Westphalian rocks

Westphalian rocks were formed during the Westphalian Epoch of the Carboniferous Period between about 316 and 306 million years ago. The name Westphalian is derived from Westphalia in north Germany.

Westphalian rocks in Great Britain

The rocks are predominantly of sedimentary origin, although volcanic rocks are present in parts of Great Britain. Westphalian rocks are commonly known as the 'Coal Measures' after the coal seams which they contain. Because of their coal, iron ore and clay reserves the Westphalian rocks comprise one of the most economically significant parts of the geological column in Britain. These were the raw materials which were central to the development of Britain as a world power during the late 18th and 19th centuries.

The outcrop of Westphalian rocks in Britain is illustrated in (Figure 14). Britain can boast some of the best-exposed sequences of non-marine Upper Carboniferous strata anywhere in Europe.

The Coal Measures of the Midland Valley of Scotland, Northern England, the Midlands, the Pennines, South Wales, the Forest of Dean and the Bristol-Somerset area comprise some of Britain's most important former coalfields. Very substantial areas of Coal Measures rocks, concealed beneath younger strata, have been extensively mined for coal in eastern Yorkshire, the Midlands and Kent. The extensive Coal Measures, proved beneath Jurassic rocks in Oxfordshire have never been exploited.

Coal seams tend to look much like one another. Owing to their economic importance it became important to be able to correlate.

Marine bands are thin layers of sediment deposited during discrete marine incursions formed during periods of high global sea level. They are present over very wide areas and contain characteristic fossil assemblages, so that they have become the primary means of correlation within and between coalfields.

Tonsteins are mudstones rich in clay minerals, which are interpreted as having originated as layers of fine airborne volcanic dust. They typically occur as thin beds in coal seams and have proved important for establishing correlations in continental Europe.

In addition the Westphalian is divided into a number zones based on fossils. Five main groups of fossils have been used: goniatites (ammonoids), conodonts, non-marine bivalves, miospores and plants.

The Coal Measures rocks of Great Britain provide important evidence of late Carboniferous environmental conditions and of the fauna and flora at the time. They were deposited as a series of large delta complexes in discrete basins, separated by barriers which formed areas of non-deposition and sometimes erosion. Repeated subsidence of the deltaic coastline, followed by rebuilding of the delta, led to the deposition of a cyclic (cyclothemic) sequence similar to the 'Yoredale' succession (Figure 9), distinguished by thicker coals and the general absence of limestone. The typical order in which the main rock types follow one another within the Westphalian is:

Coal

Seatearth

Sandstone

Siltstone

Mudstone (marine band may occur at base)

Coal (of next cycle down)

During Westphalian times equatorial forests of huge primitive trees, ferns and other vegetation flourished on swampy delta slopes and thick deposits of peat derived from the partial decay of this vegetation accumulated from time to time on this surface forming the material that eventually produced coal. The great diversity of form and chemical composition amongst coal 'types' is due, in part, to essential differences in the plant material from which they have evolved, as well as to geological processes, which progressively alter the nature and maturity of coals (see page 27).

Geological SSSIs

There are no sites in County Durham specifically designated for Westphalian rocks within the Geological Conservation Review.

Durham County geological sites

Binchester Crags [NZ 210 330]

Causey Burn [NZ 199 556]

Craghead Crags, Lintzford [NZ 1409 5732]

Gaunless River [NZ 2173 3014]

Middridge railway cutting [NZ 250 251]

Underground tunnels at Easington Colliery [NZ 437 443]

Spurlswood Beck and Quarter Burn, Eggleston [NZ 022 268]

Wear River Gorge at Durham City [NZ 273 417]

Westphalian rocks in County Durham

Outcrops of Westphalian Rocks comprises 75,227 hectares, almost 34% of the surface area of County Durham.

The 'exposed' coalfield occupies a broad outcrop over 32 km wide extending eastwards from Consett, Crook and Woodland towards the coast. East of a line approximately through Sherburn Hill and Shildon and extending to the offshore area, Westphalian rocks dip beneath the Permian rocks to form the 'concealed' coalfield. Rocks up to the level of the Ryhope Five-Quarter Coal (Seam B) crop out within the 'exposed' coalfield east of Pittington. The Westphalian rocks of the Durham and adjacent coalfields were laid down in a single depositional basin, which occupied the area between the Southern Uplands High, in Scotland, and the Wales- Brabant High to the south. Rocks of the Lower and Middle Coal Measures crop out within County Durham.

Lower Coal Measures

Traditionally the base of the Coal Measures (Westphalian) in County Durham was taken at the Ganister Clay Coal, considered to be the lowest workable seam. This no longer accords with palaeontological evidence from other coalfields in Britain and north-west Europe, where the base of the Coal Measures is defined by a marine band containing the goniatite Gastrioceras subcrenatum. This fossil has yet to be found in North-East England. In 1962 a borehole was drilled for the Geological Survey at High Kays Lea Farm, near Woodland [NZ 0909 2769] with the objective of fixing the position of the G. subcrenatum Marine Band and establishing a local geological succession. The borehole indicated that, in the absence of the diagnostic fossil, the most appropriate place to take the base of the Coal Measures in North-East England was at the Quarterburn Marine Band, which is exposed in Quarter Burn [NZ 0170 2676].

The rocks between the Quarterburn Marine Band and the Ganister Clay Coal contain only thin and sporadic coals and are characterised by a high proportion of sandy strata. They were formerly referred to collectively as the Third Grit, of the old 'Durham Millstone Grit Series', thereby emphasising the similarity between this part of the Coal Measures and the highest beds of the underlying Namurian. A marine band at the top of this 'Third Grit', known as the Roddymoor Marine Band, can be seen in Spurlswood Beck [NZ 0172 2660].

The remainder of the sequence, above the Ganister Clay coal, contains widely persistent coals although seams thicker than 0.9m, and most of the productive seams, are largely confined to the beds above the Brockwell Coal. Below the Brockwell seam sandstones tend to be coarse and some are siliceous enough to be termed ganister.

Middle Coal Measures

As with the Lower Coal Measures, sandstone forms more than half of the Middle Coal Measures The Middle Coal Measures contain the majority of the workable coals, together with most of the marine strata and the best-known flora and fauna. The base is taken at the base of the Harvey (Vanderbeckeii) Marine Band. Fossils are recorded from several levels in the sequence. An important mussel band, sometimes with fish debris at the base, occurs closely above the Harvey Marine Band and is one of the most persistent marker bands of the Durham Coal Measures. A maximum of about 210 metres of Middle Coal Measures above the High Main Coal, probably as high as the Hebburn Fell Coal (Seam A), are present beneath Permian rocks in the 'concealed' coalfield. In the Durham coalfield as a whole these beds contain five marine bands, named in upward succession the High Main, Little, Kirkby's, Hylton and Ryhope. The Middle Coal Measures above the High Main include massive sandstones, such as the High Main Post, overlying the High Main Coal, and the Seventy Fathom Post, which was worked for grindstones.

Coal Seams

Traditionally, each colliery applied its own set of seam names. This led to much confusion and to a proliferation of local names. Thus, not only were individual seams given numerous local names, but where the same name was used in different collieries it was commonly applied to different coals. Later, standard sets of names were established separately in County Durham and Northumberland, but only in a few instances (notably in the lower measures) were similar names used for the same coals. This led to further confusion, a situation made worse by the frequent miscorrelation of seams within and between the two counties. In 1957 The National Coal Board, Durham Division, devised a system to indicate the correlation of coal seams “… in order to end the confusion which has resulted from the use of names alone". The workable coals present in the Coal Measures of County Durham were all referred to twenty-one principal horizons and each horizon was allocated a standard county name and also a correlation index letter. The purpose of the index letter system was to ensure accurate correlation even when seams were split or linked with another seam. The system was later extended to include the coals of Northumberland and for the most part the Durham names were retained.

In addition to the principal seams listed in (Table 3), there are other, smaller seams, both separate horizons and leaves of larger seams, which have not been listed. Some of these may have been of sufficient thickness and quality to have been mined over limited areas. Most of the productive seams were concentrated in the middle of these strata from the Brockwell to the High Main. With the advent of opencast coal extraction practically every coal greater than a few centimetres in thickness has been excavated at some point.

The coal names themselves provide a fascinating avenue for study and interpretation:

One of the most famous of the Durham seams is the Hutton, its name being almost a household word during the first half of the 20th century. At the end of 1959, the seam was being worked at thirty-nine collieries within Durham. The lowest important member of the group of seams lying above the Harvey Marine Band, the seam is found at an average distance of about 30 metres above the marine band. Although the origin of the name Hutton is obscure, its use can be traced back for over 200 years. The earliest reference obtained is in connection with the “Grand Allies" who, in 1727, worked royalties in the Pontop area and formulated a scheme for the regulation of the sale of coal, in which the output of a Hutton Pit is mentioned.

The coals of Durham have been mined extensively from both exposed and concealed portions of the coalfield. They cover a range of rank from coking coals in the west to lower rank, high-volatile bituminous coals in the east.

Even though Westphalian rocks underlie such a high percentage of the county, it is not easy to examine them in Durham. They are extensively concealed by glacial drift and exposure is confined the banks of the major rivers and their tributaries, abandoned quarries and clay pits, and to isolated outcrops, commonly of sandstone, on steeper or higher ground. Natural sites are generally disappointing and excavations are few and ephemeral. Quarries are most commonly in sandstone. Much of the stratigraphical information on the Coal Measures of Durham has come from borehole, shafts and underground workings. However, the advent of large-scale opencast coal extraction in the second half of the 20th century provided the opportunity for detailed examination of the rocks in active opencast sites. Consequently the sections used for most of the recent research and advances in understanding of the Westphalian rocks in Durham have either been quarried away or buried on completion of coal extraction.

Influence on the landscape

In the western parts of the coalfield the landscape of the Durham Coalfield Pennine Fringe is made up of broad ridges and shallow valley heads of the coalfield valleys. The soft and thinly bedded sandstones, shales and coals of the Coal Measures are here generally free of drift or locally masked by boulder clays giving rise to gently rounded convex slopes. Occasional thicker sandstone beds are marked by steeper bluffs. The Tyne and Wear Lowlands within County Durham are everywhere underlain by Coal Measures rocks, though an extensive mantle of superficial deposits greatly limits their direct influence upon the landscape. Exposures of Coal Measures rocks are here mainly restricted to incised valley sides, though sandstone outcrops are traceable as ridges where superficial cover is thin valleys.

Centuries of coal working have greatly modified the natural landscape. The general settlement pattern in the coalfield consists of small, scattered communities that developed around individual collieries Substantial areas have been greatly altered by opencast coal extraction and subsequent infilling since the Second World War II. Over the years, areas affected by opencast coalmining have spread to cover a significant proportion of the exposed coalfield with over 120km^2 having been worked or had approval for working see (Figure 16). The pattern of open- casting in Durham, with large numbers of relatively small sites, and re-working of areas has led to a widespread loss of traditional landscape features and associated wildlife. This has had a significant impact on the area, with the loss of subtle landscapes developed over centuries, which not even sympathetic restoration schemes can recreate adequately.

The coalfield is now generally seen as a predominantly rural landscape with a rich industrial heritage, which is preserved and celebrated in The North of England Open Air Museum at Beamish and the Timothy Hackworth Victorian and Railway Museum at Shildon. The Durham Coast, at one time one of the most despoiled in Europe, has been the subject of a major reclamation initiative in the Turning the Tide Project and much of it is now designated as Heritage Coast.

Influence on biodiversity

Over moorland parts of the county the Westphalian rocks support a vegetation pattern extremely similar to that found on the Namurian rocks above the Great Limestone. On poorly drained ridges and plateaux, peaty gleys and deeper peats have formed, supporting heathland vegetation of heather, bilberry and acid grassland and locally oak-birch woodland. Valley sides incised through the superficial deposits into the Coal Measures rocks are typically wooded. An extensive mantle of Quaternary deposits, mainly boulder clay or till, conceals substantial parts of the Coal Measures outcrop. In such areas the biodiversity typically reflects the nature of these superficial deposits rather than the underlying Coal Measures rocks. Although the extensive opencasting in the county has lead to a loss of natural wildlife, modern restoration schemes have increasingly taken into account wildlife considerations and several successful habitat creation schemes have been undertaken.

Economic use

Coal

The Northumberland and Durham coalfield was the first British coalfield to be developed commercially. The earliest mention of coal-mining by the monks of Durham is in 1188, but workings only seem to have become important during the 14th century, when a considerable revenue began to be derived. In 1820 a new era opened when Hetton Colliery shaft was sunk through the Magnesian Limestone to the Hutton Seam in the concealed part of the coalfield. In its peak years of production almost the entire output of coal from the Durham coalfield was obtained from underground mines. In 1913 over 41 million tons of coal were raised and 132,000 men employed in the collieries of the county. Exhaustion of reserves and economic factors led progressively to the closure of the large deep coal mines in the 1980's. During the final years of deep mining coal extraction became concentrated in a handful of amalgamated coastal collieries in which workings extended up to 5 km offshore. The closure of Park Drift Mine, near Willington in 1999 brought underground coal mining in Durham to a close. Opencast extraction, which started during the Second World War, reached its peak in the early 1990's when over 14,000 tons were extracted annually.

Fireclay

Fireclays are non-marine sedimentary mudstones and occur as seatearths, the fossil soils on which coal-forming vegetation once grew, which underlie almost all coal seams. The term 'fireclay' is used to describe seatearths which are of economic interest and they are generally named after the overlying coal. The Durham coalfield has historically been an important source of fireclay. Up to the Second World War, before the advent of opencast coal mining, all fireclay was extracted by underground mining. The last two fireclay mines near Bishop Auckland closed in 1975. Originally fireclays were valued as refractory raw materials, because of their relatively high alumina and low alkali contents. Demand today is comparitively low for refractory purposes, but some fireclays with low iron contents compared with other brickmaking clays are now valued for the production of buff- coloured facing bricks and pavers. They are often blended with red-firing brick clays to give a range of fired colours.

Fireclay production is today dependent on the level of opencast coal activity. Several fireclays within the Lower Coal Measures are of economic interest for brick manufacture, most notably those associated with the Tilley and Busty seams and, to a lesser extent, the Victoria and Brockwell.

Brick-making

Small brickworks mainly producing 'common' bricks' from locally won raw materials, including clay, mudstone (shale) and fireclay were formerly a common feature in many industrial areas of Britain.

The Union brickworks near Birtley lies in Gateshead Borough, although the clay working which supplies it is in County Durham. Mudstones which meet the requirements of the brick industry today are very limited, but bricks are produced at two locations in County Durham based primarily on Coal Measure mudstone won from on-site pits. Both plants are in the Bishop Auckland area and also consume varying tonnages of fireclay brought in from opencast sites. The plant at Todhills produces a range of red and buff facing bricks using the soft-mud process. Buff bricks are based on a blend of fireclays, the red bricks are made primarily from mudstone. The Eldon plant produces a range of red and buff facing bricks using the extrusion process and also makes class 'B' engineering bricks.

Sandstone

Coal Measures sandstones have been widely used as building stones. The finest examples of their use within the county are in Durham Cathedral and Castle, though they were also widely used across the coalfield. Sandstones from the Coal Measures have been much used in dry stone walls in the western parts of the coalfield. Coal Measure sandstone is still quarried at Quickburn, near Satley [NZ 080 428].

Future commercial interest

Future commercial interest in the coalfield is likely to be confined to sites suitable for opencast extraction. The economics of coal extraction have changed with time, allowing coals with higher overburden ratios to be extracted. Some sites, or parts of sites, have been worked on more than one occasion and may be worked for deeper coal in the future. However

sites worked within the last 25 years are likely to have exhausted the economically recoverable coal resources. County Durham still contains reserves of coal suitable for opencast extraction and although extraction today is on a much smaller scale than in the past it is likely that as one site closes operators will wish to open another. Only one opencast coal site was in active production in April 2004, at Southfield, south-east of West Auckland. Continued interest in the working of fireclay, brickclays and sandstone may be expected.

Wider significance

During their long history of exploitation the Coal Measures rocks of County Durham have contributed greatly to the understanding of Westphalian rocks both in Great Britain and beyond. The exposure in the Quarter Burn, near Woodland, is the type locality of the Quarterburn Marine Band, the bed taken in North-East England to mark the base of the Coal Measures. However, exposures of Coal Measures rocks available within the county today pale into insignificance by comparison with the extensive coastal sections of these rocks in Northumberland.

Environmental issues

Centuries of underground coal mining have left an indelible mark on the county both above and below ground. The widespread dereliction left by the industry affected the quality of the landscape, the health of the environment, and the image of the county to those outside of it. A major reclamation programme lead by Durham County Council has been operating since the early 1960's to considerable effect, and has reclaimed over 44 square miles (144 km^2 of derelict land. Over much of the coalfield it is now hard to find evidence of coalmining. Those features which survive — old waggonways, viaducts and coke ovens — are now valued as part of the area's mining heritage. The nature of modern opencast working involving the movement of large amounts of material makes it a particularly suitable method of addressing contaminated and/or derelict land. Since 1997 several opencast schemes have successfully addressed areas of contamination.

During the course of underground mining vast quantities of waste rock were brought to the surface. Accumulations of such spoil are associated with most mines, large and small. Colliery spoil typically comprised waste shale, often with high concentrations of pyrite, and in places a significant content of inferior or undersized coal. Oxidation of these materials can result in spontaneous combustion or, more commonly, the development of highly acidic groundwaters. Leachates from such spoil heaps may present significant threats to land and the ecosystems of water courses. Contaminated water leaching from colliery spoil in the headwaters of the Stanley Burn, near Annfield Plain, have been successfully remediated by a purpose-built wetland system. Whereas the largest and most disfiguring spoil heaps have today been removed by a variety of reclamation and landscaping schemes, these mostly involved the redistribution of the waste over the surrounding ground and its covering with topsoil. However, unless appropriate remedial measures were incorporated into the reclamation method, the potential for significant environmental problems may remain. Even after a very few years such reclaimed ground may be very difficult to identify. It is therefore important to ensure that the nature and extent of such accumulations of spoil are adequately mapped and recorded.

The environmental aspects of dumping of colliery waste on the Durham coast are discussed briefly below (see Spoil Heaps).

Significant areas of the exposed coalfield are affected to some extent by surface collapse or subsidence, one of the most obvious manifestations of underground coal mining. In addition to the possibilities of damage to buildings and structures, subsidence may impede effective drainage through surface water courses and may result in temporary or even permanent flooding of land. Although reactivated movement or subsidence associated with known faults in exposed Coal Measures rocks is well known form other parts of Great Britain, for example in Staffordshire and South Wales, this phenomenon is not known to have been recognised to date in the exposed part of the Durham Coalfield. Ground stability related to possible reactivation of faults and fissures in the Magnesian Limestone are discussed briefly below (see Magnesian Limestone).

Although pumping of mine water continues at several places in the county, ground water levels in some areas of former mining are known to be rising. Such groundwater may be highly acidic and heavily charged with a variety of chemical elements, notably iron, manganese and aluminium. In uncontrolled situations this water may discharge naturally to the surface via former mine openings or even through geologically controlled pathways such as faults, fissures, or permeable rock formations. Serious contamination of land and water courses, accompanied by attendant effects on biodiversity, may result. A number of such discharges may be seen in County Durham: a particularly striking example is that at Stony Heap, near Lanchester where thick deposits of ochre are being deposited on the banks and bed of the stream. Controlled pumping and conditioning of the discharged water is being undertaken elsewhere in the county, for example at Kimblesworth and at Edmondsley.

Most coals and coal-bearing rocks contain significant quantities of methane, commonly known as 'firedamp'. Efficient ventilation was imperative in working collieries to avoid explosions. Methane may continue to be released long after workings are abandoned. In old and unventilated workings large volumes of de-oxygenated air, otherwise known as 'black damp' or 'stythe' may form. These gases may find their way to the surface, often driven by rising water levels. Discharge may not be restricted to former mine openings. Faults, fissures and permeable rock units, especially where a protective surface cover of superficial deposits is thin or absent, may form very effective pathways conveying gases to the surface, in some cases many tens or even hundreds of metres from the workings in which they were formed. In confined or poorly ventilated situations, these gases may present serious risks to health and safety. Instances of surface discharges of mine gas are understood to have affected several parts of the county.

Subsidence, mine water contamination and mine gas problems all impact upon biodiversity, human safety, and economic activity. Their successful management and remediation depends upon the application of a detailed knowledge and understanding of the key factors of the county's geodiversity.

Selected references

Atkinson, 1968; Burgess and Holliday, 1979; Cleal and Thomas, 1996; Dunham, 1990; Galloway, 1882; Jevons, 1915;Johnson, 1970;

1973; 1995; Magraw, 1975; Mills and Holliday, 1998; Mills and Hull, 1976; Scrutton, 1995; Smith, 1994; Smith and Francis, 1967; Taylor et al, 1971.

Figures, photographs and tables

(Figure 14) Distribution of Westphalian rocks in Great Britain the coal-bearing rocks between different coalfields. In the absence of many distinguishing features within the coals themselves two types of 'marker horizon' have been used for correlation: marine bands and tonsteins.

(Figure 15) Distribution of Westphalian rocks in County Durham.

(Figure 16) Location of Opencast Coal Sites in County Durham.

(Photo 13) Reconstruction of Coal Measures swamp. BGS, ©NERC, 2004.

(Photo 14) Prior's Close Opencast Coal Site, Great Lumley. Fossilised log of Cordiaites in sandstone. Photographed 1997. B Young, BGS, ©NERC, 2004.

(Photo 15) Cobey's Carr Quarry, near Willington. Typical Coal Measures shales and sandstones. B Young, BGS, ©NERC, 2004.

(Photo 16) Panoramic view from Mountsett, near Stanley. Landscape typical of the western part of the Coalfield. BGS, ©NERC, 2004.

(Photo 17) Brusselton Hill, near Shildon. Landscape of the eastern part of the Coalfield with the Magnesian Limestone escarpment in the distance. BGS, ©NERC, 2004.

(Photo 18) Horden Colliery, photographed in 1973. B Young, BGS, ©NERC, 2004.

(Photo 19) Hown's Quarry, Consett. Underground quarries in the sandstone between the Marshall Green and Victoria coals. BGS, ©NERC, 2004.

(Photo 20) Iron-rich minewater discharge. Stony Heap, near Lanchester. B Young, BGS, ©NERC, 2004.

(Photo 21) Gas vent to allow drainage of mine gases from old workings. B Young, BGS, ©NERC, 2004.

(Table 3) Principal coal seams in County Durham.

Full references

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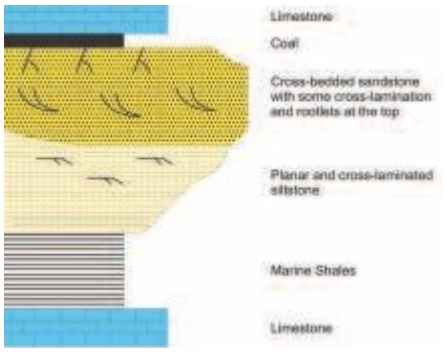
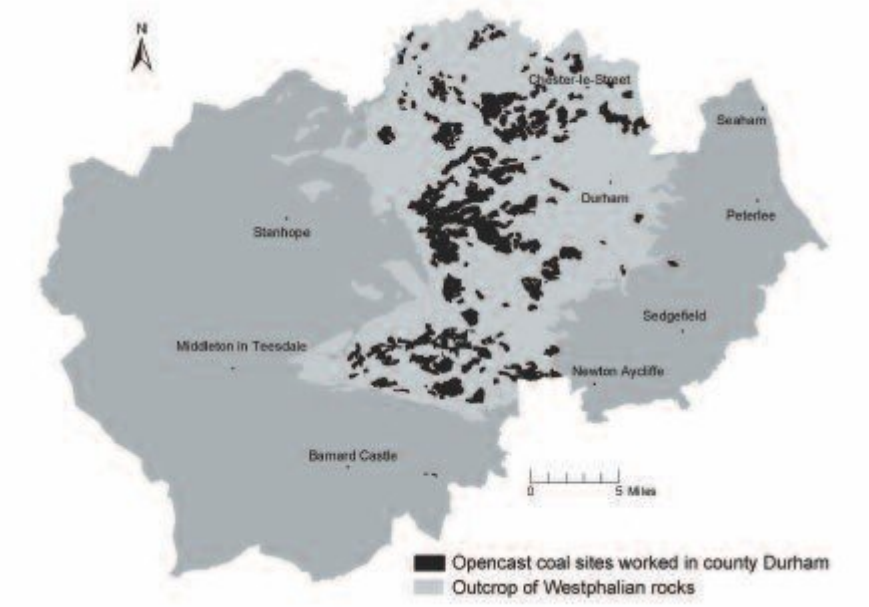


(Figure 9) Idealised 'Yoredale' cyclothem.

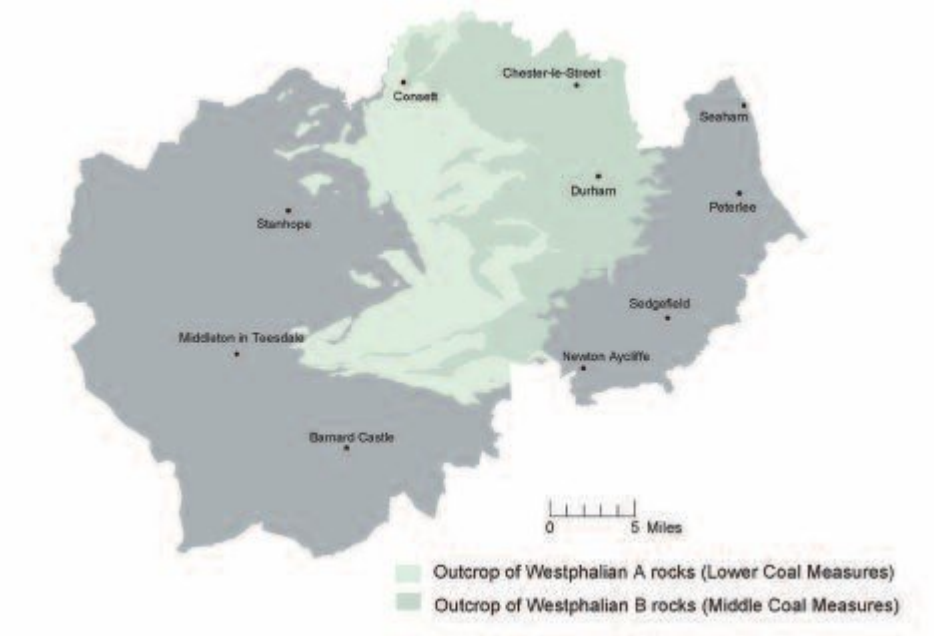
County Index letter applied by the National Coal Board	County Durham	Remarks on local names
A	*[Seam A]*	Hebburn Fell
B	*[Seam B]*	Usworth
C	Ryhope Five-Quarter *[Seam C]*	
D	Ryhope Little *[Seam D]*	
E	High Main	Houghton Three-Quarter, Seaham Five-Quarter
F	Five-Quarter *[Main]*	Dawdon Seven Quarter
G	Main *[Yard]*	North West Durham Brass Thill
H	Maudlin	Bensham
J	(Durham) Low main	Tyne Six-Quarter
K	Brass Thill	Tyne Five-Quarter
L	Hutton	Main of North-West Durham
M	Ruler *[Plessey]*	Ruler of North-West Durham
N	Harvey	Beaumont of West Durham
O	Hodge	Hodge of North-West Durham
P	Tilley	Yard, Constantine of West Durham
Q	Busty	Five-Quarter of West Durham
R	Three-Quarter	Seggar seam of West Durham
S	Brockwell	Main of West Durham
T	Victoria	
U	Marshall Green	
V	Ganister Clay *[Seam V]*	

[Plessey] = Combined Northumberland and Durham name

(Table 3) Principal coal seams in County Durham.



(Figure 16) Location of Opencast Coal Sites in County Durham.



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