maker of images.

Clearly 'Coalbrookdale by Night' is a representation of industry by an artist who was not interested in its technology, nor the social world of its protagonists. He crafted an image of industry as an exhilarating and heroic spectacle to stir the senses and not the intellect. The result is one of the defining images of early industrial Britain, but not necessarily an image that the Bedlam workforce would have identified with.

De Loutherbourg's other well-known view of the area was published in his *Romantic and Picturesque Scenery of England and Wales* of 1805 (Fig 160). Again it has been interpreted as Bedlam, on the basis that the water in the foreground is the River Severn (Smith 1979a, 48). This interpretation should now be given up, for two reasons. Firstly, the image looks nothing like Bedlam could conceivably have looked and looks even less like Bedlam than 'Coalbrookdale by Night'. Secondly, although the print is entitled 'Ironwork, Colebrookdale', the text accompanying the illustration describes it as 'the middle steam-engine in the Dale', suggesting Coalbrookdale as the location. The middle steam engine is most likely to be the Resolution as only the Upper Forge engine stood lower down the Dale at this date, while further up was the Lightmoor works. The argument is strengthened by the fact that de Loutherbourg is known to have seen and sketched the engine (Fig 157), even though the two images have little in common except that both have a wagon boiler in front. If this is the case, then it confirms the degree of artistic licence employed by de Loutherbourg to turn sketches into finished images. He can be seen to have used the same technique in this picture as he did in 'Coalbrookdale by Night': The peasant on horseback and the cast iron strewn about, constitute the same inserted foreground device that is physically cut off from the scene in the middle distance. Once more it is the effect of light which dominates the picture, given more impact by the stacks breaking the sky line.

Two other views of Bedlam are worth consideration, especially as they were made in 1802 by two artists travelling together who have produced mutually exclusive scenes. John Sell Cotman (1782–1842) and Paul Sandby Munn (1773–1845) earned a living by making drawings and watercolours for print sellers. They visited Shropshire on their way to Wales in search of suitable material (Parris 1973, 110). Munn's view of Bedlam is so similar to 'Coalbrookdale by Night' that he probably saw and was impressed by the latter during its exhibition at the Royal Academy in 1801 (Fig 63). Again, Munn has constructed his image in three separate parts: in the foreground are anonymous, diminutive figures

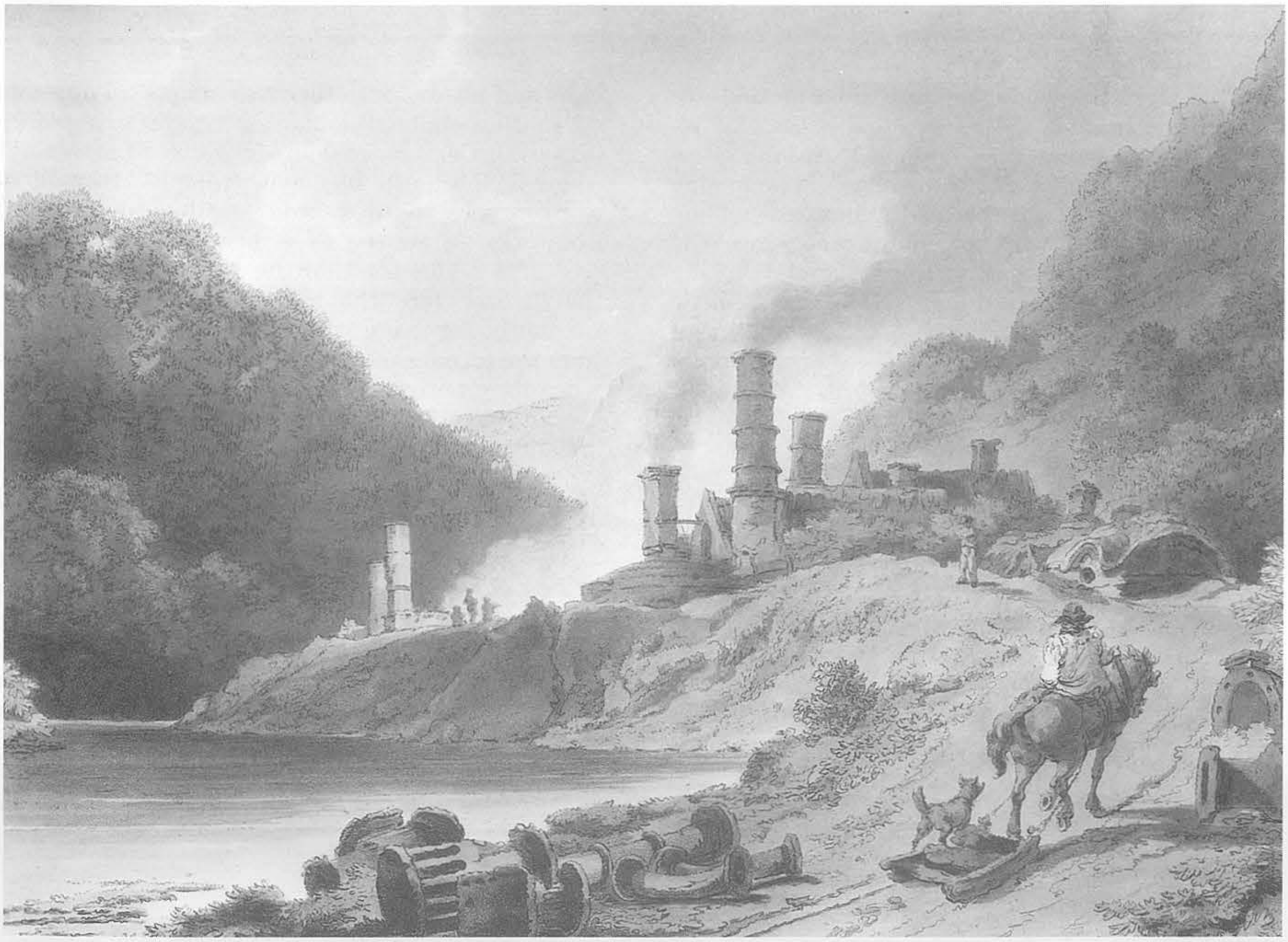


Figure 160 'Iron Works, Colebrook Dale', by P J de Loutherbourg and engraved by W Pickett, 1805. Text accompanying the engraving calls it 'the middle steam engine in the Dale' and it might therefore be a representation of the Resolution engine. (Ironbridge Gorge Museum Trust)

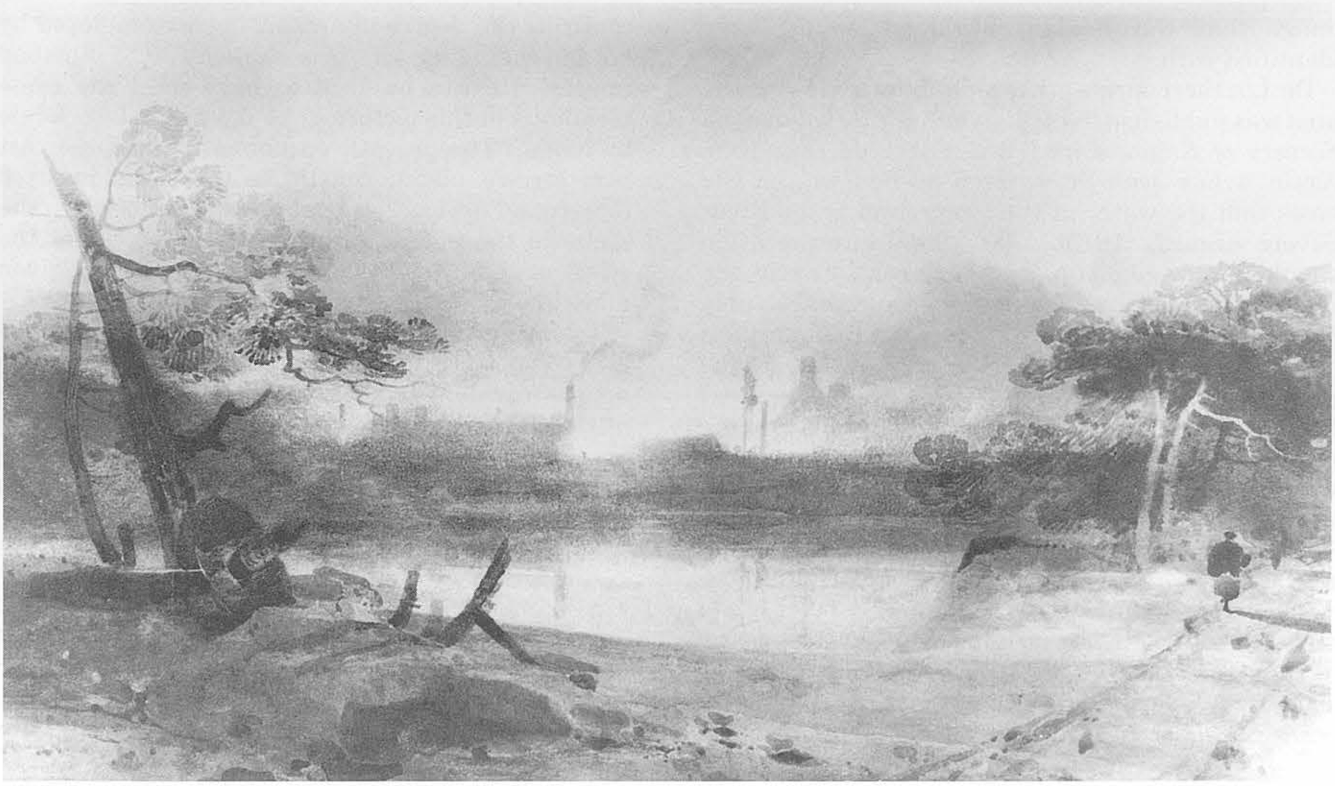


Figure 161 'Bedlam Furnace, near Madeley', by John Sell Cotman, 1802. (Ironbridge Gorge Museum Trust)

and scattered ironwork, in the middle ground are the buildings, while the background is the sky. As far as the furnaces are concerned, Munn's view differs from de Loutherbourg in showing an engine house chimney but not the casting house or a blast furnace, while in front of the furnaces are the cottages shown leased to Richard Langley on the early 19th-century plan (Fig 62). There can be little doubt, given these important differences, that Munn made his own sketches of the scene, however influenced he was by de Loutherbourg.

John Sell Cotman was a prominent member of the Norwich school of painters. His sketches of 1802 include many impressionistic views of local collieries which characteristically sacrifice detail for atmosphere. Cotman's adage was to 'leave out, but add nothing' (quoted in Wilton 1977, 37). Everyday, as well as natural scenes, could be exploited as the raw material from which he could fashion a new imaginative reality. In fact he often chose inconsequential objects like a fence, a boulder, a bark or a tree trunk for his subjects (*ibid*, 35). Cotman constructed his picture of Bedlam using light and shade, but otherwise adopts an opposite approach to de Loutherbourg's baroque exuberance (Fig 161). 'Coalbrookdale by Night' is all movement whereas Cotman's image is tranquil. Instead of using genre figures and strategically placed ironwork, Cotman uses a blasted tree and the river like a still pond for the foreground, blending the furnace into the natural scenery where de Loutherbourg made it stand out. The white glare from the furnace was not an effect readily produced when they were tapped inside casting houses. Like everything else in the picture, it was chosen for artistic reasons.

These different aesthetic approaches are important to our evaluation of the pictures as documents of industry. The views of Bedlam are of limited use as an aid to archaeological interpretation, but they are part of the diverse contemporary experience of industry. Cotman's abstract impression was made in the same year as Svedenstierna's meticulous description of the water regulator, and the difference shows how such places helped to inspire new ways of looking at the world.

11 Review of techniques and discussion

An approach to documentary and pictorial evidence

Documentary evidence played a far more prominent part in the interpretation of the sites than was expected. Guidelines for the use of documentary evidence in practical archaeological projects have never been definitively formulated and were not included in MAPII (see Chapter 1). Here the documentary sources for archaeological projects will be discussed, focusing on the kind of information which is a special feature of industrial sites, followed by a discussion on the use of contemporary art in the interpretation of archaeology. These are intended to contribute to a methodological critique of historic archaeology, identifying the potential and limits of such source material.

The original brief for documentary research, and the early revision of it relating to the verification of known sources, has already been described. With hindsight it can be seen that a belief that secondary sources would be adequate was naive. This is not a criticism of the brief but an important lesson as the Industrial Revolution in the East Shropshire Coalfield is one of the most well-researched subjects of the industrial period. However, documentary sources are self-evidently crucial in historical archaeology and have a decisive and authoritative effect on archaeological interpretation. This was seen most clearly in the case of the Upper Forge where new documentary evidence has single-handedly cancelled out many of the archaeological problems of the site. The fact that the new information more or less confirmed what had already been deduced by archaeology has a twofold significance: it demonstrates that archaeology as a process of finding out about a place works, but it also shows that certain classes of historical evidence are decisive. John Powis Stanley's version of when and why the Upper Forge was built is irrefutable compared with any archaeological interpretation of the building, however convincing its arguments might be.

It has been suggested that a brief for documentary research should not duplicate previous research effort (Wood 1994, 186). Whilst it is agreed that previous work should be consulted, it is argued here that a fresh review of known sources is not duplication and that it is important to combine primary archaeological research with primary documentary research. A small amount of additional resources for such work would significantly enhance the quality of the final product. In the present project, the consultation of well-known primary sources helped to generate confidence in the subject, which the use of secondary sources could never have done. It also paid dividends in yielding new information. The case of Bedlam is instructive. Most of the sources relating to the site had been identified by Barrie Trinder, but were used in the broader context of the industrialisation of Shropshire rather than a site-specific study. For example, the Madeley Field and Madeley Wood Furnace Reckoning for the years 1790–7 gives accounts for Bedlam furnaces from 1794 onwards and is perhaps the most detailed and informative source for the site (SRRC 271/1). This document has now been used for two main but different purposes. Barrie Trinder used it primarily to demonstrate the variety of engine types, such as the Heslop and the beamless engines, which were pioneered at the Madeley Field mines during the 1790s, an important testament to the introduction of new technology by William Reynolds. In the present study of the blast furnaces, the source was used to study the developments made by William Reynolds in relining one of the furnaces and reconstructing the foundry with an air furnace and a crane in the years 1794–6. It was in the monthly expenses for the furnace where it emerged that the water supply for the works was extracted from the River Severn, rather than from the water table. The source could and, hopefully in the future, will be used in other ways, since it gives detailed information on the quantities of iron made, the amount of coal coked, and the various amounts of ironstone stacked on the charging platform. It also lists the employees at the works, the various jobs they were undertaking, allowing a distinction to be made between male and female workers, the division of labour into twelve-hour shifts, and so on. Such information was outside the brief for the present project, but demonstrates that a primary source can be used in a number of ways and it is therefore not a criticism of previous work to insist that such sources are consulted afresh with specific new questions.

The need for a fresh appraisal of well-known sources is no less relevant for contemporary maps than for other sources. The point again is that none of the maps of Coalbrookdale had been scrutinised for the same purpose as charting the decline of the Upper Works foundry in the 19th century and nor had the plan of the Upper Works made by Slaughter been explained in terms which rendered it an important and reliable record of the site in the mid-18th century (Figs 11 and 12). Confidence in the documentary and cartographic sources can only be generated by a first-hand knowledge of them.

Much of the important information regarding the major Ironbridge monuments, and this is true of many archaeological sites and buildings of the industrial period, is provided by witnesses. It is clear from a consideration of their motives that some sources are more reliable than others. No one would seriously doubt the veracity of Svedenstierna's account of the water regulator at Bedlam, for example, or Thomas Butler's description of two furnaces blown on one side and one furnace blown on two sides. When ironworks were open to inspection upon application to the works office, visitors could closely observe some of the processes: Joseph Banks' description of the foundries at Coalbrookdale, of making sand moulds in flasks and filling them from ladles, is a good account of working practices that will survive into the 21st century. In addition, Banks was one of a number of visitors who was able to record his conversations with works managers, allowing him to give a reliable description of the iron rails that were being cast at Horsehay (Trinder 1988, 28–31).

Witnesses are not always reliable, however. In one famous case an American visitor to the Madeley Wood Company was told by the company's chief engineer that the Lloyds pumping engine was a genuine Newcomen-type engine built in the late-18th century, which further documentary evidence as well as archaeological evidence showed could not have been so (Leese 1912; Hayman 1997a). Two descriptions of the Hay Inclined Plane made within ten years of each other are mutually exclusive. In 1818–19 Jean Dutens said the incline was double-tracked, while in 1826–7 Carl von Oeyenhausen and Heinrich von Dechen said that the incline had only three rails, the central one being common. Contradictory statements like these are an inevitable hazard of using first-hand accounts, and demonstrate why contemporary descriptions should be used critically. For example, the visitors to the Coalbrookdale Upper Works were principally interested in technological matters. They may have disagreed about the diameter of the waterwheels (although the figures were probably estimated and certainly were not measured), but they consistently noted the same features at the works, namely the use of cast-iron pipes and waterwheels, and the replacement of the bellows with cylinders at an early date. This is the kind of information which would not be readily available from other sources, and which the archaeologist has a special interest in.

The case of pictorial representations is slightly different. Discussion of art for archaeologists is not a new subject and there is no definitive way in which such sources should be used. It is always worthwhile thinking aloud the problems and potential of this kind of evidence, of developing a critical and positive approach to the subject matter, and establishing that archaeological analysis can contribute to an enhanced understanding of the works of art (Hague 1986; Hayman 1987). There are a variety of views which have been associated with Bedlam that provide ample raw material for a useful discussion. This can be contrasted with a similar study of views of the mills and waterfall at Aberdulais Falls in South Wales, the differences being that at Aberdulais the art compensates for the lack of any archaeological evidence for that period of the site history, while at Bedlam the art is complementary to a site which has survived to a substantial degree. Aberdulais also provides a cautionary tale in that two mills and a waterfall could be rendered by artists with any combination of those ingredients. Even something so dramatic as a waterfall was sometimes entirely omitted.

An analysis of de Loutherbourg's 'Coalbrookdale by Night' and Paul Sandby Munn's painting of Bedlam from a similar viewpoint has already been given, but has been written from the perspective of a completed project. Although the images contributed little to the final analysis of Bedlam, at the beginning of the project they were naturally regarded as an important source. The recognition in 'Coalbrookdale by Night' of the original engine house helped a rethink of the engine in use at Bedlam, given that it was originally thought that the pumping engine would have been replaced by a blowing engine by the end of the 18th century (Fig 156). Similarly the coke hearths directly behind the furnaces are at a level lower than the top of the engine house. Rightly or wrongly, and in conjunction with Paul Sandby Munn's watercolour (Fig 63), which shows the charging platform at a similar level, this was used to argue that the present steep slope above the furnace site was a product of raising the ground level at a later date, requiring the original charging houses to have been demolished. Archaeological evidence later demonstrated the same thing in a more scientific way but, although de Loutherbourg's painting did not say anything definitive about the archaeology of the site or provide information which was not better authenticated from other sources, the painting was nevertheless part of the process of finding out about the site.

'Coalbrookdale by Night' is fundamentally a landscape of the imagination, however authentic small details of the picture are. The contrast between his painting and his sketches has already been discussed and is an ample demonstration of why an image drawn from nature is infinitely more valuable than an image constructed in a studio. This critical approach to the material is important if it is to be used effectively and if the subtleties in this kind of evidence are to be appreciated. It is no use taking an extreme point of view that artistic licence renders any image unverifiable or that the works of creative artists can be interpreted as if they are photographs. Both of these viewpoints avoid the interpretive challenge of this kind of evidence.

The use of pictorial evidence can also be extended to cartographic evidence, for which the same critical approach should be adopted. Coalbrookdale and Madeley Wood provide good case studies of this kind of evidence with their unusual wealth of material. The tithe map of Madeley is well-known for its attention to detail, although the quality of tithe maps generally is uneven. Even so, it was argued that a blast furnace was omitted from the plan of Bedlam, although this was not specifically the kind of evidence tithe maps were designed to record. Lease maps, of which there are several covering the two areas, present different opportunities and problems. In the case of Coalbrookdale, the maps covering the years 1805, 1827, and 1838 document in detail the decline of ironworking before the reorganisation and concentration on decorative work which is represented on the tithe map. The three lease maps of Bedlam, of the early-19th century, 1858, and 1889, need to be interpreted with more care. The later plan is of the least interest because it was copied from the Ordnance Survey. The primary purpose of the maps was to show the extent of land covered in the lease. Additional factors may also have been important, such as a clause in the leasehold agreement that the ironworks and other buildings should be standing or have been replaced by similar buildings at the expiration of the lease. The early plan and the 1858 plan show the land leased to the Madeley Wood Company as identical in every detail. By contrast, the area surrounding the leasehold land was newly surveyed, the earlier plan showing Bedlam Hall, while the later showed the Ironbridge Gas Works which was built on the same site in 1839. The 1858 plan does not, however, show the brickworks erected in 1841 or indicate that the ironworks buildings had been substantially demolished. As a record of the site in 1858 the plan is therefore fundamentally misleading.

The earlier plans of Coalbrookdale and Bedlam are potentially even more significant as historical sources. George Young's 1786 plan of Coalbrookdale, surveyed especially to depict the new Upper Forge and its culverts, provided the kind of evidence an archaeologist is only likely to come across once in a blue moon (Fig 39). The plan of Bedlam by George Perry, the reliability of which was greatly enhanced by its comparison with Edward Dayes' wash drawing, is another crucial source with its careful itemisation of the buildings (Figs 60 and 61). The plan of Coalbrookdale by Thomas Slaughter is another matter, however, as its convention of showing the buildings in elevation might give the false impression that it is unreliable (Fig 11). For example, three elevations of the Coalbrookdale lower furnace are portrayed on the map, giving the initial impression of more buildings at the Lower Works than there really were, but this can be rectified by careful analysis. Slaughter's plan displays other subtleties, such as the use of red ink to define a drop in ground level, which effectively proves that the pools were retained by walls rather than earth banks. This also shows the importance of consulting the original documents, rather than tracings or photocopies, the former being particularly vulnerable to errors. Among the many map tracings held at IGMT is a tracing of the Madeley tithe map showing the Hay Inclined Plane, which incorrectly omits the stack and shows three tracks instead of two!

The extent to which documentary research should be written into an archaeological brief has yet to be resolved. In practice there is no definitive answer, but the ideal position would be for an interactive relationship between historical sources and archaeological recording, with a brief to examine as many primary sources as possible.

In practical terms, there is certainly a case for arguing that previously known sources are consulted afresh, for the reasons outlined above, and that this is undertaken at the beginning as part of the evaluation. The probability of unearthing unknown sources is not quantifiable, but the necessity of writing briefs which keep the quantity of historic research under control is understood. During the project there should be scope for returning to historical sources while fieldwork is in progress and hypotheses are being developed. Documentary research is part of the thinking process and should not be underestimated as merely the acquisition of data. It is important that the archaeologist is personally responsible for the research and that the historical material is not treated as a separate specialist contribution. The archaeologist needs to develop multi-disciplinary skills for the historic periods as the archaeological and historical evidence should be subject to a single process of interpretation.

A basic prescription can be offered for documentary research which covers sources in local record offices, libraries, and SMRs. These are:

- Primary sources which appear in SMR entries or in the references to secondary works (of which the Victoria County Histories are crucial).
- Trade directories are important from the late-18th century onwards.
- Enclosure, estate, or lease plans, together with tithe and Ordnance Survey maps should all be consulted. Later maps should not be neglected as they often provide important information on the abandonment of sites.
- Some libraries and records offices will conduct searches depending upon the resources they have available, although some private institutions charge for the service.
- Local history societies may be able to provide information about primary sources in addition to being able to impart local knowledge.

Fieldwork and interpretation

There is a direct correlation between the extent of archaeological recording and the level of interpretation. At the beginning of the project, the sites considered most likely to yield the most rewarding new information were the early and difficult structures such as Bedlam and the Upper Forge. This underestimated the importance of recording the later sites, however. While sites like Blists Hill blast furnaces can hardly be described as difficult to interpret, it became apparent that the actual process of recording was as rewarding as the end product. The fieldwork, documentary research, and writing up should be the work of the same person or persons. In the present project this was rarely possible, not least because several sites had to be recorded simultaneously, but it is a policy that should be adopted if at all possible. The actual process of measuring and drawing is a structured way of thinking about a building or a site, and cannot be wholly compensated for by photographs or the drawings of others. Similarly the documentary evidence is likely to make more sense to those who know the site intimately. It is important to stress that archaeological interpretation is a process which cannot be separated from the accumulation of data in the field.

The most definitive interpretations were those where recording had been most extensive. This is an important point because there is still a tendency to assume that industrial buildings can be understood with less intensive recording than for earlier sites (Palmer and Neaverson 1998, 92–5), but for certain complex structures housing machinery, this is simply not the case. The Blists Hill Brick and Tile Works, the latest of the structures studied, is the least understood of all the sites precisely because the recording of the buildings was more limited than elsewhere. Later industrial buildings tend either to be built of repeated components or units, or else are highly specialised and housed machinery which had a relatively short working life and became obsolete very quickly. The brick and tile works is a good example of the latter category.

The recording project was principally concerned with standing structures. Where this was combined with extensive groundworks, as at the Upper Forge, the interpretation of the site was greatly enhanced. This was the most frustrating aspect of studying the Upper Works and Bedlam, where excavations are most likely to reveal significant new information. The need for excavation is especially relevant for these industrial structures because the footprints which the various industrial processes leave are most likely to be found in the ground rather than on the walls. For example, at Coalbrookdale, the positions of the boring and turning machinery could be located by finding evidence of their mountings, not to mention a casting pit like those excavated at the Wealden ironworks. The same is true of the bellows and later blowing cylinder at Bedlam and the interior of the Upper Forge.

The lack of comprehensive ground investigations has ensured that the last word on each of the sites has yet to be written. In general terms, the structural analysis did provide meaningful interpretation and phasing of them could be related to definite periods of a site's history. Careful attention was paid to using mortar types for identifying changes in structures. Like drawing, collecting mortar samples was an integral component of the ongoing analysis of the structures and would be justifiable purely on those terms. At the Upper Forge eighteen mortar types were identified, although they need some qualification. Some of the mortars represented repointing rather than structural change; where similar mortars are discretely distributed in different walls, it was not possible to prove that they belonged to the same phase. Therefore the actual number of mortars used at the Upper Forge was considerably less than eighteen, although the exact number is uncertain. In the event they were found to be complementary to, but in effect secondary to, structural information such as butt joints, changes in course work, evidence of openings and fixtures, and the use of hand-moulded or machine-moulded brick.

At Bedlam, mortars came into two broad types: white or cream mortars and grey mortars with coal flecks. The grey mortars were secondary but any temptation to link grey mortars from across the site was resisted. This kind of mortar, common to industrial and many other 19th-century buildings, was composed more or less of ash, coal dust, and lime mixed by hand. This method is unlikely to produce sufficient uniformity between mixes to establish the relative chronology of, say, light-grey and dark-grey mortars. Again, in the final analysis the mortars played a secondary role in the interpretation, but were nevertheless an important part of the process of interpreting the site.

In conjunction with mortar samples, brick courses should be marked on drawings where resources allow. Apart from its value as an aid to interpretation, it made the marking up of repairs such as repointing and rebuilding much easier (see Appendix 2). The difference between recording brick and stone structures is also significant, because brick coursing is comparatively easy to record. By contrast it is time consuming to record rubble stonework by hand, which is where the value of photogrammetric plots asserts itself.

Those sites which had been restored in the 1970s posed additional problems of interpretation and were a convincing argument for the need to document repairs to a structure if it is to be studied at some future date. Much new fabric was incorporated into sites like Bedlam and Blists Hill furnaces at that time. Some consisted of reclaimed materials, but in practice the structures required analysis to determine what was newly introduced in the 1970s and what was merely repointed in cement mortar. This can be particularly difficult in the case of rubble stonework. At Bedlam, for example, photographs taken in the early 1970s, before any repairs had taken place, were crucial to establishing exactly what had occurred and why in the later 1970s.

Recording the first-generation repairs slowed down the interpretation but was again an important part of interpreting the sites. In many ways the repairs of the 1970s obscured archaeological information and hampered understanding of the buildings, especially at Bedlam where interventions were major. An easily-cited example is in the south engine house at Blists Hill where a doorway was made in the east wall in the 1970s. Analysis of the structure showed this originally to have been a window, the sill of which was knocked out to allow the removal of machinery in 1918. Therefore a damaged window, narrating one of the key phases of the building (ie the removal of the engine) was incorrectly reinterpreted in the 1970s as a doorway (Fig 100). There are other less obvious examples of this, which reinforce the argument for prior archaeological recording and analysis in the conservation of sites, industrial or otherwise.

The argument for standardised recording methods in buildings archaeology remains a weak one, however, simply because aims and resources are so varied. The purpose of any individual project will vary and the approach will be structured around various criteria such as date, function, type, rarity, and survival of the subject matter. Techniques of building recording have developed rapidly in recent years: Survey work conducted in Ironbridge in the 1980s generally omitted 20th-century features as insignificant, an approach which is untenable today. Archaeological recording in conjunction with repairs has become much more common with the production of PPG15 in 1994, but there has never been a consensus of how building recording should be achieved. There have been exchanges of views, notably between archaeologists and buildings historians in *Vernacular Architecture* (Ferris 1989; Meeson 1989; Smith 1989) and under the auspices of the IFA buildings special interest group (Wood 1994). In practice, the only effective strategy for recording is a targeted one based on specific questions, whether research or curatorial related. Rigid systems inhibit creative thinking and ideally fieldwork techniques should allow a certain space for an individual approach, and accept that fieldwork is part of the thought process, not merely the clinical acquisition of information. Details of the approach to field drawings adopted during the project are given in Appendix 2.

A comparison with techniques used in other major building recording projects shows a variety of techniques developed for specific ends. Like the present project in Ironbridge, repairs to the castle and timber-framed gatehouse at Stokesay in Shropshire were recorded using longitudinal elevations at a scale of 1:50, therefore producing drawings which would be suitable for use by architects and other consultants (Tolley *et al* 1991). An archaeological survey at Quarry Bank Mill for the National Trust, in advance of developing the museum galleries, also produced drawings at a scale of 1:50 with details at 1:20 (Milln 1995). The building was annotated by means of numbered 'events', similar to the components adopted at Ironbridge except that its primary concern was phasing and not function. Brick coursing was not added as it was not required for this purpose. A completely different approach is adopted by the Royal Commissions, whose fieldwork is generally concerned with making records and is not normally produced in conjunction with interventions except demolition. Generally the Commissions draw up their fieldwork in the office rather than in the field.

The approaches used by the Royal Commissions vary according to the classes of building and the geographical extent of survey. In the IGMT archaeology unit's experience of assessing vernacular buildings in Wales, the orthodox methodology of identifying plan form and diagnostic features has proved its worth, but would hardly be suitable for recording specialised industrial buildings. In conjunction with the RCAHM Wales survey of the colliery industry, Brian Malaws has advocated the value of process recording, the close observation using notes and photographs of industrial processes, asking questions of the subject matter that would not otherwise be susceptible to archaeological interpretation (Malaws 1997). The IGMT archaeology unit found the technique similarly useful in the recording of a foundry in Walsall (Hayman 1997b). The pace of technological change is accelerating and the more modern a building is, the quicker the technology it was built to house is likely to have been superseded, while there is a decreasing likelihood of being able to identify diagnostic features once machinery has been removed. The value of process recording is best demonstrated where it is absent – at the Blists Hill Brick and Tile Works. Its buildings can certainly be understood in basic terms but the machinery used in clay preparation does not leave a signed print on the ground. It had been hoped that an archive of oral histories relating to the Brick and Tile works collected in 1980 would be a worthy substitute to process recording. In the event oral history was occasionally useful. Contradictory statements often rendered the evidence ambiguous, but its two fundamental limitations soon became apparent. Firstly, evidence confined to a late period of use may give a misleading impression of what happened earlier. Secondly, personal accounts only answer the questions that are asked, which proved not to be the kind of information relevant to archaeological interpretation.

Archaeologists have advocated the use of technologically advanced survey methods and the use of contexts, matrices, and pro forma sheets (Wood 1994; Ferris 1989). While these undoubtedly produce accurate and objective records it should be remembered that however rigorous and exacting is the accumulation of the data, the answers can only be as good as the questions. Contexts were tried briefly at Ironbridge but were not pursued. The cross referencing proved excessively time consuming for no obvious benefit and they tended to dictate thought processes to the extent that an engine house and a boiler setting are simply reduced to wall A and wall B. Techniques that inhibit explanation are not worth pursuing. The use of photogrammetry and EDM surveys with CAD software has already been alluded to in chapter 1. These solutions have been enthusiastically endorsed by the Lancaster University Archaeology Unit (Wood 1994) and it is easy to see their worth in a repairs project where accuracy is a special virtue. CAD was not used during the present project and it is not clear what benefit it would have offered in recording such complex and irregular structures. It would of course have provided impressively accurate information but it would still have been necessary to check closely the data on site to avoid the inevitable pitfall of remote techniques – the danger of interpreting the drawings rather than the site.

Constraints on archaeological work

The drawback of the approach to fieldwork outlined above is that archaeology can be constrained by access problems. If structures such as the charging houses at Blists Hill are to be recorded by hand then scaffolding is the only way of achieving it, which can only be justified as part of a repairs project (Fig 162). However the biggest factor affecting the scope and content of the archaeological work in the present project was the necessity of closely following the repairs. This affected not only what archaeological work was done on each site, but even which monuments were studied.

From a research perspective, the monuments discussed in this volume are not a totally random selection because most of them are scheduled, a status which *a priori* highlights their archaeological survival and potential. The three blast furnace sites are by far the best preserved of all the ironworking sites in the East Shropshire Coalfield and contain evidence for the major stages and advances in technology in the 18th and 19th centuries. Of the sites not studied at all, lime kilns were not seen as a national priority during the planning stage of the project (see Table 1). The Bower Yard lime kilns underwent limited vegetation clearance and the addition of safety features such as mesh grilles across the draw arches, but there was little scope for archaeological work beyond record photography (Fig 163). A second bank of lime kilns in the centre of Ironbridge also formed part of the property transfer, but no repair work was carried out at all.

Repairs to the structures above ground at the scheduled sites were comprehensive so there was a correspondingly full programme of archaeological recording, although there is plenty of evidence below ground awaiting investigation. The upper furnace has been so well preserved beneath its cover building since 1981 that few structural interventions were necessary. This is a happy state of affairs, the minor down-side being that less new archaeological information was gained about the furnace than from the other structures at the Upper Works. The principal constraint with regard to the listed buildings was the limited extent of recording, the Blists Hill Brick and Tile Works being the most obvious example.

The last constraint, as for most other projects of this scale, relates to overall project programming, management, and communications. For example,

Figure 162 The scaffold erected in front of the charging houses at Blists Hill blast furnaces.

Figure 163 Bower Yard lime kilns, on the south side of the River Severn. The structures were not repaired in the present project.

there were initial delays in the repair works and then much of it was undertaken simultaneously. Thus it was essential to ensure that there was the time and available archaeological staff to undertake the necessary tasks and that we were being kept informed of events.

Recommendations for future projects of this type

The time-scale of the Severn Gorge Repairs Project was nearly ten years; from its initial inception in the late 1980s, the establishment of the working group and the development of the briefs in 1990, the works from 1991–5, office work from 1995–7, and the production of a report for publication in 1998. During this time there have been major policy changes in British archaeology and the scope, nature, and methodology of a project of this type can easily become outdated. Some flexibility is therefore needed to amend the objectives, scope, and methodology in line with new policy guidelines, but this should be managed in such a way that it does not put additional financial demands on either the recipient or the grant-giving body.

As the project was conceived prior to PPG16, there were no preliminary evaluations. This was a serious drawback at the Upper Forge where a trial excavation and initial documentary research would have saved the extra money and administration that was devoted to redesigning the gabion wall at the back of the building. The concentration of archaeological structures and deposits underneath the Upper Forge led to the structural engineer becoming increasingly concerned about the stability of the building. This led to further ground investigations, in turn leading to further archaeological features and more concern regarding structural stability, becoming a vicious circle. The moral is clear: an archaeological evaluation would have benefitted the engineer and may well have reduced costs for CNT in their role as developer.

It is true that the project would probably have ended with much the same results whether or not a preliminary evaluation had been carried out. But the project would have been more efficient with an evaluation phase, as it would have led to improved selection and would have reduced the unexpected financial demands both on English Heritage and CNT. Any such evaluation would have informed the design of the repairs more effectively, although this was partially counteracted by the degree of communication before the designs were finalised and also during the course of the works. A small repairs project at Lloyds Engine House in Madeley Wood, undertaken in 1995–6, began with an evaluation to establish a research agenda and areas of archaeological sensitivity, followed by recording before and after the repairs were undertaken (Hayman 1997a). This methodology was effective enough and the project ran all the more smoothly for establishing a repairs policy and demarcating the roles of the contractors, including the archaeologists, from the beginning.

Regarding building recording, the degree of selection is important. If the present project had been proposed after the publication of PPG15, there would have been fuller recording of the listed buildings and this would have required increased funding. Clearly the best option is full recording of the subject structures, but if the proposed repairs or alterations are to be minimal or confined to small areas, this can be hard to justify. On the other hand, recording only the individual walls or areas to be repaired can have less meaning from a research perspective. A good compromise is to select building components, for example, the south engine house at Blists Hill blast furnaces, which can stand alone and have meaning. An initial assessment is likely to be beneficial if it can identify research priorities and target specific parts of a site where recording should be a priority (cf Molyneux 1994).

For multi-phase buildings and monuments requiring detailed recording, architects' drawings were not found to be appropriate as a base. Even minor dimensional inaccuracies which are irrelevant to architects and contractors alike, can lead to considerable problems in recording important, but often small details. In the present project, it was usually more cost effective to start an archaeological drawing from the beginning rather than constantly trying to amend an existing drawing. Architects' drawings were used in a subsequent project at the Broseley Pipeworks and, although quite detailed, they were time consuming to amend (IGMTAU 1997f; Hayman and Horton 1999a). With very complicated buildings, there are considerable advantages in the archaeologist undertaking the recording, simply to learn about the structure. But archaeologists need to be realistic. For buildings without complicated phasing, architects' drawings can be used as a base for archaeological recording, either for marking on areas of repair or taking photographs and cross-referencing them with the drawings. At a subsequent major recording project at the John Rose building, part of the Coalport Chinaworks, architects' drawings of the 20th-century buildings were simply amended, while the early 19th-century range was drawn by the archaeologists by hand, born of a need to prioritise (IGMTAU 1999). Surveys by photogrammetry of the dam wall at the Upper Works and by EDM of the Shropshire Canal were offered to the archaeology team and would be accepted every time, although the qualifications discussed above with regard to these techniques should still apply.

The preferred solution was found at Bedlam where the archaeologists were commissioned by the architects to produce survey drawings for all the consultants. However, it was the architect not the archaeologists who decided what was drawn, a situation rectified during the project when the more important archaeological elevations were added (eg Fig 72). Clearly, the production of survey drawings by one consultant which can be used by all the other consultants saves money, although this is not so obvious to all the parties if they are funded from different sources. As archaeologists generally require the most detailed and dimensionally accurate drawings, they are often the best candidates for undertaking such surveys.

The benefits of pooling building recording between consultants is also true of site investigations. It is often possible to design trenches and boreholes to serve several functions, for example, archaeological, structural, geotechnical, and hydrological. In some cases, although not in this project, contamination investigations can also be undertaken concurrently. Where major structures are known to exist, it may be possible to move the groundworks to avoid them. This was achieved at the Coalport Chinaworks, where the archaeological project manager succeeded in diverting a main drain away from the grinding mill block (Barker and Horton 1999). In cases where features may be present but their survival and potential are not known, the archaeologist should be able to specify where ground investigations are undertaken.

In the present project, the archaeology was funded separately from the repairs, which can make it more difficult for separate funding parties to see the benefits of this approach. This is a matter that needs to be considered carefully at the beginning of major projects of this type, as it may be possible to share out the costs in some way and gain overall. For example, the archaeologists could be grant aided to produce the survey drawings, whilst the main funding agency or developer employs the archaeologists as contractors to dig and record trenches in archaeologically sensitive areas. And most importantly, archaeologists should strive to achieve their own research objectives while accepting their curatorial responsibilities and working as closely and creatively as possible with other consultants.

Towards an agenda for future research

The Severn Gorge Repairs Project was principally concerned with the conservation of upstanding archaeological remains. The primary role of the archaeologist is to explain these remains. From this perspective, it would not have been possible to produce the body of work presented here in so short a space of time unless it was part of a larger repairs project. It is unrealistic to expect that such archaeological information could have been obtained for purely research purposes. Although this might have the negative effect of meaning that third parties determined most of what was investigated, thus influencing the research agendas, the general requirement for an archaeological strategy that best exploits the opportunities for furthering our knowledge of historic sites is one of the main conclusions of the project.

In Chapter 1 it was argued that the initial aim of the project was to provide definitive accounts of the case-study sites, in particular to explain their mode of operation over time in a manner that documentary sources are unable to do. This has been achieved to a satisfactory level for the time being but there is clearly scope for future enquiries. The other principal theme highlighted at the beginning was the general enquiry into technological change. Archaeology has been able to refine our understanding of technological change in the 18th and 19th centuries, undermining some previous assumptions.

For example, there has been a tendency to see the development of engine technology through the 18th century as a steady progression, beginning with the simple colliery pumping engines, which were then applied to water-recycling systems for the ironworks, followed by the beam blowing engines and winding engines. If the names of William Reynolds, John Wilkinson, and James Watt were added to the equation, then the East Shropshire Coalfield can be portrayed as a land of heroes where one technical triumph leads inexorably to the next. A similar model might also be applied to the development of the iron trade, beginning with Abraham Darby I and continuing with the Cranage brothers, Wilkinson's boring machines, all paving the way to Henry Cort and puddling.

Clearly progress cannot be understood in such simple linear terms, which the archaeological work has been able to demonstrate effectively. The general trend to greater technological complexity is obvious, but the example of water power at Bedlam, leading to one of the unexpected conclusions of the project, is a reminder that technological development was not axiomatic and progress not always immediately beneficial. Such evidence allows a fresh appraisal of technological change. Viewed from the perspective of 1750, the developments over the next fifty years look erratic and unpredictable. For example, the presence or influence of Watt, Heslop, Trevithick, Sadler, and Glazebrook presents a picture in which engine technology is more prominent than it was from an everyday perspective. The documentary evidence is biased towards the remarkable, while it was argued above in Chapter 9 that the archaeological evidence for the iron industry favours the unremarkable, sometimes to an extreme degree.

The historical evidence also offers the archaeologist a cautionary tale in the nature of technological change, especially to archaeologists of earlier periods who do not benefit from copious documentary evidence. It has become commonplace in recent years that archaeologists study specific events and not totalities. This was an important point to establish because one of the principles espoused in the processual archaeology of the 1970s was that archaeologists could speak of societies but never of individuals. Where individuals could be seen to have made a significant impact upon society, it was in a context where if a particular individual had not materialised, the environmental or social system would have created other individuals to take their place. In the case of Ironbridge, technological achievements in the 18th century were actually the work of a tiny minority – Abraham Darby I, Abraham Darby III, William Reynolds, and John Wilkinson – who exerted a disproportionate influence on events and dominate the retrospective understanding of the age. After Reynolds' death in 1803, the social system did not produce another individual to take his place. Instead, the impetus shifted to new areas and new ideas, with a result that change in Ironbridge was slower than it might otherwise have been.

In the future, it is hoped that the understanding of technological change can be taken further to a broader social context, but this would not necessarily require the kind of intensive site work described in this volume. The formulation of future research agendas was always seen as one of the eventual aims of the project. Of course future enquirers may take issue with what is recommended here, but it is nevertheless worthwhile identifying problems and the potential for new work, from the perspective of a completed project. What follows is not intended to be an all-encompassing brief for future work in Ironbridge, but concentrates on enlarging upon what has been learnt in the present project. There are, for example, potworks and brick and tile works on the south bank of the River Severn, which are worthy of a research agenda in their own right.

Chronological development and technological context have been established as the fundamental requirements of site-specific studies of industrial sites. The same requirement should be fulfilled for at least one other local site, namely the lime kilns at Bower Yard, a site which is not satisfactorily understood at present and whose context in the local landscape makes it especially worthy of attention (Fig 163). The Blists Hill Brick and Tile Works is the only site discussed in this volume whose buildings have not been fully recorded, which must be a priority for future enquiries at the site.

Further information on functional, technological, and chronological issues will be forthcoming if below-ground investigations are ever undertaken at any of the key sites. An important proviso is that many of them are scheduled, so excavations are likely to be small scale or rescue work. The latter is a possibility in the long-term given the unstable geology and steep slopes of the gorge. In each case, geophysical surveys should be attempted first, while the importance of excavated evidence from 18th- and 19th-century sites should be acknowledged.

At the Blists Hill Brick and Tile Works, excavation could be profitably undertaken of the kilns, ideally in association with their consolidation. The site of the earliest brickworks at Blists Hill is likely to be in the area of the northernmost kiln, so this is a significant area for future research. Too little is known of brickworks in the Ironbridge Gorge before 1850, mainly due to their ephemeral nature. It is known, for example, that there were brickworks at the Lloyds and at Coalport, but their exact locations are not known. A further historical evaluation will be required before the development of a research strategy here.

Research into the Hay Inclined Plane engine house has hitherto concentrated upon upstanding remains. The earliest phase of the site, however, is not fully understood and any future excavation should seek evidence of how the incline was powered before the engine was built. There are other features associated with the Shropshire Canal worthy of investigation. The most significant is the Coalport Warehouse at the terminus of the canal, where goods were transhipped from the canal to the river and where the technology for achieving this is not understood.

At the Coalbrookdale Upper Works, excavation may yield evidence of the early foundry on the east side of the upper furnace, principally a casting pit and the base of an air furnace. Similarly, investigation of the wheelpit and former blowing house might provide further information on these structures, as well as locating the blowing cylinders which had replaced the bellows by 1775. Mention has already been made of the possibility of finding the bases of lathes and spindles in the boring and turning mill. The success of excavations at the near-contemporary Bersham Ironworks is indicative of the potential at Coalbrookdale (Grenter 1992, 1993).

Excavations within the Upper Forge have thus far been minimal and, in future, could provide more information on the position of the shingling hammer and perhaps even the earlier slitting mill stands. Evidence of the engine bed and the base for the blowing cylinder may also allow an estimation of the engine specification. The south wing of the building has not thus far yielded a convincing explanation, but future excavation may provide evidence for the blacksmith's hearths or air furnaces which appear to be shown in Joseph Farington's sketch of Coalbrookdale made in 1789 (Fig 40).

No geophysical surveys or archaeological excavations have ever been undertaken at Bedlam, with the exception of the small excavation for a gas main which revealed the wooden waggonway (N W Jones 1987). In the 1970s the bases of two boilers are said to have been uncovered before subsequent backfilling. Their exposure would greatly enhance the interpretation of the site, but there are other potential features to be uncovered at Bedlam which would be more significant from a research perspective. The location of air furnaces would add significantly to our knowledge of the early period of the works, as would investigation east of furnace II where the other waterwheel and bellows room shown by Perry were situated (Fig 60). Excavation of the base of a blowing cylinder and regulator, together with the strong possibility of tunnels beneath at least furnace I to house the blast main, and of course the elusive furnace III on the east side of the site, would contribute much to our understanding of the later period of the works. Meanwhile, the coke ovens erected in 1789 and situated on the east side of the works would clearly provide archaeological evidence of national significance if substantial remains were found, although any archaeological evidence will survive at some depth below the current level of spoil.

The potential of evidence below ground could be extended to include ironworking sites where no substantial remains are now visible above ground. In many cases, such as the Coalbrookdale Lower Works and the Calcutts ironworks, redevelopment has significantly reduced the possibility of archaeological enquiry, but several other sites on the south side of the river have great potential: Barnetts Leasow, Benthall, Coneybury, and Willey.

A key theme for future work is to enlarge the scope of enquiry from the site to the landscape. The groundwork for this approach was established by the Nuffield Survey in the 1980s (Alfrey and Clark 1993), but there is still opportunity for studying the social and economic integration of the diverse activities of the Coalbrookdale Company and the Madeley Wood Company, as alluded to in Chapters 8 and 9.

The social context has rarely been a subject for primary archaeological analysis in the current project, except at the Upper Forge where evidence for a dwelling was found attached to the building, while documentary sources provide evidence for many more dwellings close by. More consideration needs to be given to the close relationship between works and dwellings in the 18th century, a characteristic of other industrial enterprises, since sites in the landscape are usually categorised in terms where domestic and industrial are mutually exclusive. The Upper Works contained dwellings in the 18th and 19th centuries, while the relationship between dwellings and furnaces at Bedlam would benefit from a closer examination. Indeed it may be found that the cottages north-east of the furnaces, cellars of which have survived, as well as the tenements of the former Bedlam Hall, were to all intents and purposes a part of the Bedlam coke yard, at least from the perspective of those who lived in them. Previous work on Ironbridge has understandably focused on the technological achievements which had a wide influence on industrialisation. But there are clearly different perspectives on the subject and given that the majority of its protagonists may not have considered themselves as players on such a grand stage, it is important that archaeology reflects the workaday world of its inhabitants.

The archaeology of Ironbridge before Abraham Darby I has had relatively few champions, despite a survey of its ancient woodlands and a historical study of its early industries (Wiggins 1986; Wanklyn 1982). It is probable that the landscape bears the imprint of this period to a greater degree than has hitherto been recognised. A recent survey of woodlands found much evidence of woodland exploitation, principally in the form of charcoal platforms, some of which may well be earlier than the 18th century and related to the period when the Coalbrookdale upper furnace and the Upper Forge were charcoal fuelled (IGMTAU 1996d). Large areas of woodland in Benthall and the Lloyds remain to be investigated for evidence of early mining. Of particular significance is the potential for finding early wooden railways, the historical records for which have been studied in detail (Lewis 1970). Evidence

Figure 164 Rose Cottages, Coalbrookdale, consisted of four dwellings by 1642 but may have been adapted from an earlier agricultural building.

for such activity in the Lloyds is directly relevant to Bedlam as the source of its raw materials.

The area in Coalbrookdale between and including the Upper Forge and Rose Cottages has been argued as a site of national archaeological importance (see Appendix 4). It is of particular significance for its potential evidence of early industrial activity in Coalbrookdale. The site of the old Upper Forge is now mostly beneath the road, and consequently retains some archaeological potential (Figs 38 and 39). The former steel house, built in the early-17th century and converted to a malthouse by 1734, is now a picnic site, suggesting that archaeological deposits remain undisturbed. Rose Cottages consisted of four dwellings by 1642, but it has been suggested that the dwellings may have been created by inserting upper floors and partitions into an earlier farm building (Fig 164) (Mercer 1979, 196). Even so, the cottages are the oldest surviving buildings connected with the Coalbrookdale iron industry and were perhaps associated with Basil Brooke's manufacture of steel under his own patent. Brooke's innovation is a reminder that the Industrial Revolution did not begin with Abraham Darby I, or with any other single event. If archaeology can effectively ensure that the potential of such areas in the Ironbridge Gorge is recognised, protected, and at some future date investigated, then it will have fulfilled much of its intentions to integrate curatorship with research into the archaeology of industry.

12 Glossary

Air furnace Also known as a reverberatory furnace. In an air furnace the metal and the fuel are placed in separate chambers. The heat is drawn across the metal by the draught of a tall chimney. An air furnace did not require blowing with bellows.

Arris In a building, the edge formed by the meeting of two planes.

Axle-tree The axle or shaft of a waterwheel on which cams are fixed in order to depress bellows or raise a hammer.

Bat machine In a tile works, a type of pug mill (qv) where clay was extruded in a continuous strip and cut into bats on a wire cutting table. Bats were slightly larger than finished tiles and were sent to tile presses for finishing.

Bloom A lump of iron removed from the finery (qv) for shingling.

Boring mill A mill in which the internal diameter of an engine cylinder was bored to the correct specification. Boring could be achieved vertically or horizontally, depending on the type of machine used. Using a vertical mechanism, a cylinder was attached to a sliding frame which was lifted via pulleys and then lowered on to a rotating drill bar. Using the horizontal mechanism, the object was attached to a rotating shaft. The drill rod was fixed to a wheeled carriage, attached to a rack via cogs. A weighted handle moved the rack forward so that the carriage and drill rod went forward into the cylinder. *See also* turning mill.

Boshes That part of a blast furnace which tapers outwards from the well to join the stack. It is the widest part of the furnace.

Brass making Brass was made from zinc oxide heated in crucibles in reducing conditions with copper and charcoal. After the brass had been formed it could be beaten into hollow ware or sheets, or cast into moulds.

High breastshot waterwheel A waterwheel which turns by means of the weight of water in its buckets, but where the buckets are filled from a point below the top but above the level of the axle.

Bridge house *See* charging house.

Calcining In the iron industry, the roasting of ironstone to remove impurities before smelting.

Chafery In the production of wrought iron, a charcoal-fired hearth used to reheat the iron ready for drawing into bars under a hammer.

Charging house The building above a blast furnace from where raw materials were prepared and tipped into the tunnel head (qv) of the furnace.

Cinders Slag from the blast furnace.

Condenser In a steam engine, a cylinder into which steam is drawn to be condensed. The condensing cylinder is housed below the power cylinder in a condenser pit.

Copper smelting Copper ore was smelted in a reverberatory furnace after it had been crushed. It was then run into moulds for later use.

Core A shape made in sand or loam to form the hollow part of a casting.

Core-drying oven A brick-built chamber for drying cores (qv), consisting of a double skin of bricks with a cavity between them. Larger cores were lifted from the ovens to the casting pits by cranes.

Cornish boiler A horizontal boiler with one fire-tube, used for raising steam at high pressure.

Crucible *See* well.

Cupola A tall furnace charged from the top, with tuyères and a tap hole at the bottom, used intermittently for melting pig and scrap iron.

Dam The firebrick wall at the front of a blast furnace, adjacent to the tap hole.

Damper A plate for controlling the draught, volume of exhaust gas, or rate of combustion in a kiln.

Downdraught kiln A variety of intermittent kiln with one or more holes in the floor communicating with the main flue or chimney stack. Heat is generated in fireboxes around the kiln chamber and is deflected down from the chamber vault to the flues. The downdraught allows even distribution of heat. The temperature in such kilns is easier to control than in an updraught kiln or continuous kiln.

Finery A hearth fired with charcoal, coal, or coke in which iron is decarburised by exposing it to a blast of air.

Firebrick A refractory brick made from fireclay with 28% to 43% alumina.

Fireclay An alumino-silicate material, the most widely-used clay for refractory bricks.

Flask work A flask is usually called a moulding box, which is a box of metal or wood with an open top and bottom. Used for sand moulds (qv).

Forehearth The lower front of a blast furnace where the molten iron and slag were tapped.

Frog The hollow recess on the top of a brick designed to retain the mortar used in brickwork and thus strengthening the bonding of the bricks.

Hand-moulded bricks Bricks shaped by hand before firing. Until the late-19th century, most building bricks and almost all firebricks were hand made. More recently hand-moulded bricks have tended to be special products.

Haystack boiler A boiler in the shape of a traditional haystack, used for producing steam at atmospheric pressure.

Hearth Strictly speaking the bottom of a blast furnace, but often used to refer to the well or crucible as well.

Intermittent kiln A kiln consisting of a single chamber which is allowed to cool completely after firing, as opposed to a continuous kiln which is multi-chamber and allows at least one chamber to be constantly fired. Intermittent kilns are less fuel efficient than continuous kilns, which were introduced from the mid-19th century, but are easier to control, more flexible, and better suited to small-scale production.

Kibble To crush, hence **kibbling mill**, also known as a **grist mill**, where animal feed is milled.

Lancashire boiler A mid-19th century development of the Cornish boiler (qv), having two firetubes instead of one.

Launder A raised aqueduct, usually of timber, used to convey water to a waterwheel.

Loom work Also known as loam moulding. The mould is made of a mixture of sand, clay, straw, and horse manure or some other binder. It was the most common method of moulding in a foundry before the introduction of sand moulding (qv). Hence loom house or loam house.

Overshot waterwheel A wheel which is fed with water at the top and turns by virtue of the weight of water in the buckets.

Pan mill A term for an edge runner mill used to crush raw materials, especially clay.

Penstock A small reservoir with sluices, allowing the control of water to a waterwheel.

Pitchback waterwheel A kind of overshot wheel (qv) whereby, because of the angle of the buckets, the wheel turns in the opposite direction to the flow of water along the launder.

Pit wheel In a mill, the gear attached to the waterwheel shaft which transmits power to the machinery.

Pug mill A machine used for mixing clay or other material with water, usually consisting of a central shaft to which blades are fitted. Pugging produces homogeneous clay and adds to the strength of the fired product.

Putlog hole A hole for inserting a horizontal scaffold beam.

Refractory A heat-resistant material which is difficult to fuse and which is therefore important in the construction of kilns. Hence refractory bricks (or firebricks) and refractory tiles.

Sand moulding A method a preparing a mould by impressing a pattern into sand, then removing it to allow the molten iron to be poured in. The important feature of sand moulding is that the pattern can be reused. For large items, a pattern was impressed into a bed of sand, the mould being filled either from ladles or channels cut in the sand. For small items, boxes in two parts known as flasks were used. The bottom half of the flask was filled with sand and the pattern impressed into it. Then the top flask was laid over it and filled with sand before being lifted away to allow removal of the pattern. The mould was then ready for pouring. *See* flask work.

Semi-plastic process A method of making bricks and tiles by pressing a semi-dry or damp material in a mould. Especially appropriate for raw materials with insufficient plasticity which are passed through a mixing machine. Also known as the semi-dry process.

Shingling In a forge for refining pig to wrought iron, the hammering of a bloom to expel slag.

Spur gear In a mill, a large gear wheel by which means the shafts of the millstones are driven.

Stack That part of a blast furnace between the top of the boshes and the throat, or charging level.

Tunnel head The short stack at the top of a blast furnace to carry fumes above the charging level.

The tunnel head had apertures or filling holes to facilitate charging.

Turning mill A mill similar to a boring mill in which the exterior of an engine cylinder was machined and polished to a smooth finish. *See also* boring mill.

Tuyère The end of a blast pipe conveying air to a furnace.

Updraught kiln A form of intermittent kiln where heat enters the bottom of the chamber and rises up through openings in the roof. Cheaper and easier to construct than downdraught kilns, which require underground flues. The heat distribution in updraught kilns was nevertheless difficult to control.

Wagon boiler A low-pressure steam boiler, commonly used in the late-18th century for Boulton and Watt engines, whose name derives from its visual similarity to a covered wagon.

Well The lowest part of a blast furnace, between the hearth and the boshes.

White bricks A variety of brick with a white or yellow appearance often made from fireclay.

Bibliography

Manuscript sources

Birmingham University Library (BUL)

Copy of Journals and Notebooks of Joshua Gilpin, 1790–1801, Vol XXXIII (Original in the Division of Public Records, Pennsylvania Historical and Museum Commission)

Boulton & Watt Collection, Birmingham Central Library (B&W)

Catalogue of Old Engines
Letter book 5
Letter book 9
2R William Reynolds to James Watt, 19/5/1780
3/10/19 William Reynolds to B & W, 18/1/1796
3/10/20 William Reynolds to B & W, 26/8/1796
3/10/25 William Reynolds to B & W, 2/8/1798
4/3/6 Shropshire Canal Committee to Boulton & Watt, 18/7/1788
4/3/7 Shropshire Canal Committee to Boulton & Watt, 20/8/1788
4/3/8 Shropshire Canal Committee to Boulton & Watt, 1788
4/14/26 William Reynolds to Matthew Boulton, 17/12/1795
MII/5/10 List of Ironworks in Britain, 1794
MII/15/2 List of Furnaces in Great Britain, 1806
MII/17/1 Blast Furnaces in Britain, 1823, 1830
MII/17/2 Iron Furnaces in Great Britain & Ireland, 1825
Portfolio 547 Drawings for Resolution pumping engine at Coalbrookdale, 1781
Portfolio 238 Drawings for a forge engine at Horsehay Ironworks, 1784
Portfolio 703 Drawings of a blowing engine for Wright & Jesson
Portfolio 681 Drawings of a blowing engine for Wright & Jesson
Steamship Box Plan of proposed Shropshire Canal, by G Young, 1788

Dundonald Collection, Scottish Record Office (Scots RO)

GD233/109/H/1 Lord Dundonald to William Reynolds, 6/11/1787
GD233/109/H/4 Lord Dundonald to William Reynolds, 26/2/1789
GD233/109/H/21 Lord Dundonald to William Reynolds, 10/11/1799

Ironbridge Gorge Museum Trust (IGMT)

CBD 59.82.3 Coalbrookdale Company Minute Book, 1789–97
CBD 59.82.4 Coalbrookdale Company Settling Journal, 1798–1808
CBD 59.82.21 Coalbrookdale Company profit and loss accounts, 1805–52
CBD 59.130.1 View of Coalbrookdale from Paradise Fields, by Joseph Farington, pencil sketch, 1789
1970.66.1 Lease of farms in Madeley and Much Wenlock, 1840
1970.66.3 Alterations to Lease of Madeley Wood works and Demise of fireclay, 1846
1970.66.4 Lease of Madeley Wood works, 1840
1970.66.5 Plan of Madeley Wood works, nd
1986.5331.4 R.A. Mott, *Revolution in Iron*, Vol 1, unpublished ms
1986.6999 Plan accompanying lease of Coalbrookdale Ironworks, 1827
1986.7002 Plan of Coalbrookdale Works, 1912
1992.11941 Letter Book of Richard Ford and Thomas Goldney, 1732–7
1994.527 Drawing of blowing engine at New Bedlam, 1800, by G Potts
T42 Transcript of interview with Fred Lloyd, 1981 (Oral History Collection)
T46 Transcript of interview with J Jarvis, 1982 (Oral History Collection)

Public Record Office (PRO)

C12/1693/17 Chancery proceedings, Rathbone & Co versus John Powis Stanley, 1786
Rail 869/1 Shropshire Canal Company Minute Book (Copy on microfilm held by IGMT)

Science Museum Library (SML)

Goodrich E2 Goodrich Collection, 'Journey to the North in 1803'

Shropshire Records and Research Centre (SRRC)

245/1 Sale of Madeley Manor to Robert Brooke, 1544
245/14 Diary of Thomas Boycott, 1801–6
245/140 Account of Horsehay Ironworks *c* 1876, by W Norris

271/1 Madeley Field and Madeley Wood Furnace Reckoning, 1790–7
1681/132/24 Sale of 1/13 share in Madeley Wood Furnace Company to Joseph Biddle, 1760
1681/138/4 Lease of Coalbrookdale Ironworks, 1794
1681/138/7 Lease of Coalbrookdale Ironworks, 1805
1681/138/8 Lease of Coalbrookdale Ironworks, 1838
1681/138/10 Conveyance of Coalbrookdale Works to Coalbrookdale Company, 1845
1681/139/1 Lease of Ironworks in Coalbrookdale, 1714
1681/139/7 Lease of Coalbrookdale Ironworks, 1774
1681/139/8 Draft article of agreement, William Elwell and Abraham Darby, 1776
1681/139/9 Lease of ironworks in Madeley, 1781
1681/143/20 Lease of Madeley Wood works, 1840 (abstract dated 1843)
1681/153/11 Lease of ironworks in Coalbrookdale, 1843
1681/179/1 'Plan of the part of Coalbrookdale bounded by the lands of John Powis Stanley', by G Young, 1786
1681/181/20 Plan showing lands belonging to Hay Farm, 1803–4
1681/181/21 Statement of land use on lands belonging to Hay Farm, 1803–4
1681/183/8 Partners in Lightmoor Coalworks, 1758
1681/183/10 Partners in Lightmoor Furnace, 1758
1681/183/14 Partners in Madeley Wood Furnace, 1760
1681/184/1 Lease of Limeworks at Gleedon Hill, Much Wenlock, 1824
1681/184/2 Lease of Madeley Wood works, 1858
1681/184/6 Lease of Madeley Wood works, 1889
1681/184/7 Lease of Limeworks in Madeley, 1836
1681/185/1 Articles of Agreement between LNWR and J Reynolds
1681/185/1 Proposed London and North Western Railway, 1857
1781/6/28 Letter from Gilbert Gilpin to William Wilkinson, 1804
1987/20/1 Lease of Upper Furnace Pool, Coalbrookdale, 1866
1987/35/2 Lease of Coalbrookdale Ironworks, 1734
1987/58/3 Profits of the Coalbrookdale Company and Memorandum of conduct, 1798
1987/58/13 Agreement between Abraham Darby I and John Thomas, 1707
1987/58/21 Accounts of Profit of the Dale works, 1739–45
1987/60/1 'List of buildings etc. at Madeley Wood'
1987/60/2 'List of buildings belonging to Madeley Wood Co'
1987/60/3 Madeley Wood Furnace Co Stockholders' accounts, 1776
1987/60/4 Memo of Agreement between William Elwell and Abraham Darby, 1776
1987/60/5 Madeley Wood purchase papers, 1776
1987/64/6 A Description of Coalbrook Dale Iron Works and the Environs (*c* 1801 and transcribed in Trinder 1979)
6001/300 Inventory of Coalbrookdale Works, July 1718
6001/328 Sales Book of Abraham Darby I, 1708–9
6001/331 Coalbrookdale Company Cash Book, 1732–49
6001/333 Horsehay Waste Book, 1767–1774
6001/334 Horsehay Day Book 1794–8
6001/2366 Plan of Calcutts Ironworks *c* 1800, included with Broseley Hall Estate Survey
6001/3190 Letter book of Richard Ford, 1732–6
6008/35 Plan of proposed Shropshire Union Railway, 1846

Staffordshire Record Office (Staffs RO)

D876/155 William Reynolds' Executors Accounts, 1803–10
D876/ADD/3/1 Madeley Wood Annual Settlement, 1826–51
D876/ADD/3/2 Madeley Wood Annual Settlement, 1852–75
D876/ADD/3/3 Madeley Wood Annual Settlement, 1877–1913
D876/ADD/3/4 Madeley Wood Company Sales (late-19th century)

Wedgwood Collection, University of Keele Library

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

Printed Sources

Alfrey, J & Clark, C, 1993 *The Landscape of Industry: Patterns of Change in the Ironbridge Gorge*. London: Routledge
Ashton, T S, 1951 *Iron and Steel in the Industrial Revolution*, 2nd edition. Manchester: Manchester University Press
Atkinson, M, & Baber, C, 1987 *The Growth and Decline of the South Wales Iron Industry, 1760–1880*. Cardiff: University of Wales Press
Auden, J E, 1912 *Shropshire*. London: Methuen
Ayris, I, Nolan, J, & Durkin, A, 1998 The archaeological excavation of wooden waggonway remains at Lambton D Pit, Sunderland, *Industrial Archaeology Review*, **20**, 5–22
Bagshaw, S, 1851 *History, Gazetteer and Directory of Shropshire*. Sheffield: the author

Barker, D & Horton, W, The Development of the Coalport Chinawork: analysis of ceramic finds, *Post-Medieval Archaeology*, **33**, 3–93

Bashforth, G R, 1948 *The Manufacture of Iron and Steel*. London: Chapman & Hall

Baugh, G C (ed), 1985 *The Victoria History of the Counties of England: A History of Shropshire*, Vol XI. London: University of London Institute of Historical Research

Betjeman, J & Piper, J, 1951 *Shropshire: A Shell Guide*. London: Faber & Faber

Birch, A, 1952 Midlands Iron Industry during the Napoleonic Wars, *Edgar Allen News*, **31**, 231–3

British Parliamentary Papers, 1842 *On the Employment of Children and Young Persons in the Coal and Iron Mines of South Staffordshire and Shropshire, and in the Iron Smelting Works of those Districts*, Children's Employment Commission, Vol 16 (Appendices and Evidence)

Broadbridge, S R, 1971 Joseph Banks and the West Midlands Iron Industry, *Journal of the Staffordshire Industrial Archaeology Society*, **2**, 1–20

Brown, I, 1969 Some industries in the vicinity of the Blists Hill Museum site, *Shropshire Newsletter*, **37**, 39–42

Brown, I, 1996, The Pithead Baths at Kemberton Colliery, Shropshire, *Bulletin of the Peak District Mines Historical Society*, **13**(1), 38–41

Brown, I, 1980 *Blists Hill Brick and Tile Works*. Unpublished report in IGMT Library

Butler, D & Duckworth, S, 1993 Development of an Industrial Heritage Attraction: The Dunaskin Experience, *Built Environment*, **19**(2), 116–36

Campbell, R H, 1961 *Carron Company*. Edinburgh: Oliver & Boyd

Chaloner, W H, 1949 'Smelting Iron Ore with Coke and Casting Naval Cannon in the Year 1775': Marchant de la Houlière's Report on English Methods, Part 2, *Edgar Allen News*, **27**, 213–15

Cherry, J, 1982, Duddon Bridge Iron Furnace, *Post-Medieval Archaeology*, **16**, 226–8

Clark, C, 1993 *English Heritage Book of Ironbridge Gorge*. London: Batsford

Clark, D K, 1890 *The Steam Engine: A Treatise on Steam Engines and Boilers*, Vol 3. London: Blackie & Son

Cleere, H & Crossley, D, 1995 *The Iron Industry of the Weald*, 2nd edition. Cardiff: Merton Priory Press

Cossons, N (ed), 1972 *Rees's Manufacturing Industry, 1819–20*, Vol 1. Newton Abbot: David & Charles

Cox, N, 1990 Imagination and Innovation of an Industrial Pioneer: the First Abraham Darby, *Industrial Archaeology Review*, **12**(2), 127–44

Cranstone, D (ed), 1985 *The Moira Furnace: a Napoleonic Blast Furnace in Leicestershire*. Coalville: NW Leicestershire District Council

Crossley, D, 1975, Cannon-Manufacture at Pippingford, Sussex: The Excavation of Two Iron Furnaces of *c* 1717, *Post-Medieval Archaeology*, **9**, 1–37

Crossley, D, 1990 *Post-Medieval Archaeology in Britain*. Leicester: Leicester University Press

Crossley, D, 1995 The supply of charcoal to the blast furnace in Britain, in G Magnusson (ed), 367–74

Daniels, S, 1992 Loutherbourg's Chemical Theatre: Coalbrookdale by Night, in J Barrell (ed), *Painting and the Politics of Culture: New Essays on British Art, 1700–1850*, 195–230. Oxford: Oxford University Press

Dawes, N M, 1979 *A History of Brick and Tile Production in the Coalbrookdale Coalfield*. Unpublished report in IGMT Library

Dickinson, H W, 1923 An Eighteenth-Century Engineer's Sketch Book, *Transactions of the Newcomen Society*, **2** (for 1921–2), 132–40

Dickinson, H W & Jenkins, R, 1927 *James Watt and the Steam Engine*. (Facsimile edition 1981, Ashbourne: Moorland Publishing)

Dinn, J, 1988, Dyfi Furnace Excavations 1982–7, *Post-Medieval Archaeology*, **22**, 111–42

Dobson, E, 1893 *A Rudimentary Treatise on the Manufacture of Bricks and Tiles*. London: Crosby Lockwood

Doughty, M W, 1979 Samborne Palmer's Diary: Technological Innovation by a Somerset coalmine owner, *Industrial Archaeology Review*, **3**(1), 17–28

Douglas, G, & Oglethorpe, M, 1993 *Brick, Tile and Fireclay Industries in Scotland*. Edinburgh: RCAHM Scotland

Egerton, J, 1979 *English Watercolour Painting*. London: Phaidon

Elsas, M (ed), 1960 *Iron in the Making: Dowlais Iron Company Letters 1762–1860*. Cardiff: Glamorgan County Council/GKN

Evans, C (ed), 1990 *The Letterbook of Richard Crawshay 1788–1797*. Cardiff: South Wales Record Society

Evans, C, 1993 *'The Labyrinth of Flames': Work and social conflict in early industrial Merthyr Tydfil*. Cardiff: University of Wales Press

Farey, J, 1827 *A Treatise on the Steam Engine, Historical, Practical and Descriptive*. London: Longman, Rees, Orme, Brown & Green

Ferris, I, 1989 The Archaeological Investigation of Standing Buildings, *Vernacular Architecture*, **20**, 12–17

Fletcher, H A, 1879 The Heslop Engine, A Chapter in the History of the Steam Engine, *Proceedings of the Institution of Mechanical Engineers*, 85–95

Flinn, M W, 1961 The Travel Diaries of Swedish Engineers of the Eighteenth Century as Sources of Technological History, *Transactions of the Newcomen Society*, **31** (for 1957–9), 95–109

Flinn, M W (ed), 1973 *Svedenstierna's Tour of Great Britain 1802–3: The Travel Diary of an Industrial Spy*. Newton Abbot: David & Charles

Gale, W K V, 1971 *The Iron and Steel Industry: A Dictionary of Terms*. Newton Abbot: David & Charles

Gloag, J, & Bridgwater, D, 1948 *A History of Cast Iron in Architecture*. London: Allen & Unwin

Gould, S, 1994 Coke Ovens at Vobster Breach Colliery, *Industrial Archaeology Review*, **17**(1), 79–85

Graves, A, 1901 *A Dictionary of Artists, from 1760 to 1893*. (Facsimile edition 1969, Bath: Kingsmead Reprints)

Grenter, S, 1992 Bersham Ironworks Excavations 1987–1990: Interim Report, *Industrial Archaeology Review*, **14**(2), 177–92

Grenter, S, 1993 A Wooden Waggonway Complex at Bersham Ironworks, Wrexham, *Industrial Archaeology Review*, **15**(2), 195–207

Griffiths, S, 1873 *Griffiths' Guide to the Iron Trade*. London: the author (facsimile edition 1967, Newton Abbot: David & Charles)

Hadfield, C, 1960 *The Canals of South Wales and the Borders*. Cardiff: University of Wales Press

Hadfield, C, 1966 *The Canals of the West Midlands*. Newton Abbot: David & Charles

Hadfield, C, 1967 *The Canals of South West England*. Newton Abbot: David & Charles

Hague, D, 1986 The Artist as Witness, *Industrial Archaeology Review*, **8**(2), 127–46

Hall, J W, 1927 Joshua Field's Diary of a Tour in 1821 Through the Midlands, *Transactions of the Newcomen Society*, **6**, 1–41

Hammond, M, 1977 Brick Kilns: an illustrated survey, *Industrial Archaeology Review*, **1**(2), 171–92

Hammond, M, 1979 *The Blists Hill Brickworks Project*. Unpublished report in IGMT library

Hancock, H & Wilkinson, N, 1961 Joshua Gilpin: An American Manufacturer in England and Wales, 1795–1801, *Transactions of the Newcomen Society*, **32** (for 1959–60), 15–28

Hanks, A D, 1988 *The 1988 Institute Training Excavation: The Upper Forge, Coalbrookdale*. Unpublished report, Ironbridge Institute

Harris, J R, 1988 *The British Iron Industry 1700–1850*. London: Macmillan

Hay, G D & Stell, G P, 1984 *Bonawe Iron Furnace*. Edinburgh: HMSO

Hay, GD & Stell, GP, 1986 *Monuments of Industry: An Illustrated Historical Record*. Edinburgh: HMSO

Hayman, R, 1987 Artists' Impressions of Aberdulais Mill, *Industrial Archaeology Review*, **9**(2), 155–66

Hayman, R, 1996 Culverts at Cyfarthfa, *Industrial Archaeology News*, **98**, 2–3

Hayman, R, 1997a Lloyds Engine House, Ironbridge, *Transactions of the Shropshire Archaeological and Historical Society*, **72**, 38–51

Hayman, R, 1997b The Archaeologist as Witness: Matthew Harvey's Glebeland Works, Walsall, *Industrial Archaeology Review*, **19**, 61–74

Hayman, R & Horton, W, 1999a Broseley Pipeworks, *Industrial Archaeology Review*, **21**(1), 25–39

Hayman, R & Horton, W, 1999b *Ironbridge: History & Guide*. Stroud: Tempus Publishing

Higgins, D A, 1983 Engine House at the Tuckies, Jackfield, *West Midlands Archaeology*, **26**, 98–9

Higgins, D A, 1988a Bedlam Furnaces Charging Ramp, Ironbridge, in M Trueman (ed), 1988, 147–60

Higgins, D A, 1988b Madeley Wood Company Brickworks, in M Trueman (ed), 1988, 55–6

Höltgen, K J, 1982 Old Furnace Enigma Solved, *Ironbridge Quarterly* **1982**(3), 5

Hulme, E W, 1930 Statistical History of the Iron Trade of England and Wales, 1717–1750, *Transactions of the Newcomen Society*, **9**, 12–35

Hurst, D G, 1968 Apley Forges, *Post-Medieval Archaeology*, **2**, 193

Hyde, C, 1973 The Iron Industry of the West Midlands in 1754: Observations from the travel account of Charles Wood, *West Midlands Studies*, **6**, 39–40

Hyde, C, 1977 *Technological Change in the British Iron Industry, 1700–1870*, 2nd edition. Princeton: Princeton University Press

IGMTAU, 1988a *The Upper Works, Coalbrookdale: A Rescue Excavation*. Unpublished report, Ironbridge Archaeological Series, **13**

IGMTAU, 1988b *Lightmoor Brickworks: An Historical Evaluation*. Unpublished report, Ironbridge Archaeological Series, **23**

IGMTAU, 1993a *The Blists Hill Canal, Hay Inclined Plane and Coalport Canal: A Site Investigation*. Unpublished report, Severn Gorge Repairs Project Report No 3

IGMTAU, 1993b *The Blists Hill Blast Furnaces: A Site Investigation*. Unpublished report, Severn Gorge Repairs Project Report No 4

IGMTAU, 1993c *The Hay Inclined Plane, Blists Hill*. Unpublished report, Ironbridge Archaeology Series, **32**

IGMTAU, 1994 *The Bedlam Furnaces, Ironbridge*. Unpublished report, Severn Gorge Repairs Project Report No 6

IGMTAU, 1995 *The Cyfarthfa Ironworks, Merthyr Tydfil: An Archaeological Evaluation*. Unpublished report, Ironbridge Archaeological Series, **40**

IGMTAU, 1996a *Upper Furnace Pool Dam, Coalbrookdale*. Unpublished report, Ironbridge Archaeological Series, **62**

IGMTAU, 1996b *The Upper Forge, Coalbrookdale*. Unpublished report, Severn Gorge Repairs Project Report No 13

IGMTAU, 1996c *Bedlam Furnaces, Ironbridge*. Unpublished report, Severn Gorge Repairs Project Report No 12

IGMTAU, 1996d *Severn Gorge Countryside Trust Land Holdings: An Archaeological Assessment*.

Unpublished report, Ironbridge Archaeological Series, **61**

IGMTAU, 1997a *The Darby Furnace and Associated Structures*. Unpublished report, Severn Gorge Repairs Project Report No 15

IGMTAU, 1997b *The Dance School Wall, Coalbrookdale*. Unpublished report, Ironbridge Archaeological Series, **66**

IGMTAU, 1997c *Blists Hill Blast Furnaces*. Unpublished report, Severn Gorge Repairs Project Report No 16

IGMTAU, 1997d *Blists Hill Brick and Tile Works*. Unpublished report, Severn Gorge Repairs Project Report No 17

IGMTAU, 1997e *The Hay Inclined Plane*. Unpublished report, Severn Gorge Repairs Project Report No 14

IGMTAU, 1997f *Broseley Pipeworks*. Unpublished report, Ironbridge Archaeological Series, **72**

IGMTAU, 1998a *The Upper Furnace Pool Dam, Coalbrookdale*. Unpublished report, Ironbridge Archaeological Series, **76**

IGMTAU, 1998b *Blists Hill General Stores: Site Excavation*. Unpublished report, Ironbridge Archaeological Series, **77**

IGMTAU, 1999 *The John Rose Building, Coalport*. Unpublished report, Ironbridge Archaeological Series, **82**

Ince, L, 1991 *The Knight Family and the British Iron Industry*. Birmingham: Ferric Publications

Ince, L, 1992 The Boulton and Watt Engine and the British Iron Industry, *Wilkinson Studies*, **2**, 81–9

Ince, L, 1993 *The South Wales Iron Industry, 1750–1885*. Birmingham: Ferric Publications

Jones, E, 1987 *A History of GKN. Part One: Innovation and Enterprise 1759–1918*. London: Macmillan

Jones, N W, 1987 A Wooden Waggonway at Bedlam Furnace, Ironbridge, *Post-Medieval Archaeology*, **21**, 259–62

King, P W, 1996 Early Statistics for the iron industry: a vindication, *Historical Metallurgy*, **30**(1), 23–46

Klingender, F, 1972 *Art and the Industrial Revolution*, 2nd edition. London: Granada

Knight, J, 1992 *Blaenavon Ironworks*. Cardiff: Cadw

Kohn, F, 1869 *Iron and Steel Manufacture*. London: William Mackenzie

Lee, C E, & Gilbert, K R (eds), 1971 *Railways in England by C von Oeynhausen and H von Dechen* (translated by E A Forward for the Newcomen Society). Cambridge: W Heffer

Leese, J, 1912 Old English Power Plants, *Power*, **36**(4), 108–9

Lewis, M J T, 1970 *Early Wooden Railways*. London: Routledge & Kegan Paul

Lindsay, J, 1968 *The Canals of Scotland*. Newton Abbot: David & Charles

Loutherbourg, P J de, 1805 *The Romantic and Picturesque Scenery of England and Wales*. London: Robert Bowyer

Magnusson, G (ed), 1995 *The Importance of Ironmaking: Technical Innovation and Social Change*. Stockholm: Jernkontorets Bergshistoriska Utskott

Malam, J, 1982 *Archaeological Recording at the Old Furnace, 1981–1982*. Unpublished report, Ironbridge Gorge Museum Trust

Malaws, B, 1997 Process Recording at Industrial Sites, *Industrial Archaeology Review*, **19**, 75–98

Matkin, R, 1986 *John Rennie's Diary of a Journey Through Northern England, 1784*. East Kent Maritime Trust Historical Study No 2

McCutcheon, W A, 1965 *The Canals of Northern Ireland*. Dawlish: David & Charles

Meeson, R, 1989 In Defence of Selective Recording, *Vernacular Architecture*, **20**, 18–19

Mercer, E, 1979 *English Vernacular Houses*, 2nd edition. London: HMSO

Milln, J, 1995 Power development at the northern end of Quarry Bank Mill, Styal, Cheshire, *Industrial Archaeology Review*, **18**(1), 8–28.

Mitchell, C, 1934 *Building Construction and Drawing*, Vol 1. London: Batsford

Molyneux, N A D, 1994 Targeted Recording for Limited Alterations: Secular Buildings, in J Wood (ed), 155–62

Moore, P, 1988 *The Industrial Heritage of Hampshire and the Isle of Wight*. Chichester: Phillimore

Morgan, K (ed), 1992 *An American Quaker in the British Isles: the travel journals of Jabez Maud Fisher, 1775–1779*. Oxford: OUP

Mott, R A, 1958a The Shropshire Iron Industry, *Transactions of the Shropshire Archaeological Society*, **56**, 68–81

Mott, R A, 1958b Coalbrookdale: The Early Years, *Transactions of the Shropshire Archaeological Society*, **56**, 82–93

Mott, R A, 1961a Abraham Darby (I and II) and the Coal Iron Industry, *Transactions of the Newcomen Society*, **31** (for 1957–9), 49–93

Mott, R A, 1961b The Coalbrookdale Group Horsehay Works: Part I, *Transactions of the Newcomen Society*, **31** (for 1957–9), 43–56

Mott, R A, 1961c The Coalbrookdale Group Horsehay Works: Part II, *Transactions of the Newcomen Society*, **32** (for 1959–60), 271–88

Mott, R A, 1983 *Henry Cort: The great Finer*. London: The Metals Society

Muter, W G, 1979 *The Buildings of an Industrial Community: Coalbrookdale and Ironbridge*. Chichester: Phillimore

Mutton, N, 1970 The Forges at Eardington and Hampton Loade, *Transactions of the Shropshire Archaeological Society*, **58** (for 1965–8), 235–43

Newman, J, 1995 *The Buildings of Wales: Glamorgan*. London: Penguin

Palmer, M, & Neaverson, P, 1992 *Industrial Landscapes of the East Midlands*. Chichester: Phillimore

Palmer, M, & Neaverson, P, 1998 *Industrial Archaeology: Principles and Practice*. London: Routledge

Parris, L, 1973 *Landscape in Britain* c *1750–1850*. London: Tate Gallery

Percy, J, 1864 *Metallurgy*. London: John Murray

Peskin, C, nd *Early Recollections, 1897–1937*. Unpublished ms in IGMT library

Pevsner, N, 1958 *The Buildings of England: Shropshire*. Harmondsworth: Penguin

Pigot, 1828 *Directory of Shropshire*. London: Pigot & Co

Pigot, 1835 *Directory of Shropshire*. London: Pigot & Co

Pigot, 1842 *Directory of Shropshire*. London: Pigot & Co

Plymley, J, 1803 *General View of the Agriculture of Shropshire*. London: McMillan

Preston, J M, 1977 *Industrial Medway: An Historical Survey*. Rochester: the author

Raistrick, A, 1953 *Dynasty of Ironfounders*. London: Longmans, Green & Co

Raistrick, A (ed), 1967 *The Hatchett Diary*. Truro: D Bradford Barton

Raistrick, A, 1975 *The Coalbrookdale Ironworks: A Short History*. Ironbridge: IGMT

Raistrick, A, 1980 The Old Furnace at Coalbrookdale, Shropshire, *Industrial Archaeology Review*, **4**(1), 117–33

Randall, J, 1880 *History of Madeley, including Ironbridge, Coalbrookdale and Coalport*. Madeley: the author

Randall, J, 1883, *The Old Court, Madeley*. Madeley: the author

Randall, J, 1908 Industries, in W Page (ed), *The Victoria History of Shropshire*, Vol 1, 415–81. London: Archibald Constable

RCHME, 1996 *Recording Historic Buildings: A Descriptive Specification*, 3rd edition. Swindon: RCHME

Riden, P, 1993 *A Gazetteer of Charcoal-fired Blast Furnaces in Great Britain in use since 1660*, 2nd edition. Cardiff: Merton Priory Press

Riden, P, 1995 The Blast Furnace in Great Britain: Survival and Conservation, in G Magnusson (ed), 319–26

Riden, P, & Owen, J, 1995 *British Blast Furnace Statistics, 1790–1980*. Cardiff: Merton Priory Press

Rix, M, 1955 Industrial Archaeology, *The Amateur Historian*, **II**, 225–9

Robson, 1840 *Commercial Directory of London and the Western Counties* Vol 2. London: William Robson & Co

Rolt, T, 1977 *Landscape with Canals*. London: Allen Lane

Scarfe, N, 1995 *Innocent Espionage: The La Rochefoucauld Brothers' Tour of England in 1785*. Woodbridge: Boydell Press

Schubert, H R, 1957, *History of the British Iron and Steel Industry, from 450 BC to AD 1775*. London: Routledge & Kegan Paul

Scrivenor, H, 1854 *History of the Iron Trade from the earliest records to the present period*, 2nd edition. London: Longman, Brown, Green & Longmans

Shrewsbury Chronicle, 18/2/1786

Shrewsbury Chronicle, 18/4/1794

Shrewsbury Chronicle, 15/3/1912

Shrewsbury Chronicle, 27/12/1929

Smith, J T, 1989 The Archaeological Investigation of Standing Buildings: A Comment, *Vernacular Architecture*, **20**, 20

Smith, S, 1979a *A View from the Iron Bridge*. Ironbridge: IGMT

Smith, S, 1979b New Light on the Bedlam Furnaces, Ironbridge, Telford, *Historical Metallurgy*, **13**(1), 21–30.

Smith, S, 1981 Blowing Engine at Bedlam Furnace, Ironbridge, Shropshire, *Historical Metallurgy*, **15**(1), 16–17

Tew, D, 1984 *Canal Inclines and Lifts*. Gloucester: Alan Sutton

Tibnam, 1828 *The Salop Directory*. Shrewsbury: Tibnam & Co

Timmins, S (ed), 1866 *The Resources, Products, and Industrial History of Birmingham*. London: Robert Hardwicke

Tolley, R, Babbington, C & Chitty, G, 1991 *Stokesay Castle, Shropshire*. London: English Heritage (reprinted from the *Transactions of the Association for Studies in the Conservation of Historic Buildings*, Vol 15)

Tonkinson, R, 1964 *Inclined Planes on the Shropshire Canal*. Unpublished thesis, Birmingham School of Architecture (SRRC MS 5660)

Trinder, B, 1975 Introduction, in J Randall, *History of Madeley*. Shrewsbury: Salop County Library

Trinder, B, 1978 *The Hay Inclined Plane*. Ironbridge: IGMT

Trinder, B (ed), 1979 *Coalbrookdale 1801: a contemporary description*. Ironbridge: IGMT (Transcript of SRRC 1987/64/6)

Trinder, B, 1981 *The Industrial Revolution in Shropshire*, 2nd edition. Chichester: Phillimore

Trinder, B, 1982 *The Making of the Industrial Landscape*. London: Dent

Trinder, B (ed), 1988 *'The Most Extraordinary District in the World': Ironbridge and Coalbrookdale*, 2nd edition. Chichester: Phillimore

Trinder, B, 1996 *The Industrial Archaeology of Shropshire*. Chichester: Phillimore

Trueman, M (ed), 1988 *Archaeology in Ironbridge 1981–5*. Unpublished report, Ironbridge Archaeological Series, **26**

Truran, W, 1855 *The Iron Manufacture of Great Britain*. London: E & F Spon

Wanklyn, M D G, 1973 Iron and Steelworks in Coalbrookdale 1645, *Shropshire Newsletter*, **44**, 3–6

Wanklyn, M D G, 1982 Industrial Development in the Ironbridge Gorge before Abraham Darby, *West Midlands Studies*, **15**, 3–7

Watkins-Pitchford, W, 1935 *Bygone Traffic on the Severn, with Special Reference to the Port of Bridgnorth*. Bridgnorth: Bridgnorth Historical Society

Wiggins, W E, 1986 *Ancient Woodland in the Telford Area*. Unpublished report, Telford Nature Conservation Project

Williams, W H, 1965 The Canal Inclined Planes of East Shropshire, *Industrial Archaeology*, **2**, 91–105

Wilson, A, 1988 The Excavation of Clydach Ironworks, *Industrial Archaeology Review*, **11**(1), 16–36

Wilton, A, 1977 *British Watercolourists 1750 to 1850*. London: Phaidon

Winkworth, A, 1990 *The North Engine House, Blists Hill Furnaces*. Ironbridge Institute, unpublished essay

Wood, J (ed), 1994 *Buildings Archaeology: Applications in Practice*. Oxford: Oxbow Monograph, **43**

Appendix 1 Approach to conservation during the Severn Gorge Repairs Project

The project adopted a consistent conservation philosophy from the outset. Approaches to conservation have changed over time, as a comparison of the repairs of the 1970s with those of the 1990s makes all too obvious. This has been partly determined by new techniques of repair and new understandings of materials and how they work, but is also partly explained by both the increased resources available for conservation and changing fashions. The approach to conservation will also depend upon the context of the monuments and the level of archaeological information available.

The repairs policy was to match like with like, the original fabric and repaired fabric being differentiated only through archaeological documentation. By contrast, previous repairs were usually more obvious, often using modern materials which clashed with the historic fabric. Building materials at this time were often donated or were acquired cheaply, introducing a combination of brick types: new blue bricks, new and reused firebricks and common bricks may be found on any one site. Concrete was used for structural purposes, for example the cappings of the furnace bases at Blists Hill and the vaulting over the wheel pit at Bedlam. Lack of archaeological recording, however, meant that archaeological information was lost during the previous generation of repairs.

Details of the conservation briefs adopted in the present project included the following general items: Mortars were designed to match the original in terms of colour and texture. All were lime mortars, many purely lime and sand, whilst others were composite mortars of lime, sand and cement. The sand came from a variety of sources depending on the colour required: yellow, red, green, or brown. Many of the Ironbridge monuments are bonded with dark grey mortar, so foundry sand from the Coalbrookdale Foundry was commonly used for black coloration. However, batches varied in colour and texture, and in the ability of the resulting mortar to set. This was dependent upon the sulphur content and it was especially important to test batches and then produce sample panels. The hardness of a new mortar depended upon the hardness of the original fabric but also on function. Pointing mortars could be relatively weak, for example a 1:4 mix of lime and sand, whilst capping or flaunching mortars tended to be harder and might include a pozzolonic additive such as pulverised fuel ash (PFA), available from the local power station. The snapper furnace was found to have an extremely hard, pale-coloured mortar, such that the brickwork was eroding, leaving the mortar standing proud. The mortar was so hard it appeared to have been vitrified, perhaps when the snapper furnace was incorporated within foundry buildings during the 19th century. Matching mortar samples were prepared and that chosen was a very hard 1:1:3 mix of lime putty, white cement, and sand. White cement was found to be suitable in composite mixes as it lacked the distinctively modern grey-brown coloration of ordinary Portland cement (OPC).

Second hand bricks to match were used in small areas of rebuilding. Some of these came from IGMT's store of building materials, which includes a variety of specials as well as common bricks. Because of the problem of sourcing second hand bricks, they were not used in larger areas of rebuilding, although in practice such areas were few and far between. New bricks were chosen to match the original as closely as possible. Stone, where required, was chosen to match in colour, texture, and size.

In certain cases new building work was deliberately made to stand out. At the Upper Forge, the upper storey of the mill (formerly engine house) was reconstructed, based on photographs of the 1950s (Fig 165). The new build was separated from the original by a band of recessed blue bricks. At the Upper Works a part of the charging platform had to be rebuilt as it had collapsed in the 1980s. Second hand bricks were laid, but it was not possible to replicate the mortar which had previously been used. To acknowledge this, it was therefore pointed with a green-brown mortar which was totally different from any other at this particular site. In some instances, new brick structures were required which bore no relation to any historic structures. A good example is at the snapper furnace, where new brickwork was required on the top of the monument to aid drainage. New blue brick was used so that it could not be confused with original fabric and it was constructed in such a way that it is barely visible from ground level. Old railway sleepers were used for retaining or protecting structures, which are clearly distinguishable from original materials without being prominent. For example, they were laid over the wheelpit walls and above the cellars at the Upper Forge (Fig 53). Old ironwork was normally treated with micaceous oxide and sometimes painted brown, whilst new structural steelwork was painted black. Timber lintels were generally replaced with blackened, pre-cast, concrete lintels rather than new timber, simply as the best long-term solution. Most upper surfaces were capped. However, lead flashing and tiles were used at the

Figure 165 The Upper Forge, photographed looking east in 1995 after repairs and showing the reinstated upper storey of the former mill.

Upper Works, although the consultant architect continued to have reservations about the conspicuous appearance of the former.

A major element in the repairs project was the insertion of tie rods and anchors. The former were needed to link free-standing walls, whilst many of the high, ruined structures had to be pinned back to the hillside to prevent vertical rotation. Ties were normally fixed to walls using tie plates. Some were merely replacements, tie rods being a common feature of the area. The tie plates could be copies of the original plates, whilst others were completely new. Most of the new ones were oval in shape and some were made in the IGMT foundry at Blists Hill. Anchors were often drilled straight through the face of rubble-stone walls, but in brick walls, bricks were removed and replaced after the anchor had been inserted.

Sacrificial brickwork was frequently laid on surfaces vulnerable to weathering. Sometimes a sacrificial floor was laid over the original floor, to match as closely as possible, as in the building north of the boiler bases at the Hay Inclined Plane. The upper surface of Blists Hill furnaces required more major works. A self-draining, concrete cap was laid over the whole area, preceded by excavation of the former upper surface. Exposed features above the level of the capping were repaired *in situ*, while features found below the capping level were reconstructed on the top of the capping.

Appendix 2 Conventions for archaeological drawings

A large project requires consistency in the presentation of its finished drawings, the initial proviso of which is reasonable consistency in the field drawings. The content and style of field drawings was progressively refined during the fieldwork phase of the project. Most of these drawings were elevations, while most of the important structures at Ironbridge are brick-built. The addition of brick courses to the drawings, with the annotations H and S to distinguish between headers and stretchers, quickly proved its worth. It was useful in expressing on the drawings subtle changes in the structures which would not have been so apparent had this simple exercise not been undertaken. Where it occurred, masonry was normally drawn stone by stone. The exception was interventions in the 1970s, which were recorded in outline only, or where resources were insufficient and the structure did not justify it. The resulting field drawings were therefore more complex than many archaeologists will be used to. Colour was introduced to distinguish different elements or materials within a structure and was a form of note taking rather than a formal phasing. The colour could be used in two different ways, one of which was to draw in pencil and then to shade in colour afterwards, the other to use coloured pencils from the outset. In practice the extent and the technique of using colours depended upon the individual.

Conventions for finished drawings were established before the final reports were produced. Given that some of the drawings were intended to be used by the architects and other consultants, as well as for future repairs and maintenance, they were mainly produced on A1 or A0 sheets. The principal drawings were reduced to A3 and bound in with the finished reports, but the full-size drawings were presented in separate folders. The standard scale was 1:50, with 1:20 being adopted for drawings of specific details.

The advantage of large-format drawings is that they can bear a greater level of detail and annotation and are compatible with engineers' and architects' drawings. It also means that a range of pen sizes can be used effectively in a universal convention which has been tabulated for ease of reference (Table 2). The basic principle is that the larger pen sizes define the salient elements, the line thickness decreasing to show openings in the structures, with the thinnest lines used for brick courses or individual stones. Iron and steelwork are blacked in. Openings were drawn to the standard recommended by RCHME in 1990, but were formulated before the recent edition also adopted a convention for pen sizes (RCHME 1996). Groundworks were drawn using orthodox practices of archaeological draughtsmanship.

House style in the layout of the drawings was developed with key information in standard places, which again followed the convention used by engineers and architects with the box detailing personnel and client information in the bottom right corner (Table 3). This was also extended to encompass uniform borders, point sizes for annotations,

Table 2: Standard pen sizes for finished drawings

Drawing Type	Description	Pen size
Elevations and sections	External walls and ground floor	0.7mm
1 : 50 or 1 : 100	Upper floor levels, dividing or partition walls, direction of floor boards and joists or beams, main windows and doorways	0.5mm
	External ground level, secondary openings and blocked openings, pipes, recesses	0.35mm
	Minor blocked openings, lintels, door and window frames, ironwork, areas of render, electrical or gas fittings	0.25mm
	Brick courses, stonework, window and door details	0.18mm
Building plans	Building outlines and end of excavation lines	0.7mm
1 : 50 or 1 : 20	Dividing or partition walls, modern drains, pipes, manhole covers	0.5mm
	Window sills, position of upper-floor beams, features on brick floors	0.35mm
	Blocked openings, floor boards, window and door frames	0.25mm
	Brick floors	0.18mm
Groundworks 1 : 20	End of excavation lines, external walls	0.7mm
	Ground level, subsidiary walls, services	0.35mm
	Layers, features and cuts	0.25mm

Table 3: Layout of standard information on finished drawings

	Top left	Top right	Bottom right	Bottom left	Marginal column
Titles	*				
Location plan		*			
Box			*		
Scale bar				*	
Levels					*
Key					*
North point		*			

scales, north points, and so on. All annotations were printed through a laser printer on to self-adhesive clear film.

The drawings were presented in three basic forms (Fig 166). Survey drawings showed the structures as found, without any annotations. An additional set of survey plans were annotated with levels above Ordnance Datum (AOD). The same drawings were then presented with explanatory information, known as record drawings. Excavations were presented as record drawings only because survey drawings would have been superfluous when recording information that was subsequently destroyed.

It had been intended to annotate the record drawings with notes. However the first site to be written up was Bedlam, which yielded complex drawings on which textual annotations would have been impractical. Instead component numbers were adopted in conjunction with a key, with written annotations being confined to identification of major structural components such as furnaces and engine houses. It was important to think through a strategy for achieving this and to resist the temptation as archaeologists simply to use previous experience of excavations and apply them to buildings. Buildings archaeology deserves its own approach, but an additional problem was foreseen of needing to use both buildings and excavation drawings, to some degree, on all of the sites, but especially the Upper Forge. In an excavation drawing, a cut and its fill would be given separate numbers, but it is rarely useful to do the same thing for a building, ie giving the jambs of a window one number and the infill of that window another. It is important to use numbers as a convenient intermediary between drawings and text. To apply the method dogmatically would introduce obfuscation. Component numbers were not given to every feature by rote, but only where necessary. Some scholars would of course find any numbering sequence excessive for a building, but where detailed descriptive texts were needed for the future management of the monuments and as a prelude to documenting repairs, component numbers emerged as the most effective solution.

A single sequence of component numbers was used for both the buildings and excavated features. The only exception was the Upper Forge where building component numbers were given in square brackets and each excavation drawing had its own numerical sequence always beginning with the number one and denoted as an excavated feature by round brackets. The mistake of having several features with the same component numbers, one in square brackets and several in round brackets, was only made once. The sequence of numbers was not extended to drawings of borehole drilling, primarily because these were undertaken in the preliminary phase of work.

A series of phased drawings was produced for reporting on the preliminary work at Bedlam. The idea was not carried through to the final reports, mainly because limited resources could be better targeted elsewhere. Likewise there were insufficient funds for anything but the most rudimentary reconstruction drawings. Sites like Bedlam and the Coalbrookdale Upper Works would undoubtedly benefit from accurate and detailed reconstruction drawings, but in practice they would consume an enormous amount of time.

The third major form of drawings were the repairs drawings. In most cases these were the survey drawings with the repairs marked on, although in many cases, especially at the Upper Forge where the upper storey of the former mill was reinstated from photographic evidence, additional recording in the field was necessary.

A standard convention was used for denoting repairs. This took the form of the application of tone for different forms of intervention. It was important to distinguish superficial repairs like repointing from more substantial work such as rebuilding. New building was differentiated from rebuilding and was an important element of the repairs, particularly sacrificial brick courses which were regularly employed for fragile brick structures such as those at Bedlam and the Hay Inclined Plane. Ground anchors were marked, as were free-standing items such as the steelwork which was used to buttress the wheel chamber walls at Bedlam. An additional classification was made for capping or flaunching. The repairs drawings were also designed to accompany future management documents, unlike the record drawings which documented the buildings before any interventions were made.

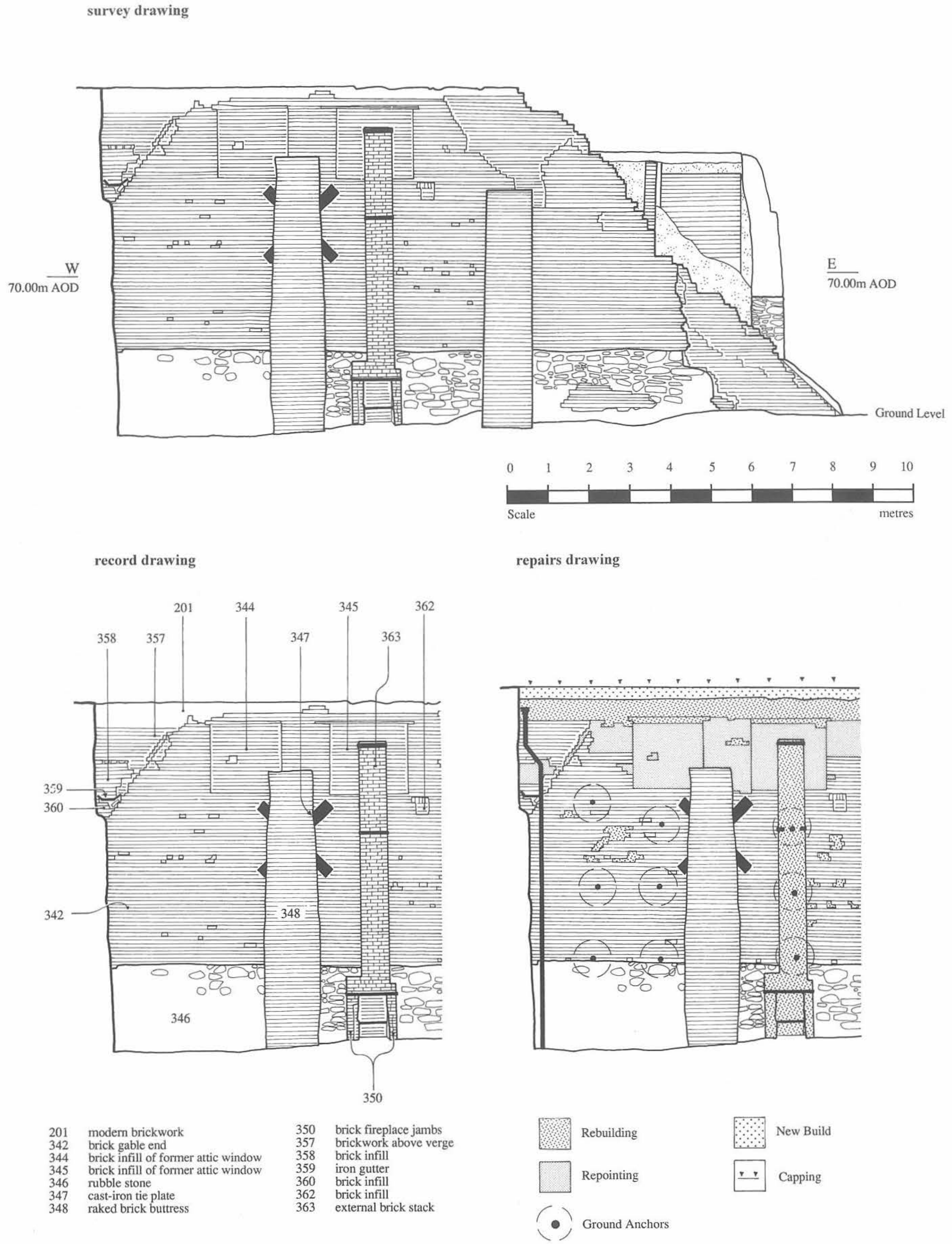


Figure 166 An example of survey, record, and repairs drawings from the charging platform at the Upper Works.

Appendix 3 Project management

Project programming

Project programming should be divided into two parts, fieldwork and post-excavation work. In the present project, the timetable for the fieldwork was for the most part set by others, as the repairs were the primary purpose of the project, whilst the subsequent office work involved only the archaeologists. The programme for the repairs and archaeological fieldwork was set by the project coordinator, in this case the lead architect, and had to account for a whole range of financial and practical constraints. The main funding body was the Commission for the New Towns, and it was necessary to spread financial payments and complete the work in accordance with the timetable. For IGMT it was important to limit disruption to visitors as much as possible, to manage access restrictions, and maintain quality. The consultants had to deal with twenty subject sites simultaneously, so needed a programme which was practically achievable. Consecutive scheduled monument consents were needed at sites such as Blists Hill furnaces and it was important to ensure that this was allowed for in the programme.

The archaeological project manager, like the consultants, was asked to comment on the programme to ensure that it was practicable with the resources available. A complicating factor was that the archaeological funding came from a different source. English Heritage grants are allocated yearly rather than on a project basis, so some system of phasing had to be retained for the archaeologists in order to allocate packages of work to particular financial years. It was necessary to confirm specifications and timetables with each individual consultant. In practice this was not always easy, particularly when new investigations were added for which the archaeologists had no funding or when the order of works was changed. However, it did mean that the archaeological project manager was involved in the design and detail of the works.

There were delays at the beginning of the project, which led to slippage in the site-by-site programme. At the outset, the date for completion of the repairs was to be June 1993, but in the end all works were finished by March 1995. The work was concentrated towards the end of the programme, so that 1994 was a very busy year for everyone involved.

A series of virements was used to move tasks around between phases, to fit the new site-by-site programme devised by the consultant architect. Virements of tasks within the archaeological programme were also used to cope with the inevitable changes in the repairs themselves. Site investigations and all the subsequent interventions were bound to produce new information and reveal unknown problems with complex and unstable structures of this type. Thus new solutions or revisions to specifications were required with a knock-on effect on the archaeological schedules. Clearly this is something which cannot be changed and the importance of using the most appropriate method of repair is paramount.

The second phase of project programming relates to the office work phase, from 1995 to March 1997, the deadline for the submission of all archaeology reports relating to the project. Here, the archaeologists were reliant on no other consultants, so detailed programmes were devised and agreed with English Heritage and regular monitoring meetings were held.

Resource requirements and funding

The resources required for any archaeological project of this type are money and staff. The number of staff, including the project manager, varied from four to six throughout the project, a small team compared to many others. It was at the peak of the repairs during 1994 that six members of staff were needed and this was probably the maximum that could be comfortably accommodated. If the number had risen to seven or eight, there would have been both a shortage of desk space and drawing boards and a sharp increase in the amount of capital equipment required. English Heritage funding allowed for the purchase of capital assets such as cameras, computers, and a contribution towards a vehicle. More than six staff would have meant the need for another set of cameras, a second topographical level, and difficulties in transportation between sites. It is therefore useful to gauge a cut-off point in staff numbers, beyond which serious practical and funding difficulties would arise.

The archaeological briefs for the project were closely linked to the repair specifications, which were broken down into individual tasks. A cost was allocated to each item on a person-day basis, for example:

Archaeological monitoring of two boreholes
(2 days fieldwork, 2 days drawing up)

Detailed recording of area prior to laying Terram membrane.
(1 day fieldwork, 1 day drawing up)

Repair cracks to underside of arches by stitching and consolidation
Archaeological monitoring of works and recording of fabric behind rubble.
(1 day fieldwork, 1 day drawing up)

An allowance was also made for producing written reports, normally about one sixth of the number of days allocated for fieldwork and drawing up. Costing by person-days involved a formula based on an average of individual staff costs for project work and administration, plus materials, capital equipment, and overheads. Small increases were allowed for inflation in each subsequent phase.

Breaking down the work into tasks and costing on a day basis worked well for the monitoring of repairs, groundworks, and for office work. The largest site project was at Blists Hill blast furnaces where the repairs contract lasted for over a year. At least one archaeologist had to be on site almost continuously for this period and the costings worked out to be surprisingly accurate. Allowances for report writing were tight in some cases, but possibly because the reports tended to be more than in the old definition of 'site narratives'. In particular, more funding should be allowed for final reports than interim reports to allow for the increased time and costs for finalisation, good presentation, and editing. Problems arose in the early stages due to lack of PPG16-style evaluations and in the initial recording work (see Chapter 2), but the briefs and terms of reference for the project were amended later to get around these problems. It is recommended that an initial evaluation and then the initial building recording work are costed separately from the subsequent task by task monitoring works.

Tools for project management

Programmes for the repairs themselves were produced by the project coordinator (lead architect) and were circulated to all the consultants and relevant IGMT staff. They were drawn up by hand on A3 sheets and were updated every two or three months. The sites were set against months of the year and arrows were used to show the following: tender, notice, SMC, works, delays, and completion. At first the archaeological project manager used these charts to devise archaeological programmes which showed office work as well as fieldwork. As the repairs became bunched up, however, any proposals to undertake office work had to be abandoned, whilst all hands concentrated upon the recording work. These archaeological programmes generally used a spread sheet as a base, with hand-coloured or toned bars.

For the office work stage, project management software was considered, resulting in the purchase of Microsoft Project. Although information can be displayed in a number of ways, gantt charts and tracking gantt charts proved to be the most useful. These related firstly to the overall project, showing all the sites against time, and secondly for showing a breakdown of tasks for individual sites. Gantt charts for the overall project were compiled by the archaeological project manager, whilst charts for individual sites were produced by the member of staff responsible for writing that report. This helped staff to monitor the allocated number of days for each task themselves and to review their progress in relation to the overall programme. Internal meetings were held to review spending and progress as and when the need arose, whilst meetings with English Heritage were approximately bimonthly.

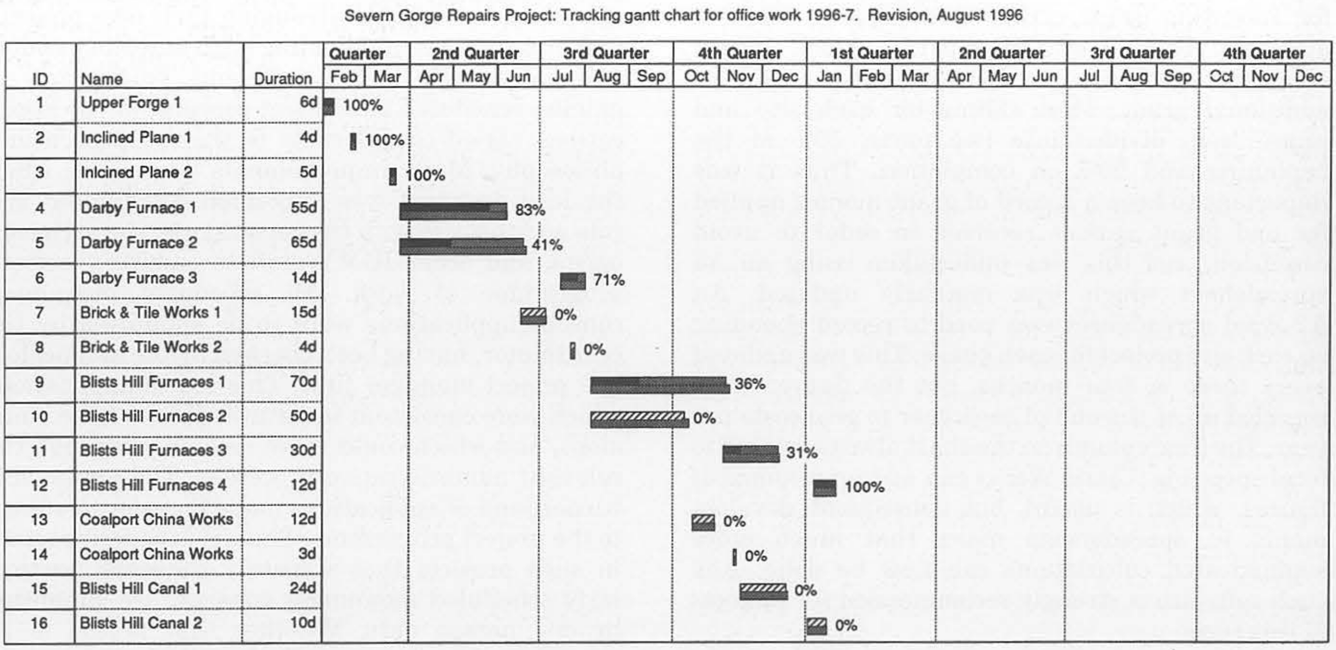


Figure 167 Tracking Gantt chart for office work, 1996–7.

The software was found to be particularly useful for individual sites, where there were consecutive tasks and a clear final goal. For the overall programme it was less useful because there were several final goals. The software, at the time of writing, is very much designed for tasks which converge towards one final goal, but in archaeological projects of this type, the problem is often dealing with divergence, where there are several projects running concurrently and where staff are moving between projects. It is not possible to show breaks on the gantt chart where a site project is worked on intermittently. Instead, it is necessary to start a new row on the chart, resulting in maybe five or six rows for each site project. Holiday periods can be calculated within the software, but again no break is shown on the printed programme. The tracking gantt chart shows progress against the original chart (Fig 167). Completed work is shown as a dark bar, and the percentage completion is printed at the end of this bar. This means it is necessary to convert the number of days spent into a percentage for all entries, and this calculation has to be repeated whenever the chart is updated.

Despite some constraints, the gantt charts are useful for presentation and the tracking gantt charts provide a particularly efficient method of revising and updating programmes. Revisions for hand-drawn charts often involve redrawing bars from scratch, which is very time consuming and it is less easy to show, and therefore monitor, progress. Thus, project management software is recommended for use in projects of this type. Perhaps in the future an archaeologist will be able to design project management software to fulfil the particular needs of archaeologists, and in particular to manage divergence.

Spreadsheets using Claris Works software were used for two main purposes during the project; for recording grant claims and keeping internal accounts. There were 44 separate grant claims altogether, covering nine sites, three phases, and an additional grant. Most claims for each site and phase were divided into two parts, 50% at the beginning and 50% on completion. Thus it was important to keep a record of grant monies applied for and grant monies received in order to avoid confusion, and this was undertaken using an A4 spreadsheet which was regularly updated. An A3-sized spreadsheet was used to record spending on each site project for each phase. This was updated every three or four months, but the figures were rounded up at the end of each year to give costs per year. The final column on the chart always related to total spending. Claris Works can add up columns of figures, which is useful, but subsequent developments in spreadsheets mean that much more sophisticated calculations can now be done. Any such software is strongly recommended for projects of this type.

Day to day organisation

Day to day organisation during the fieldwork required liaison with the consultants and contractors to define where staff should be and when. Normally one archaeologist was the principal fieldworker at each site, so it was very important for him or her to develop a good relationship with the contractors, particularly the site manager. On some occasions, particularly during substantial groundworks, it was necessary to have more than one person on site and arrangements were normally made informally at the beginning of each day.

Monitoring progress was a significant aspect of day to day organisation. At the end of each week, all members of staff would fill in a time allocation sheet to record the sites on which they had been working and the phase. At first these were designed on a half daily basis, but this did not provide sufficient detail, so they were changed to half hourly. At the end of each month a member of staff would produce a breakdown of the time spent by each person on each site project. This information was then transferred to a spreadsheet for the purpose of internal accounting. The monthly breakdown itself was sent to IGMT's Head of Finance, who could input the data into the IGMT's accounts for auditing purposes. The resulting accounts ledgers were sent back to the archaeological project manager to be cross-referenced and checked.

Liaison with consultants and contractors

The engineers, architects, and quantity surveyors were commissioned directly by the managing body (firstly TDC and subsequently IGMT) to undertake their specialist work. At first the consultants were relatively free agents, arranging their own projects and programmes and dealing with statutory bodies individually. This led to problems, particularly in gaining scheduled monument consent, as the applications varied considerably in their approach and philosophy. Major improvements were made when the lead architect was appointed coordinator. His role was to liaise with the consultants, the archaeologists, and other IGMT staff to ensure a smooth programme of work. All scheduled monument consent applications were to be submitted by the coordinator, having been checked by the archaeological project manager first. This led to applications which were consistent in nature, did not have omissions, and which could move smoothly through the relevant administrative processes. The predictable turnaround of applications made it easier to adhere to the project programme. Thus, it is very important in such projects that statutory consents, particularly scheduled monument consent, are submitted by one person only. Whether that person is an architect, archaeologist, engineer, or someone else involved in the project is immaterial. However, they should always be sent to the archaeologist first for comment and so that the relevant archaeological information can be attached.

Each site project had a lead consultant, normally one of the architects but sometimes an engineer where the works were predominantly of a structural nature. The lead consultant was responsible for issuing site instructions to the contractors, with copies sent to the other consultants, archaeologists, IGMT, and CNT. However, the archaeologists were sometimes allowed a 'stop provision' on scheduled sites, in case of unforeseen damage being caused to the monument or if it was not possible to undertake the necessary recording. In practice, it was never necessary to use the 'stop provision' and solutions were found through negotiation with the relevant parties. Regular site meetings were held, attended by all the consultants, English Heritage or local authority representatives, archaeologists, and IGMT staff. As well as reviewing progress and inspecting work, mortar and brick samples were chosen, detailed methodologies for individual items were discussed, and matters relating to conservation philosophy were reviewed. The archaeological project manager was fully involved in these discussions and gave advice on the effect of the proposed methodology on the historic fabric and the implications for archaeological recording. Thus, the archaeologists had input into the design of the repairs, not only at this stage but also in advance of the works.

Although each package of work on each site was let out to tender, a few contractors won tenders for several packages of work, so it was possible to develop good working relationships. The archaeological fieldworker was normally aware of what was happening on site on an informal basis, in addition to the formal methods of communication. Because archaeological recording was an intrinsic part of the project, a provision for standing time was allowed in the contractors' tender documents. Standing time would apply particularly to monitoring or supervising groundworks, but it was normally possible to come to an arrangement with the contractors where they could, for example, backfill the trench behind, whilst the archaeologists recorded the trench in front. Even at the Upper Forge, where groundworks produced archaeological remains of far greater extent and significance than anyone had anticipated, it was often possible to arrange working practices so that the contractors were not left standing. Some contractors were careful to record the presence of the archaeologist on site in the same way as their own staff and subcontractors, which made the archaeologists feel included and would have been helpful if any dispute had arisen.

As is so often the fate of archaeologists, there were a few incidents at the beginning, particularly during the site investigations, where contractual work began without the archaeologists being informed. A rather more unexpected problem was the opposite, where the archaeologists were informed of a start date but the contractors never arrived, wasting a considerable amount of time. As there was no contingency for this sort of eventuality, a clause was inserted into the subsequent tender documents, whereby the contractors had to pay a penalty for standing time by the archaeologists. This clause was acted upon once.

Several clauses, in fact, were inserted into the tender documents relating to archaeology, which varied according to circumstance. The archaeological project manager was informed that such clauses might be difficult to enforce legally as they were inserted into a standard building contract, but the main aim was to keep the contractor informed and avoid unnecessary delays. As well as being required to give 24 hours notice of the intention to commence or delay works, the contractor was provided with a description of the type of archaeological work to be undertaken and what the archaeologist would actually do. Detailed archaeological specifications were also included along with time-scales and the order in which the tasks were to be performed. The contractor was informed of those tasks which could only proceed with an archaeologist in attendance. For scheduled sites, it was pointed out that it could be a legal offence to undertake work without an archaeologist present. It is likely that these clauses helped to build good working relationships. Very often problems arise with contractors because they are unaware that archaeologists will be present on site and do not understand why they are there and what they are doing. Full information at the earliest possible stage, and certainly before tenders are let, is the easiest way of avoiding these pitfalls.

Appendix 4 Future management

Informing future management

A major repairs programme may finish, but management never stops. There is immediately a need for inspections, routine maintenance activities, and planning for future repairs. The individual site projects at Ironbridge were completed between late 1994 and early 1995, since when it has been necessary to spray vegetation and carry out minor consolidation of exposed brickwork. A brick skin built up in front of corework at the south-west angle of the snapper furnace during the repairs project needed to be extended upwards to prevent children from picking at the corework. This was undertaken with scheduled monument consent in Autumn 1997. It should be remembered that the repairs were not comprehensive and focused on the highest areas where access was the most difficult and which had been affected most by the weather. Areas omitted were generally closer to ground level, the most notable being the brick and tile works and the furnace bases at Blists Hill. At the time of writing, superficial repairs are becoming necessary at some of the sites, mainly the capping of walls, flaunching, and repointing.

To manage the sites in the long term, a series of maintenance handbooks has been produced by the consultant architects (Wheatley Taylor Stainburn Lines) with input from the other consultants and the archaeologists who worked on the project. The handbooks are modelled on the quinquennial system used for churches. The first section in each volume is primarily a historical record of the work undertaken at each monument and includes: project parties; summary description; summary history; architects' specifications and drawings; engineering specifications; legal approvals; architects' instructions; archaeologists' repairs drawings; services information; trade brochures and guarantees. The second part is more concerned with future work and includes management guidelines taken from the recommendations sections of the archaeologists' final reports. As well as a routine building watch, six-monthly, yearly, and five-yearly inspections are suggested at different levels of detail. The quinquennial inspections are designed to be very thorough, and to result in recommendations for the subsequent five year period. A comprehensive photographic survey of the buildings and monuments was undertaken by the IGMT archaeologists in May 1997, with recommendations that the process be repeated every two or three years for the ruined structures and every five years for the buildings. Site-specific maintenance recommendations list different fabric types against a maintenance solution with the proposed frequency. These are relatively brief, for example: 'Wall tops: 0.5 year: Reflaunch with 1:3 mortar as in specification to match colour of base mortar.'

A further, more detailed document was provided on masonry repairs and consolidation. As well as providing guidance for future repairs methodology, it highlights the need to review the performances of the materials and methodologies used in the repairs programme, and to draw attention to recent and forthcoming research into techniques and materials. Examples are the recent moratorium on mortar mixes containing both hydraulic and non-hydraulic limes (English Heritage, technical policy statement, 1997) and research into lime mortars gauged with cement, which are not currently in favour (Smeaton Project, 1994). It is interesting that the latter mortars were used successfully at the Hay Inclined Plane and at the snapper furnace where a particularly hard mix was required to match the original. Though it is early days, there seems to be little obvious reason why some mortar mixes used in the repairs project have fared better than others. However, this project can hardly be seen as a controlled experiment, because the mortar mixes, existing fabric, condition, and location of the monuments varied. The competitive tendering process ensured that the sites were repaired by a number of different contractors, whilst the time of year and weather were additional factors. Despite all this, it would be an interesting exercise in ten years time to assess the survival of the many different mortars used during this project.

The archaeologists recorded the areas of each monument where repairs had taken place along with the type of repair, for example, repointing, rebuilding, or flaunching. Whilst advice is given in the maintenance handbooks for general mortar mix ratios (for example a 1:3 lime:sand mix), it would have been advantageous if the archaeologists had also recorded the exact materials used in the mortar mixes. Although in the future particular sand quarries may no longer be functioning or may be producing sand from different strata, such detailed information would help considerably. Not only could materials for repairs be acquired quickly and easily, but any mortars which had not stood the test of time or did not have the right appearance could be avoided.

It is hoped that five-year rolling programmes of scheduled monument consents can be devised for routine maintenance tasks. Standard methodologies can be written for different types of routine work, with basic information such as brick types, joint widths, and coursing patterns. These can then be amended to suit the particular circumstances. Any one-off or unpredictable problems would require individual scheduled monument consent in the normal way.

The recent concept of conservation plans (Heritage Lottery Fund, March 1998) can act as a framework for rolling, five-year programmes, as well as for management regimes in general. The emphasis on impact statements fits well with the recommendations sections in the final archaeology reports produced during this project. These focused on areas of archaeological sensitivity and priorities for future research and included zoned maps. For example, at Bedlam furnaces there were considered to be four zones of archaeological sensitivity (Fig 168):

Zone 1 is the ground surface around the extant lower level structures and the area to the south. This is closer to the original ground level than the remainder of the site, so was considered to have the highest level of sensitivity.

Zone 2 is the charging platform, where the current ground level is below the charging level during the latter part of the working life of the furnaces.

Zone 3 is the car park in front of the monument. This area almost certainly contains archaeological remains below ground (see Fig 60), including the foundations of a casting house, moulding room, and loam house, as well as possible wooden waggonways, plateways, and air furnaces.

Zone 4 is the slope on the east side of the site, which is made up of spoil dumped after the closure of the works. However, well preserved archaeological remains may survive a long way below the ground surface.

Although Zone 1 is considered to have the highest sensitivity, it is not really possible to rank the other zones. Rather than being of higher or lower sensitivity, they are simply different. The impact of any particular intervention would not be the same and different strategies and mitigation measures would be needed. Information regarding sensitivity also needs to be correlated with the plans showing priority areas for future research. If a proposed intervention is found to be in one of these priority areas, extra care needs to be taken to ensure that no historic information is lost. Further mitigation measures may be necessary to ensure that any new features revealed are properly protected. The areas of sensitivity relate mainly to ground surfaces, whether at a higher or lower level. For the purposes of the maintenance regime, it will also be important to look at the vulnerability of the extant fabric. Again, the impact of any proposed intervention

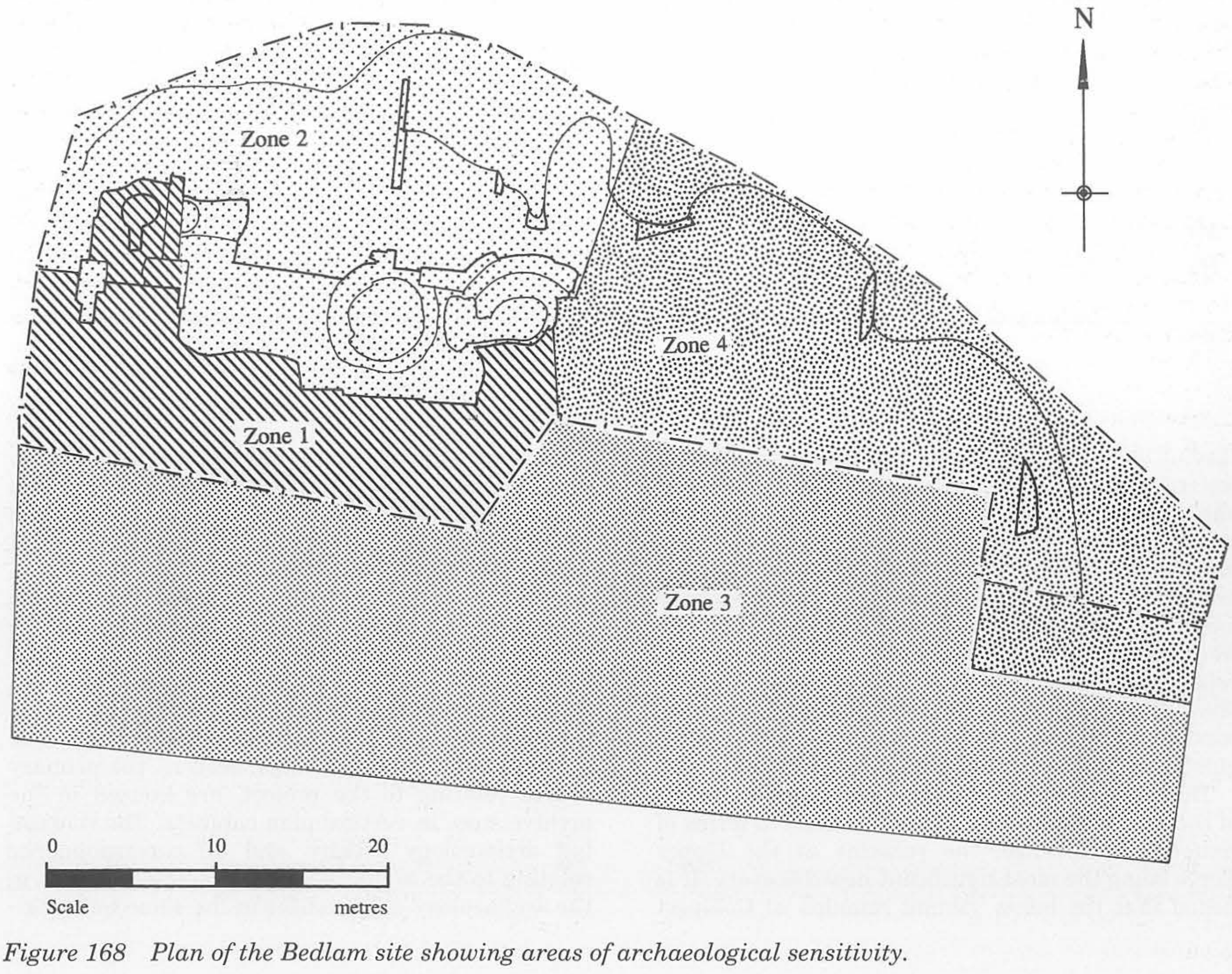


Figure 168 Plan of the Bedlam site showing areas of archaeological sensitivity.

needs to account for the vulnerability of each area of the monument and mitigation measures devised. The main factors in devising a maintenance regime are as follows:

Background to proposals
|
Archaeology
|
Description
+
Summary interpretation/appraisal
+
Areas of archaeological sensitivity (ground surfaces)
+
Areas of vulnerability (fabric)
+
Priority areas for future research
|
Interventions
|
Location of proposed interventions
+
Nature of proposed interventions
+
Reasons for interventions
|
Impact
|
Impact of proposed interventions in each area
|
Recommendations
|
Mitigation measures before or during the works (possibly leading to revisions to the specification)
+
Archaeological recording strategy

Having obtained the necessary consents, the recording strategy should be put into action. Although only one minor piece of work, to the snapper furnace, has been undertaken since the end of the repairs programme in Ironbridge, it was decided that the archaeological repairs drawings should act as a base for either a five- or ten-year period depending on the frequency of activity. At the end of the period, the repairs drawings should be redrawn and inked to show all the repairs of the intervening period. It is most important to date the drawings and to distinguish different types of work by colour or tone.

The archaeological work has established that each of the sites can legitimately be discussed in terms of national importance, the remains at the Upper Forge being the most significant new discovery. It is hoped that the below ground remains at Coalport and the Upper Forge, and above and below ground structures at the Blists Hill Brick and Tile Works will be considered carefully as part of the Monuments Protection Programme. None of them are scheduled monuments but all of them should be.

Regarding the sites which are already scheduled, it was recommended in nearly all cases that the constraint boundaries should be amended. They were scheduled in the early 1970s, before or simultaneously with the early excavations and restorations undertaken by IGMT. Thus the boundaries are out of date, not only because of the findings of the current project, but because of the results of these large-scale previous excavations. In the archaeological report on Blists Hill blast furnaces, for example, it was suggested that the constraint boundary should be amended to follow the outline of the areas of archaeological sensitivity, which means enlarging the area (Fig 169).

At the Upper Works, several amendments were suggested (see Fig 20). The snapper furnace forms part of the scheduled area but the boundary on the map is the retaining wall which crosses the structure from its south-east to north-west corners. Consideration should therefore be given to including the north-east half of the structure within the constraint area. During the course of the project, three vaulted chambers were found to project into the pool dam and it is suggested that the constraint boundary is moved back from the face of the dam by 3m (see Fig 22C). Scheduling the pool dam in its entirety should not be ruled out. On the south side of the Upper Works, the boundary is arbitrary, coinciding with the top of the south–north slope which was formed during the 1959 excavations. However, this is in an appropriate position for two reasons: the northern, lower part of the site is more sensitive because important features are likely to be exposed just below the current ground surface, and because the earliest and most significant structures at the Upper Works were at the north end with a gradual expansion southwards in the 19th century. Following the completion of the Monuments Protection Programme, it is hoped that as well as the ability to 'spot-schedule' sites, it will be possible to seek amendments to boundaries where informed by the results of new work.

The Ironbridge Gorge Museum Trust is a repository of primary archives and the archive store is environmentally controlled to BS 5454. All the documents relating to the repairs project are housed in the archive store, each site having its own shelving compartment, with the specification drawings folded in A4-sized polypropylene wallets. The archaeological field drawings, seen as the primary source relating to the project, are housed in the archive store in vertical plan cabinets. The remaining archaeology archive and all correspondence relating to the archaeology programme are kept in the archaeology unit's offices in the same building.

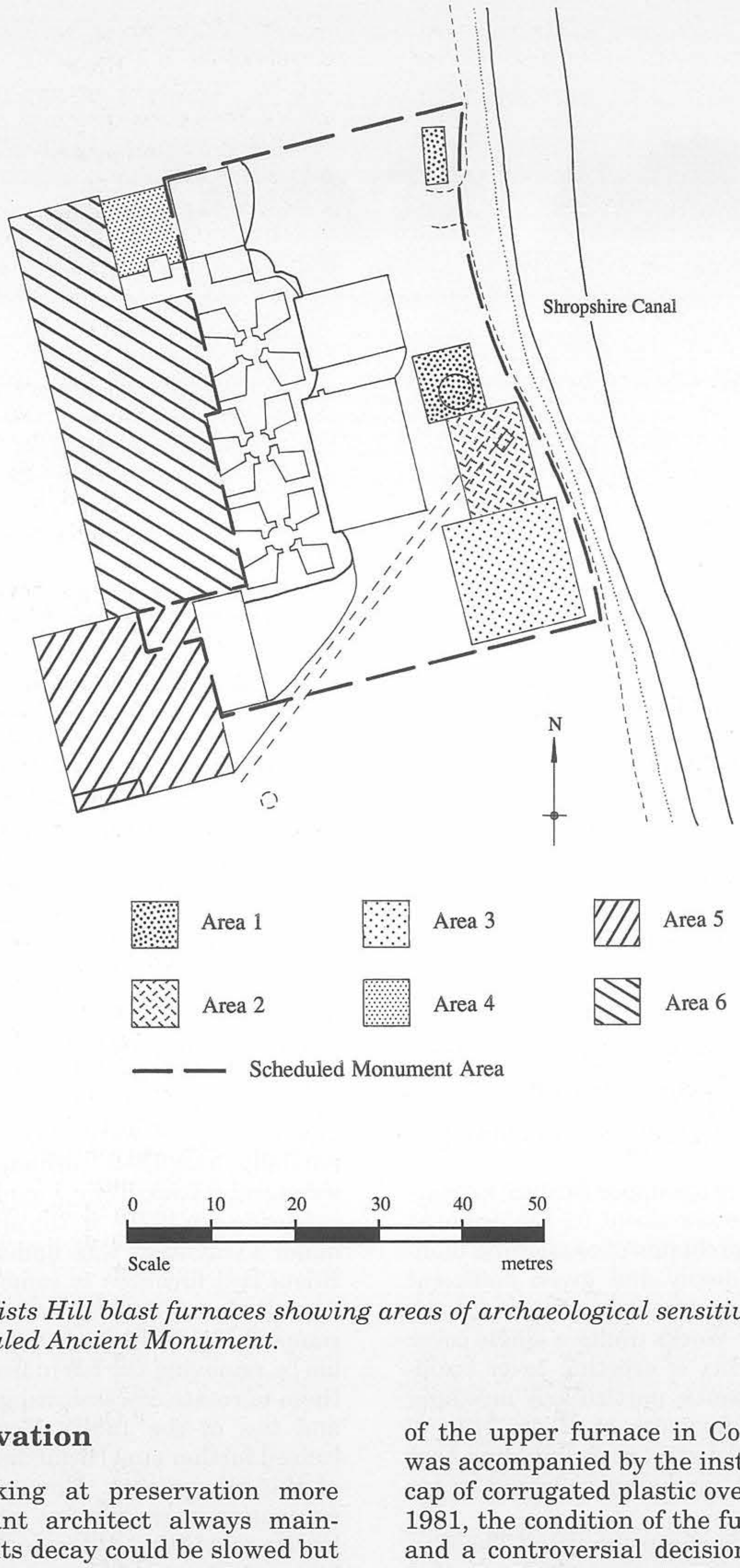


Figure 169 Plan of Blists Hill blast furnaces showing areas of archaeological sensitivity and the present boundary of the Scheduled Ancient Monument.

Long-term preservation

It is also worth looking at preservation more broadly. The consultant architect always maintained of Bedlam that its decay could be slowed but not stopped, its long-term survival dependent upon geological factors. In the main, however, conservation work can ensure the long-term sustainability of the monuments. Sacrificial surfaces in particular, are helpful in protecting fragile monuments open to the vagaries of the weather. Going one step further, one can erect buildings or structures over the top of monuments to protect them. This occurred in Ironbridge in 1959 with the excavation and restoration of the upper furnace in Coalbrookdale. The work was accompanied by the installation of a pyramidal cap of corrugated plastic over the furnace stack. By 1981, the condition of the furnace had deteriorated and a controversial decision was made to erect a cover building over it (Fig 8). The glass and steel building with its triangular profile can in no way be confused with the original fabric of the furnace, but in visual terms, the furnace is now dislocated from its surroundings (Fig 170). However, the furnace has been protected from the weather, particularly frost action, and vegetation growth. As a result, only limited repairs were required to the monument and those at the top resulted almost entirely from

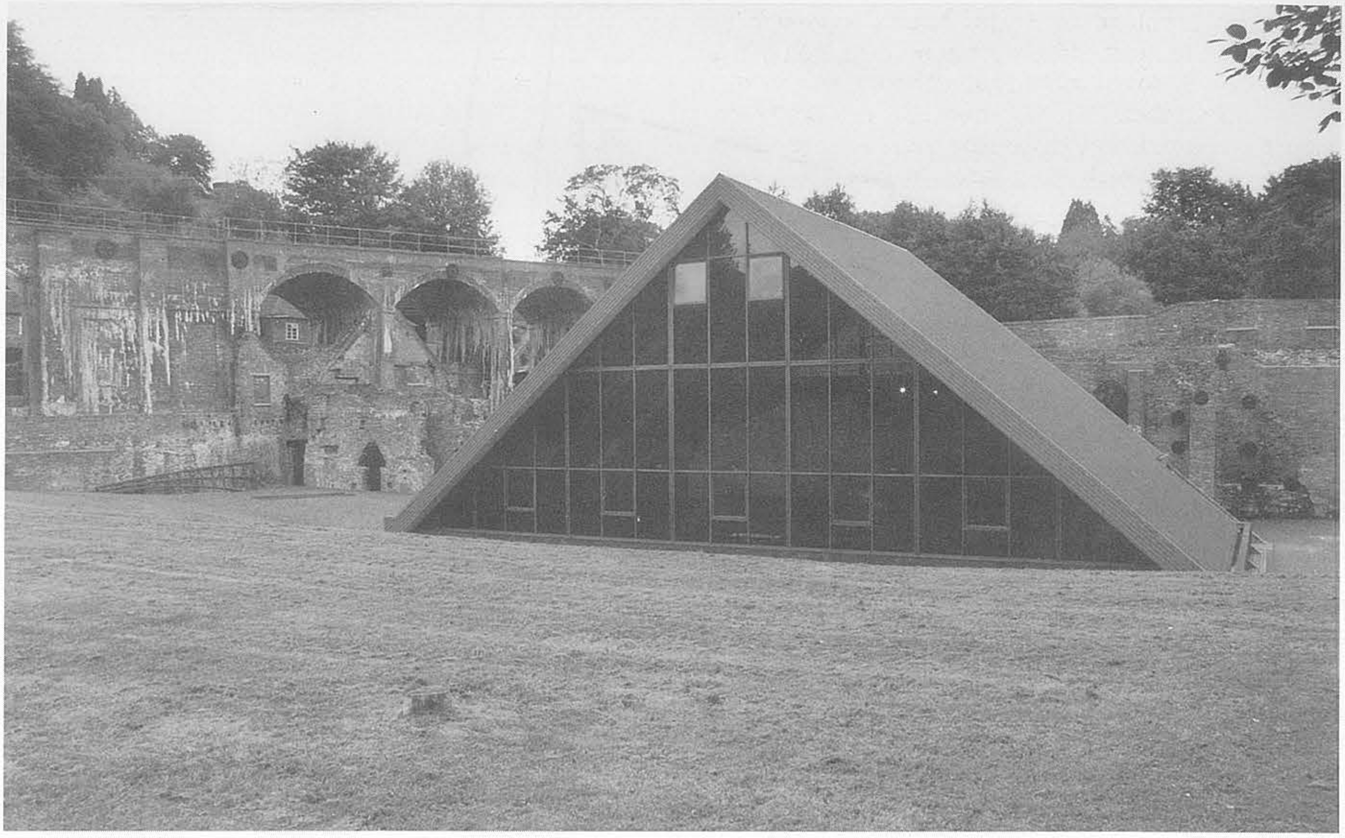


Figure 170 The cover building erected over the upper furnace at Coalbrookdale in 1982, photographed looking north in 1998.

vandalism: bricks had been picked off and needed to be reset for safety reasons. In the three years since the repairs programme finished, the furnace has required no routine maintenance, in sharp contrast to the surrounding structures. In the long term, the benefit of the cover building in terms of preservation arguably outweighs the negative factors relating to visual amenity.

The cover building over the upper furnace is nearing the end of its life; debate about its replacement highlights many of the problems of conserving monuments of this type. Ideally and given sufficient resources, it would be pertinent to protect all the structures at the Upper Works under a single cover structure. The practicality of erecting cover buildings over other monuments, particularly anything as large as the blast furnaces at Blists Hill, is limited, while a glass and steel cover building over the Hay Inclined Plane engine house would be too intrusive.

What of other methods of conservation? The ultimate form is backfilling, a cheap and simple solution which preserves the monument for future generations. Interpretation can be provided by recording the remains in advance of backfilling, or even reconstructing remains above the backfill, as was done on the Blists Hill blast furnaces charging platform. The few structures backfilled during the current project included the smuggler kiln at the Coalport Chinaworks, which survived as an unstable circular void, the outer ring of which was slowly collapsing. The kiln was recorded because most of the stoking pits survived. These were covered in a Terram membrane and an outer ring was reconstructed in new blue brick. Fill was then deposited flush with the surrounding floor surface. The boilers at the brick and tile works were cleared of loose debris and partially backfilled, although in retrospect, more substantial backfilling would have been beneficial.

During the 1970s, in the pioneering days of IGMT, major excavation was undertaken at Bedlam and Blists Hill furnaces to remove fill which had been deposited, or had fallen in front of them. The removal of this fill made the structures more unstable by removing the toe in front of them and causing them to rotate, necessitating the high-level anchors and ties of the 1990s. Exposure to the weather caused further superficial damage to the lower areas of the monuments. However, without this early excavation work, the two ironworks would be little known and little understood. In general, one should be wary of large scale excavation, whatever its benefit in terms of access and interpretation, without making long-term management plans.

In conclusion, the methods of conservation chosen are a balance between the importance of the monument, its value in terms of interpretation and accessibility, and the financial resources available. In the case of very significant monuments, such as the three blast furnace sites, it is important that they are accessible to the public. They also need to be preserved, the most effective method for long term survival being cover buildings, although not everybody will like their heritage hermetically sealed in this way. Second best is routine maintenance little and often, for which long-term funding must be available. For less important sites, or small areas of sites which are not prominent, backfilling is an ideal solution as long as the remains can be recorded first.

Reuse of buildings can also be a method of preservation, and this is nothing new in Ironbridge. The furnaces at Coalbrookdale were blown out in the early-19th century and incorporated within large foundry buildings until the early-20th century, helping to protect them for today. The Upper Forge was converted to a kibbling mill and stable by 1838. This has helped to preserve the building, in particular the engine house for the Boulton and Watt blowing engine. Industrial buildings were often constructed to serve short-term needs. Obsolescence would have been the fate of many without reuse.

Modern reuse can involve low, medium, or high intervention. The former Methodist chapel in Coalbrookdale underwent relatively minor repairs as part of this project and was then let out as a workshop. The internal fittings had been removed several decades previously, so the workshop makes use of an existing open space and makes no permanent impact upon the integrity of the building. This is a good example of low intervention reuse. The Upper Forge was converted for educational purposes (Fig 165). This is a combination of low and medium intervention, since internal partitions have been inserted into the former engine house along with toilets and services. The Museum of Iron in Coalbrookdale is a converted warehouse of 1838 (Fig 2). It is a large building which required all its contents to be removed before the repairs could proceed. Although the museum contains a café, shop, and services, the floors are otherwise open, and the character of the original building is retained. The repairs included the insertion of much structural steelwork, particularly to support the clock tower, and joist hangers for the joist ends. Although bold and clearly modern, this metalwork is sympathetic to the character of the building. No properties underwent high intervention conversion in parallel with this project, but a subsequent Heritage Lottery-funded scheme undertaken at the John Rose building in Coalport, involved its conversion to a youth hostel. Although high intervention in terms of the addition of partitions in formerly large open spaces, services, and health and safety features, many of the partitions could easily be removed in the long term if so required.

It is hard to imagine converting monuments such as blast furnaces or pottery kilns to alternative uses, but they clearly have strong cultural value as well as indirect economic value. Conservation of whole landscapes is also important economically as well as culturally. Dereliction can undermine the self esteem of communities, as happened in Ironbridge in the 1950s, leading to lack of investment and a spiral of decline. The work of the Telford Development Corporation and IGMT from the late 1960s has been instrumental in turning this situation around and imparting the Ironbridge Gorge with the status of World Heritage Site which it acquired in 1986. The conservation project undertaken in the 1990s can only help to retain this status.

Access, enhancement, and interpretation

By making the monuments more safe, the repairs programme has allowed the possibility of improved public access, whilst the increased understanding of the sites offers an opportunity for a fresh interpretation. Enhancement in this context mainly means the removal of unsightly modern fabric, which can cause damage due to its hardness, inflexibility, and lack of porosity. Such fabric was removed from the upper furnace and the Museum of Iron, but on other sites, it was generally outside the scope of the works. The upper furnace could be further enhanced by inserting transparent glass into the front of the cover building so that it can be viewed from a distance. At present, the building contains window glass which has a darkening effect (Fig 170).

The Upper Works is fully accessible and has been for many years. There are some interpretation panels inside the upper furnace cover building, but the site is interpreted much more comprehensively inside the Museum of Iron. The other scheduled monuments are currently not accessible because of safety considerations but they are clearly visible. Bedlam is surrounded by a fence but it is possible to walk around its perimeter (Fig 171). The monument is built against a hillside and has steep slopes and vertical falls. It is in an isolated location and is not staffed. However, consideration could be given to providing visitor access to the lower levels of the site, provided that the fragile interiors of the furnaces and wheel chamber are properly protected. Some enhancement was possible during the repairs project, such as covering up modern fabric and laying chippings over the concrete surface above the bellows room. Further work of this type could be undertaken, particularly removing the modern brickwork in the opening between the engine pit and wheel chamber, which gives a misleading impression of the original structure (Figs 72 and 73). Although there are still unsolved factors in the interpretation of Bedlam furnaces, there is enough knowledge to explain the extant structures, and effort should also be made to interpret the features which are hidden from view.

Similarly isolated and hazardous is the Hay Inclined Plane engine house. Proposals have been put forward to replace the temporary chestnut paling fence with more permanent metal railings,

Figure 171 Bedlam, photographed looking north west in 1995 after its repair. Public access to the monument will always have to be restricted on safety grounds.

though the fixing method needs careful consideration. The aim should be to allow the best visibility of the structure whilst ensuring public safety, while it may also be possible to provide a close-up viewing area immediately north of the extant brick structures. Enhancement of the dock walls should involve replacing cement pointing with lime mortar. The project has allowed significant new interpretations of the monument, both in terms of how it functioned and earlier phases for which there is little visible evidence. These could be interpreted by illustrated display panels.

An access scheme has also been proposed for Blists Hill blast furnaces. The aim is to allow access to the furnace bases at lower ground level, which will only be possible if repairs are undertaken concurrently. The furnace bases and vaulted tunnels were the only component of the site not repaired in the present project and they are in a poor state, despite repairs during the 1970s (Fig 91). The objective would be to consolidate the bases and lay walkways between them, which would bridge the tunnel access shafts. Access into the chambers below the charging platform would be relatively easy to arrange (Fig 95). Even if these chambers are not particularly significant relative to other parts of the monument, they would be impressive and allow the visitor a good view of the rest of the site. This scheme should be undertaken simultaneously with a full interpretation and the archaeology programme has resulted in the most extensive explanation to date.

The restoration works which were carried out at Blists Hill Brick and Tile Works in the 1970s and 1980s are generally in keeping with the original. There are some exceptions, mainly windows and small openings where it is difficult to see what the original fabric would have been. During the early days of the present project, the arched gables of drying shed 2 were reconstructed to the wrong profile (Fig 119). When works are next undertaken, they should be rebuilt to the correct semi-circular profiles.

Public access to the brick and tile works was provided in 1995 (Fig 172). Access is now available into drying shed 1 (Fig 118), and the eastern range of the clay preparation block, with a view into the western range and engine house. A more distant view is available from the opposite side of the canal. Interpretation panels within the accessible area explain clay-working and brick-making processes whilst there are exhibits in the drying shed. It is

Figure 172 The Blists Hill Brick and Tile Works photographed looking south across the yard to the clay preparation block in 1998, showing the path provided during access works in 1995.

hoped that access to the rest of the site can be provided in the future, but substantial funds will be required. This would be of significant interest to visitors and would allow a complete interpretation of the site. Any scheme of this kind would require comprehensive repair of the remaining structures (particularly the kilns) and their continual maintenance, and so would impart considerable conservation benefits.

Index

Illustrations are denoted by page numbers in *italics* or by *illus* where figures are scattered throughout the text.

COUNCIL FOR BRITISH ARCHAEOLOGY

Archaeology and Conservation in Ironbridge

The Ironbridge Gorge is the physical embodiment of the profound technological and social changes that underlie the Industrial Revolution of the 18th and 19th centuries. The Ironbridge Gorge Conservation Area, a World Heritage Site since 1986, spans both banks of the River Severn and encompasses the industrial monuments that represent such significant technological developments as the first use of coke of smelting iron ore in 1709 and the construction of the world's first significant cast-iron bridge in 1779.

A major recent repairs project has provided a much needed opportunity to reassess a number of the most important sites and attempt to understand them as integrated elements of a historically complex industrial landscape. Focusing on six of the key archaeological monuments of the gorge this volume brings together primary historical sources with the results of comprehensive survey of the sites to develop a uniquely pragmatic, yet theoretically informed approach to the study of standing archaeology as part of a conservation project.

As well as drawing valuable conclusions in their interpretations of the sites within the wider contexts of both the landscape and the period as a whole, the authors have provided a necessary methodological contribution to the study of the archaeology of the recent past, under the constraints of modern archaeological practice.

COUNCIL FOR BRITISH ARCHAEOLOGY • BOWES MORRELL HOUSE • 111 WALMGATE • YORK YO1 9W