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The International COLLIERIES STUDY

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1 INTRODUCTION

THIS IS THE MOST recent in a series of industry studies prepared for the World Heritage Secretariat of ICOMOS on behalf of TICCIH as part of the Global Strategy for the 1972 UNESCO World Heritage Convention, examining areas of the international heritage considered to be under-represented on the World Heritage List. It is not a list of the international collieries deemed to be most worthy of inscription on the World Heritage List: such examples are chosen by national governments that are States Party to the Convention and approved for inscription by the World Heritage Committee. Its primary aim is to define criteria of especial relevance for the selection of colliery monuments for nomination to the List and to provide international examples to which the criteria could be applied. These examples have not been confined to Europe, where so many historically significant collieries with fine buildings continue to exist, but include an internationally diverse range of examples.

The study originated with Stephen Hughes, Head of Survey at the Royal Commission on the Ancient and Historical Monuments of Wales at Aberystwyth, and Professor Dr. Rainer Slotta, Director of the German Mining Museum, Bochum. Both were involved in the preparation of nomination documents for the inscription of collieries on the World Heritage List and with published studies of the context of each. Big Pit Colliery at Blaenavon (United Kingdom) and Zollverein XII Colliery at Essen (Germany) were inscribed on the World Heritage List in December 2000 and December 2001, respectively at the meetings of the World Heritage Committee in Cairns (Australia) and Helsinki (Finland).

The draft structure of the study was discussed at the intermediate TICCIH conference on the Industrial Heritage of Mining and Iron Metallurgy held in Miskolc (Hungary) on 26 September 1999. The draft study document was discussed at a meeting of the Collieries Special Interest Group of TICCIH at Cardiff (United Kingdom) on 4 September 2000 with representatives of nine nationalities present. In October 2000 the study was also posted on a mining history discussion group (*mining-history@jiscmail*), with over 360 international members from twenty countries, for further comment. The completed study was approved by the TICCIH Board in the autumn of 2001 and forwarded to the World Heritage Secretariat of ICOMOS.

The evaluation criteria devised for the study are based on criteria i–iv in paragraph 24 of the *Operational Guidelines for the Implementation of the World Heritage Convention*, WHC/2/Revised January 1999: UNESCO). They could equally be used for any forthcoming study of non-ferrous metals mines for the Global Strategy. They classify mines for inscription on the World Heritage List as: a unique achievement; a masterpiece of the creative genius; to have exerted great influence on developments of technological importance; an outstanding example of a type of structure or feature which illustrates a significant stage of history or directly associated with economic or social developments of outstanding universal significance. Areas of significance within these criteria include technology, economy, social factors, landscapes, and documentation. The renewal of parts of functional structures over a period of time is accepted as part of the evolution of a working monument and does not exclude the monument from consideration for inscription on grounds of authenticity.

Stephen Hughes

2 THE DEFINITION OF A COLLIERY

A COLLIERY is a human-engineered mine for the extraction of coal. It may be of outstanding universal value from the point of view of history or technology, either intrinsically or as an exceptional example representative of this category of cultural property. It may be a monumental, or an integral component of a complex cultural landscape.

3 POSSIBLE CATEGORIES OF WORLD HERITAGE COLLIERY

INTERNATIONALLY SIGNIFICANT collieries might be considered for World Heritage Status by conforming to one of four types:

- Individual or groups of significant structures or monuments on colliery sites and adjoining colliery settlements;
- Large colliery complexes and adjoining coal-miners' settlements;
- Integrated industrial areas, either manufacturing or extractive, which contain collieries as an essential part of the industrial landscape. The existing World Heritage sites of the Ironbridge Gorge and Blaenavon, both in the United Kingdom, fall into this category.
- Colliery landscapes, some with associated by-product processing and colliery housing and worker settlement institutions.

4 GENERAL INTRODUCTION TO COAL-MINING HISTORY

COAL WAS WORKED in the Roman period but to what extent is a matter for further study. Many major European coalfields were in small-scale use again by the 13th and 14th centuries. Until the mid-16th century most manufacturing processes still used charcoal as a fuel and the demand for coal working remained on a modest scale.

By 1700 the world's first Industrial Revolution was gaining momentum in Great Britain, using coal as a basic fuel. Coal production there may have been the largest globally by 1550, when 200,000 tonnes were produced annually, and this had risen to about 3 million tonnes by 1700.² As the effects of the Industrial Revolution spread to the European continental homeland between 1785 and 1850 there was a great expansion in the coalfields of Saint-Etienne (France), Silesia (Prussia: now Poland), Wallonia (Belgium), and the Saarland and Ruhrgebiet (both in Germany). Despite this spread Britain remained the international centre of coal mining until *c* 1900: by 1850 Britain was producing over 50 million tonnes annually, the USA 8 million, Germany 6 million, and France 5 million.

In 1900 93% of total global energy consumption was supplied by coal and international production had reached some 740 million tonnes. By the early 20th century there was a fundamental re-adjustment in comparative national and regional outputs. From 1900 the United States of America overtook Britain consistently as the world's largest producer of coal, so that by 1912 it was producing some 485 million tonnes of coal annually; this was almost twice the production of Britain, which was producing some 264 million tonnes. Germany was catching up with British output and producing 172 million tonnes annually, while France was fourth with 39 million tonnes. Not far behind came Russia with 26 million tonnes and Belgium with 26 million tonnes. Asia was beginning to emerge as a significant producer in the 20th century, with Japanese coal production reaching 17 million tonnes in 1912.

In terms of the global influence of the coal trade Britain remained the key player in the early 20th century. It exported by sea no less than 68 million tonnes of coal, compared to the much lesser total of 28 million tonnes of sea-borne coal produced by the *rest of the world*. The balance of production between coalfields in Britain was also changing. The Great Northern Coalfield of the north-east of England had been the largest in Britain from before 1700 until 1912, sustained by the great demand for sea-borne coal from the empire metropolis of London. However, by 1913 British coal production had peaked; the vast demand for coal from the hugely increasing steamship fleets of the world and the rapidly industrializing Mediterranean area resulted in South Wales becoming the largest coalfield in Britain between 1913 and 1926 and the world's largest coal-exporting coalfield.

The World Energy Conference survey of energy resources (1974) showed that in the pre-1925 period three nations – the United States of America, Germany, and the United Kingdom – accounted for 80% of all coal and lignite (soft brown coal) mined up to that date.³ In that year those three countries accounted for 76% of world production and were the only countries producing over 100 million tonnes of coal a year. An additional fourteen countries, half of them outside Europe, were producing more than 10 million tonnes a year.

By the later 20th century the situation had changed completely. An additional four countries were producing over 100 million tonnes of coal a year by 1971. In 1976 the Soviet Union was the largest producer in the world, producing over 630 million tonnes annually, China had an output of 415 million tonnes, Poland 185 million tonnes, and Czechoslovakia 113 million tonnes.

In the last quarter of the 20th century Australia, South Africa, and India have become major producers.

In simplistic terms representative sites and landscapes of the most important international coal-mining industries might be expected to be found in Britain between 1700 and the early 20th century and in the USA, Germany, and Russia within the first half of the 20th century. However, the survival of coal monuments and landscapes of international importance is obviously partly dependent on the vagaries of permanence of initial building, the chance factors of survival, and the possible re-use of structures.

5 EVALUATION CRITERIA FOR THE STUDY

IT IS PROPOSED that a colliery site should be considered to be of outstanding international importance in relation to the following criteria (slightly adapted from criteria i–iv in paragraph 24 of the *Operational Guidelines for the Implementation of the World Heritage Convention*, WHC/2/Revised January 1999: UNESCO).

1 A unique achievement; a masterpiece of the creative genius

There are certain colliery complexes which are magnificent ensembles of buildings and machinery. Some collieries are outstanding examples of functional architecture and design.

2 To have exerted great influence on developments of technological importance

The first time a new technology is applied to civil engineering, mechanical engineering, or architecture is of particular significance to the history of mankind, depending upon how widely applicable and useful that particular innovation is. Collieries have historically been very important as the means of providing a basic fuel, allowing the evolution of developed societies with a high degree of economic and commercial interchange. The application of existing, or new, technologies to the evolution in sophistication of collieries' infrastructure is particularly significant in that process. Also significant is the process of technology transfer between countries and continents, particularly with regard to the ways in which this has significantly progressed the economic well-being of mankind and facilitated the development of sophisticated societies. Such arguments can be applied equally to individual colliery structures, to whole collieries, to large coal-mining landscapes with mining settlements and their institutions; and to integrated industrial areas such as the mining fields of metal-smelting works. However, the present condition of sites, structures, and buildings are obvious weighting factors in assessing the significance of such types of structure. It may well be that the present condition of the most significant sites as built does not warrant their designation as sites of world importance whereas sites nearby, or even at a distance, now represent more adequately an important stage in the evolution of world collieries.

3 An outstanding example of a type of a type of structure or feature which illustrates a significant stage of history

This can include colliery structures or complexes representative of the world's first Industrial Revolution as it spread from Britain to Belgium and the rest of the European continent at the end of the 18th and during the 19th century. Coal mines and their workers' settlements illustrating the spread of ideas and technology across the rest of the world are also significant: they illustrate how earlier concepts and engineering were adapted to suit local conditions and cultures.

4 Directly associated with economic or social developments of outstanding universal significance

The economic developments associated with the Industrial Revolution have already been discussed. Industrial communities, among which those associated with coal mining were prominent, led to many innovatory ideas in social engineering and evolution. Better housing, social clubs and institutions, and wider educational provision were all fostered in these new concentrations of population and led to the foundation of modern society.

5 Authenticity in functional structures

Like many other types of industrial archaeological feature, collieries are important because of their functional use. However, this functional use itself will mean that parts of a mechanism or infrastructure have to be maintained, modified, or renewed in order to maintain the primary function of an operational colliery. That this concept of renewal will not result in the automatic rejection of a site as being of world importance has already been accepted by the World Heritage Committee at its meeting on authenticity in Nara (Japan). It was also recognised in the 1994 and 1996 International Canal Heritage study that a significant element of the heritage of an industrial monument is its evolution over the course of time.

6 The level of existing legal protection and management

Mechanisms are not considered of great importance in this advisory study as States Parties can introduce such mechanisms prior to any formal intended application for World Heritage status. It is, moreover, explicitly stated in the *Operational Guidelines* that ‘Nominations of immovable property which are likely to become movable will not be considered’ (paragraph 25).

6 AREAS AND VALUES OF SIGNIFICANCE WITHIN THE COLLIERY HERITAGE CRITERIA

6.1 Technology

The following are the areas of technology which may be of significance:

- The engineering structures of the colliery with reference to comparative structural features in other areas of architecture and technology;
- The development of the sophistication of constructional methods;
- The transfer of technologies.

6.2 Economy

The production of coal as a basic fuel has been fundamental to global economic development. Collieries are of continuing economic use despite the growing importance of alternative fuels such as oil, gas, nuclear power, and solar, wind, and water power. The following factors are important:

- Nation building;
- Industrial development;
- Generation of wealth;
- Development of engineering skills applied to other areas and industries.

6.3 Social factors

The building of collieries had social consequences:

- The redistribution of wealth with social and cultural results;
- The movement of people and the interaction of cultural groups.

6.4 Landscapes

Such large-scale works had an impact on the natural landscape. There was also the generation of new industrial settlement patterns from rural dispersed populations to the creation of urban nuclei.

Note: There are potentially some additional areas of significance associated with classifications of historic towns and natural criteria.

6.5 Documentation

The understanding of a monument's significance can often only come from an adequately preserved corpus of contemporary documentation. This includes design drawings, plans, and photographs as well as documentary textual references.

Modern documentation enhancing the value of the monument, complex, or landscape can arise from modern survey and archaeological and architectural analysis. Oral history can help to foster the understanding of the social architecture and institutions of worker communities.

7 DEFINITION OF THE FUNCTIONAL ELEMENTS OF A COLLIERY AND THEIR EVOLUTION

7.1 The planning and design of collieries

TO AN EXTENT the form and scope for design was determined by the number of constituent parts of a colliery in any one period. With time collieries became larger, with more sophisticated and diverse constituent parts. It was inevitable that long-established collieries should assume a rather random plan as they became somewhat disparate assemblages of structures from a range of different periods.

Already in 18th century Britain collieries were beginning to be fairly large and were producing coal either for export or for use in the growing manufacturing and smelting sectors. The prime function of a colliery was to produce coal in the cheapest and most efficient manner. Those colliery proprietors who were landowners or metal-works proprietors had sufficient capital to run collieries but were most concerned to fund their considerable functional infrastructure. However, newly built collieries could be designed and arranged symmetrically. Thus one British colliery erected in 1767 by a copper-smelting concern had a circular walled horse-engine walk interrupted at equidistant intervals by attached stores ('a warehouse'), a colliers' lodge, and stables. To the north of it in 1768 were designed a formal layout of five houses for 'head colliers.'

As already discussed, the emergence of steam and subsequently of electrical power gave first permanency and then a new common focus to the planning of collieries on a much larger scale than hitherto.

7.2 Collieries underground

Underground mining was the predominant type of coal production until the huge mechanical and capital resources of the later 20th century made it feasible to lift deep areas of overburden and to work coal by opencast methods on a very extensive scale which in many regions is supplanting underground mining.

An actual underground mine is the extractive part of any colliery, and obviously the surface installations only exist to aid the production and processing of the mineral produced.

Recent excavation of early mine sites has shown the extent of their sophistication. In the 15th century in the English Midlands mines had developed gallery systems and rudimentary systems of ventilation. By the early 19th century the largest coal-mines had many miles of galleries.

Substantial lined shafts and galleries existed in all mines and increased in scale and complexity with period. Vaulted shaft-bottom galleries led into an ever-expanding network of main haulage ways equipped with haulage engines.

There are, of course, much greater difficulties of preservation with underground remains and with water-pumping unless gravity drainage is possible.

7.3 Winding coal

Horse- and waterwheel-powered winding apparatus was pioneered in non-ferrous mines, particularly the large developed installations in German-speaking central Europe. Waterwheel winding spread to the Great Northern Coalfield of Britain in the 17th century and horse engines of varying sophistication were common by the 18th century. The abundance of water in upland Wales also encouraged the use of water-balance apparatus. The spread of steam and then electric winding is discussed elsewhere in this document.

7.4 Colliery shafthead frames and towers

The growing scale of these features, so much a popular icon of coal mining, is largely due to the depth of the shaft and the type and form of motive-power employed.

First of all manual power was used for winding on well-head type windlasses, and such two-man windlasses were in common use by the 18th century

More sophisticated apparatus had to be elevated to a higher level and kept clear of the shafthead. Some of the types of high supports for winding pulleys are discussed in the relevant sections.

7.5 Water pumping

Water- and steam-powered pumps and their housing have already been mentioned.

7.6 Mine ventilation

Coal and oil-shale workings require even more ventilation than mines for other ores or minerals because inflammable gases such as methane are often present. In shallow mines carbon dioxide occurs naturally and can cause an oxygen deficiency. The largest coal production in the 17th century was in British mines and effective ways of circulating the air were developed here. Two air paths were essential for each working place: one for air entry and one for it to leave. Two shafts were often used, and to aid the process buckets containing fire were often suspended in one of the shafts.

In the 19th century fire buckets were often replaced by permanent furnaces. On the surface these took the form of distinctive chimneys, and some continued in use until about 1950.

In the 19th century Britain was still the largest coal producer in the world, and in the early part of the century mechanical wind pumps were developed by engineers such as John Buddle. From the 1830s large-diameter steam-driven fans with distinctive housings were adopted in the larger mines.

By 1900 the USA had overtaken Britain as the largest coal producer, and Germany and France were also becoming large-scale producers. New types of smaller-diameter electrically driven centrifugal and axial-flow fans were developed.

7.7 The use of compressed air

There were problems in using steam underground and so compressed air was developed as an alternative. It was first used successfully in France in 1845 when it was transmitted a distance of 228.45m (750ft) in a coal mine. Its use internationally was rapid and in 1849 the pneumatic rock-drill was invented in the USA.

7.8 Preparation of coal for sale

Prior to the early 19th century little surface treatment was necessary as quality was maintained by selective working by hand in the mine itself. Simple timber-built screens were built on the surface and hand-picking was practised.

After *c* 1880 more elaborate and mechanized jigging screens and picking belts were introduced and coal washers were constructed to clean coal. Coal washeries were introduced at about the same time to clean coal. To facilitate the most effective flow of materials, screens and washing facilities were usually built on stilts so that railway wagons or road vehicles could be loaded below.

Rather different in form and purpose were the huge coal breakers developed in the United States for the processing of hard anthracite coal. These were developed in the period of the late 19th century as that country became the largest coal producer in the world. They somewhat resembled non-ferrous mines processing floors but were much higher and extended from the tops of headframes down to discharge points over railroad tracks. The cladding of these huge buildings tended to be of timber.

7.9 Workshops and stores

Stores and workshops would have been required from the days of the earliest collieries, and certainly by the 18th century storehouses are shown on colliery plans. By the early 19th century even quite small collieries had one or two smithies with a carpenter's shop. As the size and sophistication of collieries increased in the 19th and 20th centuries so did the number

of functional buildings designed to serve specialist purposes (*see* Figure A). Subsidiary buildings often included stables, fitting shops, sawmills, electricians' shops, lamp rooms, explosives' magazines, and locomotive sheds.

7.10 Colliery offices

By the early 19th century colliery managers had offices, often in their on-site houses. As 19th century collieries became larger so did their administrative organization, and by the early 20th century substantial office blocks were being built on colliery sites. For a sizeable workforce of 3000 there might at least be a general manager, an engineer, and a surveyor assisted by draughtsmen and clerks.⁴

7.11 Pithead baths

Some pithead baths were available to miners in Germany, France, and Belgium from 1880 and were in common use there from the beginning of the 20th century, when legislation in Germany ensured their use. Legislation in Britain followed in 1911. Early British baths were copied from mainland European practice, and from the 1930s bath buildings in the modernist style were based on the work of the Dutch architect W M Dudok. Other welfare buildings such as medical facilities and canteens were based in bath buildings.

8 TECHNOLOGY TRANSFER OR INDIGENOUS DEVELOPMENT

THE IDEA OF A STRUCTURE having an international, or indeed global, influence is obviously central to it being viewed as of relevance to the heritage of a large part of mankind. However, initially, and before the end of the 18th century, such a process of diffusion of knowledge is difficult to document. A single very large coal industry was confined to one country in that period (the United Kingdom) and many fundamental innovations in the industry were made there. Archaeological excavation has now revealed the existence of developed mines with galleries in 15th century England, but how widespread such features were internationally in this period is unknown.⁵ By the end of the 18th century British collieries often had many miles of underground galleries.

Large-scale water-powered non-ferrous mining technology with long watercourses and reversible waterwheels had been developed by German-speaking miners in central Europe by the 16th century and widely publicized internationally by the publication of Georgius Agricola's *De Re Metallica*.⁶ The precise metamorphosis of the examples of the machinery illustrated there into the numerous 'coal mills' found on the 17th century Great Northern Coalfield of (north-eastern) England or in the many 18th century waterwheels used in other British coalfields is impossible to establish. The lighter duty of winding on the extensive central European non-ferrous mines was carried out by elaborate horse-powered winding apparatus with roofed circular horse-walks. Edward I of England had imported German mining expertise to Wales in the 13th century, and from the 16th century German-speaking miners were brought in in large numbers to many non-ferrous mines. There must have been some transfer of skills into the rather different practices of coal mining in Britain but these are difficult to quantify. Rather interestingly, horse-engine ('horse-gin') construction in Britain was generally less elaborate than in Germany and the machinery and their human and animal operatives were not given the shelter of a roof. This emphasis on the functionality of British practice without elaboration of architecture, later followed in North American practice, seems to be a key difference from German mining cultural practice right into the 20th century.

New steam-powered water-pumping technology was evolved at the end of the 17th century and in the early 18th century, to be followed by steam-powered winding technology at the end of the 18th century. Pumping engines were integral with their large masonry housing and pivoted on a thick wall, but others of the growing number of elements in a colliery could be executed in much more temporary materials. Colliery surface layouts up to the mid 19th century in Britain, even on the biggest mines of the Great Northern Coalfield (*see* Figure B), were dominated by simply designed tall masonry beam-engine houses with elevated winding gear on spindly timber supports leading to irregularly profiled timber-clad shaftheads. The layouts were completed by timber-framed and clad screen buildings elevated over colliery railways and stone ventilation chimneys capped by timber wind-vanes.⁷ Smaller stone-built sheds huddled around these might include boiler houses, offices, workshops, and, often in larger collieries, coking ovens.⁸ Once again the prime design motive was effective production enhancement in any one period and not aesthetic considerations. In the later 19th century many individual colliery buildings and some colliery layouts were given a more permanent

form in both in Britain and on mainland Europe. In Britain and in the United States of America this still often meant the simple and functional ‘industrial vernacular style’ with round-headed windows and rock-faced masonry in stone-building areas. In continental Europe a long cultural tradition of the ornamentation of large buildings that transferred to the industrial sector was much in evidence in elaborate buildings and layouts using Classical and Gothic Revival styles.

The most striking example of a great expansion in elaborate colliery architecture was in the sinking of the many deep coal mines between *c* 1855 and *c* 1880 in the Ruhrgebiet area of Germany, leading to its becoming Europe’s largest and most intensively developed industrial area. The pulley wheels (sheaves) over the shaft were not supported by timber or iron headframes but by high brickwork Malakoff Towers (*see* Figure C) which lent themselves to elaboration better than their flimsier predecessors and the high costs of construction of which were met by banking capital from the wealthy bankers of Cologne.⁹ The Malakoff Tower became associated with the innovative Koepe winding system which was developed by the Krupp Company in the surviving Malakoff Tower at the Hannover Pit in Bochum. This used continuous winding-cables held by narrow pulleys positioned at the top of the tower and foot of the shaft, dispensing with the wide twin-cable drums that had characterized earlier practice. The use of both Malakoff Towers and of Koepe winding spread widely in mainland Europe.

In some of the British coalfields, such as the South Wales coalfield (then serving the needs of the largest copper- and iron-smelting works in the world), there was a separate and earlier development of masonry shafthead towers, but these were smaller and constructed of unadorned rubble masonry.¹⁰ Later 19th century stone and brick shafthead towers were built at No 3 shaft at Seaham Colliery (Great Northern Coalfield) and at the Winstanley Shaft (extant) at Chatterley Whitfield Colliery in Midlands England. Both were exceptionally plain but the latter is seen as being of ‘German’ type; it is, however, much plainer and has obliquely sloping side-buttresses of a type not seen on the much more elaborate Malakoff Towers in Germany. The Koepe winding with narrow friction pulleys was hardly used in Britain before nationalization in 1947, when it was widely adopted: the surviving Koepe winder of 1923, set on top of a plain tapering concrete tower, at the former Murton Colliery, was only the second built in the Great Northern Coalfield.¹¹

Colliery surface layouts had originally been given substantial permanence by the need to give steam engines considerable holding structures. In the 19th century there was a growth in the number of ancillary structures, but it was the switch from steam to electrical technology that provided a spur for the reorganization and regularization of new colliery planning. In Britain most large collieries had been established for a very long time and were being continually modernized and altered as the need arose. By 1900 the dominant area in the growth of the coal industry in Europe was the Ruhr, and it was here that a new concept in the surface planning of a mine was evolved.

Construction of the colliery yard of Zollern 2–4 at Dortmund began in 1900–2 using a regular layout on a new site and employing Historicist architecture. By 1902 it had been decided to build the first common engine hall, or machine house (*see* Figure D), into which all the generators, compressors, and winders were inserted by completion of the housing in 1904 (its 1904 electric winder is the oldest in the world).¹² It was also one of the first colliery buildings to be elaborately ornamented in a new style of architecture (in this case *Art Nouveau*) rather

than being finished in decoration derived from Classical or Gothic Revival sources. Its design concepts seem to have been influential internationally almost immediately.

At this time there was a great boom in the South Wales coalfield, prompted by the large increase in demand for coal for steamships, which made the coalfield Britain's largest in 1913 (the year of maximum production for British coal). The coalfield also became the largest coal-exporting area in the world. Completely new colliery layouts were being laid out to meet this boom. Only two years after the completion of the engine hall at Dortmund one was being built by the colliery engineer and architect George Hann at Penallta (1906–9) in South Wales (Hann may have been of German extraction).¹³ However, one difference between the two sites was that Hann considered the relative merits of steam and electrical power and decided to adopt the former: the very long Penallta engine hall (*see* Figure E) included steam engines, winders, compressors, and a ventilating fan. In 1910–14 the new Britannia Colliery nearby was given a similar engine hall and was all-electric, with much of the electricity generated by waste gases from the engines at Penallta. Other engine halls of the same type followed in quick succession in this fast-expanding coalfield. Most are in very utilitarian style in local rubble-stone with some Classical Revival detailing.

The same steam-coal boom in Wales produced a noteworthy attempt at systematic colliery planning in a colliery grouped on two hillside terraces with matching twin engine houses flanking twin headframes and culminating in a tall central chimney. This Crumlin Navigation Colliery (1907-11) now unfortunately lacks its headframes but retains buildings designed in a basic Classical style executed in rich polychrome brickwork. The design concept of a colliery vista terminated by a tall chimney was one taken up in the design of the Zollverein XII shafthead at Essen in the Ruhr.

Zollverein XII (1928–32) is remarkable for the quality of its buildings designed in strict International Modernist style (*see* Figure F) set amongst lawns and laid out on a grid with two axes, one culminating in a giant A-frame headframe straddling a shafthead tower and the second axis culminating in the boiler-house tower with its central chimney. Functionally it was designed to rationalize the infrastructure of the existing Zollverein Colliery, which already had eleven dispersed shafts, and to concentrate coal winding at this new central installation. The colliery was built as Germany became the largest coal producer in Europe and was greatly influential in terms of design and operation. It was inscribed on the World Heritage List in 2001.

The influence of Zollverein XII is clear in the large mining complex at Faulquemont (near St Avoild) in France which was constructed in a similar Modernist style between 1933 and 1935. Neat square blocks were set amongst lawns flanked a central avenue aligned on the power-house chimney (the complex has mostly been demolished). Somewhat diluted versions of the symmetrically planned mine, but spaced out and lacking visual foci, were built in England at about the same time at Coventry (demolished) and Houghton Main Collieries.¹⁴ Nationalization in Britain later freed resources for combined mine rationalization projects such as Zollverein. One of the first built in Britain (1948–53) was Maerdy (Mardy) Colliery in the Rhondda Valley in South Wales, which was laid out in closely grouped functional blocks on a grid-plan but lacking the visual focus planned at Zollverein. Rather similar were the new mines of the 1950s built on the South Wales anthracite coalfield at Abernant and Cynheidre.

What is more difficult to establish is any connection in planning through to the American coal industry, which was the world's largest by 1900. German and other European miners did emigrate there but the nearest European precedents to the giant anthracite breakers of north-eastern Pennsylvania are probably non-ferrous mine processing floors.

Some aspects of the design of colliers' housing can also be seen to have an international spread. The 'cluster house' was a group of four houses set in each corner of a single block, of approximately square plan and set in a spacious garden. Such houses were usually provided for supervisory or skilled workers within a textile factory. The type originated in the England of the 1790s, with surviving examples in the Derwent Valley of Derbyshire at Belper and Darley Abbey (both inscribed on the World Heritage List in 2001). It was later used in the Cité Ouvrière in Mulhouse (France) in the 1850s and from there spread to the Ruhrgebiet. Examples can be seen in the housing estates surrounding the Zollverein Colliery.¹⁵

9 THE CRITERIA APPLIED TO MAJOR SITES AND MONUMENTS

9.1 Individually significant structures or monuments on colliery sites

Case 1: Worsley Canal Mines, United Kingdom

With the contiguous Bridgewater Canal this was considered by contemporaries to be (and indeed is) a founding monument of the world's first Industrial Revolution. The mines supplied the affordable coal that allowed the steam-powered textile mills of Manchester to make it the cotton-spinning capital of the world, using cotton from North America, Egypt, and the rest of the world.

The building of James Brindley's economically very successful Bridgewater Canal in 1759–61 had a profound influence on nine decades of canal building in Europe and North America. The 11.7km (7.27 miles) long canal was merely an extension of what were eventually 67.5km (42 miles) of navigable coal-mining tunnels on four different levels. This use of mine drainage to provide a means of underground and surface transport was widely copied in both Britain and in mainland Europe, where the published work of 'industrial spies' describing their visits underground made the Worsley Mines world famous.

The earliest mention of coal mining at Worsley was in 1376, and in the mid 17th century construction was begun of the first of three fairly shallow colliery-drainage tunnels that were between 1000 and 1700 yards (915–1554m) long.¹⁶ The much deeper twin navigable (still watered) entrances to the coal mines of 1759–61 (*see* Figure G) are set in the base of a high quarried sandstone cliff with a conserved canal basin at the entrance. Nearby are several rows of 18th century brick-built workers houses which surround the former workshops of the colliery and canal complex.

The tunnels continued to be maintained for mine drainage purposes until 1968; the entrance is designated an Ancient Monument and has been conserved. One of the most striking monuments inside is the inclined plane of 1795–96, which links canals at two levels and was drawn by a French 'industrial spy' soon after construction. The main mining level canal ran parallel to a fault and the many coal seams it intersected were each served by two branch waterways following the seam outcrop at that level. The main level had an elliptical arched top and half its depth was flooded as a canal. Spoil from the colliery helped to build the embankments on the Bridgewater Canal and was also taken by a special canal branch to start the reclamation of the nearby bog of Chat Moss. The beginning of complicated junctions, many vaulted in brick, was started in 1771 when a second parallel entrance tunnel was built that converges with the first some 500 yards (460m) inside. An upper canal was created from 1773 by widening the old 'Massey Sough' drainage tunnel that had been begun in 1729 and which was eventually 2.8km (1¾ miles) long.

Case 2: Le Grand-Hornu, Belgium

Le Grand-Hornu is important for retaining an early planned layout of the elements of a colliery complex. It is situated in the Borinage area of Wallonia, Belgium, the first area of the European mainland to be industrialized as the Industrial Revolution spread across the globe from Britain. Coal from the area was widely used in northern France as well as Belgium. The French coal merchant Henri de Gorge married into the rich wholesale merchant family of Eugénie Legrand of Lille.¹⁷ He acquired Hornu Colliery in 1810 and combined with the socially idealistic architect Bruno Renard in planning a complete coal-mining township between 1816 and 1835.¹⁸ By 1870–1921 there were some 2300 workers and 250,000t of coal were produced annually.

The Neo-Classical central complex comprises two grand courtyards which have now been mostly conserved. The pedimented triple-arched portal leads through the 100m long entrance façade with its hipped-roof corner pavilions into the entrance court, which housed stables, vehicle sheds, and hay and straw stores. A second gateway led through to a large arcaded elliptical central court which has high-vaulted engineering workshops for constructing steam engines (1831) facing a pedimented office block with cupola. The cathedral-like three-aisled seven-bay workshops included a foundry and an assembly shop. The two semicircular ends of this great enclosure are terminated by continuous curved arcades that once fronted other small workshops, for garaging a fire-engine, and iron, oil, and pattern stores.¹⁹

Surrounding these former workshops and offices are some 425 workers' houses, providing homes for some 2500 people (*see* Figure H) which were exceptionally comfortable for the period and were set in a rectilinear layout of paved roads flanked by pavements. Each collier's house had a communal room, a kitchen, and a bedroom on the ground floor with three bedrooms upstairs. In the rear garden were a shed and toilet. A well and oven were provided communally for every ten houses. The settlement is ornamented by two squares: the Place Verte, which formerly had a bandstand where the town band gave concerts twice a year in the summer, and the Place Saint-Henri facing the original de Gorge family residence. A school, library, baths, a ballroom, and eventually a hospital (the latter now demolished) were also added to this colliery settlement, which had been created on enlightened social lines.

The Grand-Hornu Colliery itself closed in 1954 and most of the functional surface elements of the shaftheads have been demolished. However, the workshops, stables, and offices together with the workers' settlement still form a complex of international importance.

Case 3: Ruhr Malakoff Towers, Germany

Thirteen tall masonry shafthead Malakoff towers, built to contain colliery winding gear in the second half of the 19th century, survive in the Ruhr and were influential internationally both as types of structures and as housings for the innovative Koepe system of winding. They formed the central elements of the well planned large complexes of substantial well designed buildings that were the vehicle for the rapid rise of the Ruhr as one of the most productive deep mining coalfields in the world. These impressive towers are up to 30m (100ft) in height with wall thicknesses up to 2.5m (8ft). Adjacent buildings contained winding and pumping engines at right-angles to or in line with the towers. The heights of the towers increased as coal pits became deeper and their appearance became more decorative, with the application of castellated architecture. Corner towers with separate staircases were added as fire escapes and steel headframes were often erected in, or on top of, Malakoff Towers. The towers were built in some numbers in the Saarland (where none remain) and in Upper Silesia.²⁰

The oldest of the Malakoff Towers is that at the Carl Pit in Essen-Altenessen of 1856–61. The influential Koepe system of winding with a continuous cable was developed at the Hannover Pit in Bochum, where the tower over Shaft 1 is preserved with a steam winding-engine of 1893 still preserved in the engine-house alongside.²¹

9.2 Large colliery complexes

Case 4: Chatterley-Whitfield Colliery, United Kingdom

This colliery is important for being the only large 19th century colliery surface layout to remain intact in England and as a representative of the collieries that were the world's largest at that time. It achieved fame as one of the first mines to produce over 1 million tonnes annually. The multi-shaft layout and the incremental growth of the surface buildings and buildings are characteristic of 19th century collieries in Britain.

The Platt Shaft, the first of an eventual six, was sunk in 1843. Latterly electrical power was used in the colliery, but the horizontal twin-cylinder steam winding-engine of 1914 at the Hesketh Shaft remains intact with 914.4mm (36in) diameter cylinders and a 6.096m (20ft) diameter winding-drum in a large engine house.²² Elsewhere on the site are the Institute, Middle, Engine, and Winstanley shafts: the steel headframes over the Hesketh, Institute, and Platt shafts are the standard type of British headframe evolved in the late 19th century.²³

By contrast, the headgear of the Winstanley Pit is carried on a tall masonry tower which has been described as of German type: it is seen as a plainer version of the elaborate Malakoff Towers but without Koepe continuous winding-gear.

Case 5: Zollern 2–4 Colliery, Germany

This complex at Dortmund in Germany is particularly important for representing a complete rethink in the planning and rationalization of collieries. In a deliberate act Emil Kirdorf, the then director-general of Gelsenkirchener Bergwerks AG, created a model colliery layout merging the disparate engine houses into one common engine hall. That process was facilitated by the new energy source of electricity that was provided to replace the earlier universal use of coal.

The original machinery installed in the Dortmund engine hall has mostly survived: most importantly the world's oldest *electric* winding-engine dating from 1904 remains *in situ*, as do the generators, compressor, and converters. This concentration of a colliery's machines in one engine hall (or machine house) was of international importance and can be demonstrated to have been copied internationally.

The engine hall is of some architectural importance as an outstanding example of the new international *Art Nouveau* (known as *Jugendstil* in Germany) architecture. The buildings in the colliery yard area were built by the architect Paul Knobbe between 1900 and 1904 in the Historicist architecture that had been traditional in grander colliery layouts up to that period. The industrialist Paul Knobbe had seen the pavilions built by the structural engineer Reinhold Krohn and the architect Bruno Möhring at the Düsseldorf Exhibition in 1902 and subsequently commissioned them to build an engine hall with a steel framework

incorporating glass and brick. Möhring designed the main portal in the form of a shell on the outside and on the inside as a vine arbour. Panes of glass in violet, green, and blue light interior idiosyncratic features such as those in the electrical control centre. A brass clock hangs from the ceiling while the fittings themselves were inset into the marble walls between Egyptian-style *Art Nouveau* portals and pilasters. Möhring took his inspiration for the bright green external paintwork used on the steel framework of the machine house from the entrances to the Paris Métro designed by the French architect Hector Guimard.²⁴

The original headframes to the two shafts were to the north and south of the engine hall and were demolished following closure, but they have been replaced by contemporary headframes brought in from Gelsenkirchen and Herne Collieries. The demolished shafthead building from the winding shaft has been replaced by a replica. The washery and neighbouring coke works have also been demolished.

All the buildings were laid out on a regular grid. The approach road from the attached colliery workers' settlement was flanked by trees. The colliery entrance was flanked by two brick buildings of 1902: the gatehouse and first-aid station. To the north are the carpenter's shop, blacksmiths' forge, fitting shop, stables, outbuildings, sheds, coachman's rooms, and the fire-fighting equipment. To the south are the former wages room, the workers' baths, magazines, the lamp room, and rooms for the caretaker, shift foreman, and the young miners in one large building.

9.3 Colliery landscapes

Case 6: Zeche Zollverein (Colliery), Germany

This large colliery at Essen in the Ruhr mining district of Germany eventually comprised twelve shafts on five main sites: four shafts and a coke works remain on immediately adjacent sites by Zollverein XII. It is remarkable for the quality of the buildings and the layout of the shafthead of Zollverein XII, which was designed as the central shaft of the complex in 1928–32 at a time when German coal production was becoming the largest in Europe.²⁵

The importance of the complex is enhanced by the survival of parts of the earlier pits of the colliery and by the extensive colliery workers' housing which surrounds the cluster of shaftheads. Zollverein XII is a fine piece of International Modernist functional architecture designed by the specialist colliery and industrial architects Martin Kremmer and Fritz Schupp. The adjacent coke works, which had been intended as part of the original scheme, was completed by Fritz Schupp in 1958-61.

The layout of the Zollverein XII pithead is a grid with the road access based on two axes flanked by buildings and lawns (the 'Westphalian Style') and terminated by two impressive and centrally aligned engineering features. One is the great winding-frame (supported by four symmetrical inclined struts) with Koepe winding over the tall brown-brick tower of the shafthead and the other is the central tower and tall chimney of the boiler house. Most of the machinery of the colliery has been conserved intact among a successful programme of re-use. All surface buildings have been retained including the washery.

The Zollverein complex was producing over 1,000,000t by 1890 and about 2,300,000t by 1890 and the workforce rose from 2000 to 6526 people. By 1914 architects were involved in the design of 543 workers' houses.

In 1926 the Zollverein Pits became part of Europe's largest mining complex as part of the new steel/coal combine Vereinigte Stahlwerke AG. This large group instituted a rationalization programme based on the construction of a small number of pits with high outputs. Zollverein XII was one of these. In 1932 and 1934–49 the production of the Zollverein Colliery was the largest in the Ruhr and in 1937 production peaked at a maximum output of 3,588,000t. In the 1950s there was a change to skip winding at Zollverein XII and in 1957 and 1972 the shaft was deepened to an eventual 1005m. In 1986 the whole of the Zollverein Colliery closed except for pumping at Zeche (Shaft) XII. The coke works closed in 1993.

The re-use of the Zeche XII buildings has retained much of the plant intact, including a low-pressure compressor, a turbo compressor, a boiler, and the washery.

The industrial cultural landscape of the Zollverein Colliery was nominated as a UNESCO World Heritage site, comprising everything within the boundary of the whole Zollverein colliery as it operated from 1847 to 1986. This included the several estates of extensive colliery housing that were constructed from 1847 onwards, including interesting social experiments such as the 'Pestalozzi Villages' built from 1953 for young miners living with married couples who acted as surrogate parents (*see* Figure I). The predominant housing type on the other extensive estates were buildings subdivided into four, each apartment provided with a generous plot of about 640m² so that vegetables could be grown.²⁶ In the event only the industrial installations of Zollverein were inscribed on the List, but the surrounding estates were included in the buffer zone within which there are constraints on construction activities that might have an adverse impact on the World Heritage site.

Two of the four earlier shafthead complexes of the Zollverein Mine (two to three shafts each) retain a more eclectic mix of structures and machinery, including some earlier structures.

The shafthead complex of Zollverein shafts I, II, and VIII are sited immediately next to the shafthead of Zollverein XII and the Zollverein coking plant. When Zollverein XII was built it was used solely for winding coal, the miners entering and leaving via shafts I and II. Zollverein I, sunk in 1847, has a brick winding-engine house of 1903 (designed by the architect Fuller) capped by a barrel-shaped roof and was re-equipped with a 2860kW electric winding-engine in 1957. The adjoining Zollverein II of 1847, deepened to 1005m, is surmounted by a tertiary enclosed steelwork tower capped by a 2000kW Koepe winding engine of 1950. The tower was designed in 1950 by the colliery architect Fritz Schupp and was moved from a colliery at Bochum to replace a 1923 headframe over shaft II in 1964–65. The common engine hall of 1903, with its twin barrel-shaped roofs and round-headed windows, is part of the same layout as the shaft I winding-house and originally contained a steam-turbine generator and a compressor and fan. A separate fan-house of 1917 was re-equipped with an axial electric fan in 1964 and was designed by the architect Stolze, as were the engine shed (1921), the stores (1922), and the colliery baths (1906) with its barrel-shaped roof. The oldest building on the site was designed in the same Classical Revival style as the original Malakoff Towers (demolished): it was the two-storey hipped-roof colliery offices of 1878 which were converted to office workers' housing when New Neo-Baroque offices were

built by Stolze in 1906. Adjacent to the original offices is a colliery manager's house built in matching style.

Zollverein III/VII were sunk in 1881 but were reduced in importance and partly demolished after the new central winding-shaft at Zollverein XII was opened in 1932. Remaining is the headframe of Zollverein X, which was added in 1913. The adjoining twin winding-engine houses and converter were built as a three-aisled structure in 1913–20. A 741kW electric winder of 1920 and contemporary converter remain *in situ*. An engine hall of 1913–17, partly demolished in 1952, contains a crane of 1918 and a turbo compressor of 1952.

Case 7: The Scranton Anthracite Mining Landscape

The emergence of the United States of America as the world's largest producer of coal at the end of the 19th century was achieved with strictly functional colliery layouts, often of timber, that have not largely survived in an intact state. However, in the important coal-mining state of Pennsylvania, the Scranton Anthracite Museum administers the two sites. Pioneer Coal Mine Tunnel is 427m (1400ft) long and retains working areas on a steeply pitched seam. The tunnel is accessible by a mine railway for the public and outside a steam locomotive is used to carry visitors along an old coal-mines railway to view old strip (ie opencast) mines. The Eckley Anthracite Village was built as a coal company township in 1854–61 with 54 buildings: four were added later.²⁷

Case 8: The Sorachi Coal-mining Landscape, Hokkaido, Japan

By 1910 Japan was the biggest coal producer in Asia.²⁸ The industry's production had grown almost fourfold by 1940, when national production was 56,313,000t. A second peak was achieved in the 1960s, but after 1966 national production fell below 50,000,000t and has been in continual decline ever since. There are considerable colliery buildings and settlements remaining in the largest Japanese coalfield in the Sorachi District of the northern island of Hokkaido; they show a mix of the adaptation of UK, German, and American coal-mining technology and the indigenous development of housing and settlement types.²⁹ In the 1930s coal production at the Hokkaido coal mines attained 22% of the Japanese national total and in the 1950s it represented 37–60%. In 1998 the Sorachi Regional Government started a project to document the considerable heritage of the colliery settlements and associated mines and to found a large eco-museum.

Particular local conditions determined the particular characteristics of the Hokkaido industry. The very inclined, deep (more than 600m) and thin (less than 1m) coal seams led to the use of relatively few large shafts with considerable washeries. The large amounts of rock waste led to the characteristic landscape of waste tips over 150m in height. Very cold winter conditions compelled most Hokkaido coal-mines to have large steam-driven electrical generation stations. The high levels of methane in the mines encouraged the use of high-pressure water cutting at the coalface, as in the Kami-Sunagawa, Sumitomo-Akabira, and Haboro-Chikubetu Coalmines.

Yubari Tanko (1890–1977), with an annual production of 2,000,000t, was the largest colliery in Japan (see Figure J) and its workers settlement of Yubari City housed a population of 110,000. The biggest shafthead at *Yubari Seisaku Sho* and its washery are preserved monuments. Many colliery tunnel portals survive, such as those at Chitose and Kitakami. In

the attached settlement is the biggest of the coal-mining company's clubs – the Hokutan Shikanotani Kurabu (now conserved) – and the four distinctive miners' townships of Fukuzumi, Shakou, Sumizome, and Takamatu.

A shafthead such as that at the extant *Sumitomo Ponbetu* (1960–71) shows the influence of imported technology. The A-frame headgear, similar to the earlier example at Zollverein XII in Germany, was constructed by the Japanese Mitsubishi Zousen Company. There are four pulley wheels (sheaves) on the frame, supporting double cages and using the German Koepe continuous winding system. The combination of man and machinery winding was the first dual-use system in Japan. The horizon mining-system combining work on the Ponbetu and Yayoi coal seams used technology from the GHH Coalmining Company in Germany. The mine achieved a production of 1,420,000t in 1970, but in 1971 its underground workings were combined with those of the neighbouring Akabira Coalmine and the Sumitomo Ponbetu shafthead ceased active production. The shafthead is the most significant and comprehensive collection of colliery structures and machinery of its period in Japan.³⁰

The *Sorachi Industrial Heritage Landscape* includes 115 distinct structures, complexes, and areas. These include coal-mine shaftheads, mining tunnel portals, coal washeries, coal-miners' settlements, coal offices, social clubs, and coal-waste heaps. There are four mining machinery collections and 24 social institutional landmarks, including schools, public baths, cinemas, a photo studio, and a barber's shop. Also included are 27 structures and features from the dense railway system that serviced the coalfield. Eighteen features have also been defined from the cultural heritage of the area. There are ten archives, museums, and research institutes covering the mining field.

The existing World Heritage industrial cultural landscapes of the Ironbridge Gorge and Blaenavon in the United Kingdom also both contain significant coal-mining elements.

10 THE ORIGINATORS OF THE INTERNATIONAL COLLIERIES LIST

Stephen Hughes	Head of Survey, Royal Commission on the Ancient and Historical Monuments of Wales, United Kingdom
Professor Dr. Rainer Slotta	Director of the German Mining Museum, Bochum, Germany.

The research carried out for three publications has served as the foundation for this work:

M Ganzelewski & R Slotta	<i>Die Denkmäl-Landschaft "Zeche Zollverein"</i> (Bochum, 1999); also available as an English-language CD <i>The "Zeche Zollverein" Landscape of Monuments</i> (Bochum, 2000);
S Hughes, B Malaws M Parry, and P Wakelin	<i>Collieries of Wales: Engineering & Architecture</i> (Aberystwyth, 1995);
S Hughes	<i>Copperopolis: Landscapes of the early Industrial Period in Swansea</i> (Aberystwyth, 2000).

The draft structure and consultation network of this study were presented and discussed at the intermediate TICCIH *Conference on the Industrial Heritage of Mining and Iron Metallurgy* held in Miskolc, Hungary, 26 September 1999

The participants at the *Meeting of the Collieries Special Interest Group of TICCIH*, held in Cardiff, United Kingdom, 4 September 2000 were:

Professor Eiichi Aoki (Japan)	Dr Per Oestensen (Norway)
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Mr Martin Gantenberg (Germany)	Mr Peter White (UK)
Mr Jan Geijerstam (Sweden)	Mr Richard Wittasek (Austria)
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Dr Friedhelm Henseler (Germany)	Mr John Yates (UK)
Mr Stephen Hughes (UK)	Dr Peter Wakelin (UK)
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Internet Consultation: In October 2000 the draft list was made available to the 280 international members of the mining history discussion group at mining-history@jiscmail and further comments were received.

Other consultees were:

Mr Eric DeLony (Chief, Historic American Engineering Record, USA)
Mr Michael Workman (Ihtia, West Virginia University, Morgantown, USA)
Mr David Worth (freelance industrial archaeologist, Fish Hoek, South Africa)

11 NOTES AND REFERENCES

1. The definition of an industrial monument is based on the Information Document on Heritage Canals produced for presentation to the World Heritage Committee by the expert meeting under the auspices of Canadian Heritage in 1994 (hereafter referred to as the 1994 'Heritage Canals Document').
2. I J Brown, 'Coal Mining' in B Trinder (ed), *The Blackwell Encyclopaedia of Industrial Archaeology* (Oxford & Cambridge (Massachusetts), 1992), 161–64.
3. R Vielvoye, 'The Significance of Coal as a World Energy Resource' in *Coal: Technology for Britain's Future* (London, 1976), 8–28, 13–16.
4. S Hughes, B Malaws, M Parry & P Wakelin, *Collieries of Wales: Engineering & Architecture* (Aberystwyth, 1996), 137.
5. Excavations on the modern opencast coal-mining site at Coleorton, Leicestershire, in the East Midlands have demonstrated this sophistication of early mines which have been dated dendrochronologically to 1450 and 1463 (R York & S Warburton, 'Digging deep in mining history', *Bulletin of the Association of Industrial Archaeology* (Vol 18, No 4), 1–2).
6. Examples of such non-ferrous mining landscapes in central Europe are already World Heritage sites: eg Rammelsberg in the Harz Mountains of Saxony (Germany) and Banská Štiavnica (Slovakia).
7. Many of the largest collieries in the world at the time were situated in the Great Northern Coalfield of England and were illustrated by Thomas Hair in 1844 in a book on the Northern Coalfield. Most of these were subsequently republished in W Fordyce, *A History of Coal, Coke and Coal Fields and the Manufacture of Iron in the North of England* (Newcastle, 1960).
8. S Gould & D Cranstone, *Monuments Protection Programme: the Coal Industry* (London, unpublished report for English Heritage, 1992), 10.
9. A Föhl, 'Ruhrgebiet' in B Trinder (ed.), *op. cit.*, 650–54.
10. Crimea Pit is an example surviving from 1854: see S Hughes & P Reynolds, *A Guide to the Industrial Archaeology of the Swansea Region* (Aberystwyth & Ironbridge, 1988).
11. S Gould & I Ayris, *Colliery Landscapes: An aerial survey of the deep-mined coal industry in England* (London, 1995), 52.
12. M Ganzelewski & R Slotta, *The "Zeche Zollverein" Landscape of Monuments – A Coal Mine as Part of the World Cultural Heritage?!* (Bochum, 1999), 77-79.

13. The buildings at Penallta have been retained and are to be re-used. For details of the site see S Hughes, B Malaws, M Parry, & P Wakelin, *op. cit.*, 14–16 & 170.
14. Ganzelewski & Slotta, *op. cit.*, 154–55.
15. B Trinder, ‘Transfer of technology’ & ‘Cluster house’ in B Trinder (ed), *op. cit.*, 771–73 & 160.
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17. K Hudson, *World industrial archaeology* (Cambridge, 1979), 58–62.
18. J Liebin, ‘Les charbonnages’ in L-F Genicot & J-P Hendrickx (eds) *Wallonie-Bruxelles: Berceau de l’Industrie sur le Continent Européen* (Louvain-La-Neuve, 1990), 43–56, 46.
19. ‘Le Grand-Hornu’, *Patrimoine de l’industrie* (3, 2000), 108–09.
20. A Föhl, ‘Malakoff tower’ & ‘Ruhrgebiet’ in B Trinder (ed.) *op. cit.*, 440–41 & 650–654.
21. Ganzelewski & Slotta, *op. cit.*, 75.
22. R Sherlock, *Industrial Archaeology of Staffordshire* (Newton Abbot, 1976), 92, 192.
23. F Brook, *The Industrial Archaeology of the British Isles: 1 The West Midlands* (London, 1977), 136–37.
24. Ganzelewski & Slotta, *op. cit.*, 77–79.
25. *Ibid*, 1–46.
26. *Ibid*, 244–49.
27. I J Brown, ‘International Guide to Museums’ in ‘Guide to the Coalfields’ in *The Colliery Guardian* (1995), 25–27.
28. *The Colliery Year Book and Coal Trades Directory 1940* (London, 1940), 668.
29. H Yamada, *The Industrial Heritage of Coalmining in Hokkaido and its Preservation as an Eco-Museum* (Written paper given at TICCIH 2000, London & at the TICCIH Collieries Special Interest Group), 1–2.
30. *Ibid*.

Figure A Early architecturally sophisticated centralized colliery workshops at Le Grand-Hornu (1820–52) in Wallonia (Belgium)



Figure B One of the large early collieries in the Great Northern Coalfield of England, c 1839.
Church Pit, Wallsend, Newcastle (United Kingdom)

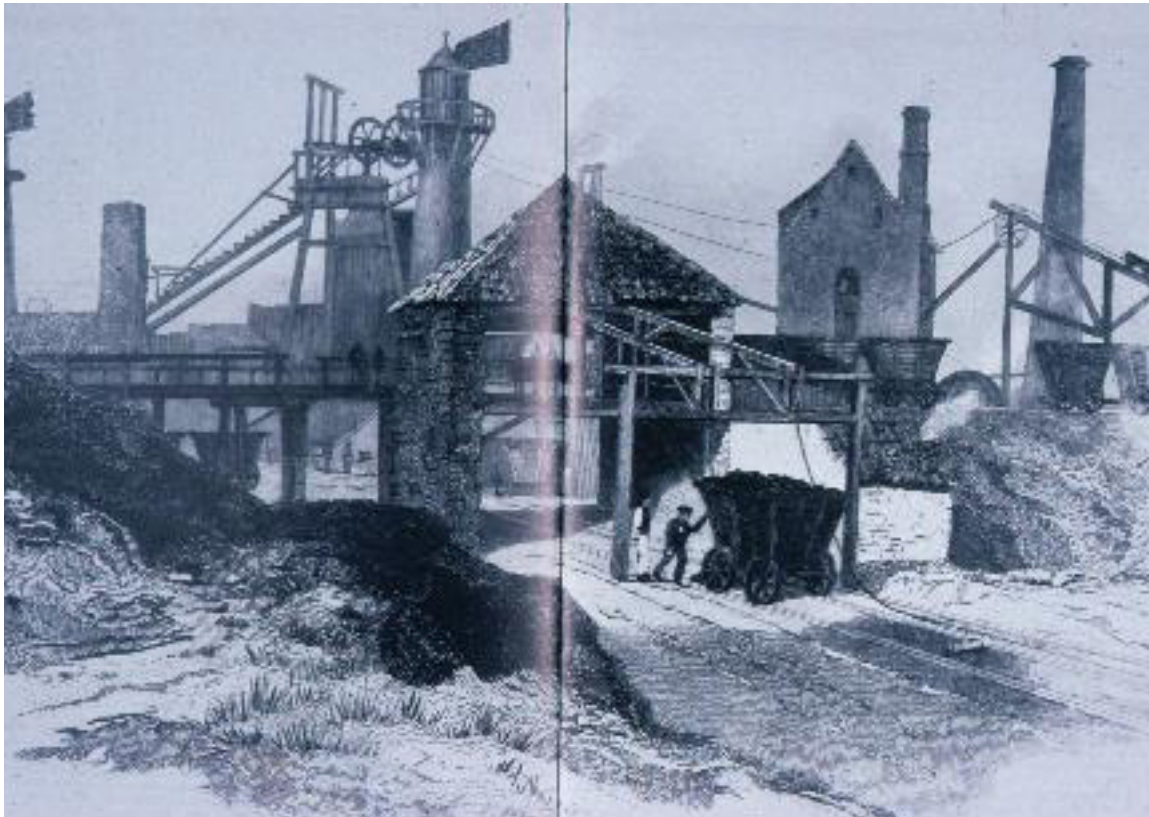


Figure C Formal layout including twin Malakoff towers at Zollverein I/II Colliery (1847–50), Essen, Ruhrgebiet (Germany)

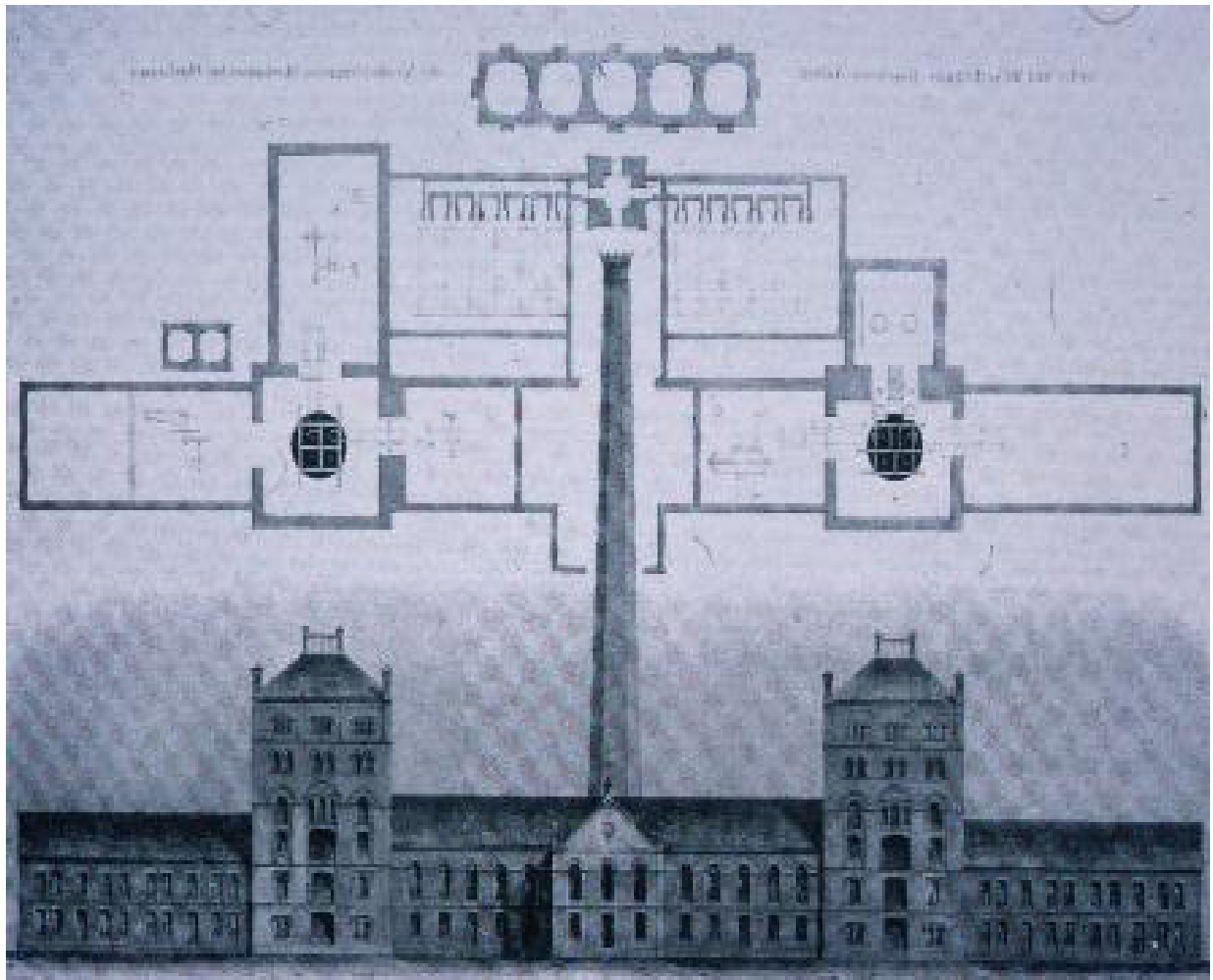


Figure D Early 20th century engine halls at Waltrop 1/2 Colliery in the Ruhrgebiet (Germany)



Figure E Cross-section of the Penallta Colliery Engine-hall (1906–09),
South Wales (United-Kingdom)

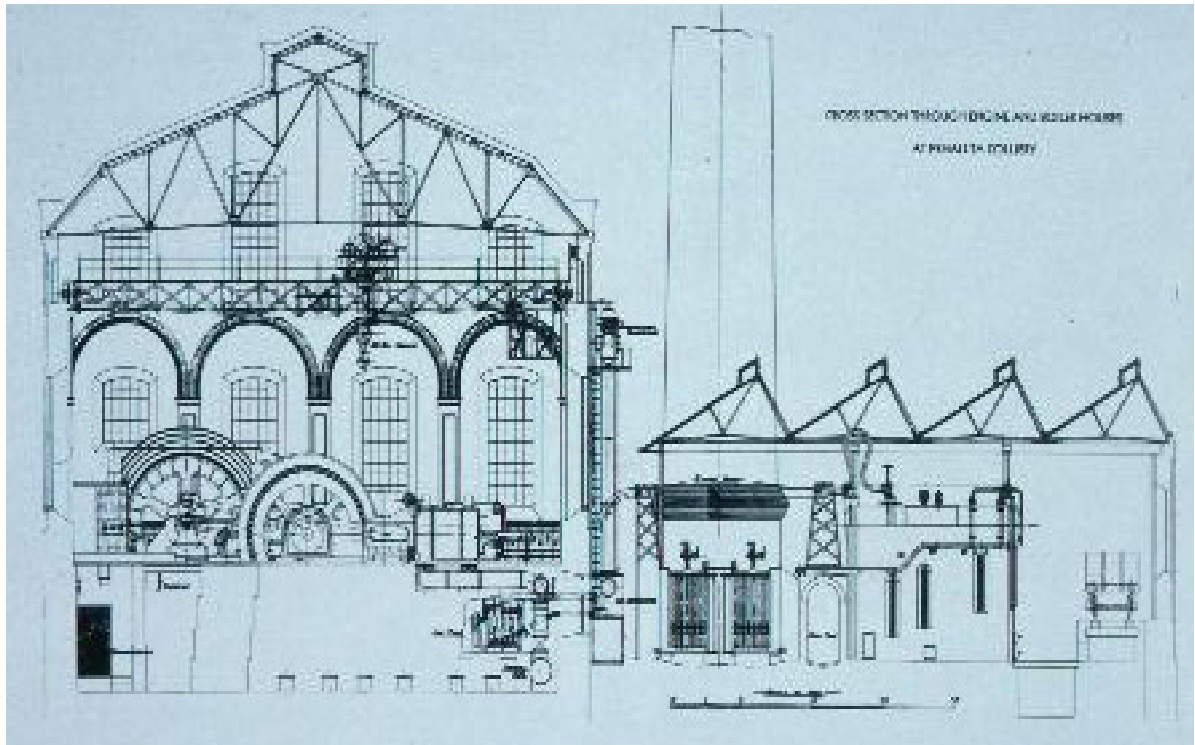


Figure F Interior of former compressor house built in the International Modernist style at the Zollverein XII Colliery (1928–32) at Essen in the Ruhrgebiet (Germany).
A turbo-compressor has been retained as part of an adaptive re-use scheme for the building



Figure G Entrance to the main canalized colliery tunnels (1759) at Worsley, Manchester, England (United Kingdom)



Figure H Part of the large colliers' town at Le Grand-Hornu (1820–52) in Wallonia (Belgium)



Figure 1 Early 20th century miners' housing at Zollverein Colliery, Essen (Germany)



Figure J Types of mining and coal processing used at the Hokkaido Coalmines (Japan) in the later 20th century

