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Coal Resource Appraisal Maps: methodology and datasets used

Economic Minerals Programme

Commissioned Report CR/06/159N



BRITISH GEOLOGICAL SURVEY

ECONOMIC MINERALS PROGRAMME

COMMISSIONED REPORT CR/06/159N

Coal Resource Appraisal Maps: methodology and datasets used

N S Jones

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Keywords

Coal resources, Great Britain, GIS.

Bibliographical reference

JONES, N.S. 2006. Coal Resource Appraisal Maps: methodology and datasets used. *British Geological Survey Commissioned Report*, CR/06/159N. 19pp.

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British Geological Survey offices

Keyworth, Nottingham NG12 5GG

☎ 0115-936 3241 Fax 0115-936 3488
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.geologyshop.com

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e-mail: scotsales@bgs.ac.uk

London Information Office at the Natural History Museum (Earth Galleries), Exhibition Road, South Kensington, London SW7 2DE

☎ 020-7589 4090 Fax 020-7584 8270
☎ 020-7942 5344/45 email: bgs london@bgs.ac.uk

Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast, BT9 5BF

☎ 028-9038 8462 Fax 028-9038 8461

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

☎ 01491-838800 Fax 01491-692345

Sophia House, 28 Cathedral Road, Cardiff, CF11 9LJ

☎ 029-2066 0147 Fax 029-2066 0159

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Acknowledgements

I would particularly like to thank Keith Adlam, Marieta Garcia-Bajo and Russell Lawley for their GIS input into the project. Bob Cooper is thanked for his cartographic work and Steve Hurst is gratefully acknowledged for provision of the digital coal prospecting site data. In addition I would also like to thank Tony Myers and Graham Lott for their invaluable contribution to the project.

From the Coal Authority the author would like to thank John Delaney, for guiding and managing this work package, and Simon Cooke and Joe Dearden for provision of data.

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Summary

This report forms part of a study carried out on behalf of the Coal Authority (Contract No. CA/18/1955 – HQ – COAL APPRAISAL MAP, BGS project Code E2377R74). The work was carried out between 12.06-17.08.06 at the offices of the British Geological Survey, Keyworth, Nottingham.

The objectives of the project were to provide maps to show the remaining potential for coal exploitation by opencast and deep mine methods. This report describes the data and methodology used to create these coal resource appraisal maps. The maps were constructed digitally using ESRI® ArcMAP™ 9.1 GIS software. Sample paper maps of North Derbyshire were provided at 1:100,000 and 1:50,000 scale. It is intended that maps for other areas of Great Britain will be provided upon request.

1 Introduction

One of the roles of the Coal Authority is to promote the working of coal in this country and, as part of this, they wish to gain a better understanding of the extent of the remaining coal resource in Great Britain suitable for opencast and Deep Mine extraction. To this end the Coal Authority commissioned the British Geological Survey (BGS) to carry out a study mapping the extent of the remaining coal resources within Great Britain.

The primary objective of the study was to build a series of GIS layers from which customised maps can be produced as required, which will identify resource areas. These resource areas may have future potential for coal extraction by both surface and deep mining. Construction of a GIS will allow greater flexibility for data manipulation and will allow for changes in cartographic design. It will also allow the data to be readily updated and adapted for other possible uses, e.g. for defining coal safeguarding areas. The information gathered is primarily aimed at:

- a) Mineral Planning Authorities, to assist them to identify future working areas and for safeguarding purposes, as required, and
- b) To assist the coal industry in identifying future coal prospects.

This brief report describes the methodology used for the production of coal resource appraisal maps for Great Britain. This report forms part of a study carried out on behalf of the Coal Authority (Contract No. CA/18/1955 – HQ – COAL APPRAISAL MAP, BGS project Code E2377R74). The work was carried out between 12.06-17.08.06 at the offices of the British Geological Survey, Keyworth, Nottingham. Analysis of data was carried out digitally using ESRI® ArcMAP™ 9.1 GIS software. Certain digital files used during the course of this study are available on the CD-Rom supplied with this report. Data compilation, GIS development and digital cartography was carried out by K.A. Adlam, M. Garcia-Bajo, R.J. Cooper, S.E. Hurst, N.S. Jones, R.S. Lawley, G.K. Lott and A.H. Myers

2 Datasets

A number of GIS layers were used for this project:

2.1 NON-COAL THEMES

These include the main National & European Designations. The data is available online from Natural England, MAGIC, Countryside Council for Wales and Scottish Natural Heritage and is not supplied with this report. The themes used are:

- **Areas of Outstanding Natural Beauty (AONB)** (National Designation): These are created by the Countryside Agency, under the National Parks and Access to the

Countryside Act 1949. Their purpose is to conserve and enhance the natural beauty of the area.

- **Ancient Woodlands:** Land that has had continuous woodland cover since at least 1600 AD.
- **National Nature Reserves (NNRs):** Established to protect the most important areas of wildlife habitat and geological formations in Britain, and as places for scientific research.
- **National Park:** Protected area administered by its own National Park Authority.
- **Ramsar sites (Wetlands):** Ramsar sites are wetlands of international importance designated under the Ramsar Convention.
- **Sites of Special Scientific Interest (SSSI):** Areas preserved by reason of any of its flora, fauna, geological or physiographical features.
- **Special Areas of Conservation (SACs):** These are areas designated under the European Directive commonly known as the 'Habitats' Directive. Together with Special Protection Areas, SACs form the Natura 2000 network of sites.
- **Special Protection Areas (SPAs):** These are strictly protected sites classified in accordance with Article 4 of the EC Directive on the conservation of wild birds (79/409/EEC), also known as the Birds Directive.
- **World Heritage Site:** These are places of international importance for the conservation of mankind's cultural and natural heritage, as administered by the UNESCO.

2.2 COAL-RELATED THEMES

The following themes are represented in the GIS and on the sample maps:

- **Opencast licence:** This represents an area where a Coal Authority licence is in existence as of February 2006. Data was supplied by the Coal Authority.
- **Deep mine licence:** This represents an area where a Coal Authority licence is in existence as of February 2006. Data was supplied by the Coal Authority.
- **Worked opencast sites:** These are polygons that show the extent of possible opencast coal workings. These data were supplied by the Coal Authority in February 2006. Note: The areas of worked opencast coal shown should not be taken to imply that all the coal in place has been exhausted. The economics of opencast coal extraction has changed with time, allowing coal with higher overburden ratios to be worked. Some sites have been worked on more than one occasion and may be worked for deeper coal in the future. However, modern sites worked within the last say 30 years are likely to have removed all the coal in place. In addition, the polygons do not always represent the area of total extraction of coal. In some instances some instances these polygons represent the actual worked areas, in other instances they represent the site area. It has not been possible to distinguish these areas from the data supplied and it is recommended that interested parties review the opencast completion plans, which are available by visiting the Coal Authority.
- **Opencast prospect areas:** In 2001 the BGS took possession of the British Coal Prime Geological Record Collection, which it holds on behalf of the Coal Authority. This

dataset consists principally of deep mine information, opencast coal prospecting site data, seismic survey, plans and coal analyses. The opencast prospecting site (OPS) dataset represent areas where some coal exploration has been carried out and consists of paper-based information on some 8000 sites, filed in 3618 boxes. The data stored in these boxes includes borehole data, proposed coal tonnages, plans and seam analyses. This data is of variable age and quality and is held in analogue form at the NGRC, British Geological Survey, Keyworth, where it is available for examination. This is an historic dataset and does not distinguish whether sites have subsequently been worked. Each of the prospecting sites were identified on British Coal paper index site maps which, prior to this project, were scanned, geo-rectified and site outlines captured digitally as polygons. These site areas and associated metadata are now stored as a GIS layer which can be viewed on the BGS web site (www.bgs.ac.uk/geoindex/index.htm - click on minerals in the Sector Themes). This data is also used in the GIS and maps associated with this project.

- **Opencast Prospect areas with potential tonnage data:** During this study the Coal Authority made available the British Coal 1993 Appraisal of Resources dataset. This is a paper record that lists prospective opencast sites and the proposed tonnages available for some 646 sites across Great Britain in 1993. It represents a more modern assessment of tonnages than the OPS data. As part of this study the site name, site number, potential tonnage and overburden-to-coal ratio were digitised. Unfortunately the British Coal 1993 Appraisal of Resources records do not contain centroid grid references or any means of locating the sites. However, in many (but not all) instances it was found that the site numbers matched those of the site numbers present within the OPS dataset. Using this common factor it was possible to join the two datasets and hence assign a potential tonnage value to a polygon shape and area. Hence opencast prospect sites with potential tonnage data are identified in this theme.
- **Primary coal resource area:** This is a polygon-based dataset that identifies the main target for opencast coal extraction; it comprises a zone where a relatively closely spaced succession of variable but generally thick coals are present at surface. Further details on the definition and derivation of this resource area are given later in this report. The data was derived mainly from BGS DiGMap-50 digital data, partly from BGS (1999), with some additional GIS cartography. This data is suitable for viewing at a scale of 1:50,000 and it is important that the data should not be over-enlarged, e.g. do not use 1:50,000 nominal scale data at 1:10,000 or 1:25,000 scale. The compilation of geological lines is probably no better than 1 mm, which equates to 50 m on the ground at 1:50,000 scale.
- **Secondary coal resource area:** This is a polygon-based dataset that identifies the secondary target for opencast coal extraction. It comprises a zone in which opencast coal resources are present at surface but the coals are generally thinner and less concentrated in vertical and areal distribution. Further details on the definition and derivation of this resource area are given later in this report. The data was derived mainly from BGS DiGMap-50 digital data, partly from BGS (1999), with some additional GIS cartography. This data is suitable for viewing at a scale of 1:50,000 and it is important that the data should not be over-enlarged.
- **Tertiary coal resource area:** This is a polygon-based dataset that identifies a tertiary target for opencast coal extraction. These are coals that are locally present in the Late Carboniferous Warwickshire Group succession, where they can occur interbedded with thick sandstones of the Pennant Sandstone Formation and Halesowen Formation or alternating with red-bed successions. There are also a number of isolated coals present in the Namurian of England and Wales that have been ranked as tertiary. Further details on the definition and derivation of this resource area are given later in this report. The data was derived mainly from BGS DiGMap-50 digital data, partly from BGS (1999), with

some additional GIS cartography. This data is suitable for viewing at a scale of 1:50,000 and it is important that the data should not be over-enlarged.

- **Buried coal resource overlain by up to 50 m overburden:** In some areas, particularly downdip of the main area of mapped resources, coals are present in the subsurface covered by younger strata. This polygon-based dataset identifies the zone where coals are overlain by less than 50 m of overburden. The overburden is defined as bedrock; the thickness of superficial deposits is not considered here. Coals in this zone have not been ranked as primary, secondary or tertiary. Further details on the definition and derivation of this resource area are given later in this report. The data was derived mainly from BGS DiGMap-50 digital data, partly from BGS (1999), with some additional GIS cartography. This data is suitable for viewing at a scale of 1:50,000 and it is important that the data should not be over-enlarged.
- **Deep Mine prospects.** These represent the major underground mining prospects identified by British Coal in their Plan 2000 exploration phase. There is no implication that these areas are suitable for underground mining. Deep Mine prospects were derived from a variety of sources including the BGS (2004a) study for DTI, in part from IMC (1999), and some additional data supplied in analogue form by the Coal Authority. These are extremely generalised areas and it is recommended that this data is viewed at a scale of about 1:200,000.
- **2 m thick coal, 600-1200 m depth.** These represent generalised areas where boreholes indicate that coals of 2 m or greater thickness are present between the depths of 600-1200 m below surface. This dataset was taken from the BGS (2004a) study for DTI. The data was derived from BGS (1999). These are extremely generalised areas and it is recommended that this data is viewed at a scale of about 1:200,000.
- **Deep coal areas.** These represent coals in the subsurface, buried by greater than 50 m of overburden. The thickness of superficial deposits is not considered here. The data was derived from BGS (1999).
- **1200 m line on top Coal Measures:** This represents the 1200 m contour line on the top surface of the main coal-bearing succession. In most of England and North Wales the main coal-bearing succession is the Pennine Coal Measures Group, in South Wales, Bristol and Somerset it is the South Wales Coal Measures Group and in Scotland it is the Scottish Coal Measures Group. The data was derived from BGS (1999).

2.3 OTHER THEMES

- **Superficial thickness counters, 10m, 30m, 50m.** Superficial Deposits are the youngest of the geological formations (less than 2.6 million years old) and cover much of the bedrock of Britain. They are largely unconsolidated sands, gravel and till (boulder clay) and include man-made material such as coal tips and quarry infill. Contours of their thickness at intervals of 10, 30 and 50 metres are shown. These contours were derived from the BGS superficial deposits astm digital dataset (see BGS 2004b).
- **Ordnance Survey data:** Topography is based on the Ordnance Survey 1:50,000 maps; Ordnance Survey licence number 100037272 / 2006.

3 Resource areas: definitions & derivation

The UK contains extensive resources of coal, both at surface and in the subsurface. Onshore the surface deposits (not including the Warwickshire Group) cover an area of approximately 11,000 km², with the subsurface onshore extensions to these coalfields covering a further 28,000 km². The major coalfields of the UK are of Carboniferous age (Fig. 1). The exceptions to this are small accumulations of Tertiary lignites in Devon (Fig. 2) and Northern Ireland, which are not considered here and a Mesozoic (Jurassic) bituminous coal deposit in Brora, northeast Scotland. In England and Wales the majority of the coalfields are of Westphalian age (Upper Carboniferous) and belong to a stratigraphical unit known as the Pennine and South Wales Coal Measures Groups, divisible into lower, middle and upper units known as formations (Fig. 1). Thin coals are also known locally from the upper part of the Namurian. In Scotland and north-east England there are coalfields of Westphalian age, but important coal-bearing successions also occur earlier in the Carboniferous (Namurian and Dinantian) (Fig. 1).

The main coalfields of the UK are located on the eastern, southern and western flanks of the Pennines; the Nottinghamshire-Yorkshire, South Lancashire, Warwickshire, North and South Staffordshire coalfields are some of the largest (Fig. 2). Other important coalfields include South Wales, Kent and those in the Midland Valley of Scotland. The names of the coalfields are generally taken from the areas where the coals are present at surface, although these coalfields typically have subsurface (concealed) extensions, where coals are present buried beneath younger strata (Fig. 2). For each coalfield area in Great Britain (where coals are present at surface) it was possible to define resource areas based on the thickness, vertical spacing and lateral extent of coals. Three main orders of coal resources (primary, secondary and tertiary) were identified, defined in detail in the following section. In addition a fourth category was identified; these are areas where coal is present in the subsurface, buried by less than 50 m of overburden.

3.1 RESOURCE AREA DEFINITIONS

3.1.1 Primary resource area

The primary resource area constitutes the main target for opencast coal extraction and comprises a relatively closely spaced succession of variable but generally thick coals. These coals typically occur within a certain discrete stratigraphic interval, which comprises the succession from the middle to upper part of the South Wales and Pennine Lower Coal Measures formations to the lower part of the South Wales and Pennine Upper Coal Measures formations (Fig. 1). In other areas e.g. North Staffordshire, the whole of the Pennine Upper Coal Measures Formation contains numerous thick coals and can also be ranked as primary. In Scotland primary resources occur in the Scottish Coal Measures Group, the Namurian aged Limestone Coal and Upper Limestone formations; and locally in the Passage Formation (e.g. around the former Westfield opencast site area, near Cardenden, Lochgelly) (Fig. 1).

CHRONOSTRATIGRAPHY				LITHOSTRATIGRAPHY (SOUTH WALES)		LITHOSTRATIGRAPHY (N.E. ENGLAND)		LITHOSTRATIGRAPHY (E. MIDLAND VALLEY: SCOTLAND)							
SYSTEM	SUBSYSTEM	SERIES	STAGE	GROUP	FORMATION	GROUP	FORMATION	GROUP	FORMATION						
CARBONIFEROUS	SILESIAN	WESTPHALIAN	WESTPHALIAN D	WARWICK-SHIRE GROUP	GROVESEND Fm.	PENNINE COAL MEASURES GROUP	PENNINE UPPER COAL MEASURES FORMATION	SCOTTISH COAL MEASURES GROUP	SCOTTISH UPPER COAL MEASURES FORMATION						
			BOLSOVIAN		PENNANT SST Fm.				SCOTTISH MIDDLE COAL MEASURES FORMATION						
			DUCKMANTIAN	SOUTH WALES COAL MEASURES GROUP	S. WALES UPP. C.M. Fm.				PENNINE MIDDLE COAL MEASURES FORMATION	SCOTTISH LOWER COAL MEASURES FORMATION					
			LANGSETTIAN		SOUTH WALES MIDDLE COAL MEASURES FORMATION				PENNINE LOWER COAL MEASURES FORMATION						
		NAMURIAN	CHOKIERIAN-YEADONIAN	TENBY GROUP	QUARTZITIC SANDSTONE FORMATION		YOREDALE GROUP		STAINMORE FORMATION	CLACKMANNAN GROUP	PASSAGE FORMATION				
			ARNSBERGIAN								UPPER LIMESTONE FORMATION				
			PENDLEIAN								LIMESTONE COAL FORMATION				
		DINANTIAN	VISEAN	BRIGANTIAN	PEMBROKE LIMESTONE GROUP						ALSTON FORMATION	STRATHCLYDE GROUP	LOWER LIMESTONE FORMATION		
				ASBIAN							TYNE LIMESTONE Fm. (Scremerston Coal Mbr.)		WEST LOTHIAN OIL SHALE FORMATION		
				HOLKERIAN							BORDER GROUP		FELL SANDSTONE FORMATION	ARTHUR'S SEAT VOLCANIC FORMATION	GULLANE FORMATION
				ARUNDIAN											
				CHADIAN											
	TOURNAISIAN		COURCEYAN	AVON GROUP		INVERCLYDE GROUP		BALLAGAN FORMATION			INVERCLYDE GROUP		BALLAGAN FORMATION		
					KELSO VOLCANIC Fm.				KINNESSWOOD FORMATION						
					KINNESSWOOD FORMATION				KINNESSWOOD FORMATION						

Figure 1. Generalised Carboniferous stratigraphy for the South Wales, North East England and Scotland (Midland Valley) areas.

The main coal-bearing intervals are marked in grey. Coal-bearing stratigraphic units of Dinantian and Namurian age occur in the Midland Valley of Scotland, although coals are not always persistent across the entire Midland Valley area. In general, coals tend to be more common in these units in the Fife and Clackmannan areas.

3.1.2 Secondary resource area

The secondary resource represents one or more zones that contain opencast coal resources, but in which the coals are generally thinner and less concentrated in vertical and areal distribution. Coals from this resource zone have been exploited and continue to be worked, albeit on a smaller scale than the primary area coals. The zone typically spans a number of stratigraphic intervals, listed below:

- Dinantian aged West Lothian Oil-Shale Formation (Scotland).
- Dinantian aged Lower Limestone and Sandy Craig formations are locally coal-bearing in Fife
- Parts of the Dinantian aged Tyne Limestone Formation, Scremerston Coal Group and Alston Formation (N.E. England).
- Namurian aged Passage Group (Scotland), except around the former Westfield opencast site area, Fife.

- The lower part of the South Wales and Pennine Lower Coal Measures formations in England & Wales (Fig. 1).
- The upper part of the South Wales and Pennine Middle Coal Measures formations in England & Wales (Fig. 1).
- The lower part of the South Wales and Pennine Upper Coal Measures formations in England & Wales (Fig. 1).
- Jurassic Brora Shale Formation (Scotland).

3.1.3 Tertiary resource area

In certain coalfields (e.g. South Wales, Bristol-Somerset) coals are locally present in the Late Carboniferous Warwickshire Group succession. Here they typically occur interbedded with thick sandstones of the Pennant Sandstone Formation and Halesowen Formation (Fig. 1). These coals form a resource and some of these coals have been previously deep mined. However, they do not generally form an attractive target for opencast mining due to factors such as high overburden ratios and hardness of the overburden. In the Midlands the Warwickshire Group typically comprises red-bed successions that locally contain individual coals. In other areas of England and Wales thin coals exist in the Namurian. All these types of coal occurrences are grouped together as tertiary resources.

3.1.4 Buried coal resources overlain by up to 50m overburden

In some areas, particularly down-dip of the main area of mapped resources, coals are present in the subsurface covered by younger strata. A fourth zone has been identified by this study, which represents the area where coals are present overlain by less than 50 m of overburden. In this case the overburden is defined as bedrock; the thickness of superficial deposits is not considered here. In theory such areas may have opencast potential, depending on the thickness and type of overburden and the thickness of the coals below. These underlying coals have not been further ranked in terms of whether they represent primary, secondary or tertiary resources.

3.2 DERIVATION OF THE RESOURCE AREAS

3.2.1 Primary resource areas

Primary resource areas were mapped on a coalfield-by-coalfield basis. Examination of the stratigraphy of each coalfield allowed the vertical spacing and thickness of coals to be determined (Fig. 3). Parts of the succession that comprise thick, relatively closely spaced, laterally continuous coals were defined as primary resource zones. The boundaries between the resource zones were usually taken at the positions of distinct marker coal horizons. For example the base of the primary resource zone in the South Wales Coalfield was taken at the Gellideg

Coal and the top was taken at the position of the Two-Foot-Nine Coal (Fig. 3). The marker horizons that define the top and base of each resource zone per coalfield are listed in Table 1.

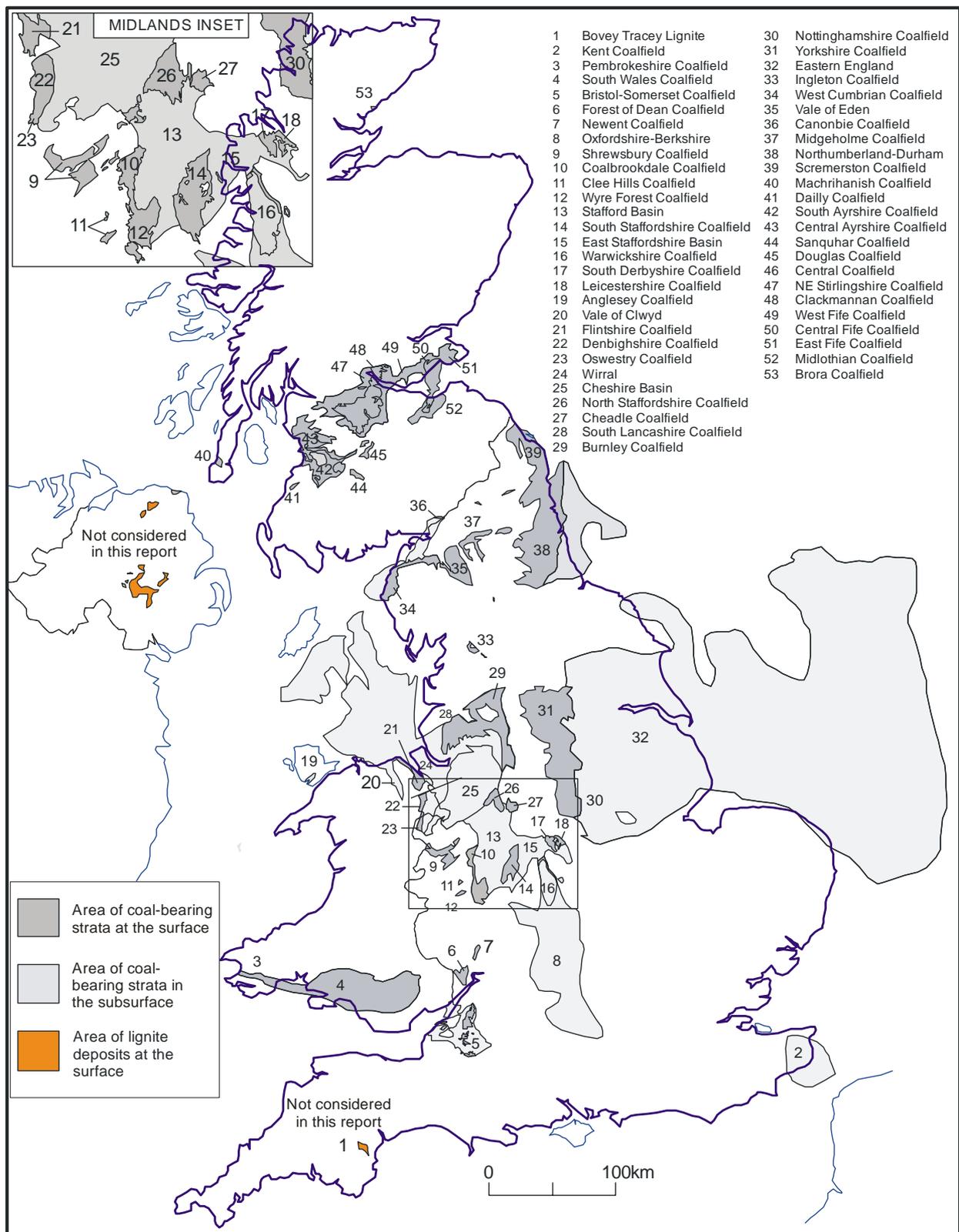


Figure 2. Locations of the main coalfields in Great Britain.

Once the bases and tops of each resource type were defined it was then necessary to map these zones. The BGS DiGMapGB-50 digital dataset for Great Britain was used (gb_50k_bedrock.shp & gb_50k_linear.shp, v. 3.14). In the linear dataset (gb_50k_linear.shp) coals are represented as attributed lines; attribution includes such features as the stratigraphy and seam names. Thus the tops and bases of resource zones could be defined by interrogating this dataset. Polygons were then created using these copal seams to mark the top and base of the resource.

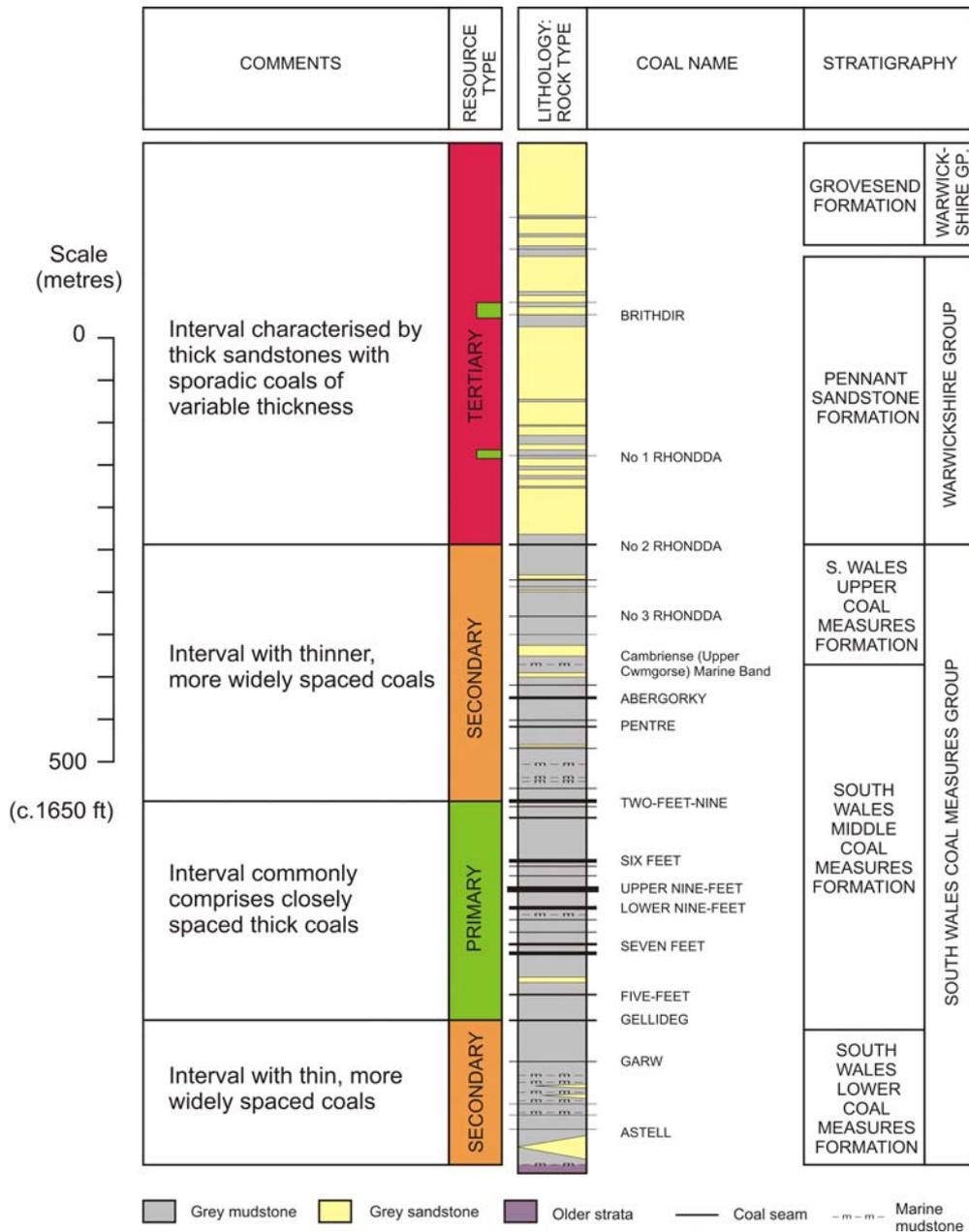


Figure 3. Generalised stratigraphic column for South Wales showing the zones of primary, secondary and tertiary coal resources.

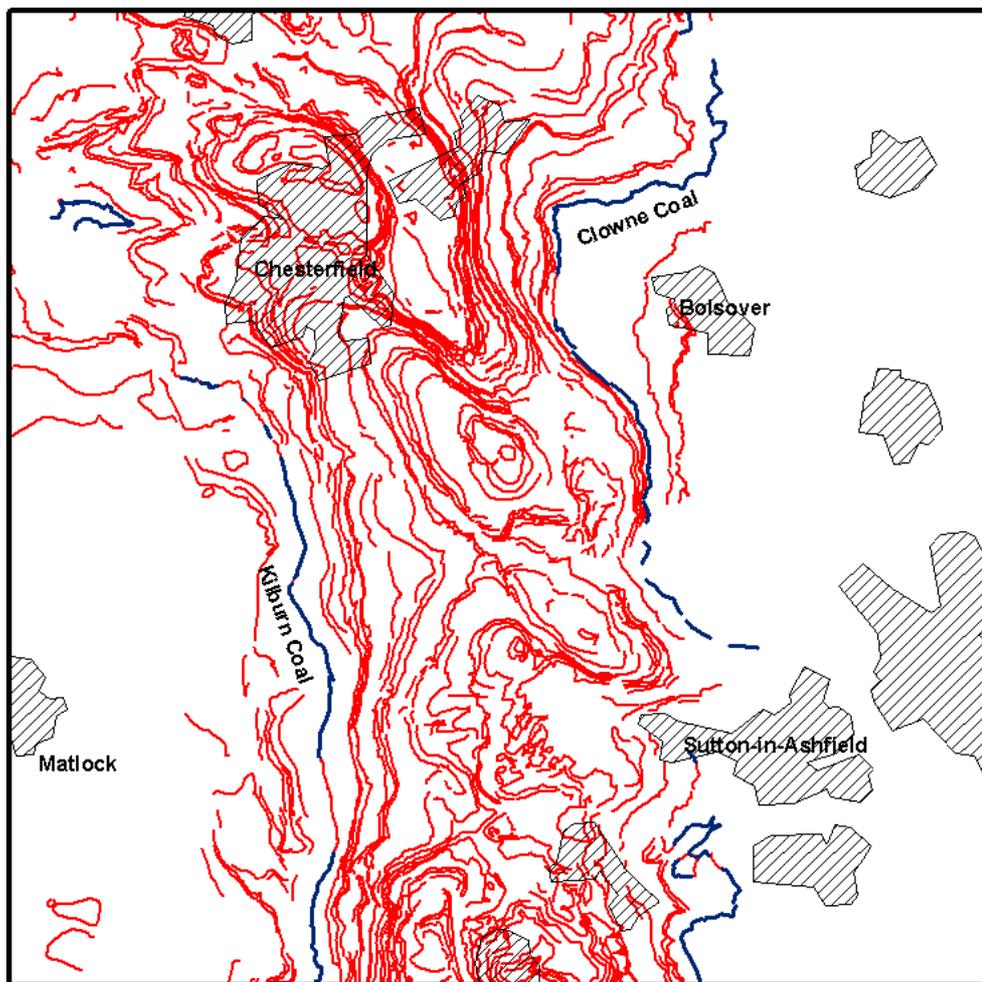


Figure 4. Map to show the use of the mapped positions of the main coal seams for resource area delineation, North Derbyshire area. The area is 25 km square.

Coal seams are in red. The primary resource is the area between the Kilburn seam at the base and Clowne seam at the top, shown as dark blue lines. Note the discontinuous nature of the mapped positions of the coal seams. Clearly there are large areas where either it has not been possible to map the Kilburn and Clowne seams or the coal seam stratigraphy is unknown. This is particularly the case where surface exposures are poor. This can makes resource area mapping problematical.

It is not always possible to determine the coal seam stratigraphy so not all seams are named in the DiGMap dataset. This meant that the coals that define the resource zone often formed discontinuous line segments (Fig. 4). Hence an understanding of the geological structure was also necessary in order to create polygons from this linear dataset (Figs 5 & 6). In areas of unknown seam stratigraphy it was necessary to take the lowermost coal in a group of closely spaced seams as the base of the primary resource zone.

3.2.2 Secondary resource areas

Parts of the Carboniferous succession that comprise intervals with thin, well-spaced, discontinuous coals were defined as a secondary resource zone. There are usually two secondary

resource zones in any one coalfield. Typically the lowermost coals in the Pennine and South Wales Lower Coal Measures formations tend to be thin and discontinuous; they can generally be grouped as a secondary resource. The base of this resource zone is taken at the base of the formation rather than at a coal horizon. The base of the Pennine and South Wales Lower Coal Measures formations is taken at a prominent dark marine mudstone known as the Subcrenatum Marine Band. The boundary between this lowermost secondary resource and the overlying primary resource zone is taken at a known, defined coal seam. A further secondary resource zone can usually be defined above the main primary resource zone (Fig. 3). The top of this is usually taken at either the base of the overlying Permian succession or, where present, the base of the Warwickshire Group (Figs 1 & 3). The coals in the Jurassic Brora Shale Formation in NE Scotland and the Scremerston Coal Member around Berwick-upon-Tweed are classified as secondary and the resource zone is taken at the mapped position of the top and base of these formations. Locally there are secondary zones present in the Warwickshire Group, e.g. in the Forest of Dean, but these tend to be uncommon. The methodology for defining polygons is similar to that described in Section 3.2.1.

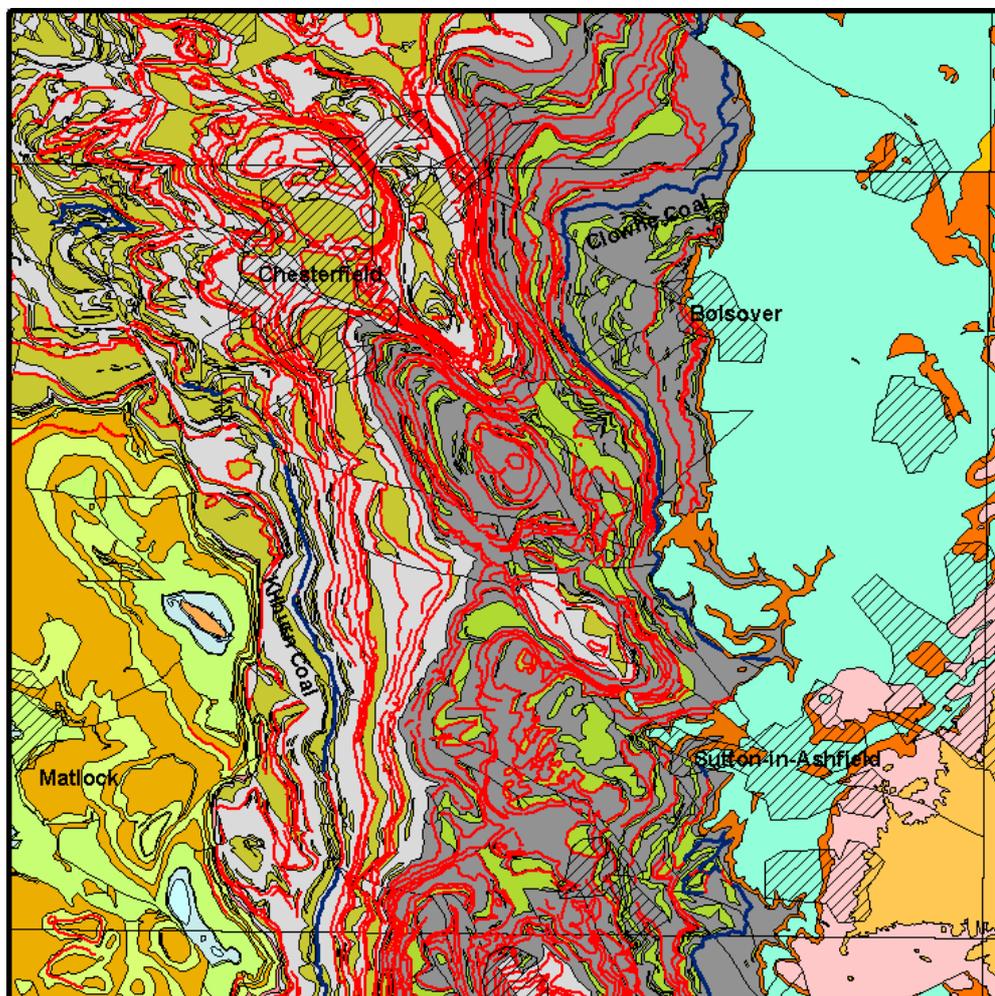


Figure 5. Map to show the relationship between the mapped positions of the main coal seams and the underlying geology, North Derbyshire area. The area is a 25 km square.

The geology shown is the DiGMapGB-50 dataset. Construction of the resource polygons requires an understanding of the underlying geology, both in terms of the structure and stratigraphy.

3.2.3 Tertiary resource areas

The tertiary resource zone typically comprises individual seams often separated from other coals by thick interseam lithologies, with the overburden varying dependant of the area of the country. In South Wales for example the overburden typically comprises thick sandstone of the Pennant Sandstone Formation. In other areas, e.g. the Midlands, there are often red-bed successions that separate these individual coals. In the Namurian and Dinantian of Northern England single coals often occur within isolated within non-coal strata. These coals are generally thin and can be highly variable laterally.

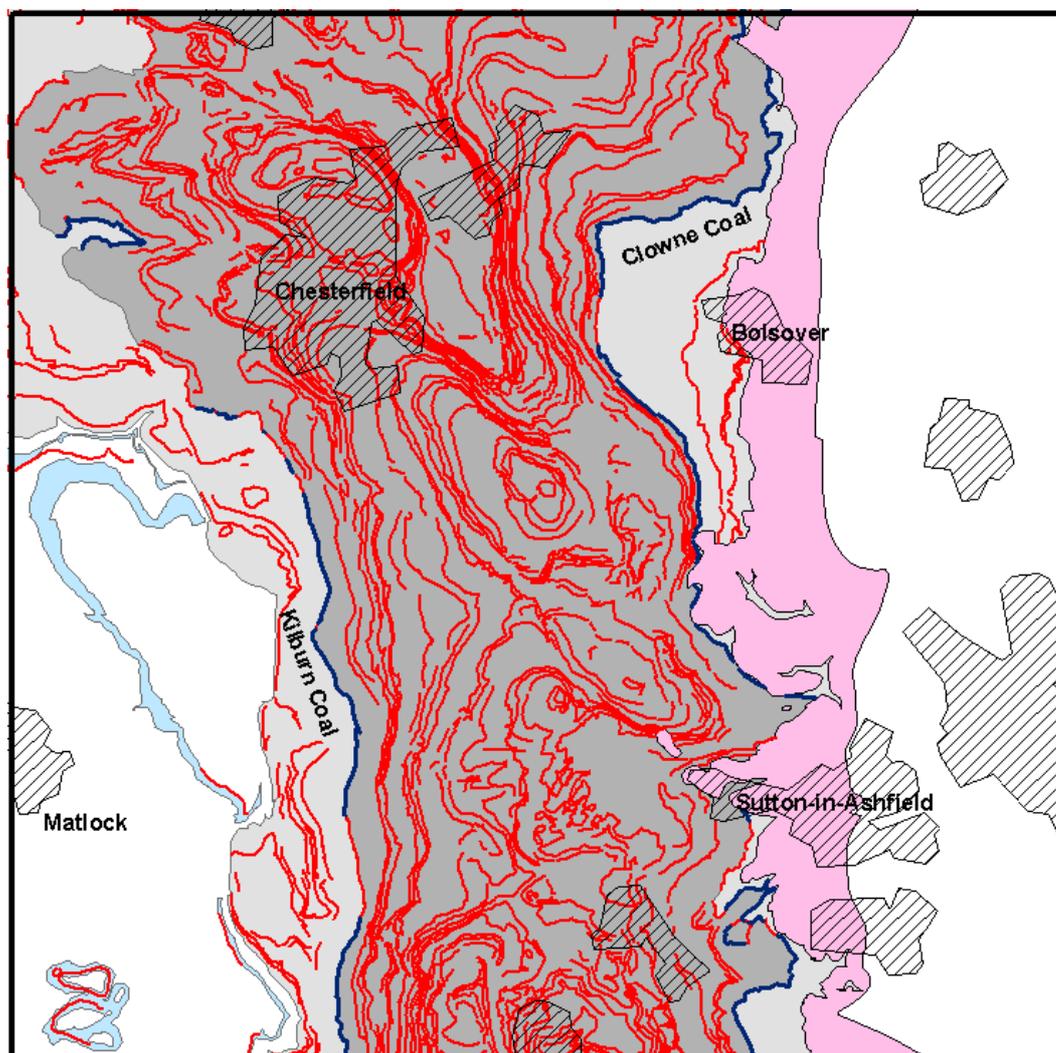


Figure 6. Map to show the mapped positions of the coal resource areas, North Derbyshire area. The area is 25 km square.

The primary resource area is shown in dark grey, secondary resource areas are in light grey, tertiary resource areas are in light blue and the area where there is less than 50 m of overburden is shown in pink. Coal seams are in red, except for the mapped positions of the Kilburn and Clowne seams, which are in dark blue.

Where these coals occur in the Pennant Sandstone Formation (Warwickshire Group) of South Wales and Bristol-Somerset then a tertiary resource zone is defined as the mapped base and top of the formation. Other parts of the Warwickshire Group in the Midlands with multiple coals in a predominantly red-bed succession were treated the same way, i.e. the resource boundary is taken at the top and bottom of the relevant geological formation within which the coals occur.

In the case of the isolated coals that occur in the Namurian and Dinantian of Northern England, it was not deemed sensible to include the entire formation as a tertiary resource. The reason for this is that these coals typically occur as individual seams in a formation that may be tens or hundreds of metres in thickness. In order to deal with these coals were treated separately and a 100 m buffer zone around each coal was produced. These curvilinear to vermicular polygons represent tertiary resource zones (Fig. 7).

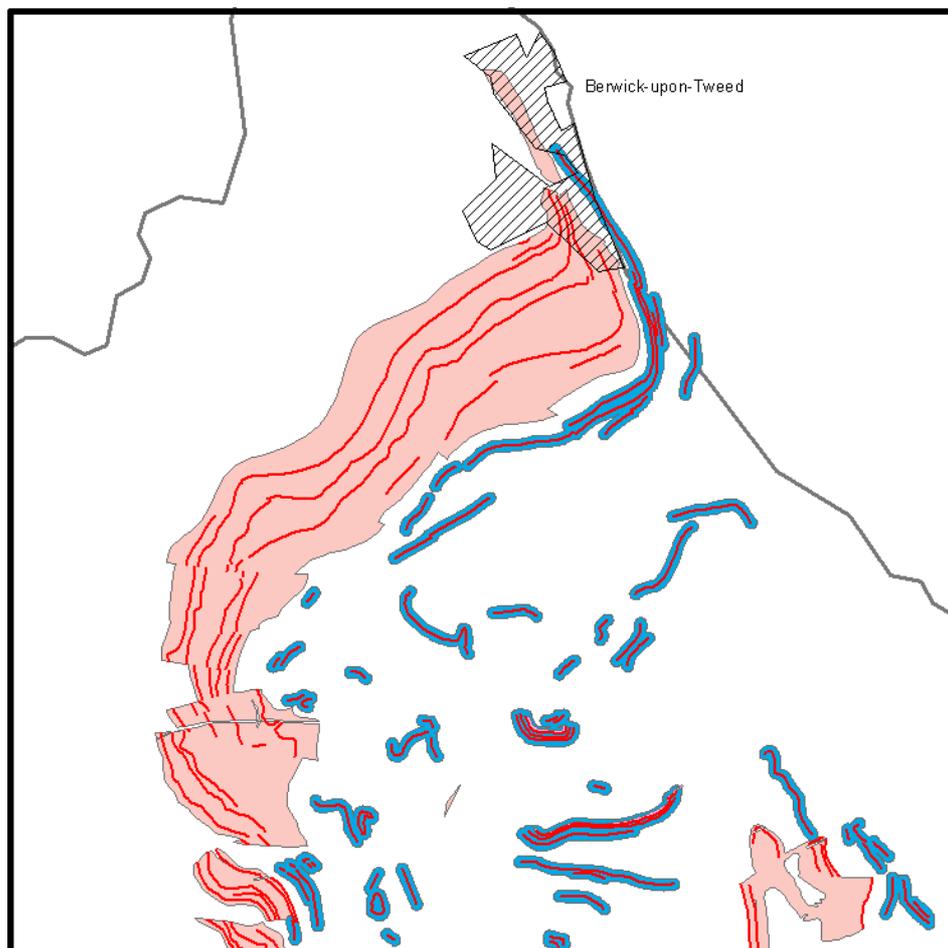


Figure 7. Area to the south of Berwick-upon-Tweed to show an example of the secondary and tertiary resource zones. The area is 16 km².

Coal seams are in red. The secondary resource zone (in pink) comprises the outcrop of the Scremerston Coal Group. Individual coal seams (or sometimes more than one) occur in the overlying succession to the south-east. The tertiary resource zone (in blue) has been derived by creating a 100 m polygonal buffer around the coals.

3.2.4 Buried coal resources overlain by up to 50m overburden

These are the areas where coal resources are covered by up to a maximum of 50 m of bedrock overburden. In most instances it was possible to use the linework derived for the 1999 Coal Resources Map (BGS 1999), which defined a ‘Shallow coal with less than 50 m overburden’ theme and a ‘Deep coal between 50m and 1200m’ theme. However, in some areas it was found that the line between these two zones, which should mark the position where overburden was 50 m in thickness, was incorrect. These areas included North Staffordshire (Stoke area), Northumberland-Durham, North Wales and the East Midlands. To produce more realistic linework would require a detailed borehole study and contouring of the thickness of the overlying bedrock overburden. However, time constraints within the project precluded this and a more simplistic methodology was defined. The following methodology was used to define the ‘buried coal resources overlain by up to 50 m overburden’ line in these areas:

- In the case of North Staffordshire the line between the Pennine Upper Coal Measures Formation and the Etruria Marl Formation was buffered by 300 m. This figure was derived by a rapid assessment of boreholes along this boundary to obtain Etruria Marl thickness information and then using a simple trigonometric calculation to derive the buffer distance. A polygon was then created using this buffered zone. This assumes that the Etruria Marl Formation maintains a constant dip, which might not be the case.
- In the Northumberland-Durham area the Buried Coal Zone was created by buffering by 500 m along the geological boundary between the Permian and the Pennine Coal Measures Group. This figure was derived by a rapid assessment of boreholes along this boundary.
- In North Wales an extremely generalised line was derived from a sparse number of boreholes along the eastern flank of the Coal Measures. It is likely that this line is not very accurate.
- In the East Midlands the Buried Coal Zone was derived by an assessment of the thickness of the Permian in numerous boreholes adjacent to the Coal Measures. The line was then derived using a combination of the Permian thickness and the positions of faults.

It must be stressed that these represent fairly unsophisticated attempts to produce the linework and more detailed studies should be carried out if accurate overburden thickness information is required.

4 Deliverables

The main product of the study are a series of GIS layers (shapefiles) showing the remaining coal resource areas in Great Britain. It is intended that these shapefiles be supplied to the Coal Authority who will hold them confidentially for internal non-commercial use within a GIS developed, held and maintained by the Coal Authority. It was not the intention of this project to print paper maps for each coalfield, although paper copies of maps can be printed on demand to interested parties. These would carry a modest cost for reproduction. In order to keep these costs to a minimum we have designed a standardised template for map production. Example maps at

1:100,000 and 1:50,000 scale have been produced for the Nottinghamshire-North Derbyshire-South Yorkshire area.

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Appendix 1 Table of metadata defining the tops and bases of the main resource zones per coalfield

COALFIELD	PRIMARY RESOURCE AREA		SECONDARY RESOURCE AREA		TERTIARY RESOURCE AREA	
	BASE	TOP	BASE	TOP	BASE	TOP
Bristol-Somerset	The cluster of coals around Yate and the east-west trending group of coals at Bristol can be grouped as primary.		Small areas classify as secondary, including the area to the north of Shepton Mallet, the area to the east of Knowle, Bristol and around Coalpit Heath, Winterbourne.		Areas comprising the Warwickshire Group	
South Wales	Gellideg Coal	Two-Foot-Nine Coal	Base South Wales Coal Measures Formation	Gellideg Coal	Warwickshire Group - Pennant Sandstone Formation	
			Two-Foot-Nine	Base Warwickshire Group		
Forest of Dean	None present		Two rings of secondary resources defined around the main outcropping coal seam areas		Tertiary resource zone comprises the relatively coal free areas of outcropping Warwickshire Group	
Newent	None present		None present		Outcropping areas of Warwickshire Group to the west, SW and north of Newent	
Leicestershire	Kilburn Coal, or first significant coal in the Pennine Lower Coal Measures Formation	Base of the Triassic Sherwood Sandstone Group	Base Pennine Coal Measures Formation	Kilburn Coal, or first significant coal in the Pennine Lower Coal Measures Formation	None present	
South Derbyshire	Kilburn Coal	Base of the Permian or Pennine Upper Coal Measures Formation	None present		None present	
Warwickshire	Lowermost continuous unnamed coal in Pennine Lower Coal Measures Formation	Uppermost continuous unnamed coal in Pennine Middle Coal Measures Formation	Base Pennine Lower Coal Measures Formation	Lowermost unnamed coal seam in Pennine Lower Coal Measures Formation	None present	
			Uppermost continuous unnamed coal in Pennine Middle Coal Measures Formation	Base of the Warwickshire Group		
South Staffordshire - Cannock, Dudley	Mealy Grey Coal (or Deep Coal)	Base of the Warwickshire Group	Base Pennine Lower Coal Measures Formation	Mealy Grey Coal or lowermost unnamed coal in the Pennine Lower Coal Measures Formation	Locally the Etruria Formation contains thin coals - tertiary resource taken at outcrop of Etruria Formation. Note: Not all areas of Etruria Formation contain coals so not all areas of outcropping Etruria Formation are marked as tertiary	
Clee Hills	None present		Entire outcrop of Pennine Coal Measures Group is regarded as a secondary resource		None present	
Shrewsbury	None present		None present		Salop and Halesowen formations locally contain thin coals, ranked as tertiary	
Coalbrookdale-Telford-Bridgnorth	Lowermost continuous unnamed coal in Pennine Lower Coal Measures Formation	Uppermost continuous unnamed coal in Pennine Middle Coal Measures Formation	Base Pennine Lower Coal Measures Formation	Lowermost unnamed coal seam in Pennine Lower Coal Measures Formation	Locally the Etruria Formation contains thin coals - tertiary resource taken at outcrop of Etruria Formation. Note: Not all areas of Etruria Formation contain coals so not all areas of outcropping Etruria Formation are marked as tertiary	
North Staffordshire - Stoke area	King Coal (or Two-Foot Coal)	Moss Coal (or Five Feet Coal)	Base Pennine Lower Coal Measures Formation	King Coal (or Two-Foot Coal)	Locally the Namurian and the Halesowen Formation (Warwickshire Group) contains thin coals, taken as tertiary resources	
	Twist	Great Row Coal (or Spencroft Coal)	Great Row Coal (or Spencroft Coal)	Base Etruria Formation		
Cheadle	Crabtree Coal	Base of the Triassic Sherwood Sandstone Group	Base Pennine Lower Coal Measures Formation	Crabtree Coal	None present	
North Wales	Premier Coal (or Bychton Two Yard or Queen coals)	Powell Coal (or Threequarters, Crank coals)	Base Pennine Lower Coal Measures Formation	Premier Coal (or Bychton Two Yard or Queen coals)	None present	
Anglesey	None present	None present	All coals in the Anglesey Coalfield are ranked as secondary		None present	
Lancashire-Warrington area	Arley Coal (or Rushy Park Coal)	Lyons Delf Coal	Base Pennine Lower Coal Measures Formation	Arley Coal (or Rushy Park Coal)	Thin coals present in the Namurian	
			Lyons Delf Coal (or Bin Coal)	Base Permian or Base Etruria Formation		
Lancashire-Wigan area	Arley Coal	Bin Coal (or Ince Yard or Riding Coal)	Base Pennine Lower Coal Measures Formation	Arley Coal	None present	
			Bin Coal (or Ince Yard or Riding Coal)	Base Permian or Base Etruria Formation		

COALFIELD	PRIMARY RESOURCE AREA		SECONDARY RESOURCE AREA		TERTIARY RESOURCE AREA	
	BASE	TOP	BASE	TOP	BASE	TOP
Burnley area	Arley Coal	No top present	Base Pennine Lower Coal Measures Formation	Arley Coal	Thin coals present in the Namurian	
Bolton area	Arley Coal	Bin Coal (or Ashclough Coal)	Base Pennine Lower Coal Measures Formation	Arley Coal	None present	
			Bin Coal (or Ashclough Coal)	Base Permian or Base Etruria Formation		
Salford area	Arley Coal	Radley Coal	Base Pennine Lower Coal Measures Formation	Base: Arley Coal	None present	
	Bradford Four-Foot Coal	Openshaw Coal	Radley Coal	Bradford Four-Foot Coal		
			Openshaw Coal	Base Permian or Base Etruria Formation		
Stockport-Macclesfield area	Arley Coal	New Jet Amber Coal (or Stubbs Coal)	Base Pennine Lower Coal Measures Formation	Arley Coal	None present	
			New Jet Amber Coal (or Stubbs Coal)	Base Permian or Base Etruria Formation		
Nottinghamshire	Kilburn Coal	Clowne Coal	Base Pennine Lower Coal Measures Formation	Kilburn Coal	None present	
			Clowne Coal	Base Permian		
South Yorkshire - Sheffield	Whinmoor Coal (or Kilburn Coal)	Swinton Pottery Coal (or Clowne Coal)	Base Pennine Lower Coal Measures Formation	Whinmoor Coal (or Kilburn Coal)	None present	
			Swinton Pottery Coal (or Clowne Coal)	Base Permian		
Yorkshire - Huddersfield-Bradford-Leeds	Better Bed Band Coal	Swinton Pottery Coal	Base Pennine Lower Coal Measures Formation	Better Bed Band Coal	None present	
			Swinton Pottery Coal	Base Permian		
North-west of Ripon	None present		None present		All Pennine Lower Coal Measures Formation ranked as tertiary	
Stainmore-Brough	None present		None present		All coal outcrops classified as tertiary	
Ingleton	None present		All outcrop of Pennine Coal Measures Group classified as secondary		None present	
Alston	None present		None present		All coal outcrops classified as tertiary	
Plenmeller-Hexham	Lowermost continuous unnamed coal in Pennine Lower Coal Measures Formation	Uppermost continuous unnamed coal in Pennine Middle Coal Measures Formation	Base Pennine Lower Coal Measures Formation	Lowermost unnamed coal seam in Pennine Lower Coal Measures Formation	None present	
West Cumbria	Lower Threequarters Coal	Brassy Coal	Base Pennine Lower Coal Measures Formation	Lower Threequarters Coal	None present	
			Brassy Coal	Base Permian or Whitehaven Sandstone Group		
Durham	Marshall Green Coal (or Bottom Marshall Green Coal)	Ryhope Five Quarter Coal (or Top Ryhope 5/4)	Base Pennine Lower Coal Measures Formation	Marshall Green Coal (or Bottom Marshall Green Coal)	Thin coals present in the Namurian & Dinantian	
Northumberland to Berwick	Marshall Green Coal (or Bottom Marshall Green Coal)	Ryhope Five Quarter Coal (or Top Ryhope 5/4)	Base Pennine Lower Coal Measures Formation	Marshall Green Coal (or Bottom Marshall Green Coal)	Thin coals present in the Namurian & Dinantian	
			Base of Scremerston Coal Member	Top of Scremerston Coal Member		
Lothians	Scottish Coal Measures Group, Limestone Coal Group & Upper Limestone Formation		Passage Formation, locally the West Lothian Oil-Shale Formation		None present	
Clackmannan	Scottish Coal Measures Group, Limestone Coal Group & Upper Limestone Formation		Passage Formation		None present	
Central Midland Valley	Scottish Coal Measures Group, Limestone Coal Group & Upper Limestone Formation		Passage Formation		None present	

COALFIELD	PRIMARY RESOURCE AREA		SECONDARY RESOURCE AREA		TERTIARY RESOURCE AREA	
	BASE	TOP	BASE	TOP	BASE	TOP
Fife	Scottish Coal Measures Group, Limestone Coal Group & Upper Limestone Formation, locally the Passage Formation		Passage Formation, locally the Sandy Craig Formation and the Lower Limestone Formation		None present	
Ayrshire	Scottish Coal Measures Group, Limestone Coal Group & Upper Limestone Formation		Passage Formation		None present	
Douglas	Scottish Coal Measures Group, Limestone Coal Group & Upper Limestone Formation		Passage Formation		None present	
Canonbie	Scottish Coal Measures Group		None present		None present	
Sanquhar	Scottish Coal Measures Group		None present		None present	
Machrihanish	None present		Scottish Coal Measures Group, Limestone Coal Group & Upper Limestone Formation		None present	
Thornhill	None present		None present		None present	
Brora	None present		None present		All tertiary	

Appendix 1. Table of metadata defining the tops and bases of the main resources zones per coalfield