Introduction

Coal, in its various forms, is found in all the continents of the world and has been valued for hundreds of years for the heat and power that it can generate. Coal fuelled the Industrial Revolution (**379**), starting in the UK and then spreading to continental Europe and subsequently around the world. During the eighteenth century industrial goods were moved mainly by canal. In the nineteenth and first half of the twentieth century, coal was moved within countries by locomotives on the newly created railways and from country to country by ships. The steam locomotives and steam ships in their turn increased the requirements for the coal with which they were powered.

Producing coal from underground mines is a dangerous enterprise and technology was developed gradually to combat dangers such as gas explosions and roof falls. But such technology was often expensive and only adopted when enforced by legislation or when it enabled the coal to be produced at a greater profit. The social status of miners echoed the social conditions of other workers in each country, ranging from slaves, serfs and convicts to miners with better conditions and pay than other industrial employees.

Coal is, however, bulky and dirty, so from just before WWI it began to be replaced by oil (**404**), less of which was required to produce the same amount of power. Throughout the twentieth century coal mines began to be closed, either because of the use of the cleaner and less bulky oil or natural gas or because less expensive coal could be imported from countries where it could be produced more cheaply. The dangers of climate change and global warming became increasingly apparent, caused partly by the burning of coal. The Cop 21 Paris Agreement, signed in 2016, saw many countries pledge to phase out all use of coal, although the largest users or producers, America, Australia, China, India and Mongolia, continue to rely heavily on coal.

Museums devoted to the history of coal mining and coal miners are to be found on every continent. This book deals with coal-mining museums, heritage centres and preserved colliery sites throughout the world. It is not a history of coal mining worldwide, but rather the depiction of that history by the places discussed in this publication. This introduction deals with some aspects that go towards illustrating the development of coal mining and coal-mining cultures around the world. The concordance at the end of the volume deals with 18 aspects of coal-mining history that are to be found at a large number of sites. Certain aspects that are covered in the entries are not included in the introduction or the concordance, such as governance or methods of funding, but can be found by going through the entries in the volume. It is hoped that this publication can be used to illustrate the different ways in which museums and heritage centres present the subject; to provide a data base for those interested in pursuing a particular line of research or interest; and to compare and contrast approaches in different parts of the world – for example, museums in communist or former communist countries may display details of senior company staff or awards to miners for high productivity (*e.g.* **348.1**).

Coal occurs in various grades. Anthracite, known as black or hard coal, is the highest grade of coal, because it has the highest carbon content, the fewest impurities and the highest energy density of all types of coal. It produces little ash or smoke, so was especially valued for domestic heating. Bituminous coal, also classified as black coal, contains asphalt or bitumen, a tar-like substance; it releases more methane than other types of coal, so stringent safety precautions, such as good ventilation and gas monitoring, are essential during mining to prevent explosions. It is especially used in electricity generation. Dry bituminous coal was particularly used to power steam ships. Coking bituminous coal, known as metallurgical coal, is used to make coke for smelting iron ore (**379**). Falling between anthracite and bituminous coal is thermal coal, known as steam coal, which was especially used for powering steam locomotives. Lignite, or brown coal, has a carbon content around 25 to 35 *per cent*. Also known as brown coal is sub-bituminous coal, which contains 35 to 45 *per cent* carbon. Brown coal is the least valued, because it produces a lot of smoke with relatively little heat, and is difficult to store or transport, being liable to self-combust. Many eastern European countries have large lignite deposits, which they had to use to produce electricity during the communist era (1947-91), leading to major pollution and serious health issues amongst the population. Coal was not necessarily used just as it was mined (known as run-of-mine), but often had to be mixed with other types of coal to obtain the best results; for example, in the UK after 1972 semi-bituminous Kentish coal used in coke manufacture for foundry usage was increasingly added to higher-volatile coals from West Durham (Trueman 1954, pp. 160-1).

Early history and development of technology

Coal deposits are found widely throughout the world. Each country where coal is found developed its own mining culture, although developments in technology tended to spread rapidly around the world.

Development of technology

The first use of coal appears to have been in Czechia in the late Palaeolithic, before 8,000 BCE (**70**), and continued in

Europe with collection on the surface from outcropping seams. Coal seems to have been exploited in the Late Iron Age and used extensively for industrial processes in the Roman period (Travis 2008, pp. 159-73). There are documentary references to Roman coal mining in France and Italy (**introductions to France and Italy**) and evidence for Roman coal mining in the Saarland (**226**), Serbia (**314**), Spain (**331**) and the UK (**352**). There is then a break in evidence for coal mining in Europe during the Early Middle Ages (CE 478 to about 1000), although coal was probably still collected by local people where it outcropped (**103**), as also happened in Japan (**261**). Folk stories are often told about how coal was discovered (*e.g.* **10, 261, 314**).

The earliest documented use of coal in medieval Europe (Benoit and Verna 1999 for pre-Industrial Revolution use of coal in Europe) comes from Bulgaria in the tenth century (**45**) and from Germany in 1113 (**97**), with examples in France in the twelfth and thirteenth centuries (**introduction to France**), the UK in the later-thirteenth century (**361, 368**) and then in Spain in the late-sixteenth century (**introduction to Spain**). Coal mining was often initiated by religious houses and artisan mining went on in these early areas until the nineteenth century. Surprisingly very little information about coal mining and coal-mining sites has come from archaeological excavations, although landscape archaeologists have contributed considerably to the study of coal mines in the landscape (for examples see [Debrabant] 2009). There have been very few excavations by archaeologists. Professional excavation at Le-Molay Littry uncovered the mid-nineteenth-century foundations of the heapstead, the top of the shaft and the foundations of the steam boilers (**91.1**) and at Caphouse Colliery the foundations of a miner's cottage (**386**). In some cases clearance and restoration of abandoned sites has included a limited degree of excavation to identify elements on the site (**393.2**).

Most of the evidence for early coal mining has been obtained instead from opencast sites cutting through bell pits by workings close to the surface, showing the typical bell shape in profile (**241, 395.3**). Mining by bell pits went on until the nineteenth century, although there is evidence in England for shaft mining from the early-fourteenth century (**395**). In north-western Germany the first documented case of mining with a vertical shaft, as opposed to an adit, is from the early-eighteenth century (**128**).

In the High and Late Middle Ages (1000 to 1500 CE) Germany was the leading country for mining, both in technological developments and publications (**108**). In the seventeenth century Sweden took over as the leader in mining technology and mining education. The longwall system, however, is believed to have been developed in England in the first quarter of the seventeenth century (**379**) and in the eighteenth and nineteenth centuries it was the UK that had become the leading coal-mining country and the major exporter of coal overseas.

The UK and Germany developed various new technologies, materials and techniques in the nineteenth and twentieth centuries, when coal became essential to industrial development for powering machinery, for trains as railways spread and replaced horse-drawn vehicles, and fast steam ships displaced windjammers, as well as providing coal gas for heating and cooking. At the other end of the history of coal mining, the availability of gas and oil began the decline in the use of coal. This started in the UK in 1913 (**404**) and accelerated throughout the twentieth century and into the twenty-first, including in competition with clean energy such as windfarms and photovoltaic panels. In Europe the European Coal and Steel Community (ECSC) programme started pit closures as early as the 1950s (**37**). The last of the small mines of the Ruhr shut in 1976 (**148**). The last deep coal mine closed in the UK in 2015 and in Germany in 2018. In 2016 Belgium became the first country in Europe to phase out coal-fired electricity supplies completely, followed by Austria in 2020. Despite the ECSC programme, many people would not accept the likely demise of coal (**386**) and some mine operators still went ahead with modernisation, only to have to shut down with the new installations barely completed (**190**). Steam-powered winding engines were still being manufactured as late as the 1960s (**200**).

Problems

The major problems that arose in coal mining were water, subsidence and gas. Major exploitation of coal in the UK and then elsewhere was triggered by the discovery of how to smelt iron ore with coke made from coal (**379**) and how to deal with water underground. Groundwater moves downwards and enters underground areas, which are then in danger of flooding. The water produced in coal-bearing strata (**327**) can be either dangerous or beneficial. The dangers of water were illustrated graphically by nineteenth-century disasters (**30, 384**) and then by the Lofthouse Colliery disaster (**383**), while water could impede shaft sinking (**97, 370**). A number of museums have displays about methods of removing water underground (*e.g.* **327**). The earliest method was to drive a channel underground, although this did not work where the conditions were very wet (**84**), and some mines were designed with a slope so that water could drain away naturally, which also allowed tubs to be moved more easily by gravity (**122, 148**). Some mines used a pump operated by a horse-driven whim gin to dewater the pit (**235**).

In the UK Thomas Newcomen invented the atmospheric steam engine in 1712, both to remove minewater and to raise coal to the surface. One was installed the same year at Dudley (**360**) in England, while the 1795 engine at Elsecar survives *in-situ* (**371.1-2**). There are a working replica at Dudley (**360.2**) and models in Austria (**21.1**) and Hungary, where two Newcomen engines were installed in 1722 (**235**). A Newcomen engine was installed in France in the middle of the eighteenth century (**91**). Three later rotative Newcomen engines, which were operated manually, also survive (**398**). In 1783 in the UK James Watt patented an improved double-acting engine. An example, probably from 1802, is preserved in France (**91.2**). Sometimes pits were so wet that the conditions defeated modern methods of removing water and had to close (**130**). Once mines shut, they continue to produce water, which can cause surface flooding if not controlled. This has especially been a problem in Germany (**110, 143, 214**) and the UK (**384, 386**).

On the other hand, minewater has been used to provide good-quality potable drinking water to communities in Poland (**304**) and Sweden (**338**), and to water livestock (**386**). The deeper mines went, the greater the heat; hot water pumped to the surface can be used for heating buildings (**113, 386**) or for mineral-rich *onsen* (**250**) or hydrotherapy baths (**154**). In Poland water underground was so plentiful that it was used to form canals on which coal could be moved (**298, 301**).

The need for ventilation to supply fresh air to the miners and remove toxic, explosive or suffocating gases was another major problem. Methane gas, known as firedamp, was the greatest threat to life underground, as it is highly explosive (**88, 323, 332**); small animals were used to detect carbon monoxide after explosions (**327**). Compressed-air, hydraulic and pneumatic systems were used to power machines safely underground without risking explosions (**112**). In the nineteenth century, furnace shafts were used to draw fresh air into the pit for the miners to breathe (**284, 386**), but with the risk of igniting any methane gas present. Fresh air was moved around the mine by small children opening and closing air doors underground, known as trappers in England (**378.1**) and doorboys or nippers in America (**426**). Another method was to use bellows, mechanically driven by a waterwheel or an animal (**327**). All modern mines, including demonstration mines that come under mining legislation (**96, 112, 239, 329, 386, 388**), have to have effective ventilation, either natural (**56, 291**) or provided by fans on the surface (**239, 388**). Fire underground, whether from an explosion or the ignition of methane, could cause devastating loss of life (*e.g.* **234**). In one case fire spread to the underground from a forest fire (**314**).

The realisation that coal dust in the air could also result in explosions (**80**) meant that it became essential to suppress the dust. This was usually done by stone dusting (**80)** and later also water spray (**370**), as had been recommended in the UK in 1901 (**350**). In Russia and Japan blasting the coal out of the seam with a high-pressure jet of water was used to reduce coal dust (**251**), although this technique failed in Germany (**179**).

To deal with the results of these dangers, countries established mines-rescue stations with training facilities (**68, 354.2**) in surface galleries (**263**). Many museums display equipment used by mines-rescue teams (**264, 309, 398**), sometimes displayed on models (**274, 321**). Amongst the equipment of each mines-rescue station was an emergency winder, or winch, that could be moved to any colliery where the winding engine was out of action and miners were trapped underground. With the closure of so many mines, the emergency winder is now sometimes housed at a museum (**381, 386, 388**).

One problem in mining areas is subsidence on the surface (Orwell 1927, pl. [5]). In the past this happened slowly as roadways collapsed underground. As roof supports were removed with retreat mining (**382**) during the twentieth century, subsidence occurred almost immediately. On occasion buildings or headframes had to be demolished because of subsidence (**231, 232, 391**) or were affected by opencasting (**402). One** mine in Czechia was filled underground to avoid subsidence on the surface (**69**) and in Japan areas of subsidence on the surface were filled with waste rock (**258**). Both subsidence and opencasting resulted in voids on the surface, which are now often filled with water to provide recreational tourist areas (**72, 77, 111, 119, 121, 123.1, 230, 245**).

A large proportion of museums deal with the development of technology in sinking shafts, driving roadways, cutting coal and raising it to the surface. Shaft sinking was hazardous work, as was the subsequent maintenance of shafts, which was done by men suspended in a kibble (**33.2, 241, 328, 355.2, 386**; see also image Henriksson 1996, p. 188). An alternative was to drive a sloping roadway, known as an adit, or drift, from the surface down to the level of the coalface.

Early mining worked the coal by pillar-and-stall (**47**) in Europe, Japan and northern America (**47, 48, 49, 238, 250, 253, 307, 388, 398.2, 429, 430**), with fires and later gunpowder and then other explosives often used to bring down the coal (**324, 339**). The pillar-and-stall system continued up to the twentieth century in some areas, such as America, as it suited working by individuals, but was generally replaced by the more efficient longwall working by a group of miners. Originally this was done by advance mining, until during the twentieth century retreat mining was adopted as more cost-effective (**382**). Both methods involved various problems, such as flowblow, where the roadway ballooned upwards (**250**), with the floor sometimes even reaching the roof. Other problems included that of working in very confined areas, for example, where the roadways went out under the sea (**248, 254.2, 260, 324, 370**).

Transport underground

Effective movement of the coal underground became a necessity with the development of large-scale mining. Initially coal had been carried in baskets on the backs of mineworkers or dragged along on wicker corves (**386.4**). In Scotland the baskets were transported to the surface by women climbing long steep ladders (*cf.* **250, 273**). At first horses were used only on the surface to transport coal for local use and to provide power for winding gins (**372.1-3**). Rails for moving tubs of coal underground were developed in the eighteenth century. Ponies underground are first recorded in the mid-eighteenth century, although they could not work in very low seams (**91**), where boys still moved the coal in tubs, one pushing and one pulling (**378.1-2**). In the UK the 1842 Act, and even more so the 1872 Act (**378**), made ponies indispensable in moving coal from the coalface to the shaft, and ponies were used in very large numbers (**18**). In the Ruhr pit ponies were first used in 1853 (**212**). Mules were used rather than ponies in Spain (**325.1**) and America (**419, 424, 429**), as well as oxen (**424**).

Ponies were trussed to be lowered down the shaft (**33, 356**), as otherwise some would have panicked in the shaft or refused to go underground (**370**), although others came to love it (**18**). Many museums have displays or collections about pit ponies/horses or display stables where they were kept (**33, 45, 90, 107, 112, 132, 277, 299, 309, 314, 360, 362, 369, 370.4, 385, 388, 395**). One aspect not usually dealt with in museums is that, where ponies were kept underground, the oats for their feed attracted mice or rats (Orwell 1937, p. 22). The two were never found together, as rats would always kill or drive out the mice. Miners took their food underground in vermin-proof metal containers, known as snap tins in the UK. Miners' meals underground usually consisted of bread and dripping or lard (**90**), never butter which would go rancid in the hot conditions, and a bottle of cold coffee or tea (*ibid*., p. 20).

The heavy work meant that pit ponies often had a low life expectancy, although legislation was passed in attempts to protect them. Miners believed that ponies were regarded as more important than them, because pit ponies had to be bought. In Japan ponies were eaten at the end of their lives (**276**), while after disasters trapped miners on occasion ate either one of the ponies (**80, 384**) or else the corn stored to feed them (**375**).

Ponies went on being used in mines that had not mechanised or where it was difficult to supply electricity because there were very tight spaces, such as where the roadways went out under the sea (**370**). The last pit pony in Germany retired in 1951 (**232**), in Australia in 1990 (**9**) and in England in 1994 (**370**). In Australia monuments have been erected to the memory of the ponies (**10, 18**).

Ponies were gradually replaced by mechanised transport underground, such as mine cars and locomotives. The first electric locomotive was introduced underground in 1882 (**227.1**) and eventually diesel-powered locomotives were developed. This led to armoured face conveyors, although locomotives were still used to transport miners from the shaft to the coalface and back.

Various countries in Europe, especially Germany and the UK, and also northern America and Japan, developed machinery such as roadheaders and heliminers for driving roadways, shearers for cutting coal and conveyor systems for transferring it to the shaft or drift bottom and then on to coal-sorting facilities on the surface. Each new development was usually adopted quickly by mines (**19, 255, 355**) and by companies producing mining machinery, and then improved further. So there was a constant movement of development, modification and transfer of technology around the world. Many museums highlight specific innovations developed in their area; for example, in Silesia (then part of Germany, now in Poland) the first powered roof supports and many other technological innovations (**298**), or in Germany the first mine theodolite in 1836 (**105**). Similarly the first electrically driven main-shaft winding engines in Europe (**129**), as opposed to the oldest European working steam-winding engines using the traditional system of winding with two wheels (**298, 314**).

Raising coal to the surface

Headgears, or headframes, were similar throughout the world, although there was experimentation, especially in Germany. The monumental Malakoff headframe was developed in the 1850s (**127.1, 149, 163, 168, 181, 184, 197, 209, 231**) and in the early-twentieth century a headgear was designed with a third leg, known as the *Zschetzsche* design (**207, 210, 218**). In 1901 a *Hammerkopfturm*, an enclosed tower winder, was designed with the winding engine on the top (**147**). This form of headgear was used at a number of other German mines until the end of the 1920s (**147, 189**), when a new form – a high rectangular cube – was designed, which became the model for modern oil rigs (**144, 205**).

Also invented in Germany in 1887 was the *Koepe*, or friction-winding, system, which did not require any headgear (**127.2**). This was widely adopted, first in Germany (**105, 113, 147, 153, 165, 200**) and then throughout Europe (**68, 298, 303, 366, 381, 396**). In Turkey it was modified to work with a headgear and a winding engine on the ground (**347**). The system was expensive, but more effective for deeper mines (**366**). The use of concrete for colliery construction was pioneered in Germany, the first concrete headgear being constructed in 1910 (**104.1**). The first concrete headgear in Canada appears to date to 1913 (**52.1-2**), the same year as one in England (**104**), and in America to 1923 (**425**).

Other aspects

Miners sometimes resisted the introduction of new techniques, which often had unforeseen consequences; for example, rails laid underground to make it easier for miners to move coal tubs, then enabled the owners to use younger children and women to move the tubs (**378.1-2**). Similarly much work was done to devise a safer light for use underground, resulting in the Davy lamp (**331.1, 355**), but miners found it gave less light by which to work. Also the greater protection meant more-gassy mines being worked, resulting in a succession of devastating explosions in the UK, of which the Oaks Colliery (**355**) was just the worst example. Miners preferred the older wooden pit props, which creaked when a roof collapse was imminent, to the stronger metal ones (Orwell 1937, pp. 41-1).

Conflict and coal mining have also often been intertwined ([Debrabant] 2016) and the bitterness from the sufferings of war had an effect on mining communities. So the offer of assistance by German mines rescuers after the Courrières disaster was at first rejected because of the bitterness from the Franco-Prussian War, 36 years earlier (**80.2**). Indeed on being told in 2018 that the Germans appeared to have the earliest use of concrete for headgears, a Belgian responded that he was not surprised because the Germans were always keen on the use of concrete, "we still have some of their concrete constructions along our border" (*i.e.* from the pre-WWII Siegfried Line). One of the major reasons for creating the EU was to decrease this level of bitterness and to avoid yet another pan-European war, such as had been fought in 1914-18 with the loss of 20 million lives and 1939-45 with the deaths of 75 million people.

Sometimes systems developed independently in parallel. For example, in Taiwan blue, white and yellow helmets designated different jobs (**344**). In the UK miners wore white helmets, trainees yellow and mines-rescue service red; in Germany managers wore white, coalface workers yellow and mines-rescue service red helmets. This sort of colour-coding system does not seem to have been used in other countries. Some countries developed specific greetings between miners. In German-speaking countries this was *Glückauf*, 'good luck' (**110, 210, 226**), including Poland until 1945, after which it became *Szęść Boże*, 'God bless' (**introduction to Poland**), while in Japan the common greeting was *go anzen ni*, 'be safe' (**248**).

Surface features

Surface facilities were essential to the running of any mine. The winding-engine room with a tiled floor was always kept scrupulously clean and only the winding enginemen were allowed to enter. In addition to the winding-engine house and whichever winding system was in use, there were administrative buildings and various workshops. Particularly important were the joiners' and blacksmiths' workshops, in which all mine machinery was repaired and many items were produced, including shoes for the pit ponies (**68**). Many of these buildings have been preserved for use as museums and, where suitable, other purposes such as community centres. Some museums still display the early form of powering workshop machinery with line shafting (**132, 255.3, 328.2, 386**).

Deep mines are extremely hot, so that miners usually worked naked except for helmet with cap lamp, belt to carry the cap-lamp battery and boots (Orwell 1937, p. 20). This meant that the coal dust in the air coated their entire bodies, already wet with perspiration. Originally colliers had to go home 'in their dirt', as washing facilities were not provided (*ibid*., pp. 33-4, pl. [6]; **344**). The first pithead baths in the UK that were constructed to a recommended standard opened in 1928 (**391**). These had an individual stall for each miner, as also in later pits in Belgium (**32**), whereas in Taiwan bathing facilities were communal (**344**). Miners changed from their everyday clothes before going underground and, in the UK and the Campine coalfield in Belgium, their work clothes were stored in heated lockers after they finished work to allow them to dry. In America, Japan and continental Europe, clothes were stored on either hooks (**424**) or in birdcage lockers, which were open baskets suspended from the ceiling by ropes with a padlock at the bottom of each, to which only the individual miner had the key (**63.1, 70, 276.2, 334**).

Coal comes to the surface either by conveyor belt up the drift or in tubs up the shaft. The building housing the shaft top, with the wheels above, is known as the heapstead (**87.1, 99.3, 280.2, 304.2, 387.4**). Material coming out of a coal mine consists of coal, stones and dirt, and so needs to be sorted on the surface in what is known as a screens building (**378**). In recent years this has been done mechanically, but in the past it was sorted by women (**244.2**) or by miners either too young, too old or too disabled to work underground (**426;** Orwell 1937, p. 4). In the UK it used to be said that every miner was a child twice in his career – at the very beginning and very end of his working life. Once sorted, the coal was usually cleaned in a washery; where the sorting and washing facilities were in the same building, it was known as a coal-preparation plant. The coal then dropped through hoppers into waggons or tubs underneath (**46.1, 52.1, 64, 78.2, 334.2, 342.2, 344.2, 364, 386.1**), with the waste material deposited on spoil heaps. These could reach massive proportions and in some areas, such as Wales, looked remarkably like Iron Age hill forts. Because of the inefficient way in which coal was sorted from waste by hand, the spoil heaps still contained small pieces of coal; miners and their wives struggled to recover this broken coal during times of unemployment or strike action, despite the dangers involved (*ibid*., pp. 93-6, pls [1, 3]).

In many cases the spoil heaps have now disappeared. In the Netherlands the spoil heaps were removed (**280**). In some countries, such as the UK, the heaps often were washed in the 1970s and 1980s to retrieve the small coal, after which the remaining waste was spread out so that it no longer looked like a traditional spoil heap. In other cases spoil heaps were levelled to provide a base for a building (**327, 380**), the shape used for the design of an office building (**189**), turned into a dry rock garden (**113**), grassed (**226**), planted with flowers (**345**) or turned into a country park (**390, 391.1, 395**). In Japan the spoil from mines on small adjacent islands was dumped between the islands to create a single large island (**260, 261**), while in Germany tunnels were dug into one spoil heap to provide an air-raid shelter during WWII and later a training tunnel and testing area for new underground machines (**161**). The largest spoil heap in the Puertollano coalfield has been landscaped to form an urban park (**326**), while spoil heaps in Germany and Sweden have their own name (**109, 226, 338.2**).

Many spoil heaps have developed their own microclimates and are rich in animal and plant life (**28, 130**). In some cases guided tours are offered of the heaps to describe the birds, reptiles and mining heritage (**81, 90**). Access is sometimes provided by steps cut into the spoil heap (**22, 269**), so that visitors can reach the vantage viewing point at the top (**115, 215**). The Hoheward and Hoppenbruch spoil heaps, which together form the largest spoil-heap landscape in Europe, have two arches which form the 'horizon observatory' (**231.3**).

A number of impressive spoil heaps are preserved in Japan (**269, 271**; see also **252, 258**), but it was in northern Europe that spoil heaps really came into their own. The north European plain, where WWI was predominantly fought (**79, 81**), is extremely flat without distinguishing features. There the spoil heaps form a major part of the landscape (**28, 35, 81, 97, 160**) and have contributed to the Nord-Pas-de-Calais being granted World Heritage Site status (**77**). Two organisations, the Chaînes des Terrils, were set up in 1986 to protect and display the spoil heaps in Belgium (**28.1-2**) and France (**81.1-2**). Where spoil heaps were threatened; for example, in Belgium where the 20 *per cent* coal remaining in the heaps could have been reclaimed by washing, the authorities moved in to protect them (**38**). Spoil heaps are used for a variety of purposes: paragliding (**38**), mountain biking, orienteering, skiing, luge (**81**), skating and hiking (**113**) or as a base for works of art (**22**). These spoil heaps are all safeguarded by regulating what activities are permitted on them and regular biological monitoring.

Once brought to the surface and sorted from the waste, coal had then to be moved to where it was to be used. Transport, coal and the uses of coal are inextricably linked. Coal is dirty, heavy and needs to be supplied in bulk. In medieval Europe, movement of goods was usually by packhorse or water-borne, so working of coal tended to be on a small scale and usage strictly local. Yet in the Roman period there is proof of coal being moved considerable distances (Travis 2008, pp. 133-58). In the Middle Ages coal tended to be moved further afield only from those places that were close to the sea, such as Bristol and County Durham in the UK from where coal was shipped to London (**361, 368, 375, 399**). Use of coal locally increased once chimneys had been invented, which allowed more salubrious domestic consumption of coal. Chimneys began to be used on the European Continent as early as the twelfth century, but were regarded with suspicion in England, where widespread adoption did not really come until the seventeenth century and only then with the appointment of wardens in cities to control chimney fires (https://ultimatehistoryproject.com/chimneys.html).

From the early-eighteenth century it became possible to move bulky goods by canal (**concordance**) and in the nineteenth century by railway (c**oncordance**), sometimes constructed specifically for moving the coal (**271**). The locomotives were powered by coal, so increasing demand, while permitting movement of coal to areas where it could be used both for steam engines in factories and for domestic heating. The final stimulus to coal mining came from the switch from wind to steam power for shipping (**261**); indeed the cost of the journey from Chicago to Liverpool dropped by two-thirds between 1873, when using sail, and 1884, using steam (Mount 2021, p. 18). In Japan Nagasaki, with its coal supply, became important as the closest port to China and a stopover where foreign commercial ships and naval vessels could refuel (**261**). The coal mines of Zonguldak made it an essential supply base for the Ottoman navy (**introduction to Turkey**). The British Navy established a network of international coaling stations to maintain the fleet at sea (**278**), while the American navy favoured Pocahontas coal, because it did not produce smoke (**428**).

The workforce

The workforce used in the mines differed greatly from country to country. In some areas and at certain times miners were well-paid and regarded as highly skilled, whereas in others they endured appalling working and living conditions and were often trapped by their status in society.

Training and dissemination of knowledge

Once invented, mining technologies tended to spread widely, partly by publications and training in schools of mines and partly by movement of miners. Mining is a skilled occupation and training is required for miners to be effective, as well as safe. Originally miners learned on the job and there are still echoes of this in the Forest of Dean, where legally anyone meeting certain conditions and experience is entitled to become a Free Miner (**367**), although the mines inspectorate now ensures that those working underground are properly qualified. In Czechia and Slovenia miners were apprenticed for training underground and were initiated into the trade by 'jumping the leather' (**67, 316**). In the nineteenth century mining companies in the Nord-Pas-de-Calais provided vocational-training centres, including training for work in the mines (**77**). In Germany earlier galleries and tunnels dug into spoil heaps have been used for training (**112, 161**), as well as a tunnel created in 1932 under the university in Cologne specifically to train mining engineers (**96**).

The facilities or collections of some museums are used in countries still dependent on coal for energy to train and encourage young people to enter the mining profession (**349**). In Ukraine large machines belonging to the museum are kept in the grounds of the adjacent technical college (**349**). The museum's simulated roadways in India were specifically designed both for the public and as a training facility for mining engineers in an area producing much of India's coal (**238.2-3**). The drift mine of the Zonguldak Maden Müzesi (**347**) is still used as a training centre for mineworkers. In America the underground roadways of the Portal 31 Mine are used by universities to train mining engineers (**417**). The eyesight and reflexes of winding enginemen have to be tested regularly and miners who make up mines-rescue teams have to be extremely fit and undergo specialist training in rescue techniques. In Japan a simulated underground roadway on the surface (**263**) and in Taiwan the underground drift (**344**) are used for mines-rescue training and practice. Conversely some museums began life as mines-rescue training facilities (**68, 347**).

As mining became more technical, independent schools of mines were established. Apart from the dangers of gas and explosions involved in coal mining, there was little difference between the techniques of mining coal, copper, gold, lead and silver. So schools of mines taught general mining techniques, perhaps the earliest being the eighteenth-century mechanical laboratory at the Falun copper mine (**introduction to Sweden**), with the earliest tertiary institution being at *Selmecbánya* in Hungary (**316**). These schools had aids such as models and geological collections, and some are now open to the public as museums. The earliest is probably the museum of the school of mining in Russia (**311**), while in 1807 the École Pratique des Mines provided an impetus to the development of mining in the Saarland in Germany (**105**). In Japan the Kaijima Company provided vocational training for unskilled workers (**258**), while in New Zealand, where coal and gold mining are still important, some 30 schools of mines were established in the nineteenth century. Two of these are preserved, together with their collections (**289, 290**). In Poland a school of mines established in 1889 is now a major museum, with the training roadways created in 1927 now providing an underground experience (**300**). In Sweden an early-twentieth-century mining school is now a museum (**338.1**) and in Germany a museum was created in 2007 in a 1929 mining-vocational school (**232**), as in France in 1986 (**90**).

Knowledge of mining technology was also disseminated by publications, the earliest and most famous of which is Agricola's 1556 *De Re Metallica* (**108.3**). In France in 1777 the eminent chemist, Lavoisier, published material about early mining from outcropping coal seams (**92**) and Thury produced a manuscript in 1800 on the techniques of the Compagnie des Mines de Littry (**91**).

Women and children

Women and children worked underground in a number of countries. Generally legislation was passed to outlaw this practice, at different times and in different places. It appears that children still work in coal mines in Colombia, India and North Korea. It is usually assumed that the use of children was a practice that only developed in Europe and Asia with the Industrial Revolution (**379**). The Spanish National Archaeological Museum in Madrid, however, has the Roman gravestone from Cástulo of a child miner, four years old, carrying a pick and a basket (inventory number 16744), who would have worked in a lead/silver mine. So it is quite likely that children would similarly have worked underground in Roman coal mines.

In many pits during the nineteenth century women worked half-naked alongside completely naked men, to whom the women were not necessarily related. Impetus for legislation came from this immorality with its danger of sexual assault (**378, 386**), combined with the appalling conditions underground and the heavy work involved, especially for children (**378.1-2, 387, 394, 397**). The earliest legislation in Europe appears to have been the 1842 Act in the UK (**378**), followed by Austria/Hungary in 1854, France 1874, Germany 1878, the Netherlands 1906, Italy 1907, Norway 1915, Bulgaria 1917, Belgium 1919, Poland 1924, Hungary 1928 and Romania 1928 (Romano and Papastefanaki 2020, pp. 203-4). The lateness of legislation in some places was because it was simply confirmation of long-standing practice, such as laws in 1900 in Spain (Verde, Soto and Gómez 2020; **324**) and Sweden (Henriksson 1996, p. 202).

Outside Europe legislation was passed in Australia in 1901/29, South Africa 1911, Canada 1917/25, Nigeria 1917, China 1923, New Zealand 1915/26, Japan 1928, India 1929, Chile 1931 and Brazil 1932 (Romano and Papastefanaki 2020, pp. 203-4). In India, Japan and Taiwan miners worked in family groups of men, women and children from at least the nineteenth century (Chatterjee 2020, p. 192; **250**), which to some extent protected women from sexual assault. In the early-twentieth century India and Japan were the only industrialised countries where women worked underground in considerable numbers (Khaitan 2020), but at the same time boys as young as nine were working underground in American mines (**426**). In Taiwan legislation in 1964 was driven by the danger of both husband and wife being killed together, leaving children without parents (**344**). Many museums have displays describing the work of women underground (**90**), especially in Japan (**250, 253.2, 273, 277**).

Often there was little employment available for women after they stopped working underground (**146**) and many continued to work on the surface, especially sorting coal from waste material (**244.2, 264, 378.3**; see also image in Henriksson 1996, p. 191, in Sweden). Women often played an important support role during mining disputes; for example, in America (**416, 420, 431**), where children were also sometimes involved (**431**), and the UK (**373, 394**), and with the formation of the Miners Women's Auxiliary in Australia in 1934 (**18, 19**).

Slavery and forced labour

Coal mining is, and always has been, a dirty job involving considerable danger and hard labour. It is not surprising, therefore, that in the past some mine owners have used forced labour. These workers fall into various categories. The most extreme were the seventeenth- and eighteenth-century collier-serfs of Scotland, who were bound to their masters for their lifetime (**387**), and the nineteenth-century slaves in America, who worked under the supervision of free skilled miners (Frantel 2008). This was also the case with convicts, prisoners-of-war and slaves in Roman mines (Travis 2008, p. 110).

In recent centuries coal has played an important part in warfare ([Debrabant] 2016). In areas occupied by enemy forces, it was common for the occupiers to use forced labour. In some cases, prisoners-of-war were transferred to work in the mines, whether or not they were skilled miners. In the Ruhr during WWI German miners who had joined the army (**127**) were replaced by French prisoners-of-war, who were often trained miners and, despite the 1878 legislation, by French women (**150**). During WWII when energy sources, including coal, were at a premium, half of the workforce in the mines of Czechoslovakia were prisoners-of-war (**69**). Russian prisoners-of-war were forced to work in mines in Germany (**115**), Poland and Belgium, only to be replaced in Belgium after the war by German prisoners-of-war (**26**). Other forced labourers worked in the mines in Serbia and Germany (**97, 127, 129, 187**).

Forced labour was also used in nineteenth-century Japanese coal mines, with the death penalty for those who tried to escape (**250**), as well as convicts (**introduction to Japan**). In the twentieth century Japan used forced Chinese and Korean labourers in coal mines in Japan and Japanese-occupied China (**introduction to China**), and during WWII more than 13,000 prisoners-of-war (**259**). Between 1837 and 1878 work in the mines of Tasmania in Australia was punishment for the most recalcitrant British convicts, with those who were already skilled miners working at the coalface (**7**). Other countries also forced prisoners to work underground. Convicts from Hong Kong and India were shipped to Malaysia, although this unskilled labour led to increased accidents and lower levels of productivity (**278**). Similarly prisoners were brought from all the Dutch colonies of Asia to work in Indonesia under very oppressive conditions (**239**). Russian prison-labour camps, known as *gulags*, were established in the far north-west of Russia above the Arctic Circle, where prisoners worked in the coal mines between 1937 and 1943 (**313**).

Asian indentured labour was a system that replaced slave labour in which unskilled workers, known offensively as coolies, signed contracts to work overseas for five or more years without pay, either to repay debt or for compensation at the end of the contract. Indentured labourers from India worked in the Natal coal mines in South Africa from the middle of the nineteenth century (**318**). Finally there are the cases of Asian labourers, such as those in Canada, who were paid only half the rate of their white counterparts (**49**).

Religion

Mining is a dangerous occupation and miners have often sought divine protection. Throughout mainland Europe supplication has been to Saint Barbara (**96**), also known as the Great Martyr Varvara (**306**). Images of Saint Barbara were found at collieries, as well as chapels and churches dedicated to her in mining areas (**26, 77.3, 109**), along with some to the Virgin, named as Our Lady of Miners (**77**). Coal-mining centres were called after the saint (**322**). There is an underground chapel of Saint Barbara in Slovenia (**316**) and claims of similar underground chapels in Bulgaria (**45**). Chapels formed meeting places for miners (**103**) and in some places they gathered for prayers before descending underground (**227**). A chapel was provided for the miners at one French mine as early as 1804 (**91**).

In many places in continental Europe the feast of Saint Barbara is still celebrated each year on 4 December, the date of her supposed martyrdom (**96**). There are church services, parades, preparation of special dishes, shooting salutes and meetings of Barbara associations (**322**). Some mining museums have entire sections devoted to her cult (**131, 299**) and many museums have statues (**95, 109, 226**), paintings (**306**), an altar tablecloth (**91.3**) and a banner (**226**); the Deutsches Bergbau Museum (**108**) has probably the largest collection of such items relating to the saint. Celebration of her martyrdom day was taken to Turkey (**introduction to Turkey**) and the tradition of invocation of Saint Barbara to Brazil (**43**).

In the extreme west of Europe, in Ireland, Saint Barbara was supplanted by the Virgin Mary, with a statue of Our Lady over the entrance to the mine (**240.2**). In eastern Europe invocation in Bulgaria was to Saint Ivan of Rila and an iconostasis of the saint is displayed underground (**45**). In the eastern Orthodox Church the Holy Great Martyr Saint Propocius of Scythopolis is the protector of miners, so in Serbia a church of Saint Procopius was dedicated in 1900 to commemorate miners killed on his name day (**314**). Nevertheless there was veneration of Saint Barbara even in Orthodox areas, such as memorials in Russia (**309**) and Ukraine (**349.3**), perhaps because her supposed relics were kept in Kyiv (**96**).

Protestantism and in particular non-conformism, or Methodism, in Wales (**394**) and parts of northern England, was opposed to the veneration of saints. So there was no tradition of invocation of saints for protection, even in Catholic areas such as Glasgow, despite one claim otherwise in the French press (**355**). Chapels were found underground in Wales (**388**) and during the 1904/1905 Great Revival most pits in Wales seem to have held a prayer meeting before starting work (Thomas 1986, p. 24). Prayers were said underground elsewhere, such as in the north-east (**388**). In disasters where miners survived several days underground before dying, heart-breaking messages were found referring to prayers by individuals or groups of doomed miners (**375, 400**). Protestant traditions were also strong in America, where a preacher even gave a sermon underground (**419**). Churches were built at mining camps, which also served as community centres (**407.3**).

In Japan simple shrines were common in mines, sometimes to the goddess of the mine (**272**), although most were to Ōyamazumi no Kami, the god of mountains, oceans and mines (**272**). It was common for miners to pray at the shrine each day before descending underground (**255**). Replicas or the original shrines are still preserved (**248.3, 255, 272.2**). As in Europe, there were special festivities on 11 and 12 May, the feast day of the Shinto shrine (**272**). In South Korea one museum has a shrine where relatives can pay their respects to dead miners and in the adjacent village there is a traditional shrine with a well used by the community (**320**).

Health

Miners are vulnerable to a number of medical problems ([Debrabant] 2020). Those who survived such incidents as accidents with machinery, explosions and roof falls, often suffered from broken bones, crushing or problems with breathing. Hospitals in areas where coal mining was a major industry usually had lung specialists for pulmonary disease and orthopaedic surgeons skilled in dealing with extensive bodily injuries. Nystagmus, caused by straining to see in poor lighting, was mainly a condition from the nineteenth century, but miners suffered from silicosis and pneumoconiosis well into the twentieth century. Silicosis is caused by breathing in tiny pieces of silica, from rock, causing lung scarring. This is found in all types of mining, and in coal mining usually occurs in miners responsible for driving roadways through stone. Pneumoconiosis is the commonest respiratory illness found in coal miners, caused by breathing in coal dust. As recently as 2018 in Appalachia in America, 21 *per cent* of long-term coal miners were found to have some degree of pneumoconiosis (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7055360/) and the Mungyeong SeokTan BakMulGwan has a shrine for those who have died from pneumoconiosis (**320**).

There is no cure for silicosis or pneumoconiosis, only treatments to ameliorate the symptoms, such as provision of oxygen. The most important preventative measures are the use of masks (Musa 2011, p. 232) and to try to reduce exposure to stone or coal dust. This was realised as early as the mid-sixteenth century by Agricola (**108**), who stressed the need for ventilation underground. Effective respiratory equipment was being provided in Europe from the later-nineteenth century (**67**), as well as the watering of roadways to dampen down dust (which also reduces the risk of coal-dust explosions), but such provisions for the health of miners were absent in India (Chatterjee 2020). Many museum displays deal especially with pneumoconiosis, which affected miners throughout the world (**96, 241, 276, 320, 323**). In Japan in the Edo period many miners died before the age of 30 and the Tomoko miners' organisation had provision for the proper burial of miners (**276**). In Austria the Bruderlade and in Germany the Knappschaftskassen provided social-security benefits to its members from as early as the Middle Ages (**108, 297**).

What is not usually covered in museums are the general health and injury problems suffered especially by miners, such as the blue scars by which miners always recognise miners from other areas, caused by coal dust being sealed inside cuts (Orwell 1937, p. 32). Although many museums display examples of miners' housing (**4.1-2, 57.2, 77.1-2, 111.1, 118.1-2, 257.1, 260.1-2, 360.3, 389.2, 398.3, 407.2**), these are often sanitised and do not show the often-appalling pre-WWII European dwellings that contributed to the ill health of the occupants (Orwell 1937, pp. 46-68, pls [7-14]).

Provisions to support the health of miners began in France in the early-nineteenth century, when relief funds provided by the mining companies paid for hospitals, clinics and pharmacies for miners and their families (**77**). In Spain, even in the twentieth century, only the Mina San Vicente gave treatment to families (**327**), although the industrialised area of San Blas did have a small pharmacy for both workers and their families (**328**). In Germany it became normal from the early-twentieth century to provide shelter for miners in wet clothes going from underground to the pithead baths (**185**). Some mines had underground treatment rooms (**424**), but most first-aid facilities were on the surface, as displayed by a number of museums (**16, 327, 328.3**). The Musée de la Mine Marcel Maulini is devoted entirely to treatment of the Ronchamp miners' lung diseases between 1947 and 1978 (**92**).

Trade unions and strike action

Coal mining throughout the world involved hard labour and dangerous conditions, as well often as poor living conditions. The result was that miners joined together into trade unions to try to improve their situation. Many museums include general information about miners' organisations, covering the records of mining trade unions and their activities in Africa, America, Australasia, Europe and Japan (**9, 32, 225, 243, 249, 276, 286, 287, 314, 327, 349, 410, 416**), including collections and displays of the banners that are so associated with mining unions (**5, 236, 368.3, 373.1-2, 385, 386, 387, 388, 404**). Also important are the roles of the Japanese Tomoko organisation in training and authorising miners (**249, 276**), and the Austrian Bruderlade and the German Knappschaftskassen in representing the employment interests of their members (**108, 297**); these mutual-support organisations developed fraternal traditions that survive throughout continental Europe, including the hammer-and-chisel insignia (**206**), the black miner's costume (**68.2**) worn in traditional annual processions to church services on Saint Barbara's day (**96**), and the miners' greeting (**110, 210, 226**).

To improve matters, miners' unions frequently resorted to strike action: over safety concerns in Canada (**50**), France (**80**) and America (**426**); for improved working conditions in Canada (**49, 50**), Ireland (**241**), Italy (**245**), Slovenia (**316**), Spain (**332, 335**) and the United States (**423**); together with the demand for higher wages in Canada (**50**), Spain (**335**), Wales (**388, 394**) and Vietnam (**432**). Negotiations without strike action did sometimes result in better conditions, as in Germany (**195**), while occasionally, in Australia (**18**) and Spain (**327**), miners were able to take over production at their mine.

One particular grievance was how mining companies controlled the way that miners lived, by sinking pits in areas distant from any other employment; the provision of housing from which miners' families could be evicted during strikes;

and instead of cash, payment in the form of tokens that had to be redeemed at company-controlled stores, where prices were higher than in non-company stores. This was the case in the nineteenth century in Europe (**23, 77, 382**) and Japan (**250, 258**), but continued into the twentieth century in America and Chile (**introduction to Chile, 406, 417, 426**).

Some strikes were political in nature, such as the Labin miners' strike in Croatia in 1921 in protest against fascist violence (**65**) and passive resistance and strikes by German miners in 1923 against the French occupation of the Ruhr (**127**). Mining unions participated in general strikes during times of economic depression: in Australia during the Great Depression (**19**) and in Belgium during the general strikes of 1936 and 1960/1 (**24**). The British prime minister, Margaret Thatcher, framed the 1984/5 Miners' Strike as being politically motivated (**404**).

Later, as coal failed to compete with oil and gas, there were protests against redundancies and pit closures, such as the sit-ins underground in Australia in 1962 (**18**) and at the Sardinian mines in 1984 and in 2012 (**introduction to Italy, 246**). There were also demonstrations against closures, with banners and placards (**35, 225**). In the UK there were major strikes against pit closures in 1972 and 1974 (**370**), followed by a strike in 1981 when the government backed down (**373**), then culminating in an epic struggle in 1984/5 between the union and the prime minister. This effectively ended in defeat for the union (**368, 382, 388, 394, 403, 404**), as also happened in Japan in 1912 and 1960 (**276**). In Australia, the UK and the United States, women's groups were formed to support the struggle of the unions (**18, 19, 373, 420, 431**).

The authorities often fought back against what they saw as union militancy. As early as 1812 the bishop of Durham used his own troops to break up a strike (**368**). Following the 1906 Courrières disaster, Clemenceau sent in the troops to disperse the demonstrators (**80**), as Churchill did in the UK in the 1910/11 Cambrian Combine Dispute (**394**) and Franco in Spain in 1962 (**335**). In Canada it was believed that the union organiser, Ginger Goodwin, was shot deliberately in 1918 to silence him (**49**). In Poland in 1919 seven miners were killed by border guards (**303**), seven were shot dead in Italy in 1920 and in 1929 troops fired on the miners in Romania (**306**), as German occupiers threatened to do in the Netherlands during WWII (**introduction to the Netherlands**). But it was in America that there was the most violent reaction to union activity: in 1877/78 20 miners belonging to the Mollie Maguires were hanged, or judicially murdered (**426**), and in 1914 the dead, including women and children, appear to have numbered up to 56 (**431**).

Disasters and their results

The one thing that everyone seems to know about coal mines is that there are disastrous explosions killing large numbers of miners at regular intervals. Apart from the serious loss of life and its disastrous effect on the lives of those left behind, major disasters had two main effects. The first was legislative and the second was on the political and social life of the area or in fact the country.

Legislation following a disaster

It was a sad fact that all too often legislation was enacted only after a disaster, rather than proactively, even though the dangers were often already very obvious. In the UK after the 1838 Huskar Pit disaster, the condolences expressed by Queen Victoria and publicity about the conditions in which small children were working all gave impetus to the passing of the 1842 Mines and Collieries Act forbidding women and girls and boys younger than 10 working underground. Then in 1872 the Mines Regulation Act was passed forbidding the full-time employment of boys under the age of 12 (**378**).

Within seven months of the 1862 Hartley Colliery disaster, legislation was passed requiring pits to have two shafts (**375**). The 1893 Thornhill Colliery disaster stopped the practice of using naked-flame lamps in wet pits and the enquiry after the 1947 disaster at the same colliery recommended that lead rivets in lamps be replaced with magnetic locks and a better relighter be adopted (**400**).

From 1850 British managers had to keep a working plan of their colliery for government inspectors, who had first been appointed in 1843, and in 1872 plans of abandoned workings had to be deposited, as well as requiring managers to have state certification of their training. It was, however, the 38 deaths at the Montagu View Pit in 1925 that led to a central repository for plans being established to avoid miners breaking through into flooded abandoned workings, as had already been demanded after the 75 deaths at Heaton Colliery, 110 years earlier (**384**).

The 1934 Gresford disaster with 266 deaths contributed to the pressure that led eventually to the nationalisation of the collieries in 1946 (**359**). The 1969 Mines and Quarries (Tips) Act to ensure that spoil heaps were safe resulted from the 144 deaths in 1966 at Aberfan and this was further consolidated in the 1999 Quarries Regulations to avoid any instability of spoil heaps (**351**). Finally the 1973 Lofthouse Colliery disaster, in which seven men died, led to the 1979 regulations to guard against inrushes of gas or water (**383**).

In the eighteenth century France was in advance of other countries, with the first mines inspector being appointed in 1781, but after that tended to lag behind Germany and the UK in safety legislation, so practices often continued long after they had been forbidden in those countries. The 1906 Courrières disaster (**80**), the worst in Europe, was almost certainly caused by a methane-gas explosion ([Debrabant] 2006). The result was finally a ban in France on naked-flame lamps underground. Two independent means of escape were also made mandatory, more than 40 years after this had been enacted in the UK. This was followed in 1910 with the opening of the central Liévin mines-rescue station.

After seven miners were killed in Germany in 1875, the authorities insisted on a second shaft to improve ventilation at the Zeche Unser Fritz (**151**), while legislation replacing gasoline safety lamps with electrical safety lamps resulted from the deaths of 349 miners at the Zeche Radbod in 1908 (**146, 198**). In adjacent Austria, the authorities banned the *Firstenulmbau* method after six deaths in 1902. There was probably more proactive initiating of legislation and regulations without the impetus of responding to a disaster in Germany than in other countries.

One major difference was that in the UK controls were done nationally, with legislation enacted by the government, whereas in Germany it was sometimes done at the local level. Thus in the UK the 1887 Coal Mines Regulation Act controlled all aspects of closed flame-safety lamps and the 1911 Coal Mines Regulation Act included that fans should be able to be reversed to pump in fresh air (**350**), while also granting miners an eight-hour day. The first mines-rescue station was set up in 1902 (**80**). In Germany naked-flame lamps had been banned in 1846 in the Ruhr (**80**), but not until 1900 in Dortmund (**199**); electric mining lamps were introduced by regulation in 1909 (**80**). In America it was not until 1952 that the lobbying of John Llewellyn Lewis led to the first Federal Mine Safety Act (**416**).

Political consequences following a disaster

The 1906 Courrières disaster led to widespread strikes in the Nord-Pas-de-Calais, which Clemenceau put down using the army. This strong response aided him to become prime minister of France the same year (**80**). The 1908 Zeche Radbod disaster led to the widows being jailed for disorderly conduct for demonstrating for more financial support (**146**). The militia were sent in to put down industrial unrest on Vancouver Island in 1914 after hundreds of miners were killed in explosions (**50**).

After WWII many western European countries were short of labour and brought in men from poorer countries to work in the mines. Sixteen different nationalities worked in the Belgian mines (**28**), until over 150 Italian miners were killed in disasters in 1953 and 1956 (**29, 31**). These ended the movement of Italians to Belgium and resulted in much stricter mining regulations in Europe. Yet in Germany a further 13 Turkish miners were killed in 1988, along with 38 Germans (**121**), which ended mining in Hesse.

Aftermath of disasters

There were often formal enquiries after a disaster, leading to legislation, but relatively few prosecutions for breaching legislation. There were relatively negligible fines for negligence after the 1913 Senghenydd explosion (**350**). In a number of cases, the disaster resulted in the closure of the colliery concerned (**179**).

Relief funds were usually set up to assist the widows and children left behind, and royalty, corporations and individuals gave generously (**351, 375**), although the funds often ran out while dependents were still destitute. Items were sold to raise funding, such as crockery (**355.1**), engraved glasses (**356**) or prints showing the scene (**227**). The rescuers were also sometimes rewarded with cash or medals (**375.3, 388.3**) or a monument in cases where they were killed (**355**).

Memorials

So numerous were major accidents that it would be impossible to cover all the memorials to the dead in this publication, so only the memorials of a few important disasters are considered. Memorials to the dead of major mine disasters take various forms and were erected at various locations. On occasion the memorial has been placed at the site of the disaster (**285**), at the entrance (**31**), including where the colliery concerned has become a mining museum (**29**), in parks (**121, 227**), in the centre of their community (**80**) or in prominent locations (**355**).

Some monuments were erected in the churchyard or the cemetery, frequently amongst the burials of the dead miners (**137, 146**, **355.3, 370.1, 375.1**). In Europe miners were very badly paid, so often the families were so poor that they could not afford gravestones (**355, 400**). Memorials bearing the names of all those killed served to remember all the victims, although that at Méricourt marks the grave just of victims of the 1906 Courrières disaster whose bodies could not be identified (**80.3**). Monuments were usually erected soon after the disaster (**227**), although poor communities continued to remember their dead and, when they could afford it, later erected memorials, which were often smaller and more restrained (**29**). New memorials have been erected in recent years, often 100 or 150 years later, and are often works of art in their own right (**350**, **355, 383, 400**).

The form of these monuments foreshadows those erected to commemorate the dead of WWI (Fontaine 2016, p. 211; Saunders 2004). The memorial to the 27 rescuers of the Oaks disaster, erected in 1913, the year before WWI broke out, shows the winged Greek goddess, Pallas Athena, carrying a wounded warrior (**355**). This is comparable to the winged angels sometimes shown on war memorials supporting dead soldiers or bearing their bodies up to heaven.

As well as conventional monuments, some disasters were commemorated by artwork, such as a bronze sphere (**29**) or a bronze bust (**398**). The paintings in remembrance of the 1862 Hartley Colliery disaster **(375.2)** and the 1912 Zeche Lothringen disaster (**187.1**) both show the reaction of the monarch of the time. It became the accepted response for royalty either to visit (**227**) or to send a message of sympathy (**378**, **400, 403**). Memorial cards were also printed (**400, 403.3**) and some tragedies were immortalised in song, as after the 1904 Gresford disaster (**359**) and about the 1914 Ludlow Massacre (**431**). The most expensive monument is probably the church erected after the 1893 Senjski Rudnik mine disaster (**314**). At the

Mungyeong SeokTan ParkMuelGwan museum there is a shrine in honour of miners who died of pneumoconiosis (**320**).

A separate class of monuments are those erected in memory of all miners, not just those who were victims of major disasters. The steady holocaust of miners killed every day by rock falls or accidents with machinery is brought home by the provision in some collieries of a mortuary to receive the bodies of miners killed in everyday accidents (**167**). In eastern Saxony there were more than 1,000 deaths from 1914 until mining ended (**110**), while in Canada a database lists over 2,500 fatalities in Nova Scotia between 1838 and 1992 (**54**). In the UK the full tally of mining deaths is shown by a website listing over 23,000 miners (of coal and metal) who can be identified as having been killed in northern England (**369**), where in the 1930s it was estimated that the odds on a miner being killed during his career were 20 to one (Orwell 1937, p. 39). Most such memorials were dedicated to miners in a particular area: Alabama (**406**); central Jutland (**74**); the region of Cornwall (**10**); Durham (**368**); the Emil Mayrisch Mine (**100**); the district of Grey (**285**); Hesse (**121**); Hückelhoven (**131**); Kent (**380.2**); the Kleinzeche Renate Mine (**103**); the Kuznetsk (**309**); Walsenburg (**431**); and miners in the western Donbass killed while at work (**349.3**). The 2016 memorial at the Pozo Sotón commemorates all miners killed in the employment of the Hunosa company since 1967 (**335**), while the memorial at Søby commemorates 51 miners killed at work (**74**). One unusual monument is to over 2,000 pit ponies of the Illawarra coalfield (**18**).

There are a few memorials not relating to underground colliery disasters. Miners played an important role at the front during WWI and they have only recently been honoured (**79.1**). The most poignant memorials are the graves of children: the 26 of the 1838 Huskar disaster (**378**) and the 116 of the 1966 Aberfan catastrophe (**351.1**). Of the three that she sent, the message from Queen Victoria after the Huskar disaster helped the seventh earl of Shaftesbury to get legislation passed to prevent such a loss of young life again. It is fitting that the one mining-related memorial in the very centre of the capital, London, is a fountain in honour of the earl's humanitarian work (**378.4**).

Operational sites open to the public

Very few tours are offered of operating underground mines (**56, 315**) and most tours of working mines are usually of opencast mines. Use of coal is being phased out in western Europe, but is still a major source of power in much of the world, while exports are a valuable source of income. The largest opencast mine in the world is in Colombia (**61**) and the second largest is in Russia (**308**). Much opencast coal is exported, like that from Australia. The coal produced in American and Canadian opencast operations is mainly for internal consumption (**51, 408, 411-14**). In the Russian Federation, tours of the opencast mine have made Neryungri into a tourist destination (**312**), as also in Germany (**230**). In Czechia (**72**) and Spain (**333**) specialised tour operators offer a variety of tours suited to the age and interests of the visitors, while also giving tours of the restored landscape following opencasting, as in Thailand (**345**) and many sites in Germany. Opencast machinery is extremely large and impressive; where operations have finished, only a few places can offer the space to display some of the machinery used (**106.1-2, 114.1-3, 121.2, 309**). An alternative is to save only part of the machine and explain its operation with models (**15.1-2**). Guided tours are also offered of traditional mining village where tourists can meet the residents (**248, 260, 342**). The most unusual tours offered to tourists are by mine locomotive to view fireflies at night in Taiwan (**344.1**).

Mining museums

Coal-mining communities have frequently wished to preserve a memory of their earlier work, especially as coal was being displaced as the major form of energy. One of the earliest coal-mining museums in Europe, and probably in the world, is the 1907 Musée de la Mine in Le-Molay Littry (**91**), although the underground of the great copper mine at Falun in Sweden was available for visits from the time of the Napoleonic wars (1803-15).

Coal-mining museums occupy a surprising variety of buildings, but effectively fall into two main groups: those occupying former colliery sites and those in either purpose-built structures or other buildings converted for use by the museum. This section will not consider every example, but will look at just some outstanding examples, with German museum buildings dealt with in the introduction to Germany.

Architecture

It is said by coal miners that the first shovel-full of coal taken out of a mine is the first shovel-full towards its closure. So generally colliery buildings were not constructed to be permanent and this was used, for example, as an excuse for not providing pithead baths (Orwell 1937, p. 33). At most collieries, the one building on which care was lavished was the winding-engine house (**129.4, 255.1-2, 302.1, 338.2, 365.1, 382.1-2, 386.1, 395.1, 404.1**). This was usually of stone, rather than wood or corrugated iron, was tiled inside and kept spotlessly clean by the winding enginemen, who were the only ones allowed inside.

The modernist headstocks and associated building of Clipstone Colliery were very unusual in being designed by professional architects (**366**) and the winding-engine house of Snowdon Colliery was preserved as a good example of modernist architecture in an industrial context (**396**), although this was the norm in Germany. The 1923 concrete winding unit of the O'gara Mine Number 12 (**425**) is reminiscent of modernist design. The Nederlands Mijnmuseum is housed in an elegant square red-brick building beside the winding-engine house (**280.1**), the 1918 red-brick buildings of the Szyb Wilson were architect-designed (**305**), those of Národní památkový ústav were designed in 1915 by the professor of urbanism (**70**) and the Site du Grand-Hornu is renowned for its superb neoclassical architecture (**37.1-2**). The concrete and red-brick buildings in the neoregional style of Le Centre Denis Papin were saved from demolition by their quality (**82**) and the wooden derrick of the Museo de la Mina de Arnao is considered to be a masterpiece of industrial architecture (**324**). Some buildings have become landmarks of the city where they are located, such as the administrative buildings of the colliery companies now used by the Pernik – Podzemen Minen Muzei (**45**) and the National Museum of Unity (**293**), as well as the headframe of the Schacht Gerdt (**157**). In Japan the Sasebo-shi Sechibaru Tankō Shiryōkan occupies an unusual building constructed in 1912 in the western-European style (**266.1**), while in China the old housing for miners and other industrial workers covers three very different styles (**58**).

A variety of non-colliery buildings have been utilised to house mining museums. The Muzium Chimney is located in a colonial-style building (**278.1**) and the museum in Aldenhoven is housed in a former Capuchin monastery (**100**), the Bergbau- und Heimatmuseum in another monastery (**102**), the Heimat- und Braunkohlemuseum, in a seventeenth-century parsonage (**119**), and the Hessisches Braunkohle Berbaumuseum Borken occupies a timber-framed building (**121.1**). The most impressive are probably the Etnografski muzej Istre, which is housed in a former castle dating back to 983 (**63**); the Narodni muzej Labin in a baroque palace (**65**); the Központi Bányászati in the baroque Esterhazy Palace (**235.1**); the neogothic building of the Museo de la Siderurgia y Minería de Castilla y León (**328.1-2**); and the early-nineteenth-century neoclassical building with classical interiors of the mining school now used for the Sankt-Peterburgskiy Gornyy Universitet (**311.1-2**). The Bidala Audyogik Tatha Praudyogikee Sangrahaalay occupies an impressive and elegant building designed in 1959 (**238.1**).

The 1930 purpose-built monolithic main building of the Deutsches Bergbau Museum is very typical of its era (**108.1**). Approaches to new buildings have varied in recent years. New buildings at the NCMME (**386**) between 1985 and 2010 reflected the changes that were taking place in colliery architecture in the UK over those 25 years, while the main building on the site of the Pozo Norte Mine is based on a coal-preparation plant, with the original headgear of the mine in the centre (**326**).

In other cases striking new buildings have been erected, even on colliery sites. The Cutter at Woodhorn is designed to look like a horizontal cutting machine (**404.2**) and the building housing the Arigna Mining Experience echoes sloping coal seams (**240.1**). The Svalbard Museum occupies a low dark building that stands out against the snow-covered background, but does not obstruct the view (**295.1**). The new building on the Museu de les Mines de Cercs colliery site is faced with a reflective surface (**332.3**), while the building of the Muzej Rudarstva i Železnice is designed to look like a miner's lamp (**41**).

Art

Many museums have art collections, including audio-visual productions, coins, drawings, engraved glass, engravings, films, furniture, installations, jewellery, paintings, photographs, posters, prints, sculpture, tapestries and decorative items with representations of mines, such as clocks, crockery and furniture. The largest museums have comprehensive collections covering all, or almost all, these facets (**78, 108, 311, 386, 388**). The Nakamura Museum, with ceramics, glasswork, inkstone, paintings and sculpture, is presented as 'the museum of artwork from the period of coal mining' (**273**).

Illustrations in the form of drawings, engravings, paintings and sculptures showing the hard life and work of miners are found in Belgium (**33**), Germany (**98**), Japan (**276**), Slovenia (**316**) and Ukraine (**349.2**). The Centro Italiano della Cultura del Carbone has a comprehensive archive of historic photographs, including images taken in 1950 of women working in the screens (**244.2**), while the Archivio Storico Minerario has nineteenth-century images of armed guards (**243**). The Winding House has a photographic record of Welsh miners and their family life in the 1970s (**403**). Sculptures commemorating miners are to be found in Belgium (**29**), Germany (**113**), Spain (**326**) and the UK (**380.2**), and other sculptures are to be found in Belgium (**33**), Germany (**212**), Japan (**277**) and Russia (**307.2**).

Some museums have collections of paintings or other items made by miners, such as in Hungary (**235**), Poland (**302**), Russia (**307, 313**) and Ukraine (**349**). The works of the Pitmen Painters are now very valuable, and two museums have large collections of their work (**386, 404**). Collieries in Belgium (**25**) and Germany (**130, 160, 171, 186, 188, 215**) have been used for art installations based on mining equipment and sites.

The most famous works of literature about coal mining and miners are those by Takahashi Kiichirō (**276**) and Zola's novel *Germinal* (**33**), which was used as the basis for a film in 1993. Some of the props used were borrowed from the Musée de la Mine d'Harchies (**33**), while displays at the Musée de la Mine de Blanzy (**87**) and the Besucherbergwerk Rischbachstollen (**107**) are based on the descriptions in *Germinal*. The novel *Subterra* by Baldomero Lillo about the lives of the miners of Lota was made into a film in 2003 (**57**).

Particularly valuable are the historical items, including jewellery made from jet on display in China (**60**) and Russia (**311**), and the 1751 *Selmecbánya* table decoration in the form of the surface of a mine (**235.2**). In some cases there are also more esoteric items like decorated stoves (**89, 98, 110, 120, 252.2, 363, 426**) and choral performances, which are a feature of the Cape Breton Miners' Museum (**48**) and the Parque Minero (**333**).

Fossils

Coal mines have been an important source of information about extinct animals and plants. The Nova Scotia coalfield is so famous for Carboniferous fossils that a discovery centre is dedicated just to those fossils (**55**). Many museums have displays about the formation of coal in the Carboniferous period. A few have full-size reconstructions of the conditions at that time (**99.4, 226, 241**) or display fossilised remains from that period (**252.1, 387**), while fossilised freshwater mussels from Germany (**131**) show that the coal seams there came from inland water. There are also displays of the range of fossils found during mining (**62, 250**) or a model of the first dinosaur found in Spain (**331**). An internationally important collection of 30 complete igaunodons was found in a Belgian mine (**33**). Some German and Japanese museums have outdoor wooded areas with plant species from which coal developed, such as dawn redwood trees (**120, 263, 277**).

Most important are where new species were identified from specimens found in coal mines. The *Pantelosaurus saxonicus* is known only from parts of six individuals found in the Königin-Carola-Schacht (**99.2**) and the *Keraterpeton galvani* was identified at Jarrow Pit (**241.2**). The only evidence for the presence of pantodonts in Europe comes from Gruve 7 in Svalbard (**295.3**).

The future

Underground coal mining has now essentially ceased in western Europe and Japan, but still continues in large measure in Australia, China, eastern Europe, India, Mongolia and Russia. It had been calculated that by 2020 renewable energy would be cheaper than new coal in many of the countries dealt with in this publication: America, Australia, Austria, Bulgaria, Croatia, Czechia, Denmark, France, Germany, Hungary, India, Ireland, Italy, Japan, Malaysia, Netherlands, Poland, Romania, Russia, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Turkey and the UK (Gray and Sundaresan 2020).

A number of museums have accepted that coal mining cannot have a secure long-term future in light of the 2016 Paris Agreement to control global warming, so are including displays on alternative energy. Sometimes this is to bring the story of fuel up to the present day, as in Australia (**1**) and in Denmark (**73**), while the Beckley Exhibition Coal Mine deals with clean-coal technology (**407**) and the Mae Moh Mine Museum stresses the importance of saving energy (**345**). ENERGETICON in Germany opened in 2014 to explain the need to move from fossil fuels and nuclear energy to renewable power (**109**). The Arigna Mining Experience demonstrates new renewable-energy systems (**240**), while the statutes of the Ecomusée du Bois-du-Luc include the objective of raising public awareness of sustainable development, and changed its name to reflect this aim (**23**). At present most tend to be relatively straightforward, concentrating especially on solar energy, wind power and heat-pump technology (**394**), without examining in too much detail drawbacks, such as the number of birds and bats that are killed every year by wind-turbine blades.