4: Coal

Text by Mike Gill. Additional material from John Barnatt, Graham Brooks, Ivor Brown, Nigel Chapman, David Cranstone, Paul Deakin, James Fussell, Shane Gould, Fred Hartley, Phil Newman, David Poyner and Rob Vernon

4.1 Locality

Coal occurs over large areas of midland and northern England, with smaller coalfields in Somerset and Gloucestershire, Devon and Kent. Much of it remains unworked, however, because it exists at too great a depth. Nationally the industry's archaeology is not evenly spread, with large tracts of surface evidence having been removed by opencast mining, urbanisation and landscaping, but the Bristol, Nailsea, North Somerset, and Forest of Dean coalfields have a relatively high proportion of well-preserved sites, although important remains can be found in almost all coalfields. There are also significant remains of coal mining in the Pennines, mostly dating from the 18th and 19th centuries, but with some older and a few more recent. Archaeological evidence also survives in some places where coal has been sought, but never found or worked. There are also massive coal fields in South Wales, which, although outside the brief of this assessment, need to be considered in any general statement about the archaeology of coal. Records for coal mines, collieries and associated infrastructure are contained to a greater or lesser extent in the HERs for Cheshire, Cumbria, Derbyshire, County Durham, Gloucestershire, Kent, Humber, Lancashire, Leicestershire, Manchester, Northumberland, Nottinghamshire, Shropshire, Somerset, Staffordshire, Tyne and Wear, Warwickshire, Worcestershire, North Yorkshire, South Yorkshire, West Yorkshire, Yorkshire Dales NP, North York Moors NP.

4.2 Consumption

Coal is a dirty fuel and, depending on its rank (carbon content), some is more so than others. This dirt, in the form of ash and volatile matter, especially sulphur, is a particular problem for many applications. Where such coal was directly in contact with the raw materials being treated it contaminated the product. Nevertheless, coal was used as a domestic fuel from Roman times when it was also used for lime burning and smithing.

Consumption of coal in Roman times is hinted at in various archaeological contexts (Dearne & Branigan 1996) though its use was probably on a small scale. Even by the 13th century, when early documentary evidence of coal usage is available, it was not favoured as a domestic fuel and wood and peat were preferred. Rapid population growth, especially in towns, in early post-medieval times outstripped the traditional domestic fuel supplies and led to the coal industry becoming well established by the 17th century. Some land owners may have responded by reserving their wood for industrial rather than domestic purposes, but recent work in the Wyre Forest suggests a local preference for burning wood well into the late 17th century (Poyner & Evans 2000). The authors of that study admit this activity was probably atypical because people there were able to easily obtain firewood. The change to coal was certainly not universal and many other rural areas continued using wood or peat for domestic fuel, where for many the only outlay was in the effort of gathering it.

Earlier writers, for example Nef, might lead one to conclude that demand for a larger output of coal was met by innovative changes in the industry's structure and management plus larger, much more highly capitalised mines (Nef 1966). On the contrary, however, as Burt demonstrated for metal mines and as Hatcher also points out, with few exceptions, these increases were achieved by sinking more small mines and using traditional techniques (Burt 1989; Hatcher 1993, 10). The domestic demand was for lump, preferably low-sulphur, coal whereas small coal and 'slack' was sold for lime burning or salt making, aiding the viability of many rural and coastal collieries.

Because it was difficult to transport bulk loads, most English collieries were small affairs, serving local markets, until the 18th century. The coal trade grew disproportionally in the Tyneside and Wearside area, where larger collieries appeared, on account of the coastal trade with London. This lead was sustained by the introduction of wagonways in the 17th century which allowed mining to spread both north and south of the Tyne. Similar developments on a smaller scale occurred in West Cumberland, supplying the Irish market, and collieries around Coalbrookdale, in the Severn Gorge, where the river was used to ship coal to Worcester and Shrewsbury. This trade was enhanced by using local coal and limestone to produce lime. The same mines also produced ironstone with their coal and an iron making industry was well established before 1709 when Abraham Darby began the commercial smelting of iron with coke.

Darby's success coincided with Newcomen's introduction of the atmospheric engine, near Dudley, in 1712. Pig iron made with coke was better for precision foundry uses than that made with charcoal, which helped advance the atmospheric engine's development. Together they raised demand for coal and, in turn, facilitated deeper and more centralised collieries. Nevertheless, these two developments, while paradigmatic in their approach, only steadily increased the market for coal, but they allowed major advances in engineering, manufacturing techniques and skills to evolve.

In 1848 the Scottish chemist James Young (1811-1883) began trying to extract liquid fuels from cannel coal at Alfreton in Derbyshire. This supply soon ran out, however, and Young found an alternative supply at Bathgate in Scotland. Also in the 1840s was the first commercially produced Benzene from coal tar sources and these two events marked the start of a massive demand for coal from the chemical industries,

A major advance in markets came with the canal age, when rural and urban areas became linked and bulk transport between inland areas independent of navigable rivers became possible. By the 19th century, therefore, the economy had reached a critical mass, with an insatiable demand for raw materials, especially fuel – now almost exclusively coal and coke.

Steam power was paramount in the 19th century and the only significant fuel available to power it was coal. It drove mills, mines, railways, steamships, foundries, breweries, potteries and practically all other means of production. In addition, the metallurgical and coking grades of coal were in great demand for iron smelting and gas making. Some collieries became larger and deeper and often worked a number of seams from a central site. By far the majority, however, remained quite small.

Coal prices and production regularly oscillated in the 19th century following a roughly five year cycle, but what historians call 'the coal famine' occurred between 1871 and 1873. This caused the price of coal to rise from around 9s 6d per ton to 21 shillings over two years before falling back to 10s 10d in 1876 (Meade 1882, 310). The cause appears to have been a relatively small under-supply in an otherwise buoyant market, and many new collieries were sunk in consequence of it. A further knock-on effect was that alternative fuel supplies were sought, and much experimentation and investment in the commercial development of peat occurred in areas of England and Ireland where the fuel was plentiful. However, these were mostly unsuccessful.

Employment data for the coal industry are not available until the mid 1890s, but it is possible to gauge the number of English collieries from 1854 onwards. The *List of Mines* shows a rise from 1,845 mines in the year 1855 to a maximum of 2,596 in 1880. From 1885 to 1895 it averaged 2,245 before beginning a steady, but relentless decline (Gill 2007). The decline from 1895 onwards partly reflects the closure of older, smaller and shallower mines and their replacement with fewer, larger, often deeper, and more efficient mines. Over the long term, however, it reflects over-capacity in the face of changing markets, with the rate of increase in coal production starting to slow after 1870 and production declining after 1913 (Mitchell 1984).

Coal mines were highly labour intensive, and, from the 1860s onwards, some owners responded by introducing mechanical coal cutters to cut production costs (Gill 2009, 116-23). However, by far the majority did not do so until the early 20th century, when electricity, gas and oil were changing the shape of the market for fuel. For example, the launching of the Royal Navy's first oil fuelled battleships (Queen Elizabeth class) in 1913 began a rapid changeover to oil. In addition, competition from coal mined overseas badly hit Britain's export market. From the early 1920s, therefore, it was government policy to encourage the closure or merger of collieries into larger, more productive units.[1] Production quotas were set in order to avoid even higher unemployment, with many mines working only part-time.[2] As part of this process of rationalisation, the Conservative Government nationalised coal reserves in 1938, with effect from July 1942.[3] The mines themselves were nationalised from January 1st 1947 under the National Coal Board (NCB).[4]

Between 1926 and 1937 the national electricity grid was built, in order to link power generators and encourage the use of electrical power by industry. The Nationalisation of the power generators in April 1948 was followed by moves to build large new, often coal-fired, power stations on the coalfields.

From its onset the NCB followed the policy of merging collieries, closing unproductive mines and absorbing their reserves into the takes of neighbouring collieries. Some mines were closed to provide land for opencast mining. Throughout the 1950s and 1960s marginal, high-cost coalfields (Somerset, Shropshire, Cumberland and West Durham) were run down and their workforces were encouraged to move to 'long life' collieries in Yorkshire, Derbyshire, Nottinghamshire and the Midlands. This diaspora will be reflected in settlement patterns and regional demography as, particularly in Durham, whole areas of housing stock were classified for demolition, sometimes to make way for opencasts.

The markets shifted again in the 1950s and 1960s as industry turned to oil, electricity and gas for its power. This move was accelerated by Clean Air legislation and the use of diesel and electric-powered railway locomotives. As well as continuing to rationalise its mines, the NCB also sought to mechanise them wherever possible and concentrated on supplying the electricity generators.

Nevertheless, nuclear, oil and gas-powered generating stations made major inroads into coal's principal remaining market and the industry had shrunk to fifteen large mines when the NCB mines were privatised in 1994 and by 2011 that number was reduced to five: Kellingley, Hatfield, Maltby, Thoresby and Daw Mill.

Their principal market remains the electricity generators, but Maltby also serves the Monckton coke works. There are also smaller mines at Eckington, Clayton West and in the Forest of Dean.

4.3 Geology

Most English coal deposits, traditionally referred to as the Coal Measures, were laid down during the Westphalian regional stage of the Carboniferous period when, between 313.5 and 306.5 Mya (million years ago), extensive freshwater swamps sometimes flourished on deltas or behind coastal barriers at tropical latitudes.[5] There are also the Culm measures of north Devon which are problematic in age, but are probably Westphalian. They are anthracitic in nature and were probably formed on the margin of the main delta.

The sediments were predominantly sands, silts and mudstones, but where they broke waters the surface peat accumulated in swamps, which rotted under anoxic conditions and eventually formed coal. It is estimated that it took the peat approximately 10,000 years to reach a thickness of 10 metres; enough to make around one metre of coal. These deltaic areas subsided slowly (from 1 to 5 mm per year) as, under their increasing weight, the sediments became compressed.

The rate of subsidence was often equal to the rate that sediments accumulated, but occasionally the process was interrupted. Commonly, the process of peat formation would be ended by the deposition of mud. However, tectonic activity could also cause the landmass, which provided the source material for the deltas, to be uplifted at a faster rate. Such an event would increase the rate of erosion on the land and permit the deposition of sand or grit in the deltaic area. Sediment would cover the peat, and the peat was often eroded by the changing river patterns. More rarely, an increase in the rate that the delta subsided could result in a marine incursion. Marine bands that result from such incursions as a rule usually form the roof of coal seams, and are useful for correlation purposes.

Generally, the cycle of deposition followed a set sequence. The peat would be covered by mud grading upwards into sand. Eventually vegetation would become established in the semi-submerged sand, which would then be invaded by roots, to form a seatearth, or fireclay, on which the peat would accumulate. This characteristic sequence of deposition is known as a cyclothem. This cycle of swamp–subsidence–flooding–sediment infill–swamp was repeated many times over, which is why coalfields usually have a sequence of coal seams, and may reach a total thickness of hundreds of metres, even though all the sediments were deposited in shallow water.

Faulting also affected deposition. The slow movement of basement faulting beneath the deltas could cause variations in sedimentation. If these ancient faults remained active, it led to differential rates of subsidence on either side of them. While sediments might continue to accumulate on one side, therefore, on the other they might become flooded and covered with sediment until a new swamp formed. Thus what had been a thick seam might appear to split into two or more thinner ones. This process could also happen where surfaces subsided differentially for other reasons, but it always had a profound effect on the layout of mines and their workings (Williamson 1999, 5-27).

The coal fields in central and northern England were uplifted when the Pennines formed and, except for small outliers left by major faults (e.g. the Ingleton and Sleightholme coalfields), those areas have eroded to reveal the core of older rocks. Subsequent ground movements caused further, localised uplift, tilting, buckling and fracturing of the strata. Again, these effects are major determinators of a mine's layout. In particular it meant that seams outcropped, allowing early miners to find them and work them from drifts or shallow shafts, before progressing to deeper, concealed coal. Of all Britain's coalfields only Kent's does not outcrop. Its presence was realised by extrapolating French geology westward and it was then discovered by boreholes.

Older coal seams, in Brigantian (330 to 326.4 Mya) and Namurian (326.4 to 313.5 Mya) strata, were also worked (Gill 2008).[6] Although generally quite thin, these seams were of considerable local importance for lime burning and domestic fuel. Sometimes their coal was cokeable, which added value. The Namurian seams in particular were formed on an active paleo-surface of river channels, sand banks, flood plains and lagoons, in which coal swamps formed on sand or mud substrates. It is possible, therefore, for seams to be broadly coeval, but not necessarily conjoined. Periodic incursions of sediment-rich water into the lagoons from river channels, or sea, caused the high ash content common to such seams.

Younger coals have also been worked in Bajocian age rocks of the Mid Jurassic epoch, dating from 171.6 to 167.7 Mya, on the North Yorkshire Moors (Gill 2010). Unlike the Carboniferous-age coals, these Permian–Jurassic coalfields originated in temperate latitudes. Small deposits of lignite, an even younger, soft brown coal, found in Chalk (145 and 65 Mya), were worked at Cobham in Kent. Lignite was also worked around Bovey Tracey in Devon (Pengelly & Heer 1863). It formed in the Lower Miocene epoch, of the Neogene Period, and dates from between 23 and 15.9 mya.

As well as coal, the Carboniferous Coal Measures supported a range of extractive industries. These included clay for brick making, sandstones which were quarried for building stone, and the seatearths for fireclay and ganister. Clay ironstones were also locally important. They were formed in the reducing conditions within the freshwater swamps where iron went readily into solution. When oxidized the iron would precipitate and combine with carbonates to form sideritic mudstone. Some iron-rich horizons formed thick ironstones that were economically important, like those in the West Midlands or the Tankersley Ironstone of Yorkshire, for example (Raistrick 1939; Hemmingway 1974). Ironstone could occur in beds, as nodules or, less often, impregnated sandstone. Iron also combined with sulphur, which was freely available in swamps, to form iron pyrites (FeS_4), which occurs as nodules in some seams and was used for making copperas ($FeSO_4.7H_2O$). Sulphur was also a major pollutant in some coals.

4.4 Historical Research

Much has been written about the UK coal industry, but we know relatively little about it in detail. The major recent work, a British Coal-sponsored five-volume study of *The History of the British Coal Industry* deals with the industry nationally (Flinn 1985; Hatcher 1993; Ashworth 1986; Church 1986; Supple 1987). These volumes give a useful outline of the industry's progress within the national context of markets, legislation, attempts to increase productivity etc. A six volume compilation of sources *Coal in Victorian Britain* by Benson *et al,* is planned to appear in 2011 and 2012 (Benson *et al* forthcoming). The pre-1982 literature is summarised in Benson *et al* (1981). There is a very considerable literature on the social history of coal mining, both on the miners themselves and their communities and also the trade unions and industrial relations (Benson 1989). Page Arnot's multi-volume history of mining trade unionism until the mid-20th century remains a key text (Page Arnot 1949, 1953, 1961, 1979) while more recent writers have focussed on the disputes of the 1970s and 1980s.

The *Gazetteer of UK Collieries*, designed as a research tool by Mike Gill, is a comprehensive listing of post-1854 collieries and their locations, where known (69% of around 12,700) (Gill 2007, 64-75). Older sites are included where details are known, but there are many to be added. A separate database includes details of ownership, management and numbers employed from 1855 onwards (NMRS database)

County and other volumes on 'industrial archaeology', such as the former David & Charles series, e.g: Lancashire (Ashmore 1969), North-west England (Ashmore 1982) and the East Midland (Smith 1965), normally include substantial coverage of any coal mining within their geographical area if coal was produced there. Unlike metal mining, however, there have been comparatively few 'in-depth' studies of specific collieries or coal mining areas (but *see* below). Railways served a major function in coal mining but railway historians tend to enthusiastically follow the track up to the colliery gate, but rarely look over it. There is a wealth of 'Blood on the coal' local studies of explosions, inundations, strikes, lockouts and mining communities, but these rarely give technical details about the mines concerned or consider their economic history and can contribute little to the understanding of the archaeology. The last twenty years has seen a growing number of mining historians showing interest in coal mining and guides have been written to aid those beginning a project (Hill 1991; 2000; Martell 1999; Henesey 2004). A high proportion of modern books have been based on collections of photographs (e.g. Bower 1993; Ellis 1995; 2002; Franks 2000). While arguably not advancing our knowledge much in themselves, they are potentially of great use to archaeologists in identifying component parts of some sites.

Studies of those collieries which worked in non-Westphalian rocks have also appeared recently. These were largely ignored by the Monuments Protection Programme (MPP), which deemed them to be of low national interest/value. Nevertheless, these mines, which generally worked thin seams with high ash contents, were often of local importance over several centuries and their remains may be better preserved than collieries in the main coal-producing areas. Barnatt and Heathcote's studies of workings in the Namurian (Millstone Grit) rocks on the east and west flanks of the Pennine Anticline in

Derbyshire appear in various issues of the PDMHS *Journal* and *Newsletter*. In the Yorkshire Dales, the Namurian has also supported extensive collieries (Preston Moor Colliery, in Wensleydale, has around 200 shafts in an area 3 km long by 1½ km wide). Where plans have survived, these shafts are shown to have served complex areas of pillar and stall workings. The Visean in the Yorkshire Dales also produced coal, much of which was used for lime burning. Tyson and Spensley are working currently on specific collieries, while Kelly and Gill have recently written complementary overviews of the west and east parts of this region respectively (Tyson 2007 and *forthcoming*; Spensley *forthcoming*; Gill, 2008; Kelly 2008).

In the North Pennines, there are some Namurian (Millstone Grit) coals, but the most extensive seam was that below the Little Limestone. Normally a bituminous coal, in places around Alston, its rank (carbon content) has been raised to that of a semi-anthracite by heat and pressure during the intrusion of the Whin Sill. Much work remains to be done on this area, but Graham Brooks is currently researching the western fringe of the North Pennines and the Caldbeck area, on the northern edge of the Lake District (Brooks 2009, 124-36).

Coal also occurs in areas where the strata is more recent than Westphalian. For example, on the North Yorkshire Moors there are extensive areas of coal workings in Jurassic rocks (Gill 2010, 19-31). The Lignite formation of Bovey Tracy, in Devon, known as 'Bovey Coal' and first described by Milles in 1759 (Milles 1759, 534-53), however, appears to have received scant attention since Pengelly and Heer's work in 1862; understandably perhaps as the opencast filled with water in the 20th century and the surrounding area has been extensively developed. The same lack of research is true of the culm/anthracite workings around Bideford, which are also within Westphalian strata.

4.5 Historical studies of the English coalfields by county

Cheshire

The area exploited for coal in Cheshire is a southern extension of the Lancashire coalfield (*see* below), but coal working was restricted to the Pennine fringe to the east of the county and Neston, on the Wirral to the west. The Neston collieries have been researched by Annakin-Smith (2006) and a history of the mines around Poynton area, near Stockport has been published (Shercliff *et al* 1983). Elsewhere in the county the deposits are too deep to be worked economically, being covered by Permian and Triassic strata.

Cumberland

The coal industry has been included on the pages of the *Transactions of the Cumberland and Westmorland Antiquarian and Archaeological Society* (Old and New Series) from a surprisingly early date including Isaac Fletcher's 'The Archaeology of the West Cumberland Coal Trade' (1877, 66-313) but more recently Oliver Wood's work on *West Cumberland Coal 1600-1983* (Wood 1988). Other themes covered are colliery settlements (Harris 1974, 118-46). In the eastern part of the county, there is

Webb's useful study of Lord Carlisle's rail network, serving his pits on the Tindale Fell and Midgeholme coalfields (Webb 1978) and in the west, Brayton Domain collieries have been covered by Thomas (1986). A recent study by Cranstone has reported on various historical aspects of coal in the Whitehaven area and highlighted the potential of a number of untapped documentary sources that could be informative for this area of West Cumberland (Cranstone 2007).

Devonshire

From at least the 17th century, narrow, vertically bedded lenses of anthracite in the Lower Culm Measures were worked at Hartland and from Abbotsham eastwards through Bideford to Hawkridge in the Taw valley. The peak period of production was in the 1840s, at East the Water on the Torridge at Bideford, but small scale working continued into the 1920s. Associated paint pigment working at the Bideford Black Mine did not cease until the 1960s and Claughton recorded inclined shafts and adits in Cleave Wood, extending east for 400 to 800 metres (Claughton 1994, 1-4).
A small area of anthracite, or culm, was worked near Bideford until the early 1960s. As well as being used as a fuel, this product supported a local paint works. Claughton recorded inclined shafts and adits in Cleave Wood, extending east for 400 to 800 metres (Claughton ###).

Lignite was worked at Bovey Tracey intermittently from about 1750 until 1945. Several early references to the works exist, such as that by Milles (1759) and Pengelly (1862) and a recent historical summary has been provided by Edwards (2011).

Derbyshire

In Derbyshire, the main coalfield is a southern extension of that of Yorkshire and so reflects its geological character in many aspects. In turn, it dips eastwards into Nottinghamshire and north-east Leicestershire. There was a significant ironstone mining industry around Clay Cross.

Members of the Peak District Mines Historical Society have been active in recording the workings in this county. The latter work has been published in *Mining History* from 2002 onwards, predominantly by Heathcote (2002). There are also regular reports on small coal workings by Barnatt in the PDMHS *Newsletter* over the same period. The latter also undertook detailed surface archaeology surveys/analyses of Goyts Moss colliery (Barnatt & Leach 1997, 56-80). There have also been studies of mining around Whaley Bridge (Leach 1992) and in the Buxton coalfield (Roberts & Leach 1985). Heanor & District Local History Society (1993) have researched collieries in that area, including Bailey Brook, and Alfreton has been examined in terms of post-war change (Knifton 1985). The *Derbyshire Archaeological Journal* carries papers on Swanwick mine (Johnson 1953, 114-20) and West Hallam (Postles 1979, 221). (*see also* Leicester, below)

Durham

Relatively little recent work published, but there is the Durham Mining Museum Website.[7] This also covers Cumberland, Westmorland, Northumberland and North Yorkshire. It is a very useful site, but has some problems with the reliability of information given. Emery covered the technical development of collieries, coke making and pit villages (Emery 1992). Recent surveys include Temple (1994 and later volumes); Guy and Atkinson (2008, 41-75) includes an excellent outline of the coal industry in West Durham (which covers most of the exposed coalfield).

Forest of Dean and Newent

This area is famed for its Free Miners, which appear to make it the only coalfield with any form of organization, which was broadly analogous to the King's Fields of lead mining history. Coal mining is documented here from the 13th century (Youles *et al* 2008, 51). As well as coal mining, this area supported an important iron industry. Coal is still raised in this area occasionally though in a very small way. Youles has reported on a project to record an area with a high density of pre-17th century coal pits, many less than 20m apart, which appear to have worked three thin seams. (*see* archaeology section; Youles 2003; 2004). Mining in the Newent coalfield, an outlier of the above, appears to have ended in 1880 (Bick 1979).

Gloucestershire – Bristol and Somerset

The Bristol coalfield runs north-east from the Bedminster area, under what are now the eastern suburbs of Bristol, to Yate, and is associated with the Coalpit Heath syncline and the Kingsdown anticline. Two smaller, satellite coalfields were also worked. The Severn Coalfield, in the Avon Mouth basin, lies five miles north-west of the city centre and runs under the Severn estuary to Portskewett. The Nailsea coalfield lies with a syncline seven miles west of the city centre. A small inlier of coal measures has also been worked at Clapton in Gordano.

These coalfields are rich in 18th and early 19th century remains and have been studied by the South Gloucestershire Mines Research Group and the Bristol Industrial Archaeological Society. As well as books (Anstie 1965; Cornwell 2001; 2003), there are papers in the *Journal of the Gloucestershire Society for Industrial Archaeology*, the *Proceedings of the Somerset Archaeological and Natural History Society* and the *Industrial Archaeology Review*.

To the south, the Bristol coalfield appears to have been left unworked in a syncline before re-emerging in north Somerset, where it was worked extensively. The Somerset coalfield is roughly rectangular, eight miles wide by seven high, and centred on Midsomer Norton which has been subject to detailed studies by Gould (1999; *see* archaeology section) but an early history was published by Down and Warrington (1971). See also the Somerset Coal Canal (below).

Kent

There was a small lignite mine at Cobham, near Rochester, which worked until 1953 (NMRS List of Coal Mines). Coal was discovered in 1890 during borings for a proposed Channel Tunnel and development began in 1896 with the sinking of Dover or Shakespeare Colliery. Mining ended with the closure of Betteshanger Colliery in 1989. Kent was rare in having productive seams in the Upper Westphalian and is probably the only coalfield to have more suspended sinkings than working collieries. Scarcely any historical research on this coalfield has been published; the main source of information to date is Dover Museum's Coalfields Heritage Initiative Kent website[12] which has a very informative education pack. However, a recent monograph by Hollingsworth (2010) has covered much of the economical and social history of the area.

Lancashire and Greater Manchester

The northern part of the coalfield between Colne and Blackburn has a number of papers and monographs covering its history and geology, including works by Nadin who has examined the mines of Nelson and Colne (Nadin 1996), East Lancashire (Nadin 1997), Accrington and Blackburn (Nadin 1999). A short report on Martholme Pit has been published by Bond (1984, 31-7) and Williamson has explored the Burnley Coalfield (Williamson 1999, 6-27).

The more important southern area, with its steeply dipping and heavily faulted seams, has not been covered in the same detail although the Oldham area has been discussed by Fanning (2001) and the Manchester coalfields by Hayes (1988) and several collieries in the Worsley area have been researched by Atkinson (nd). Like parts of Staffordshire and Shropshire, the Wigan area produced large amounts of cannel coal which was favoured for gas making (Davies & Hudson 2001).

Leicestershire & South Derbyshire

The main coalfield lies in a ten mile square area centred on Ashby-de-la-Zouch in Leicestershire, extending across the county boundary into Derbyshire. There were probably small pits on Swannington Common before the Norman Conquest, where coal was regarded as a common asset of the free men of the village. Documentary references begin in the 13th century at Swannington and Worthington. There were mines at Staunton Harold in the early 14th century, and by the 1420s the nearby village of Overton Saucy was sufficiently well-known as a supplier of coal to be renamed "Coal Overton", later shortened to "Coleorton" (F Hartley *pers comm*)

A large opencast mine at Coleorton – the 'Lounge' Site - operating from 1988-1994 produced a wealth of evidence of earlier mining activities, particularly from the late 15th century, when well-organised pillar and stall mines were being accessed by timber-lined shafts at depths of 30m or more below the surface. There was also much evidence from the 16th century, and some items from more recent times. Hundreds of finds from this site are stored by the Leicestershire County Council Museums Service, mainly at Snibston Discovery Museum (*see* archaeological section below).

On the western side of the coalfield mines at Swadlincote (in Derbyshire) are mentioned in 1294, and Leicester Abbey had mines at Oakthorpe probably in the 14th century, but certainly by 1477 (F Harley *pers comm*). By this date there were probably also mines in the Derbyshire villages of Stanton and Newhall.

Through the 16th, 17th and 18th centuries mines were developed to gradually greater depths in the Swannington-Coleorton and Oakthorpe-Donisthorpe-Measham areas.

In the early 19th century the Earl of Moira developed mines, an ironworks and a new settlement called Moira on the southern part of Ashby Wolds, served by the Ashby Canal. Between the 1820s and the end of the century, gradually deeper mines were sunk to concealed reserves south of the Eastern Basin, as far as Desford.

During the 19th and 20th centuries most collieries set up an adjacent brick and tile works, and a network of railways evolved to link them to the national railway system. Ashby Wolds, an area of former open common land between the Leicestershire and Derbyshire mines, became in addition a major centre of sanitary ware manufacture.

In the late-19th and early-20th centuries the area developed a pattern of settlement which is still obvious to this day, with scattered terraces of housing in and around the collieries, and ribbon development along roads from village to village. The Burton and Ashby Light Railway, an electric tramway system, was constructed through Woodville and Swadlincote.

Twentieth-century developments were mainly concerned with linking existing mines underground and improving surface handling facilities. Most of the 19th-century mines survived into the 1960s, before the rapid abandonment of deep mines in the 1970s and 1980s.

There is considerable evidence of coal mining in the form of earthworks around Coleorton, where five areas of pits have been scheduled as Ancient Monuments, with features probably dating from the 14th to the 17th centuries. A Newcomen engine house survives (sadly much modified in recent times) at Moira, and there is a late 19th-century winder house at Calcutta Colliery in Swannington.

The buildings at Snibston, which are mainly of mid to late-20th-century date, but include some elements from the mid-19th century, form one of the best surviving groups of deep coal mine buildings still existing in the UK, and are accessible to the public as part of the Snibston Museum site.

The Nottinghamshire coalfield (*see* below) has been traced across the boundary in Leicestershire and in the 1980s it was proposed to sink new 'super' mines in the Vale of Belvoir. A mix of economic and political pressure meant that only one, at Asfordby, was allowed in 1986. This was at the southern edge of the coalfield and had significant geological and mining problems. In 1989, a Monopolies and Mergers Commission report on the British Coal Corporation noted 'we have been puzzled by the history of the Asfordby new mine project' and concluded that it 'has always been marginal in financial terms'.[10]

The history of the Leicestershire coalfield from 1200-1900 has been covered in considerable detail by Colin Owen (Owen 1984) but for the 20th century and the complex story of the small pits, fireclay mines and potteries on Ashby Wolds, the coalfield lacks a comprehensive history and detailed researched accounts for individual mines have not yet been attempted. A bibliography of papers and books on (mainly) geological aspects of the Leicestershire coalfield, produced by the British Geological Survey, is available on the web[11]

Lincolnshire

A small and short-lived speculative coalfield sprung up in the Lincolnshire Wolds in the early 19th century, based around a misunderstanding of the local geology and the actual depth of the seams (Czajkowski 2000).

Northumberland

This coalfield has the widest geological range, with Namurian and Westphalian coals, but very little historical material has been published recently. Geologically, Northumberland and Durham form one continuous exposed coalfield (the 'Great Northern Coalfield'); some sources treat this as one (Atkinson 1966), whereas others separate the two counties. For the combined coalfield, Hair (1844) forms an invaluable if perhaps over-used visual record of 1830s-40s collieries, and Atkinson (1966) is a relatively recent introduction. There have been papers in *Archaeologia Aeliana*, by The Society of Antiquaries of Newcastle upon Tyne, and the *Industrial Archaeology Review*. For Northumberland specifically, the recent literature includes Tuck (1993 and later volumes), Ayris & Vickerman (1978) and Bainbridge's volumes entitled *Coal Mines of North Northumberland* (1994; 1996).

Nottinghamshire

Unlike parts of South Yorkshire (*see* below) this area has very few workable coals above the Barnsley or 'Top Hard' coal. This results from a mixture of seam thinning and erosion. Nottinghamshire's coalfield comprises a thin band of territory on the extreme south-west of the county bordering Derbyshire. Although it is claimed that coal mining existed in Nottinghamshire as early as the Roman period, the *Historic Landscape Characterization* for the county concluded that only late 19th and 20th century working have made a notable impact on the landscape.[8] Only one colliery is still producing coal, at Thoresby. Although there has been much historical research into the Nottinghamshire coalfield, most of the published material is now quite aged and up to date material is scarce for this county. Early important papers include Bond (1924, 222-39) and Green (1935a and b). Transport networks associated with coalfields have been researched by Hopkinson (1959, 22-41) and Stevenson (1969, 45-53). The most recent monographs are Griffin's *Mining in the East Midlands* (1971) and *The Nottinghamshire Coalfield* (1981). The same author has published a report on Brinsley Colliery (Griffin 1972, 28-47). Economic Geography of the coalfield has been considered by R S Smith (1966, 235-41) and George (1993, 31-46). Additional, more peripheral material concerning the Nottinghamshire coalfield exists. A few pre-1998 papers on Nottinghamshire mining have been listed by Brook, while Griffin gives an overview of the pre-nationalised industry there (Brook 1998). A particularly useful source is on the Nottinghamshire Heritage Gateway website[9], which includes a comprehensive bibliography for the historical study of coal mining in the county.

Shropshire

This county has a number of small coalfields. The Denbighshire coalfield runs into the northern part of the county and has been worked around St Martin's: there is an outlier near Oswestry. There are also small outliers of Westphalian strata around Westbury, Pontesbury, Hanwood-Shrewsbury, Wrentnall and Dryton

The Shropshire coalfield has benefitted from an active group of historical researchers and fieldworkers (*see* archaeological section). There is a general summary of the county's mines by Pearce (1995) and a forthcoming volume will provide an account of the Shrewsbury coalfield (Shaw *forthcoming*). The main or East Shropshire Coalfield, in the Ironbridge-Telford area, has received particular attention from Ivor Brown who has published some substantive accounts of collieries (Brown 1968; 2007) and a monograph on *The East Shropshire Coalfields* (Brown 1999), whereas the Clee Hills and Wyre Forest (partly in Worcestershire) coalfields have been covered by others (Poyner & Evans 2000). Many small but important items of research have been published in the *Journal*, newsletter (*Below*) and *Accounts* of the Shropshire Caving and Mining Club and other mining history societies. The most authoritative historical study on the Clee Hill Coalfield remains an unpublished PhD thesis of the late Ken Goodman (1978); more recent work is of variable quality.

Staffordshire

This coalfield is traditionally treated as being in two main parts, a northern one around Stoke on Trent and a southern one around Cannock and the Birmingham conurbation, but modern geological knowledge shows it to be continuous through an unworked central area. The former area is also associated with two outlying coalfields to the east. One, a thin strip of coal measures, runs north-south around Shaffalong and had no modern mining. The other, a larger area, is centred on Cheadle and was worked until the 1990s.

This coalfield also lacks an up to date general study but a great deal of work has been done on a more site-specific scale. This includes a number of papers by N A Chapman discussing for example, collieries at Heath (1994, 6-23); Bournehills (1995, 41-6); Blakeley Hall and Bromford (1996, 125-133); Sandwell Park (1997) and several smaller articles (1983, 34-9; 1987, 35-43; 1997b, 93-6; 1997c, 156-61; 1999, 56-63; 1999b, 64-73; 2000, 26-34; 2004, 47-57). Chapman has also published a more general monograph on *A History of Coal Mining Around Halesowen* (1999) as has Deakin (2004) for North Staffordshire, and Stone has produced a largely pictorial general history of the Staffordshire coalfield (2007). The Cannock Chase Mining History Society has researched some mines in their area, including Lea Hall 1948-90 (Edwards & Warberton 2006) and Brereton (Edwards 2005) and a general study of Cannock Chase (various 1990). Quarnford has been covered by Leach (1996).

Warwickshire

This coalfield runs south from the very northern part of this county, around Polesworth, and contains Daw Mill Colliery, which is currently England's largest coal producer. It continues under Coventry and remains largely unworked. Like Leicester and Nottingham, the coalfield in Warwickshire has drawn scant attention from historians although aspects of individual collieries have been published including Hawksbury (Court 1937, 221-8). Grant (1978) has provided a historical account of Griff colliery in the 17th century and the Coventry to Nuneaton area has been covered by White (1970).

Westmorland (modern Cumbria)

This area has a small outlier of Westphalian rocks, preserved by faulting, at Stainmore. Brooks has studied one of a number of small, Namurian coal pits (Brooks 2010).

Yorkshire, North

The history of the small, Ingleton coalfield is available as a monograph (Bentley *et al* 2005). The Selby coalfield, Britain's newest, closed on October 26th 2004 when Riccall colliery stopped coaling. As yet, no complete history of this project has been written. Kellingley colliery, sunk between 1958 and 1962, is still working.

Yorkshire, West & South

This region had large areas of coal, ironstone, fireclay and ganister mining. From the lowest seam (Halifax Soft Bed) to the highest (Shafton) there are some forty seams, all of which have been worked to some extent. Generally speaking, the lower seams have higher ranks (carbon content) and are more likely to be used as coking coals, whereas the higher ones are free-burning.

Ironstone occurs from Huddersfield to Bradford and on to north-east Leeds and is intimately linked with the Better and Black Bed Coals. An extensive network of tramways and railways linked the pits to large iron works, especially at Low Moor and Bowling, near Bradford. Isolated pieces of archaeology remain between housing, industrial estates etc.

Another important area of mining for coal measures (Tankersley) ironstone was around the village of Emley, in the south-eastern corner of the region. Some of these workings, which run into South Yorkshire, may be medieval, but most have the appearance of 18th century remains.

A small area of the Lancashire coalfield extends into West Yorkshire and has been worked at Todmorden. Fireclay from this area and from Halifax was used for making sanitary ware, especially salt-glazed pipes and many collieries in the lower part of the middle coal measures, around Leeds and Wakefield, were associated with brickworks.

The switch from town to natural gas, the replacement of steam with diesel locomotives, clean air legislation and the change to generating electricity using oil or nuclear power in the late 1960s reduced markets and forced the NCB to rationalise its mines. Many of the thinner seam mines were unsuitable for mechanisation and the fairly high ash, sulphur or chlorine contents of lower coal measures seams meant that their coal was unacceptable to the large, coal-fired electricity stations. As a result a swathe of older, shallower West Yorkshire mines closed from the late 1960s and production was concentrated to the east of the M1.

Large areas of mined landscape have been cleared for housing, industrial estates and motorways since the Second World War. Coal has also been extensively opencasted between Leeds and Wakefield, producing archaeologically barren landscapes, apart from the stark remains of the opencasts.

Two large collieries are still working (Hatfield and Maltby), plus a much smaller one (Hay Royds) near Huddersfield, but the *Gazetteer of British Coal Mines* lists some 1200 coal, clay & iron mines in West Yorkshire from 1854 onwards. To these must be added large (unknown) numbers of older pits.

As with other coalfields, various collections of photographs and reminiscences are available on the web. The *Yorkshire Archaeological Journal* contains a few papers on coal related matters but apart from general memories of specific mines and strikes, the most recent general books are Goodchild's *West Yorkshire Coalfield* (Goodchild 2000) and Williams' *Images of Yorkshire Coal* (Williams 2005). Hill's (2002) *The South Yorkshire Coalfield: A History and Development* gives a good general overview, with some detail (Gray 1976, 31-44). John Goodchild has written over many years about the various coal owning/working dynasties in this coalfield (Goodchild 2000). Henesey's paper on the Garforth area is also useful (Henesey 2010). There has been some private research and at least one community archaeology report covering mining around Sheffield (Battye 2004; Kennett 2006). Medlicott (1983) has published material on the Sheffield colliers and Taylor has covered some of the South Yorkshire mines (Taylor 2001). Historic research at various levels has been undertaken, focussing on individual collieries including Rowles' (1992) history of Birley East, and Fordham's works at Bentley (Fordham 2009a), Brodsworth (Fordham 2009b), Askern and Instonville (Fordham 2009c).

4.6 Technology

Coal mining can be seen as one end of the spectrum of overall mining technology, with copper, lead and tin at the other; the mining of a high-bulk, low-value seam mineral, as opposed to a low-bulk, high value vein deposit. While there are fundamental similarities between all mining technologies, and cross-adoptions and adaptations in both directions, there are also significant and consistent differences. Coal has tended to take the lead in bulk material-handling, notably railed transport, and in ventilation because explosive gas, which is rare in other types of mining, is present.

Substantial and technologically advanced coal mining can be identified from the later Middle Ages onwards, from historical evidence in County Durham and from archaeological evidence in Leicestershire (Guy & Cranstone 2001; Hartley 1994, 91-101). That the latter was unexpected from the historical evidence emphasises the need for archaeological work to check, confirm and at times modify or even refute the conventional picture derived largely from (for the earlier periods particularly) a limited range of potentially selective and untypical historical sources. However, most of the technological information we have is derived from 18th-20th century historical sources, which describe coal mines in use at that time and as this assessment is concerned with the full temporal range of this industry, the data for the later period are more detailed.

In the 17th century, technological advance was broadly centred on the development and spread of surface railed transport in order to meet demand by allowing the expansion of large-scale coal-mining into areas more remote from river and sea transport. Most notable were the wagonway systems which extended the workable 'Great Northern Coalfield' far into the hinterland of the Tyne, the Wear, and the smaller Northumberland coastal ports. Also the Wollaton wagonway in Notiingham which was the earliest in the UK.

The 18th century was marked by the development of the beam engine; the use of the Newcomen engine for pumping allowed the working of deeper and wetter seams, and was centred in coal mining areas where its high fuel consumption, of small coal which would otherwise have gone to waste, was acceptable. The introduction of the true steam engine (Boulton & Watt and descendants) allowed still deeper and more powerful pumping, and the rotary motion necessary for direct steam-powered hauling. Miners paid a heavy price in the explosions which became common, however, as deeper and gassier seams became accessible. Inventions such as the steel mill for lighting, and ventilation by 'coursing the air' and later by furnace-ventilation, only partly mitigated the problems.

In the 19th century, the range and power of steam engines grew rapidly, and by the middle of the century the horizontal engine increasingly replaced the vertical-cylinder beam engine. Railway technology also developed rapidly, both on the surface and underground. From the middle of the century, fan ventilation developed, with an increasing range and power of fan installations. Compressed air developed for underground use to power cutting equipment, and coal screening and washing led to the development of increasingly complicated pithead layouts.

In the 20th century, electrical power replaced steam on the surface, and allowed increasingly mechanised extraction and transport underground, eventually with sophisticated mechanical coal-cutting, self-advancing roof supports, and armoured face conveyors. Screening and coal-washing also developed dramatically (stimulated by and permitting the switch in consumption from lump house coal to small coal for electricity generation). In the second half of the century, self-emptying skip hauling in shafts was gradually replaced by the use of conveyor-drifts, at shallow mines and seams, feeding via washeries into huge storage bunkers which in turn fed automated 'merry-go-round' trains to the power stations. These aspects of mining are examined below.

4.6.1 Prospecting

It is likely that the first coal seams were discovered by looking for outcrops in cliffs or river banks, or at the detritus from mole and rabbit holes. In order to trace and follow the seam across the landscape, however, it was necessary to dig trenches across the likely line of any outcrop. Extensions of the seam into a hillside could be found by sinking shafts. Though used in China several centuries before, the practice of boring for coal, using long rods with a chisel end, is attributed to Huntington Beaumont who first used the technique in England in the early 17th century (Smith 1957).

From the late 19th century a range of geophysical and chemical methods of prospecting began to appear. The former included resistivity and seismic surveying (Vernon 2008, 4-30). The recovery of borehole cores also became possible, as did later the geo-logging of boreholes. All of these techniques, ancient and modern, have left little detectable archaeological evidence.

4.6.2 Extracting coal

As with most forms of mineral extraction, early coal miners focussed on the most accessible, i.e. shallowest, deposits which could be exploited with the least effort, and deeper seams were worked later as technology and knowhow improved. However, as so little archaeological evidence of the underground sections of early coal mines is available, the chronology of these developments is not particularly refined and interpretation relies heavily on surface and documentary evidence.

Following discovery, extraction generally began along the outcrops of the seams, often in places which have long since lost their obvious link to the industry, and then migrated down dip, frequently necessitating deeper sinkings. An example of this is the Rivock Edge – Howden Gill outcrop, near Keighley, where most of the surviving evidence dates from the 17th century (Gill 2004, 24-5). Where they survive, workings along a seam outcrop of this type show that a range of techniques might be used, including a small amount of opencasting (the modern process would remove all traces), drifts (*see* below), and shallow shafts. The latter are often referred to as bell pits and history books have a range of explanations as to how this name originated and what it represents, which is generally just a very rudimentary form of mining.

The correct definition of a bell pit is a shallow shaft which 'bells out' at the bottom to extract as much of the seam as possible over a relatively small area. Work would continue until flooding, lack of ventilation, or the danger of collapse necessitated abandonment of a shaft and commencement of another nearby. Sinking-dirt and other spoil could be used to backfill the neighbouring, abandoned pits so, at the surface, this was likely to produce a cluster of shallow hollows surrounded by minimal amounts of spoil. Weathering, ploughing or land improvement may have obliterated all obvious traces of such slight features.

The use of the term 'bell pit' is subject to heated debate. The main problem is that an earthwork feature is often described as a bell pit based only on surface evidence of a spoil heap with a central backfilled shaft, without consideration of what lies below ground. However, such evidence could represent a number of underground techniques which were well in advance of the crude, small-scale, unsupported affairs implied by the term bell pit. Mining historians and informed archaeologists now tend to replace bell pit with the term shallow shaft, which has its own issues, not least the definition of shallow [up to around 100 feet]. Establishing the true nature of these remains will be problematical until additional underground evidence is recorded. This will be achieved with difficulty because it is unlawful to enter abandoned coal mines.

{Illustration suggestion – Aerial view of 'bellpit' surface evidence. EH to provide]

Other productive and slightly more enduring means of extracting coal underground are the 'pillar and stall' (sometimes referred to as room and pillar) and 'longwall' techniques both of which may be served by shafts with similar surface remains to the bell pits. Using the former method, the seam was worked laterally by driving headings and cross-headings to create rooms or 'stalls' but sections or 'pillars' were left in place between them to support the hanging wall (roof). When the boundary of the seam was reached the pillars were removed as work retreated.

Longwall working involves tackling a seam by establishing a linear vertical 'coalface' whereby a long edge section of the seam may be removed laterally as a continuous operation. As work progresses, the roof of the worked areas, behind the workers at the coal face, is supported by artificial props, usually of timber, though in modern mines hydraulic supports are employed.

Pillar and stall was the earlier of the two methods to be developed and was certainly in use by the 15th century. Longwall workings, although traditionally assumed to be much later, have been found to have been in use in the early 16th century in Leicestershire (Hartley 1994, 94). Both methods have survived and been adapted to the modern highly mechanised systems in use in the present day in various parts of the world. Hatcher has sounded a note of caution when using these terms, claiming they are too prescriptive and don't accurately reflect the vast differences in coal working techniques which were dictated more by geological condition and available resources than tradition or precedent (Hatcher 1993, 201).

Very shallow pillar and stall workings have been noted in the Peak District where, in a few places, there are also workings with very close spaced opencast pits and shafts adjacent to outcrops (J Barnatt *pers comm*). These may represent multi-phased, early ad-hoc extraction. In many other cases, however, very shallow mining is found in the context of soughs (*see* below) driven in the seam, which was then worked up dip but stopping short of surface to avoid the drainage problems of peat ground. Where dating evidence exists, these workings, which have regularly spaced shafts only tens of metres apart, are often of 17th to 19th century origin. Earlier workings are very restricted in location and lateral spread, which may reflect medieval working and/or a transition to the other method as the discovery was assessed and found to be workable. While some regularly-spaced shafts to pillar and stall are spaced commonly in the 20-30 metre range, many are significantly less.

There is a photograph of small-scale roughly-circular coal workings, uncovered by more recent opencasting at Stretton in Derbyshire, but most bell pits which have been studied were associated with ironstone mining (Griffin 1971, 20). Several 'belled' features, which are at the foot of an obvious shaft, at the horizon of the ironstone immediately above the Little Ryhope Coal, were recorded at Craghead, near Edmondsley in Co. Durham (Hedley 1995). At no point, however, had these workings penetrated the coal. Similar 'belled' features were seen between the shafts, but with no shaft. They were interpreted as being the front or rear parts of the bell associated with either an intended shaft which had not been cut or one that had been destroyed. Nevertheless, because the cover was not stripped off to allow the plan of any workings to be seen, they could equally represent the ends of stalls or banks from a more complex system of working.

The term bell pit has also been used by 20th – century writers to describe more substantial, annular tips immediately surrounding a shaft sunk to work any mineral. Where a vein was being worked, however, this usage is totally inappropriate, and even where a bedded mineral was sought it is at best misleading because experience suggests that such shafts are associated with more complex systems of working. In view of the above, therefore, use of the term bell pit should be avoided for the description of surface evidence because it is based on an assumption of something which cannot be seen (viz the layout of workings).

Shaft Sinking

Once found, the coal could be worked opencast along the outcrop, but the increasing depth of overburden usually meant that the seam was followed underground. At early extractive sites, this would be done from shallow shafts and, particularly where drainage was needed, drifts or day holes. Where deeper access was required, more substantial and enduring shafts were needed.

Where the coal remained fairly shallow it was usual to sink new shafts as the workings progressed. This had the advantage of aiding ventilation, but primarily it cut down the distance that coal was hauled from the face to the pit bottom. This has left distinctive landscapes, with rows of fairly regularly spaced shafts forming a grid, which until the mid 19th century were known collectively as collieries.

Timber-lined shafts would be either square or rectangular; the medieval examples revealed at Coleorton were 3-5ft square with mortise and tenon main frames (Hartley 1994, 91). Later, circular shafts were lined with stone or brick, although they were often left unlined when they passed through competent strata. In some areas the bricks were laid without mortar in order that they could be recovered for reuse. By the late 19th century cast-in-situ concrete linings were beginning to appear. As collieries increased in size and depth, shafts were sunk at larger diameters [seldom more than 25 feet] to allow larger cages or skips to be used for winding. Nevertheless many shafts were less than ten feet in diameter.

As they became deeper it was often necessary to sink through soft ground or aquifers and a range of techniques were developed to do this. Near the surface interlocking piles might be driven down to the rock head, but this method was probably limited to the first one hundred feet or so. After that, iron tubing or an open caisson could be used to get through flooded or soft strata. As the caisson was undermined it would sink and new sections were fixed on top until solid ground was reached.

The first successful method for boring shafts through heavily watered strata was developed by Kind. It relied on tubing to support the shaft sides and used a large trepanner to bore the shaft. Kind's initial attempt to sink a shaft in Belgium failed, but M.J. Chauldron redesigned and greatly strengthened the tubing and made the trepanner much heavier. As the Kind-Chaudron system, however, this method proved its worth and was dominant from 1852 until the early 1900s, when grouting and freezing made it obsolete. The system was first used in England to sink Littleton colliery, Cannock.

Where the strata was fissured and flooded it was possible to inject concrete in order to make a solid, dry area through which the shaft could be sunk. For much of the 20th century, however, it became usual to sink boreholes around the area of the proposed shaft(s) and pump near freezing brine through them. This eventually froze the area solid and meant that shaft sinking could proceed as if there was no water.

Some collieries in the Peak District and Yorkshire Dales worked under extensive areas of peat, it was necessary to construct causeways across bogs to serve individual shafts. The procedure used to sink a shaft through peat has not been studied, but in some cases catch-water drains were dug on the upslope side of shafts to keep surface water out.

As collieries became deeper, or multiple seams were worked at once, it became more cost effective to sink a central mine and work out from it. This was especially important where surface facilities, such as a railway or canal, was involved. Additional, pits might then be sunk some moderate distance away in order to improve ventilation, provide pumping, or for coal winding. In some cases the whole operation might eventually migrate to the remote pit. An example of this is Daw Mill, England's largest surviving colliery, which was sunk between 1957 and 1959 as a satellite shaft for Dexter colliery, itself a satellite of Kingsbury Colliery.

Drifts and slants

Where mines were troubled with water or the coal outcropped on a hillside, drifts, which rose at a slight gradient, were driven into the slope in order to work and drain the working area. A variety of local names for these workings includes: level, sough, adit, day hole, drift, waterloose and footrill.

As well as draining water from the mine, which was cheaper than pumping, graded drifts allowed the use of railways/tramways directly from the face to the surface and could use gravity to assist in the movement of the materials. Inclined drifts, dips or slants, were used to get at shallower seams especially after the introduction of wire rope in the late 1830s. The method was used earlier, however, and, near Padiham on the northern edge of the Lancashire coalfield, amateur historians are uncovering traces of a coal mining complex which used a waterwheel for pumping and winding from inclined drifts in the 18th and early 19th centuries (Jefferys & Mathews 2008).

Where workings met water, adits (soughs or waterlooses) were driven, from a lower point on the surface, at a slight upward gradient until they intercepted the seam and drained it. Examples of this practice are known from medieval Derbyshire and other coalfields (i.e. Guy & Cranstone 2001, 34). Adits might also have later been used to drain water pumped from deeper workings. In the late 19th and 20th centuries mine owners often cooperated in drainage schemes in which water from a number of mines was channelled through dedicated water gates to a central pumping station.

The increasing use of conveyor belts in the 1960s meant that drift mines became even more efficient and at many collieries drifts were driven to replace shafts.

Another important method of working, seen in the Peak District often at greater depths, involved driving soughs (in two cases used as canals) in the seam, which in some situations was accessed by cross-measure drifts. Fewer shafts were needed and they were only used for ventilation, unless, as at Thatch Marsh (*see* below) after the canal had collapsed, for steam-powered winding.

Breaking the ground

Fire Setting

This method of using fires, burning wood or coal, to break or soften hard rock, which could then be removed using crowbars, hammers and picks, was common in metal mines during the 16th and 17th centuries (Barnatt & Worthington 2006) and was probably first used in the prehistoric period. Writing in 1556, Agricola described it as an ancient technique (Agricola 1556). Obviously in coal mines it was used for breaking through country rock rather than the coal itself, to which the following example testifies. In 1706 at Colsterdale Colliery, near Masham, a shaft was being sunk which had hit a bed of hard sandstone and the agent, John Robinson, wrote to Sir Abstrupus Danby that:

> *I stay here to Sett a fire of wood and coals in your sinking pit which is so ill to blast or cut with picks I hope it will tender and open ye joints that spends all ye powder to no purpose* (Tyson 2007).

Unfortunately, such references are rare and the lack of archaeological exploration underground has so far provided no evidence for this practice.

Blasting

The development of explosives as a useful force in metal mining was underway by the mid-17th century and is discussed elsewhere in this report. Its use in coalmines, if not contemporaneous, followed shortly afterwards. In Yorkshire, Abstrupus Danby made an agreement on October 4th 1690 with Edward Hodgekinson, Robert Archdale and Peter Smith, all miners of Pateley Bridge, to drive a level at his Colsterdale Colliery. "*They were to find at their own charge all tools, workgear, Gunpowder, except iron, steel and boards*", which Danby was to provide (Tyson 2007, 34).

According to the Chirk and Powis manuscripts, Sir R. Middleton's miners used gunpowder at the Carreghofa mine in 1692 (Lewis 1967) – its first known use in Wales.

The use of high-explosives, in longer shotholes, began to displace gunpowder. This process was encouraged when sheathed, or flameless, explosives were developed. Nevertheless, while it was increasingly replaced by high explosives, gunpowder was still used for blasting in the early 1950s, and probably later in non-flamelamp (safety lamp) mines.

Opencasts

Some coal has been worked opencast since the beginnings of mining, but it was developed on a large scale as an emergency wartime measure by the Ministry of Fuel & Power from 1942. Except in those areas where coal was alienated (sold back to the original owners) under the 1938 Act and working was controlled by planning authorities, responsibility passed to the NCB in April 1952. Since 1995 it has rested with the Coal Authority.

Opencasting was usually undertaken by contractors who operated a range of large earth-moving plant for stripping and moving overburden. Where a single seam was being worked, this was usually placed behind the working face, so that the excavation resembled a cutting moving sideways. At some sites the overburden was stripped by large, walking draglines which steadily dug the overburden and deposited it where smaller machines could load it into dump trucks for removal. Modern opencasts tend to be much deeper, however, and work a series of seams, each with its own bench. This requires the total removal of overburden until the final landscaping phase begins. In this case, large 360-degree hydraulic excavators are used to load massive dump trucks. The coal seam is then exposed by smaller machines and any rock etc removed in order that a very clean product can be sent from the mine.

Where seams have already been mined using partial extraction techniques, like board and pillar or bank work, archaeological examination of exposed workings in more recent opencasts has provided valuable knowledge (*see* archaeology below). If a seam has been worked longwall, however, it is unlikely that much information will be recovered, apart from packing techniques.

4.6.3 Winding

On shallow shafts of the type used at early coal extraction sites, a jackroll or windlass, was used to lift coal or rock in a small kibble. This technology is known to have survived at small-scale operations into the 19th century, but as shafts progressed to depths significantly beyond 100 feet they were increasingly wound by horse gins or whims lifting larger kibbles. Some collieries used waterwheels for winding and a few used water balance systems. In the 18th century, the reciprocating action of atmospheric and steam engines was soon applied to winding drums. Various arrangements were favoured over time, with flat ropes winding onto a cage, or tapered hemp ropes or chains onto a cylindrical drum. By the late 18th century powerful, horizontal condensing steam engines with wire ropes and conical drums had become the norm for deep shafts. Flat ropes, made by stitching a number of round ones together, were used at the Duke of Norfolk's collieries in Sheffield by John Curr in 1798 (Patent No.2272, 17/11/1798).

A German system of winding, invented by Carl Friedrich Koepe in 1876/1877, used a continuous rope running from the top of one cage, over a shaft-head pulley, around a cylindrical, wood-lagged drum (with one or two laps), then back over a second shaft head pulley and down the shaft to the top of the other cage. Another continuous rope linked the cage bottoms and ran around a pulley in the sump. The friction drive allowed for much higher winding speeds and the use of lighter ropes. As well as in mining, it is used in modern lift systems. Koepe's first patent had the winder at ground level and close to the headgear, giving the ropes a very steep angle of ascent. Shafts sunk or modernised between the 1950s and the 1980s, especially where skip winding was used, were often fitted with powerful electric winders using Koepe's system. The system's advantage was that it was much more efficient, using typically between 25% and 30% less electricity, and it used less winding rope. The latter needed to be changed at two year intervals, however, rather than the usual three years.

A development of Koepe's system was the Koepe tower, in which the electric winding mechanism was placed at the top of a substantial tower, directly over the shaft. Although adopted more slowly in the UK, the first was installed at Plenmeller Colliery, near Haltwhistle in Northumberland, in 1914 and most of the major coalfields eventually had examples of them. They can still be seen at Kellingley, Maltby and Harworth Collieries. Conservation work was undertaken on the example at Murton (Ayris 1994) now obliterated.

4.6.4 Pumping

At first water might be baled from shafts using buckets on ropes, but as well as indications of late-medieval coal mining, Moorhouse Woods near Durham is the site of the earliest (1486-87) recorded use of horse-powered pumps (Raine 1837). The latter were of unknown type, but in the 16th century horse gins were adapted to drive 'rag and chain pumps'. By the 18th century water wheels were also being used for pumping and winding from shafts. The importance of these wheels has been eclipsed by the steam engines, but their presence is recorded as water courses at Vobster, in Mendip (Gould 1996, 14-26), as coal mills on Tyneside (Clavering 1994, 124-32), and as a wheel pit at Read in Lancashire (Jeffery & Mathews 2008).

The introduction of Newcomen's atmospheric engine in 1712 meant that massive, masonry engine houses quickly appeared on many coal pits. These, and later Watt or Cornish, engines were principally used for pumping, but during the 19th century an increasing number of horizontal, winding engines were employed on collieries. At deep shafts, many of these were compound engines which required large houses, but some areas preferred a vertical cylinder, which drove a winding drum through a crank mechanism vertically above it. The latter houses were much smaller in plan, but often three storeys high. Most coalfields, including the non-Westphalian ones, have examples of engine houses, but Somerset and Bristol has more than most including at Nailsea (Morris 1996). Good examples also survive in Shropshire at Muxton Bridge among others (Pearce 1995, 40). In cases where the house has been demolished, there is a good chance that the even more massive foundations, or bed, for the engine remain. No major study or typology of colliery mine engine houses is known, but Bick wrote of some Welsh examples (Bick 1989, 84-93) (*see* archaeology below).

All steam engines needed a boiler house, the size of which varied to suit the engine. Early engines used haystack boilers, which were like a large kettle sat over a fire. In 1812 Trevithick developed the Cornish boiler, which was cylindrical with a single fire-tube. Such boilers were suitable for pumping engines which made comparatively small demands for steam. Fairbairn's introduction of the Lancashire boiler in 1844, with its double fire tubes, was well suited to the much greater demand for steam made by the large winding and textile engines then being developed.

Boiler houses tend to be fairly lightweight constructions, in order to allow replacement of boilers, and chimneys are the most likely survival. Nevertheless the masonry seatings for boilers and their blow-down drains may still survive. An egg-ended boiler working from 1843 to 1869, is still on site at Engine Pit in Colsterdale (Tyson 2007) and a range of Lancashire boilers survive in situ at Chaterley Whitfield near Stoke.

4.6.5 Ventilation

It was necessary to provide a flow of fresh air through a colliery in order to clear methane, carbon dioxide and air-borne dust from the workings as well as maintaining a reasonable working temperature and humidity (Hill 2000). Rock temperature always increases with depth, and Britain has one of the world's highest geothermal gradients.

Furnaces – Small mines, especially those with a shaft and an adit often managed with natural ventilation, where warm air rose up the shaft and drew fresh air into the adit. Such a system might be enhanced by hanging a firebasket in a shaft, especially where the problem was carbon dioxide. This evolved into a furnace, with a tall chimney, near the shaft top. From the 1780s, larger mines increasingly had furnaces at the foot of an upcast shaft in order to create a rising column of warm air. This was more efficient, but had obvious hazards in terms of methane explosions and their use at mines employing more than thirty persons or in gaseous seams was discouraged by the 1911 Act. New installations were not allowed in larger collieries from that date, but some existing furnaces (e.g. Walsall Colliery) continued in use until the 1950s at least.

Fans – A variety of mechanical devices were tried, but from the 1830s a range of fans was designed specifically for the task. Probably the most widely used type was by Guibal, a Belgian civil engineer, but in the 20th century Sirocco fans also became common. Although fans were more expensive to install than furnaces they were much safer and cheaper to run. Their speed and the volume of air moved could also be regulated, or even reversed. Too large an air flow could encourage spontaneous combustion in some seams.

Some are set over upcast shafts, with the area around the shaft totally enclosed with a mixture of masonry and a metal box structure, with air locks. There will also be traces of ductwork running from the fan to the shaft top (e.g. Grange or Monckton Main). Traces of fans and their engines also survive. There was a Guibal fan at Mackintosh Colliery in Somerset where partial remains of the stone-built fan house survive (Gould 1996, 16-26) and more modern ones at Clipstone and Chatterley Whitfield.

Upcast shafts with furnaces often had a cupola or chimney over them to improve air flow. A survival, converted to a dwelling, has tentatively been identified at Whalely Bridge (Gould 1996, 16-26).

A definite survival is the ventilation chimney at Golden Valley Colliery, Bitton near Bristol (J Fussell *pers comm*). A complete ventilation furnace remains at the entrance to a drift in Beathall Woods, at Ironbridge, but the iron chimney has been removed and is being used nearby as a culvert (I Brown *pers comm*). The furnace pit at Caphouse has been repaired and, while it lacks a chimney, it is proposed to include the bottom of it in the underground tour.

4.6.6 Transport

At the earliest sites coal was moved using pack-horses or carts and spoil was dumped into heaps using wheelbarrows. Early mines may exhibit traces of hollow-ways, or sunken tracks, which served them.

There are such tracks around Thorpe Fell colliery, near Grassington, and at various mines above Buxton. At small coal pits the material brought up the shaft was transported by sledge (marks left by their use have been recorded) or wheelbarrow, but where the coal was brought up the shaft in baskets, called corves, these were detached from the rope and loaded onto trolleys or sledges. Mines in areas of peat were served by distinctive pavements running to each pit. Good examples have been recorded at Goyt's Moss and Tan Hill collieries (Barnatt & Leach 1997, 56-80; Tyson *forthcoming*).

Many collieries were associated with canals or railways, some of which were pioneering developments. More than any other industry, coal may be credited with being one of the greatest influences on the development of transport networks in England.

Canals

The first manmade waterway, the Bridgewater Canal opened in 1761 designed by Brindley was specifically dug to provide haulage of coal between the mines at Worsley and Manchester's industrial areas, providing a model for future canal projects. Horizontal canal tunnels allowed bulk loads to be carried directly from the interior of the mine. Other contemporary examples of this system were installed at Thatch Marsh and Blackclough near Buxton. In the 1790s the Somerset Coal Canal was conceived to provide a means of shipment, in conjunction with a system of tramways, for a number of separate collieries in the North Somerset Coalfield (M Chapman 1987).

Tramways, wagonways and railways

Although, now an important part of modern life, years before rail passenger transport was conceived, railways were developed for hauling coal and iron. Their first recorded use was in 1603-4, when Huntingdon Beaumont built the Wollaton Wagonway from Stelley to Wollaton, at Nottingham (Lewis 1970).

The wooden rails used on early wagonways soon deteriorated and in the later 18th century engineers sought to replace wood with cast iron. One of the first to do so was Richard Reynolds, manager of the Coalbrookdale Works in Shropshire, who in 1767 replaced the wooden rails used around the company's works and mines with iron rails (Smiles 1863). Advances were also made underground when, in 1783, John Curr laid wagonways, using beech rails, at Sheffield Park Colliery. The use of horse-drawn, four-wheeled corves is recorded in January 1784 and in 1787 Curr began replacing wooden rails with cast-iron plates (Medlicot 1983, 51-60)[13]

Next came William Jessop who, in 1789, used fish-bellied cast-iron edge rails, with flanged wheels, on a horse-drawn railway for coal wagons at Loughborough. In the following year Jessop went into partnership with Benjamin Outram and two others to form what became the Butterley Iron Works, for manufacturing iron rails. Outram, on the other hand, favoured L-shaped iron plate-rails and, in 1793, he used them on a tramway which ran from Bullbridge Wharf on the Cromford Canal to a limestone quarry at Crich, in Derbyshire (Hylton 2007). This line was a little over a mile long with a gauge of 3 feet 6 inches, but Outram soon settled on a 4 feet 2 inch gauge for later lines.

Outram described his lines as 'railways', but the term 'tramway' (or 'tramroad') was already in widespread use and it came into general use for lines using his flanged rails. The term 'railway' was more widely used after the opening of the Liverpool and Manchester Railway, which used steam locomotives running on edge rails, in 1830. Thereafter, the 'tramway' (or 'tramroad'), with L-shaped rails, and 'railway', using edge rails, were used to describe two distinct modes of rail transport. Within the Lancashire coalfield, many of sthe mall mines were linked by chain hauled tramways locally called 'ginneys'.

Some surface tramways continued working until the early 20th century, but many small mines, especially those working thin seams, used them until the 1960s. Edge rails were also extensively used underground carrying tubs with capacities ranging from 10 cwts to mine cars of up to five tons.

Complex tub circuits were laid out at the pit bottom and top for taking full wagons to tipplers, where they were emptied, and returning empty ones to the shaft.

Richard Trevithick is credited with designing the first viable steam locomotive, which in February 1804, hauled ten tons of iron, 70 passengers and five wagons from the ironworks at Penydarren for nine miles to the Merthyr-Cardiff Canal (Rattenbury & Lewis 2004). Unfortunately the heavy loco broke the rails and the project was soon abandoned. Trevithick later visited Tyneside to build an engine for a colliery there.

The Middleton Railway, a private, horse-drawn colliery line near Leeds, was the world's first railway line to be authorised by an Act of Parliament in 1758 when it was extended from the colliery to staithes near Leeds Bridge. Faced with a shortage of horses during the Napoleonic Wars, John Blenkinsop, the colliery manager, worked with local engineering firms to build a steam locomotive in 1812. The resulting loco, called *Prince Regent*, worked on a rack & pinion system developed to cope with steep gradients, was soon joined by a second loco, named *Salamanca*. Leeds went on to build more locomotives than any other centre in the UK. Similarly, the Lake Lock Rail Road Company, formed in 1796, opened what was arguably the world's first public railway, to the north-west of Wakefield, because it served more than one colliery owner and also carried goods for all comers.

Long before the Rainhill trials of 1829, George Stephenson, no doubt inspired by Trevithick's efforts, designed his first locomotive, with flanged wheels. Named *Blucher*, this was in 1814, it hauled 30 tons of coal up a hill at 4 mph on the Killingworth wagonway. Many of these early locomotives had problems with being under-boilered or with breaking the cast iron rails then being used. William Losh, a local iron master, worked with Stephenson to overcome the latter problem, but it was not beaten until much later, with the introduction of rolled steel rails.

Work began on the Stockton and Darlington Railway in 1821 under the supervision of George Stephenson, and his son Robert, who had persuaded the proprietors to abandon their original plan of using horses to draw coal carts on metal rails in favour of locomotives. The 25-mile railway connected various collieries near Bishop Auckland and passed through Darlington on the way to the River Tees at Stockton. A useful contemporary account of this railway exists, and others of the period including that from Hetton Colliery to Sunderland, by the Prussian mining engineers Von Oeynhausen and Von Dechen (Forward 1971).

As the national railway network grew in the 19th century, many collieries had extensive sidings on which trains could be assembled. The wagons were loaded by parking them under the screens to receive a particular grade of coal.

In order to serve the electricity generating stations more efficiently, many NCB collieries with rail links were fitted with Rapid Loading Bunkers from 1965. Coal from the washery was loaded, by conveyor belt, into the bunker which stood astride a specially graded section of railway track. The non-stop merry-go-round train, of thirty or so, top-loading and bottom-emptying, 33 tonne wagons, would be hauled under the bunker by a loco which had been fitted with a slow-speed control, which allowed it to move at about ½ mile per hour. Once loaded it was off to the power station, where it was automatically unloaded while on the move.

Ponies were used to pull trains of wagons underground from the late 18th century, but from the 1850s compressed air and then electrical motors were used to drive endless rope or main and tail haulages on main routes (Brown 1989, 78-88). Haulages were also driven by endless power ropes which ran from an engine at the surface either down the shaft or along a drift. This had a circular wire rope, running on pulleys and round a drive drum, to which trains of wagons could be lashed, clamped or clipped. Smaller haulages, with a single rope, were used locally within the mine.

Fixed haulage systems did not give the flexibility of horses, however, and so efforts were made to develop locomotives which were safe for use in collieries. A ten ton battery locomotive is said to have been experimented with at Tilmanstone Colliery in Kent, in 1922 (Hill 1991; Report of H.M. Chief Inspector of Mines for the years 1939-46, 25). The first diesel locomotive was used underground at Kingshill No.1 Colliery, near Cambusnethan in Ayreshire, Scotland, in 1935 (Oglethorpe 2006, 196-7). In 1939 the first 'flameproof' locomotives in England were used underground at Rossington and Bentley collieries near Doncaster, which were both safety lamp mines.

Ropeways

Although there had been earlier attempts to make a functioning aerial ropeway, the first patent for a monocable ropeway was granted to Henry Robinson in 1857 (Patent No.1786, AD1856). He was described as a coal agent from Settle, in Yorkshire, but he also had a limestone quarry at Ingleton (Johnson 2010, 1977). His system used an endless rope supported at intervals by pulleys mounted on posts or pillars. At either end the rope passed around larger pulleys, one of which was driven by a power source. Loads were suspended at intervals from the rope. The last ropeway of this type, at Claughton brickworks near Hornby in Lancashire, worked until early 2010.

An 'improved' ropeway was designed by Charles Hodgson, of Richmond in Surrey, in 1868 (Patent No.2281, AD1868). This had a fixed, endless rope, on which the loads ran, suspended from pulleys. A second rope, which linked the buckets, was used to haul them.

Ropeways of both types found favour at quarries and mines, and were generally used at collieries for taking spoil from the screens/washery to the waste heap as at the infamous Easington and Blackhall colliery sea dumps in County Durham. Many ropeways were replaced by conveyors or dump trucks from the later 1960s.

4.6.7 Sources of power

Like metal mines, the development of underground technology in the coal industry depended on the introduction and adaptation of new forms of power as it advanced. The man-powered windlass and the horse whim or gin for raising materials and water; then water power followed by steam power for pumping and hoisting. Finally, by the 20th century, electricity and compressed air were the norm for powering equipment underground.

Endless power ropes, running down shafts from an engine at the surface, were used to drive main haulages, but could also drive fans or pumps at a distance from the pit bottom.

Many late-19th and 20th century collieries used compressed air to provide power underground. This required a number of stationary compressors, driven by electric motors or steam, in a surface power house. Nearby would be a bank of air receivers (often converted boilers) which provided a reservoir of air. The air was then taken underground in large steel pipes, called ranges, and split between the districts.

4.6.8 Drills, air-picks and mechanised cutters

Until the late-19th century shotholes were drilled by hand using a long chisel which was hit by a heavy hammer. Various mines experimented with compressed air drilling from the 1870s, but the drive for this came from civil engineering tunnel work. The early machines were both bulky and heavy, however, and their use tended to be restricted to driving levels. In mines with soft rocks, like shale or coal, the rotary hand drill found favour because it was much lighter. In these the rotary action of a handle was converted, through gearing, at right angles to drive a twist drill. Such drills were better suited to boring in coal and softer strata than percussive drills.

Improvements to compressed air drills in the early 20th century made them much lighter and more reliable (Chapman 1993, 104-27). Moreover, advances in electrical power meant that hand-held borers were widely introduced on coal faces.

Coal cutters were often driven by compressed air, especially in gaseous workings. Such machines demonstrated a rule of physics, whereby a rapidly expanding gas produces a cooling effect. This gave problems in high-temperature-humidity workings where the exhaust produced mist and seriously reduced visibility on the return side of the machine. Ice also tended to accumulate on the exhaust and sometimes choked it.

In the late 18th century it was realised that the mechanisation of coal cutting had the potential to reduce labour costs significantly. Early attempts often mimicked the picking action of a collier, but lacked a suitable source of power. An early example in Shropshire failed because it could not compete with manpower and the men were not prepared to use it. One of the first viable machines, driven by compressed air, was introduced at West Ardsley Colliery, near Leeds, in 1861 (Gill 2009, 116-23).

It should be borne in mind that pre 1960s references to coal being cut by machine usually refer to undercutting where the coal was subsequently brought down by blasting or wedges and loaded by hand. In 1945, for example, 28% of all coal worked was still undercut by hand this produced lump coal, giving the (then) best price.

The first use of electricity in an English coal mine is uncertain, but it was thought to be at Trafalgar Colliery, in the Forest of Dean, where a small electric pump was installed in the early 1880s (Hill 2011). As already noted, Pleasley Colliery used electricity to light its pit bottom around that time.

In pre National Grid times collieries often generated their own electricity in power houses. After linking to the National Grid, mines would have transformer sub-stations. Power houses might also contain a number of compressors for supplying the mine's compressed air needs. This air was usually stored in a rank of receivers (boiler-like pressure vessels) nearby.

4.7 Coal Preparation

When coal was cut by hand the colliers were fined for sending out too much dirt or fine coal, but whole machine cutting of coal meant that some means had to be found for removing rock from in-seam dirt bands, pyrites etc. The larger pieces could be seen and removed on a picking belt prior to screening into a range of sizes. This was done in a metal framed or brick vaulted building which stood over a series of parallel railway tracks. The screened coal dropped, via chutes, straight into wagons.

The washing and separation of small coal was pioneered in Germany, by the likes of Luhrig and Baum, in the late 19th century. They developed what dressers at metal mines would recognise as jigs and called them wash boxes. At first their capacity was limited to a few tons per hour, but around 1900 Baum developed a washer which used compressed air to aid separation and increased the through-put to nearer 100 tons per hour. From the 1920s Baum washeries became standard at most British collieries. Typically they are characterised by their mass-concrete elevated, conical settlement tank, which was almost the same height as the washery building.

4.7.1 Coke

The production of coke, frequently occurred at or near the pithead and has provided a wealth of material remains. Coke was being made using the charcoal burner's practice of covering a heap of coal with earth (a meiler) and roasting it by controlled combustion by the mid-17th century, when its use was recorded for providing heat for malting, lead smelting and alum calcining (Beaver 1951, 133-48). This process was replaced after the introduction of Beehive coke ovens, which are first recorded in the Newcastle area and Cumbria in the 1760s. These were non-recovery type ovens, in which the coal charge did not fill the oven. Space was left above the charge in which the gas and other volatile matter liberated from the coal was burned. Jars describes three banks of three ovens, of around 3ft diameter with a loading door and a steep conical vault leading to a small top opening (Jars 1774, 209-11; 365-6; Pl. IX). By the late 1760s or early 1770s banks of up to six ovens were being built, and a diameter of about 9ft (2.7m) was considered normal (NRO 3410/Wat/2/10, p.229); these ovens had iron doors, but there is no mention of any top opening.

In the 1890s more complex coking plants began to appear. In these, gases were captured and piped away for condensation into tar, sulphuric acid and ammonia. The remaining gas was then either burnt as part of the process or sold into the town gas supply. Such modern ovens were larger and had automated charging and discharging to increase their capacity and efficiency.

Beehive and other types of coke ovens survive in various places in England including scheduled examples at Fountains Fell [SM 29531] in the Yorkshire Dales, Tow Law [SM 30929] (which has been archaeologically excavated), Hedleyhill Colliery [SM 30931] County Durham, Maryport in Cumbria [32857], Vobster Breach in Somerset (Gould 1996, 21). An open-heap site (meiler) has been scheduled at Little Clifton, Allerdale Cumbria [SM 27814],

One of the last remaining, working coking plants in England is at the site of Monckton Main Colliery at Royston near Barnsley.

There are many other techniques used in modern coal washing including spirals, cyclones, dense media, froth flotation *etc.* However, as most such installations were of a period that undoubtedly would have seen all recoverable materials removed after disuse of a colliery and their housing structures demolished, then archaeological evidence is seldom an issue.

4.8 Field Archaeology

4.8.1 Archaeological Context

Many former coal mining areas have been assiduously landscaped or have been subject to opencast mining and then redeveloped for a variety of uses. Apart from the obligatory sheave wheel (winding pulley) or tub set into a block of concrete, which marks the site of some former NCB collieries, it is now much easier to find traces of 18th-century collieries than late 20th-century ones. New roads, like the M1 and M62 'joined the dots' in terms of obliterating disused collieries, presumably because they formed islands of derelict, hence cheap, land, and they had spoil heaps which could be incorporated into embankments. Indeed, work on the M1 in West Yorkshire often halted for the NCB to remove any payable coal, but never for archaeological recording of the many early coal mines that were exposed and subsequently erased, such were the policies in the 1960s. The last twenty years or so has seen a tendency for roads to be built along the course of former railways which served collieries. Nevertheless, using historical mapping and aerial photography, it is possible to recreate many of the complex landscapes of shafts, drifts, tram and railway lines formed in areas of coal and ironstone mining. A good example of this is the Low Moor – Bowling iron works complex of southern Bradford, in West Yorkshire where large parts of this landscape remained intact until the early 1970s but were then cleared in order to build the M606 link to the M62 and developed into a series of industrial estates. Now only traces remain of a complex series of coal-iron pits and the rail/tramways which fed the ironworks. Some areas of partly-intact colliery landscape do still survive, however, such as Whitehaven in Cumbria, which has recently been the subject of a detailed surface survey (Cranstone 2007).

Until the introduction of PPG16 (and later PPG15 for standing buildings), professional archaeologists did remarkably little work on coal mining. This situation has changed greatly for surface features, though development-related archaeology of underground workings (where these are exposed by, for example, opencasting) has remained patchy. As with all development-related archaeology under the PPG system, the majority of reports remain in unpublished 'grey literature'.

Besides their historical studies, mining historians have increasingly developed multi-disciplinary, and equally professional, approaches to their subject. But the archaeological study of coal has a long way to go before it delivers data on the scale that the historical research has indicated the potential for, although following the erasure of the industry of course, much is now beyond retrieval.

At National Level, English Heritage's Monument Protection Programme turned to mining in the early 1990s and its Step 1 Report (Gould & Cranstone 1993) and Step 3 assessments (Instone & Cranstone 1994) were the first major archaeological approach to the coal industry. This was of course subject to the serious constraint of being a search for sites of potential national importance and much of what was deemed to be of regional importance or just mundane was disregarded. Since then the English coal industry has practically disappeared and its remaining mines were privatised. However, one of the achievements of this work was to assemble all available knowledge on the various industries, and for the archaeology of the coal industry, this was a seminal step. During this process, both the Royal Commission (RCHME) and English Heritage (EH) commissioned photographic surveys of the industry (Thorne 1994; Gould & Ayris 1995). The aerial photographs resulting from these projects are available in the National Monuments Record (NMR) together with a large number of individual site survey reports completed in advance of and during the pit closure programme by the former RCHME – the NMR also holds other relevant information.

The English coal industry has not yet been the subject of a national archaeological project and regional studies are few and far between. However, the exception is Gould's study of the Somerset Coalfield, which focussed on spatial distribution, field archaeology, standing buildings and documentary evidence. The work resulted in a number of publications (Gould 191; 1994; 1996; 1999; 2005) and established the national importance of an under-reported coalfield, which has a high number of standing buildings and field remains, due to much of it being abandoned before British Coal's 'environmental' policies took effect.

Like that for metal mines, the record of coal mines up until the present arises from the usual categories of archaeological activity.

Landscape studies of the type commissioned by national parks, AONBs, and conservation areas, have been instrumental in increasing knowledge of all the extractive industries. For coal, the Clee Hills (Shropshire) conservation plan is an exemplar of how successful this type of work can be (Barratt *et al* 2007). In this project, evidence of the coal industry from several periods was recorded using a varied methodology, resulting in a thorough record of coal in the landscape. Other areas that have benefitted from landscape studies with a coal component on a lesser scale are Nidderdale (LUAU 2000), Hedleythorpe Fell, County Durham (Peters 2007) and Whitehaven in Cumberland (Cranstone 2007). Smaller-scale assessments comprising desk-top surveys, rapid field assessments and walkover surveys have been commissioned in many counties, and have often swelled the numbers of recorded coal sites.

Aerial survey has proved a useful tool in the recording of mainly early coal mining sites, though usually as part of research with broader goals. Nevertheless, coal was covered by the NMP projects covering the Forest of Dean (Small & Stoertz 2006, 97-100), Durham (Radford and Pallant 2008) and elsewhere. Although the data arising from these surveys is seldom assimilated into a useful conclusion specific to industrial research, this is one of the few landscape techniques available that can reflect all surviving aspects of the landscape and in the case of coal is able to demonstrate early surface evidence, the erasure of the 20th century industry and the dramatic legacy of more recent opencasts. Aerial surveys with outcomes specific to coal have been completed by Cox (2000) and Gould & Ayris (1995).

Watching briefs and pre-construction assessments are usually a precursor to the destruction of a site and the main contribution to this topic from the professional archaeological units. Such studies usually have highly focussed briefs dictated by the developer paying the bill. They are often limited to photographic and descriptive material. Excavations have been commissioned though are rarely conducted in response to research questions but rather to the impending destruction of a site and frequently aimed at non-coal related aspects. Exceptions are Coleorton (Leicestershire), Sharlstone (Wakefield) and Deepcar (Sheffield) (*see* below), and Broseley in Shropshire where a sequence of desk-based assessment (Page-Smith 2010), followed by earthwork survey (Page-Smith 2011) and trial trenching enabled the recording of a number of features including capped shafts and some buried brick foundations (Page-Smith 2011b). Many such developer reports are produced as 'commercial in confidence' and are often slow to reach the research community.

Research excavations have been carried out mainly by amateurs and confined to early coal mines, engine houses and other surface installations. Ironically the amateur community or independent sector are stealing the march with research excavations aimed at coal industry sites, with active groups having success in Leicester (Neaverson 2000) and Bristol (Cornwell 1991, 12-18; Hardwick & Kemp 2009, 29-42; Grudgings 2009, 43-56).

Building recording surveys to date have been mostly photographic. Surveys by RCHME and others were produced as a response to the pending loss of the resource, prior to the closure of large parts of the industry in the 1990s (RCHME 1993; 1994a–f). Smaller recording works have taken place for a variety of reasons including at Nailsea (Morris 1996), north Somerset (Gould 1996), Whitehaven (Wild 2000) and elsewhere.

HER enhancement exercises have literally put coal on the map in some counties where data transcribed from old and 1st edition OS maps has been an important source of material for HER records. Most counties have now undergone this process and those with coalfields have been able to use this information as a basis for GIS records. Historical reports written mainly by amateur researchers, from which information on the material remains may be obtained, have been transcribed into records in some HERs. However, ground truthing seldom occurs. From the late 19th century the coal industry was also well served by photographers and this is one of the best sources of information as to the appearance of long-demolished collieries.

Underground archaeology (*see* Section 11) for coal mining is extremely rare because abandoned sites are off limits to investigators, although occasionally sections of underground workings may be briefly exposed by opencasts where recording is sometimes possible (*see* Hartley 1994). However, the majority of archaeological work has had to focus on surface evidence.

4.8.2 Archaeological Recording

The main evidence for the use of coal in the Roman period in England comes from coal fragments unearthed in Roman archaeological contexts such as villas and military sites (*see* Section 2.9). Over 200 examples are known in Britain (Dearne & Branigan 1996). Tentative evidence has also been presented for Roman period coal extraction at Wigan, based mainly on the claims of a 19th-century geologist, Edward Hull, who recorded ancient workings he was convinced were of Roman date (Hull 1861). This has not been corroborated, despite the best efforts of the archaeologists working there and no other Roman period coal mine has been identified in England, although in several areas unverified claims of Roman coal pits are made, such as Haydon in Northumberland. However, it is likely that all mining fields had Roman activity though the evidence has so far proved very elusive (*see* Section 2.9.1).

Although the date may be uncertain, the earliest field evidence for coal extraction comes in the form of earthwork pits and undulations which are the surface remains of backfilled shallow shafts and bell pits (*see* above). Establishing precise chronologies for these features from earthworks is not possible but where underground sections have been dated archaeologically they have proven to be at least 15th century (Hartley 1994). The archaeological record has been derived mainly from field recording, such as at the Clee Hills of Shropshire where it is estimated that evidence of over 2000 pits survive. The surface evidence in this area was the subject of an earthwork survey by the RCHME in 1983 at 1:2500 and 1:1000 scale but more recently many have been plotted from aerial photographs as part of a major re-assessment of the area (Barratt *et al* 2007).

Two important community archaeology projects have focussed on the surface evidence of early coal workings; at Middleton Park, south of Leeds and within the Forest of Dean in Gloucestershire.

At Middleton Park, detailed earthwork surveys combined with historical research have provided an important record of the surface remains from coal pits, which facilitated some interpretation. A model was proposed whereby if the cover was less than about 20m above the coal seam one might expect to find groups of tightly spaced shaft mounds. These, it was felt, may be bell pits. As the depth of cover increased, the shafts were found to become more widely spaced and were interpreted as having served pillar and stall workings (Roe 2008). This conclusion may of course reflect site-specific geological conditions but if tested elsewhere, it would prove to be a useful technique.

The technique was tested to a good effect in the Forest of Dean, where a field investigation was augmented by a number of remote sensing techniques, including resistivity and LiDAR. The latter demonstrated particularly well the marked spatial variation of the pits within a single large area at Bromley Hill (Youles *et al* 2008).

Other mining landscapes of this type have survived, especially on unimproved moorland, with known examples at Goyts Moss (Barnatt & Leach 1997, 56-80), North Yorks Moors (Gill 2010, 19-31) and Tan Hill (Tyson *forthcoming*) but other mining archaeological deposits remains undisturbed on derelict land or in belts of woodland, where it could be identified by using LiDAR or through fieldwork.

The knowledge of the below ground features of these types of workings is less detailed and based mostly on precious few glimpses of such sites when briefly exposed, and ultimately destroyed, by modern opencast workings. This occurred recently at Deepcar near Sheffield in 2008, although inadequate recording took place (*inf* S Yorks HER), and Sharlston near Wakefield in 2009 where a watching brief maintained during coal clearance and clearance in the seams (between 10 and 20m) identified the extensive and well-preserved remains of pillar and stall workings, drainage adits, shafts, and a variety of timber props, the arrangement of which could be seen in the floor of the workings. Dating material was also retrieved and although not yet fully analysed, suggested these were 19th century workings (A Plummer *pers comm*). A full report on this work is awaited.

So far the best recorded of these sites is Coleorton in Leicester, where artefacts, discarded garments and remains of timberwork combined to provide dates for the workings in the 15th and 16th centuries (Hartley 1994). One rare occasion where underground survey occurred was at Barber's Drift, Ringinglow near Sheffield; drift workings were recorded there by a caving group, though the published version is very brief (Mathews & Crocker 1987).

Rescue and research excavations have been carried out at pithead sites, though often with limited resources. At Califat in Leicestershire foundations of two engine houses were uncovered by members of Leicester Industrial History Society. One has been excavated and published (Neaverson 2000) while excavation of the other is still in progress. Work is also in progress at an engine house and other surface features near Bristol at Coalpit Heath by the South Gloucestershire Mines Research Group. Elsewhere, within this coalfield several excavations have been undertaken by the Bristol Industrial Archaeology Society (Cornwell 1991; Lambert-Gorwyn nd; Hardwick & Kemp 2009). At Sharlston near Wakefield, an open-area excavation exposed two shafts enclosed by a pit bank, the stone bed for a pumping engine (?Newcomen-type), an associated boiler house, and evidence to suggest the presence of a horse-driven winding engine (A Plummer *pers comm*).

Archaeology and 20th-century coal mines

An exemplary paper, which outlines the recording of a disused but intact colliery, examined the site of Taff Merthyr Colliery in Wales. A detailed photographic and pictorial record of the machinery was completed before demolition of the site in 1993 (Malaws 1997). No such work on this scale has been published in England, and most of the collieries that were closed in the last decades received little archaeological recording, although photographic records undertaken by RCHME and EH (above), were published as grey reports (RCHME 1994a-f). Working in Somerset, Gould was able to record much 20th century material and various small-scale recording and mitigation surveys have taken place elsewhere. It is a sad truth however that much of England's 20th century coal industry has been effaced without adequate (or any) record. Infrastructure, settlement and housing are in many cases the only remaining signpost to this particular aspect of the recent past.

NOTES

1: In 1926, the Mining Industry Act (16 & 17 Geo. V, c.28) gave colliery owners statutory facilities for making amalgamations within the industry.

2: In 1930, the Coal Mines Act (20 & 21 Geo. V, C.28) provided for the establishment of central and district selling schemes to regulate the production and supply of coal; it also set up the Coal Mines Reorganisation Commission.

3: In 1938, the Coal Act (1 & 2 Geo. VI, c.52) set up a Coal Commission to acquire the fee simple in all coal and mines of coal.

4: Following the Coal Industry Nationalisation Act, 1946 (9 & 10 Geo VI, *c*.59). The National Coal board was set up on July 15th 1946, and to this body were transferred the functions and property of the Coal Commission and the statutory selling schemes, together with the properties and rights in the assets owned by colliery concerns and used for carrying on the industry.

5: http://www.bgs.ac.uk/education/britstrat/carboniferous.html

6: http://www.bgs.ac.uk/education/britstrat/jurassic.html

7: http://www.dmm.org.uk/mindex.htm

8: http://www.nottinghamshire.gov.uk/historiclandscape.pdf

9: http://www.nottsheritagegateway.org.uk/

10: Monopolies and Mergers Commission report on the British Coal Corporation – Presented to Parliament by the Secretary of State for Trade and Industry by Command of Her Majesty January 1989.

11: www.bgs.ac.uk/leicester/docs/Coal.doc

12: http://doverdc.co.uk/kentcoal/home.asp

13: Curr's use of wooden rails underground in 1783 may not have been an innovation, because wagons used in a lead mine at Coalcleugh, in the West Allen Valley, were said to be similar to the wagons used on Newcastle wagonways, but smaller and only two foot gauge. Fairbairn, R A 1995 *Lead Mine Wagons* British Mining **54**, 9. By 1778 a wagon, apparently running on wooden rails (planks), was in use at the Old Gin Shaft, Old Gang Mine, Yorkshire. (Warwickshire Record Office CR1248 34/R17).

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