MINERAL RESOURCES OF THE COALBROOKDALE COALFIELD— BASIS OF THE INDUSTRIAL REVOLUTION

by

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Summary

A wide variety of useful minerals is present in and around the Coalbrookdale Coalfield in Shropshire, and some of these have been extracted since at least Roman times. The occurrence of coal, ironstone, limestone and clay in close proximity, easily workable and adjacent to the navigable River Severn, was most important in the early development of the area, now often called the "birthplace of the industrial revolution". In the first half of the present century the deep mining of minerals declined appreciably, to be replaced by opencasting particularly of coal and clay. Even this however has now declined; the coalfield being small in area and long exploited is now largely worked out. The new town of Telford now covers most of the area and much derelict land has been reclaimed for industry and housing.

This paper gives an account of the economic geology of the coalfield and the importance of its mineral products. It does not however adopt the strict boundary of the Coal Measure outcrop since the area's industries have drawn heavily on minerals from adjacent areas where both older and younger strata crop out.

Historical Introduction

The Coalbrookdale Coalfield (Figures 1, 2) is the principal coalfield in Shropshire, being about 6500 ha in area. It is divided by the River Severn flowing from west to east through the Ironbridge Gorge. The river and its gorge played an important part in the development of the area, the Severn was navigable, making possible the shipment of the minerals exposed in the Gorge, and the fast flowing streams of its side valleys provided the power for the waterwheels of early industry. By the eighteenth century the iron, clay and limestone industries were well developed in the Gorge and many important innovations were brought about by the industrialists they attracted.

During the 19th century the coalfield passed its peak in importance and by the mid 20th century its basic industries were largely derelict or dying. A boost for the coalfield came in the 1960's with the development of Telford New Town, which was designed to cover a slightly larger area than the coalfield to gain economic visibility. Most of the coalfield south of the river however was not included.

There is some evidence to suggest that coal was being mined in Roman times, for local coals were found during archaeological excavation of the hypocausts at the nearby Roman town of Viroconium. Ironstone was also worked at an early date, as indicated by several documents which survive from the 13th and 14th centuries. Prior to the eighteenth century, however, the iron was smelted using charcoal and coal was used only for heating. Abraham Darby (the first) in 1709 first successfully used coke made from coal in this smelting process and, once this was accomplished in the Gorge, the two extractive industries became interwoven.

The growth of industry in the coalfield from this time is closely related to the Darby family and the Coalbrookdale Company founded in 1709. Darby had been a manufacturer of malt mills and brass pots in Bristol and, in 1707, took out a patent for casting iron bellied-pots in dry sand. In 1708 he took a lease on a furnace in Coalbrookdale and in 1709 first successfully smelted iron with coke. He chose Coalbrookdale partly because he knew that the quality of the coke made there was high; coke was used in the malting industry. He was also familiar with the easy river connections with Bristol where Quaker merchants were interested in the iron trade.

Mercian Geologist, vol. 12, no. 1,
1989, pp. 9–27.

As industry developed Darby's choice of Coalbrookdale proved to be a good one. Within the Productive Coal Measures, 17 seams of coal, 12 of ironstone, and 13 of fireclay came to be mined, along with red clay, limestone, sandstone, pyrite, 'walkers earth' and bitumen from this and adjacent geological formations. Many of these minerals were also worked at the surface; local quarries and pits also supplied building stones, sand and gravel, marl and glacial clays. Commonly, several minerals were worked from a single shaft, which might penetrate a sequence including coal, ironstone, fireclay and Carboniferous or Silurian limestone, or a succession with coal, ironstone, fireclay and red clay. This diversity of material was largely concentrated within a vertical range of 60 to 70 metres. Access and drainage were made easier by the deep Ironbridge Gorge, the repeated faulting fortuitously keeping this succession close to the surface over a disproportionately large area.

During the industrial revolution, Coalbrookdale saw the world's first iron bridge (designed and built by Abraham Darby III in 1779), the first cast iron steam engine, the first iron wheels to run on wooden rails, the first iron rails, the first iron boat, the first metal-framed building, and the first locomotive to run on rails (designed by and built for Trevithick in 1802).

Mineral working reached a peak in the latter half of the 19th century and in 1891, 86 mines were in operation—60 primarily for coal, 7 for ironstone, 4 for fireclay, 13 for red clay and 2 for limestone. However, by this time the area had been eclipsed by other industrial areas. This again reflects the geology, for when the easily obtained, shallow reserves were exhausted, the coalfield did not have the deeper reserves found in other coalfields, such as those in Staffordshire. The relative decline of Coalbrookdale also arose from problems of transport, other coalfields being better served by canals and railways (Tolley, 1972 p. 2), from the refusal of the Quaker ironmasters to exploit the profitable armaments trade and from the introduction elsewhere of new technologies, particularly the manufacture of steel. The Coalbrookdale foundries continued to concentrate on

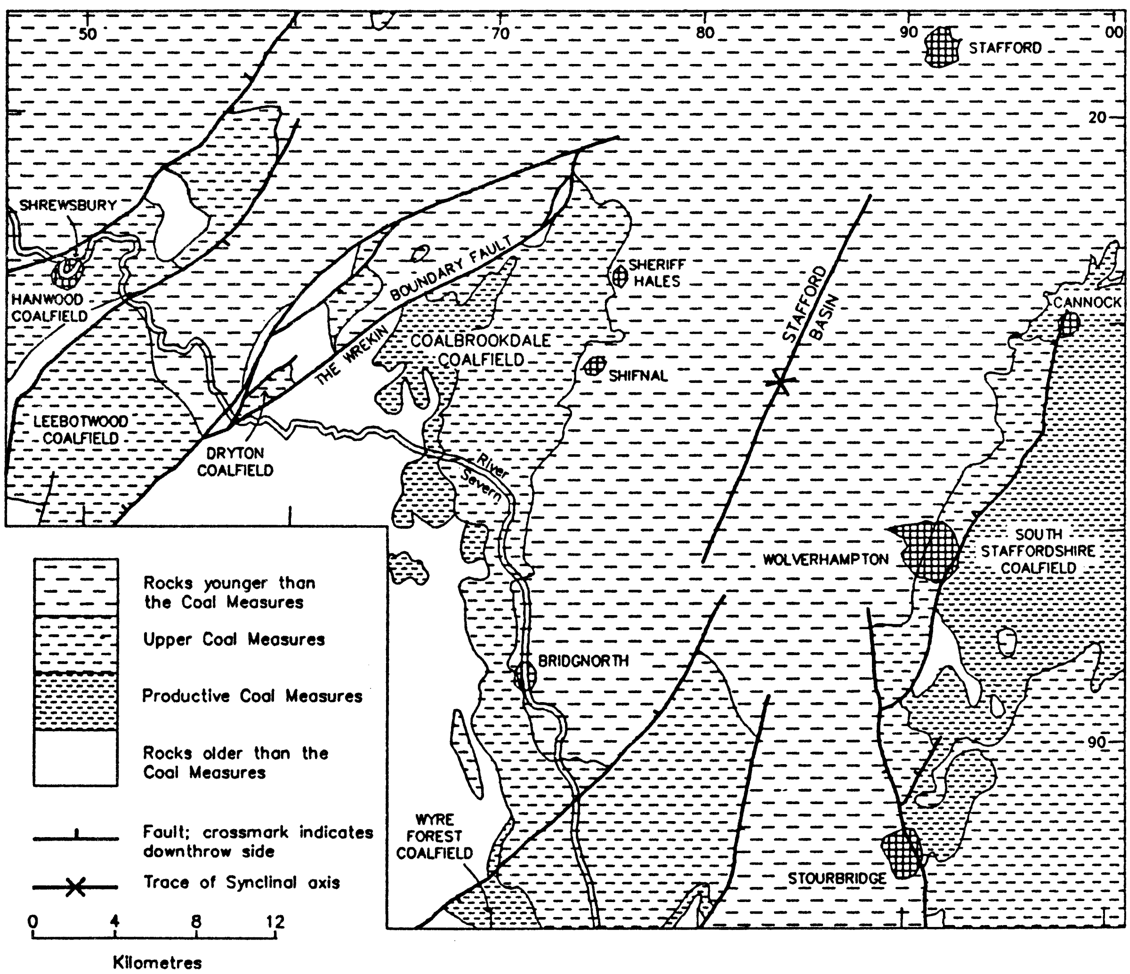

Fig. 1. The Geology of the region around the Coalbrookdale Coalfield.

cast iron, in which they were undoubted leaders, because the variety of coals and ironstones available gave them close control over the quality of their iron and enabled them to achieve high quality products. Cast iron gates and railings were a speciality of the Coalbrookdale Company and, in 1851, the company received the Council Medal at the Great Exhibition for a fountain 'Boy and Swan' and a statue of Andromeda. However, gate and railing production ceased in 1915 and during the 20th century the industry has produced more mundane products, such as cylinder blocks for internal combustion engines and Rayburn and Aga cookers. In 1959 the Coalbrookdale Company, now a part of Allied Ironfounders, celebrated its 250th anniversary by publishing a history of the company (Raistrick, 1959) and by restoring Abraham Darby's original furnace of 1709. This now forms a part of the Ironbridge Museum, the national museum of the iron industry. Finally during the 1960s, the towns of Wellington, Oakengates, Dawley and Madeley were incorporated into Telford New Town, with the intention of revitalising the industrial base of the district and reclaiming derelict land for commercial, residential and recreational use (Whitcut, 1981; Brown, 1979c, 1988).

Partly as a result of the impetus provided by the birth of the new town, the Coalbrookdale coalfield was surveyed on the 6 inch scale for the British Geological Survey by RJOH and B.C. Coppack between 1970 and 1972. One of the authors (IJB) studied the mining history of the area whilst employed as a mining and land reclamation engineer by Telford Development Corporation (Brown, 1975, 1976, 1979a,b) and the other (JE) worked as Area Geologist for the National Coal Board Opencast Executive with responsibilities which included Coalbrookdale. The combined research has revealed a fascinating relationship between the complex geology of the area and the development of extractive and manufacturing industries. The present paper attempts to assess the value and describe the exploitation of the various mineral resources in the light of the geology of the area.

Geological Succession

Coalbrookdale is remarkable for the variety of geological formations present in so small an area. A simplified geological succession is presented in Table 1, and the full succession appears as a vertical section on the 1:25,000 Telford geological map published by the British Geological Survey. To reproduce a detailed geological map here would be impracticable, but the main structural features of the area are shown in Figures 2 and 3.

North-west of the Wrekin and Boundary faults, all Palaeozoic formations up to and including the Productive Coal Measures are absent. Precambrian formations, including Uriconian tuffs and rhyolites and the Rushton Schists, are present at surface or else at shallow depth beneath Upper Coal Measures, Bridgnorth Sandstone or glacial drift. In contrast south-east of the Wrekin and Boundary faults, there are some 1800 m of Cambrian and Silurian strata, 100 m of Dinantian, 150 m of Productive Coal Measures, 500 m of barren Upper Coal Measures formations and 200 m of Permo-Trias. The Cambrian and Silurian formations outcrop south-east of the Wrekin, in the south-west of the area. They strike NE-SW and dip SE at up to 50°, with the Wrekin Quartzite uncomformably overlying the Uriconian of the Wrekin, and with successively younger formations coming to crop to the south-east. The Dinantian strata have much shallower dips and are strongly uncomformable on both Cambrian and Silurian formations.

The economically important Productive Coal Measures are present at outcrop in the centre of the area and at depth in the east (Fig. 2). Their prevailing dip is to the north and east. The Coal Measures transgression commenced from the north-east in late Namurian or early Westphalian-A times, and Coal Measures rest upon Dinantian, Ludlovian and Wenlockian strata (Fig. 2). Deposition of the Productive Coal Measures continued until early Westphalian-C (Fig. 4). The Coalbrookdale Coalfield lies towards the south-western margin of the Pennine Basin (Ramsbottom and others, 1978) and the strata form a condensed and truncated sequence compared to those of coalfields further north near the centre of the basin. The grey Productive Coal Measures are composed of a sequence of rhythms or cyclothems. Ideally each of these begins with marine mudstone and passes upwards through non-marine mudstone, sandstone, seatearth, and coal, but, in the condensed sequence of Coalbrookdale, individual members of each rhythm may be absent or repeated and the only complete cyclothem is that between the Pennystone Marine Band and Big Flint Coal.

Below the Clod Coal the Productive Coal Measures are dominantly arenaceous, with massive sandstones up to 29 m thick ('Farewell Rock'). They contain a few thin coals, of which only the Little Flint has been widely worked. The beds between the Clod and the New Mine coals are, however, dominated by coals and fireclays, all of which have been intensively worked, the fireclays passing locally into sandstones. By comparison sandstones are of less importance in the Westphalian-B/C grey measures, apart from the Big Flint Rock, and fireclays are uncommon, apart from the Fungous Fireclay; the dominant lithology is bedded non-marine mudstone. Apart from the Big Flint Coal, the thick valuable coals of Westphalian-B lie in two well-defined groups, while ironstones in the mudstones have been worked at twelve horizons.

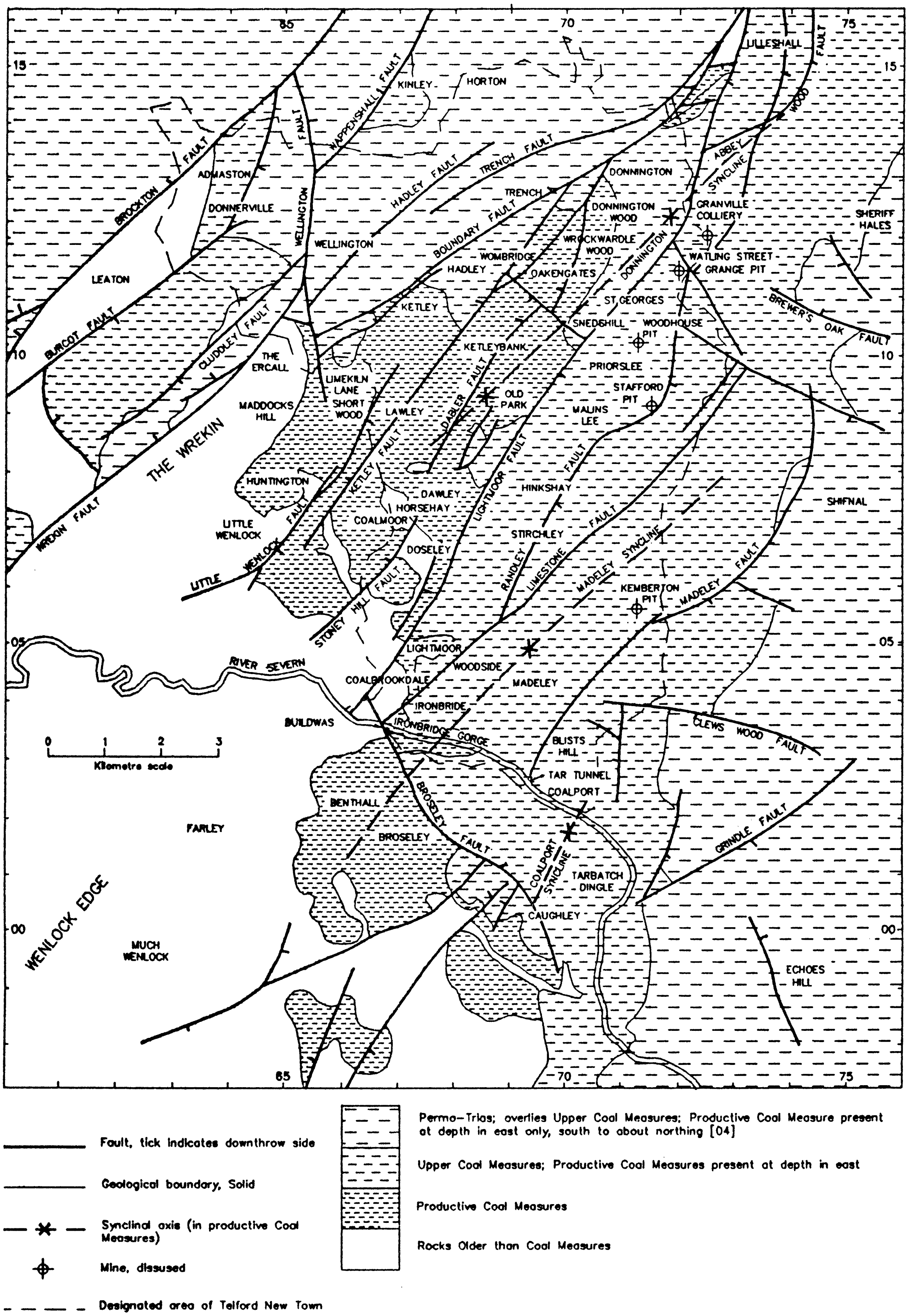

Fig. 2. Major structures of the Coalbrookdale Coalfield, and distribution of Coal Measures formations.

The Productive Coal Measures are succeeded by four formations of so-called 'barren red Upper Coal Measures', although only the Hadley, Keele and Enville Formations (Table 1) can truly be described as barren or red. The Hadley Formation, considered to be the local equivalent of the Etruria Marl of North Staffordshire, consists of red or variegated blocky mudstones alternating with lenticular 'espleys'. The latter are coarse sandstones and fine breccias, containing angular fragments of Uriconian igneous rocks and more rounded pebbles including limestones, Coal Measures sandstones and shales, in a friable matrix of sand and clay. In the north of the area the Hadley Formation is conformable on the Productive Coal Measures, but south of a line running approximately from Ketley through Ketleybank and Granville Colliery (Figure 2), it becomes unconformable. This unconformity, the famous 'Symon Fault' of the Shropshire miners, increases in scale southwards resulting in the base of the Hadley Formation cutting down progressively through the Productive Coal Measures to rest upon Silurian in the extreme south. Deposition in the north, which was contemporaneous with erosion in the south, was accompanied by folding along north-east/south-west lines, tightening the existing Caledonian folds, and by fault movement along fault lines already present in the pre-Carboniferous rocks. The Hadley Formation thus represents a significant change in sedimentary facies in Coalbrookdale at a time when Productive Coal Measures were still forming in Cannock and North Staffordshire, in which areas the Etruria Marl begins much higher in the sequence.

The Coalport Formation comprises roughly equal proportions of sandstone and argillaceous sedimentary rocks representing a return to coal-swamp conditions. The argillaceous sedimentary rocks are generally a paler grey than in the Productive Coal Measures and locally banded or mottled red and purple. The sandstones are deltaic sheets, individual units persisting over long distances. Eleven coals are known in the Coalport Formation, but only the lowest (Main Sulphur) has been widely worked; all are thin and pyritic and pass locally into cannel and black carbonaceous shale. Pale grey or brown nodular argillaceous limestones are common, and contain the freshwater worm *Spirorbis pusillus*, indicating a lacustrine origin.

The Keele Formation is composed of red and variegated marls (calcareous mudstones) with subordinate sandstones which are rarely sufficiently massive to justify quarrying for building stone. The Enville Formation, however, is dominated by calcareous sandstones and conglomerates, with subordinate calcareous mudstones.

The Upper Coal Measures are overlain unconformably in the east and south-east by Permian and Triassic formations (Table 1): the Bridgnorth Sandstone ('Lower Mottled Sandstone') composed of aeolian sandstones of assumed Permian age; the Kidderminster Conglomerate ('Bunter Pebble Beds') composed of Triassic fluvial sandstones and quartzite conglomerates and the Wildmoor Sandstone ('Upper Mottled Sandstone') composed of soft deep red sandstones of fluvial origin.

The glacial drift of the area is highly complex and includes water-lain sands and gravels, laminated lacustrine clays and tills (boulder clays). Its thickness varies widely, up to at least 36 m, as it includes infilled buried channels of sub-glacial origin (Hamblin, 1986).

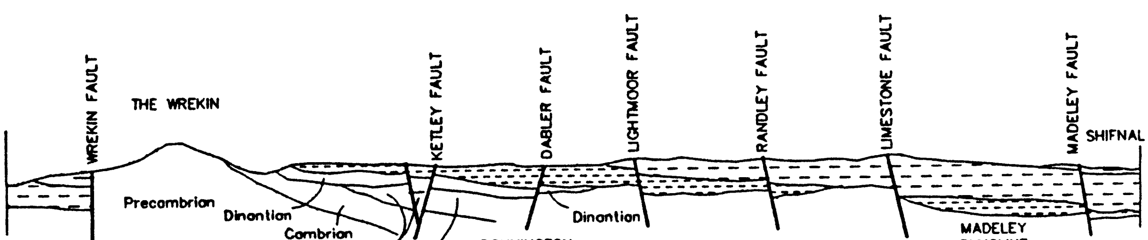

Fig. 3. Diagrammatic cross-section across the coalfield (Fig. 2), west-east from the Wrekin to Shifnal, with ornamentation as on Fig. 2.

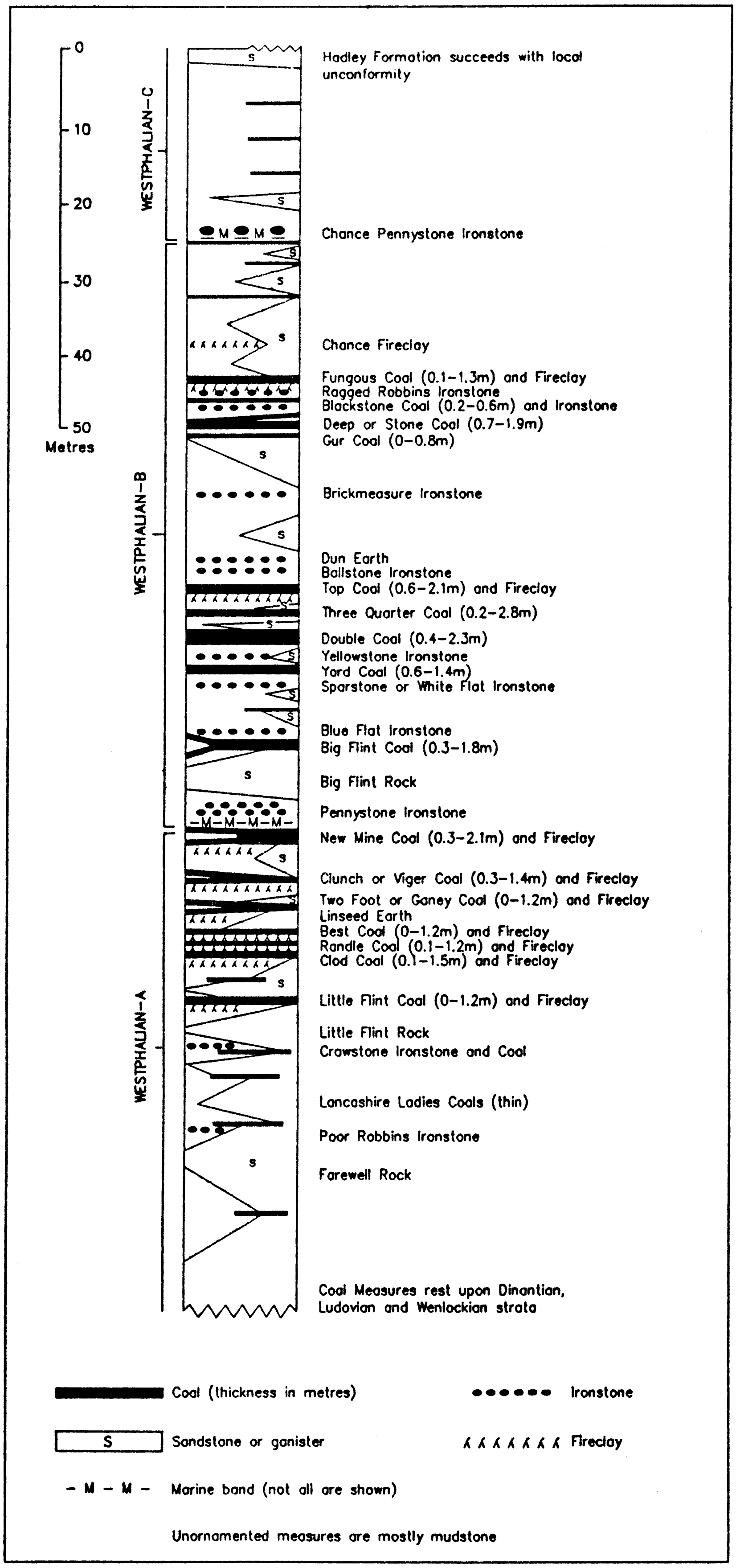

Fig. 4. Productive Coal Measures succession, showing stages of the Westphalian series. All worked seams of Coal, Ironstone and Fireclay are named.

Table 1. Geological formations represented in and around the Coalbrookdale Coalfield

Lithostratigraphy		*Chronostratigraphy* *Series*	*System*
Peat, alluvium Terrace gravels Head, scree and hillwash Lake clay, till, glacial sand and gravel			Quaternary
Wildmoor Sandstone Kidderminster Conglomerate	Sherwood Sandstone Group		Triassic
Bridgnorth Sandstone			Permian
Enville Formation Keele Formation Coalport Formation Hadley Formation	Upper Coal Measures	Westphalian	Carboniferous
Productive Coal Measures		Westphalian	Carboniferous
Upper Limestone Little Wenlock Basalt Lower Limestone Lydebrook Sandstone		Dinantian	Carboniferous
Temeside Shales Downtown Castle Sandstone Ludlow Bone Bed		Prídolí	Silurian
Upper Ludlow Shales Aymestry Group Lower Ludlow Shales		Ludlow	Silurian
Wenlock Limestone; Benthall Beds Tickwood Beds		Wenlock	Silurian
Coalbrookdale Beds Buildwas Beds	Wenlock Shales	Wenlock	Silurian
Hughley Shales Pentamerus Beds Kenley Grit		Llandovery	Silurian
Shineton Shales		Tremadoc	Cambrian
Dolgelly Beds		Merioneth	Cambrian
Upper Comley Group		St. David's	Cambrian
Lower Comley Limestone Lower Comley Sandstone Wrekin Quartzite		Comley	Cambrian
Uriconian volcanics Primrose Hill metamorphics Rushton Schists			Precambrian

In the account which follows many of the historical details are derived from documents which are not readily accessible. These are listed in Brown (1975).

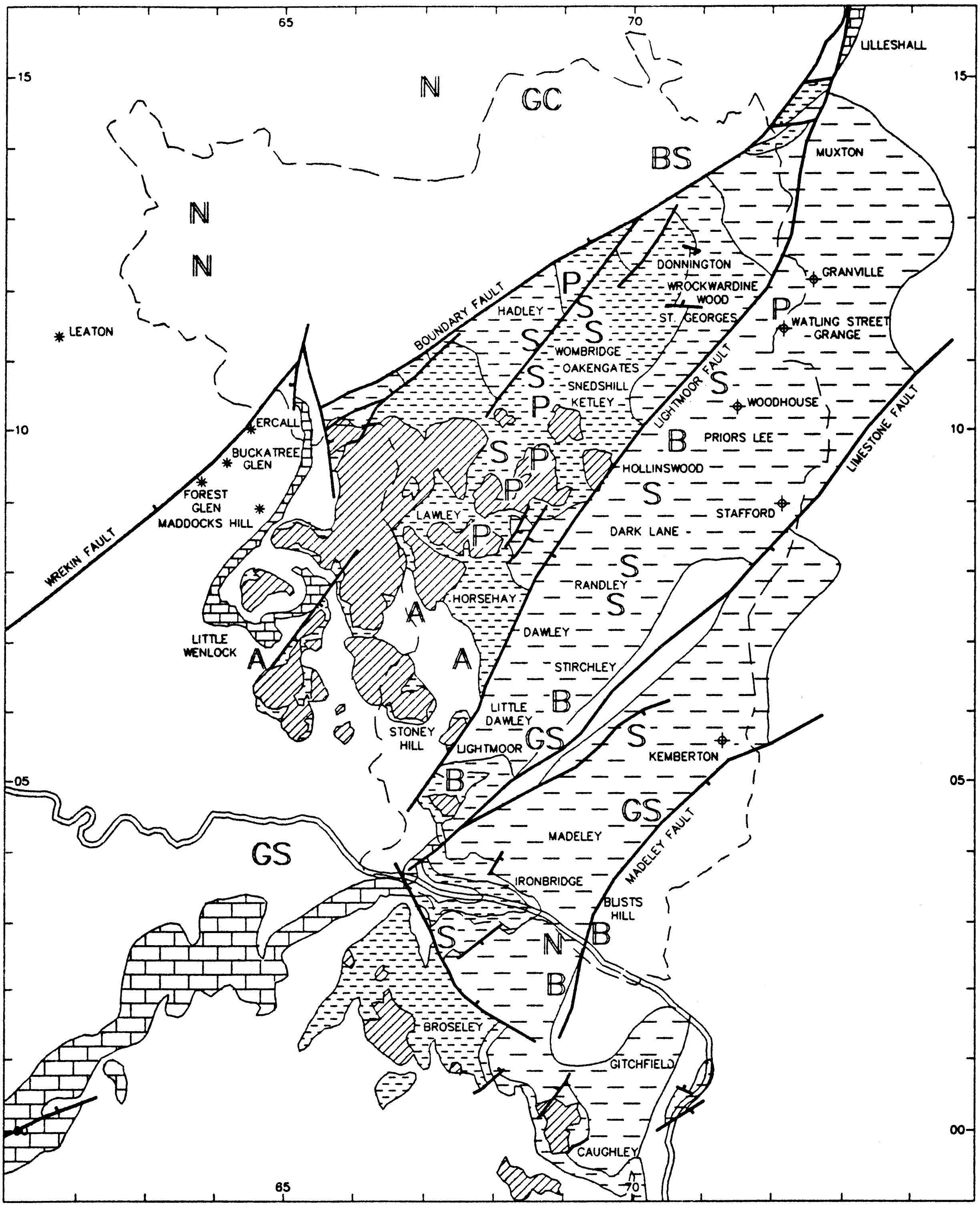

Fig. 5. Simplified representation of mining and quarrying in and around the Coalbrookdale coalfield. (Key on facing page).

Deep mining in Productive Coal Measures; coal and ironstone mined throughout this area, also fireclay (Productive Coal Measures) and red clay (Hadley Formation) in the south.

Hadley Formation at outcrop; mining and surface workings in red clay, deeper mining of coal, ironstone and fireclay in Productive Coal Measures.

Productive Coal Measures at outcrop; shallow mining of coal, ironstone, fireclay

Opencast workings for coal (completed, working, or licensed to work).

Carboniferous (Dinantian) Limestone outcrop; quarries and shallow mining.

Wenlock Limestone outcrop; quarries and shallow mining.

Fault; crossmark indicates downthrow side.

Designated area of Telford New Town.

Colliery (only some of those mentioned in the text are shown).

P Pyrite won from coal mine.

B Natural bitumen outflow

N Salt works.

GS Pit in glacial sands.

GC Pit in glacial clays.

BS Bridgnorth Sandstone worked for moulding sand.

S Sandstone quarry in Coal Measures.

A Quarry in Little Wenlock Basalt.

* Quarry in Cambrian or Precambrian strata.

Only a selection of quarries are shown.

Scale
0 1 2 3
Kilometres

Coal—Underground Mining

There is evidence that the Romans mined coal in the area for their hypocaust at Viroconium (Wroxeter), and monastic documents mention workings in 1250 and 1322, but the great expansion of coal mining followed Abraham Darby's successful use of coke instead of charcoal in blast furnaces in 1709. From then on three inter-related trends are apparent: migration of the industry to the north-east as the shallowest most easily worked seams of Coalbrookdale became exhausted (Figure 5), an increase in the depth of the mines with the introduction of steam power and thirdly, an increase in size of the individual mines.

Prior to 1709, the smiths of the iron forges distinguished only two types of coal: sweet or low-sulphur and stinking or high-sulphur. The New Mine Coal and the thin coals of the Coalport Formation are of the latter category but it was the preponderance of sweet coals in Westphalian-A and B that was one of the factors that attracted Abraham Darby to the area. These coals are of unusually low sulphur content with a low swelling number, enabling the application of the hearth-coke process, although they would not be suitable for coke production by modern processes. Also their low rank (i.e. low carbon content) made the coke relatively reactive and enabled the iron to be carbonised to yield a grey pig iron. The following table of percentage composition of the chief coals (Whitehead and others, 1928, p. 204) is based on Lilleshall Co. Ltd. analyses for the Donnington [70 12]* and Priors Lee [70 09] areas:

	Moisture	Volatile Matter	Ash	Sulphur	Fixed carbon
Fungous	7.72	31.83	3.47	1.50	53.47
Top	10.57	29.00	2.72	0.66	57.07
Double	8.41	33.38	6.24	0.92	51.04
Big Flint	9.62	34.03	5.54	1.27	49.54
New Mine	10.11	31.70	8.72	2.79	46.68
Clod	11.03	26.90	6.84	0.54	54.68

* Unless otherwise indicated National Grid references all lie within the 100 km square SJ.

During the 18th and 19th centuries there was a clear order of preference in which seams were taken, the less popular seams being worked only after the others were exhausted. This fact emerges from examination of mining records and is confirmed from old workings encountered in opencast sites. The Clod Coal was taken first and was most extensively used for smelting; it not only gave the best results (Prestwich, 1840, p. 436) but was readily available at shallow depth in the south-western part of the coalfield. As it became exhausted in each area, so the Randle and Little Flint were used, while the Best, Two Foot, Big Flint, Double and Top were also extensively utilised. The Yard was apparently less popular for coking, although inevitably as technology developed and coal availability changed, these preferences became less marked. The New Mine Coal was not widely worked, both because of its high sulphur content and its excessive brittleness, but it was utilised for lime and brick burning and steam generation. Many of the seams were adequate for domestic, malting, mill and forge purposes (Scott, 1861, p. 458).

The easily accessible seams of the Ironbridge Gorge [67 03] were largely exhausted in the first half of the eighteenth century and progressively deeper mines were sunk on the higher ground to the north; by 1803, mines 141 m deep were known. The traditional pillar-and-stall method of working survived until 1970 in small shallow mines, but the longwall system, almost certainly introduced in the seventeenth century, became so popular in deeper mines that it was known as the Shropshire Method. Recent opencasting of seams previously worked underground in the eighteenth and nineteenth centuries shows that as little as 30% extraction was achieved, 30–40% of the coal being left as solid roof and pillars and 30% as fine coal ('gob-slack'). This low extraction was acceptable as more coal was available than was needed by the iron-smelting industry. Better extraction was often achieved in pillar-and-stall workings by driving the headings or stalls on the advance and 'robbing' the pillars on the retreat to the shaft.

Seams as thin as 0.45 m (e.g. the Three-Quarter and Little Flint Coals) with dips of up to 55° (at Muxton [72 14]) have been worked, although steep dips are rare. Often a coal seam was worked in conjunction with adjacent seams and/or other minerals, for example the New Mine Coal with the Pennystone Ironstone and the Clunch Coal with its fireclays.

Coal production figures are difficult to interpret since figures published for Shropshire include the Wyre Forest, Hanwood and Oswestry coalfields as well as Coalbrookdale. However, it is clear that by the mid-nineteenth century coal production in Shropshire exceeded 1.0 million tonnes annually, reaching 1.37 million in 1871, but then started to fall. Through the 1880s it was about 0.18 million, but declined slowly until in the 1930s it was about 0.65 million. From 0.58 million tonnes in 1947 it fell to about 0.4 million in the 1960s and 0.2 million in the 1970s. In recent years the number of collieries dropped from 16 (including four nationalised) in 1952, to three in 1964, and finally one (Granville) which closed in 1979. Latterly over two thirds of the production of Granville Colliery went to the power station at Buildwas. The number of miners in Shropshire (all mines of coal, ironstone, fireclay etc) exceeded 5,000 in 1854 and 8,000 in 1874, but had fallen to just over 4,000 in 1884. It remained over 3,000 until the late 1920s, with a rise to over 4,000 in the early 1920s, but after the Second World War gradually fell, from over 2000 in 1947 to just less than 1,000 in 1968 and 500 in 1979 at the time Granville Colliery closed.

Coal—Opencast Mining

Opencast working of coal may have occurred on a small scale throughout the early history of the Coalfield, and Reynolds (in Plymley, 1803) described how he was working minerals by removing the overburden in the 1780s. Several very large depressions in the Wombridge area, now a part of the surface topography and easily overlooked, may be early opencast sites never infilled. Also drilling at Old Park [69 09] revealed a previously unrecorded infilled site which was 230 by 140 m in area and 20 m deep. Company records describe opencasting at Little Wenlock and Broseley in the 1930s when 'quarrying' for coal and clay was fairly common.

Opencast coal mining developed nationally on a large scale during the second world war, firstly under the Directorate of Opencast Coal Production, then from 1952 under the Opencast Executive of the National Coal Board (now the British Coal Corporation). In addition small amounts of privately owned (alienated) coal occur, which may be opencast, and a few private licenced sites have also been authorised. These are usually worked in association with other minerals, especially fireclays.

In the Coalbrookdale Coalfield the first sites worked as part of the wartime strategy commenced in 1942. These were probably at Short Wood [658 094], south of Wellington, although the earliest records are sparse as initially it was never conceived that opencast workings would be more than a short term emergency war measure. Small sites, however, were soon widespread north of the River Severn, although opencast sites south of the river have never been significant because of the attenuation of the Coal Measures there. There has been an almost unbroken succession of sites to the present day (Fig. 5), one of the latest areas to be proved and exploited

(1977–1980) being at Limekiln Lane [656 099] in the far west of the coalfield. Some recent sites were worked during the development of Telford New Town, in a combined large scale coal extraction and land reclamation programme, but even with this impetus production declined in the late 1970s and early 1980s and in 1983/4 no coal was worked. However, production restarted in 1985/6 and with the authorisation of the Dog Lane [66 08] and New Dale [67 09] sites production rose rapidly to 169,000 tonnes in 1986/7 and 158,000 tonnes in 1987/8. A further application has been submitted for a site at Arleston [66 08] and further sites are likely.

The Coalbrookdale Coalfield was one of the first to be intensely worked opencast due largely to the favourable structure of the western part of the coalfield which facilitated opencasting in the earliest days of low depths and overburden ratios. The seams dip consistently to the east at low angles, but are kept near the surface over large areas by a number of sub-strike faults throwing down to the west. The seams are also close together in concentrated groups.

One of the major problems in opencasts has been the extent of old mine workings. Only one site has been found totally free of old workings, a compliment to the 'old men's' wide if empirical knowledge. This is at Limekiln Lane close to the Wrekin, which may not have been exploited in the past due to the inferior quality of the coals. The seams there appear to have been affected during deposition by the proximity of upstanding Precambrian lavas which now form the Wrekin. They contain numerous irregular splits and partings and in the lower part of the succession coals are not developed at all, being replaced by mottled ferruginous mudstones and conglomerates. During opencast working it was often impossible to dig coal separately from the partings and a whole seam would be lifted, together with partings, and, when washed, more than half might be removed as dirt.

Other geological factors that have complicated opencast sites include glacial drift, hard sandstone and structural discontinuities, such as unconformities and faults. In the Coalbrookdale Coalfield, drift channels up to 20 m deep sometimes terminate and fragment coal seams, occasionally increasing overburden stability problems. However, continuous thick drift cover does not occur. Of the sandstones only the Big Flint Rock within the worked part of the sequence is at all thick and persistent. It was not usually justifiable to excavate it because on most sites the seams below would have been too deep to have been worked profitably. Where necessary, it was normally removed using large excavators and blasting, as a last resort, was used less and less as time went on.

Intra-Westphalian tectonic unconformities or sedimentary 'wash-outs' have on occasion been a significant problem, particularly the unconformity beneath the Hadley Formation, but also lesser breaks within the Productive Coal Measures. Sometimes 'wash-outs' occur as deep channels cutting through several seams, but more frequently unconformities have been discovered lying at a shallow angle, particularly affecting the Deep and Blackstone seams over wide continuous areas. The coal below the base of the unconformity is thinned but otherwise undisturbed, but immediately above the base there are up to one metre of re-sorted, predominantly coaly, material which is of unacceptable quality, but visually very difficult to distinguish on site.

The most serious of the geological difficulties has been locally intense faulting. Most of the larger faults in the coalfield consist of more than one plane, frequently extending over complex zones up to 60 m wide. The Dabler Fault is a notable example. Over parts of its length it is a single plane, but elsewhere it opens into a zone of several planes, sometimes throwing in opposite directions and creating very deep troughs. It is crossed by a series of sub-parallel faults and, where these occur, the structure becomes practically indecipherable and the coal unworkable.

A characteristic of the Coalbrookdale coal seams is that they are generally soft and friable so that, when mined, only a proportion was recovered as large marketable coal and the remaining small coal or slack was left underground. During later opencasting it is sometimes possible to lift and wash this material. In this way the equivalent of a quarter or third or sometimes much more, of the original seam thickness is often recovered, making it possible to opencast in all but the most heavily mined areas. This situation formed the basis, in the 1970's, for co-operation between the Opencast Executive (O.E.) and the Telford Development Corporation (T.D.C.). Extensive mining had taken place under Old Park [69 09], which is now part of the new Telford Town Centre. The surface of the area was an almost continuous blanket of spoil mounds and subsidence hollows, whereas the sub-surface was a honeycomb of partially collapsed old workings, pierced by numerous old shafts, mostly unrecorded. The area was an eyesore and totally unsuitable for development but contained exploitable reserves of coal. It was scheduled for development as housing and roads commencing immediately opencasting was complete. This required not only the complete removal of all old mine workings and shafts, but special restoration involving a high degree of compaction of the backfill material. The O.E. and T.D.C. jointly devised a scheme of mutual benefit whereby the O.E. excavated the whole area to an agreed depth, including parts completely void of coal, and restored and compacted it to agreed contours, making it available for immediate development. During opencasting all voids were located, mineshafts made safe, non-competent superficial deposits buried at depth, and then more competent rocks layer-placed and compacted using mechanical rollers. In this way all fear of subsequent settlement or subsidence is removed and the cost of reclamation to T.D.C. was only a fraction of what it would otherwise have been.

Ironstone

Ironstone occurs in the Productive Coal Measures in the form of impure nodules of siderite (ferrous carbonate, $FeCO_3$) with an admixture of clay minerals. At least twelve named ironstone bands have been worked in the Coalbrookdale Coalfield (Fig. 4); all occur as bands of nodules or thin beds of ironstone in a matrix of grey non-marine mudstone, except for the Crawstone, which is a continuous band of ironstone within sandstone. The nodules in the Pennystone are commonly up to 0.5 m across. Siderite has historically been a major source of iron in Great Britain, but nowadays world markets are dominated by iron oxides (magnetite, haematite) which occur as large, more economically mined masses.

The Coalbrookdale iron ores were more suitable for making thin castings than were the haematites and limonites found elsewhere in Britain. They contained sufficient phosphorous to make the cast iron fluid, but not too much to prevent the refining of cast iron to bar iron; also sufficient manganese to combine with the residual sulphur so that a weak basic slag melting at low temperature was produced. Apart from the Crawstone, all the ironstones were worked by raising the mudstones containing the nodules to the surface. For each ton of ironstone nodules produced, about eleven tons of measures were raised, spread out and weathered in heaps, with the ironstone being hand-picked by women and children. Over 90% of the older spoil mounds in the coalfield result from this activity.

Ironstone, like coal, was first exploited in the Ironbridge Gorge, due to its ready accessibility there. However, apart from the Crawstone which is best developed in the south-west, the number and thickness of seams increases towards the richest area in the north. The aggregate thickness of workable seams increases from 2.4 m at Broseley [67 01] to 21.9 m at Donnington (Smyth, 1862), and the total yield of ironstone reached a maximum of 13.794 tons per acre (34,633 tonnes per hectare) at Wombridge [68 11] (Prestwich, 1840). The most commonly worked seams are given below in descending sequence, with thicknesses and yield in kg of ironstone per cubic metre of measures shown in brackets (Smyth, 1862):

Chance Pennystone (1.8 m), Blackstone (1.2 m; 399 kg), Brickmeasure (2.1–4.9 m), Ballstone (1.8—4.0 m), Yellowstone (0.6–2.7 m; 322 kg), Blue Flat (1.8 m; 466 kg), White Flat (1.2 m; 399 kg), Pennystone (1.8–9.1 m; 665 kg), Crawstone (0.6 m). Seams rarely worked include the Dun Earth above the Ballstone and the Ragged Robins above the Blackstone, both in the northern part of the coalfield, and the Poor Robins around Lightmoor [67 05]. The metallic iron content of these ores is 35–40% and they are partly self-fluxing, with a lime content of 2.3–3.11%; full analyses are given by Smyth (1862).

Iron workings are known from at least 1250 AD, the Ironbridge Gorge area being largely worked out before coke replaced charcoal in the furnaces in the early eighteenth century. By 1720 the Crawstone was almost exhausted, and by 1767 half the ironstone used in the Gorge was Blue Flat and Yellowstone brought in from Ketley and Wrockwardine Wood [70 11]. Some 42,000 tons was produced per annum around Dawley [67 07] alone at this time, and in 1769 Banks wrote (Broadbridge, 1971) that seven kinds of stone were in use of which the Blackstone and Blue Flats were most prized.

The ironstone boom continued and by 1837 one company alone had 31 ironstone mines producing 50,000 tons of ore per annum from the Pennystone, Blue and White Flats, Ballstone and Sparstone. Prestwich (1840) believed that almost all the best seams west of the Lightmoor Fault and south of Ketley were 'nearly exhausted' and Smyth (1862) found that 'a large portion of the coalfield is absolutely exhausted', but plentiful supplies were revealed in new collieries east of the Lightmoor Fault and Dewey (1920) estimated reserves at about 30 million tons. At this time (1920) the Pennystone was the most widely used stone while the Chance Pennystone, Ragged Robins and Yellowstone were also being worked.

The thinner ironstone measures were invariably worked by the longwall method and the thicker seams by longwall, pillar-and-stall or a combination of the two. Smith (1846) described how the 7.3 m Pennystone seam was worked as six 1.2 m longwall faces, each following the other in descending order, the strong roof of Big Flint Rock allowing complete extraction. A witness at an inquiry in 1858 described an upper 1.8m longwall lift and a succeeding lower 6.4m pillar-and-stall lift involving stalls 6.4 m wide and pillars 2.7 m by 1.8–2.7 m (John Bennett v. Great Western Railway concerning proposed tunnel at Hollinswood; copy in Shropshire Record Office).

It was not until the 1870s that reasonably reliable statistics for ironstone mined in Shropshire became available, although the absolute peak of production was reached in 1869 (Tolley, 1972). During the early 1870s it exceeded 0.4 million tonnes per annum, but began to fall in the late 1870s, dropping rapidly to 0.25 million tonnes in 1880, 0.13 million in 1888, 0.05 million in 1890 and 0.02 million in 1900. Production had almost ceased by the First World War but some did continue although only at about 100 tonnes per annum. Iron was last produced by selective 'picking' of mine waste at the Madeley Wood and Lilleshall Company mines during the second world war, and extraction finally ceased at Watling Street Grange Pits [720 114] in 1947.

Clays have been worked since at least Roman times, when the Broseley area supplied the city of Viroconium with jugs, bowls and colanders. Local products of some repute over the last three centuries have included Coalport china, tiles, bricks and clay pipes; 'church warden' pipes were produced from at least 1575 until the last decade, but not wholly from local materials (Whitehead and others, 1928, p. 203).

Three types of clay have been worked; 'white', often refractory, fireclays and shales in the Westphalian-A and B Coal Measures, 'red' clays from the Hadley Formation, and glacial clays. The most valuable are the highly refractory fireclays (Fig. 4) which occur as seatearths notably between the Best and New Mine Coals, and have been exhaustively worked throughout the exposed coalfield from Ketley to Little Wenlock, Horsehay and Broseley (Fig. 5). Other seatearth clays which have been worked include that beneath the Fungous Coal and one above the Fungous at the Hydraulic Fireclay Pit, Snedshill [70 10] (Whitehead and others, 1928, p. 203). The Top Coal clay was worked around Madeley [69 04] and the Bannocks, Linseed Earth and Little Flint Coal Clay locally in the Westphalian-A Coal Measures of the southern part of the coalfield. The Clod Coal clay was worked at Ironbridge. Only the most highly refractory clays are suitable for firebricks, but the other clays, of varying refractoriness and with varying impurities, suit special purposes such as stoneware production as well as common brick manufacture. The aggregate thickness of fireclays does not vary greatly across the coalfield, representative figures being: Caughley [69 00], 7.9 m; Broseley, 14.0 m; Madeley, 16.8 m; Horsehay, 13.4 m; Lawley [668 090], 15.9 m; Wombridge, 12.2 m; Productive Coal Measures mudstones, for example those associated with the Pennystone, have been worked as a by-product of ironstone mining. In general the 'white' clays produce off-white, yellow or buff bricks while the shales produce a range of colours from blue (Pennystone) to brown.

Fireclays have been intensively mined along with coal in the past although a few mines worked fireclay alone or alternated between fireclay and coal. Six fireclay mines were in operation in 1950 but the last, the Rock Mine [683 094], closed in 1964 when the industry changed to opencast working. Production after the second world war increased dramatically due to the improved efficiency of opencast techniques combined with the approaching exhaustion of reserves in Staffordshire and Lancashire. In 1965, disposals of 343,203 tonnes of fireclay from this coalfield met 18% of UK requirements, whereas in 1968, 239,651 tonnes met 12% (Brown, 1975, p. 133). Weathered grey mudstone is still obtained from old pit mounds for mixing with the red clays used at the Hadley Brickworks [683 118].

The best 'red' clays are found in the thin development of the Hadley Formation of the southern part of the coalfield, south of the River Severn and at Lightmoor. They include one or (rarely) two tile clays and up to three refractory brick clays. The clays are not widely worked around Madeley, presumably because of their depth. Brick and tile works using 'red' Hadley Formation clays flourished in the nineteenth century, nearly 80 sites have been identified and this industry remained on the banks of the Severn after the coal and iron industries moved north. Nineteen red clay mines have operated in this area this century; most closed before 1920, five during the 1939–45 war and the last, at Gitchfield [707 014], soon after.

The marls and 'espley' sandstones of the thicker development of the Hadley Formation at Hadley, Snedshill and St. George's [710 114] give a refractory material capable of being vitrified at comparatively high temperatures under reducing conditions. They are still worked by Messrs Blockleys Ltd at Hadley for the manufacture of high-class facing and engineering bricks. The red and grey clays and marls of the Coalport Formation are less valuable than those of the Hadley Formation, but the thick clays above the Top Rock and Thick Rock were worked on a large scale at the Randley works [703 077] and in a smaller way at Blists Hill [695 035], for the manufacture of common bricks, tiles, chimney pots and pipes.

Glacial lake clays have been worked to a limited extent, but are only suitable for common bricks. Brick pits at Horton [685 145] and near Echoes Hill [SO 735 995] are situated on outcrops of lacustrine clay and not boulder clay as Whitehead and others (1928, p. 195 and 202) stated.

Table 2. Number of mines producing fireclay and red clay

Year	*Mainly Fireclay*	*Fireclay and coal*	*Red clay*
1891	4	3	13
1905	5	5	17
1921	2	5	8
1930	1	6	8
1950	2	4	-
1962	1	-	-

Table 3. Clay Production in Shropshire, largely Coalbrookdale (from mines)

Year	*Fireclay*	*Red clay*
1890	21,171 tonnes	47,627 tonnes
1900	15,237 "	72,702 "
1907	24,453 "	45,429 "
1921	10,563 "	23,027 "
1930	17,017 "	38,390 "
1938	54,908 "	33,236 "
1947	27,918 "	Not known

Table 4. Clay Production in Shropshire (from surface workings)*

Year	*Fireclay*		*Red Clay*	
1967	202,000 tonnes		966,000 tonnes	includes Hereford
1969	285,000 "		134,000 "	
1971	225,000 "		121,000 "	
1973	121,000 "		182,000 "	includes Hereford & Worcester
1976	163,000 "	includes Staffs, West Midlands	136,000 "	
1978	159,000 "		161,000 "	
1980	103,000 "		Not known	
1983	36,000 "		198,000 tonnes	
1984	90,000 "		214,000 "	
1986	121,000 "		Not known	

* from United Kingdom Mineral Statistics published annually by B.G.S.; red clay figures may include some production outside the Coalbrookdale Coalfield.

It is known that total clay production in 1938 (mines and quarries) was 139,431 tonnes. Annual clay production figures by County are no longer available but Highley (1982) estimated fireclay production to be continuing at around 150,000 tonnes per year in this coalfield.

Generally the red clay mines used a rather haphazard pillar-and-stall system of extraction, the fireclay mines used a similar system and sometimes robbed the pillars on the retreat. Longwall methods were rarely used owing to the subsidence caused, except where the clay was worked with a coal seam. South of the River Severn at Deep Pit [683 016] and Gitchfield, both 'red' and 'white' clays were worked from the Hadley Formation and Westphalian-A Coal Measures respectively.

Building Stones and Refractory Sandstones

Coal Measures sandstones have been important for building use as freestones; stone from 'the Quarry' at Broseley was used in the construction of Buildwas Abbey in the thirteenth century. The last major use was probably for bridges on the Wellington and Coalport Railway (Whitehead and others, 1928, p. 205). Prestwich (1840) listed sandstones above the Little Flint Coal, Pennystone, Big Flint Coal and Ballstone as being in use. Of these the Big Flint Rock was the most widely used, and field walls of this stone can still be seen along its outcrops at Mossey Green [685 100] and Jockey Bank [673 030]. In the north the sandstone above the Big Flint Coal yields a fine architectural freestone which was used for example for the monument to the Duke of Sutherland at Lilleshall [728 156]. The Thick Rock of the Coalport Formation has been extensively worked along its outcrop at Hinkshay [697 075], Stone Row [700 080] and Malins Lee [702 090]. There was also a large sandstone quarry in the Keele Formation at Windmill Farm [700 056] north of Madeley, and many small quarries in the Enville Formation.

The Big Flint and Little Flint rocks (Fig. 3) have refractory qualities. The former was quarried near Oakengates as Ketley Stone and used for making silica bricks. According to Prestwich (1840) the Little Flint made the best hearthstones for blast furnaces, although as furnace temperatures were increased it was replaced by brick.

Aggregates and Building Sands

Uriconian green and blue basic tuffs, cut by dolerite dykes and basaltic sills, are currently quarried for roadstone and hardcore at Leaton [618 113] (Pocock and others, 1938, p. 25). Large disused quarries in the Uriconian occur (Pocock and others, 1938, p. 14–18) at Forest Glen (Lawrence Hill) [639 093], Buckatree Glen [642 096] and the Ercall [645 100]. That at Buckatree Glen has been reopened several times and is currently working. As well as basic tuffs, olivine basalts and dolerite, these quarries worked vitric and lithic rhyolitic tuffs and flow banded, spherulitic rhyolites.

Granophyre ('Ercallite') exposed on the west side of Ercall Hill was sufficiently shattered to be worked originally with 'pick and shovel' and sold as gravel for paths and drives. The rock has a micrographic structure consisting of a coarse aggregate of quartz with a graphic intergrowth of quartz and feldspar, enclosing rectangular phenocrysts of plagioclase feldspar. The rock is intruded into the Uriconian and is of Precambrian or early Cambrian age (Cope and Gibbons, 1987); it is now being quarried along with the Uriconian at Buckatree Glen. The Wrekin Quartzite, a massive pale purplish blue or cream quartzite, is also worked extensively hereabouts.

Maddocks Hill Quarry [647 088] works a lenticular sill of 'camptonite' of possible Ordovician age, intruding the Shineton Shales. This is a lamprophyre containing albite-oligoclase feldspar, augite, serpentine replacing augite, biotite and hornblende. The adjacent thermally metamorphosed Shales are also extracted. The Little Wenlock Basalt (Dinantian) has been extensively quarried between Little Wenlock and Dawley, for example at Horsehay (closed about 1937), Coalmoor (several small workings, abandoned before 1940), Little Wenlock (not currently working but some reserves remain) and Doseley (the most extensive workings, closed 1964, but with certain faces designated in recent years as a Site of Special Scientific Interest). The formation, about 25 m thick at outcrop, is an amygdaloidal basalt with columnar jointing visible at Doseley [675 068].

'Red shale' for hardcore and for paths and drives has been obtained extensively from burned-out spoil mounds at the newer collieries, e.g. Kemberton [712 055], Woodhouse [713 103], and Stafford [715 091] pits. The older mounds generally contain too low a proportion of combustible matter to burn spontaneously. Blast furnace slag has been worked since at least 1817, firstly as a source of iron and later for hardcore. By 1928 the slag heaps at Lightmoor, Madeley, Blists Hill, Stirchley [69 06] and Dark Lane [69 08] were largely exhausted (Whitehead and others, 1928, p. 207) and quarrying ceased at Blists Hill in the late 1950's.

Glacial sands have been widely used for building purposes and large pits were worked at the Woodlands and Hills Lane [704 044], Madeley, and Moors Farm, Lightmoor [687 056], until the 1920s. The Buildwas Sands (Hamblin, 1986), glacial sands occurring as a series of hillocks, are currently intensively quarried and were used as ballast for the Severn Valley and Wenlock railways (Maw, 1864, p. 141).

Foundry and Glass Sands

Sand was essential to the iron industry for furnaces and for moulding and references to workings date back to 1255. The Coal Measures sandstones made 'soft' sand suitable for iron founding and glass making. In 1805 the Wrockwardine Wood glass works used 'Black Rock Stone', presumably a Coal Measures sandstone, from Little Dawley [681 061] and similar decomposed sandstones have been worked this century at Coalmoor and Stoney Hill [670 060]. Foundry sand must contain some clay so it can be moulded, and Prestwich (1840, p. 461) recorded some glacial sands being worked for this purpose at Lightmoor and Ketley. Sand for moulding and building has been produced from the Bridgnorth Sandstone; a pit [703 137] on the north side of the Newport-Wellington road between Donnington and Trench was worked until the 1920s (Whitehead and others, 1928, p. 206).

Limestone

The Wenlock, Benthall Beds, have been quarried and mined at Lincoln Hill [6706 0385]. They are massive, shelly, coarse-grained limestones between flaggy silty limestones. By 1801 there was 'an immensely large quarry' with 'prodigious caverns' leading off from the bottom. At that time the limestone was worked for agricultural lime and ironstone flux, although the 'ballstones' of the laterally-equivalent Wenlock Limestone reef facies were more suitable for the latter. The pillar-and-stall workings were entered by adits in the Ironbridge Gorge and by shafts up to at least 57 m deep. The pillars are small in comparison to the width and height (6–9 m) of the stalls, the height being accentuated by the 30–60° dip of the strata. The underlying Tickwood Beds (siltstones with poorly calcareous bands and abundant calcareous nodules) were rarely quarried. According to Murchison (1839

p. 210) the valuable higher beds (Benthall Beds) totalled up to 15 m, although the best beds were only 7.5 m. The workings closed in 1912. To the south-west of the Telford district, along Wenlock Edge, the Wenlock Limestone reef facies are still worked as aggregate.

Carboniferous Limestone was worked on the western margin of the coalfield from Steeraway [653 097] to the Hatch [646 084], Little Wenlock and Huntington [652 080], until The Hatch mine closed in 1920, and also north-east of the Telford district at Lilleshall. Normally only the Upper or Thick Limestone, consisting of grey rubbly or massive limestones interbedded with micaceous shales and friable calcareous sandstones, was worked. References to workings date from 1225 A.D. and by 1800 the limestone was widely extracted underground and at surface for agricultural lime and blast furnace flux. Where the limestone is at shallow depth, e.g. at The Hatch, parallel headings were driven in from the outcrop, but elsewhere well-planned advancing pillar-and-stall working was practised, with 9.0 m-square pillars separated by stalls 9.0 m wide, entered by drifts or deep shafts. At Steeraways Mine the full thickness of about 13.7 m was taken in one lift, the pillars being robbed on the retreat to the 36.6 m-deep shaft. In one instance limestone was worked from a 150 m shaft which had previously been used for coal, ironstone and fireclay extraction. Mining apparently did not occur at more than one mine in any particular area at a time, each mine being exhausted before the next shaft was sunk.

The *Spirorbis* Limestone overlying the Main Sulphur Coal of the Coalport Formation has been locally exploited around Broseley. Prestwich (1840) described the lime produced as applicable for agricultural purposes and in some cases as 'well adapted for a water cement'.

Pyrites

Iron pyrites was used for several centuries for the manufacture of sulphuric acid. Plymley (1803, p. 72) described the process at Wombridge where the pyrites lumps weighed about 13 pounds (5.9 kg) and the acid was used to extract soda from the brine produced at Kinley (see later). The main source of pyrites was the New Mine Coal, in which it formed layers up to 0.1 m thick (Prestwich, 1840, p. 435); the ore was picked from the coal at surface before the coal was used for boiler fuel or in the brickworks. About 500 tonnes of pyrites was produced annually in the 1880s, after which production declined steadily. Three mines were still working pyrites in 1905, in which year 213 tonnes were produced. The last mine, at Ketley, ceased picking the ore in 1928.

Bitumen

Bitumen-impregnated sandstones are common in the Productive Coal Measures (e.g. Little and Big Flint Rocks), Hadley and Coalport Formations. Surface springs of bitumen (known locally as 'tar') occur, for example, in Tarbatch Dingle [70 01] near Broseley. Records of shallow wells for bitumen date from 1684 (Lees and Cox, 1937); one at Broseley was only 1.5 m deep. Prestwich (1840, p. 438) referred to a shaft at Priorslee being converted into a tar well owing to the amount present in the '20 yard rock'; probably this refers to the Thick Rock at Tarry Pit [707 098]. At Mill Pit [691 061] colliers had to wear special clothing to protect them from the dripping tar.

The most celebrated occurrence is in the Thick Rock in the Coalport 'Tar Tunnel', started by William Reynolds as a canal tunnel. In 1787, when it was about 274 m long, a spring of natural bitumen was struck which yielded initially 1000 gallons (4500 litres) per week (Prestwich, 1840, p. 438). This was marketed for medicinal use as Bettons British Oil (Randall, 1865). By 1824 annual production was only 20 barrels per year, and it had ceased by 1843. The tunnel was rediscovered by one of the writers (IJB) in 1964 and is now open to the public (Brown and Trinder, 1979); tar can still be seen trickling down the walls and collecting in pools in branches of the tunnel. The material is a heavy asphaltic oil of fairly low sulphur content and negligible wax content, with appreciable quantities of vanadium and nickel.

Randall (1865) suggested that the bitumen originated in the Coal Measures. Lees and Cox (1937), however, considered that it had migrated from Lower Carboniferous strata between the Coalbrookdale and South Staffordshire coalfields, as it chemically resembles that in Carboniferous Limestone at Hardstoft, Derbyshire, while Lovely (1946) suggested that it had migrated along the Upper Coal Measures unconformity from the thick Carboniferous of North Staffordshire. However, both the latter authors admit that it could be from the Silurian, and this suggestion is supported by the presence of oil in the Wenlock Limestone at Farley [633 020] (Lees and Taitt, 1946). The most likely origin would appear to be in the marine Lower Carboniferous below the Coal Measures to the north, the oil having migrated up-dip along the Coal Measures sandstones, with the more volatile constituents being lost and only the heavy bitumen being left.

Natural Gas

Methane occurs as a hazard in all the deeper coal mines, and from the 1950s the Granville Colliery methane drainage system was connected to Wellington Gas Works. The gas was used commercially until replaced by North Sea Gas. In 1973 some 400 cu.ft/minute (115 cu.m/minute) of methane was being obtained from boreholes driven upwards from the Double Coal.

Fullers Earth or 'Walkers Earth'

'Walkers Earth' is a poor quality variety of Fullers Earth, a bentonite comprising alternating laminae of illite and montmorillonite bluish grey clays with a waxy feel. It occurs as 2 to 5-cm thick beds in the Wenlock Shales, most commonly towards the base of the Coalbrookdale Beds (Table 1), but also in the Buildwas Beds. One of the authors (IJB) noted it in the Wenlock Limestone at Lincoln Hill Mine and thin beds are exposed in Wenlock Limestone quarries at Farley. Several otherwise inexplicable adits may have sought this mineral. In 1880 Randall noted a working near the Coalbrookdale-Wellington Road: he was told that persons 'fetch it when they are galled and it is good for the eyes' and that large quantities were 'sent to Manchester'. It was sold, as a substitute for soap, for personal hygiene and also as a soothing ointment.

Common Salt

Saline springs are known at Donnerville [639 124], Admaston Spa [6375 1310] and Kinley [672 149]. The source of the salt is unknown, but it is notable that all the springs are near faults where the Keele Formation rests on Uriconian at shallow depth.

A slight mound [6724 1490] 315 m north-east of Kinley Farm, marks a disused saline well, described by Townson (1799) as a spring yielding 4,000 to 5,000 gallons (18,000 to 27,000 litres) of impure brine per day 'from out of a reddish sandstone resting on a reddish "chert" like that of the Wrekin'. The brine was used for the manufacture of salt, at cottages nearby, and by farmers as fertiliser. Two salt works were operating at Preston by 1707 but closed before 1800; both took brine from Kinley. In 1946 a borehole (B.G.S. record number SJ61SE/1109) [6696 1474] sunk north of the farm provided only slightly saline water initially, but by 1948 it had become too saline for cattle to drink and a further bore (SJ61SE/1110) was drilled [6689 1466] west of the farm. This was not saline, although it similarly proved the Keele Formation below glacial drift. Finally, a borehole (SJ61SE/24) was sunk by the Institute of Geological Sciences in 1970 [6716 1478] 150 m south of the well. Ground water salinity was measured by a conductivity probe, taking continuous readings from 1 m to 42.5 m; down to 31 m conductivity varied around 500 micromhos (normal tap water has a value of 400–600); below 31 m it gradually increased, reaching 10,000 micromhos at 35.67 m, and at 40.23 m it was in excess of 20,000 and immeasurable. The increase in salinity with depth is mainly due to gravity settling, and no rock salt was recorded in the borehole cores.

The spring at Admaston became a popular spa in the eighteenth century, and was used by a chemist in Much Wenlock as late as 1920; Pocock and others (1938, p. 288) recorded that in 1919 clear, colourless saline water rose as a spring in a well 1.8 m deep. Brine springs have also been recorded in the Coal Measures in the south of the area. Prestwich and others recorded brine in the Big Flint Coal in mines at Madeley and in the Coalport Tar Tunnel, and Townson (1799) stated that salt was formerly made from brine at Salthouse Pit, Broseley.

Land Reclamation and Development Restraints

The planning and engineering problems created by siting the New Town of Telford on an intensely worked coalfield are dealt with elsewhere (Brown, 1975, 1979c, 1988, Whitcut 1981) but it is salutary to summarise them here, since the mining history of the area has left enormous problems for the developer. At least 6,000 mine shafts and wells existed in this area, mostly unmarked, and many of the available plans of shafts and underground workings are old and of dubious accuracy.

Coal mining has been the major cause of dereliction and instability. Shafts and adits frequently remain unfilled and may contain dangerous gases. Also due to the superior quality of the Clod Coal and Crawstone ironstone these seams were often worked first in the life of a shaft rather than the simpler method of extracting the higher seams first. Landings would then be put in to enable higher seams to be worked and the shaft eventually filled above the topmost landing. As the landings rotted so the fill could become unstable.

In the exposed coalfield, workings are often shallow and poorly backfilled and may subside when loaded. Removal of water from old workings may cause subsidence by removing hydraulic support, alternatively, flooding can cause instability by increasing pore water pressure in the adjacent and overlying strata. In Ironbridge for example flooding of shallow workings has led to slip movement in fill material on the sides of the Gorge itself. Many of the earlier opencast sites were indiscriminately backfilled and are of suspect stability. However, sites which have been carefully backfilled and simultaneously compacted can be built on almost immediately and, as explained earlier, opencasting can be an economical way of restoring areas of old shallow workings. Coal at outcrop is an unsuitable foundation for building as it is weak, friable, permeable and liable to spontaneous combustion. The newer colliery spoil mounds are large and contain a high proportion of coal liable to spontaneous combustion. They may also be unstable, especially when located on a naturally unstable slope as at Woodside Colliery above Lightmoor.

Ironstones frequently have strong sandstone roofs (e.g. the Crawstone, Pennystone and Ballstone), hence adits and underground workings in these measures may not have closed up at all, and shafts may be unlined. Ironstone workings produce more spoil than early coal mining and, although this spoil is not liable to burn, huge areas of ground are covered by up to 9 m of soft weathered shale. Also blast furnace slag heaps may contain chemicals injurious to concrete.

Clay mining has led to serious subsidence, for example at the Red Church, Broseley, and clay shafts are liable to collapse. Clay opencast workings often remain open for long periods owing to the selectivity of the industry, which results in long-standing stockpiles and spoil mounds. Underground limestone workings are liable to surface 'crownings-in' owing to the great height of the pillar-and-stall workings. The instability of the limestone workings is increased by the presence between the beds of limestone of soft bands of bentonite (Walkers Earth) for, not only is this of low bearing strength, but it expands when wet, forcing apart the limestone pillars which support the workings. Brown (1988) describes how capping a limestone shaft in Telford, interrupted the ventilation of the workings, altered their humidity, and may have increased the rate of collapse of these workings.

In conclusion, it can be appreciated that whilst the siting of Telford New Town is clearly an effective means of revitalising the flagging industry of the area and reclaiming derelict land which would otherwise remain unused, it has been a difficult and expensive undertaking requiring careful planning and phasing of reclamation and development. On the other hand, it is probably true to say that the development of the New Town has made possible the growth of the highly successful Ironbridge Gorge Museum, which has increased public awareness of the historical and economic importance of this classic area of geology.

Acknowledgements

We wish to acknowledge assistance over the years from our colleagues and friends at the British Geological Survey, Telford Development Corporation and the British Coal Corporation, and also from the many private mineral companies in the Coalbrookdale district. The paper is published with the permission of the Director of the British Geological Survey (NERC).

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Plate 1a: Crawstone Ironstone mine in Ironbridge, abandoned in the early 19th century. Longwall workings (left) have been packed with sandstone to prevent collapse because of the adjacent roadway (right). The latter is 1.7 m high and has been sunk lower than the ironstone level to provide headroom. The low passage through the sandstone packing (left) leads to the advancing working face. (Photo: British Geological Survey).

Plate 1b: Coalport Tar Tunnel: natural bitumen draining out of the Thick Rock Sandstone of the Coalport Formation. This pool of tar is 2.4 m square and the back wall of the sump 2.1 m high. (B.G.S.)

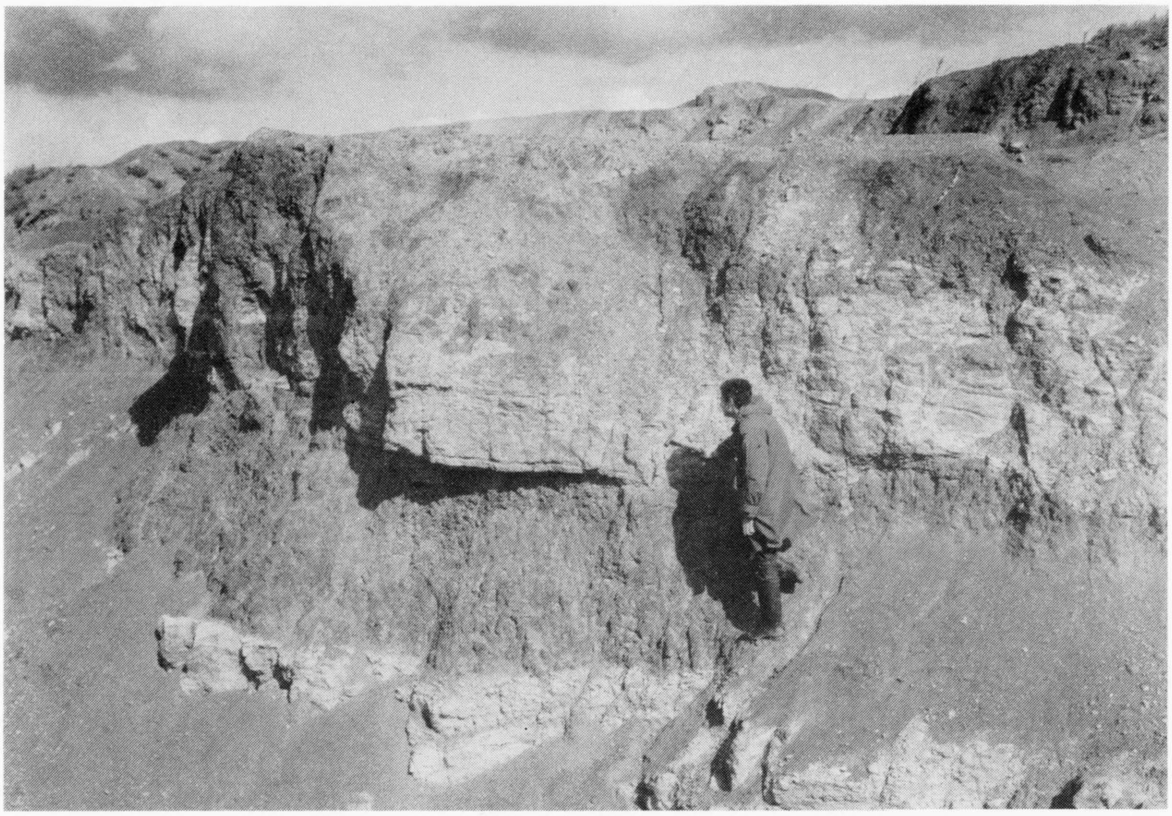

Plate 2a: Hadley Formation at Snedshill Brick Pit; blocky purple and red marls with massive "espley" sandstones. (B.G.S.)

Plate 2b: Caughley Opencast Site, a section showing the Main Ganey and Best Coals of the Lower Coal Measures. (B.G.S.)

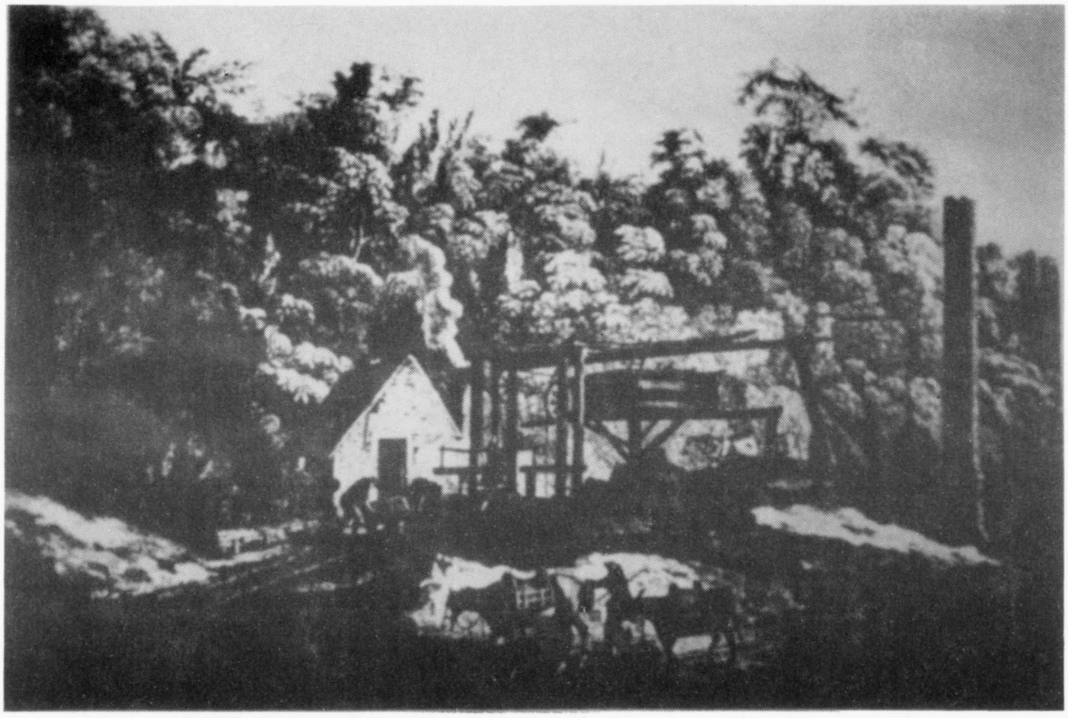

Plate 3a: 'A view of the mouth of a coal pit near Broseley' (published 1788). The gin (winding gear) is driven by two horses; this and the presence of a surface-furnace ventilation system (the chimney is on the right) indicate the mine was quite deep. (Ironbridge Gorge Museum Trust).

Plate 3b: Lincoln Hill Limestone Mine in 1975. A member of the Shropshire Mining Club is standing on a pile of debris facing a solid pillar of limestone; fourteen such pillars. 6–9 m high and about 6 m square, support the roof. (D. Stevenson).

Plate 4a: Part of Madeley Court Colliery in about 1906. Coal, ironstone and fireclay were extracted from shafts 50–90 m deep. In 1882 the surface equipment comprised one pumping engine, seven winding engines and one 'old water engine', all steam powered and of the beam type. (The late W. Harper).

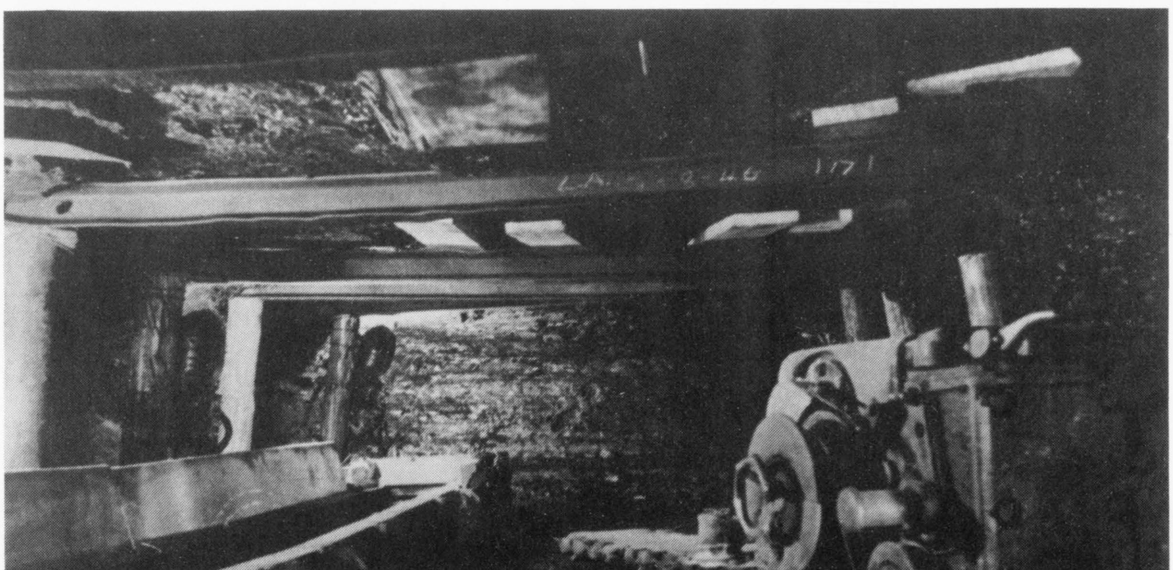

Plate 4b: Kemberton Colliery underground, 1946. A samson electric cutter (right) was used for under-cutting the coal, which was then blasted down and loaded by hand on the conveyor (left).